TELEDYNE
ADVANCED POLLUTION INSTRUMENTATION
A Teledyne Technologies Company

Operation Manual

Model T200
Nitrogen Oxide Analyzer

Also supports operation of:	when used in conjunction with:
Model T200U Analyzer	T200U addendum, PN 06861
T200U-NOy Converter	T200U addendum, PN 06861 and T200U-NOy addendum, PN 07303
Model T201 Analyzer	T201 addendum, PN 07271

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ABOUT TELEDYNE ADVANCED POLLUTION INSTRUMENTATION (TAPI)

Teledyne Advanced Pollution Instrumentation, Inc. (TAPI) is a worldwide market leader in the design and manufacture of precision analytical instrumentation used for air quality monitoring, continuous emissions monitoring, and specialty process monitoring applications. Founded in San Diego, California, in 1988, TAPI introduced a complete line of Air Quality Monitoring (AQM) instrumentation, which comply with the United States Environmental Protection Administration (EPA) and international requirements for the measurement of criteria pollutants, including CO, SO2, NOX and Ozone.

Since 1988 TAPI has combined state-of-the-art technology, proven measuring principles, stringent quality assurance systems and world class after-sales support to deliver the best products and customer satisfaction in the business.

For further information on our company, our complete range of products, and the applications that they serve, please visit www.teledyne-api.com or contact sales@teledyne-api.com.

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TRADEMARKS

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SAFETY MESSAGES

Important safety messages are provided throughout this manual for the purpose of avoiding personal injury or instrument damage. Please read these messages carefully. Each safety message is associated with a safety alert symbol, and are placed throughout this manual and inside the instrument. The symbols with messages are defined as follows:

WARNING: Electrical Shock Hazard

HAZARD: Strong oxidizer

GENERAL WARNING/CAUTION: Read the accompanying message for specific information.

CAUTION: Hot Surface Warning

Do Not Touch: Touching some parts of the instrument without protection or proper tools could result in damage to the part(s) and/or the instrument.

Technician Symbol: All operations marked with this symbol are to be performed by qualified maintenance personnel only.

Electrical Ground: This symbol inside the instrument marks the central safety grounding point for the instrument.

CAUTION

This instrument should only be used for the purpose and in the manner described in this manual. If you use this instrument in a manner other than that for which it was intended, unpredictable behavior could ensue with possible hazardous consequences.

NEVER use a gas analyzer to sample any combustible gas(es)!

Note

Technical Assistance regarding the use and maintenance of this instrument or any other Teledyne API product can be obtained by contacting Teledyne API's Customer Service Department:

Telephone: 800-324-5190

Email: api-customerservice@teledyne.com

or by accessing various service options on our website at http://www.teledyne-api.com/

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WARRANTY

WARRANTY POLICY (02024D)

Prior to shipment, T-API equipment is thoroughly inspected and tested. Should equipment failure occur, T-API assures its customers that prompt service and support will be available.

COVERAGE

After the warranty period and throughout the equipment lifetime, T-API stands ready to provide on-site or in-plant service at reasonable rates similar to those of other manufacturers in the industry. All maintenance and the first level of field troubleshooting is to be performed by the customer.

NON-API MANUFACTURED EQUIPMENT

Equipment provided but not manufactured by T-API is warranted and will be repaired to the extent and according to the current terms and conditions of the respective equipment manufacturers warranty.

GENERAL

During the warranty period, T-API warrants each Product manufactured by T-API to be free from defects in material and workmanship under normal use and service. Expendable parts are excluded.

If a Product fails to conform to its specifications within the warranty period, T-API shall correct such defect by, at API's discretion, repairing or replacing such defective Product or refunding the purchase price of such Product.

The warranties set forth in this section shall be of no force or effect with respect to any Product: (i) that has been altered or subjected to misuse, negligence or accident, or (ii) that has been used in any manner other than in accordance with the instruction provided by T-API, or (iii) not properly maintained.

THE WARRANTIES SET FORTH IN THIS SECTION AND THE REMEDIES THEREFORE ARE EXCLUSIVE AND IN LIEU OF ANY IMPLIED WARRANTIES OF MERCHANTABILITY, FITNESS FOR PARTICULAR PURPOSE OR OTHER WARRANTY OF QUALITY, WHETHER EXPRESSED OR IMPLIED. THE REMEDIES SET FORTH IN THIS SECTION ARE THE EXCLUSIVE REMEDIES FOR BREACH OF ANY WARRANTY CONTAINED HEREIN. API SHALL NOT BE LIABLE FOR ANY INCIDENTAL OR CONSEQUENTIAL DAMAGES ARISING OUT OF OR RELATED TO THIS AGREEMENT OF T-API'S PERFORMANCE HEREUNDER, WHETHER FOR BREACH OF WARRANTY OR OTHERWISE.

TERMS AND CONDITIONS

All units or components returned to Teledyne API should be properly packed for handling and returned freight prepaid to the nearest designated Service Center. After the repair, the equipment will be returned, freight prepaid.

CAUTION – Avoid Warranty Invalidation

Failure to comply with proper anti-Electro-Static Discharge (ESD) handling and packing instructions and Return Merchandise Authorization (RMA) procedures when returning parts for repair or calibration may void your warranty. For anti-ESD handling and packing instructions please refer to “Packing Components for Return to Teledyne API’s Customer Service” in the *Primer on Electro-Static Discharge* section of this manual, and for RMA procedures please refer to our Website at http://www.teledyne-api.com under Customer Support > Return Authorization.

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ABOUT THIS MANUAL

Presented here is information regarding the documents that are included with this manual (Structure), its history of release and revisions (Revision History), how the content is organized (Organization), a description of other information related to this manual (Related Information), and the conventions used to present the information in this manual (Conventions Used).

STRUCTURE

This T200 manual, PN 06858, is comprised of multiple documents, assembled in PDF format, as listed below.

Part No.	Rev	Name/Description
06858	A	Operation Manual, T200 Nitrogen Oxide Analyzer
05295	D	Appendix A, Menu Trees and related software documentation
06847	A	Spare Parts List (in Appendix B this manual)
04414	Q	Recommended Spares Stocking Levels (in Appendix B this manual)
04715	D	AKIT, Expendables (in Appendix B this manual)
04503	D	Appendix C, Repair Questionnaire
06911	A	Interconnect Diagram, T200 (in Appendix D this manual)
069110100	A	Interconnect List (in Appendix D this manual)
		Schematics (in Appendix D this manual)
01669	G	PCA 016680300, Ozone generator board 04170 with flow meter
04932	C	PCA Thermo-electric cooler board
03632	A	PCA 03631, 0-20mA Driver
03956	A	PCA 039550200, Relay Board
04354	D	PCA 04003, Pressure/Flow Transducer Interface
04181	H	PCA 041800200, PMT pre-amplifier board
04468	B	PCA, 04467, Analog Output Series Res
04522	D	PCA, Relay, Schematic
04524	D	PCB, Relay, Schematic
05803	B	SCH, PCA 05802, MOTHERBOARD, GEN-5
06698	D	SCH, PCA 06697, INTRFC, LCD TCH SCRN,
06882	B	SCH, LVDS TRANSMITTER BOARD
06731	A	SCH, AUXILLIARY-I/O BOARD

Note **We recommend that this manual be read in its entirety before any attempt is made to operate the instrument.**

ORGANIZATION

This manual is divided among three main parts and a collection of appendices at the end.

Part I contains introductory information that includes an overview of the analyzer, descriptions of the available options, specifications, installation and connection instructions, and the initial calibration and functional checks. It also has a section with Frequently Asked Questions (FAQs) and a glossary.

Part II comprises the operating instructions, which include basic, advanced and remote operation, calibration, diagnostics, testing, validating and verifying, and ends with specifics of calibrating for use in EPA monitoring.

Part III provides detailed technical information, such as theory of operation, maintenance, and troubleshooting and repair. The last section is dedicated to providing information about electro-static discharge and avoiding its consequences.

The appendices at the end of this manual provide support information such as, version-specific software documentation, lists of spare parts and recommended stocking levels, and schematics.

REVISION HISTORY

This section provides information regarding changes to this manual.

2010, T200 Manual, PN06858 Rev A, DCN5847 – Initial Release				
Document	**PN**	**Rev**	**DCN**	**Change Summary**

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PART I
–
GENERAL INFORMATION

1. INTRODUCTION

1.1. T200 OVERVIEW

The Model T200 (also referred to as T200) Nitrogen Oxides Analyzer uses chemiluminescence detection, coupled with state-of-the-art microprocessor technology to provide the sensitivity, stability and ease of use needed for ambient or dilution CEM monitoring requirements of nitric oxide (NO), nitrogen dioxide (NO_2) and the total nitrogen oxides (NO_x). The instrument:

- Calculates the amount of NO present by measuring the amount of chemiluminescence given off when the sample gas is exposed to ozone (O_3).
- Uses a catalytic-reactive converter to convert any NO_2 in the sample gas to NO, which is then measured as above (including the original NO in the sample gas) and reported as NO_x.

Since the density of the sample gas effects the brightness of the chemiluminescence reaction, the T200 software compensates for temperature and pressure changes.

Stability is further enhanced by an Auto-Zero feature which periodically redirects the gas flow through the analyzer so that no chemiluminescence reaction is present in the sample chamber. The analyzer measures this “dark” condition and uses the results as an offset, which is subtracted from the sensor readings recorded while the instrument is measuring NO and NO_X. The result gives a sensitive, accurate, and dependable performance under the harshest operating conditions.

The T200 analyzer’s multi-tasking software gives the ability to track and report a large number of operational parameters in real time. These readings are compared to diagnostic limits kept in the analyzers memory and should any fall outside of those limits the analyzer issues automatic warnings.

Built-in data acquisition capability, using the analyzer's internal memory, allows the logging of multiple parameters including averaged or instantaneous concentration values, calibration data, and operating parameters such as pressure and flow rate. Stored data are easily retrieved through the serial port or Ethernet port via our APICOM software or from the front panel, allowing operators to perform predictive diagnostics and enhanced data analysis by tracking parameter trends. Multiple averaging periods of one minute to 365 days are available for over a period of one year.

Some of the other exceptional features of your T200 Nitrogen Oxides Analyzer are:

- Ranges, 0-50 ppb to 0-20 ppm, user selectable
- Independent ranges and auto ranging
- Large, vivid, and durable graphics display with touch screen interface
- Microprocessor controlled for versatility
- Multi-tasking software to allow viewing test variables while operating
- Continuous self checking with alarms
- Permeation dryer on ozone generator
- Bi-directional RS-232, optional USB and RS-485, and 10/100Base-T Ethernet ports for remote operation
- Front panel USB ports for peripheral devices and firmware upgrades
- Digital status outputs to provide instrument operating condition
- Adaptive signal filtering to optimize response time
- Temperature and pressure compensation
- Converter efficiency correction software
- Catalytic ozone scrubber
- Comprehensive internal data logging with programmable averaging periods
- Ability to log virtually any operating parameter
- 8 analog inputs (optional)
- Internal zero and span check (optional)

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2. Specifications and Approvals

Provided here are the specifications, the EPA Equivalency Designation, and the emissions and safety compliance approvals for this instrument.

2.1. SPECIFICATIONS

Table 2-1 presents the instrument's parameters and the specifications that each meets.

Table 2-1: T200 Basic Unit Specifications

Parameter	Specification
Min/Max Range (Physical Analog Output)	Min: 0-50 ppb Full Scale Max: 0-20,000 ppb Full Scale (selectable, independent NO, NO_2, NO_x ranges and auto ranges supported)
Measurement Units	ppb, ppm, µg/m^3, mg/m^3 (selectable)
Zero Noise[1]	< 0.2 ppb (RMS)
Span Noise[1]	< 0.5% of reading (RMS) above 50 ppb or 0.2 ppb, whichever is greater
Lower Detectable Limit [2]	0.4 ppb
Zero Drift	< 0.5 ppb (at constant temperature and voltage) /24 hours
Span Drift	< 0.5% of Full Scale (at constant temperature and voltage) /24 hours
Lag Time[1]	20 seconds
Rise/Fall Time[1]	<60 seconds to 95%
Linearity	1% of full scale / 24 hours
Precision	0.5% of reading above 50 ppb
Sample Flow Rate	500 cm^3/min ± 10%
AC Power	100V-120V, 220V-240V, 50/60 Hz
Power, Ext Pump	100 V, 50/60 Hz (3.25A); 115 V, 60 Hz (3.0 A); 220 - 240 V, 50/60 Hz (2.5 A)
Analog Output Ranges	10V, 5V, 1V, 0.1V (selectable) All Ranges with 5% Under/Over Range
Analog Output Resolution	1 part in 4096 of selected full-scale voltage
Recorder Offset	± 10%
Standard I/O	1 Ethernet: 10/100Base-T 2 RS-232 (300 – 115,200 baud) 2 USB device ports 8 opto-isolated digital status outputs (7 defined, 1 spare) 6 opto-isolated digital control inputs (4 defined, 2 spar) 4 analog outputs
Optional I/O	1 USB com port 1 RS485 8 analog inputs (0-10V, 12-bit) 4 digital alarm outputs Multidrop RS232 3 4-20mA current outputs
Dimensions H x W x D	7" x 17" x 23.5" (178mm x 432 mm x 597 mm)
Weight	Analyzer: 40 lbs (18 kg) External Pump Pack: 15 lbs (7 kg)
Operating Temperature Range	5 - 40 °C (with EPA equivalency)
Humidity Range	0-95% RH non-condensing

Parameter	Specification
Environmental Conditions	Installation Category (Over voltage Category) II Pollution Degree 2
Certifications	US EPA: Reference Method Number RFNA-1194-099 MCERTS: Sira MC 050068/05 CE: EN61326 (1997 w/A1: 98) Class A, FCC Part 15 Subpart B Section 15.107 Class A, ICES-003 Class A (ANSI C63.4 1992) & AS/NZS 3548 (w/A1 & A2; 97) Class A.
[1] As defined by the US EPA. [2] Defined as twice the zero noise level by the US EPA.	

2.2. EPA EQUIVALENCY DESIGNATION

Teledyne API's T200 nitrogen oxides analyzer is designated as a reference method for NO_2 measurement, as defined in 40 CFR Part 53, when operated under the following conditions:

- Range: Any full-scale range between 0-0.05 and 0-1.0 ppm (parts per million).
- Ambient temperature range of 5 to 40°C.
- With 1-micron PTFE filter element installed in the internal filter assembly.
- Equipped with ozone supply air filter
- Gas flow supplied by External vacuum pump capable of 10 in-Hg-A at 2 standard liters per minute (slpm) or better.
- Following Software Setting:

Table 2-2: Software Settings for EPA Equivalence

Parameter	Setting
Dynamic Zero	OFF or ON
Dynamic Span	OFF
CAL-on-NO_2	OFF
Dilution Factor	1.0 or OFF
Temp/Pres compensation	ON
AutoCal	ON or OFF
Independent range	ON or OFF
Auto range	ON or OFF

Under the designation, the Analyzer may be operated with or without the following options:

- Rack mount with or without slides.
- Rack mount for external pump.
- 4-20mA isolated analog outputs.
- Zero/Span Valves option.
- Internal Zero/Span (IZS) option with:
    - NO_2 permeation tube - 0.4 ppm at 0.7 liter per minute; certified/uncertified.
    - NO_2 permeation tube - 0.8 ppm at 0.7 liter per minute; certified/uncertified.

NOTE
Under the designation, the IZS option cannot be used as the source of calibration.

2.3. CE MARK COMPLIANCE

EMISSIONS COMPLIANCE

The Teledyne API T200 nitrogen oxides analyzer was tested and found to be fully compliant with:

EN61326 (1997 w/A1: 98) Class A, FCC Part 15 Subpart B Section 15.107 Class A, ICES-003 Class A (ANSI C63.4 1992) & AS/NZS 3548 (w/A1 & A2; 97) Class A.

SAFETY COMPLIANCE

The Teledyne API T200 nitrogen oxides analyzer was tested and found to be fully compliant with:

IEC 61010-1:90 + A1:92 + A2:95

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3. GETTING STARTED

This section first introduces the instrument, then presents the procedures for getting started, i.e., unpacking and inspection, making electrical and pneumatic connections, and conducting an initial calibration check.

3.1. FRONT PANEL

Figure 3-1 shows the analyzer's front panel layout, followed by a close-up of the display screen in Figure 3-2, which is described in Table 3-1. The two USB ports on the front panel are provided for the connection of peripheral devices:

- plug-in mouse (not included) to be used as an alternative to the touchscreen interface
- thumb drive (not included) to download updates to instruction software (contact T-API Customer Service for information).

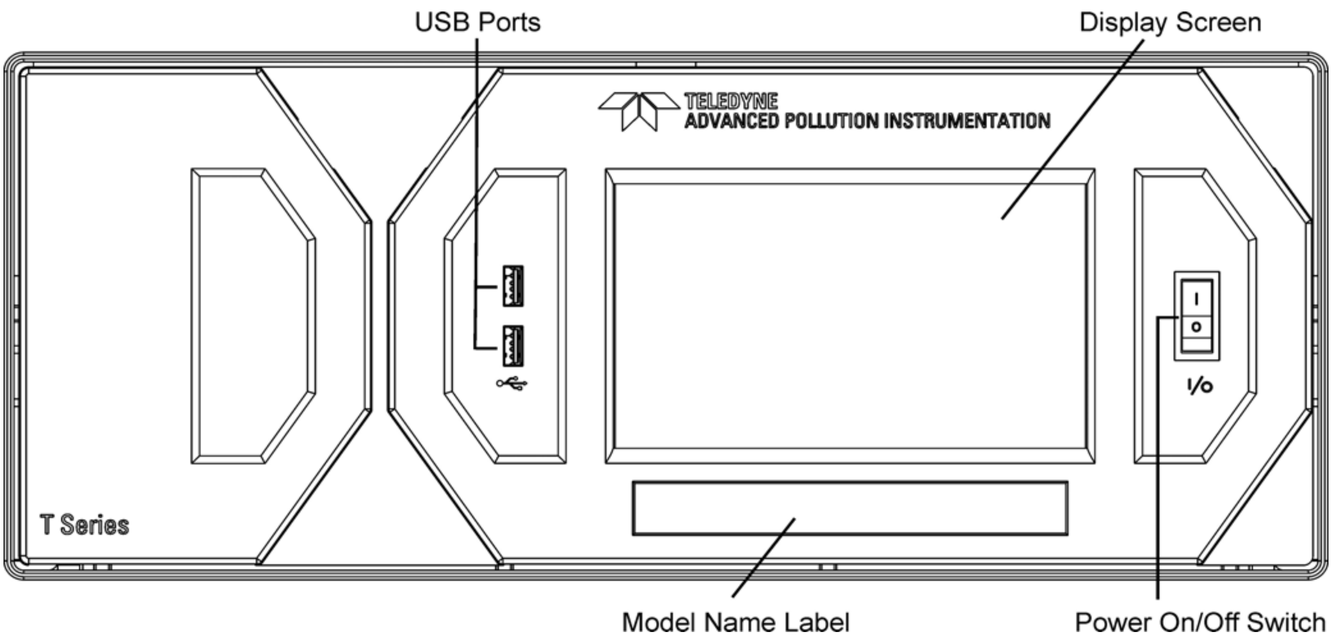


Figure 3-1: Front Panel Layout

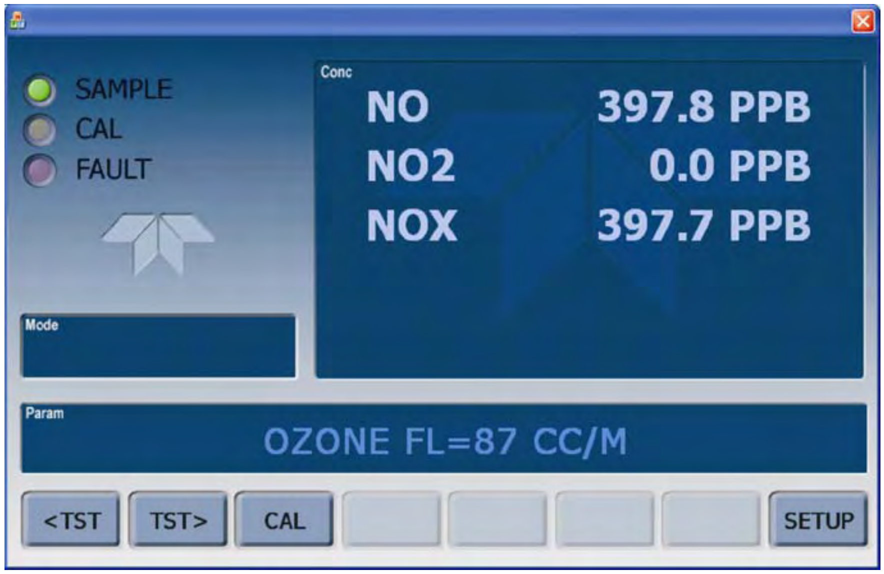


Figure 3-2: Display Screen and Touch Control

CAUTION – Avoid Damaging Touchscreen

Do not use hard-surfaced instruments such as pens to touch the control buttons.

The front panel liquid crystal display screen includes touch control. Upon analyzer start-up, the screen shows a splash screen and other initialization indicators before the main display appears, similar to Figure 3-2 above. The LEDs on the display screen indicate the Sample, Calibration and Fault states; also on the screen is the gas concentration field (Conc), which displays real-time readouts for the primary gas and for the secondary gas if installed. The display screen also shows what mode the analyzer is currently in, as well as messages and data (Param). Along the bottom of the screen is a row of touch control buttons; only those that are currently applicable will have a label. Table 3-1 provides detailed information for each component of the screen.

Table 3-1: Display Screen and Touch Control Description

Field	Description/Function			
Status	LEDs indicating the states of Sample, Calibration and Fault, as follows:			
	Name	Color	State	Definition
	SAMPLE	Green	Off	Unit is not operating in sample mode, DAS is disabled.
			On	Sample Mode active; Front Panel Display being updated; DAS data being stored.
			Blinking	Unit is operating in sample mode, front panel display being updated, DAS hold-off mode is ON, DAS disabled
	CAL	Yellow	Off	Auto Cal disabled
			On	Auto Cal enabled
			Blinking	Unit is in calibration mode
	FAULT	Red	Off	No warnings exist
			Blinking	Warnings exist
Conc	Displays the actual concentration of the sample gas currently being measured by the analyzer in the currently selected units of measure.			
Mode	Displays the name of the analyzer's current operating mode			
Param	Displays a variety of informational messages such as warning messages, operational data, test function values and response messages during interactive tasks.			
Control Buttons	Displays dynamic, context sensitive labels on each button, which is blank when inactive until applicable.			

Figure 3-3 shows how the front panel display is mapped to the menu charts that are used to illustrate the display throughout this manual. The Mode, Param (parameters), and Conc (gas concentration) fields in the display screen are represented across the top row of each menu chart. The eight touch control buttons along the bottom of the display screen are represented in the bottom row of each menu chart.

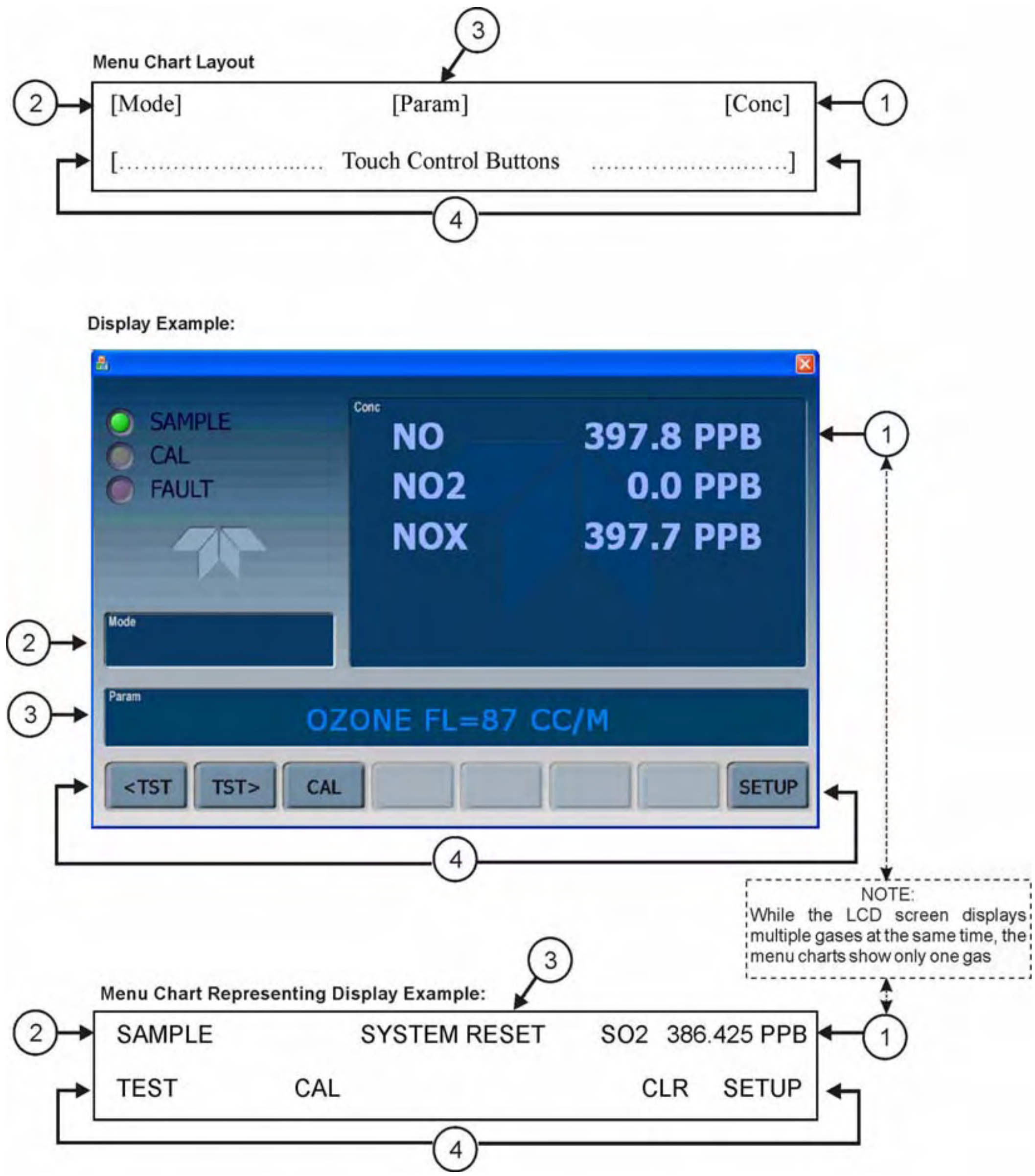


Figure 3-3: Display/Touch Control Screen Mapped to Menu Charts

3.2. REAR PANEL

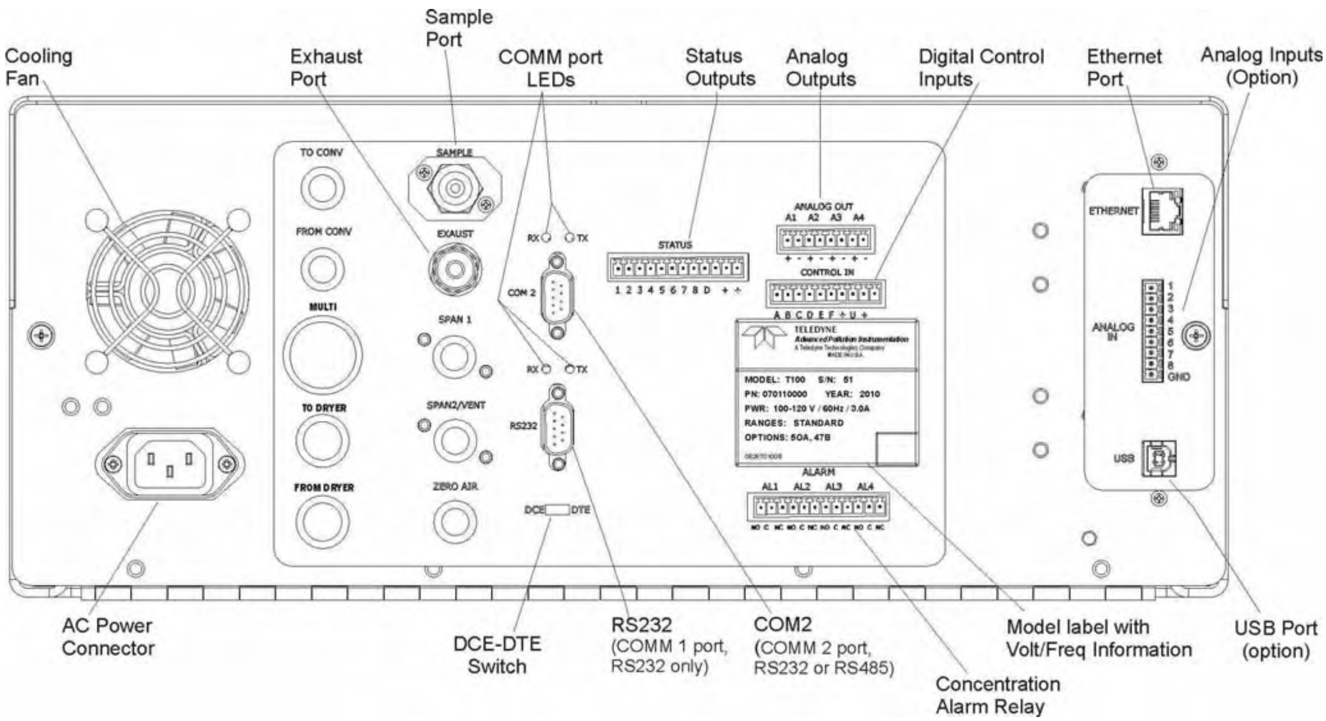


Figure 3-4: Rear Panel Layout – Base Unit

Table 3-2 provides a description of each component on the rear panel.

Table 3-2: Rear Panel Description

Component	Function
cooling fan	Pulls ambient air into chassis through side vents and exhausts through rear.
AC power connector	Connector for three-prong cord to apply AC power to the analyzer. **CAUTION! The cord's power specifications (specs) MUST comply with the power specs on the analyzer's rear panel Model number label**
Model/specs label	Identifies the analyzer model number and provides power specs
TO CONV	(not used)
FROM CONV	(not used)
MULTI	(not used)
TO DRYER	(not used)
FROM DRYER	Outlet for internal sample gas dryer; connect to external zero air scrubber (for IZS options only).
SAMPLE	Connect a gas line from the source of sample gas here. Calibration gases can also enter here on units without zero/span/shutoff valve options installed.
EXHAUST	Connect an exhaust gas line of not more than 10 meters long here that leads outside the shelter or immediate area surrounding the instrument. The line must be ¼" tubing or greater.
SPAN 1	On units with zero/span/shutoff valve options installed, connect a gas line to the source of calibrated span gas here.
SPAN2/VENT	(not used)
ZERO AIR	Internal Zero Air: On units with zero/span/shutoff valve options installed but no internal zero air scrubber attach a gas line to the source of zero air here.
RX TX	LEDs indicate receive (RX) and transmit (TX) activity on the when blinking.
COM 2	Serial communications port for RS-232 or RS-485.
RS-232	Serial communications port for RS-232 only.
DCE DTE	Switch to select either data terminal equipment or data communication equipment during RS-232 communication.
STATUS	For ouputs to devices such as Programmable Logic Controllers (PLCs).
ANALOG OUT	For voltage or current loop outputs to a strip chart recorder and/or a data logger.
CONTROL IN	For remotely activating the zero and span calibration modes.
ALARM	Option for concentration alarms and system warnings.
ETHERNET	Connector for network or Internet remote communication, using Ethernet cable
ANALOG IN	Option for external voltage signals from other instrumentation and for logging these signals
USB	Connector for direct connection to laptop computer, using USB cable.
Model Label	Includes voltage and frequency specifications

3.3. ANALYZER LAYOUT

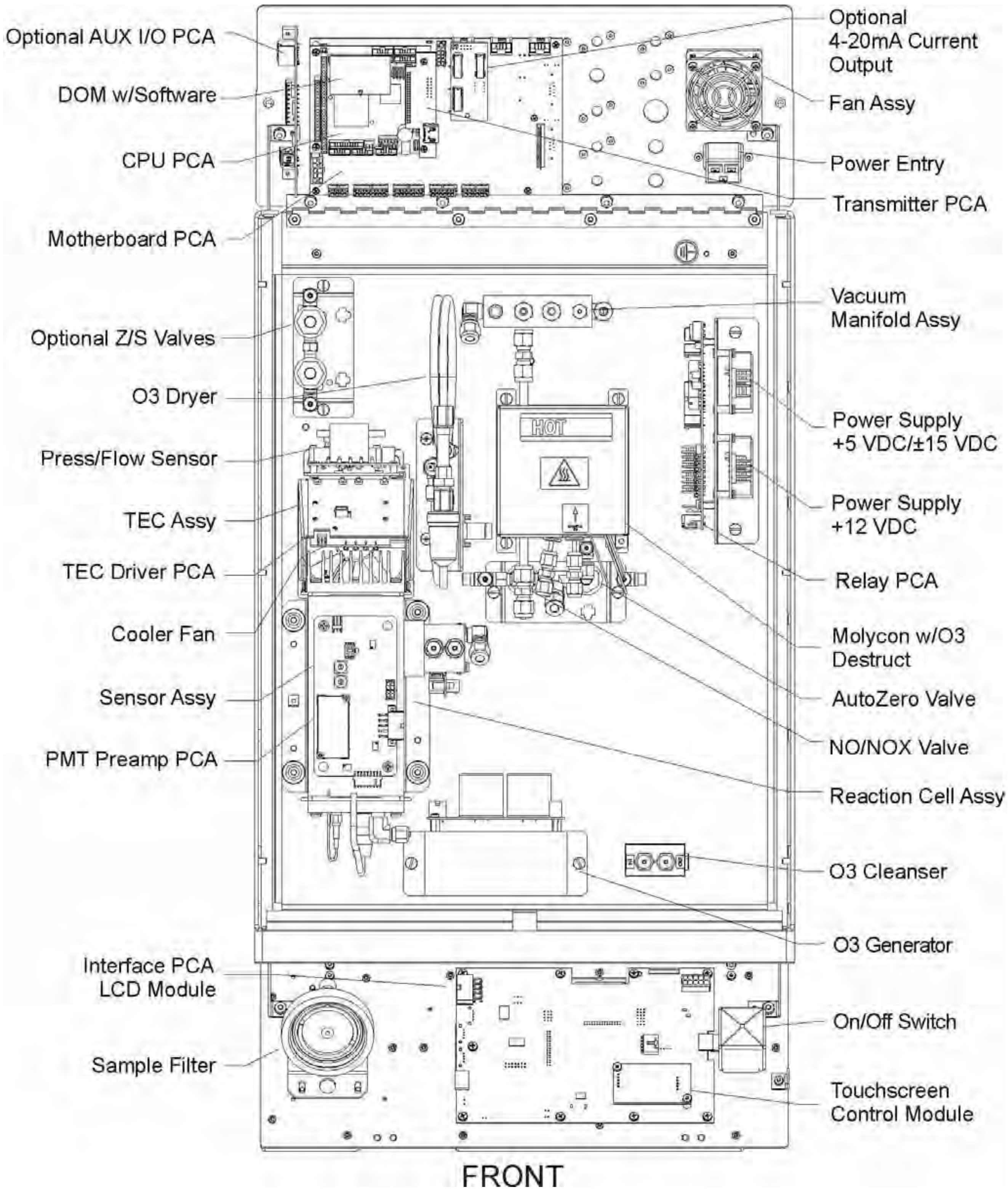


Figure 3-5: Internal Layout – Top View with IZS Option

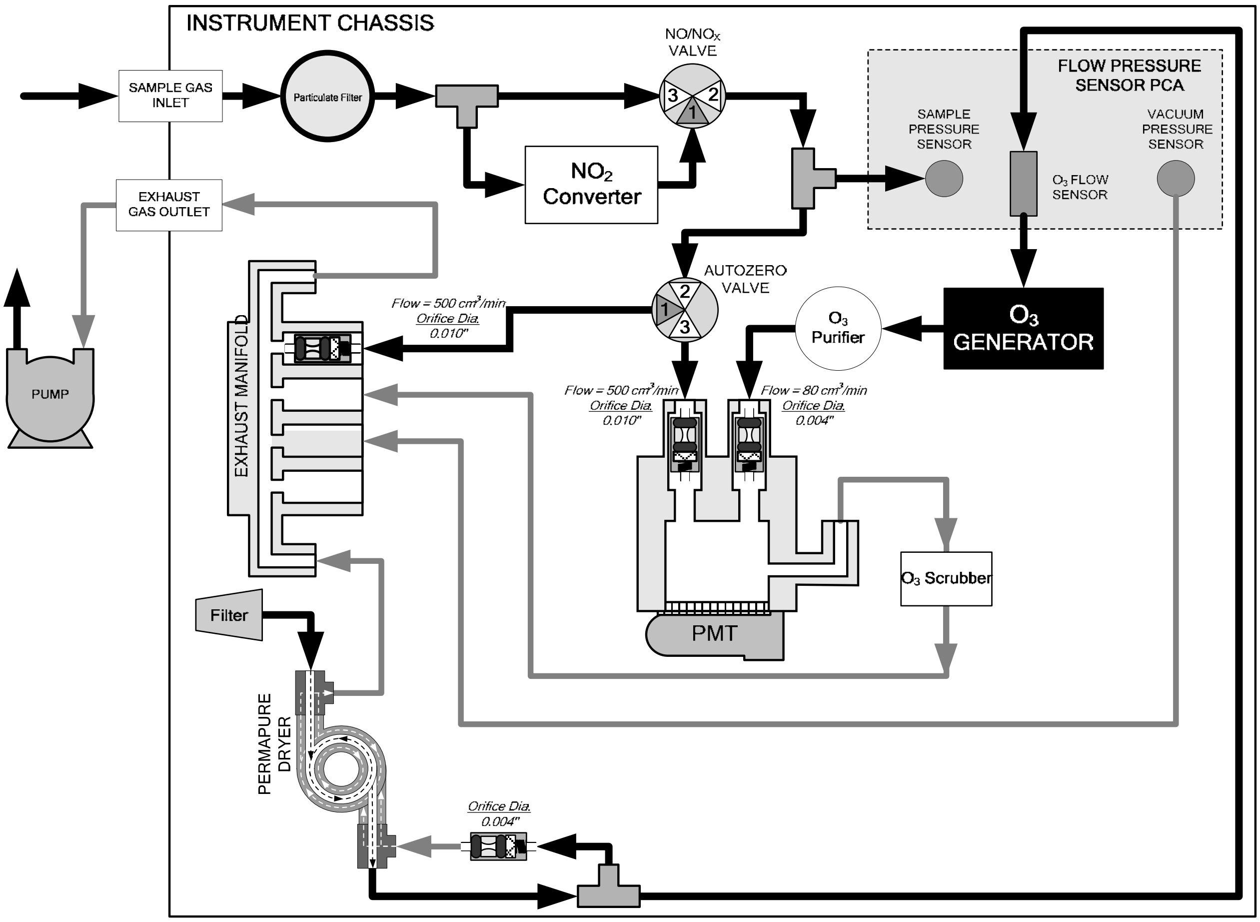


Figure 3-6: Pneumatic Diagram – Basic T200

NOTE
For pneumatic diagrams of Model T200's with various calibration valve options see Section 5.

3.4. UNPACKING THE T200 ANALYZER

CAUTION

GENERAL SAFETY HAZARD

To avoid personal injury, always use two persons to lift and carry the T200.

CAUTION – Avoid Warranty Invalidation

Printed circuit assemblies (PCAs) are sensitive to electro-static discharges too small to be felt by the human nervous system. Damage resulting from failure to use ESD protection when working with electronic assemblies will void the instrument warranty.

See *A Primer on Electro-Static Discharge* in this manual for more information on preventing ESD damage.

CAUTION

ELECTRICAL SHOCK HAZARD

Never disconnect PCAs, wiring harnesses or electronic subassemblies while under power.

CAUTION!

Do not operate this instrument until you've removed dust plugs from SAMPLE and EXHAUST ports on the rear panel!

NOTE

It is recommended that you store shipping containers/materials for future use if/when the instrument should be returned to the factory for repair and/or calibration service. See Warranty section in this manual and shipping procedures on our Website at http://www.teledyne-api.com under Customer Support > Return Authorization.

1. Verify that there is no apparent external shipping damage. If damage has occurred, please advise the shipper first, then Teledyne API.
2. Included with your analyzer is a printed record of the final performance characterization performed on your instrument at the factory.
   - This record, titled *Final Test and Validation Data Sheet (P/N 04490)* is an important quality assurance and calibration record for this instrument.
   - It should be placed in the quality records file for this instrument.
3. Carefully remove the top cover of the analyzer and check for internal shipping damage.
4. Remove the setscrew located in the top, center of the Front panel.
   - Slide the cover backwards until it clears the analyzer's front bezel.
   - Lift the cover straight up.

5. Inspect the interior of the instrument to ensure all circuit boards and other components are in good shape and properly seated.
6. Check the connectors of the various internal wiring harnesses and pneumatic hoses to ensure they are firmly and properly seated.
7. Verify that all of the optional hardware ordered with the unit has been installed. These are listed on the paperwork accompanying the analyzer.

3.4.1. VENTILATION CLEARANCE

Whether the analyzer is set up on a bench or installed into an instrument rack, be sure to leave sufficient ventilation clearance.

Table 3-3: Ventilation Clearance

AREA	MINIMUM REQUIRED CLEARANCE
Back of the instrument	**10 cm / 4 in**
Sides of the instrument	**2.5 cm / 1 in**
Above and below the instrument	**2.5 cm / 1 in**

Various rack mount kits are available for this analyzer. See Section 5.2 for more information.

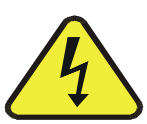
3.5. ELECTRICAL CONNECTIONS

NOTE

To maintain compliance with EMC standards, it is required that the cable length be no greater than 3 meters for all I/O connections, which include Analog In, Analog Out, Status Out, Control In, Ethernet/LAN, USB, RS-232, and RS-485.

3.5.1. POWER CONNECTION

Attach the power cord to the analyzer and plug it into a power outlet capable of carrying at least 10 A current at your AC voltage and that it is equipped with a functioning earth ground.



CAUTION

ELECTRICAL SHOCK HAZARD

High Voltages are present inside the analyzers case.

Power connection must have functioning ground connection.

Do not defeat the ground wire on power plug.

Turn off analyzer power before disconnecting or connecting electrical subassemblies.

Do not operate with cover off.

CAUTION

GENERAL SAFETY HAZARD

The T200 analyzer can be configured for both 100-130 V and 210-240 V at either 47 or 63 Hz.

To avoid damage to your analyzer, ensure that the AC power voltage matches the voltage indicated on the analyzer's model/specs label (Figure 3-4) before plugging the T200 into line power.

3.5.2. ANALOG INPUTS (OPTION) CONNECTIONS

The Analog In connector is used for connecting external voltage signals from other instrumentation (such as meteorological instruments) and for logging these signals in the analyzer's internal DAS. The input voltage range for each analog input is 0-10 VDC.

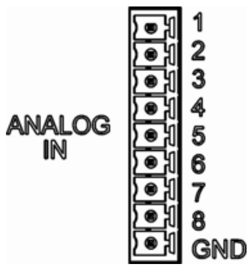


Figure 3-7: Analog In Connector

Pin assignments for the Analog In connector are presented in Table 3-4.

Table 3-4: Analog Input Pin Assignments

PIN	DESCRIPTION	DAS PARAMETER[1]
1	Analog input # 1	AIN 1
2	Analog input # 2	AIN 2
3	Analog input # 3	AIN 3
4	Analog input # 4	AIN 4
5	Analog input # 5	AIN 5
6	Analog input # 6	AIN 6
7	Analog input # 7	AIN 7
8	Analog input # 8	AIN 8
GND	Analog input Ground	N/A
[1] See Section 8.1 for details on setting up the DAS.		

3.5.3. ANALOG OUTPUT CONNECTIONS

The T200 is equipped with several analog output channels accessible through a connector on the back panel of the instrument.

Output channels **A1**, **A2** and **A3** are assigned to the NO_x, NO and NO_2 concentration signals of the analyzer.

- The default analog output voltage setting of these channels is 0 to 5 VDC with a reporting range of 0 to 500 ppb.
- An optional Current Loop output is available for each.

The output labeled **A4** is special. It can be set by the user to output any one a variety of diagnostic test functions (see Section 8.4.6).

- The default analog output voltage setting of these channels is also 0 to 5 VDC.
- See Section 8.4.6 for a list of available functions and their associated reporting range.
- There is no optional Current Loop output available for Channel **A4**.

To access these signals attach a strip chart recorder and/or data-logger to the appropriate analog output connections on the rear panel of the analyzer. Pin-outs for the analog output connector are:

ANALOG OUT

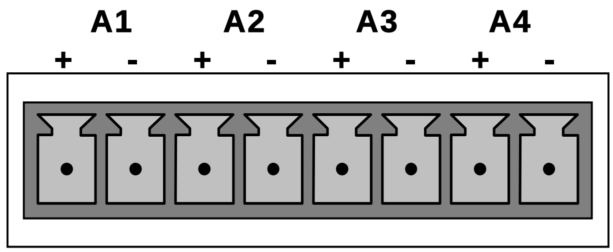


Figure 3-8: Analog Output Connector

Table 3-5: Analog Output Pin Outs

PIN	ANALOG OUTPUT	SIGNAL	STANDARD VOLTAGE OUTPUT	CURRENT LOOP OPTION
1	**A1**	NO_x **Concentration**	V Out	I Out +
2			Ground	I Out -
3	**A2**	**NO Concentration**	V Out	I Out +
4			Ground	I Out -
3	**A3**	NO_2 **Concentration**	V Out	I Out +
4			Ground	I Out -
7	**A4**[1]	**TEST CHANNEL**	V Out	Not Available
8			Ground	Not Available

To change the settings for the analog output channels, see Section 8.4.

3.5.4. CONNECTING THE STATUS OUTPUTS

The status outputs report analyzer conditions via optically isolated NPN transistors, which sink up to 50 mA of DC current. These outputs can be used interface with devices that accept logic-level digital inputs, such as Programmable Logic Controllers (PLCs). Each Status bit is an open collector output that can withstand up to 40 VDC. All of the emitters of these transistors are tied together and available at D.

> **NOTE**
>
> **Most PLC's have internal provisions for limiting the current that the input will draw from an external device. When connecting to a unit that does not have this feature, an external dropping resistor must be used to limit the current through the transistor output to less than 50 mA. At 50 mA, the transistor will drop approximately 1.2V from its collector to emitter.**

The status outputs are accessed via a 12-pin connector on the analyzer's rear panel labeled. Pin-outs for this connector are:

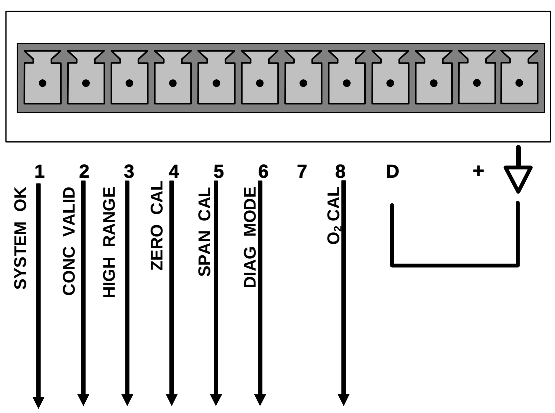


Figure 3-9: Status Output Connector

Table 3-6: Status Output Pin Assignments

OUTPUT #	STATUS DEFINITION	CONDITION
1	**SYSTEM OK**	On if no faults are present.
2	**CONC VALID**	On if O_3 concentration measurement is valid. If the O_3 concentration measurement is invalid, this bit is OFF.
3	**HIGH RANGE**	On if unit is in high range of DUAL or AUTO Range Modes.
4	**ZERO CAL**	On whenever the instrument is in **CALZ** mode.
5	**SPAN CAL**	On whenever the instrument is in **CALS** mode.
6	**DIAG MODE**	On whenever the instrument is in DIAGNOSTIC mode.
7-8	SPARE	
D	Emitter BUSS	The emitters of the transistors on pins 1 to 8 are bussed together.
	SPARE	
+	DC Power	+ 5 VDC, 300 mA source (combined rating with Control Output, if used).
	Digital Ground	The ground level from the analyzer's internal DC power supplies.

3.5.5. CONNECTING THE CONTROL INPUTS

The analyzer is equipped with three digital control inputs that can be used to activate the zero and span calibration modes remotely (see Section 10.1.2.4).

Access to these inputs is provided via an 8-pin connector labeled CONTROL IN on the analyzer’s rear panel.

Table 3-7: Control Input Pin Assignments

Input #	Status Definition	ON Condition
A	**REMOTE ZERO CAL**	The Analyzer is placed in Zero Calibration mode. The mode field of the display will read **ZERO CAL R**.
B	**REMOTE SPAN CAL**	The Analyzer is placed in Lo Span Calibration mode. The mode field of the display will read **SPAN CAL R**.
C, D, E & F	Spare	
⏚	Digital Ground	The ground level from the analyzer’s internal DC Power Supplies (same as chassis ground).
U	External Power input	Input pin for +5 VDC required to activate pins A – F.
+	5 VDC output	Internally generated 5V DC power. To activate inputs A – F, place a jumper between this pin and the “U” pin. The maximum amperage through this port is 300 mA (combined with the analog output supply, if used).

There are two methods for energizing the Control Inputs. The internal +5V available from the pin labeled “+” is the most convenient method however, to ensure that these inputs are truly isolated; a separate external 5 VDC power supply should be used.

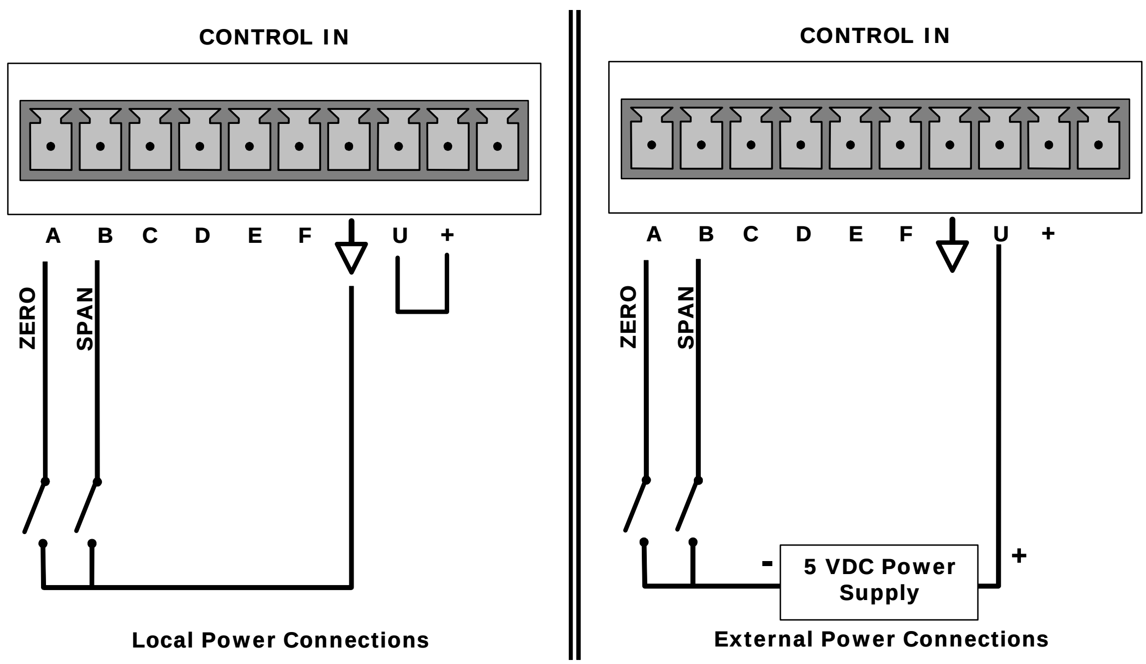


Figure 3-10: Energizing the T200 Control Inputs

3.5.6. CONNECTING THE SERIAL PORTS

For RS-232 communications through the serial interface COMM ports, refer to Section 9 for more information and instructions on configuration and usage.

For RS-485 communications, please contact the factory.

3.5.7. CONNECTING TO A LAN OR THE INTERNET

For network or Internet communication with the analyzer, connect an Ethernet cable from the analyzer's rear panel Ethernet interface connector to an Ethernet port. The analyzer is shipped with DHCP enabled by default. This allows the instrument to be connected to a network or router with a DHCP server. The instrument will automatically be assigned an IP address by the DHCP server. This configuration is useful for quickly getting an instrument up and running on a network. However, for permanent Ethernet connections, a static IP address should be used by manual configuration.

For automatic configuration (default), see Section 9.4.1.

For manual configuration, see Section 9.4.2.

3.5.8. CONNECTING TO A PERSONAL COMPUTER (PC)

The USB option can be used for direct communication between the analyzer and a PC; connect a USB cable between the analyzer and computer USB ports. Baud rates must match: check the baud rate on either the computer or the instrument and change the other to match (see Section 9.1.4). This USB connection can only be used when the **COM2** port is not in use except for RS-232 Multidrop communication.

3.5.9. CONNECTING TO A MULTIDROP NETWORK

If your unit has a Teledyne API RS-232 multidrop card, see Section 5.6.3 for a description and Section 9.2 for instructions on setting it up.

3.6. PNENUMATIC CONNECTIONS

CAUTION

GENERAL SAFETY HAZARD

Do not vent calibration gas and sample gas into enclosed areas

Sample and calibration gases should only come into contact with PTFE tubing.

3.6.1. ABOUT ZERO AIR AND CALIBRATION GAS

3.6.1.1. Zero Air

Zero air or zero calibration gas is defined as a gas that is similar in chemical composition to the measured medium but without the gas to be measured by the analyzer.

For the T200 this means zero air should be devoid of NO, NO_2, CO_2, NH_3 or H_2O vapor.

NOTE

Moderate amounts of NH_3 and H_2O can be removed from the sample gas stream by installing the optional sample gas dryer/scrubber (see Section 6.5).

- If your application is not a measurement in ambient air, the zero calibration gas should be matched to the composition of the gas being measured.
- Pure nitrogen (N_2) could be used as a zero gas for applications where NO_X is measured in nitrogen.
- If your analyzer is equipped with an external zero air scrubber option, it is capable of creating zero air from ambient air.
- For analyzers without the external zero air scrubber, a zero air generator such as the Teledyne API's Model 701 can be used. Please visit the company website for more information.

3.6.1.2. Calibration (Span) Gas

Calibration gas is a gas specifically mixed to match the chemical composition of the type of gas being measured at near full scale of the desired reporting range. To measure NO_X with the T200 NO_X analyzer, it is recommended that you use a span gas with an NO concentration equal to 80% of the measurement range for your application

EXAMPLE:

- If the application is to measure NOX in ambient air between 0 ppm and 500 ppb, an appropriate span gas would be 400 ppb.
- If the application is to measure NOX in ambient air between 0 ppm and 1000 ppb, an appropriate span gas would be 800 ppb.

Even though NO gas in nitrogen could be used as a span gas, the matrix of the balance gas is different and may cause interference problems or yield incorrect calibrations.

- The same applies to gases that contain high concentrations of other compounds (for example, CO_2 or H_2O).
- The span gas should match all concentrations of all gases of the measured medium as closely as possible.

Cylinders of the following types of calibrated NO_x and NO gas traceable to NIST standards specifications (also referred to as EPA protocol calibration gases or Standard Reference Materials) are commercially available.

Table 3-8: NIST-SRM's Available for Traceability of NO_x Calibration Gases

NIST-SRM[4]	TYPE	NOMINAL CONCENTRATION
2627a	Nitric Oxide (NO) in N_2	5 ppm
2628a	Nitric Oxide (NO) in N_2	10 ppm
2629a	Nitric Oxide (NO) in N_2	20 ppm
1683b	Nitric Oxide (NO) in N_2	50 ppm
1684b	Nitric Oxide (NO) in N_2	100 ppm
1685b	Nitric Oxide (NO) in N_2	250 ppm
1686b	Nitric Oxide (NO) in N_2	5000 ppm
1687b	Nitric Oxide (NO) in N_2	1000 ppm
2630	Nitric Oxide (NO) in N_2	1500 ppm
2631a	Nitric Oxide (NO) in N_2	3000 ppm
2635	Nitric Oxide (NO) in N_2	800 ppm
2636a	Nitric Oxide (NO) in N_2	2000 ppm
2631a	Oxides of Nitrogen (NO_x) in N_2	2500 ppm
1684b	Oxides of Nitrogen (NO_x) in N_2	100 ppm

NOTE

The NO_2 permeation tube included with the T200's optional Internal Zero Air generator (IZS) has a limited accuracy of about ±5%.

While NO_2 permeation tubes may be sufficient for informal calibration checks, they are not approved by the US EPA as calibration sources for performing actual calibration of the analyzer.

CAUTION!

High amounts of NO_2 will progressively build up unless you remove the perm tube during periods of non-operation.

3.6.1.3. Span Gas for Multipoint Calibration

Some applications, such as EPA monitoring, require a multipoint calibration where span gases of different concentrations are needed. We recommend using an NO gas of higher concentration combined with a gas dilution calibrator such as a Teledyne API Model 700E. This type of calibrator mixes a high concentration gas with zero air to accurately produce span gas of the desired concentration. Linearity profiles can be automated with this model and run unattended overnight.

If a dynamic dilution system such as the Teledyne API Model 700 is used to dilute high concentration gas standards to low, ambient concentrations, ensure that the NO concentration of the reference gas matches the dilution range of the calibrator.

Choose the NO gas concentration so that the dynamic dilution system operates in its mid-range and not at the extremes of its dilution capabilities.

EXAMPLE:

- A dilution calibrator with 10-10000 dilution ratio will not be able to accurately dilute a 5000 ppm NO gas to a final concentration of 500 ppb, as this would operate at the very extreme dilution setting.
- A 100 ppm NO gas in nitrogen is much more suitable to calibrate the T200 analyzer (dilution ratio of 222, in the mid-range of the system's capabilities).

3.6.2. BASIC PNEUMATIC SETUP FOR THE T200 ANALYZER

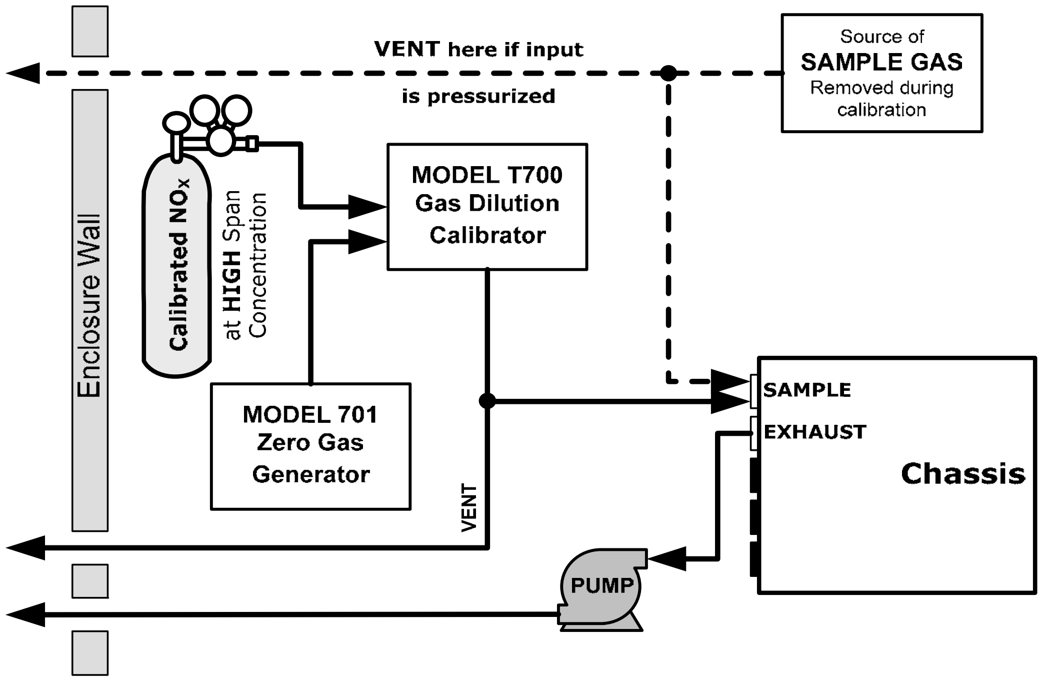


Figure 3-11: Gas Line Connections from Calibrator – Basic T200 Configuration

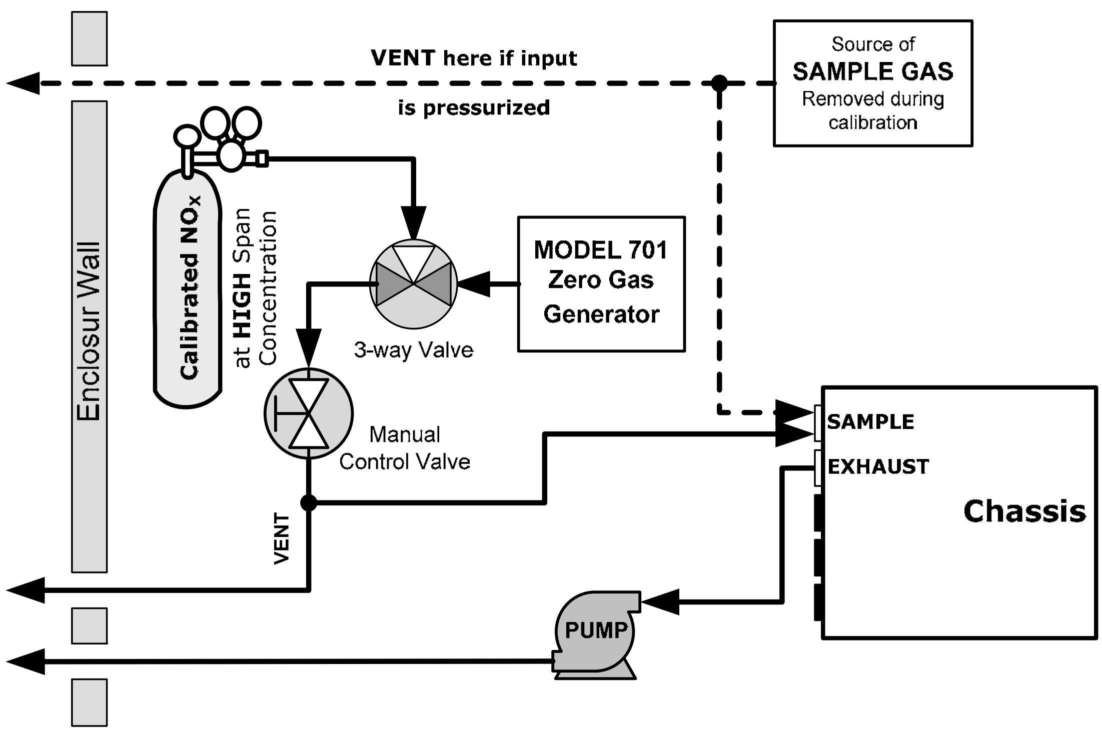


Figure 3-12: Gas Line Connections from Bottled Span Gas – Basic T200 Configuration

For the T200 nitrogen oxides analyzer in its basic configuration, attach the following pneumatic lines:

SAMPLE GAS SOURCE: CONNECT A SAMPLE GAS LINE TO THE SAMPLE INLET

- Use PTFE tubing; minimum O.D ¼"
- Sample Gas pressure must equal ambient atmospheric pressure (1.0 psig)
- In applications where the sample gas is received from a pressurized manifold and the analyzer is not equipped with one of the T200's pressurized span options, a vent must be placed on the sample gas line. This vent line must be:
    - No more than 10 meters long.
    - Vented outside the shelter or immediate area surrounding the instrument.

CALIBRATION GAS SOURCES:

- **CAL GAS & ZERO AIR SOURCES**: The source of calibration gas is also attached to the **SAMPLE** inlet, but only when a calibration operation is actually being performed.
- Use PTFE tubing; minimum O.D ¼".

VENTING: IN ORDER TO PREVENT BACK DIFFUSION AND PRESSURE EFFECTS, BOTH THE SPAN GAS AND ZERO AIR SUPPLY LINES SHOULD BE:

- Vented outside the enclosure.
- Minimum O.D ¼".
- Not less than 2 meters in length.
- Not greater than 10 meters in length.

EXHAUST OUTLET: ATTACH AN EXHAUST LINE TO THE EXHAUST OUTLET FITTING. THE EXHAUST LINE SHOULD BE:

- Use PTFE tubing; minimum O.D ¼".
- A maximum of 10 meters long.
- Vented outside the T200 analyzer's enclosure

NOTE

Once the appropriate pneumatic connections have been made, check all pneumatic fittings for leaks using the procedures defined in Sections 13.3.12.1 (or 13.3.12.2 for detailed check if leak suspected).

NOTE

For information on attaching gas lines to Model T200's with various calibration valve options, see Section 6.

3.7. INITIAL OPERATION

CAUTION!

If the presence of ozone is detected at any time, call Teledyne API Customer Service as soon as possible:

800-324-5190 or email: api-customerservice@teledyne.com

If you are unfamiliar with the T200 theory of operation, we recommend that you read Section 12.

For information on navigating the analyzer's software menus, see the menu trees described in Appendix A.1.

3.7.1. START UP

After the electrical and pneumatic connections are made, an initial functional check is in order. Turn on the instrument. The pump and exhaust fan should start immediately. The display will show a splash screen and other information during the initialization process while the CPU loads the operating system, the firmware and the configuration data.

The analyzer should automatically switch to Sample Mode after completing the boot-up sequence and start monitoring the gas. However, there is an approximately one hour warm-up period before reliable gas measurements can be taken. During the warm-up period, the front panel display may show messages in the parameters (Param) field.

Once the CPU has completed this activity, it will begin loading the analyzer firmware and configuration data. The analyzer should automatically switch to SAMPLE mode after completing the boot-up sequence and start monitoring NO_x, NO and NO_2 gases.

3.7.2. WARNING MESSAGES

Because internal temperatures and other conditions may be outside the specified limits during the analyzer's warm-up period, the software will suppress most warning conditions for 30 minutes after power up. If warning messages persist after the 30 minutes warm up period is over, investigate their cause using the troubleshooting guidelines in Section 14.1.

To view and clear warning messages, press:

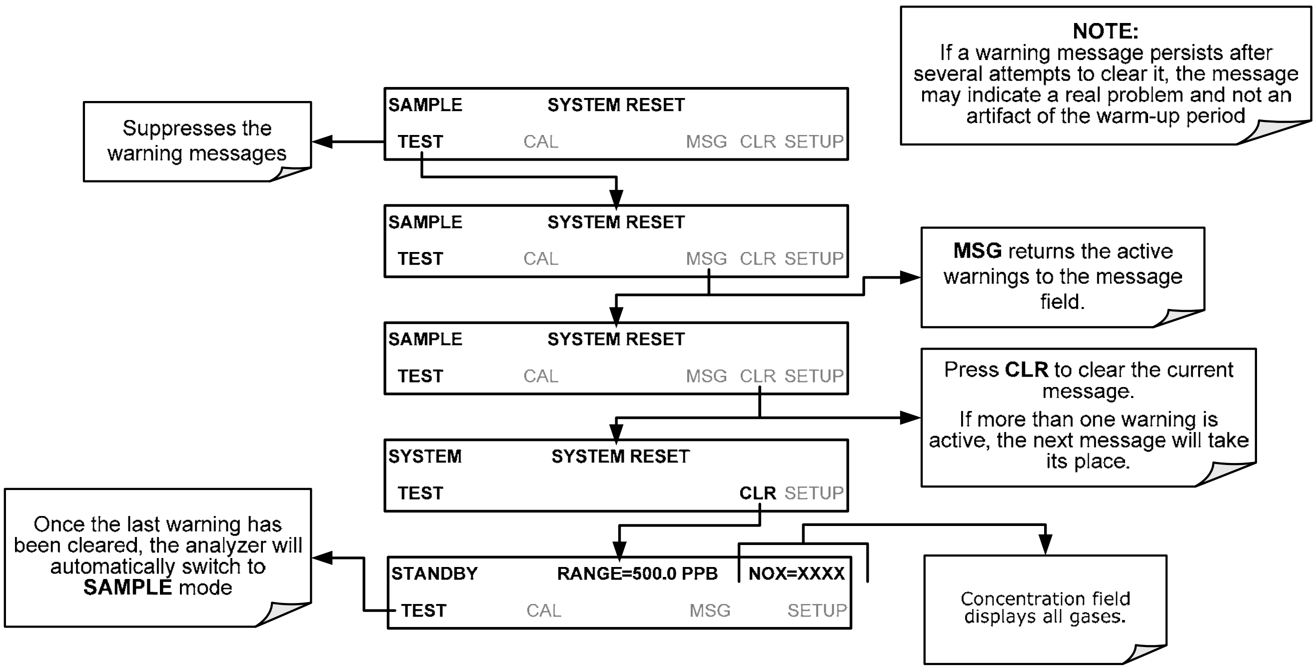


Table 3-9 lists brief descriptions of the warning messages that may occur during start up.

Table 3-9: Possible Warning Messages at Start-Up

MESSAGE	MEANING
SYSTEM RESET[1]	The computer has rebooted.
ANALOG CAL WARNING	The A/D or at least one D/A channel have not been calibrated.
BOX TEMP WARNING	The temperature inside the T200 chassis is outside the specified limits.
CANNOT DYN SPAN[2]	Contact closure span calibration failed while *DYN_SPAN* was set to *ON*.
CANNOT DYN ZERO[3]	Contact closure zero calibration failed while *DYN_ZERO* was set to *ON*.
CONFIG INITIALIZED	Configuration storage was reset to factory configuration or erased.
DATA INITIALIZED	DAS data storage was erased before the last power up occurred.
OZONE FLOW WARNING	Ozone gas flow is too high or too low for accurate NO_x, NO and NO_2 readings.
OZONE GEN OFF [4]	Ozone generator is off. This is the only warning message that automatically clears itself. It clears itself when the ozone generator is turned on. Upon power up the Ozone generator will remain off for 30 minutes. This allows the perma-pure dryer to reach its working dew point.
RCELL PRESS WARN	Reaction cell pressure is too high or too low for accurate NO_x, NO and NO_2 readings.
RCELL TEMP WARNING	Reaction cell temperature is too high or too low for accurate NO_x, NO and NO_2 readings.
IZS TEMP WARNING [5]	IZS temperature is too high or too low for efficient O_3 production.
CONV TEMP WARNING	NO_2 to NO Converter temperature too high or too low to efficiently convert NO_2 to NO.
PMT TEMP WARNING	PMT temperature outside of warning limits specified by *PMT_SET* variable.
AZERO WARN *[XXXX]* MV	AutoZero reading too high. The value shown in message indicates auto-zero reading at time warning was displayed.
HVPS WARNING	High voltage power supply output is too high or too low for proper operation of the PMT.
REAR BOARD NOT DET	CPU unable to communicate with motherboard..
RELAY BOARD WARN	CPU is unable to communicate with the relay PCA.
SAMPLE FLOW WARN	The flow rate of the sample gas is outside the specified limits.

[1] Clears 45 minutes after power up.
[2] Clears the next time successful zero calibration is performed.
[3] Clears the next time successful span calibration is performed.
[4] Clears 30 minutes after power up.
[5] Only Appears if the IZS option is installed.

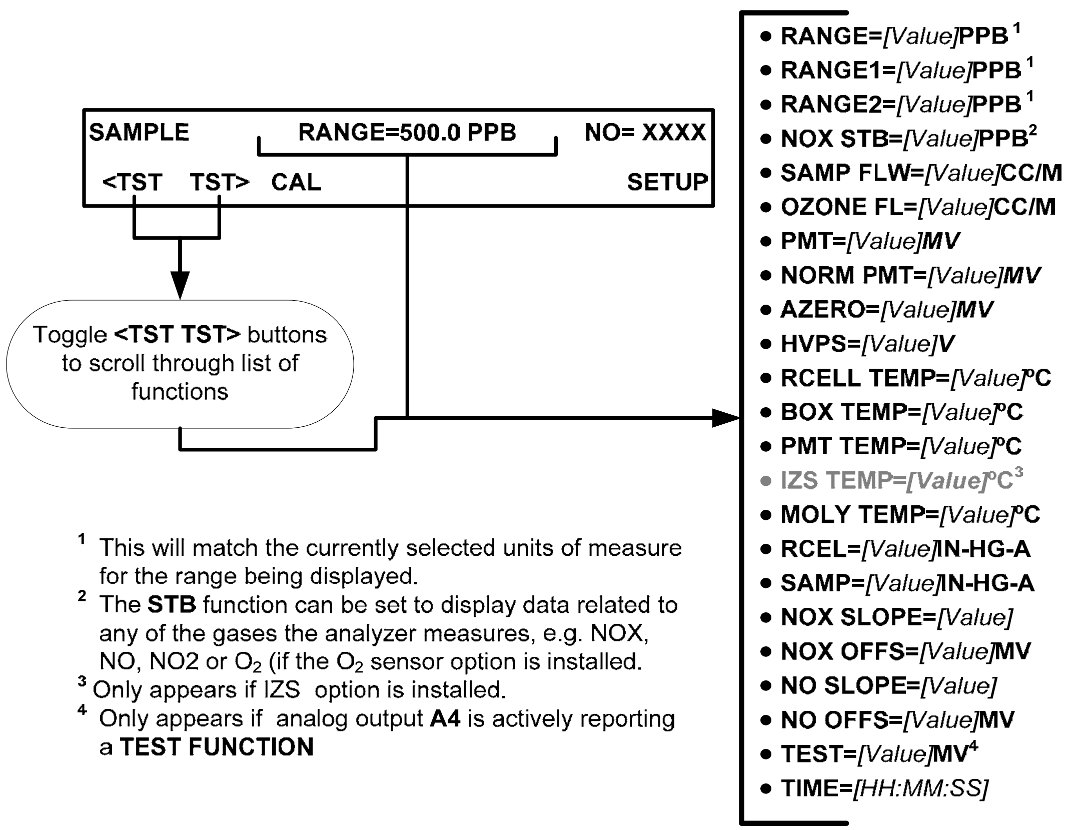
3.7.3. FUNCTIONAL CHECK

After the analyzer's components have warmed up for at least 30 minutes, verify that the software properly supports any hardware options that are installed.

For information on navigating through the analyzer's software menus, see the menu trees described in Appendix A.1.

1. Check to ensure that the analyzer is functioning within allowable operating parameters.
    - Appendix C includes a list of test functions viewable from the analyzer's front panel as well as their expected values.
    - These functions are also useful tools for diagnosing problems with your analyzer.
    - The enclosed Final Test and Validation Data sheet (P/N 04409) lists these values before the instrument left the factory.

To view the current values of these parameters press the following button sequence on the analyzer's front panel. Remember until the unit has completed its warm up these parameters may not have stabilized.



3.8. INITIAL CALIBRATION OF THE T200 ANALYZER

To perform the following calibration you must have sources for zero air and calibration (span) gas available for input into the inlet/outlet fittings on the back of the analyzer (see Section 3.6.1).

> **NOTE**
> **A start-up period of 4-5 hours is recommended prior to performing a calibration on the analyzer.**

The method for performing an initial calibration for the T200 nitrogen oxides analyzer differs slightly depending on the whether or not any of the available internal zero air or valve options are installed.

- See Section 3.8.2 for instructions for initial calibration of the T200 analyzers in their base configuration.
- See Section 10.3 for instructions for initial calibration of T200 analyzers possessing an optional Internal Span Gas Generator (OPT 51A).
- See Section 10.4 for information regarding setup and calibration of T200 analyzers with Z/S Valve options.
- If you are using the T200 analyzer for EPA monitoring, only the calibration method described in Section 11 should be used.

3.8.1. INTERFERENTS FOR NOX, NO AND NO2 MEASUREMENTS

The chemiluminescence method for detecting NO_X is subject to interference from a number of sources including water vapor (H_2O), ammonia (NH_3), sulfur dioxide (SO_2) and carbon dioxide (CO_2) but the T200 has been designed to reject most of these interferences.

- Ammonia is the most common interferent, which is converted to NO in the analyzer's NO_2 converter and creates a NO_X signal artifact.
  - If the T200 is installed in an environment with high ammonia, steps should be taken to remove the interferent from the sample gas before it enters the reaction cell.
  - Teledyne API offers a sample gas conditioning option to remove ammonia and water vapor (Section 6.5).
- Carbon dioxide diminishes the NO_X signal when present in high concentrations.
  - If the analyzer is used in an application with excess CO_2, contact Teledyne API's Customer Service Department (see Section 14.9) for possible solutions.
- Excess water vapor can be removed with one of the dryer options described in Section 6.5. In ambient air applications, SO_2 interference is usually negligible.

For more detailed information regarding interferents for NO_x, NO and NO_2 measurement, see Section 12.1.5.

3.8.2. INITIAL CALIBRATION PROCEDURE FOR T200 ANALYZERS WITHOUT OPTIONS

The following procedure assumes that:

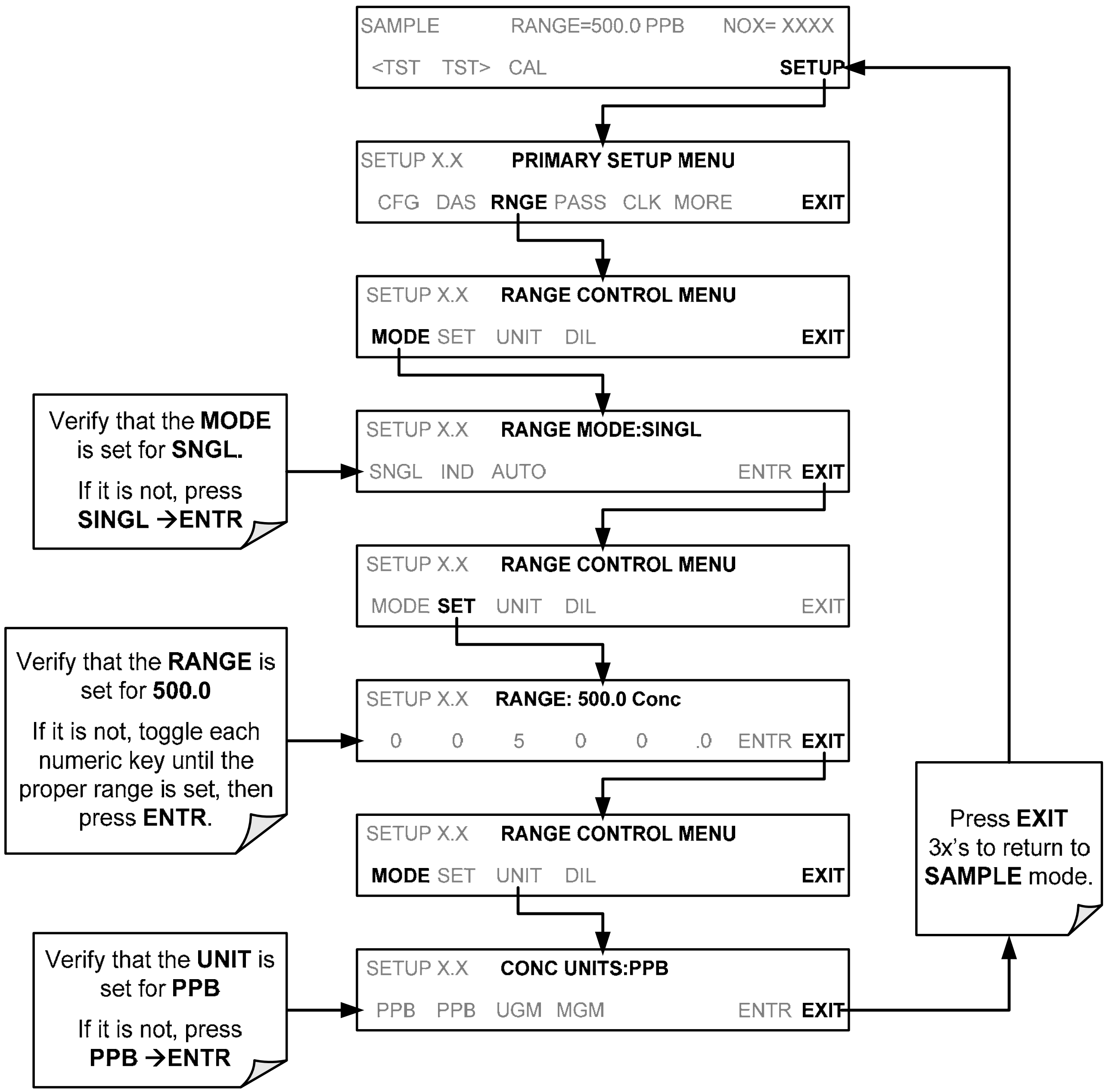
- The instrument DOES NOT have any of the available calibration valve or gas inlet options installed;
- Cal gas will be supplied through the SAMPLE gas inlet on the back of the analyzer and;
- The pneumatic setup matches that described in Section 3.6.2.

3.8.2.1. Verifying the T200 Reporting Range Settings

While it is possible to perform the following procedure with any range setting we recommend that you perform this initial checkout using following reporting range settings:

- Unit of Measure: PPB
- Reporting Range: 500 ppb
- Mode Setting: SNGL

While these are the default setting for the T200 analyzer, it is recommended that you verify them before proceeding with the calibration procedure, by pressing:



3.8.2.2. Verify the Expected NO_x and NO Span Gas Concentration

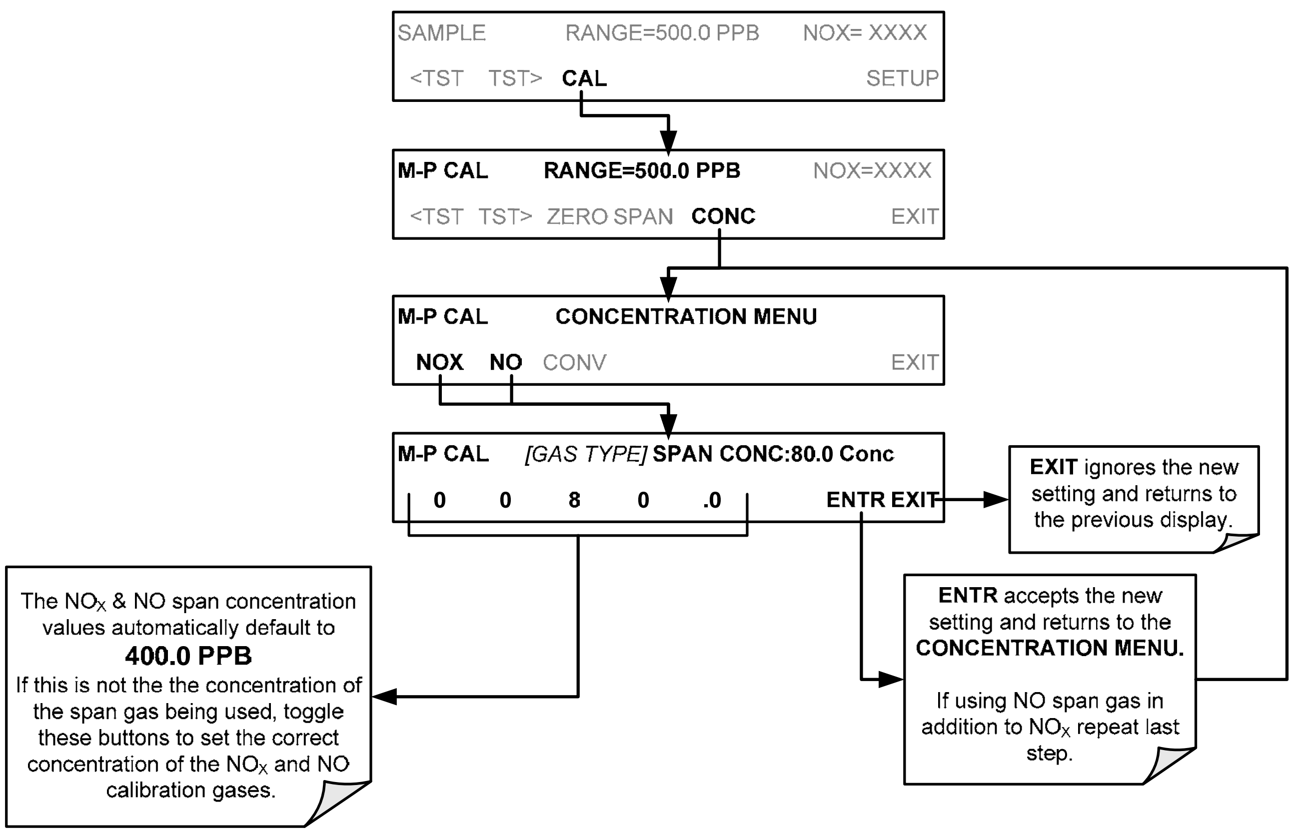
NOTE

For this initial calibration, it is important to verify the PRECISE Concentration Value of the SPAN gases independently.

If you supply NO gas to the analyzer, the values for expected NO and NO_x MUST be identical.

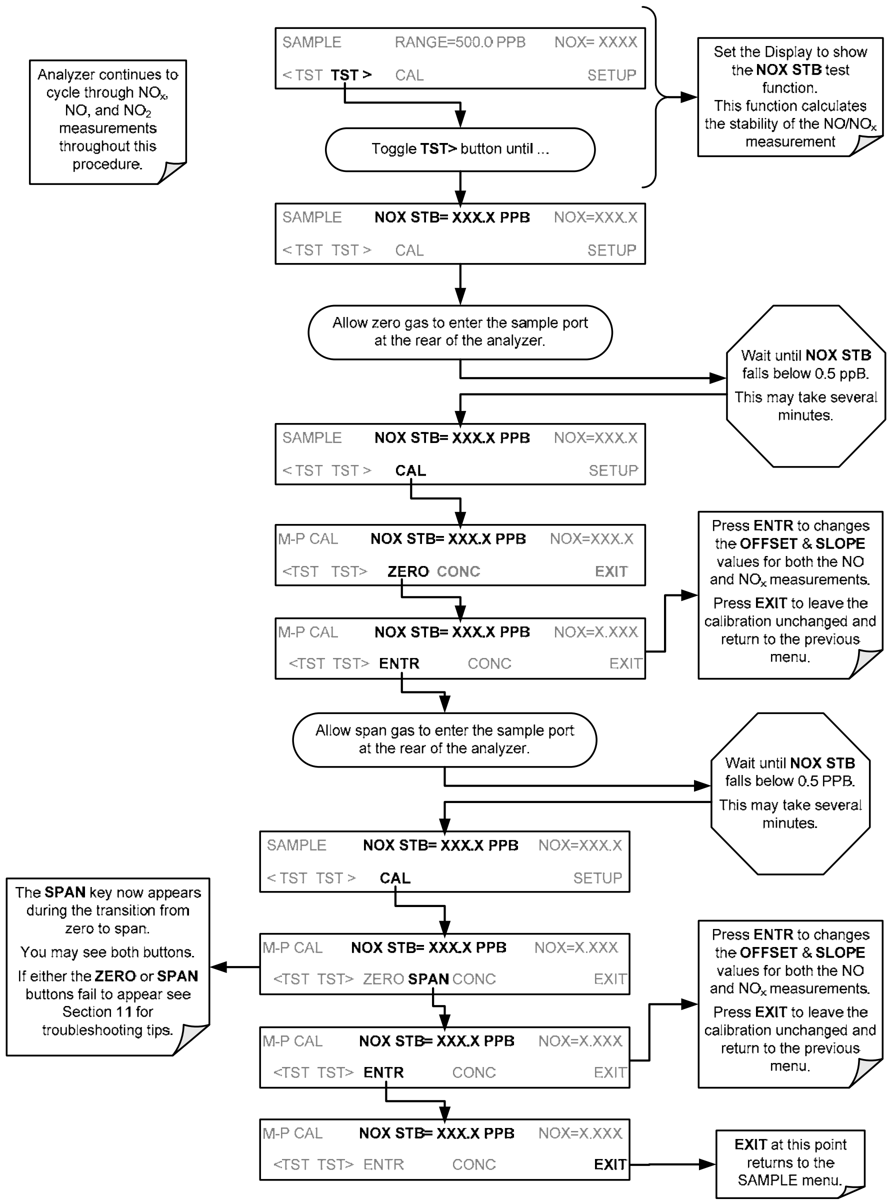
The NO_x and NO span concentration values automatically defaults to **400.0 PPB** and it is recommended that calibration gases of that concentration be used for the initial calibration of the unit.

To verify that the analyzer span setting is set for **400 PPB**, press:



3.8.2.3. Initial Zero/Span Calibration Procedure

To perform an initial Calibration of the T200 nitrogen oxides analyzer, press:



The T200 Analyzer is now ready for operation.

NOTE

Once you have completed the above set-up procedures, please fill out the Quality Questionnaire that was shipped with your unit and return it to Teledyne API.

This information is vital to our efforts in continuously improving our service and our products.

THANK YOU

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4. FREQUENTLY ASKED QUESTIONS AND GLOSSARY

4.1. FAQ'S

The following list was compiled from the Teledyne API's Customer Service Department's 10 most commonly asked questions relating to the T200 NOx Analyzer.

Q: Why does the **ENTR** button sometimes disappear on the front panel display?

A: Sometimes the **ENTR** button will disappear if you select a setting that is invalid or out of the allowable range for that parameter, such as trying to set the 24-hour clock to 25:00:00 or a range to less than 1 or more than 20000 ppb. Once you adjust the setting to an allowable value, the **ENTR** button will re-appear.

Q: Why is the **ZERO** or **SPAN** button not displayed during calibration?

A: The T200 disables certain these buttons expected span or zero value entered by the users is too different from the gas concentration actually measured value at the time. This is to prevent the accidental recalibration of the analyzer to an out-of-range response curve.

EXAMPLE: The span set point is 400 ppb but gas concentration being measured is only 50 ppb.

Q: How do I enter or change the value of my Span Gas?

A: Press the **CONC** button found under the **CAL** or **CALS** buttons of the main SAMPLE display menus to enter the expected NO_x span concentration.

See Section 10.2.3.1 or for more information.

Q: Can I automate the calibration of my analyzer?

A: Any analyzer with zero/span valve or IZS option can be automatically calibrated using the instrument's AutoCal feature.

Q: Can I use the IZS option to calibrate the analyzer?

A: Yes. However, the accuracy of the IZS option's permeation tube is only ±5%. Whereas this may be acceptable for basic calibration checks, the IZS option is not permitted as a calibration source in applications following US EPA protocols.

To achieve highest accuracy, it is recommended to use cylinders of calibrated span gases in combination with a zero air source.

Q: How do I measure the sample flow?

A: Sample flow is measured by attaching a calibrated flow meter to the sample inlet port when the instrument is operating. The sample flow should be 500 cm^3/min ±10%. Section 13.3.12.3 includes detailed instructions on performing a check of the sample gas flow.

Q: Can I use the DAS system in place of a strip chart recorded or data logger?

A: Yes. Section 8.1. describes the setup and operation of the DAS system in detail.

Q: How often do I need to change the particulate filter?

A: Once per week or as needed. Section 13 contains a maintenance schedule listing the most important, regular maintenance tasks. Highly polluted sample air may require more frequent changes.

Q: How long does the sample pump last?

A: The sample pump should last one to two years and the pump head should be replaced when necessary. Use the **RCEL** pressure indicator on the front panel to see if the pump needs replacement. If this value goes above 10 in-Hg-A, on average, the pump head needs to be rebuilt.

Q: Why does my RS-232 serial connection not work?

A: There are many possible reasons:

1) The wrong cable, please use the provided or a generic “straight-through” cable (do not use a “null-modem” type cable),

2) The DCE/DTE switch on the back of the analyzer is not set properly; ensure that both green and red lights are on,

3) The baud rate of the analyzer’s COMM port does not match that of the serial port of your computer/data logger.

See Section 9.1 for more information.

Q: How do I make the instrument’s display and my data logger agree?

A: This most commonly occurs when an independent metering device is used besides the data logger/recorded to determine gas concentration levels while calibrating the analyzer. These disagreements result from the analyzer, the metering device and the data logger having slightly different ground levels.

Use the data logger itself as the metering device during calibration procedures.

Q: Do the critical flow orifices of my analyzer require regular replacement?

A: No. The o-rings and the sintered filter associated with them require replacement once a year, but the critical flow orifices do not.

See Section 13 for instructions.

Q: How do I set up and use the Contact Closures (Control Inputs) on the Rear Panel of the analyzer?

A: See Section 3.5.5.

4.2. GLOSSARY

Term	Description/Definition
10BaseT	an Ethernet standard that uses twisted (“T”) pairs of copper wires to transmit at 10 megabits per second (Mbps)
100BaseT	same as 10BaseT except ten times faster (100 Mbps)
APICOM	name of a remote control program offered by Teledyne-API to its customers
ASSY	*Assembly*
CAS	*Code-Activated Switch*
CD	*Corona Discharge*, a frequently luminous discharge, at the surface of a conductor or between two conductors of the same transmission line, accompanied by ionization of the surrounding atmosphere and often by a power loss
CE	*Converter Efficiency*, the percentage of the total amount that is actually converted (e.g., light energy into electricity; NO_2 into NO, etc.)
CEM	*Continuous Emission Monitoring*
Chemical formulas that may be included in this document:	
CO_2	carbon dioxide
C_3H_8	propane
CH_4	methane
H_2O	water vapor
HC	general abbreviation for hydrocarbon
HNO_3	nitric acid
H_2S	hydrogen sulfide
NO	nitric oxide
NO_2	nitrogen dioxide
NO_X	nitrogen oxides, here defined as the sum of NO and NO_2
NO_y	nitrogen oxides, often called odd nitrogen: the sum of NO_X plus other compounds such as HNO_3 (definitions vary widely and may include nitrate (NO_3), PAN, N_2O and other compounds as well)
NH_3	ammonia
O_2	molecular oxygen
O_3	ozone
SO_2	sulfur dioxide
cm^3	metric abbreviation for *cubic centimeter* (replaces the obsolete abbreviation “cc”)
CPU	*Central Processing Unit*
DAC	*Digital-to-Analog Converter*
DAS	*Data Acquisition System*
DCE	*Data Communication Equipment*

Term	Description/Definition
DFU	*Dry Filter Unit*
DHCP	*Dynamic Host Configuration Protocol.* A protocol used by LAN or Internet servers to automatically set up the interface protocols between themselves and any other addressable device connected to the network
DIAG	*Diagnostics*, the diagnostic settings of the analyzer.
DOM	*Disk On Module,* a 44-pin IDE flash drive with up to 128MB storage capacity for instrument's firmware, configuration settings and data
DOS	*Disk Operating System*
DRAM	*Dynamic Random Access Memory*
DR-DOS	*Digital Research DOS*
DTE	*Data Terminal Equipment*
EEPROM	*Electrically Erasable Programmable Read-Only Memory* also referred to as a FLASH chip or drive
ESD	*Electro-Static Discharge*
ETEST	*Electrical Test*
Ethernet	a standardized (IEEE 802.3) computer networking technology for local area networks (LANs), facilitating communication and sharing resources
FEP	*Fluorinated Ethylene Propylene* polymer, one of the polymers that Du Pont markets as *Teflon*®
Flash	non-volatile, solid-state memory
FPI	*Fabry-Perot Interface*: a special light filter typically made of a transparent plate with two reflecting surfaces or two parallel, highly reflective mirrors
GFC	*Gas Filter Correlation*
I^2C bus	a clocked, bi-directional, serial bus for communication between individual analyzer components
IC	*Integrated Circuit*, a modern, semi-conductor circuit that can contain many basic components such as resistors, transistors, capacitors etc in a miniaturized package used in electronic assemblies
IP	*Internet Protocol*
IZS	*Internal Zero Span*
LAN	*Local Area Network*
LCD	*Liquid Crystal Display*

Term	Description/Definition
LED	*Light Emitting Diode*
LPM	*Liters Per Minute*
MFC	*Mass Flow Controller*
M/R	*Measure/Reference*
NDIR	*Non-Dispersive Infrared*
MOLAR MASS	the mass, expressed in grams, of 1 mole of a specific substance. Conversely, one mole is the amount of the substance needed for the molar mass to be the same number in grams as the atomic mass of that substance. EXAMPLE: The atomic weight of Carbon is 12 therefore the molar mass of Carbon is 12 grams. Conversely, one mole of carbon equals the amount of carbon atoms that weighs 12 grams. Atomic weights can be found on any Periodic Table of Elements.
NDIR	*Non-Dispersive Infrared*
NIST-SRM	*National Institute of Standards and Technology - Standard Reference Material*
PC	*Personal Computer*
PCA	P*rinted Circuit Assembly*, the PCB with electronic components, ready to use
PC/AT	*Personal Computer / Advanced Technology*
PCB	*Printed Circuit Board*, the bare board without electronic component
PFA	*Per-Fluoro-Alkoxy*, an inert polymer; one of the polymers that *Du Pont* markets as *Teflon*®
PLC	*Programmable Logic Controller*, a device that is used to control instruments based on a logic level signal coming from the analyzer
PLD	*Programmable Logic Device*
PLL	*Phase Lock Loop*
PMT	*Photo Multiplier Tube*, a vacuum tube of electrodes that multiply electrons collected and charged to create a detectable current signal
P/N (or PN)	*Part Number*
PSD	*Prevention of Significant Deterioration*
PTFE	*Poly-Tetra-Fluoro-Ethylene*, a very inert polymer material used to handle gases that may react on other surfaces; one of the polymers that *Du Pont* markets as *Teflon*®
PVC	*Poly Vinyl Chloride*, a polymer used for downstream tubing
Rdg	Reading
RS-232	specification and standard describing a serial communication method between DTE (Data Terminal Equipment) and DCE (Data Circuit-terminating Equipment) devices, using a maximum cable-length of 50 feet

Term	Description/Definition
RS-485	specification and standard describing a binary serial communication method among multiple devices at a data rate faster than RS-232 with a much longer distance between the host and the furthest device
SAROAD	*Storage and Retrieval of Aerometric Data*
SLAMS	*State and Local Air Monitoring Network Plan*
SLPM	*Standard Liters Per Minute* of a gas at standard temperature and pressure
STP	*Standard Temperature and Pressure*
TCP/IP	*Transfer Control Protocol / Internet Protocol*, the standard communications protocol for Ethernet devices
TEC	*Thermal Electric Cooler*
TPC	*Temperature/Pressure Compensation*
USB	*Universal Serial Bus*: a standard connection method to establish communication between peripheral devices and a host controller, such as a mouse and/or keyboard and a personal computer or laptop
VARS	*Variables*, the variable settings of the instrument
V-F	*Voltage-to-Frequency*
Z/S	*Zero / Span*

5. NON-GAS RELATED OPTIONAL HARDWARE AND SOFTWARE

This section and the next include brief descriptions of the hardware and software options available for the T200 nitrogen oxides analyzer. For assistance with ordering these options, please contact Teledyne API's Sales at:

TOLL-FREE:	**800-324-5190**
FAX:	**858-657-9816**
TEL:	**858-657-9800**
E-MAIL:	**api-sales@teledyne.com**
WEB SITE:	**www.teledyne-api.com**

5.1. OPTIONAL PUMPS (OPT 11A, OPT 11B, OPT 12A, OPT 12B & OPT 12C)

A variety of external pumps are available for the T200 analyzer. The range of available pump options meets all typical AC power supply standards while exhibiting the same pneumatic performance.

OPTION NUMBER	DESCRIPTION
11A	Ship without pump
11B	Pumpless, external Pump Pack/Rack
12A	Internal Pump 115V @ 60Hz
12B	Internal Pump 220V @ 60Hz
12C	Internal Pump 220V @ 50Hz

5.2. RACK MOUNT KITS (OPT 20A, OPT 20B, OPT 21 & OPT 23)

There are several options for mounting the analyzer in standard 19" racks. The slides are three-part extensions, one mounts to the rack, one mounts to the analyzer chassis and the middle part remains on the rack slide when the analyzer is taken out. The analyzer locks into place when fully extended and cannot be pulled out without pushing two buttons, one on each side.

The rack mount brackets for the analyzer require that you have a support structure in your rack to support the weight of the analyzer. The brackets cannot carry the full weight of an analyzer and are meant only to fix the analyzer to the front of a rack, preventing it from sliding out of the rack accidentally.

OPTION NUMBER	DESCRIPTION
20A	Rack mount brackets with 26 in. (660 mm) chassis slides.
20B	Rack mount brackets with 24 in. (610 mm) chassis slides.
21	Rack mount brackets only (No slides)
23	Rack Mount for External Pump Pack (No Slides)

5.3. CARRYING STRAP/HANDLE (OPT 29)

The chassis of the T200 analyzer allows the user to attach a strap handle for carrying the instrument. The handle is located on the right side and pulls out to accommodate a hand for transport. When pushed in, the handle is nearly flush with the chassis, only protruding out about 9 mm (3/8”).

Installing the strap handle prevents the use of the rack mount slides, although the rack mount brackets, OPT 21, can still be used.

CAUTION

GENERAL SAFETY HAZARD

A fully loaded T200 with valve options weighs about 18 kg (40 pounds).

To avoid personal injury We recommend two persons lift and carry the analyzer.

Ensure to disconnect all cables and tubing from the analyzer before carrying it.

5.4. CURRENT LOOP ANALOG OUTPUTS (OPT 41)

A current loop option is available and can be installed as a retrofit for each of the analog outputs of the analyzer . This option converts the DC voltage analog output to a current signal with 0-20 mA output current. The outputs can be scaled to any set of limits within that 0-20 mA range. However, most current loop applications call for either 2-20 mA or 4-20 mA range. All current loop outputs have a +5% over-range. Ranges with the lower limit set to more than 1 mA (e.g., 2-20 or 4-20 mA) also have a -5% under-range,

Figure 5-1 provides installation instructions and illustrates a sample combination of one current output and two voltage outputs configuration. Section 5.4.1 provides instructions for converting current loop analog outputs to standard 0-to-5 VDC outputs. Information on calibrating or adjusting these outputs can be found in Section 8.4.3.5.

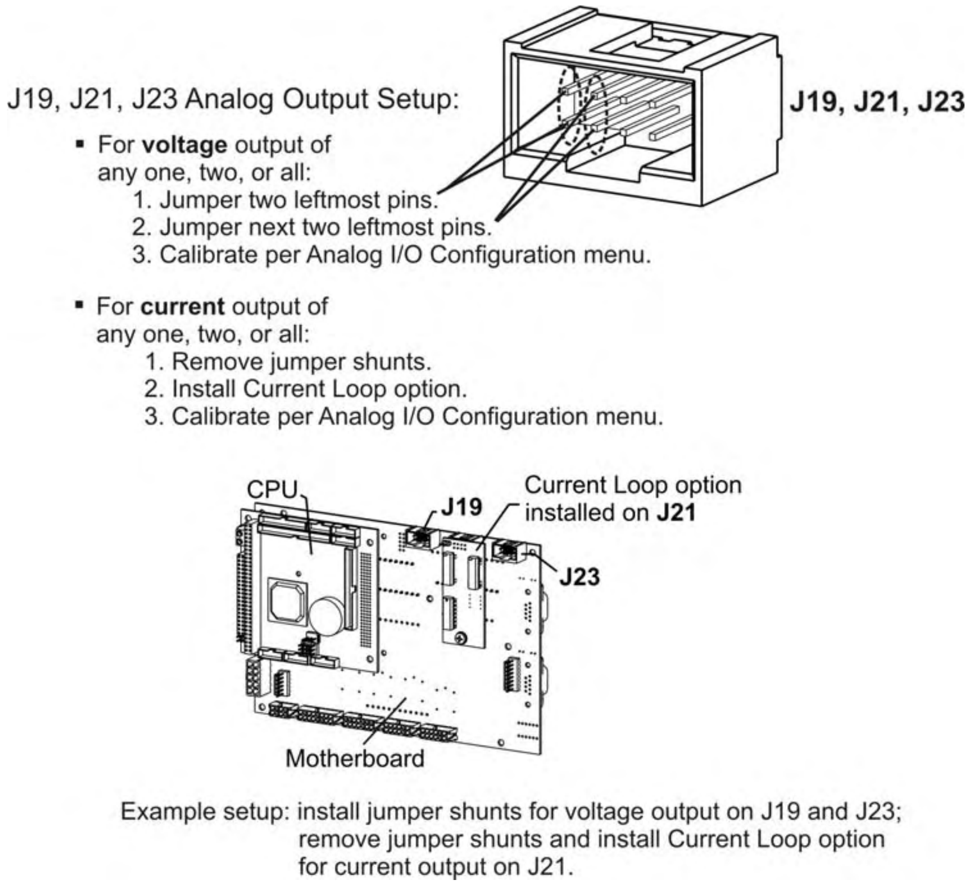

Figure 5-1: Current Loop Option Installed

5.4.1. CONVERTING CURRENT LOOP ANALOG OUTPUTS TO STANDARD VOLTAGE OUTPUTS

> **NOTE**
>
> **See Section 15 for more information on preventing ESD damage.**

To convert an output configured for current loop operation to the standard 0 to 5 VDC output operation:

1. Turn off power to the analyzer.
2. If a recording device was connected to the output being modified, disconnect it.
3. Remove the top cover.
   - Remove the set screw located in the top, center of the rear panel.
   - Remove the screws fastening the top cover to the unit (one per side).
   - Slide the cover back and lift the cover straight up.
4. Remove the screw holding the current loop option to the motherboard.
5. Disconnect the current loop option PCA from the appropriate connector on the motherboard (see Figure 5-1).
6. Each connector, J19 and J23, requires two shunts. Place one shunt on the two left most pins and the second shunt on the two adjacent pins (see Figure 5-1).
7. Reattach the top case to the analyzer.
8. The analyzer is now ready to have a voltage-sensing, recording device attached to that output.

5.5. SPARE PARTS KITS

5.5.1. T200 EXPENDABLES KIT (OPT 42A)

This kit includes a recommended set of expendables for one year of operation of the T200 including replacement sample particulate filters. See Appendix B for a detailed listing of the contents.

5.5.2. ZERO AIR SCRUBBER ZERO AIR MAINTENANCE KIT (OPT 43)

This kit includes the items needed to refurbish the external zero air scrubber that is included.

Table 5-1: Contents of Zero Air Scrubber Maintenance Kit

T-API PART NO.	DESCRIPTION
005960000	Activated Charcoal refill
005970000	Purafil Chemisorbant® refill
FL0000001	Sintered Filter for critical orifice port
FL0000003	Replacement particulate filter for zero air inlet fitting
OR0000001	O-Rings (qty: 2) for critical flow orifice(s)

5.6. COMMUNICATION OPTIONS

5.6.1. SERIAL COMMUNICATIONS CABLES (OPT 60A, 60B, 60C, & 60D)

For remote serial, network and Internet communications with the analyzer, the following cables are available:

Option	Type	Description
60A	RS-232	Shielded, straight-through DB-9F to DB-25M cable, about 1.8 m long. Used to interface with older computers or code activated switches with a DB-25 serial connectors.
60B	RS-232	Shielded, straight-through DB-9F to DB-9F cable of about 1.8 m length.
60C	Ethernet	Patch cable, 2 meters long.
60D	USB	Cable for connection between rear panel USB port and laptop computer.

5.6.2. CONCENTRATION ALARM RELAY (OPTION 61)

The Teledyne API "E" series analyzers have an option for four (4) "dry contact" relays on the rear panel of the instrument. This relay option is different from and in addition to the "Contact Closures" that come standard on all TAPI instruments. The relays have 3 pins that have connections on the rear panel (refer Figure 5-2). They are a Common (C), a Normally Open (NO), & a Normally Closed (NC) pin.

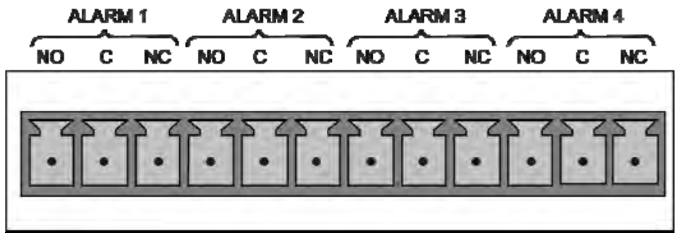

Figure 5-2: Concentration Alarm Relay

Alarm 1	"System OK 2"
Alarm 2	"Conc 1"
Alarm 3	"Conc 2"
Alarm 4	"Range Bit"

"Alarm 1" Relay

Alarm 1 which is "System OK 2" (system OK 1, is the status bit) is in the energized state when the instrument is "OK" & there are no warnings. If there is a warning active or if the instrument is put into the "DIAG" mode, Alarm 1 will change states. This alarm has "reverse logic" meaning that if you put a meter across the Common & Normally Closed pins on the connector you will find that it is OPEN when the instrument is OK. This is so that if the instrument should turn off or loose power, it will change states & you can record this with a data logger or other recording device.

"Alarm 2" Relay & "Alarm 3" Relay

The "Alarm 2 Relay" on the rear panel, is associated with the "Concentration Alarm 1" set point in the software & the "Alarm 3 Relay" on the rear panel is associated with the "Concentration Alarm 2" set point in the software.

Alarm 2 Relay	NO Alarm 1 = xxx PPM
Alarm 3 Relay	NO_2 Alarm 2 = xxx PPM
Alarm 2 Relay	NO_X Alarm 1 = xxx PPM
Alarm 3 Relay	NO_X Alarm 2 = xxx PPM

The Alarm 2 Relay will be turned on any time the concentration set-point is exceeded & will return to its normal state when the concentration value goes back below the concentration set-point.

Even though the relay on the rear panel is a NON-Latching alarm & resets when the concentration goes back below the alarm set point, the warning on the front panel of the instrument will remain latched until it is cleared. You can clear the warning on the front panel by either pushing the CLR button on the front panel or through the serial port.

In instruments that sample more than one gas type, there could be more than one gas type triggering the Concentration 1 Alarm (“Alarm 2” Relay). For example, the T200 instrument can monitor both NO & NO_2 gas. The software for this instrument is flexible enough to allow you to configure the alarms so that you can have 2 alarm levels for each gas.

NO Alarm 1 = 20 PPM
NO Alarm 2 = 100 PPM
NO_2 Alarm 1 = 20 PPM
NO_2 Alarm 2 = 100 PPM

In this example, NO Alarm 1 & NO_2 Alarm 1 will both be associated with the “Alarm 2” relay on the rear panel. This allows you do have multiple alarm levels for individual gases.

A more likely configuration for this would be to put one gas on the “Alarm 1” relay & the other gas on the “Alarm 2” relay.

NO Alarm 1 = 20 PPM
NO Alarm 2 = Disabled
NO_2 Alarm 1 = Disabled
NO_2 Alarm 2 = 100 PPM

“Alarm 4” Relay

This relay is connected to the “range bit”. If the instrument is configured for “Auto Range” & the instrument goes up into the high range, it will turn this relay on.

5.6.3. RS-232 MULTIDROP (OPT 62)

This option consists of a printed circuit assembly (PCA) card that enables Multidrop operation. If your unit has a Teledyne API RS-232 Multidrop card installed, refer to Section 9.2 for configuration instructions. Each unit in the multidrop chain will require this card (Option 62), and a cable (Option 60B).

5.7. SPECIAL FEATURES

5.7.1. MAINTENANCE MODE SWITCH

Teledyne API's analyzers are equipped with a switch that places the instrument in maintenance mode. When present, the switch is accessed by opening the hinged front panel and is located on the rearward facing side of the display/touchscreen driver PCA; on the left side; near the particulate filter.

When in maintenance mode the instrument ignores all commands received via the COMM ports that alter the operation state of the instrument. This includes all calibration commands, diagnostic menu commands and the reset instrument command. The instrument continues to measure concentration and send data when requested.

This feature is of particular use for instruments connected to multidrop or Hessen protocol networks. Call Customer Service for activation.

5.7.2. SECOND LANGUAGE SWITCH

Teledyne API's analyzers are equipped with a switch that activates an alternate set of display messages in a language other than the instrument’s default language. This switch is accessed by opening the hinged front panel and is located on the rearward facing side of the display/touchscreen driver PCA; on the right side.

To activate this feature, the instrument must also have a specially programmed Disk on Module (DOM) containing the second language. Contact Teledyne API's Customer Service Department (see Section 14.9) personnel for more information.

5.7.3. DILUTION RATIO OPTION

The dilution ratio feature is a software option that is designed for applications where the sample gas is diluted before being analyzed by the T200. Typically this occurs in continuous emission monitoring (CEM) applications where the quality of gas in a smoke stack is being tested and the sampling method used to remove the gas from the stack dilutes the gas.

Once the degree of dilution is known, this feature allows the user to add an appropriate scaling factor to the analyzer's NO, NO_2 and NO_x concentration calculations so that the measurement range and concentration values displayed on the instrument's front panel display and reported via the instruments various outputs reflect the undiluted values.

Contact Teledyne API's' Customer Service Department (see Section 14.9) personnel for information on activating this feature.

Instructions for using the dilution ratio option can be found in Section 7.4.5.

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6. GAS INLET AND CALIBRATION VALVE OPTIONS

The T200 NO_x analyzer can be equipped with a variety of option packages for controlling and managing the flow of calibration gases through the analyzer. These option packages include variations for handling pressurized and non-pressurized zero air and span gas supplied from external sources as well as internally generated span gas.

Table 6-1: List of T200 Calibration Gas Options

OPT NO.	DESCRIPTION	MANUAL SECTION
50A	**AMBIENT ZERO AND AMBIENT SPAN VALVES** • Zero Air and Span Gas input supplied at ambient pressure. • Gases controlled by 2 internal valves; SAMPLE/CAL & ZERO/SPAN.	6.1,
50B	**AMBIENT ZERO AND PRESSURIZED SPAN VALVES** • Span Gas input from external, pressurized source; • Span Gas flow rate maintained at 1 ATM by critical flow orifice & vented through VENT port. • SHUTOFF valve stops flow of Span Gas when in sample mode to preserve pressurized gas source. • Zero Air created via 2-stage scrubber & DFU. • Gases controlled by 2 internal valves; SAMPLE/CAL & ZERO/SPAN.	6.2
50G	**ZERO SCRUBBER AND INTERNAL SPAN SOURCE (IZS)** • Span Gas generated from internal NO_2 permeation tube • Zero Air created by 2-stage scrubber & DFU. • Gases controlled by 2 internal valves; SAMPLE/CAL & ZERO/SPAN.	6.3
86A	**AMMONIA REMOVAL SAMPLE CONDITIONER** A permeation gas exchange tube is inserted into the sample gas stream to remove H_2O and NH_3.	6.5
86C	**EXTERNAL ZERO AIR SCRUBBER FOR Z/S VALVES** Zero air supplied from a 2-stage Zero Air scrubber attached to the analyzer's zero gas inlet.	6.6
52B, 52G	**Replacement Perm Tubes**	6.4

The state of all valves related to the options packages described in this Section can be controlled in a variety of ways:

- Manually via the analyzer's front panel touchscreen;
- By activating the instrument's AutoCal feature (See Section 10.5);
- Remotely by using either the External Digital I/O Control Inputs (See Section 3.5.5), or the RS-232/485 Serial I/O ports (See Section 9.1.8).

6.1. AMBIENT ZERO/AMBIENT SPAN VALVES (OPT 50A)

This valve package includes:

- Two solenoid valves located inside the analyzer that allow the user to switch either zero, span or sample gas to the instrument's sensor.
- Two additional gas inlet ports (**ZERO AIR** and **SPAN1**).

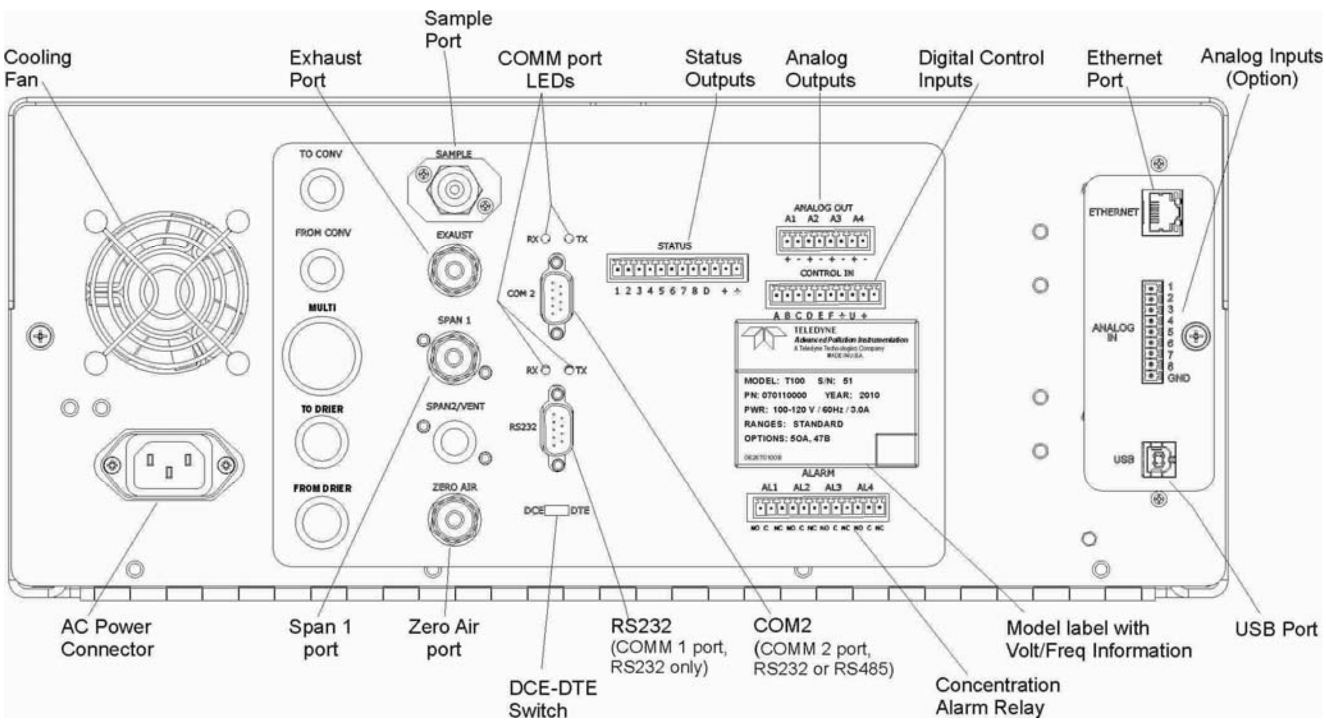


Figure 6-1: Rear Panel Layout with Z/S Valve Options (OPT 50A)

6.1.1.1. Internal Pneumatics (OPT 50A)

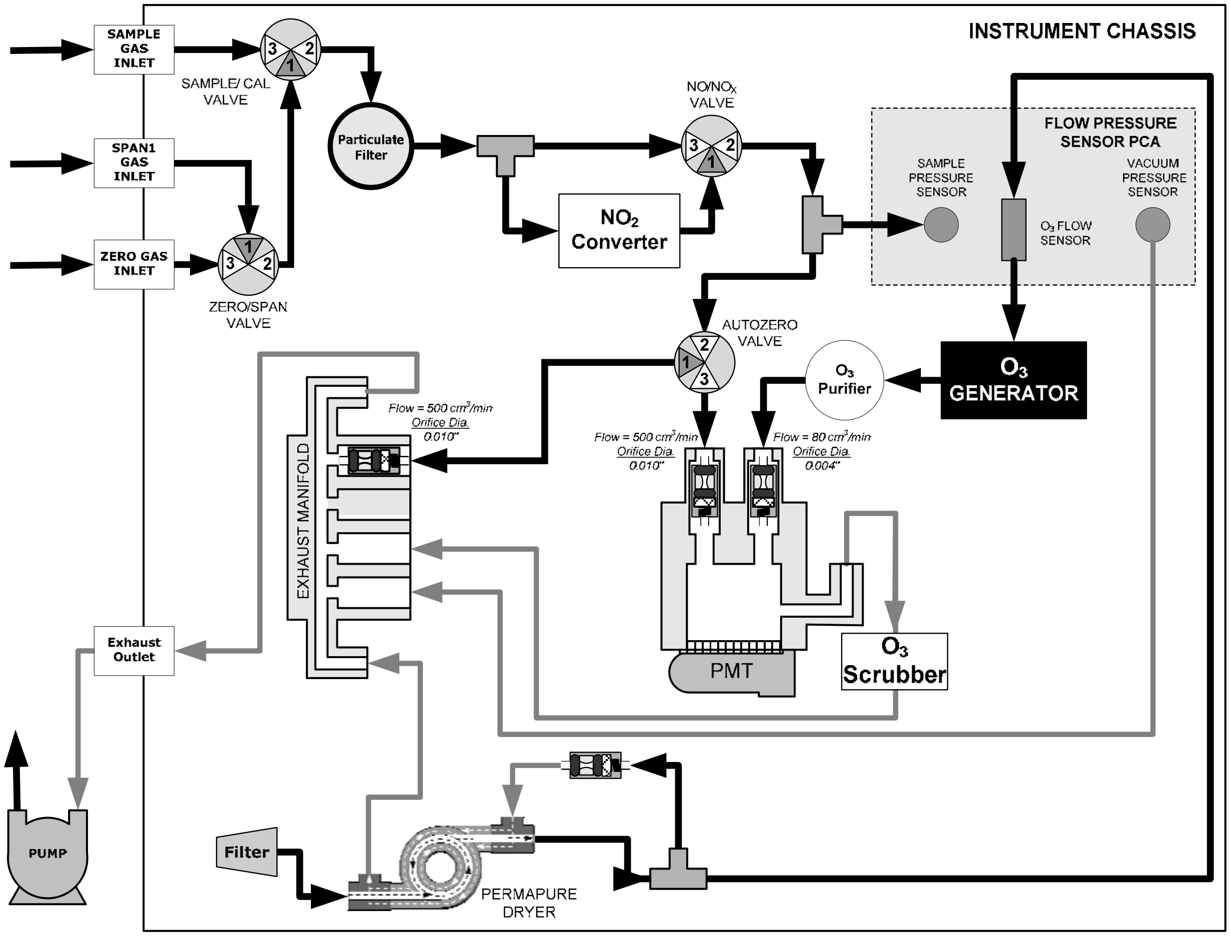


Figure 6-2: Pneumatic Diagram with Z/S Valves OPT 50A

Table 6-2: Zero/Span Valve Operating States OPT 50A

MODE	VALVE	CONDITION	VALVE PORT STATUS
SAMPLE	Sample/Cal	Open to SAMPLE inlet	**3 → 2**
	Zero/Span	Open to ZERO AIR inlet	**3 → 2**
ZERO CAL	Sample/Cal	Open to ZERO/SPAN Valve	**1 → 2**
	Zero/Span	Open to ZERO AIR inlet	**3 → 2**
SPAN CAL	Sample/Cal	Open to ZERO/SPAN Valve	**1 → 2**
	Zero/Span	Open to SPAN inlet	**1 → 2**

6.1.1.2. Pneumatic Setup (OPT 50A)

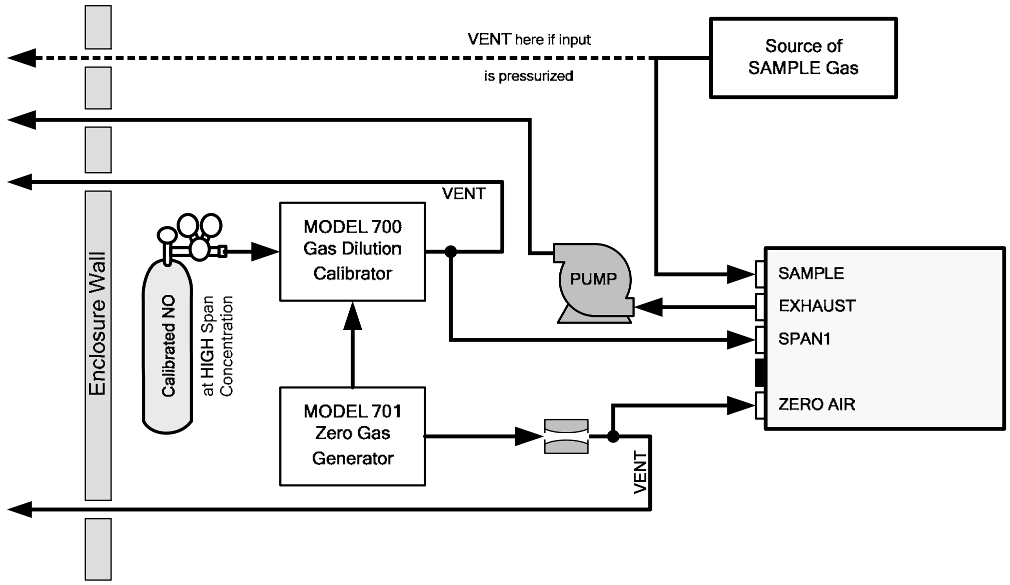


Figure 6-3: Gas Line Connections for T200 with Z/S Valves Option (OPT 50A)

SAMPLE GAS SOURCE: Attach a sample inlet line to the SAMPLE inlet fitting**.**

- Use PTFE tubing; minimum O.D ¼".
- Sample Gas pressure must equal ambient atmospheric pressure (no greater than 1.0 psig).
- In applications where the sample gas is received from a pressurized manifold, a vent must be placed on the sample gas line. This vent line must be no more than 10 meters long.

CALIBRATION GAS SOURCES:

SPAN GAS Attach a gas line from the source of calibration gas (e.g. a Teledyne API's M700E Dynamic Dilution Calibrator) to the **SPAN1** inlet (see Figure 6-1). Use PTFE tubing; minimum O.D ¼".

ZERO AIR Zero air is supplied by the zero air generator such as a Teledyne API's M701.

- Attach a gas line from the source of zero air to the **ZERO AIR** inlet.

VENTING: In order to prevent back diffusion and pressure effects, both the span gas and zero air supply lines should be:

- Vented outside the enclosure.
- Not less than 2 meters in length.
- Not greater than 10 meters in length.

EXHAUST OUTLET: Attach an exhaust line to the **EXHAUST OUTLET** fitting. The exhaust line should be:

- ¼" PTFE tubing.
- A maximum of 10 meters long.
- Vented outside the T200 analyzer's enclosure.

NOTE

Once the appropriate pneumatic connections have been made, check all pneumatic fittings for leaks using the procedures defined in Section 13.3.12.

To find instructions on calibrating a T200 with this option installed, see section 10.4.

6.2. AMBIENT ZERO/PRESSURIZED SPAN VALVES (OPT 50B)

This calibration valve package is appropriate for applications where Span Gas is being supplied from a pressurized source such as bottled NIST SRM gases. This option includes:

- A critical flow orifice and vent that maintains the Span Gas supply at 1 ATM.
- A SHUTOFF valve to preserve the Span Gas source when it is not in use.
- Two solenoid valves located inside the analyzer that allow the user to switch either zero, span or sample gas to the instrument's sensor.
- Three additional gas inlet ports (**ZERO AIR, SPAN** and **VENT**).

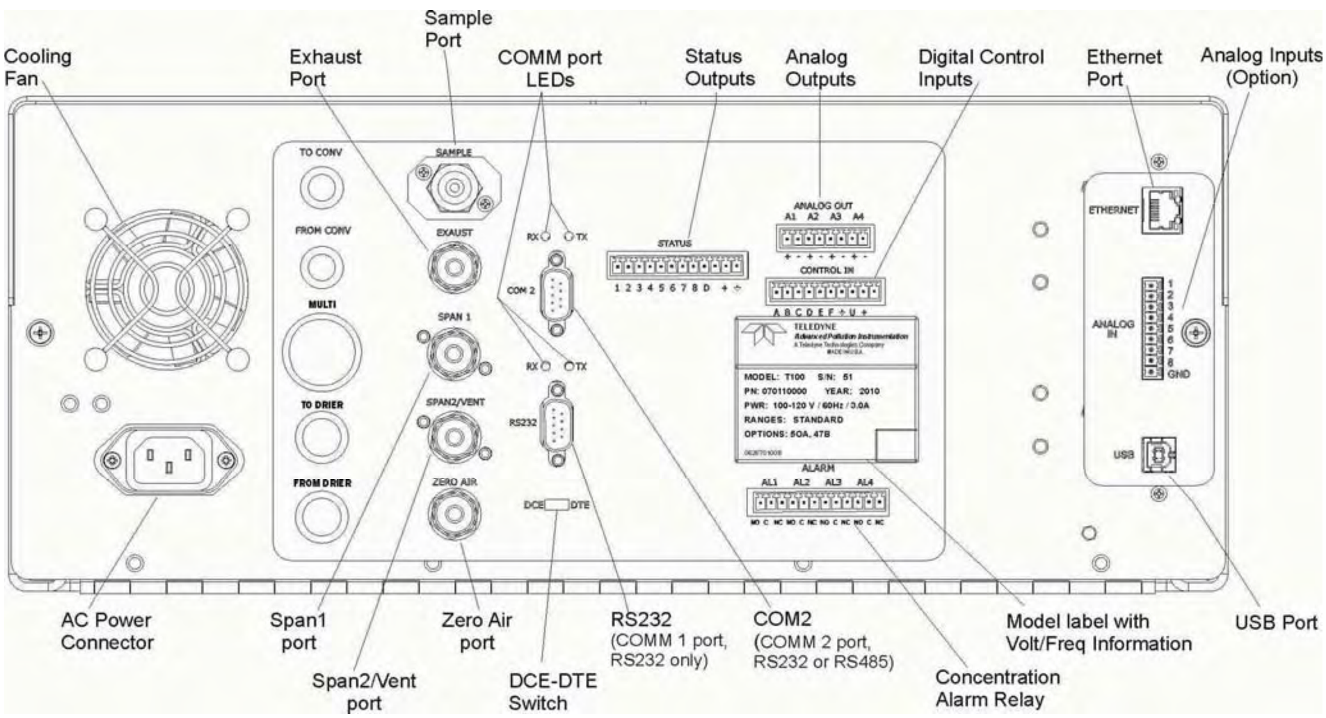


Figure 6-4: Rear Panel Layout with Pressurized Span Inlet OPT 50B

6.2.1. INTERNAL PNEUMATICS (OPT 50B)

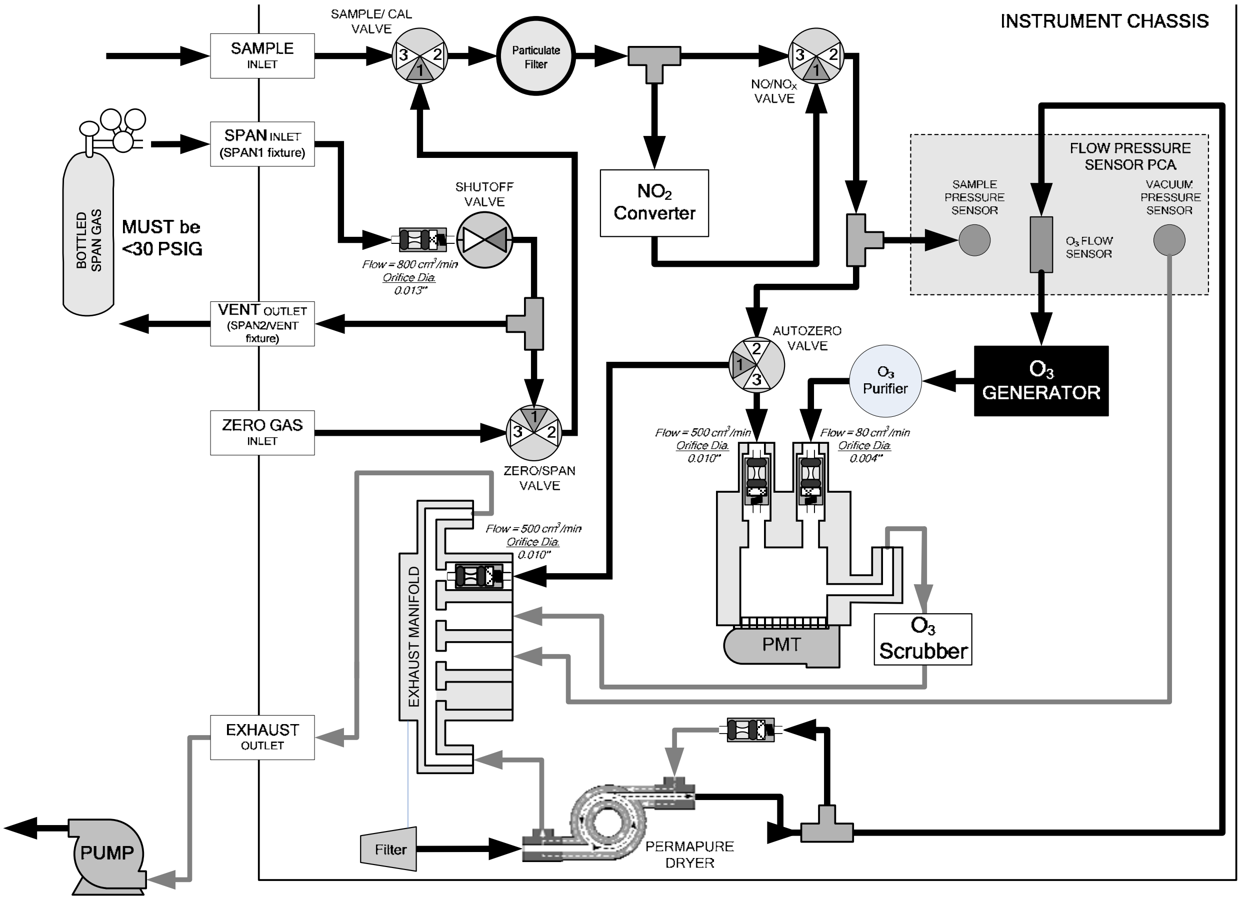


Figure 6-5: Pneumatic Diagram with Pressurized Span Inlet OPT 50B Installed

Table 6-3: Valve Operating States OPT 50B installed

MODE	VALVE	CONDITION	VALVE PORT STATUS
SAMPLE	Sample/Cal	Open to SAMPLE inlet	**3 → 2**
	Zero/Span	Open to ZERO AIR inlet	**3 → 2**
	Span Shutoff	**Closed**	
	Zero Air Shutoff	**Closed**	
ZERO CAL	Sample/Cal	Open to ZERO/SPAN Valve	**1 → 2**
	Zero/Span	Open to ZERO AIR inlet	**3 → 2**
	Span Shutoff	**OPEN**	
	Zero Air Shutoff[1]	**Closed**	
SPAN CAL	Sample/Cal	Open to ZERO/SPAN Valve	**1 → 2**
	Zero/Span	Open to SPAN inlet	**1 → 2**
	Span Shutoff	**Closed**	
	Zero Air Shutoff	**OPEN**	

6.2.2. PNEUMATIC SETUP (OPT 50B)

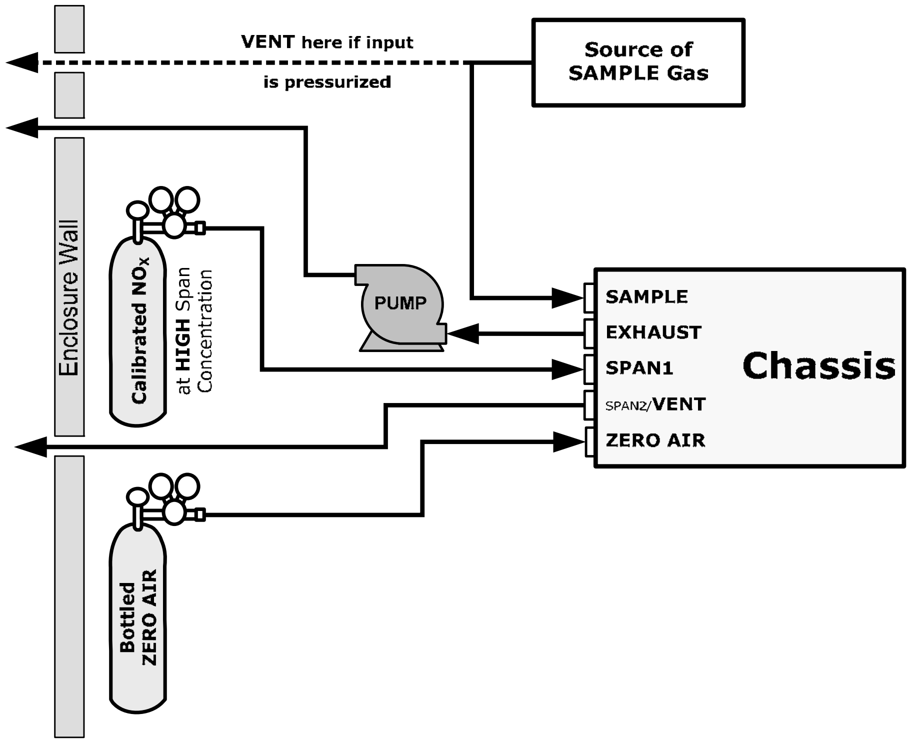


Figure 6-6: Gas Line Connections for T200 with OPT 50B

SAMPLE GAS SOURCE:

Attach a sample inlet line to the SAMPLE inlet fitting.

- Use PTFE tubing; minimum O.D ¼".
- Sample Gas pressure must equal ambient atmospheric pressure (29.92 in-Hg).
- In applications where the sample gas is received from a pressurized manifold, a vent must be placed on the sample gas line. This vent line must be:
  - No more than 10 meters long.
  - Vented outside the shelter or immediate area surrounding the instrument.

CALIBRATION GAS SOURCES:

SPAN GAS: Attach a gas line from the pressurized source of calibration gas (e.g. a bottle of NISTSRM gas) to the **SPAN1** inlet.

- Use PTFE tubing; minimum O.D ¼".

ZERO AIR: (the dual-stage zero air scrubber makes zero air)

VENTING: Attach a line to the **SPAN2/VENT** outlet. It should be:

- ¼" PTFE tubing.
- Vented outside the enclosure.
- Not less than 2 meters in length.
- Not greater than 10 meters in length.

EXHAUST OUTLET: Attach an exhaust line to the EXHAUST outlet fitting. The exhaust line should be:

- ¼" PTFE tubing.
- A maximum of 10 meters long.
- Vented outside the T200 analyzer's enclosure.

6.3. INTERNAL SPAN SOURCE - IZS (OPT 50G)

The T200 nitrogen oxides analyzer can also be equipped with an internal NO_2 span gas generator and calibration valve option. This option package is intended for applications where there is a need for frequent automated calibration checks without access to an external source of span gas.

This valve package includes:

- A 2-stage external scrubber for producing zero air.
  - 50% Purafil Chemisorbant® (for conversion of NO → NO_2).
  - 50% charcoal (for removal of the NO_2).
- A heated enclosure for a NO_2 permeation tube.
  - This option package DOES NOT contain an actual permeation tube. See Section 6.4 for information on specifying the correct permeation tube for each application.
- A special desorber that removes all HNO_3 from the calibration gas stream.
- One additional gas inlet port (**ZERO AIR**).
- One additional gas outlet port (**FROM DRYER**).
- Two internal valves for switching between the sample gas inlet and the output of the zero/span subsystem.

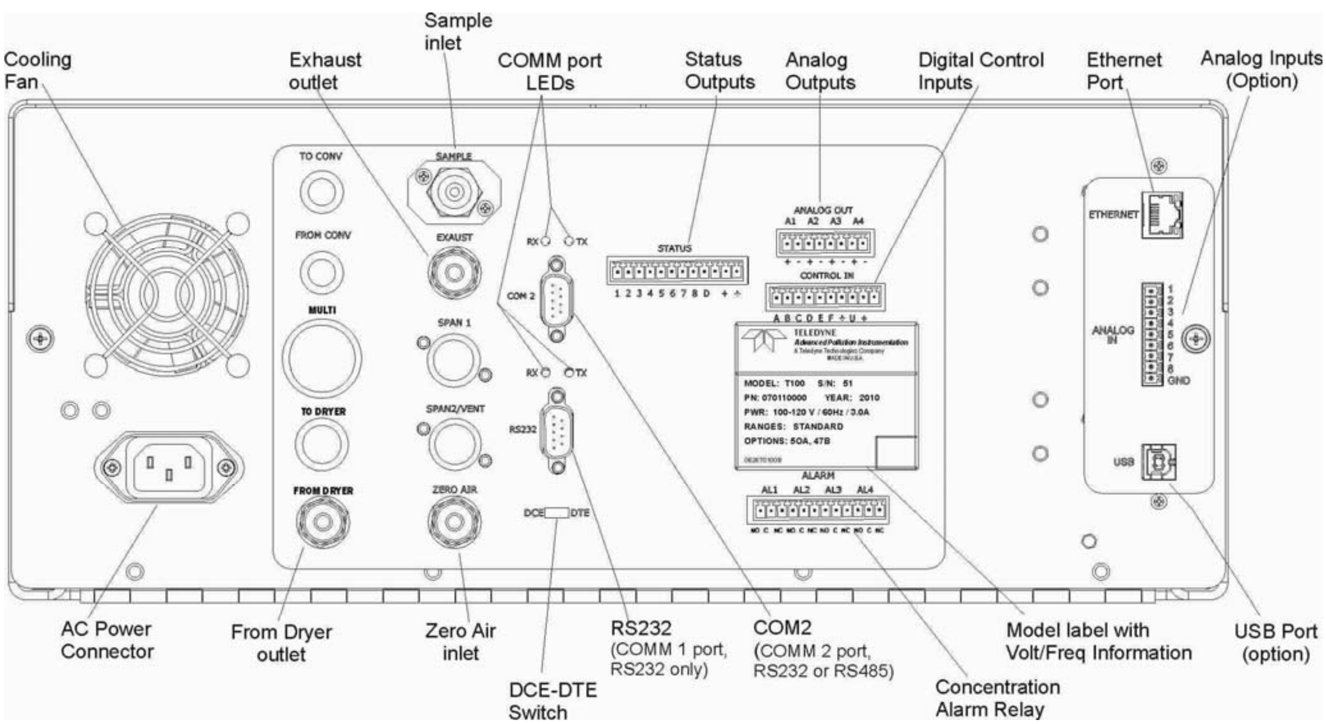


Figure 6-7: Rear Panel Layout with Internal Span Gas Generator OPT 50G Installed

6.3.1. SPAN GAS GENERATION

The primary component of the internal span option is a permeation tube containing liquid NO_2. As zero air is passed over a permeable membrane on the end of the tube, molecules of NO_2 slowly pass through the membrane mixing with the zero air.

The resulting concentration of the NO_2 span gas is determined by three factors:

- Size of the membrane: The larger the area of the membrane, the more permeation occurs.

- Temperature of the NO_2: Increasing the temperature of the permeation tube increases the pressure inside the tube and therefore increases the rate of permeation.
- Flow rate of the zero air: If the previous two variables are constant, the permeation rate of the NO_2 into the zero air stream will be constant. Therefore, a lower flow rate of zero air produces higher concentrations of NO_2.

NOTE
Gas flow must be maintained at all times for units with a permeation tube installed.
Insufficient gas flow allows NO_2 gas to build up to levels that will severely contaminate the instrument.

In the Model T200 the permeation tube enclosure is heated to a constant 50° C (10° above the maximum operating temperature of the instrument) in order to keep the permeation rate constant. A thermistor measures the actual temperature and reports it to the CPU for control feedback.

The flow rate of zero air across the permeation tube is maintained at 50 ± 10 cm³/min by a critical flow orifice located in the analyzer's exhaust manifold.

6.3.1.1. Nitric Acid and the Chemistry of NO_2 Permeation Tubes

The reaction of H_2O with NO_2 to form HNO_3 (nitric acid) takes place whenever water and NO_2 are present in the same gas mixture. In the T200 this is mitigated as much as possible by passing the air supply for the span gas generator through a special dryer, however the permeable membrane of the NO_2 tube will still allow H_2O from the ambient environment to slowly collect in the tube at increasingly higher concentrations. Over time this results in the presence of HNO_3 in the permeation tube which is exuded into the T200's pneumatics along with NO_2.

HNO_3 is a liquid at room temperature, so once the HNO_3 is released by the permeation tube it condenses and collects along the T200's wetted surfaces, While liquid HNO_3 does not directly effect the quality of NO_x measurements of the Model T200, it does give off small amounts of gaseous HNO_3 which is converted into NO by the T200's $NO_x \rightarrow$ NO converter resulting in an artificially high NO_2 concentration by 8% to 12%. This is particularly bothersome when T200 is attempting to measure a zero point, such as during calibration, since the NO_2 concentration will only reach a true zero point once the majority of the HNO_3 coating the wetted surfaces has reverted to NO_2 and this can take a very long time.

The T200 includes a special HNO_3 desorbed which eliminates any HNO_3 given off by the permeation tube before it can be converted into NO by the analyzers converter.

	**CAUTION** **GENERAL SAFETY HAZARD:** Gas flow must be maintained at all times for units with IZS Options installed. The IZS option includes a permeation tube which emits NO_2. Insufficient gas flow can build up NO_2 to levels that will damage the instrument. Remove the permeation device when taking the analyzer out of operation.

6.3.2. INTERNAL PNEUMATICS (OPT 50G)

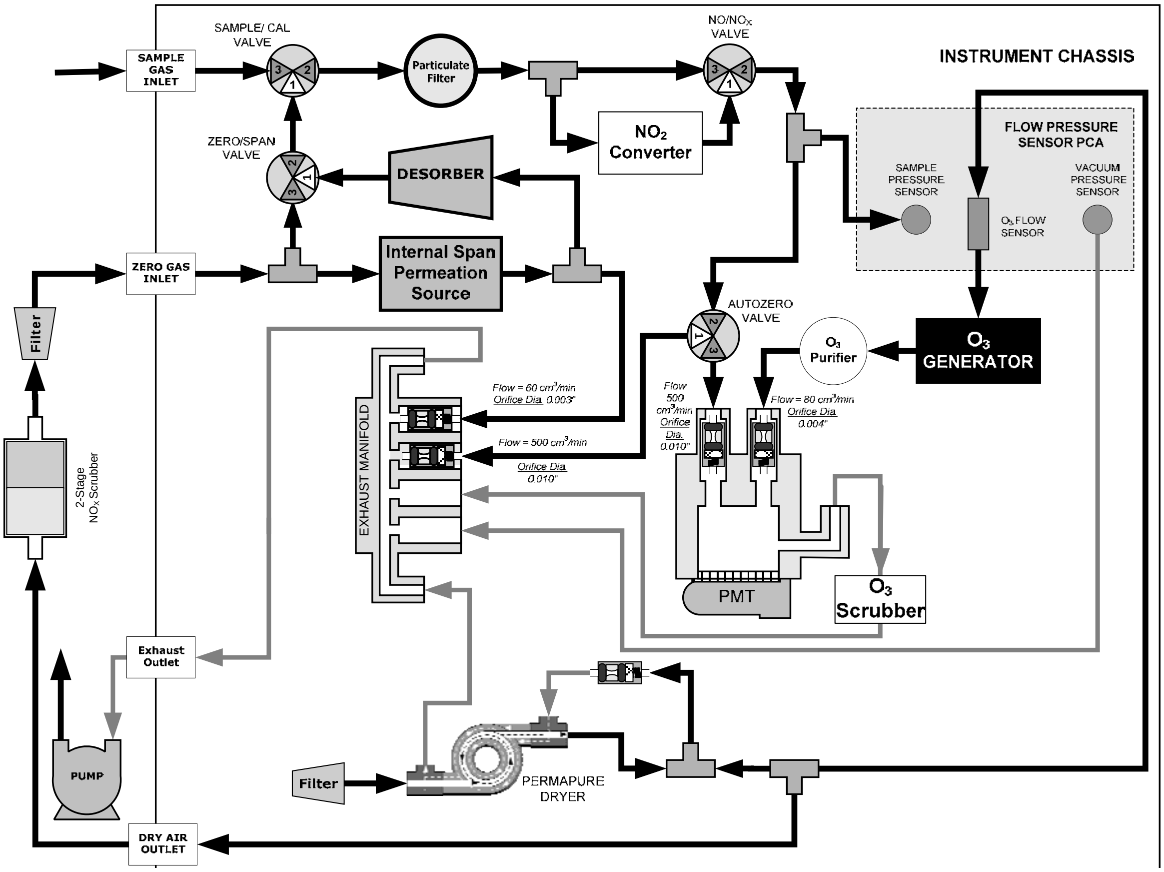


Figure 6-8: Pneumatic Diagram with the Internal Span Gas Generator (OPT 50G)

Table 6-4: Internal Span Gas Generator Valve Operating States OPT 50G

MODE	VALVE	CONDITION	VALVE PORT STATUS
SAMPLE	Sample/Cal	Open to SAMPLE inlet	**3 → 2**
	Zero/Span	Open to ZERO AIR inlet	**3 → 2**
ZERO CAL	Sample/Cal	Open to ZERO/SPAN Valve	**1 → 2**
	Zero/Span	Open to ZERO AIR inlet	**3 → 2**
SPAN CAL	Sample/Cal	Open to ZERO/SPAN Valve	**1 → 2**
	Zero/Span	Open to SPAN inlet	**1 → 2**

6.4. REPLACEMENT PERMEATION TUBES (OPT 52B & OPT 52G)

Two different NO_2 permeation tubes are available; they are identical in size and shape but are designed to have different permeation rates.

Table 6-5: Available Permeation Source Options

OPT	PERMEATION RATE (± 25%)	APPROXIMATE NO_2 CONCENTRATION @ 50ºC
OPT 52B	421 ng/min	300 ppb – 500 ppb ± 25%
OPT 52G	842 ng/min	600 – 1000 ppb ± 25%
Each tube is shipped with a calibration certificate, traceable to a NIST ± 5% @ 0.56 liters per minute.		

6.5. AMMONIA REMOVAL SAMPLE CONDITIONER (OPT 86A)

The T200 includes a Nafion® permeation gas exchange tube to remove H_2O a from the ozone generator supply gas stream to a dew point of about -20° C (~600 ppm H_2O) and effectively remove concentrations of ammonia (NH_3) up to about 1 ppm.

An additional Sample Conditioner can be added to the T200's sample gas stream.

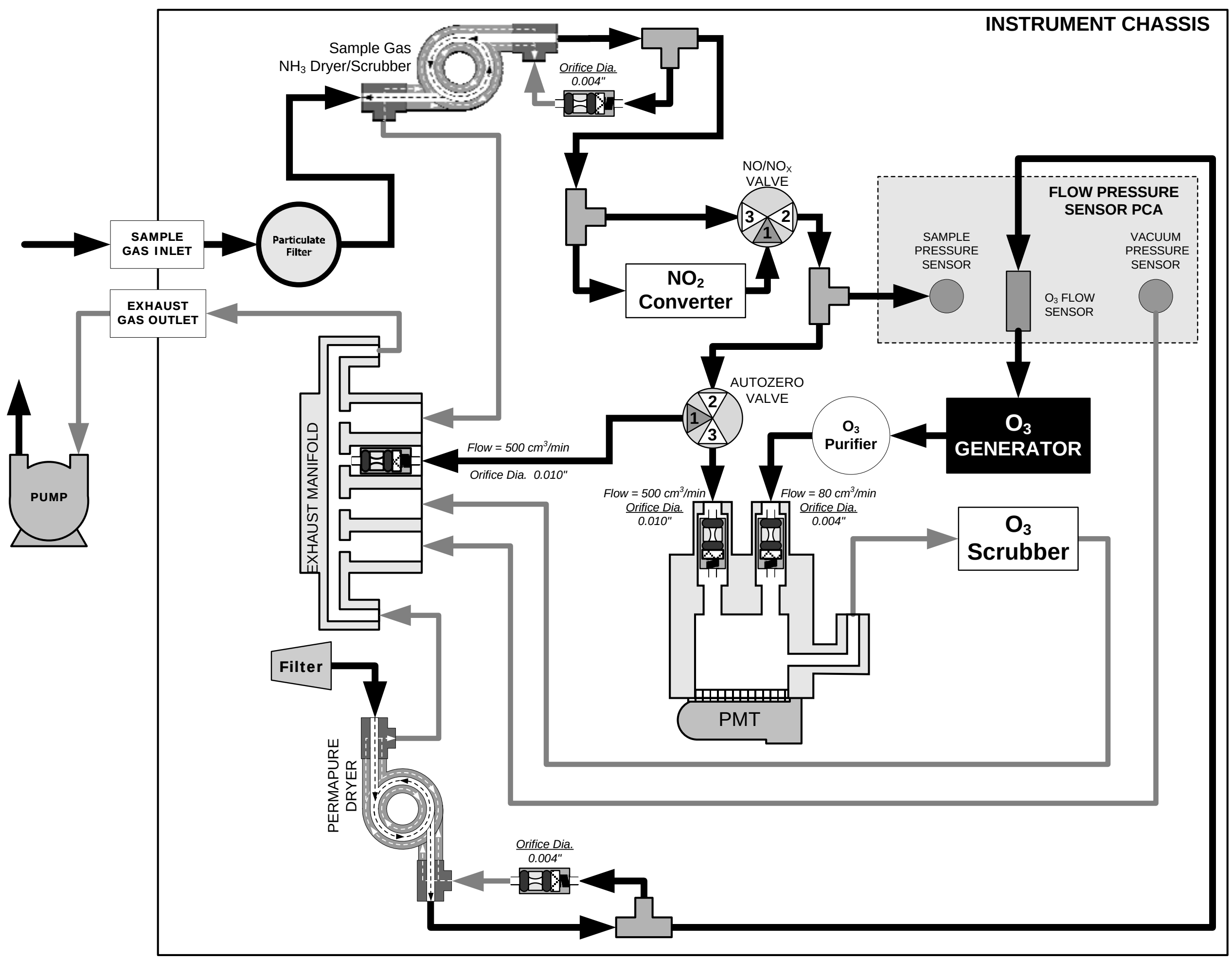


Figure 6-9: Pneumatics Diagram for Sample Conditioner OPT 86A

6.6. ZERO AIR SCRUBBER (OPT 86C), FOR Z/S VALVES

An external zero air scrubber for Z/S valves can be used in place of a zero air generator The following pneumatic diagram illustrates the internal and external flow for a T200 analyzer with a Z/S valve option and the Zero Air Scrubber (Option 86C):

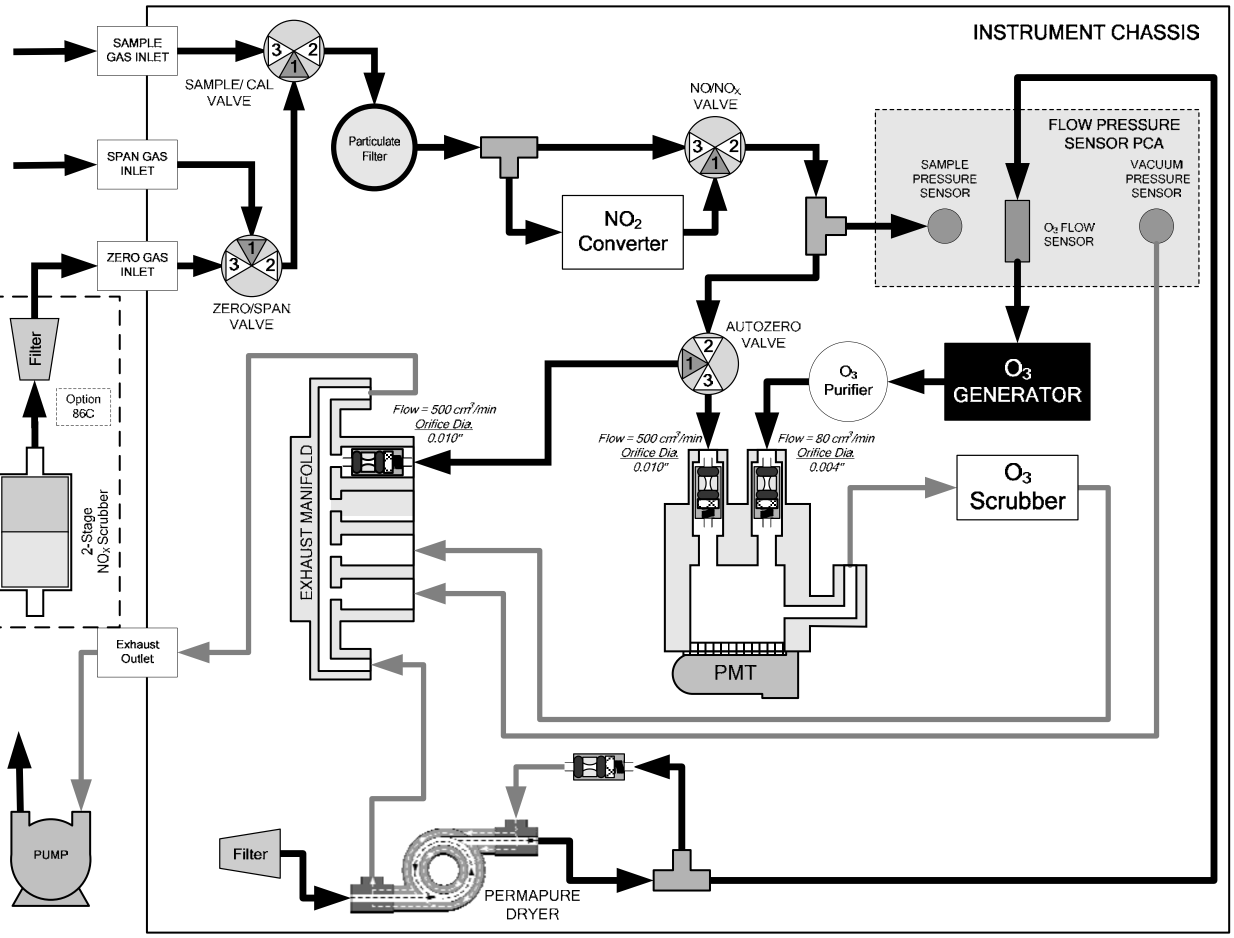


Figure 6-10: Pneumatic Diagram for External Zero Air Scrubber with Z/S Valve Option.

PART II
–
OPERATING INSTRUCTIONS

7. BASIC OPERATION OF THE T200 ANALYZER

The T200 analyzer is a computer-controlled analyzer with a dynamic menu interface that allows all major operations to be controlled from the front panel display and touchscreen through user-friendly menus (a complete set of menu trees is located in Appendix A of this manual).

This section includes step-by-step instructions for using the display/touchscreen to set up and operate the T200 analyzer's basic NO_x, NO and NO_2 measurement features and functional modes.

7.1. OVERVIEW OF OPERATING MODES

The T200 analyzer software has a variety of operating modes. The most common mode that the analyzer will be operating in is the **SAMPLE** mode. In this mode, a continuous read-out of the NO_x concentrations can be viewed on the front panel and output as an analog voltage from rear panel terminals.

The second most important operating mode is SETUP mode. This mode is used for configuring the various sub systems of the analyzer such as for the DAS system, the reporting ranges, or the serial (RS-232 / RS-485 / Ethernet) communication channels. The **SETUP** mode is also used for performing various diagnostic tests during troubleshooting.

Figure 7-1: Front Panel Display

The mode field of the front panel display indicates to the user which operating mode the unit is currently running.

Besides **SAMPLE** and **SETUP**, other modes the analyzer can be operated in are described in Table 7-1 below.

Table 7-1: Analyzer Operating Modes

MODE	DESCRIPTION
DIAG	One of the analyzer's diagnostic modes is active.
LO CAL A	Unit is performing LOW SPAN (midpoint) calibration initiated automatically by the analyzer's AUTOCAL feature
LO CAL R	Unit is performing LOW SPAN (midpoint) calibration initiated remotely through the COM ports or digital control inputs.
M-P CAL	This is the basic calibration mode of the instrument and is activated by pressing the CAL button.
SAMPLE	Sampling normally, flashing text indicates adaptive filter is on.
SAMPLE A	Indicates that unit is in SAMPLE mode and AUTOCAL feature is activated.
SETUP X.#[2]	SETUP mode is being used to configure the analyzer. The gas measurement will continue during setup.
SPAN CAL A[1]	Unit is performing SPAN calibration initiated automatically by the analyzer's AUTOCAL feature
SPAN CAL M[1]	Unit is performing SPAN calibration initiated manually by the user.
SPAN CAL R[1]	Unit is performing SPAN calibration initiated remotely through the COM ports or digital control inputs.
ZERO CAL A[1]	Unit is performing ZERO calibration procedure initiated automatically by the AUTOCAL feature
ZERO CAL M[1]	Unit is performing ZERO calibration procedure initiated manually by the user.
ZERO CAL R[1]	Unit is performing ZERO calibration procedure initiated remotely through the COM ports or digital control inputs.

[1] Only Appears on units with Z/S valve or IZS options.
[2] The revision of the analyzer firmware is displayed following the word SETUP, e.g., SETUP G.3.

7.2. SAMPLE MODE

This is the analyzer's standard operating mode. In this mode, the instrument is a calculating NO_x, NO and NO_2 concentrations. These values are displayed in the **CONC** field of the analyzer's front panel display. While the instrument is in **SAMPLE** mode, this field provides a readout of all the gas concentrations being measured by the T200: NO_x, NO and NO_2.

When the analyzer is in sample mode the **PARAM** field will display warning messages and test functions that give the user information about the operational status of the analyzer.

7.2.1. TEST FUNCTIONS

A variety of **TEST** functions are available for viewing at the front panel whenever the analyzer is at the **MAIN MENU**. These functions provide information about the various functional parameters related to the analyzer's operation and its measurement of gas concentrations. This information is particularly when troubleshooting a performance problem with the T200 (see Section 13). Figure 7-2 will display the Test Functions on the front panel screen. Table 7-2 lists the available **TEST** functions.

To view these **TEST** functions, press,

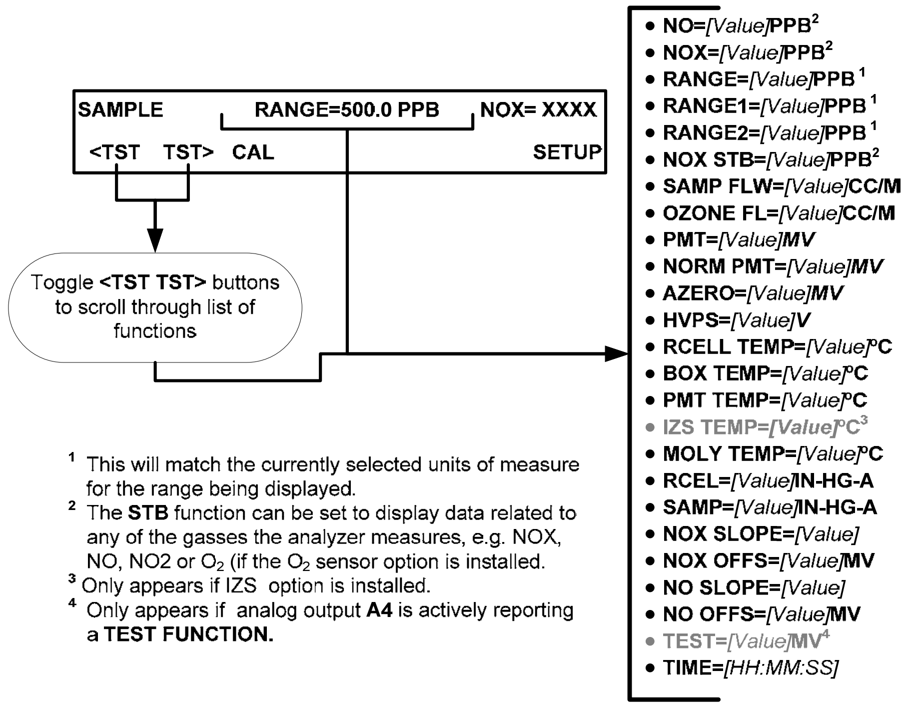


Figure 7-2: Viewing T200 Test Functions

> **NOTE**
> **A value of "XXXX" displayed for any of the TEST functions indicates an out-of-range reading or the analyzer's inability to calculate it.**

> **NOTE**
> **All pressure measurements are represented in terms of absolute pressure. Absolute, atmospheric pressure is 29.92 in-Hg-A at sea level. It decreases about 1 in-Hg per 300 m gain in altitude. A variety of factors such as air conditioning and passing storms can cause changes in the absolute atmospheric pressure.**

Table 7-2: Test Functions Defined

DISPLAY	PARAMETER	UNITS	DESCRIPTION
RANGE	RANGE	PPB, PPM, UGM & MGM	The Full Scale limit at which the reporting range of the analyzer's ANALOG OUTPUTS is currently set. **THIS IS NOT** the Physical Range of the instrument. See Section 7.4.4.1 for more information.
RANGE1 **RANGE2**			If **AUTO** Range mode has been selected, two **RANGE** functions will appear, one for each range: • **RANGE1**: The range setting for all analog outputs. • **RANGE2**: The **HIGH** range setting for all analog outputs.
RANGE1 **RANGE2** **RANGE3**			If the **IND** Range mode has been selected, three **RANGE** functions will appear, one for each range: • **RANGE1**: NO_X concentration output un **A1**. • **RANGE2**: NO concentration output un **A2.** • **RANGE2**: NO_2 concentration output un **A3.**
***[Gas Type]* STB**	STABILITY	MV	The standard deviation of concentration readings of the selected gas. • Data points are recorded every ten seconds. The calculation uses the last 25 data points. • Select Gas type via the STABIL_GAS variable (see Section 8.2).
SAMP FLW	SAMPFLOW	CC/M	Gas flow rate of the sample gas into the reaction cell.
OZONE FL	OZONEFLOW	CC/M	Gas flow rate of O_3 gas into the reaction cell.
PMT	PMT	MV	The raw signal output of the PMT.
NORM PMT	NORMPMT	MV	The signal output of the PMT after is has been normalized for temperature, pressure, auto-zero offset, but not range.
AZERO	AUTOZERO	MV	The PMT signal with zero NO_X, which is usually slightly different from 0 V. This offset is subtracted from the PMT signal and adjusts for variations in the zero signal.
HVPS	HVPS	V	The output power level of the high voltage power supply.
RCELL TEMP	RCELLTEMP	C	The temperature of the gas inside the reaction cell temperature.
BOX TEMP	BOXTEMP	C	The temperature inside the analyzer chassis.
PMT TEMP	PMTTEMP	C	The temperature of the PMT .
IZS TEMP[1]	IZSTEMP	C	The temperature of the internal span gas generator's permeation tube.
MOLY TEMP	CONVTEMP	C	The temperature of the analyzer's NO_2 → NO converter.
RCEL	RCELLPRESS	IN-HG-A	The current pressure of the sample gas in the reaction cell as measured at the vacuum manifold.
SAMP	SAMPPRESS	IN-HG-A	The current pressure of the sample gas as it enters the reaction cell, measured between the NO/NO_x and Auto-Zero valves.
NOX SLOPE	NOXSLOPE		The slope calculated during the most recent NO_x zero/span calibration.
NOX OFFS	NOXOFFSET	MV	The offset calculated during the most recent NO_x zero/span calibration.
NO SLOPE	NOSLOPE		The slope calculated during the most recent NO zero/span calibration.
NO OFFS	NOOFFSET	MV	The offset calculated during the most recent NO zero/span calibration.
TEST	TESTCHAN	MV	Displays the signal level of the Test Function that is currently being produced by the Analog Output Channel **A4**.
TIME	CLOCKTIME	HH:MM:SS	The current time. This is used to create a time stamp on DAS readings, and by the AutoCal feature to trigger calibration events.

[1]Only appears if Internal Span Gas Generator option is installed.

7.2.2. WARNING MESSAGE DISPLAY

The most common and serious instrument failures will activate Warning Messages that are displayed on the analyzer's Front Panel. They are listed on Table 7-3 as follows:

Table 7-3: Warning Messages Defined

MESSAGE	MEANING
ANALOG CAL WARNING	The A/D or at least one D/A channel has not been calibrated.
AZERO WARN	Auto-zero reading above limit specified by *AZERO_LIMIT* variable. Value shown in message indicates auto-zero reading at time warning was displayed.
BOX TEMP WARNING	The temperature inside the T200 chassis is outside the specified limits.
CANNOT DYN SPAN	Contact closure span calibration failed while *DYN_SPAN* was set to *ON*.
CANNOT DYN ZERO	Contact closure zero calibration failed while *DYN_ZERO* was set to *ON*.
CONFIG INITIALIZED	Configuration storage was reset to factory configuration or erased.
CONV TEMP WARNING	NO_2 → NO converter temperature outside of warning limits specified by *CONV_SET* variable.
DATA INITIALIZED	DAS data storage was erased before the last power up occurred.
HVPS WARNING	High voltage power supply output outside of warning limits specified by *HVPS_SET* variable.
IZS TEMP WARNING [1]	IZS temperature outside of warning limits specified by *IZS_SET* variable.
OZONE FLOW WARNING	Ozone flow outside of warning limits specified by *OFLOW_SET* variable.
OZONE GEN OFF	Ozone generator is off. This warning message clears itself when the ozone generator is turned on.
PMT TEMP WARNING	PMT temperature outside of warning limits specified by *PMT_SET* variable.
RCELL PRESS WARN	Reaction cell pressure outside of warning limits specified by *RCELL_PRESS_SET* variable.
RCELL TEMP WARNING	Reaction cell temperature outside of warning limits specified by *RCELL_SET* variable.
REAR BOARD NOT DET	Motherboard was not detected during power up.
RELAY BOARD WARN	CPU is unable to communicate with the relay PCA.
SAMPLE FLOW WARN	The flow rate of the sample gas is outside the specified limits.
SYSTEM RESET	The computer has rebooted.
[1] Only Appears if the Internal Span Gas Generator option is installed.	

7.3. CALIBRATION MODE

Pressing the CAL button, switches the T200 into calibration mode. In this mode the user can, in conjunction with introducing of zero or span gases of known concentrations into the analyzer, cause it to adjust and recalculate the slope (gain) and offset of the its measurement range. This mode is also used to check the current calibration status of the instrument.

- For more information about setting up and performing standard calibration operations or checks, see Section 10.
- For more information about setting up and performing EPA equivalent calibrations, see Section 11.

If the instrument includes one of the available zero/span valve options, the **SAMPLE** mode display will also include **CALZ** and **CALS** buttons. Pressing either of these buttons also puts the instrument into calibration mode.

- The **CALZ** button is used to initiate a calibration of the analyzer's zero point using internally generated zero air.
- The **CALS** button is used to calibrate the span point of the analyzer's current reporting range using span gas.

For more information concerning calibration valve options, see Section 5.

For information on using the automatic calibrations feature (**ACAL**) in conjunction with the one of the calibration valve options, see Sections 10.4.3 and 10.5.

NOTE

It is recommended that this span calibration be performed at 80% of full scale of the analyzer's currently selected reporting range.

EXAMPLES:

If the reporting range is set for 0 to 500 ppb, an appropriate span point would be 400 ppb.

If the of the reporting range is set for 0 to 1000 ppb, an appropriate span point would be 800 ppb.

7.4. SETUP MODE

The **SETUP** mode contains a variety of choices that are used to configure the analyzer's hardware and software features, perform diagnostic procedures, gather information on the instruments performance and configure or access data from the internal data acquisition system (DAS).

- For a visual representation of the software menu trees, refer to Appendix A-1.

The areas accessed under the **SETUP** mode are:

Table 7-4: Primary Setup Mode Features and Functions

MODE OR FEATURE	CONTROL BUTTON LABEL	DESCRIPTION	MANUAL SECTION
Analyzer Configuration	**CFG**	Lists button hardware and software configuration information.	7.4.1
Auto Cal Feature	***ACAL***	*Used to set up and operate the AutoCal feature.* • Only appears if the analyzer has one of the calibration valve options installed.	10.5
Internal Data Acquisition (DAS)	**DAS**	Used to set up the DAS system and view recorded data.	8.1
Analog Output Reporting Range Configuration	**RNGE**	Used to configure the output signals generated by the instruments analog outputs.	7.4.4
Calibration Password Security	**PASS**	Turns the calibration password feature ON/OFF.	7.4.2
Internal Clock Configuration	**CLK**	Used to set or adjust the instrument's internal clock.	7.4.3
Secondary **SETUP** Mode (Advanced **SETUP** features)	**MORE**	This button accesses the instruments secondary setup menu.	See Table 7-5

Table 7-5: Secondary Setup Mode Features and Functions

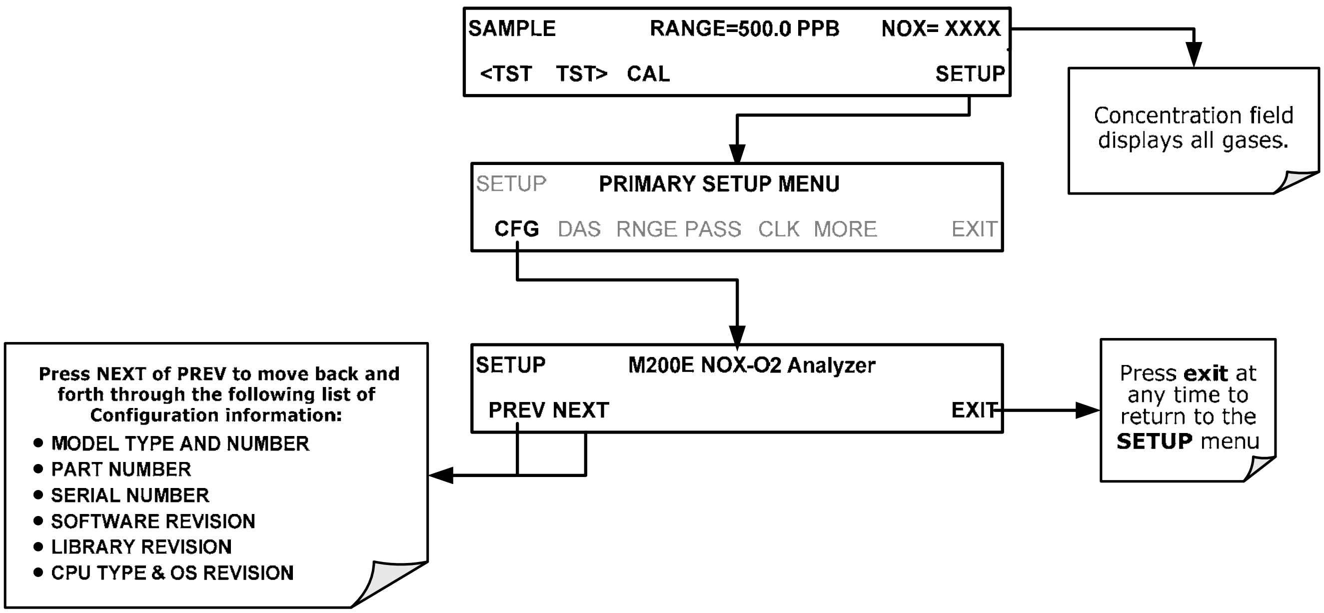
MODE OR FEATURE	CONTROL BUTTON LABEL	DESCRIPTION	MANUAL SECTION
External Communication Channel Configuration	**COMM**	Used to set up and operate the analyzer's various external I/O channels including RS-232; RS-485, modem communication and/or Ethernet access.	9
System Status Variables	**VARS**	Used to view various variables related to the instruments current operational status. • Changes made to any variable are not acknowledged and recorded in the instrument's memory until the **ENTR** button is pressed. • Pressing the **EXIT** button ignores the new setting. • If the **EXIT** button is pressed before the **ENTR** button, the analyzer will beep alerting the user that the newly entered value has been lost.	8.2
System Diagnostic Features and Analog Output Configuration	**DIAG**	Used to access a variety of functions that are used to configure, test or diagnose problems with a variety of the analyzer's basic systems. Most notably, the menus used to configure the output signals generated by the instruments' analog outputs are located here.	8.2.1, 8.3 & 8.4

7.4.1. SETUP → CFG: CONFIGURATION INFORMATION

Pressing the **CFG** button displays the instrument's configuration information. This display lists the analyzer model, serial number, firmware revision, software library revision, CPU type and other information.

- Special instrument or software features or installed options may also be listed here.
- Use this information to identify the software and hardware installed in your T200 analyzer when contacting customer service.

To access the configuration table, press:



7.4.2. SETUP → PASS: ENABLING/DISABLING PASSWORDS

The T200 provides password protection of the calibration and setup functions to prevent unauthorized adjustments. When the passwords have been enabled in the **PASS** menu item, the system will prompt the user for a password anytime a password-protected function is requested.

There are three levels of password protection, which correspond to operator, maintenance and configuration functions. Each level allows access to all of the functions in the previous level.

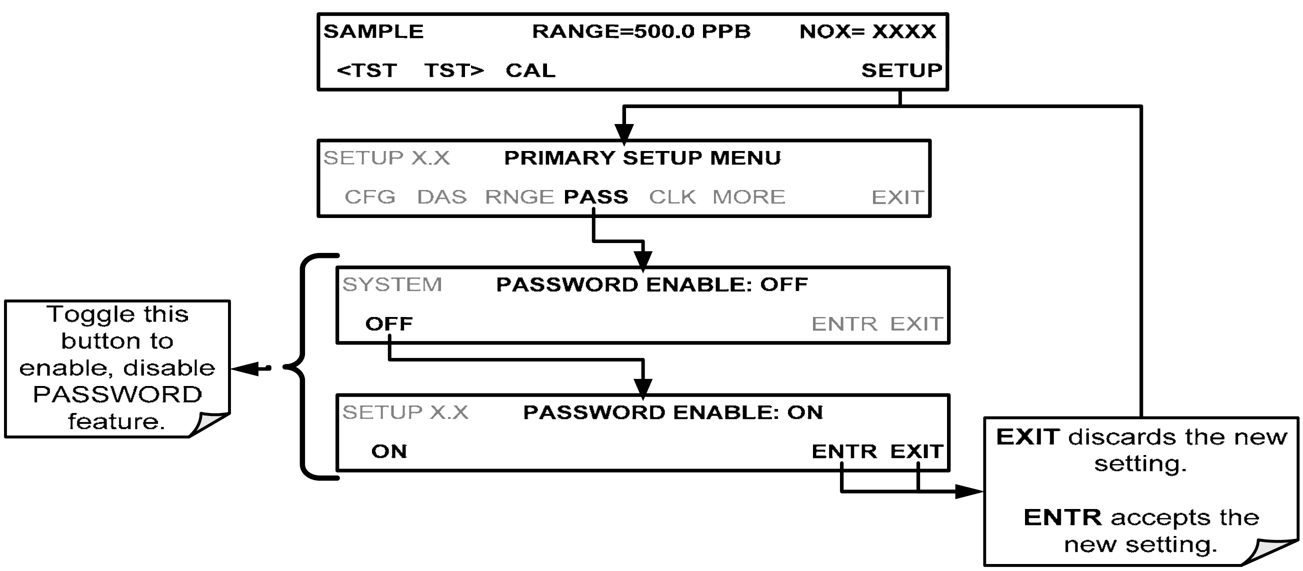
Table 7-6: Password Levels

PASSWORD	LEVEL	MENU ACCESS ALLOWED
No password	Operator	All functions of the MAIN menu: **TEST, GEN,** initiate **SEQ , MSG, CLR**
818	Operator	Access to Primary Setup and Secondary Setup Menus except for **VARS** and **DIAG**
929	Configuration	Secondary SETUP Submenus **VARS** and **DIAG**

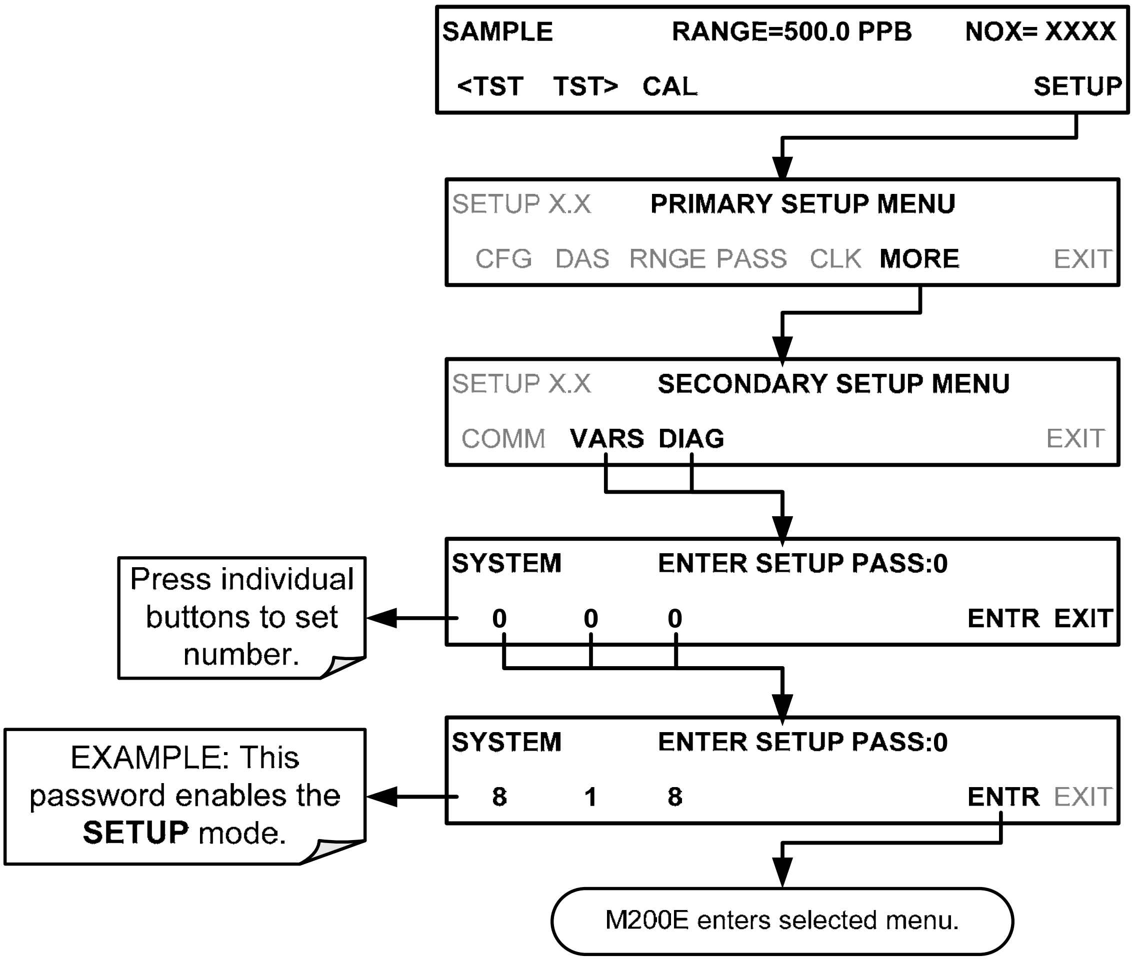
WARNING

THERE ARE MORE VARS AVAILABLE WHEN USING THE 929 PASSWORD. USE CAUTION WHEN PRESSING ANY BUTTONS WHILE IN THIS SETUP. ANY CHANGES MADE MAY ALTER THE PERFORMANCE OF THE INSTRUMENT OR CAUSE THE INSTRUMENT TO NOT FUNCTION PROPERLY. NOTE THAT IF THERE IS AN ACCIDENTAL CHANGE TO A SETUP, PRESS "EXIT" TO DISCARD THE CHANGES MADE.

To enable or disable passwords, press:



Example: If all passwords are enabled, the following touchscreen control sequence would be required to enter the **VARS** or **DIAG** submenus:



NOTE

The instrument still prompts for a password when entering the VARS and DIAG menus, even if passwords are disabled, but it displays the default password (818) upon entering these menus.

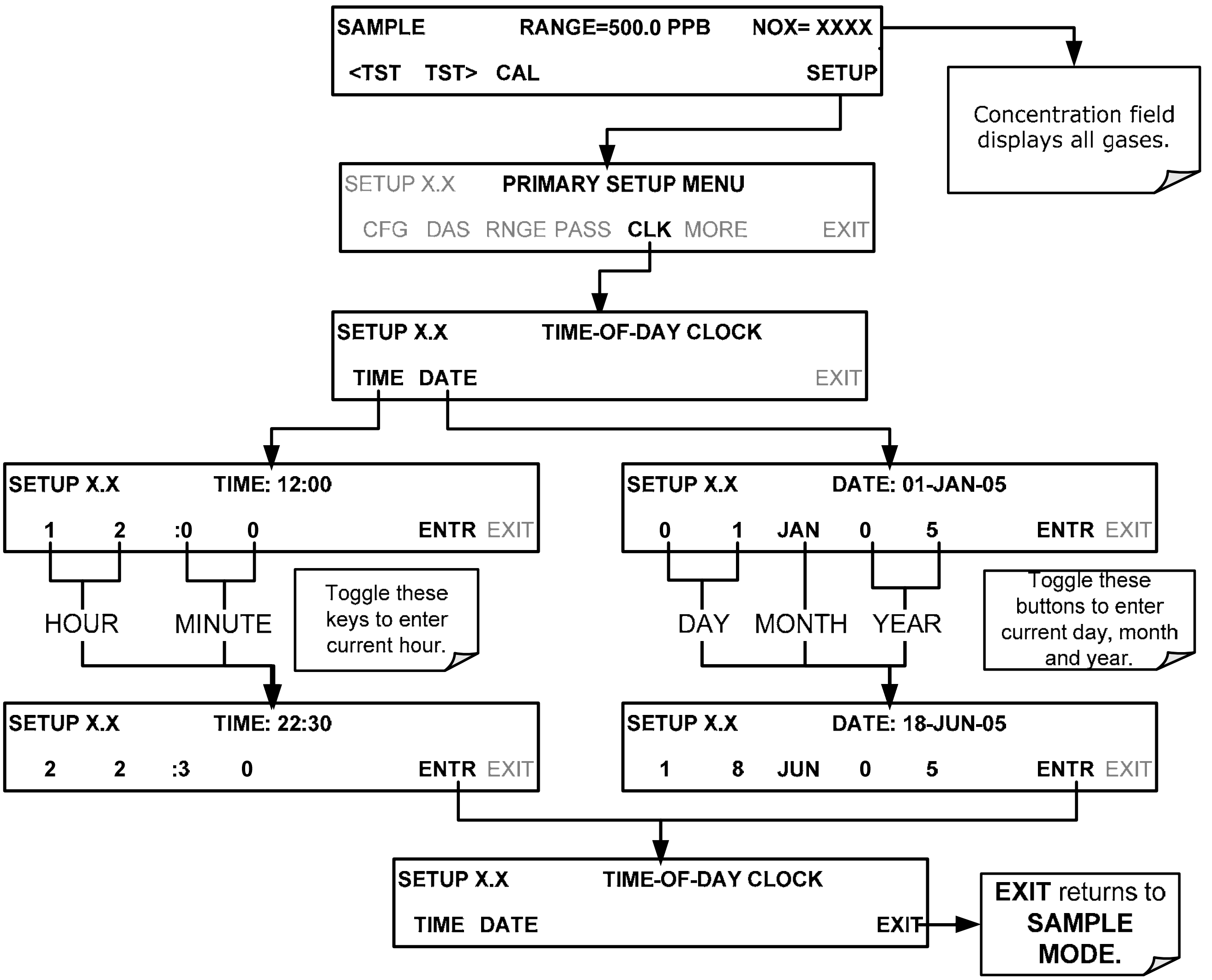
The user only has to press ENTR to access the password-protected menus but does not have to enter the required number code.

7.4.3. SETUP → CLK: SETTING THE T200 ANALYZER'S INTERNAL CLOCK

7.4.3.1. Setting the Internal Clock's Time and Day

The T200 has a time of day clock that supports the **DURATION** step of the automatic calibration (**ACAL**) sequence feature, time of day TEST function, and time stamps on for the DAS feature and most COMM port messages.

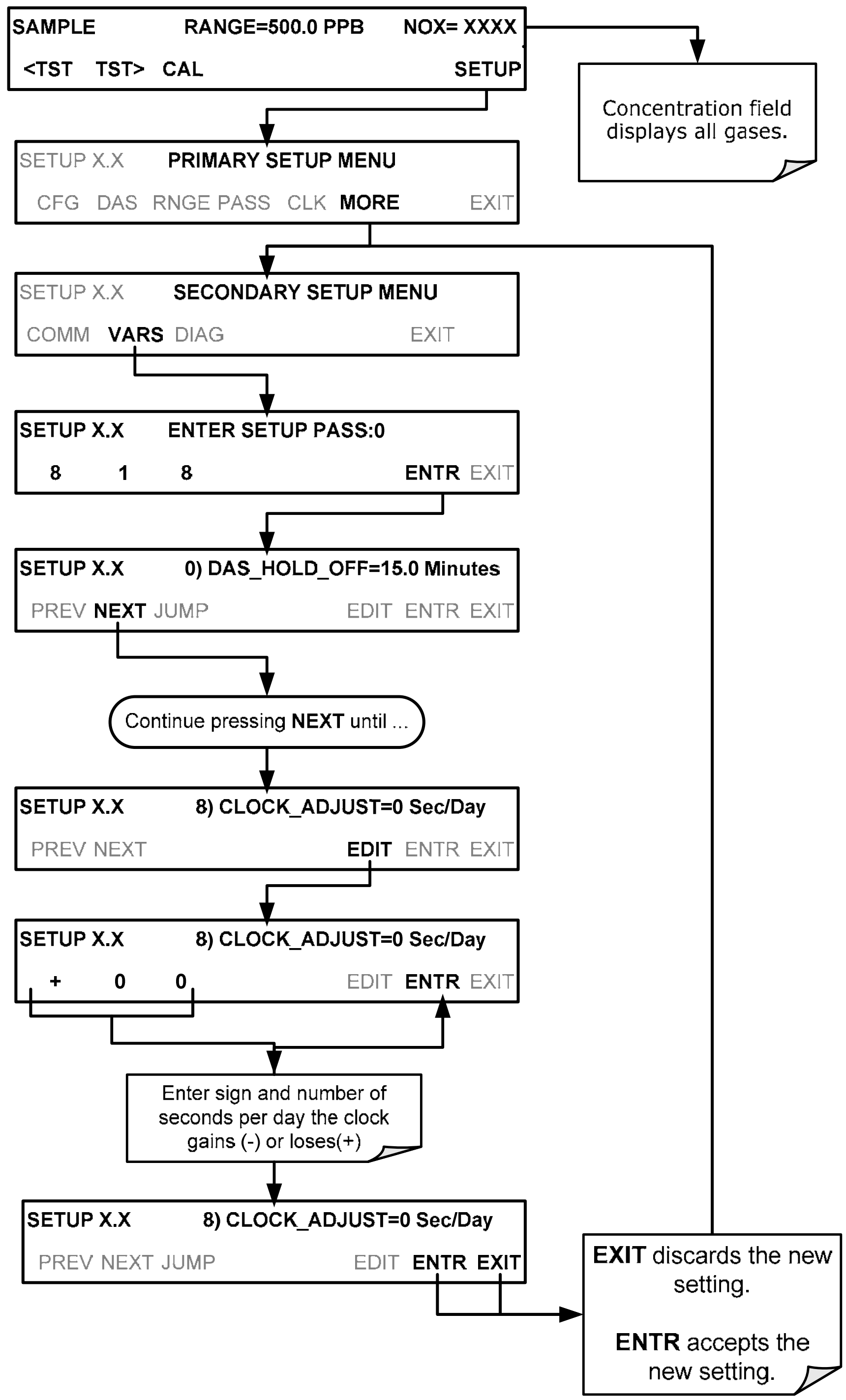
To set the clock's time and day, press:



7.4.3.2. Adjusting the internal Clock's speed

In order to compensate for CPU clocks which run faster or slower, you can adjust a variable called **CLOCK_ADJ** to speed up or slow down the clock by a fixed amount every day.

The **CLOCK_ADJ** variable is accessed via the **VARS** submenu: To change the value of this variable, press:



7.4.4. SETUP → RNGE: ANALOG OUTPUT REPORTING RANGE CONFIGURATION

7.4.4.1. T200 Physical Ranges

The T200 NO_x analyzer measures NO_x, NO and NO_2 concentrations from 2 to 20,000 ppb.

Electronically the T200 analyzer converts the 0-5 volt analog signal output by the PMT into a digital signal with 4096 counts of resolution. Since its measurement range is 0 ppb to 20,000 ppb, this only allows about 3 ppb per count. While this might be acceptable for high concentration measurements made in parts per million units (ppm), it is not good enough for lower level NO_x measurements. To overcome this limitation the T200 is designed with two physical measurement ranges:

- A **LOW** range that measures concentration from 0 ppb to 2,000 ppb with a resolution of 0.27 ppb per count.
- A **HIGH** range that measures the full 20,000 ppb range of the analyzer.

The analyzer's CPU chooses the appropriate range based on how the user sets up the reporting ranges for the instruments analog outputs when an analog range is selected with a lower limit between 0 and 2000 ppb the analyzer will utilize its low physical range. When an analog range is in use that has a reporting range with an upper limit set between 2001 and 20,000 ppb the instrument will operate in its high physical range.

Once both ranges have been using the same span gas values the analyzer's front panel will accurately report concentrations between 0 and 20,000 ppb, seamlessly switching between the low and high physical ranges regardless of the selected analog reporting range.

7.4.4.2. T200 Analog Output Reporting Ranges

For applications using chart recorders or other analog recording devices, the T200's 20,000 ppb physical range can cause resolution problems. For example, in an application where the expected concentrations of NO, NO_2 and NO_x are typically less than 500 ppb, the full scale of expected values is only 2.5% of the instrument's 20,000 ppb physical range. The corresponding output signal would then only be recorded across 2.5% of the range of the recording device.

The T200 solves this problem by allowing the user to select a reporting range for the analog outputs that only includes that portion of the physical range that covers the specific application. This increases the reliability and accuracy of the analyzer by avoiding additional gain-amplification circuitry.

NOTE

Only the reporting range of the analog outputs is scaled.

Both the DAS values stored in the CPU's memory and the concentration values reported on the front panel are unaffected by the settings chosen for the reporting range(s) of the instrument.

7.4.4.3. Analog Output Ranges for NO_x, NO and NO_2 Concentration

The analyzer has three active analog output signals related to NO_x, NO and NO_2 concentration, accessible through a connector on the rear panel.

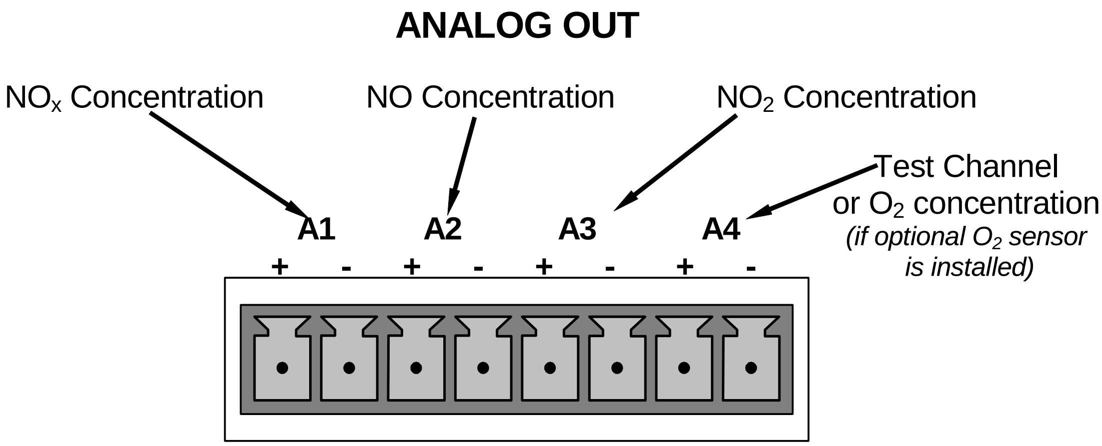


Figure 7-3: Analog Output Connector Pin Out

The **A1**, **A2** and **A3** channels output a signal that is proportional to the NO_x, NO and NO_2 concentrations of the sample gas, respectively. The T200 can be set so that these outputs operate in one of the three following modes:

- **SNGL**: Single range mode. In this mode all three of the NO_x gas concentrations are reported using the same reporting range span (see Section 7.4.4.5).
- **IND:** Independent range mode. In this mode the NO_x, NO and NO_2 analog outputs can be set with different reporting range spans (see Section 7.4.4.6).
- **AUTO**: Automatic range mode: This mode allows the analyzer to automatically switch the reporting range between two user upper span limits (designated **LOW** and **HIGH)** based on the actual concentrations being measured for each (see Section 7.4.4.7). These are not the same as the analyzer's low and high physical ranges.

Additionally the signal levels of outputs **A1, A2** and **A3** outputs can be:

- Configured full scale outputs of: 0 - 0.1 VDC; 0 – 1 VDC; 0 – 5 VDC or; 0 – 10 VDC.

- Equipped with optional 0-20 mADC current loop drivers (OPT 41, see Section 5.4) and configured for any current output within that range analog output (e.g. 0-20 mA, 2-20 mA, 4-20 mA, etc.).

Together these two set of parameters allow the user a great deal of flexibility in how the instrument reports NO_x , NO and NO_2 concentration to external devices. For example, Using the **IND** mode the following configuration could be created:

A1 OUTPUT: NO_x Output Signal = 4 – 20 mA representing 0-1000 ppb concentration values

A2 OUTPUT: NO Output Signal = 0 – 10 VDC representing 0-500 ppb concentration values.

A3 OUTPUT: NO_2 Output Signal = 0 – 5 VDC representing 0-500 ppb concentration values.

The user may also add a signal offset independently to each output (see Section 8.4.5) to match the electronic input requirements of the recorder or data logger to which the output is connected.

NOTE

The instrument does not remember upper range limits settings associated with the individual modes. Changes made to the range limits (e.g. 400 ppb → 600 ppb) when in one particular mode will alter the range limit settings for the other modes.

When switching between reporting range modes, ALWAYS check and reset the upper range limits for the new mode selection.

7.4.4.4. Analog Output Reporting Range Default Settings

The default setting for these the reporting ranges of the analog output channels **A1, A2** and **A3** are:

- SNGL mode
- 0 to 500.0 ppb
- 0 to 5 VDC

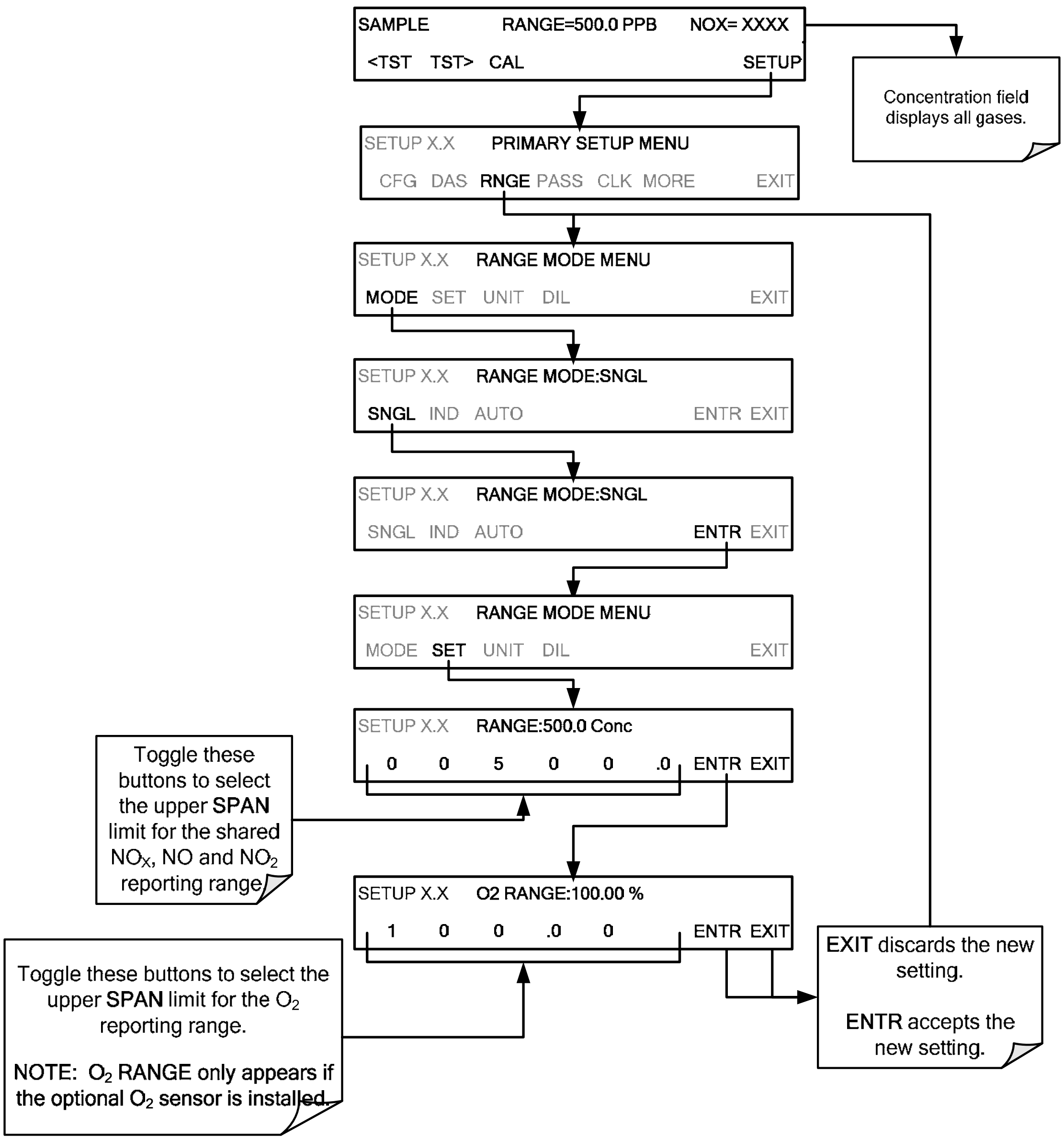
7.4.4.5. RNGE → MODE → SNGL: Configuring the T200 Analyzer for Single Range Mode

NOTE
This is the default reporting range mode for the analyzer.

When the single range mode is selected (**SNGL**), all analog NO_x, NO and NO_2 concentration outputs (**A1, A2 and A3**) are slaved together and set to the same reporting range limits (e.g. 500.0 ppb). This reporting range can be set to any value between 100 ppb and 20,000 ppb.

Although all three NO_x outputs share the same concentration reporting range, the electronic signal ranges of the analog outputs may still be configured for different values (e.g. 0-5 VDC, 0-10 VDC, etc; see Section 8.4.2).

To select **SNGL** range mode and to set the upper limit of the range, press:



7.4.4.6. RNGE → MODE → IND: Configuring the T200 analyzer for Independent Range Mode

The independent range mode (**IND**) assigns the three NO_x, NO and NO_2 concentrations to individual analog output channels. In **IND** range mode the **RANGE** test function displayed on the front panel will then be replaced by three separate functions:

Table 7-7: IND Mode Analog Output Assignments

TEST FUNCTION	CONCENTRATION REPORTED	ANALOG OUTPUT CHANNEL
RANGE1	NO_x	A1
RANGE2	NO	A2
RANGE3	NO_2	A3

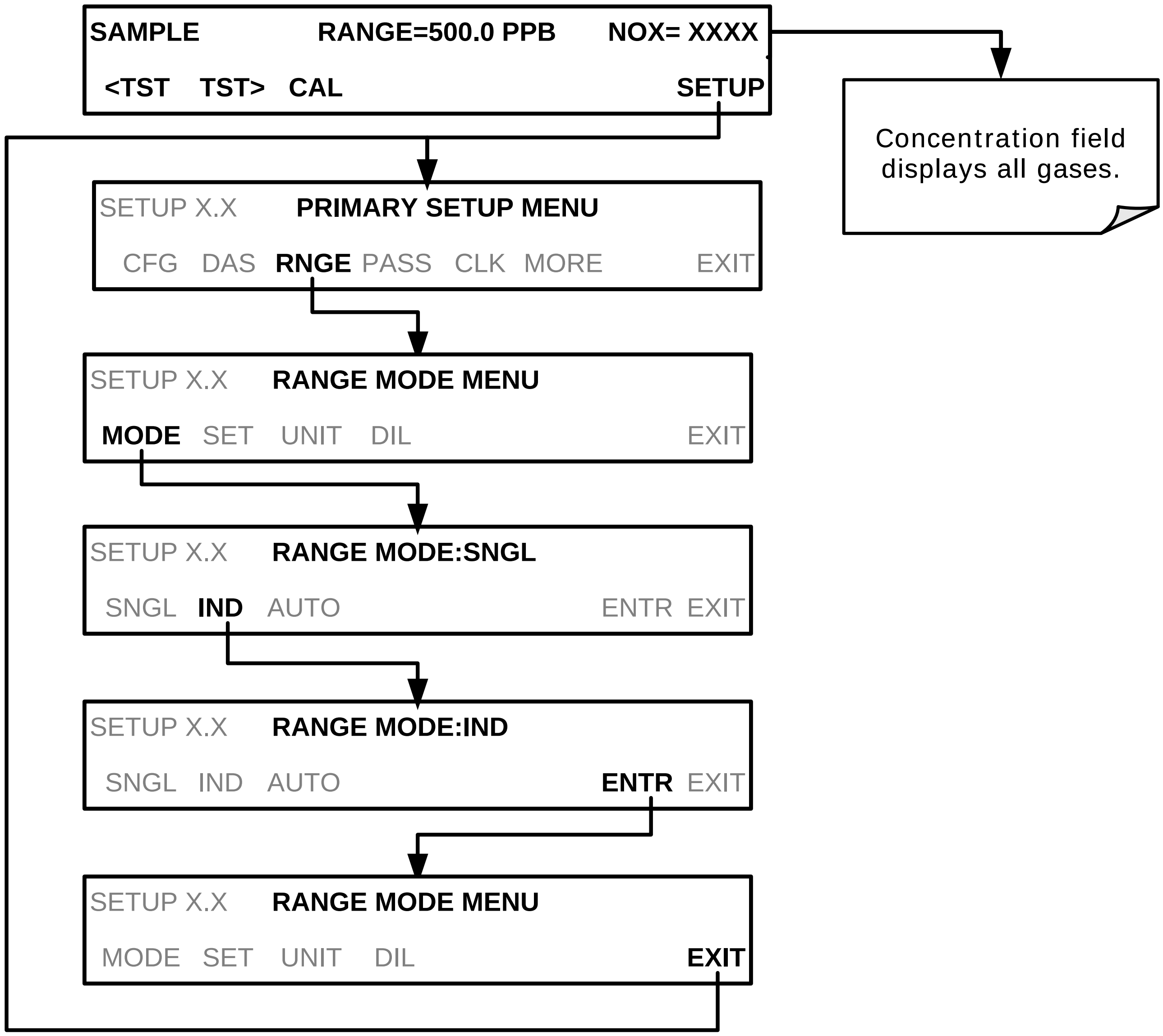
Each can be configured with a different reporting range upper limit and analog signal span:

EXAMPLE:

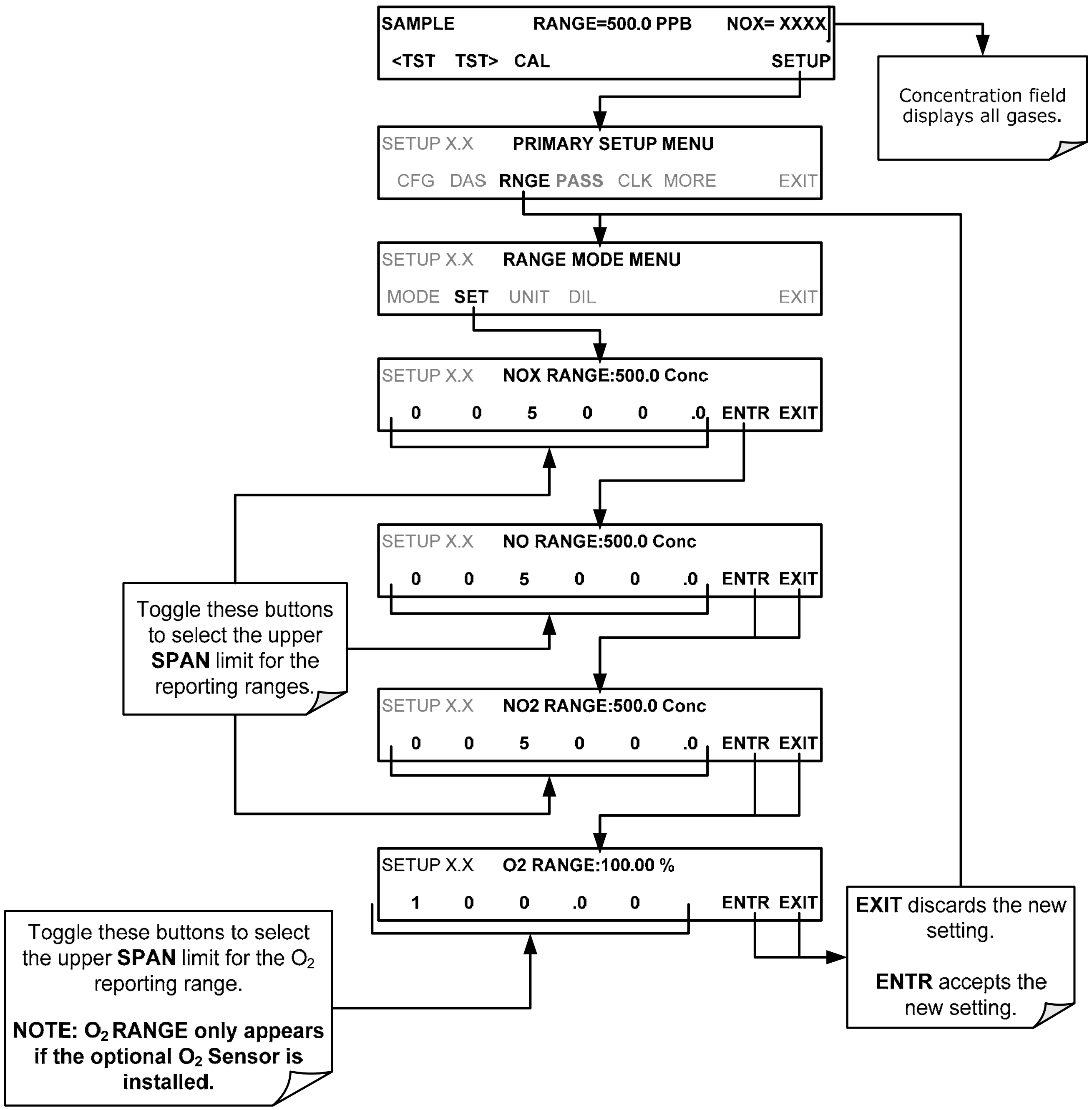
- NO_x Concentration – **RANGE1** Set for 0-800 ppb & output **A1** set for 0-10 VDC
- NO Concentration – **RANGE2** Set for 0-200 ppb & output **A2** set for 0-5 VDC
- NO_2 Concentration – **RANGE3** Set for 0-400 ppb & output **A3** set for 0-5 VDC

Setting analog range limits to different values does not affect the instrument's calibration.

To select the **IND** range mode, press the following buttons:



To set the upper range limit for each independent reporting range, press:



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7.4.4.7. RNGE → MODE → AUTO: Configuring the T200 analyzer for Auto Range Mode

In **AUTO** range mode, the analyzer automatically switches the reporting range between two user-defined ranges (**LOW** and **HIGH**). The same low and high span settings are applied equally to NO, NO_2 and NO_X readings.

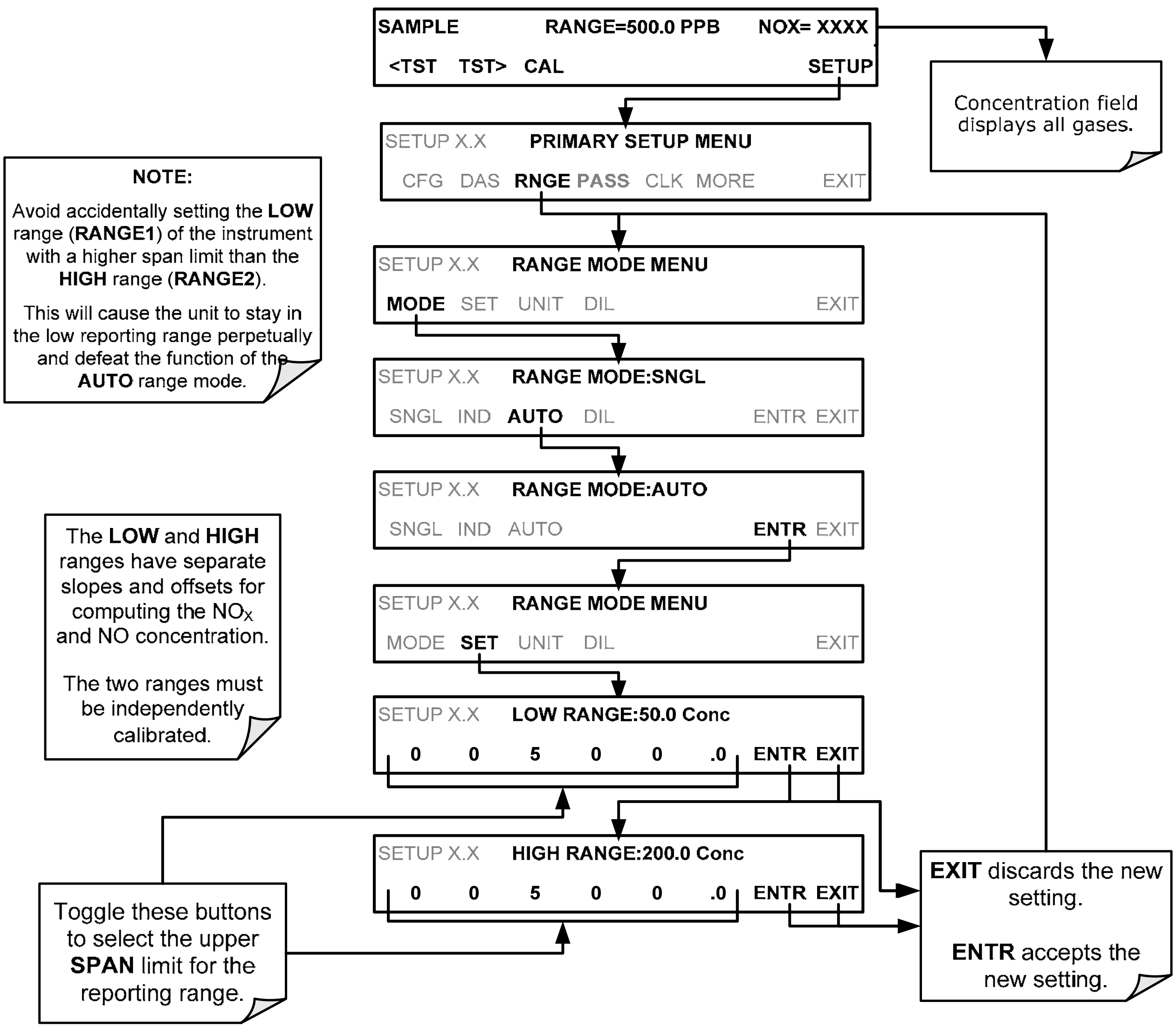
- The unit will switch from **LOW** range to **HIGH** range when either the NO, or NO_X concentration exceeds 98% of the low range span.
- The unit will return from **HIGH** range back to **LOW** range once both the NO and NO_X concentrations fall below 75% of the low range span.

NOTE
The LOW & HIGH ranges referred to here are NOT the same as the low & high physical ranges referred to in Section 7.4.4.1.

Also the **RANGE** test function displayed on the front panel will be replaced by two separate functions:

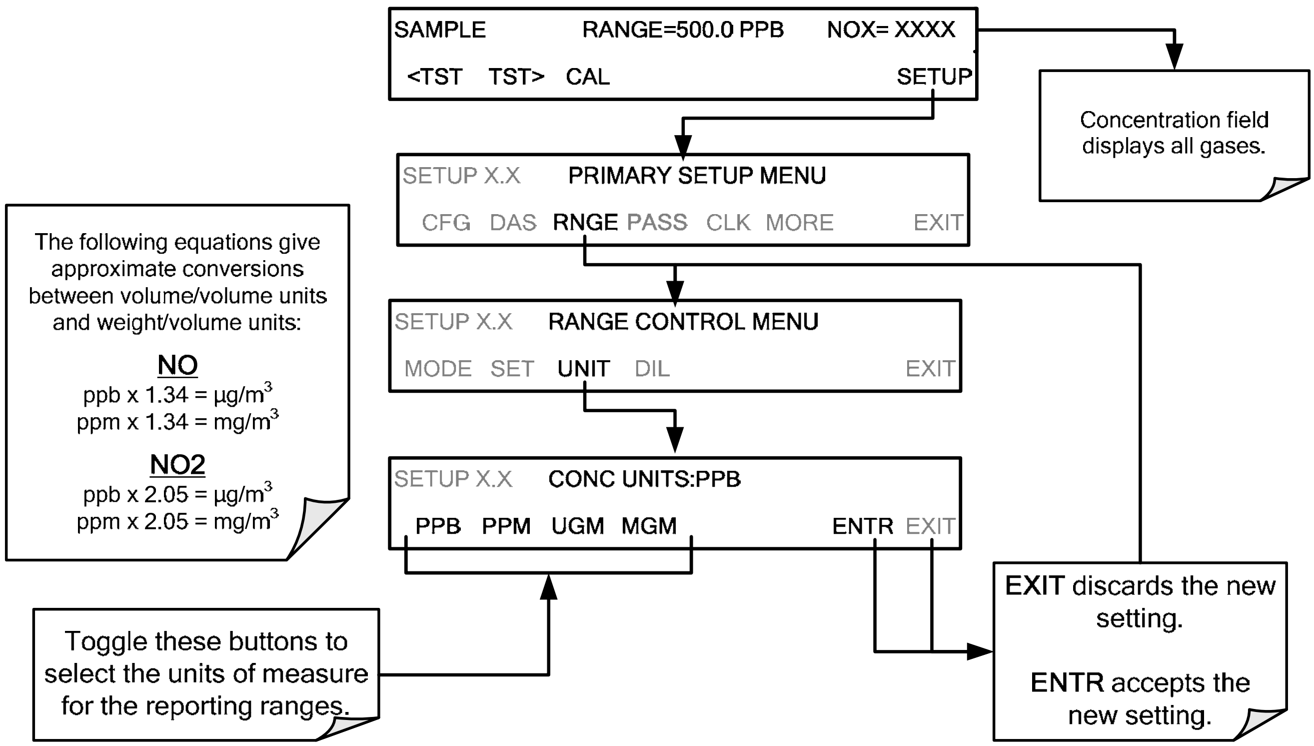
- **RANGE1**: The **LOW** range setting for all analog outputs.
- **RANGE2**: The **HIGH** range setting for all analog outputs.

The **LOW/HIGH** range status is also reported through the external, digital status bits (Section 3.5.4). To set individual ranges press the following menu sequence.



7.4.4.8. SETUP → RNGE → UNIT: Setting the Reporting Range Units of Measure

The T200 can display and report concentrations in ppb, ppm, ug/m^3, mg/m^3 units. Changing units affects all of the COMM port values, and all of the display values for all reporting ranges. To change the units of measure press**:**



NOTE

Concentrations displayed in mg/m^3 and ug/m^3 use 0°C@ 760 mmHg for Standard Temperature and Pressure (STP).

Consult your local regulations for the STP used by your agency.
(Example: US EPA uses 25°C as the reference temperature).

Once the Units of Measurement have been changed from volumetric (ppb or ppm) to mass units (ug/m^3 or mg/m^3) the analyzer MUST be recalibrated, as the "expected span values" previously in effect will no longer be valid.

Simply entering new expected span values without running the entire calibration routine IS NOT sufficient.

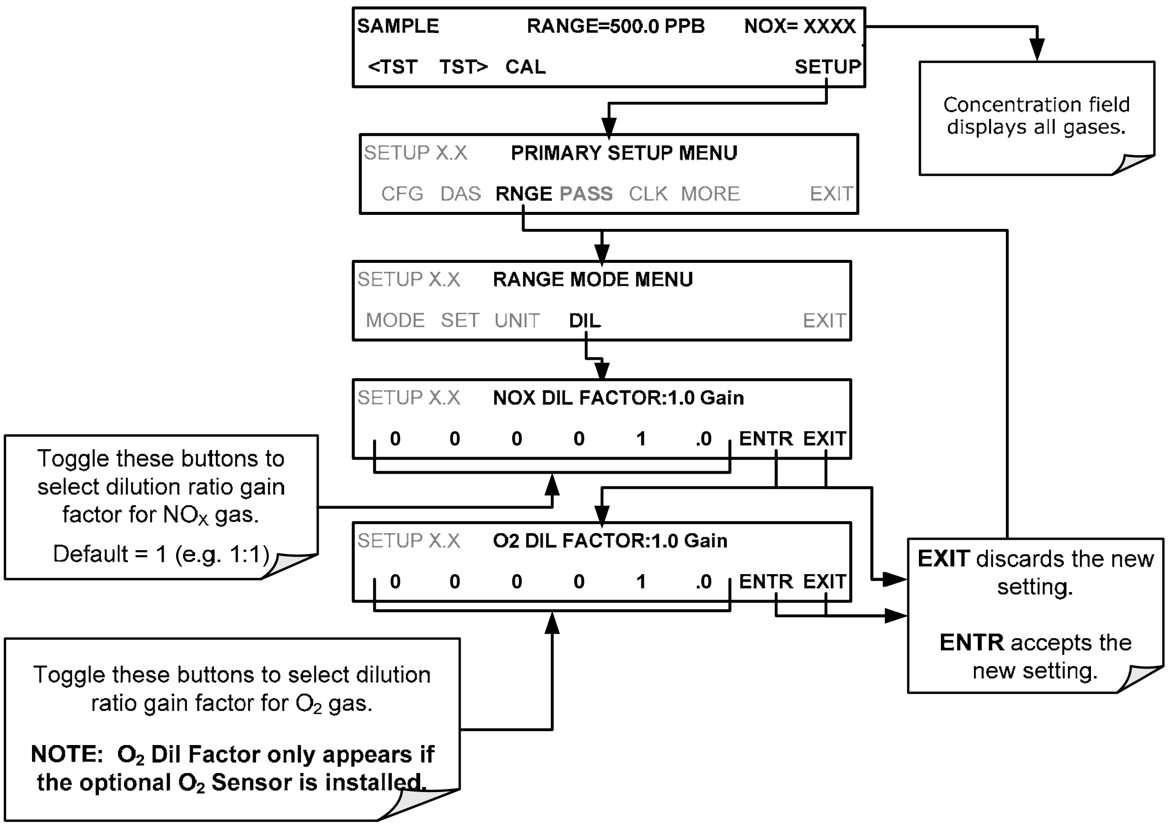
This will also counteract any discrepancies between STP definitions.

7.4.5. RNGE → DIL: USING THE OPTIONAL DILUTION RATIO FEATURE

This feature is an optional software utility used to compensate for any dilution of the sample gas that may occur before it enters the SAMPLE inlet. Typically this occurs in Continuous Emission Monitoring (CEM) applications where the sampling method used to remove the gas from the stack dilutes it.

Using the dilution ratio option is a 4-step process:

1. Select the appropriate units of measure (see Section 7.4.4.8).
2. Select the reporting range mode and set the reporting range upper limit (see Section 7.4.4). Ensure that:
   - The upper span limit entered for the reporting range is the maximum expected concentration of the **UNDILUTED** gas.
3. Set the dilution factor as a gain (e.g., a value of 20 means 20 parts diluent and 1 part of sample gas):



9. Calibrate the analyzer.
   - Ensure that the calibration span gas is either supplied through the same dilution system as the sample gas or has an appropriately lower actual concentration.

EXAMPLE: If the reporting range limit is set for 100 ppm and the dilution ratio of the sample gas is 20 gain, either:

– a span gas with the concentration of 100 ppm can be used if the span gas passes through the same dilution steps as the sample gas, or;

– a 5 ppm span gas must be used if the span gas **IS NOT** routed through the dilution system.

8. ADVANCED FEATURES OF THE T200 ANALYZER

8.1. USING THE DATA ACQUISITION SYSTEM (DAS)

The T200 analyzer contains a flexible and powerful, internal data acquisition system (DAS) that enables the analyzer to store concentration and calibration data as well as a host of diagnostic parameters. The DAS feature of the T200 can store up to one million data points, which can, depending on individual configurations, cover days, weeks or months of valuable measurements. The data records are stored in non-volatile memory and are retained even when the instrument is off. Data is stored in plain text format for easy retrieval and use in common data analysis programs (such as electronic spreadsheets).

The DAS is designed to be flexible and permits users to access stored data through the instrument's front panel or its communication ports. Users have full control over the type, length and reporting time of the data.

The principal use of the DAS is logging data for trend analysis and predictive diagnostics, which can assist in identifying possible problems before they affect the functionality of the analyzer. The secondary use is for data analysis, documentation and archival in electronic format.

To support the DAS functionality, Teledyne API offers APICOM, a program that provides a visual interface for remote or local setup, configuration and data retrieval of the DAS (see Section 8.1). Using APICOM, data can even be retrieved automatically to a remote computer for further processing. The APICOM manual, which is included with the program, contains a more detailed description of the DAS structure and configuration, which is briefly described in this document.

The T200 is configured with a basic DAS configuration already enabled. The data channels included in this basic structure may be used as is or temporarily disabled for later or occasional use.

Note

DAS operation is suspended whenever its configuration is edited using the analyzer's front panel and therefore data may be lost. To prevent such data loss, it is recommended to use the APICOM graphical user interface for DAS changes.

Please be aware that all stored data will be erased if the analyzer's disk-on-module or CPU board is replaced or if the configuration data stored there is reset.

8.1.1. DAS STATUS

The green **SAMPLE LED** on the instrument front panel, which indicates the analyzer status, also indicates certain aspects of the DAS status:

Table 8-1: Front Panel LED Status Indicators for DAS

LED STATE	DAS Status
OFF	System is in calibration mode. Data logging can be enabled or disabled for this mode. Calibration data are typically stored at the end of calibration periods, concentration data are typically not sampled, diagnostic data should be collected.
BLINKING	Instrument is in hold-off mode, a short period after the system exits calibrations. DAS channels can be enabled or disabled for this period. Concentration data are typically disabled whereas diagnostic should be collected.
ON	Sampling normally.

The DAS can be disabled only by disabling or deleting all of its individual data channels.

8.1.2. DAS STRUCTURE

The DAS is designed around the feature of a "record". A record is a single data point. The type of data recorded in a record is defined by two properties:

- **PARAMETER** type that defines the kind of data to be stored (e.g. the average of O_3 concentrations measured with three digits of precision). See Section 8.1.5.3.
- A **TRIGGER** event that defines when the record is made (e.g. timer; every time a calibration is performed, etc.). See Section 8.1.5.2.

The specific **PARAMETERS** and **TRIGGER** events that describe an individual record are defined in a construct called a **DATA CHANNEL** (see Section 8.1.5). Each data channel related one or more parameters with a specific trigger event and various other operational characteristics related to the records being made (e.g. the channels name, number or records to be made, time period between records, whether or not the record is exported via the analyzer's RS-232 port, etc.).

8.1.3. DAS CHANNELS

The key to the flexibility of the DAS is its ability to store a large number of combinations of triggering events and data parameters in the form of data channels. Users may create up to 20 data channels and each channel can contain one or more parameters. For each channel, the following are selected:

- One triggering event is selected.
- Up to 50 data parameters, which can be the shared between channels.
- Several other properties that define the structure of the channel and allow the user to make operational decisions regarding the channel.

Table 8-2: DAS Data Channel Properties

PROPERTY	DESCRIPTION	DEFAULT SETTING	SETTING RANGE
NAME	The name of the data channel.	**"NONE"**	Up to 6 letters or digits[1].
TRIGGERING EVENT	The event that triggers the data channel to measure and store the datum.	**ATIMER**	Any available event (see Appendix A-5).
NUMBER AND LIST OF PARAMETERS	A user-configurable list of data types to be recorded in any given channel.	**1** (PMTDET)	Any available parameter (see Appendix A-5).
REPORT PERIOD	The amount of time between each channel data point.	**000:01:00** *(1 hour)*	000:00:01 to 366:23:59 (Days:Hours:Minutes)
NUMBER OF RECORDS	The number of reports that will be stored in the data file. Once the limit is exceeded, the oldest data is over-written.	**100**	1 to 1 million, limited by available storage space.
RS-232 REPORT	Enables the analyzer to automatically report channel values to the RS-232 ports.	**OFF**	OFF or ON
CHANNEL ENABLED	Enables or disables the channel. Allows a channel to be temporarily turned off without deleting it.	**ON**	OFF or ON
CAL HOLD OFF	Disables sampling of data parameters while instrument is in calibration mode[2].	**OFF**	OFF or ON

[1] More with APICOM, but only the first six are displayed on the front panel).

[2] When enabled records are not recorded until the DAS_HOLD OFF period is passed after calibration mode. DAS_HOLD OFF SET in the **VARS** menu (see Section 8.2).

8.1.3.1. Default DAS Channels

A set of default Data Channels has been included in the analyzer's software for logging NO_x, NO and NO_2 concentrations as well as certain predictive diagnostic data. For the software revision being shipped with the T200 at the time of this writing, these default channels are:

- **CONC:** Samples NOx concentration at one minute intervals and stores an average every hour with a time and date stamp. Readings during calibration and calibration hold off are not included in the data.
  - By default, the last 800 hourly averages are stored.
- **CALDAT:** Logs new slope and offset of NO_X and NO measurements every time a zero or span calibration is performed and the result changes the value of the slope (triggering event: **SLPCHG**). The NO_X stability (to evaluate if the calibration value was stable) as well as the converter efficiency (for trend reference) are also stored.
  - This data channel will store data from the last 200 calibrations and can be used to document analyzer calibration and is useful for detect trends in slope and offset (instrument response) when performing predictive diagnostics as part of a regular maintenance schedule (See Section 13.2).
  - The CALDAT channel collects data based on events (e.g. a calibration operation) rather than a timed interval and therefore does not represent any specific length of time. As with all data channels, a date and time stamp is recorded for every logged data point.
- **CALCHECK:** This channel logs concentrations and the stability each time a zero or span check (not calibration) is finished (triggered by exiting any calibration menu).
  - The data of this channel enable the user to track the quality of zero and span responses over time and assist in evaluating the quality of zero and span gases and the analyzer's noise specifications.
  - The **STABIL** parameter documents if the analyzer response was stable at the point of the calibration check reading. The last 200 data points are retained.
- **DIAG:** Daily averages of temperature zones, flow and pressure data as well as some other diagnostic parameters (**HVPS**, **AZERO**).
  - This data is useful for predictive diagnostics and maintenance of the T200.
  - The last 1100 daily averages are stored to cover more than four years of analyzer performance.
- **HIRES:** Records one-minute, instantaneous data of all active parameters in the T200. Short-term trends as well as signal noise levels can be detected and documented.
  - Readings during calibration and the calibration hold off period are included in the averages.
  - The last 1500 data points are stored, which covers a little more than one day of continuous data acquisition.

These default data channels can be used as they are, or they can be customized from the front panel to fit a specific application. They can also be deleted to make room for custom user-programmed Data Channels.

Appendix A-5 lists the firmware-specific DAS configuration in plain-text format. This text file can either be loaded into APICOM and then modified and uploaded to the instrument or can be copied and pasted into a terminal program to be sent to the analyzer.

NOTE

Sending an DAS configuration to the analyzer through its COMM ports will replace the existing configuration and will delete all stored data.

Back up any existing data and the DAS configuration before uploading new settings.

List of Channels — **List of Parameters**

Name: CONC
Event: ATIMER
Parameters: 5
Report Period: 000:01:00
No. of Records: 800
RS-232 Report: OFF
Channel Enabled: ON
Cal Hold OFF: ON

PARAMETER	MODE	PRECISION	STORE NUM SAMPLES
NOXCNC1	AVG	4	OFF
NOCNC1	AVG	4	OFF
N2CNC1	AVG	4	OFF
O2CONC	AVG	4	OFF
STABIL	AVG	4	ON

Name: CALDAT
Event: SLPCHG
Parameters: 9
Report Period: N/A
No. of Records: 200
RS-232 Report: OFF
Channel Enabled: ON
Cal Hold OFF: OFF

PARAMETER	MODE	PRECISION	STORE NUM SAMPLES
NXZSC1	AVG	4	OFF
NXSLP1	AVG	4	OFF
NXOFS1	AVG	4	OFF
NOZSC1	AVG	4	OFF
NOSLP1	AVG	4	OFF
NOOFS1	AVG	4	OFF
N2ZSC1	AVG	4	OFF
CNVEF1	AVG	4	OFF
STABIL	AVG	4	OFF

Name: CALCHECK
Event: EXITMP
Parameters: 4
Report Period: N/A
No. of Records: 200
RS-232 Report: OFF
Channel Enabled: ON
Cal Hold OFF: OFF

PARAMETER	MODE	PRECISION	STORE NUM SAMPLES
NXCNC1	AVG	4	OFF
NOCNC1	AVG	4	OFF
N2CNC1	AVG	4	OFF
STABIL	AVG	4	OFF

Name: DIAG
Event: ATIMER
Parameters: 12
Report Period: 001:00:00
No. of Records: 1100
RS-232 Report: OFF
Channel Enabled: ON
Cal Hold OFF: OFF

PARAMETER	MODE	PRECISION	STORE NUM SAMPLES
SMPFLW	AVG	2	OFF
O3FLOW	AVG	2	OFF
RCPRES	AVG	2	OFF
SMPPRS	AVG	2	OFF
RCTEMP	AVG	2	OFF
PMTTMP	AVG	2	OFF
CNVTMP	AVG	2	OFF
MFTEMP	AVG	2	OFF
BOXTMP	AVG	2	OFF
O2TEMP	AVG	2	OFF
AZERO	AVG	2	OFF
HVPS	AVG	1	OFF

Name: HIRES
Event: ATIMER
Parameters: 18
Report Period: 000:00:01
No. of Records: 1500
RS-232 Report: OFF
Channel Enabled: OFF
Cal Hold OFF: OFF

PARAMETER	MODE	PRECISION	STORE NUM SAMPLES
NXCNC1	AVG	4	OFF
NOCNC1	AVG	4	OFF
N2CNC1	AVG	4	OFF
STABIL	AVG	4	OFF
SMPFLW	AVG	2	OFF
O3FLOW	AVG	2	OFF
RCPRES	AVG	2	OFF
SMPPRS	AVG	2	OFF
RCTEMP	AVG	2	OFF
PMTTMP	AVG	2	OFF
CNVTMP	AVG	2	OFF
MFTEMP	AVG	2	OFF
BOXTMP	AVG	2	OFF
O2TEMP	AVG	2	OFF
AZERO	AVG	2	OFF
HVPS	AVG	1	OFF
REFGND	AVG	1	OFF
REF4096	AVG	1	OFF

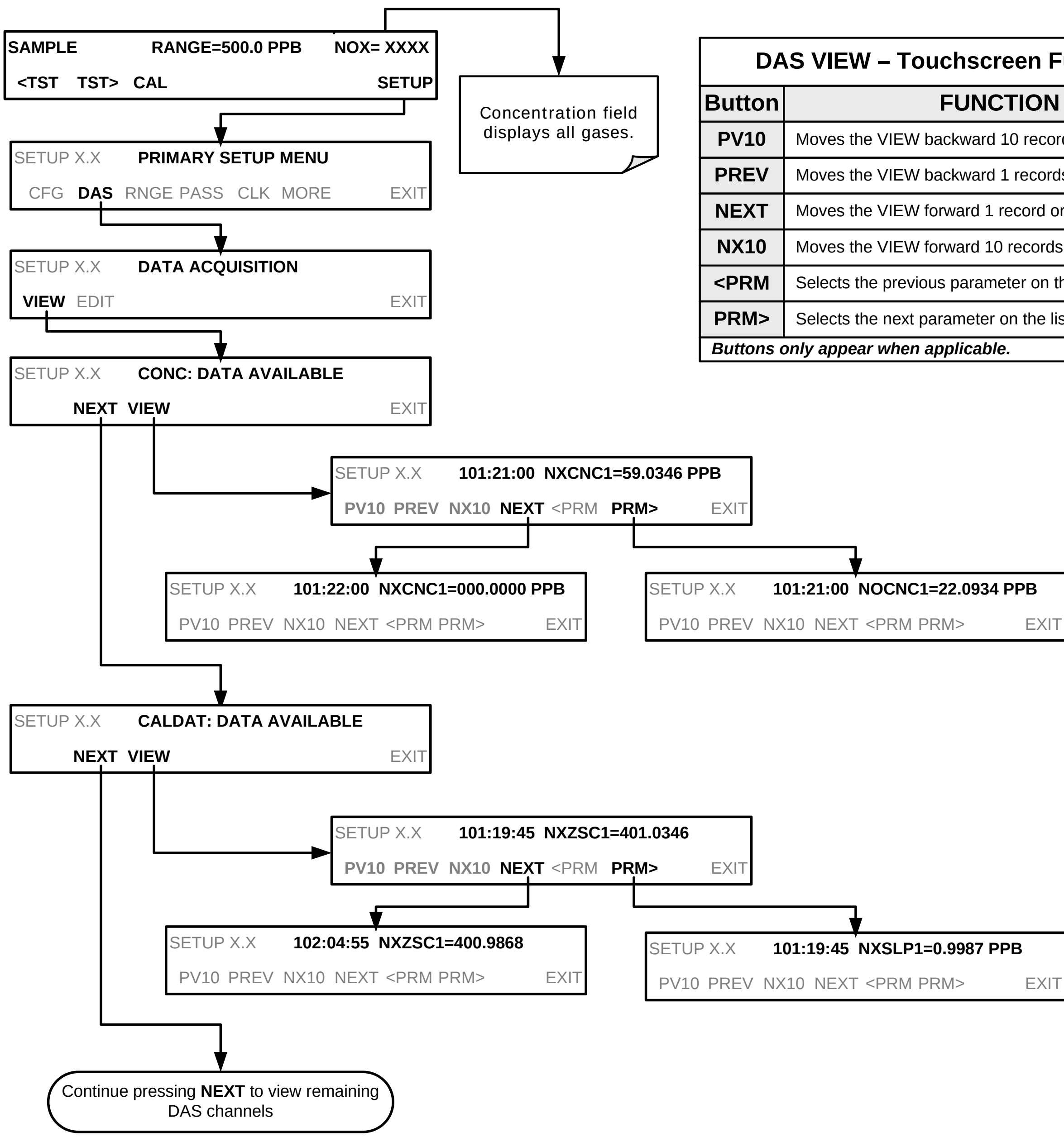
Figure 8-1: Default DAS Channel Setup

8.1.3.2. DAS Configuration Limits

The number of DAS objects are limited by the instrument's finite storage capacity. For information regarding the maximum number of channels, parameters, and records and how to calculate the file size for each data channel, refer to the DAS manual downloadable from the T-API website at http://www.teledyne-api.com/manuals/ under Special Manuals.

8.1.4. SETUP →DAS →VIEW: VIEWING DAS CHANNELS AND INDIVIDUAL RECORDS

DAS data and settings can be viewed on the front panel through the following menu sequence.



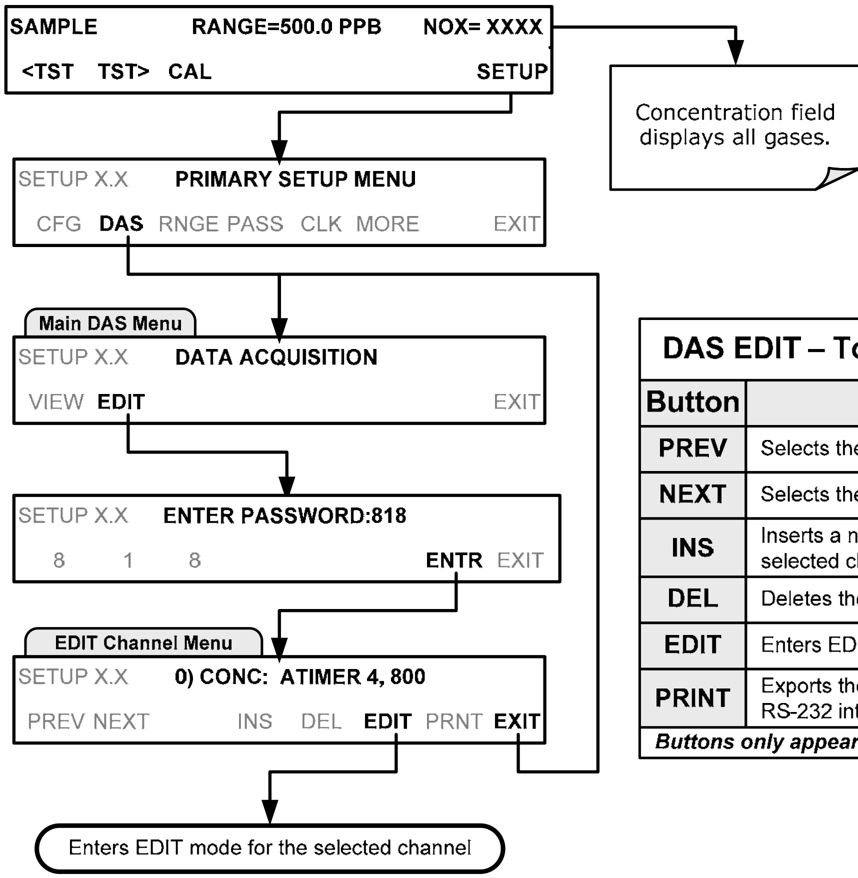
DAS VIEW – Touchscreen Functions

Button	FUNCTION
PV10	Moves the VIEW backward 10 record
PREV	Moves the VIEW backward 1 records or channel
NEXT	Moves the VIEW forward 1 record or channel
NX10	Moves the VIEW forward 10 records
<PRM	Selects the previous parameter on the list
PRM>	Selects the next parameter on the list

Buttons only appear when applicable.

8.1.5. SETUP →DAS →EDIT: ACCESSING THE DAS EDIT MODE

DAS configuration is most conveniently done through the APICOM remote control program. The following list of button strokes shows how to edit using the front panel.



DAS EDIT – Touchscreen Button Functions	
Button	**FUNCTION**
PREV	Selects the previous data channel in the list
NEXT	Selects the next data channel in the list
INS	Inserts a new data channel into the list BEFORE the selected channel
DEL	Deletes the currently selected data channel
EDIT	Enters EDIT mode
PRINT	Exports the configuration of all data channels to the RS-232 interface
Buttons only appear when applicable.	

When editing the data channels, the top line of the display indicates some of the configuration parameters.

For example, the display line:

0) NXCNC1: ATIMER, 5, 800

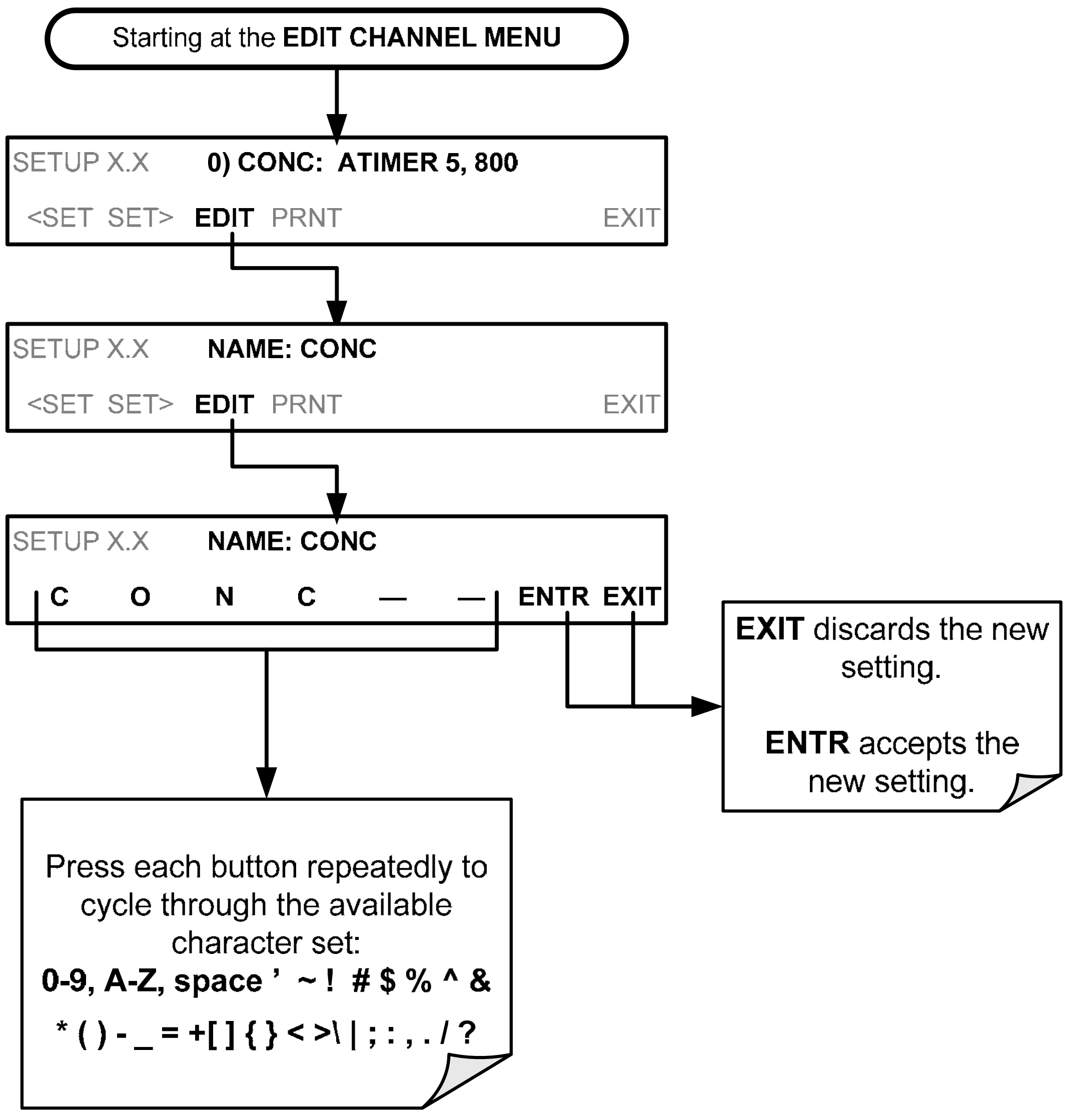
Translates to the following configuration:

Channel No.: 0
NAME: NXCNC1
TRIGGER EVENT: ATIMER
PARAMETERS: Five parameters are included in this channel
EVENT: This channel is set up to store 800 records.

To edit the name of a data channel, follow the above button sequence and then press:

8.1.5.1. Editing DAS Data Channel Names

To edit the name of an DAS data channel, follow the instruction shown in Section 8.1.5 then press:

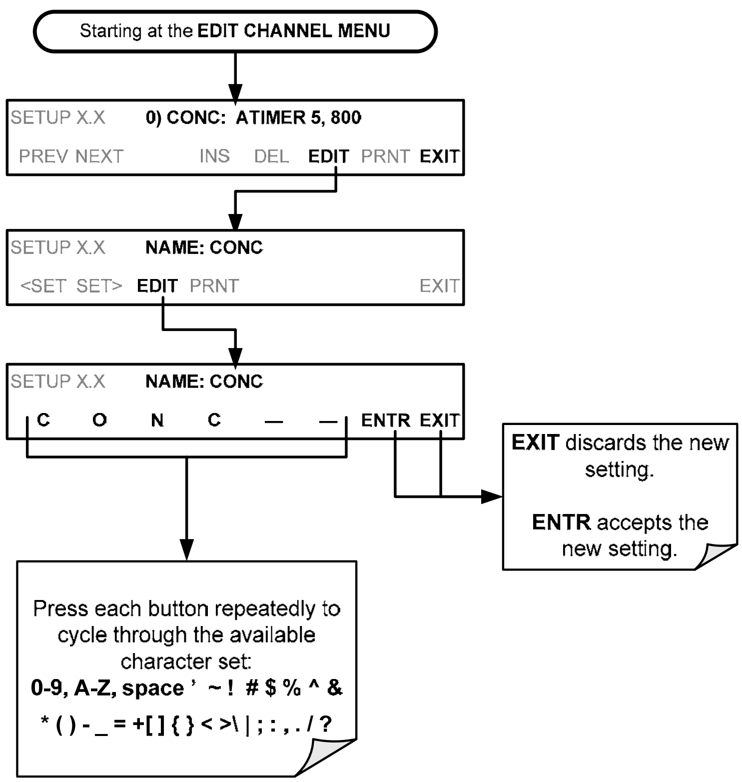


8.1.5.2. Editing DAS Triggering Events

Triggering events define when and how the DAS records a measurement of any given data channel. Triggering events are firmware-specific and a complete list of Triggers for this model analyzer can be found in Appendix A-5. The most commonly used triggering events are:

- **ATIMER**: Sampling at regular intervals specified by an automatic timer. Most trending information is usually stored at such regular intervals, which can be instantaneous or averaged.
- **EXITZR, EXITSP**, and **SLPCHG** (exit zero, exit span, slope change): Sampling at the end of (irregularly occurring) calibrations or when the response slope changes. These triggering events create instantaneous data points, e.g., for the new slope and offset (concentration response) values at the end of a calibration. Zero and slope values are valuable to monitor response drift and to document when the instrument was calibrated.
- **WARNINGS:** Some data may be useful when stored if one of several warning messages appears such as **WTEMPW** (GFC wheel temperature warning). This is helpful for troubleshooting by monitoring when a particular warning occurred.

To edit the list of data parameters associated with a specific data channel, follow the instruction shown in Section 8.1.5 then press:



NOTE

A full list of DAS Trigger Events can be found in Appendix A-5 of this manual.

8.1.5.3. Editing DAS Parameters

Data parameters are types of data that may be measured and stored by the DAS. For each Teledyne API's analyzer model, the list of available data parameters is different, fully defined and not customizable. Appendix A-5 lists firmware specific data parameters for the T200. DAS parameters include data such as NO_x, NO and NO_2 concentration measurements, temperatures of the various heaters placed around the analyzer, pressures and flows of the pneumatic subsystem and other diagnostic measurements as well as calibration data such as stability, slope and offset.

Most data parameters have associated measurement units, such as mV, ppb, cm^3/min, etc., although some parameters have no units (e.g. **SLOPE**). With the exception of concentration readings, none of these units of measure can be changed. To change the units of measure for concentration readings, see Section 7.4.4.8.

> **NOTE**
>
> **DAS does not keep track of the units (i.e. PPM or PPB) of each concentration value. Therefore, DAS data files may contain concentration data recorded in more than one type of unit if the units of measure were changed during data acquisition.**

Each data parameter has user-configurable functions that define how the data are recorded which are listed in Table 8-3:

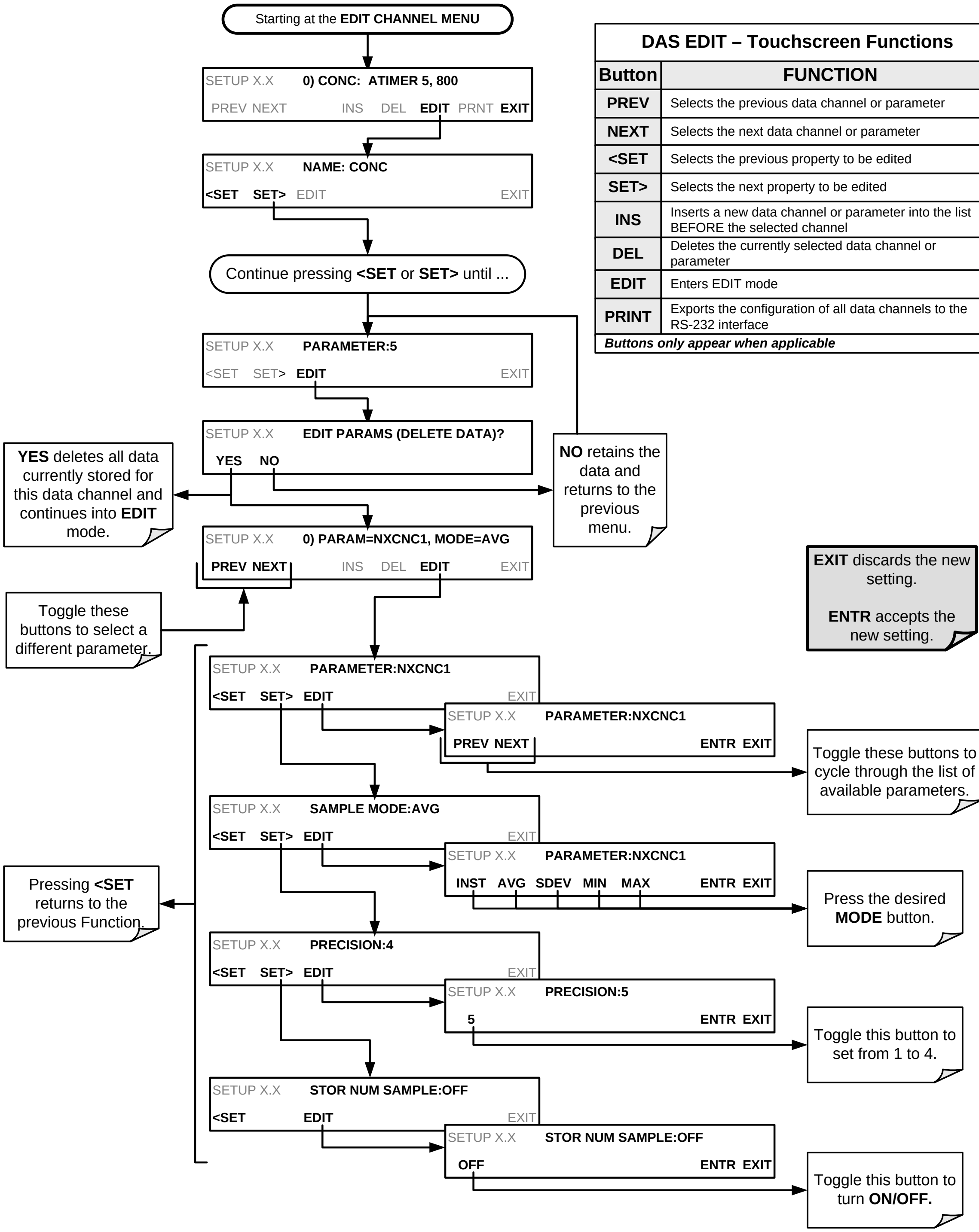
Table 8-3: DAS Data Parameter Functions

FUNCTION	EFFECT
PARAMETER	Instrument specific parameter name.
SAMPLE MODE	**INST:** Records instantaneous reading. **AVG:** Records average reading during reporting interval. **SDEV:** Records the standard deviation of the data points recorded during the reporting interval. **MIN:** Records minimum (instantaneous) reading during reporting interval. **MAX:** Records maximum (instantaneous) reading during reporting interval.
PRECISION	**0 to 4:** Sets the number of digits to the right decimal point for each record. Example: Setting **4**; **"399.9865 PPB"** Setting **0**; **"400 PPB"**
STORE NUM. SAMPLES	**OFF:** Stores only the average (default). **ON:** Stores the average and the number of samples in used to compute the value of the parameter. This property is only useful when the AVG sample mode is used. Note that the number of samples is the same for all parameters in one channel and needs to be specified only for one of the parameters in that channel.

Users can specify up to 50 parameters per data channel (the T200 provides about 40 parameters). However, the number of parameters and channels is ultimately limited by available memory.

Data channels can be edited individually from the front panel without affecting other data channels. However, when editing a data channel, such as during adding, deleting or editing parameters, all data for that particular channel will be lost, because the DAS can store only data of one format (number of parameter columns etc.) for any given channel. In addition, an DAS configuration can only be uploaded remotely as an entire set of channels. Hence, remote update of the DAS will always delete all current channels and stored data.

To modify, add or delete a parameter, follow the instruction shown in Section 8.1.5 then press:



DAS EDIT – Touchscreen Functions

Button	FUNCTION
PREV	Selects the previous data channel or parameter
NEXT	Selects the next data channel or parameter
<SET	Selects the previous property to be edited
SET>	Selects the next property to be edited
INS	Inserts a new data channel or parameter into the list BEFORE the selected channel
DEL	Deletes the currently selected data channel or parameter
EDIT	Enters EDIT mode
PRINT	Exports the configuration of all data channels to the RS-232 interface

Buttons only appear when applicable

NOTE

When the STORE NUM SAMPLES feature is turned on, the instrument will store the number of measurements that were used to compute the AVG, SDEV, MIN or MAX value but not the actual measurements themselves.

8.1.5.4. Editing Sample Period and Report Period

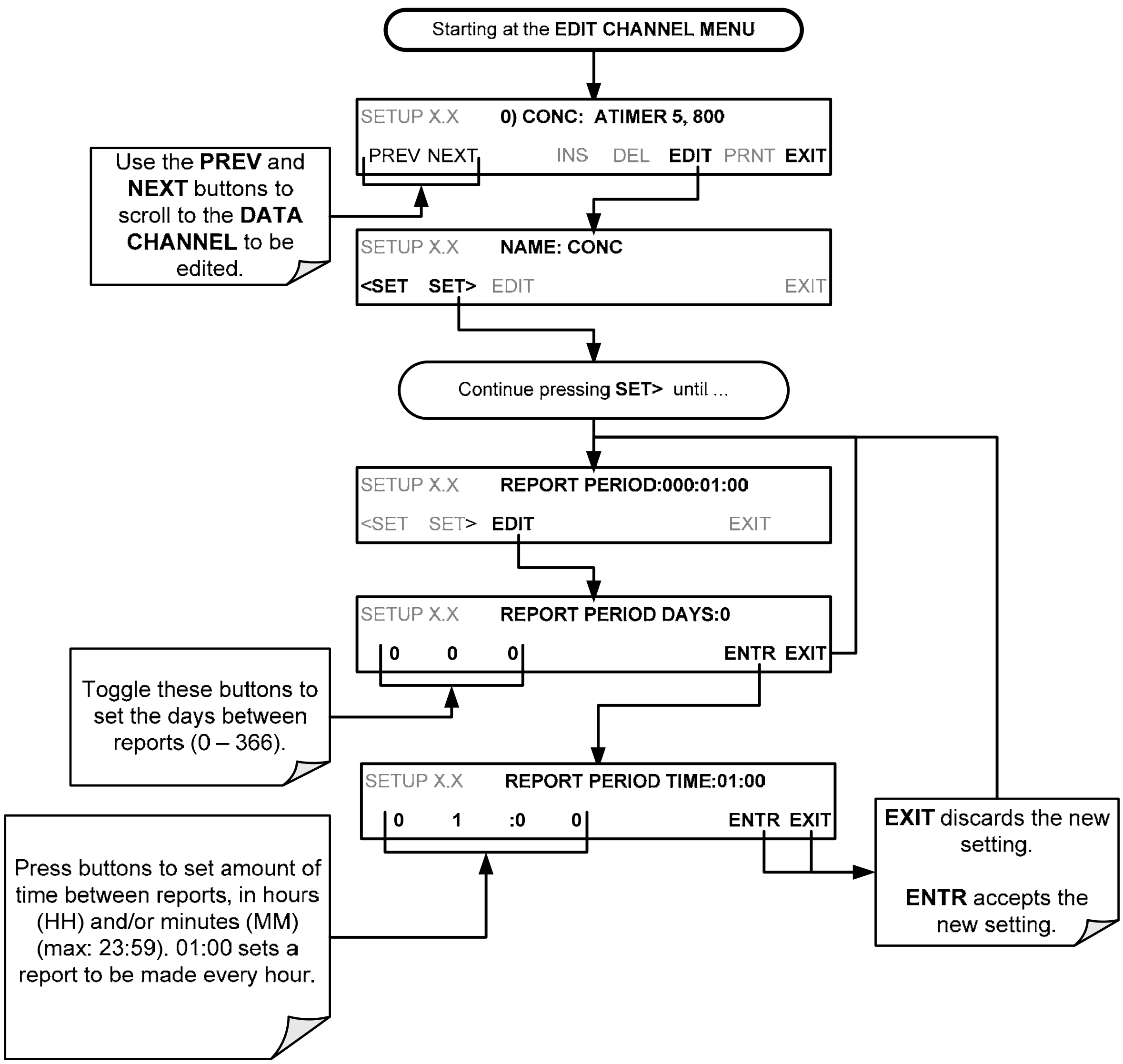
The DAS defines two principal time periods by which sample readings are taken and permanently recorded:

- **SAMPLE PERIOD:** Determines how often DAS temporarily records a sample reading of the parameter in volatile memory. **SAMPLE PERIOD** is only used when the DAS parameter's sample mode is set for AVG, SDEV, MIN or MAX.

  The **SAMPLE PERIOD** is set to one minute by default and generally cannot be accessed from the standard DAS front panel menu, but is available via the instruments communication ports by using APICOM or the analyzer's standard serial data protocol.

- **REPORT PERIOD**: Sets how often the sample readings stored in volatile memory are processed, (e.g. average, minimum or maximum are calculated) and the results stored permanently in the instruments Disk-on-Module (DOM) as well as transmitted via the analyzer's communication ports. The Report Period may be set from the front panel. If the INST sample mode is selected the instrument stores and reports an instantaneous reading of the selected parameter at the end of the chosen report period.

To define the **REPORT PERIOD**, follow the instruction shown in Section 8.1.5 then press:



The **SAMPLE PERIOD** and **REPORT PERIOD** intervals are synchronized to the beginning and end of the appropriate interval of the instruments internal clock.

- If **SAMPLE PERIOD** is set for one minute the first reading would occur at the beginning of the next full minute according to the instrument's internal clock.
- If the **REPORT PERIOD** is set for of one hour, the first report activity would occur at the beginning of the next full hour according to the instrument's internal clock.

EXAMPLE:

Given the above settings, if DAS parameters are activated at 7:57:35 the first sample would occur at 7:58 and the first report would be calculated at 8:00 consisting of data points for 7:58. 7:59 and 8:00.

During the next hour (from 8:01 to 9:00), the instrument will take a sample reading every minute and include 60 sample readings.

NOTE

In AVG, SDEV, MIN or MAX sample modes (see Section 8.1.5.3), the settings for the Sample Period and the Report Period determine the number of data points used each time the parameters are calculated, stored and reported to the COMM ports.

The actual sample readings are not stored past the end of the chosen report period.

When the STORE NUM SAMPLES feature is turned on, the instrument will store the number of measurements that were used to compute the AVG, SDEV, MIN or MAX value but not the actual measurements themselves.

8.1.5.5. Report Periods in Progress when Instrument Is Powered Off

If the instrument is powered off in the middle of a **REPORT PERIOD**, the samples accumulated during that period are lost. Once the instrument is turned back on, the DAS restarts taking samples and temporarily stores them in volatile memory as part of the **REPORT PERIOD** currently active at the time of restart. At the end of this **REPORT PERIOD,** only the sample readings taken since the instrument was turned back on will be included in any **AVG, SDEV, MIN** or **MAX** calculation.

The **STORE NUM SAMPLES** feature will also report the number of sample readings taken since the instrument was restarted.

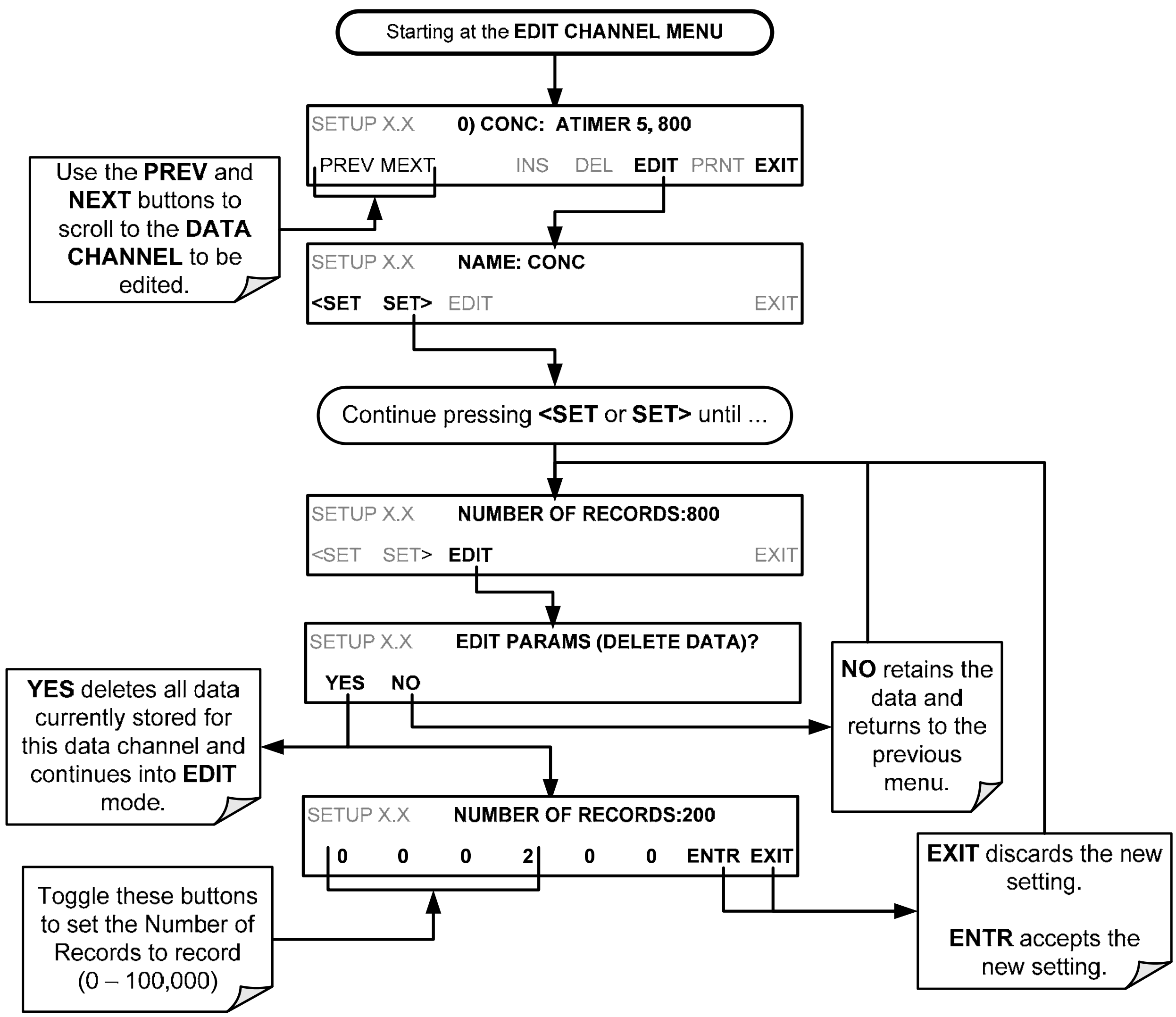
8.1.5.6. Editing the Number of Records

The number of data records in the DAS is limited to about a cumulative one million data points in all channels (one megabyte of space on the DOM). However, the actual number of records is also limited by the total number of parameters and channels and other settings in the DAS configuration. Every additional data channel, parameter, number of samples setting etc. will reduce the maximum amount of data points. In general, however, the maximum data capacity is divided amongst all channels (max: 20) and parameters (max: 50 per channel).

The DAS will check the amount of available data space and prevent the user from specifying too many records at any given point. If, for example, the DAS memory space can accommodate 375 more data records, the **ENTR** button will disappear when trying to specify more than that number of records. This check for memory space may also make an upload of an DAS configuration with APICOM or a terminal program fail, if the combined number of records would be exceeded. In this case, it is suggested to either try to determine what the maximum number of records available is using the front panel interface or use trial-and-error in designing the DAS script or calculate the number of records using the DAS or APICOM manuals.

To set the **NUMBER OF RECORDS**, follow the instruction shown in Section 8.1.5 then press:

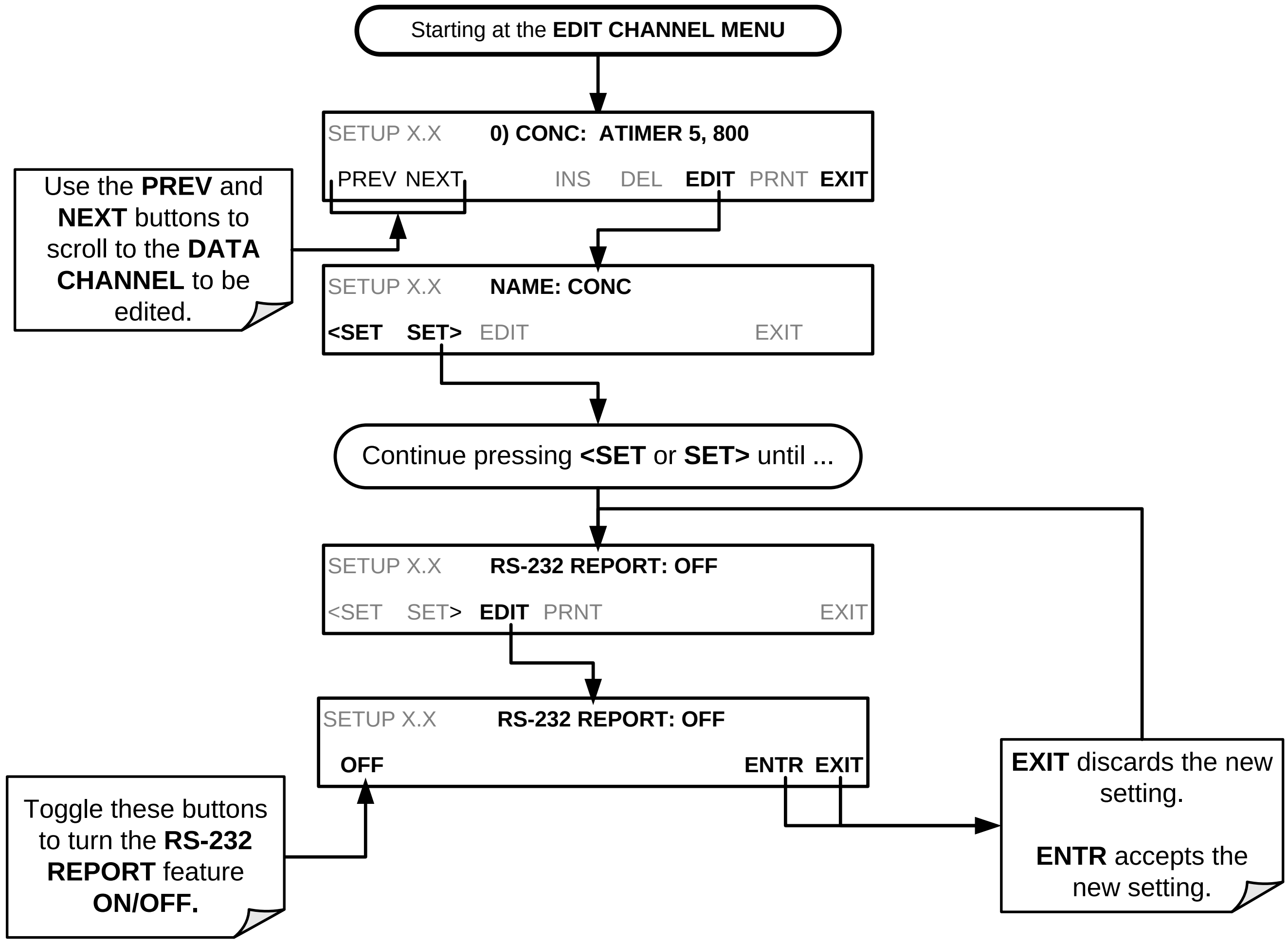
.



8.1.5.7. RS-232 Report Function

The DAS can automatically report data to the communications ports, where they can be captured with a terminal emulation program or simply viewed by the user using the APICOM software.

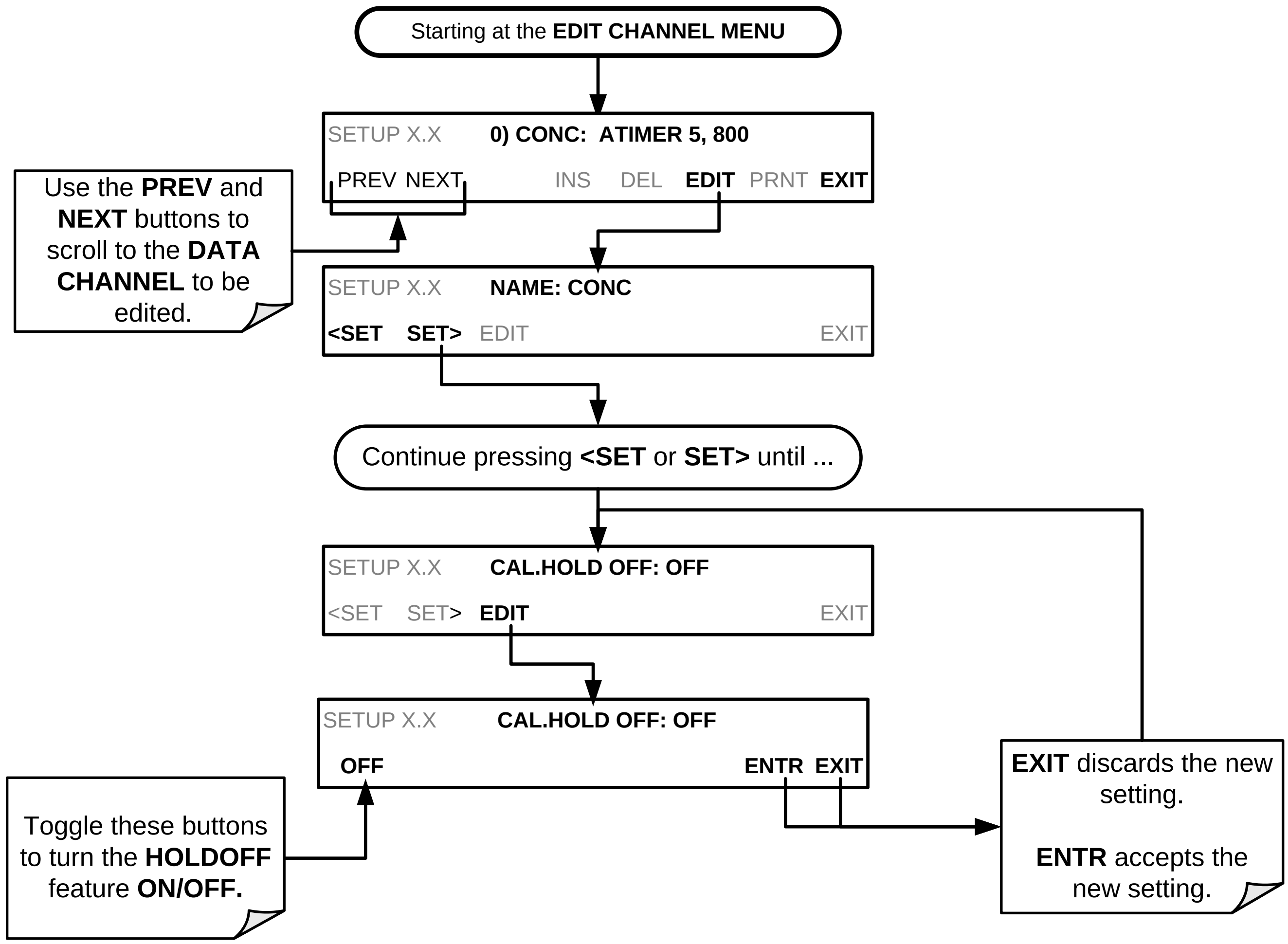
To enable automatic **COMM** port reporting, follow the instruction shown in Section 8.1.5 then press:



8.1.5.8. Enabling / Disabling the HOLDOFF Feature

The DAS **HOLDOFF** feature prevents data collection during calibration operations.

To enable or disable the **HOLDOFF**, follow the instruction shown in Section 8.1.5 then press:



HOLDOFF also prevents DAS measurements from being made at certain times when the quality of the analyzer's O_3 measurements may be suspect (e.g. while the instrument is warming up). In this case, the length of time that the **HOLDOFF** feature is active is determined by the value of the internal variable (**VARS**), **DAS_HOLDOFF.**

To set the length of the **DAS_HOLDOFF** period, see Section 8.2.

8.1.5.9. The Compact Report Feature

When enabled, this option avoids unnecessary line breaks on all RS-232 reports. Instead of reporting each parameter in one channel on a separate line, up to five parameters are reported in one line.

The **COMPACT DATA REPORT** generally cannot be accessed from the standard DAS front panel menu, but is available via the instruments communication ports by using APICOM or the analyzer's standard serial data protocol.

8.1.5.10. The Starting Date Feature

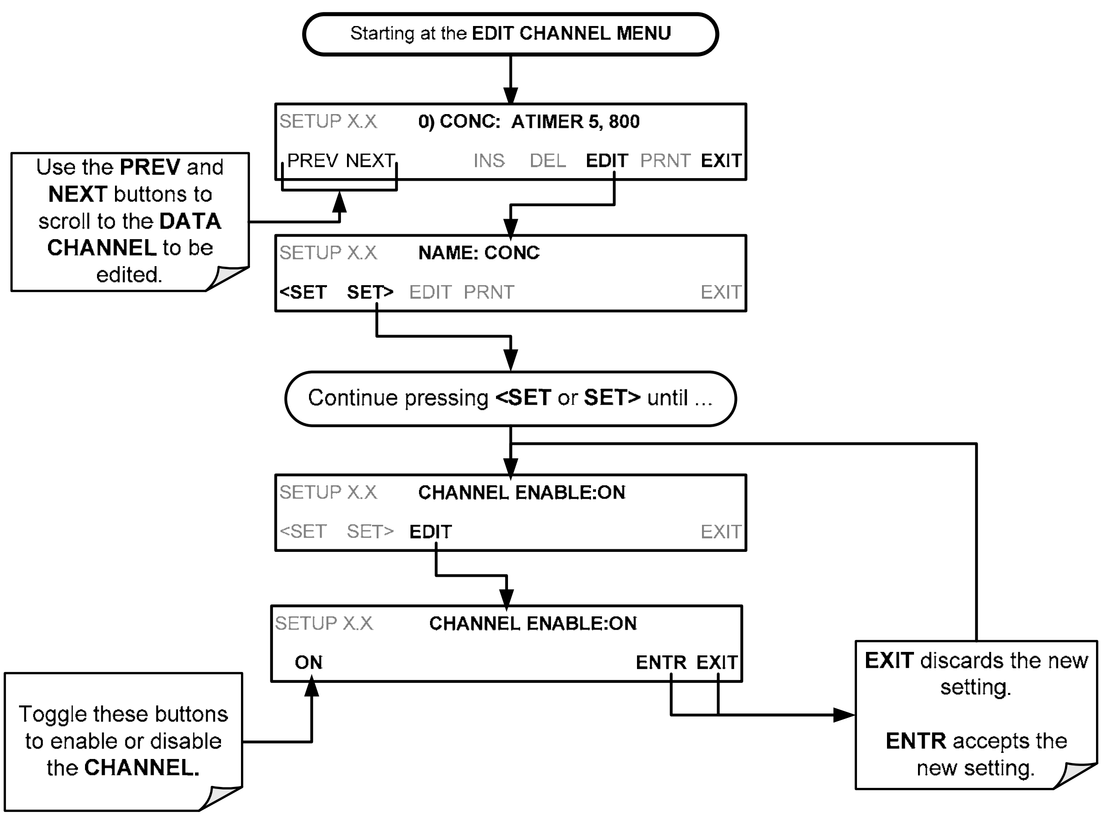
This option allows the user to specify a starting date for any given channel in case the user wants to start data acquisition only after a certain time and date. If the **STARTING DATE** is in the past (the default condition), the DAS ignores this setting and begins recording data as defined by the **REPORT PERIOD** setting.

The **STARTING DATE** generally cannot be accessed from the standard DAS front panel menu, but is available via the instruments communication ports by using APICOM or the analyzer's standard serial data protocol.

8.1.6. DISABLING/ENABLING DATA CHANNELS

Data channels can be temporarily disabled, which can reduce the read/write wear on the Disk-on-Module (DOM).

To disable a data channel, follow the instruction shown in Section 8.1.5 then press:



8.1.7. REMOTE DAS CONFIGURATION

8.1.7.1. DAS Configuration Using APICOM

Editing channels, parameters and triggering events as described in this can be performed via the APICOM remote control program using the graphic interface shown below. Refer to Section 9 for details on remote access to the T200 analyzer.

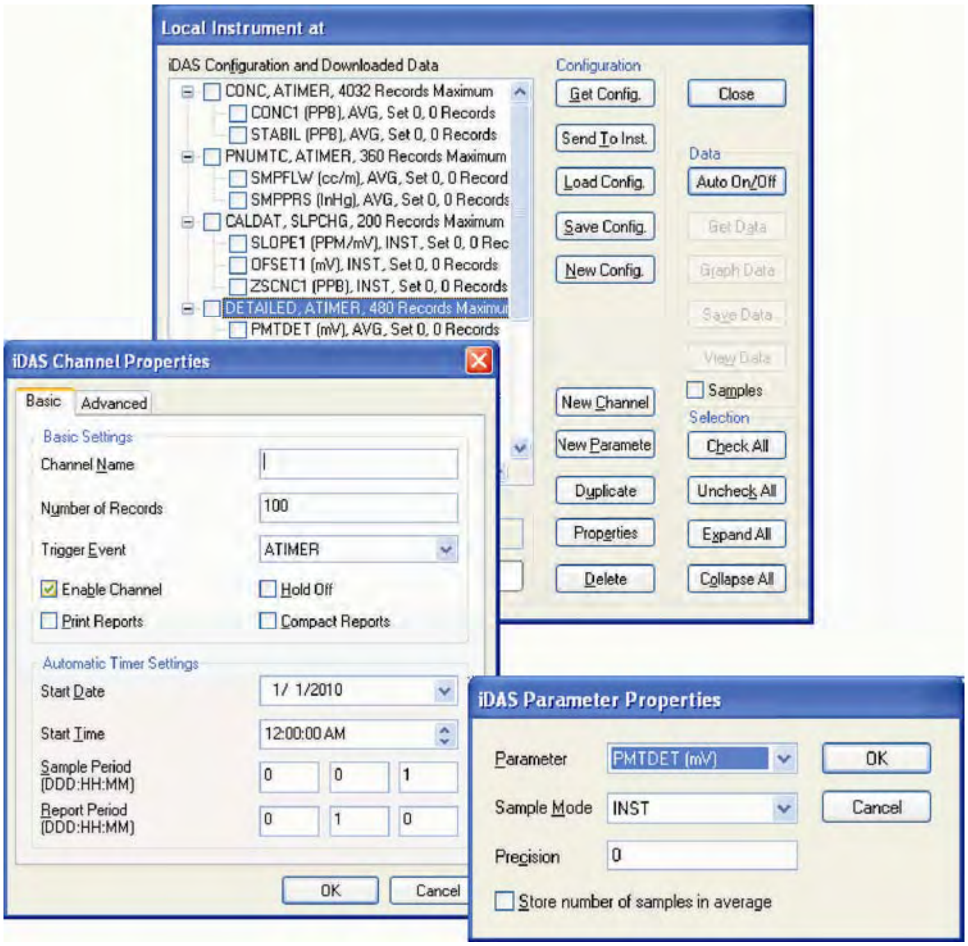


Figure 8-2: APICOM User Interface for Configuring the DAS.

Once an DAS configuration is edited (which can be done offline and without interrupting DAS data collection), it is conveniently uploaded to the instrument and can be stored on a computer for later review, alteration or documentation and archival. Refer to the APICOM manual for details on these procedures. The APICOM user manual (Teledyne API's P/N 039450000) is included in the APICOM installation file, which can be downloaded at http://www.teledyne-api.com/software/apicom/.

8.1.7.2. DAS Configuration Using Terminal Emulation Programs

Although Teledyne API recommends the use of APICOM, the DAS can also be accessed and configured through a terminal emulation program such as HyperTerminal (see Figure 8-3 for example). To do this:

- All configuration commands must be created and edited off line (e.g. cut & pasted in from a text file or word processor) following a strict syntax.
- The script is then uploaded via the instruments RS-232 port(s).

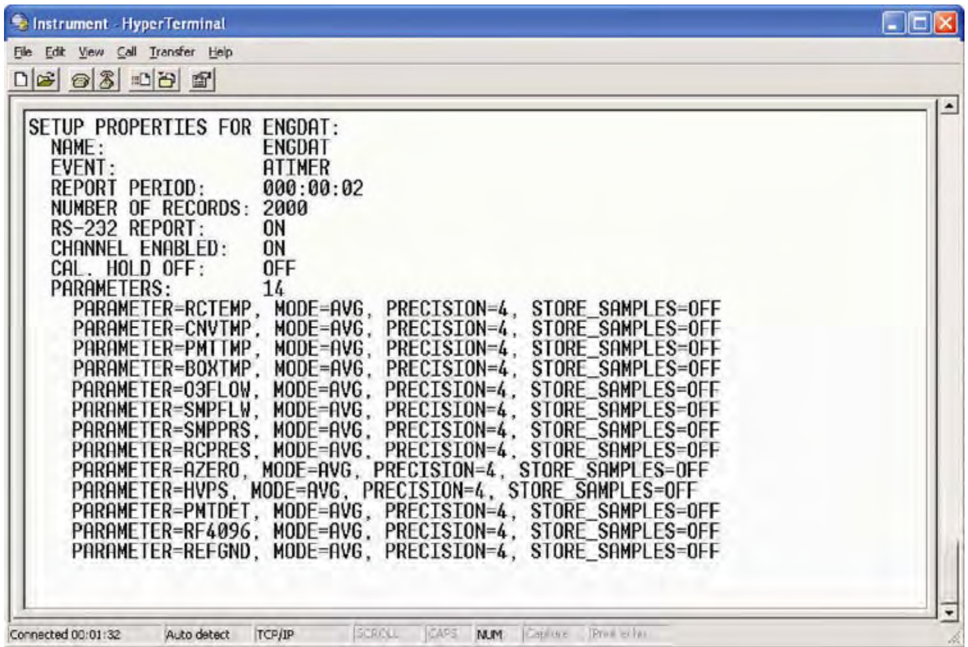


Figure 8-3: DAS Configuration Through a Terminal Emulation Program

Both of the above steps are best started by:

1. Downloading the default DAS configuration.
2. Getting familiar with its command structure and syntax conventions.
3. Altering a copy of the original file offline.
4. Uploading the new configuration into the analyzer.

NOTE

The editing, adding and deleting of DAS channels and parameters of one channel through the front-panel touch screen can be done without affecting the other channels.

On the other hand, uploading a DAS configuration script to the analyzer through its communication ports WILL ERASE ALL DATA, PARAMETERS AND CHANNELS and replace them with the new DAS configuration.

It is advised that you download and backup all data and the original DAS configuration before attempting any DAS changes.

Refer to the next Section 9 for details on remote access to and from the T200 analyzer via the instrument's COMM ports.

8.2. SETUP → MORE → VARS: INTERNAL VARIABLES (VARS)

The T200 has several-user adjustable software variables, which define certain operational parameters. Usually, these variables are automatically set by the instrument's firmware, but can be manually redefined using the **VARS** menu.

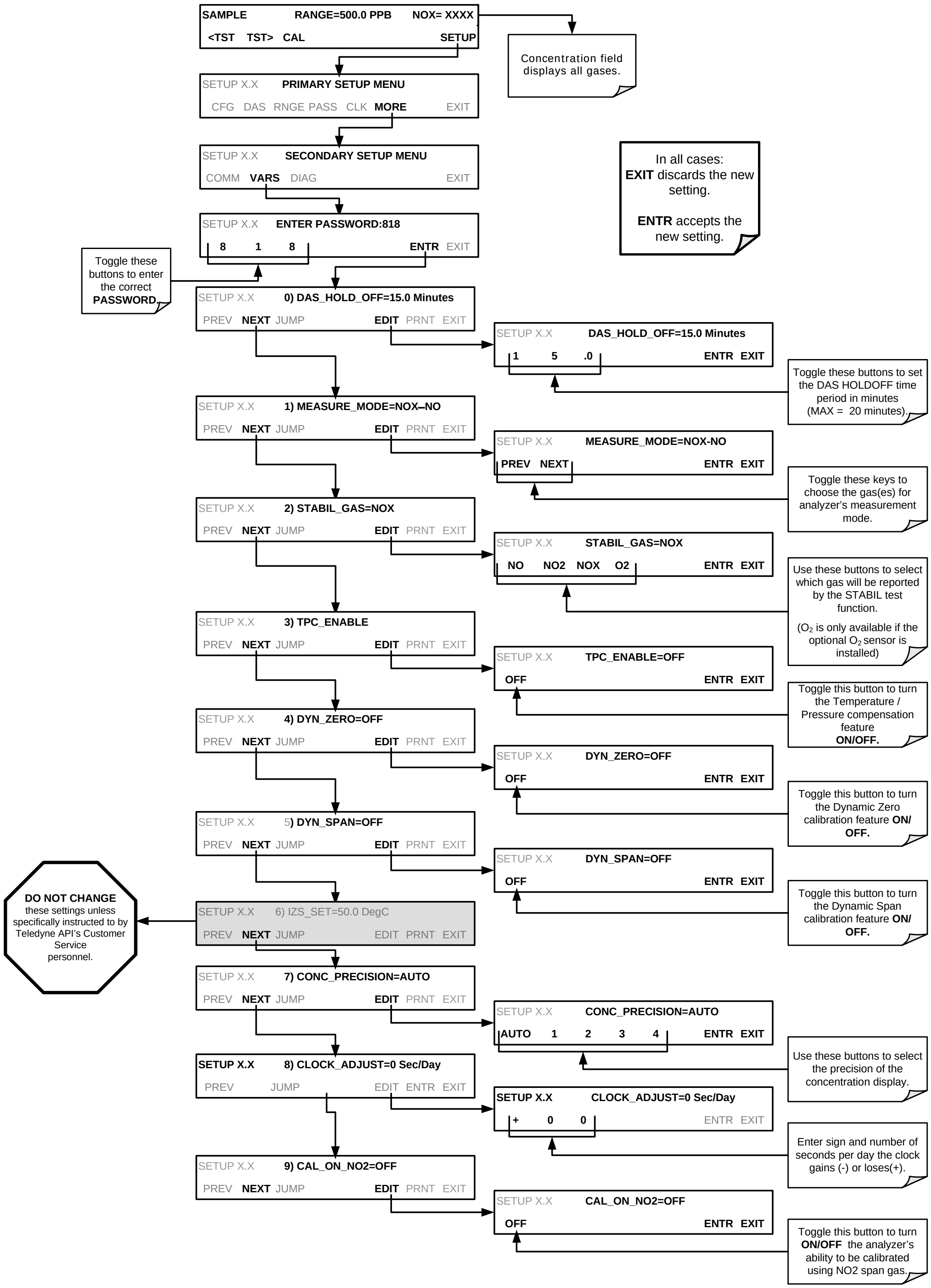
The following table lists all variables that are available within the 818 password protected level. See Appendix A2 for a detailed listing of all of the T200 variables that are accessible through the remote interface.

Table 8-4: Variable Names (VARS)

NO.	VARIABLE	DESCRIPTION	ALLOWED VALUES	VARS DEFAULT VALUES
0	DAS_HOLD_OFF	Changes the Internal Data Acquisition System (DAS) **HOLDOFF** timer: No data is stored in the DAS channels during situations when the software considers the data to be questionable such as during warm up of just after the instrument returns from one of its calibration mode to **SAMPLE** Mode.	May be set for intervals between 0.5 – 20 min	**15 min.**
1	MEASURE_MODE	Selects the gas measurement mode in which the instrument is to operate. NO_x only, NO only or NO_x and NO simultaneously.	NO; NO_x; NO_x–NO	NO_x**–NO**
2	STABIL_GAS	Selects which gas measurement is displayed when the **STABIL** test function is selected	NO; NO_x; NO_2;	NO_x
3	TPC_ENABLE	Enables or disables the Temperature and Pressure Compensation (TPC) feature (Section 12.9.2).	ON/OFF	**ON**
4	DYN_ZERO [1]	Dynamic zero automatically adjusts offset and slope of the NO and NO_X response when performing a zero point calibration during an AutoCal (see Section 10.5).	ON/OFF	**OFF**
5	DYN_SPAN [1]	Dynamic span automatically adjusts the offsets and slopes of the NO and NO_x response when performing a sp point calibration during an AutoCal (see Section 10.5).	ON/OFF	**OFF**
6	IZS_SET	Sets the internal span gas generator's permeation tube oven temperature. Increasing or decreasing this temperature will increase or decrease the NO_2 permeation rate (Section 6.3.1).	30°C - 70°C	**51°C**
7	CONC_PRECISION	Allows the user to set the number of significant digits to the right of the decimal point display of concentration and stability values.	AUTO, 1, 2, 3, 4	**AUTO**
8	CLOCK_ADJ	Adjusts the speed of the analyzer's clock. Choose the + sign if the clock is too slow, choose the - sign if the clock is too fast.	-60 to +60 s/day	**0 sec**
9	CAL_ON_NO_2	Allows turning ON and OFF the ability to span the analyzer with NO_2, in which case the instrument acts as if NO and NO_X are spanned, even though it is supplied with NO_2. The NO_2 concentration is then zero by default.	ON or OFF	**OFF**

[1] Use of the DYN_ZERO and DYN_SPAN features are not allowed for applications requiring EPA equivalency.

To access and navigate the **VARS** menu, use the following button sequence:



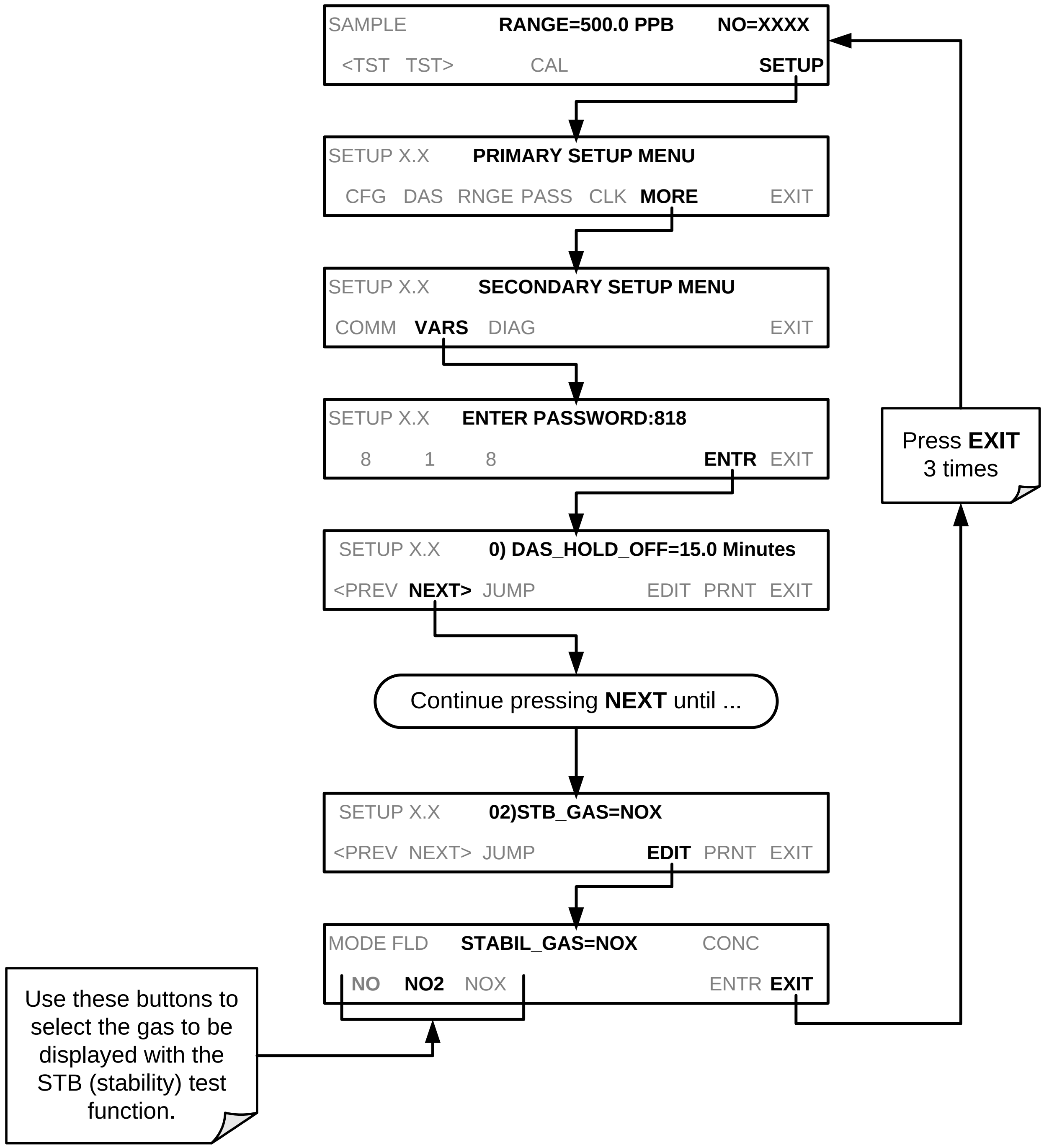
NOTE:

There is a 2-sec latency period between when a VARS value is changed and the new value is stored into the analyzer's memory. <u>DO NOT</u> turn the analyzer off during this period or the new setting will be lost.

8.2.1. Setting the Gas Type for the STABILITY Test Function

One of the most common VARS used on the T200 is the stability test function (***[Gas Type]* STB**). One of its primary uses is during calibration operations to judge when NO_x, NO and NO_2 concentration readings have stabilized sufficiently to process with the calibration. The **STB** function only displays stability for one type of gas at a time and must be reset for each gas type.

EXAMPLE: To change the **STB** test function from NO_x to NO_2, press:



8.3. SETUP → MORE → DIAG :THE DIAGNOSTIC MENU

A series of diagnostic tools is grouped together under the **SETUP→MORE→DIAG** menu. The parameters are dependent on firmware revision (see Appendix A). These tools can be used in a variety of troubleshooting and diagnostic procedures and are referred to in many places of the maintenance and troubleshooting sections of this manual.

The various operating modes available under the **DIAG** menu are:

Table 8-5: Diagnostic Mode (DIAG) Functions

DIAG SUBMENU	SUBMENU FUNCTION	Front Panel Mode Indicator	MANUAL SECTION
SIGNAL I/O	Allows observation of all digital and analog signals in the instrument. Allows certain digital signals such as valves and heaters to be toggled **ON** and **OFF**.	**DIAG I/O**	14.1.3
ANALOG OUTPUT	When entered, the analyzer performs an analog output step test. This can be used to calibrate a chart recorder or to test the analog output accuracy.	**DIAG AOUT**	14.7.6.1
ANALOG I/O CONFIGURATION	The signal levels of the instruments analog outputs may be calibrated (either individually or as a group). Various electronic parameters such as signal span, and offset are available for viewing and configuration.	**DIAG AIO**	8.4
TEST CHAN OUTPUT	Selects one of the available test channel signals to output over the **A4** analog output channel.	**DIAG TCHN**	8.4.6
OPTIC TEST	When activated, the analyzer performs an optic test, which turns on an LED located inside the sensor module near the PMT (Figure 12-20). This diagnostic tests the response of the PMT without having to supply span gas.	**DIAG OPTIC**	0
ELECTRICAL TEST	When activated, the analyzer performs an electrical test, which generates a current intended to simulate the PMT output to verify the signal handling and conditioning of the PMT preamp board.	**DIAG ELEC**	0
OZONE GEN OVERRIDE [1]	Allows the user to manually turn the O_3 generator on or off. During initial power up TMR (timer) is displayed while the Ozone brick remains off for the first 30 minutes.	**DIAG OZONE**	0
FLOW CALIBRATION [1]	This function is used to calibrate the gas flow output signals of sample gas and ozone supply.	**DIAG FCAL**	10.7
[1] These settings are retained after exiting DIAG mode.			

To access the various **DIAG** submenus, press the following buttons:

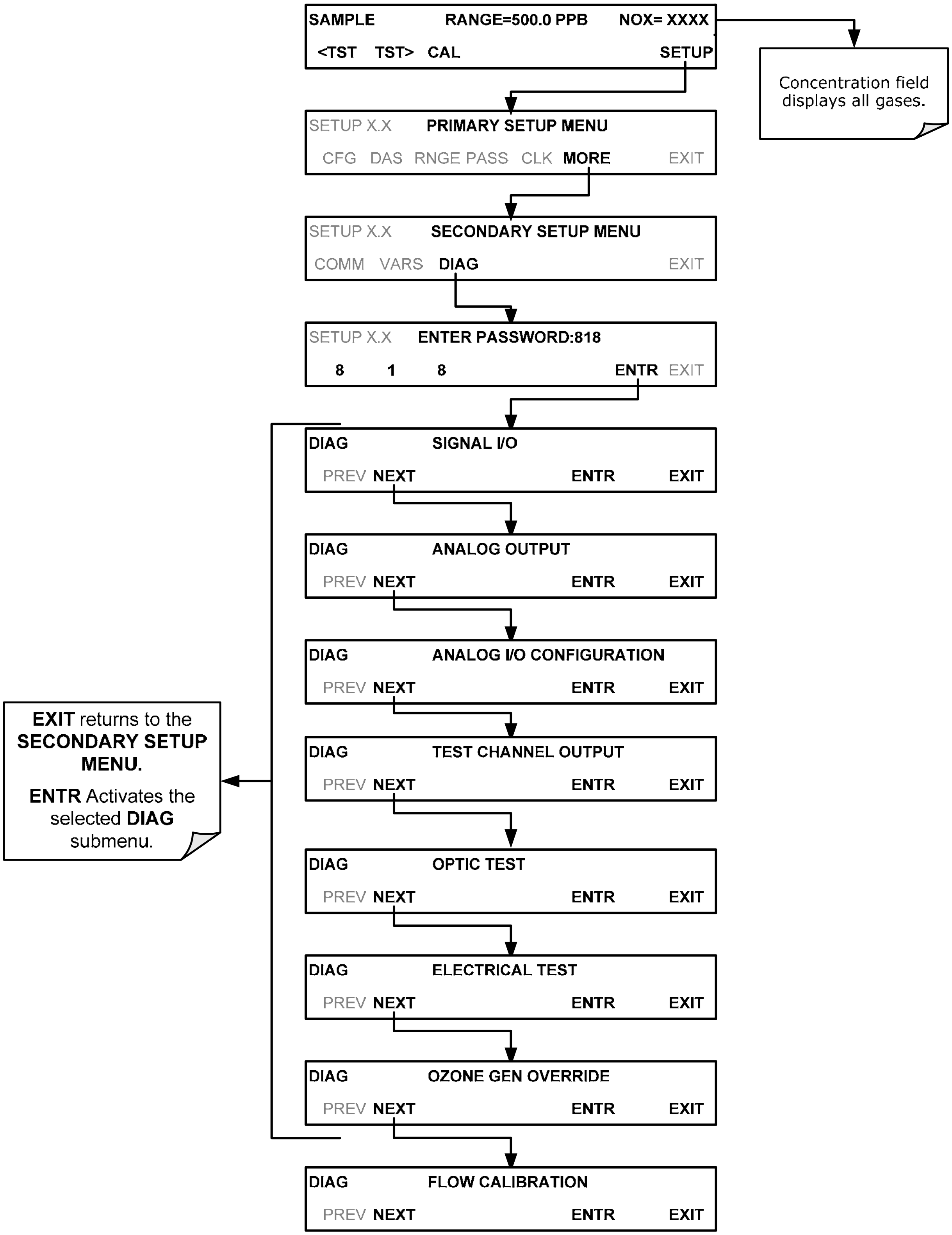


Figure 8-4: Accessing the DIAG Submenus

8.4. USING THE T200 ANALYZER'S ANALOG OUTPUTS

The T200 analyzer comes equipped with four analog outputs. The first three outputs (**A1 A2,** & **A3)** carry analog signals that represent the currently measured concentrating of NO_x, NO and NO_2 (see Section 7.4.4.3). The fourth output (**A4**) outputs a signal that can be set to represent the current value of one of several test functions (see Table 8-10).

8.4.1. ACCESSING THE ANALOG OUTPUT SIGNAL CONFIGURATION SUBMENU

The following table lists the analog I/O functions that are available in the T200 analyzer.

Table 8-6: DIAG - Analog I/O Functions

SUB MENU	FUNCTION	MANUAL SECTION
AOUT CALIBRATED	Initiates a calibration of the **A1**, **A2**, **A3** and **A4** analog output channels that determines the slope and offset inherent in the circuitry of each output. These values are stored in the and applied to the output signals by the CPU automatically.	8.4.2
CONC_OUT_1	Sets the basic electronic configuration of the **A1** output (NO_x Concentration). There are four options: • **RANGE[1]**: Selects the signal type (voltage or current loop) and level of the output • **REC OFS**: Allows them input of a DC offset to let the user manually adjust the output level • **AUTO CAL**: Enables / Disables the **AOUT CALIBRATION** Feature • **CALIBRATED**: Performs the same calibration as **AOUT CALIBRATED**, but on this one channel only.	8.4
CONC_OUT_2	• Same as for CONC_OUT_1 but for analog channel **A2** (NO Concentration)	
CONC_OUT_3	• Same as for CONC_OUT_1 but for analog channel **A3** (NO_2 Concentration)	
TEST OUTPUT	• Same as for CONC_OUT_1 but for analog channel **A4** (TEST CHANNEL)	8.4.6
AIN CALIBRATED	Initiates a calibration of the A-to-D Converter circuit located on the Motherboard.	8.4.7
XIN1 . . . **XIN8**	For each of 8 external analog inputs channels, shows the gain, offset, engineering units, and whether the channel is to show up as a Test function.	8.4.8

To access the **ANALOG I/O CONFIGURATION** sub menu, press:

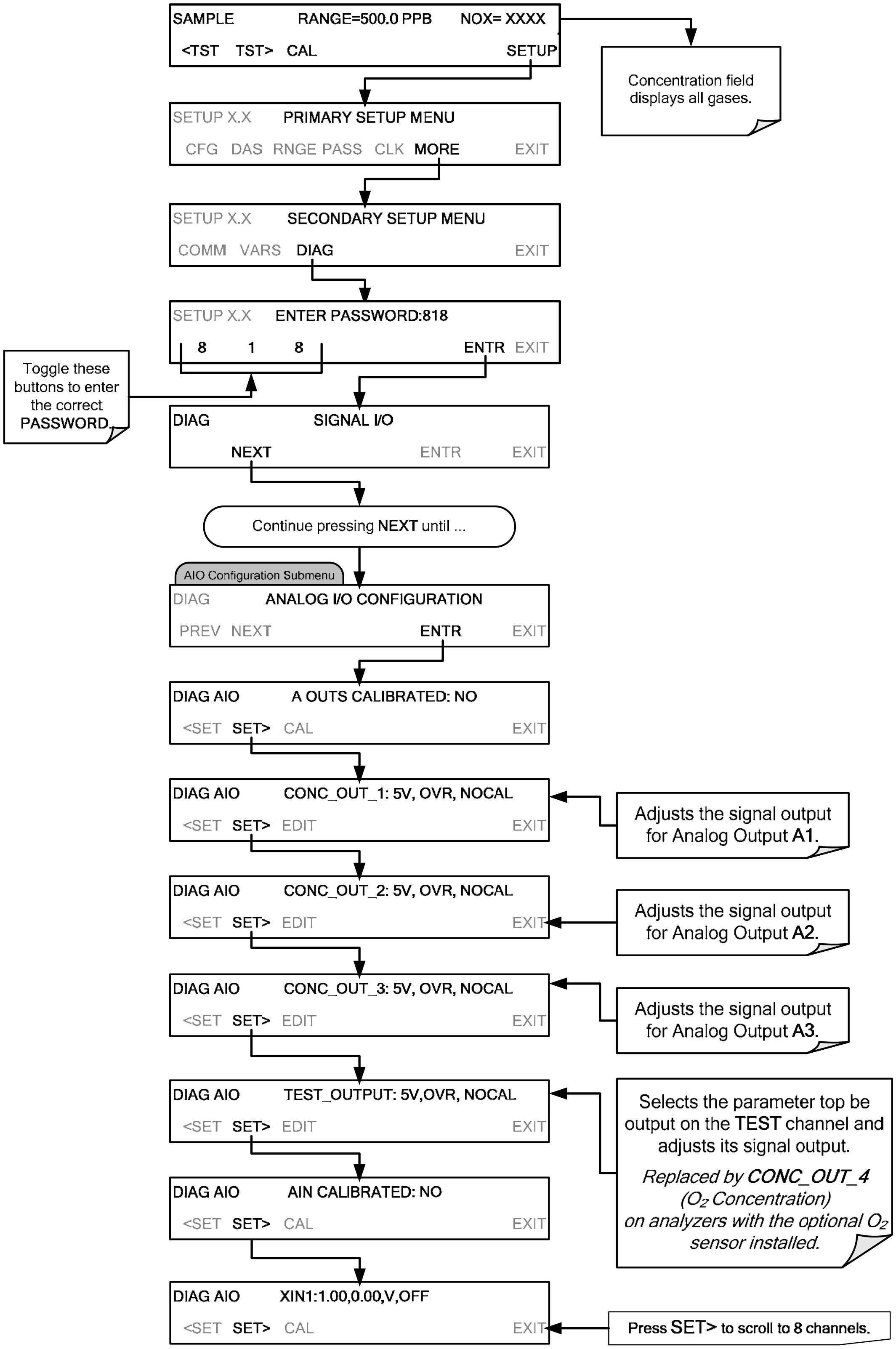


Figure 8-5: Accessing the Analog I/O Configuration Submenus

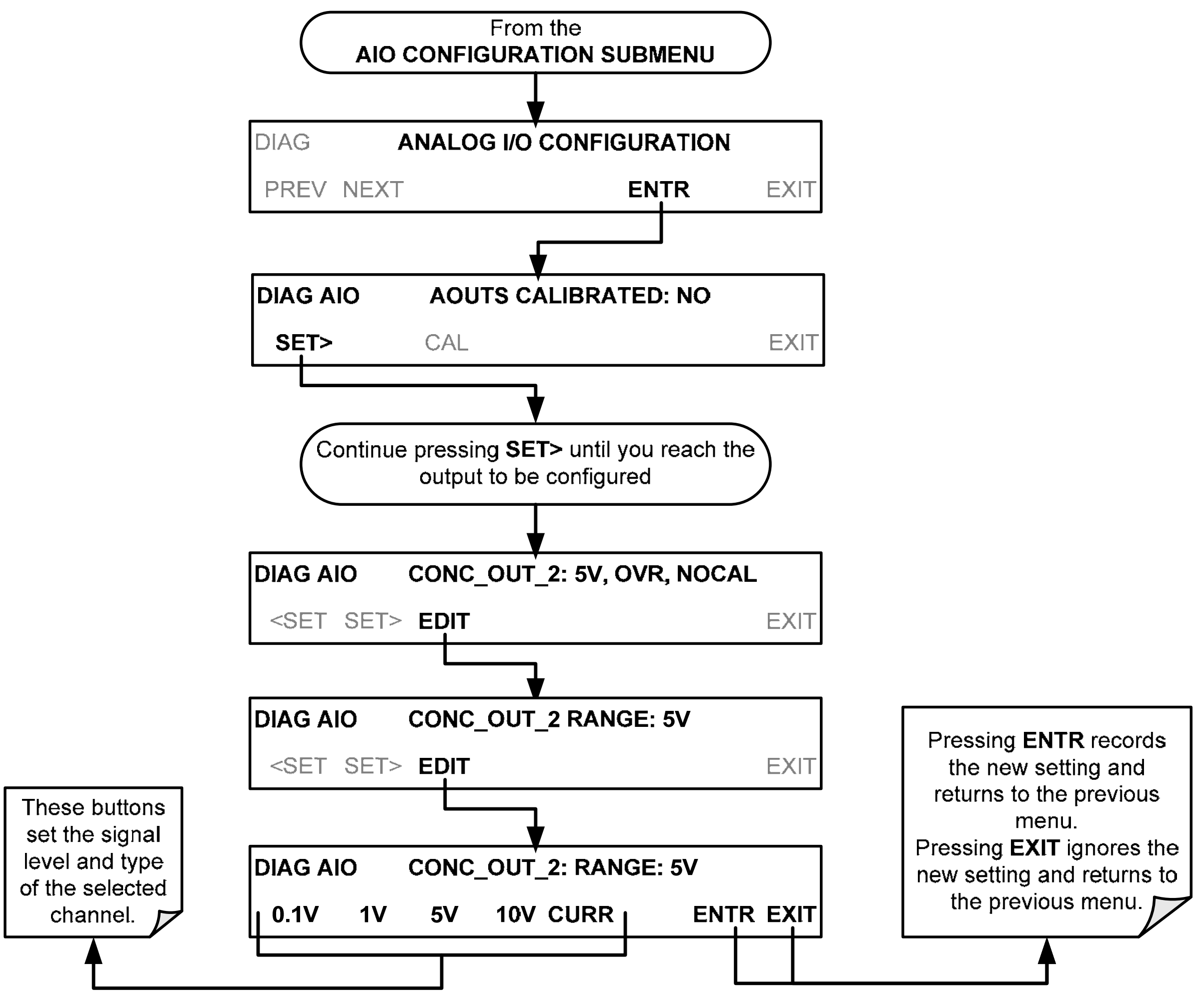
8.4.2. ANALOG OUTPUT VOLTAGE / CURRENT RANGE SELECTION

In its standard configuration the analog outputs is set to output a 0 – 5 VDC signals. Several other output ranges are available (see Table 8-7). Each range is usable from -5% to +5% of the rated span.

Table 8-7: Analog Output Voltage Range Min/Max

RANGE NAME	RANGE SPAN	MINIMUM OUTPUT	MAXIMUM OUTPUT
0.1V	0-100 mVDC	-5 mVDC	105 mVDC
1V	0-1 VDC	-0.05 VDC	1.05 VDC
5V	0-5 VDC	-0.25 VDC	5.25 VDC
10V	0-10 VDC	-0.5 VDC	10.5 VDC
• The default offset for all VDC ranges is 0-5 VDC.			
CURR	0-20 mA	0 mA	20 mA
• While these are the physical limits of the current loop modules, typical applications use 2-20 mA or 4-20 mA for the lower and upper limits. Please specify desired range when ordering this option. • The default offset for all current ranges is 0 mA.			

To change the output type and range, select the **ANALOG I/O CONFIGURATION** submenu (see Figure 8-5) then press:



8.4.3. CALIBRATION OF THE ANALOG OUTPUTS

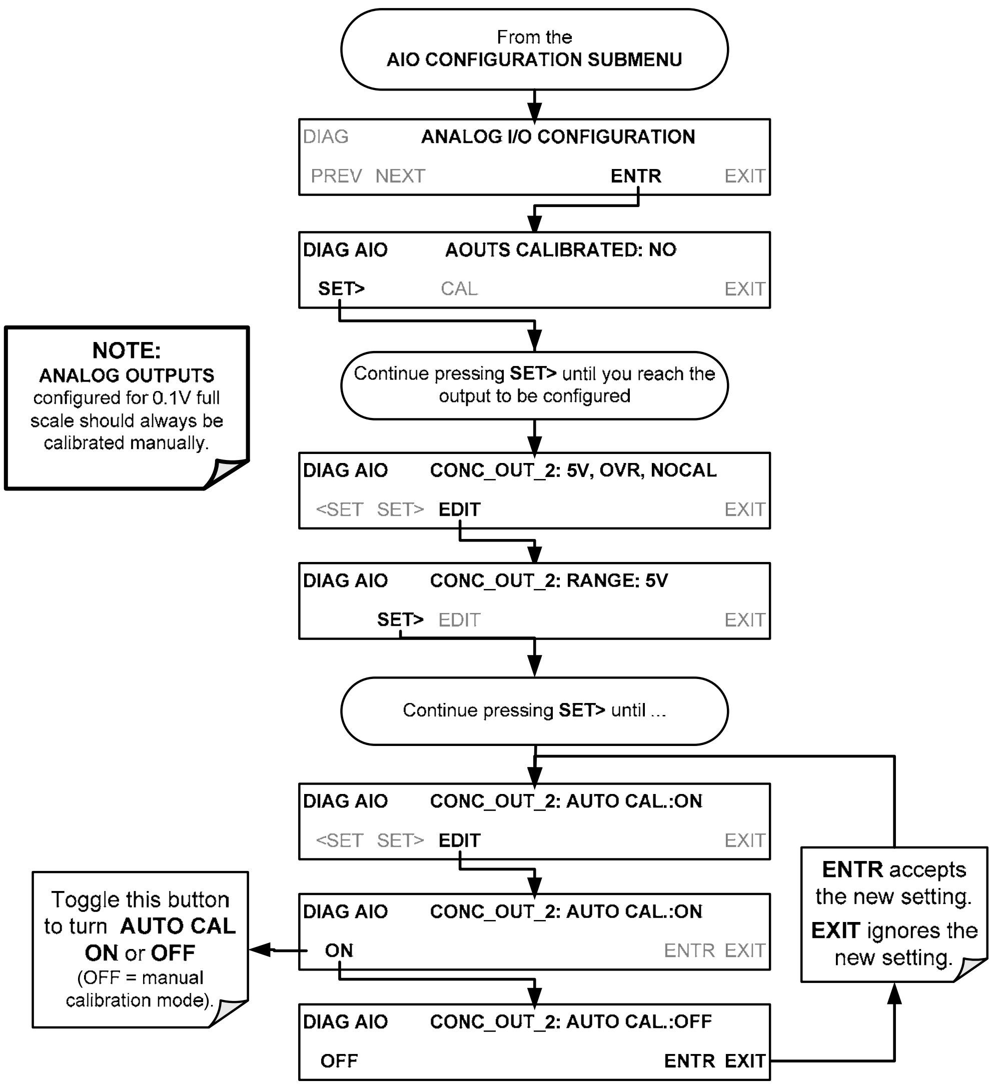
Analog output calibration should be carried out on first startup of the analyzer (performed in the factory as part of the configuration process) or whenever recalibration is required. The analog outputs can be calibrated automatically, either as a group or individually, or adjusted manually.

In its default mode, the instrument is configured for automatic calibration of all channels, which is useful for clearing any analog calibration warnings associated with channels that will not be used or connected to any input or recording device, e.g., data logger.

Manual calibration should be used for the 0.1V range or in cases where the outputs must be closely matched to the characteristics of the recording device. The AUTOCAL feature must be disabled first for manual calibration.

8.4.3.1. Enabling or Disabling the AutoCal for an Individual Analog Output

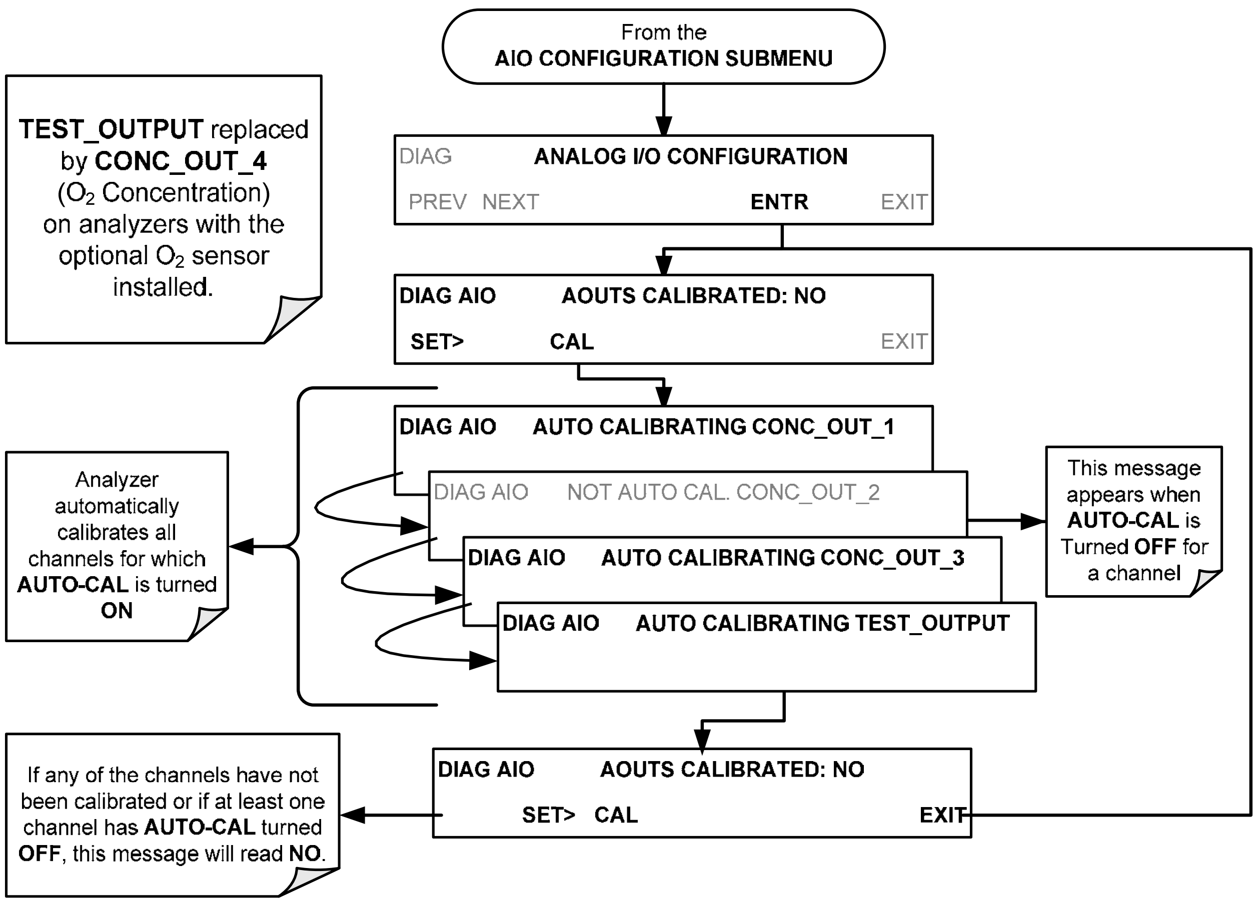
To enable or disable the **AutoCal** feature for an individual analog output, elect the **ANALOG I/O CONFIGURATION** submenu (see Figure 8-5) then press:



8.4.3.2. Automatic Group Calibration of the Analog Outputs

To calibrate the outputs as a group with the **AOUTS CALIBRATION** command, select the **ANALOG I/O CONFIGURATION** submenu (see Figure 8-5) then press:

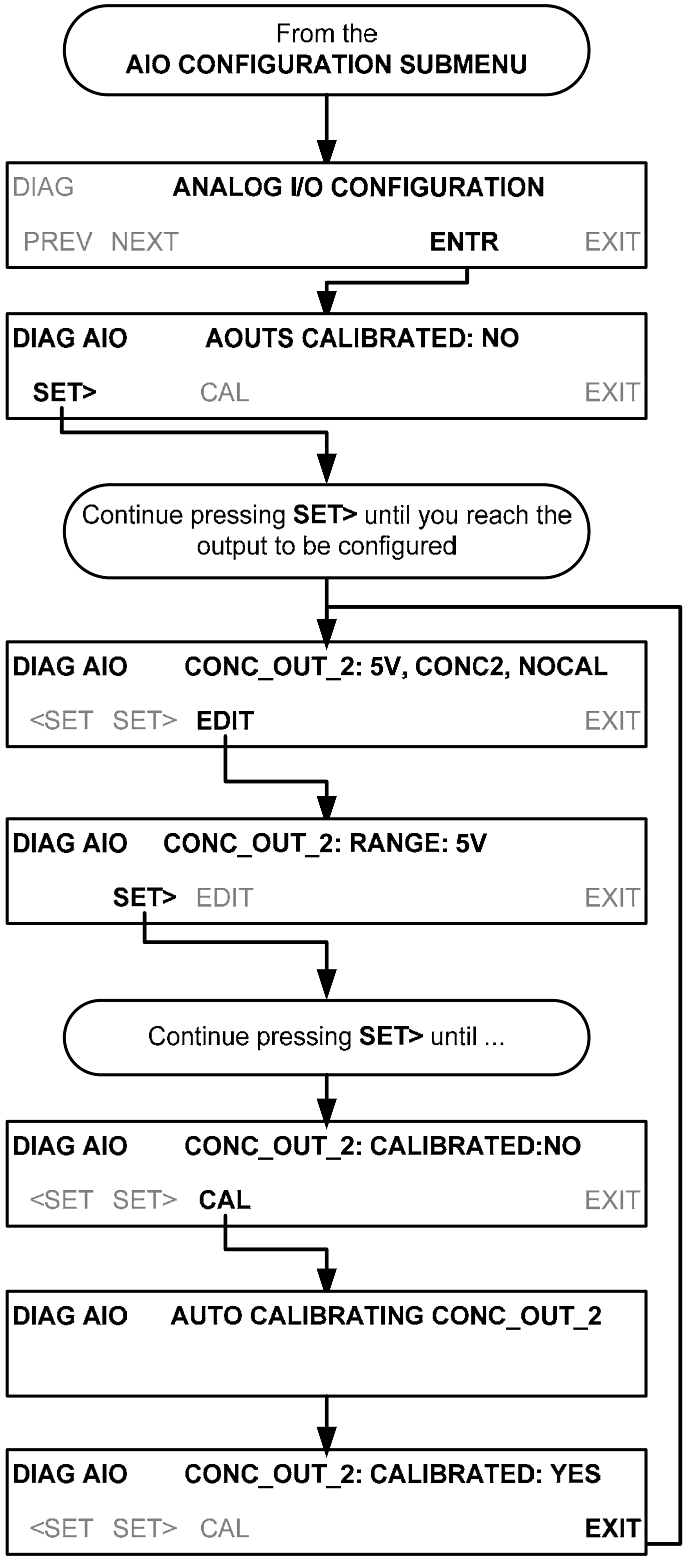
> **NOTE**
> **Before performing this procedure, ensure that the AUTO CAL for each analog output is enabled. (See Section 8.4.3.1)**



> **NOTE**
> **Manual calibration should be used for any analog output set for a 0.1V output range or in cases where the outputs must be closely matched to the characteristics of the recording device.**

8.4.3.3. Automatic Individual Calibration of the Analog Outputs

To use the **AUTO CAL** feature to initiate an automatic calibration for an individual analog output, select the **ANALOG I/O CONFIGURATION** submenu (see Figure 8-5) then press:



8.4.3.4. Manual Calibration of the Analog Outputs Configured for Voltage Ranges

For highest accuracy, the voltages of the analog outputs can be manually calibrated.

NOTE

The menu for manually adjusting the analog output signal level will only appear if the AUTO-CAL feature is turned off for the channel being adjusted (See Section 8.4.3.1).

Calibration is performed with a voltmeter connected across the output terminals and by changing the actual output signal level using the front panel buttons in 100, 10 or 1 count increments. See Figure 3-8 for pin assignments and diagram of the analog output connector.

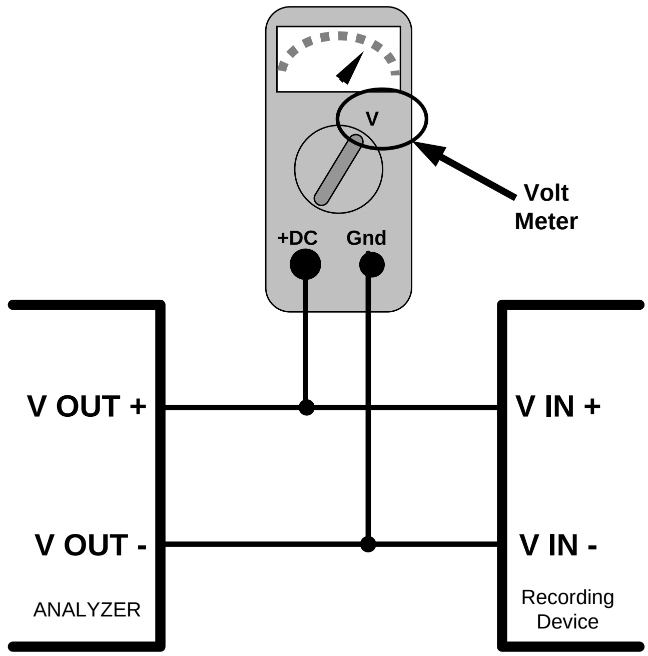
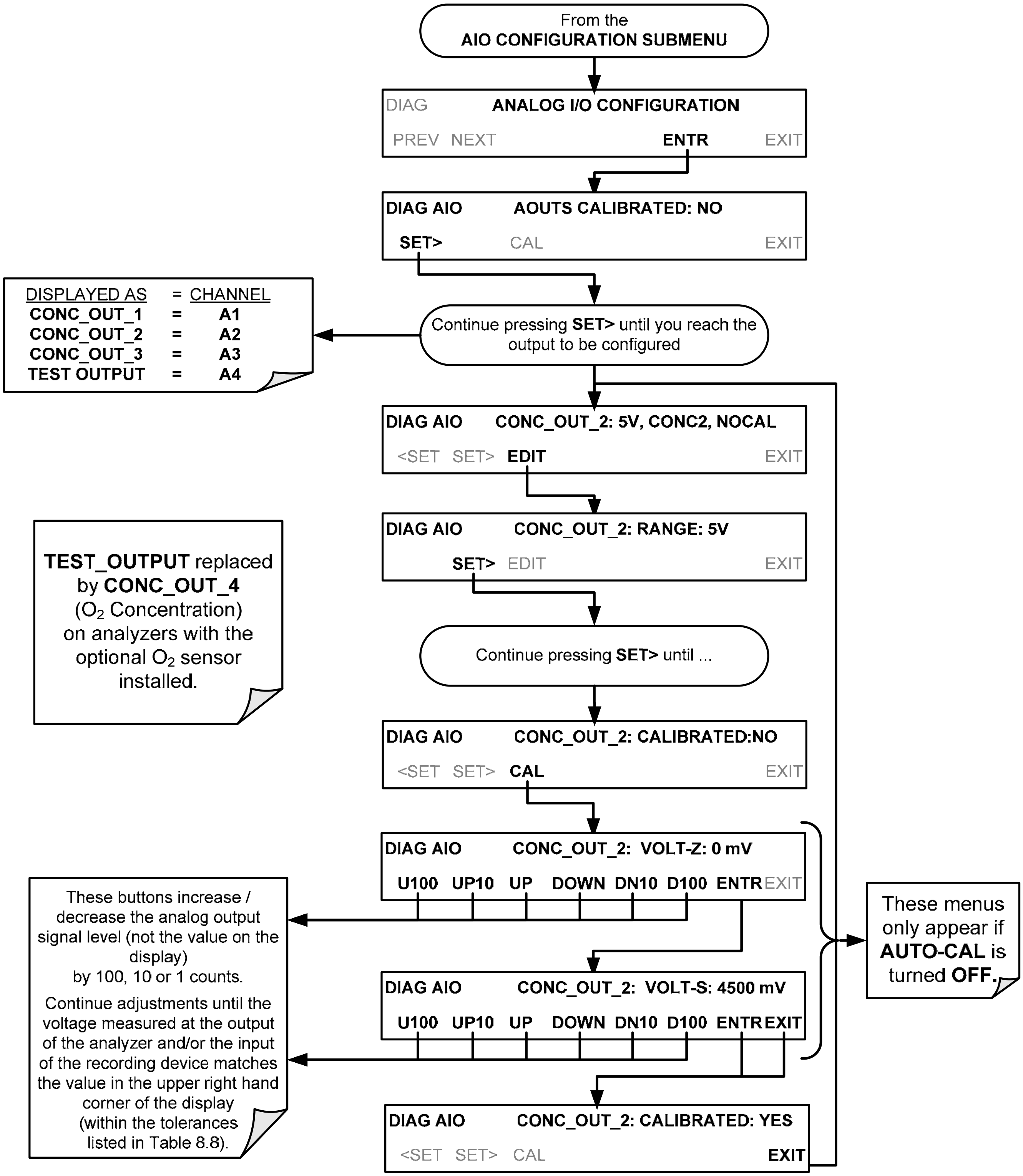


Figure 8-6: Setup for Checking / Calibrating DCV Analog Output Signal Levels

Table 8-8: Voltage Tolerances for the TEST CHANNEL Calibration

FULL SCALE	**ZERO TOLERANCE**	**SPAN VOLTAGE**	**SPAN TOLERANCE**	**MINIMUM ADJUSTMENT** (1 count)
0.1 VDC	±0.0005V	90 mV	±0.001V	0.02 mV
1 VDC	±0.001V	900 mV	±0.001V	0.24 mV
5 VDC	±0.002V	4500 mV	±0.003V	1.22 mV
10 VDC	±0.004V	4500 mV	±0.006V	2.44 mV

To adjust the signal levels of an analog output channel manually, select the **ANALOG I/O CONFIGURATION** submenu (see Figure 8-5) then press:



8.4.3.5. Manual Adjustment of Current Loop Output Span and Offset

A current loop option may be purchased for the **A1**, **A2** and **A3** Analog outputs of the analyzer. This option places circuitry in series with the output of the D-to-A converter on the motherboard that changes the normal DC voltage output to a 0-20 milliamp signal (See Section 5.4).

- The outputs can be ordered scaled to any set of limits within that 0-20 mA range, however most current loop applications call for either 0-20 mA or 4-20 mA range spans.
- All current loop outputs have a +5% over range. Ranges whose lower limit is set above 1 mA also have a –5% under range.

To switch an analog output from voltage to current loop, follow the instructions in Sections 5.4.1 and 8.4.2 (select **CURR** from the list of options on the "Output Range" menu).

Adjusting the signal zero and span levels of the current loop output is done by raising or lowering the voltage output of the D-to-A converter circuitry on the analyzer's motherboard. This raises or lowers the signal level produced by the current loop option circuitry.

The software allows this adjustment to be made in 100, 10 or 1 count increments. Since the exact amount by which the current signal is changed per D-to-A count varies from output-to-output and instrument–to–instrument, you will need to measure the change in the signal levels with a separate, current meter placed in series with the output circuit. See Figure 3-8 for pin assignments and diagram of the analog output connector.

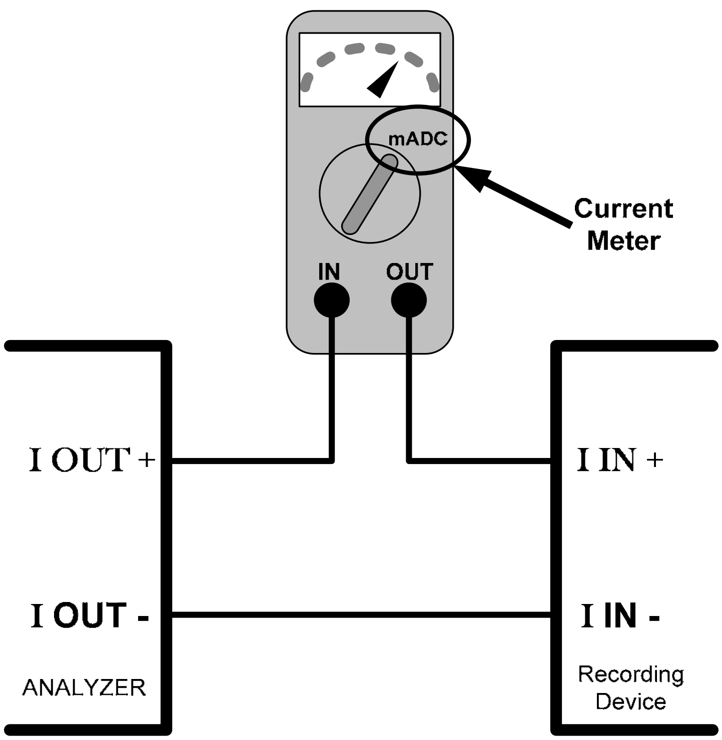
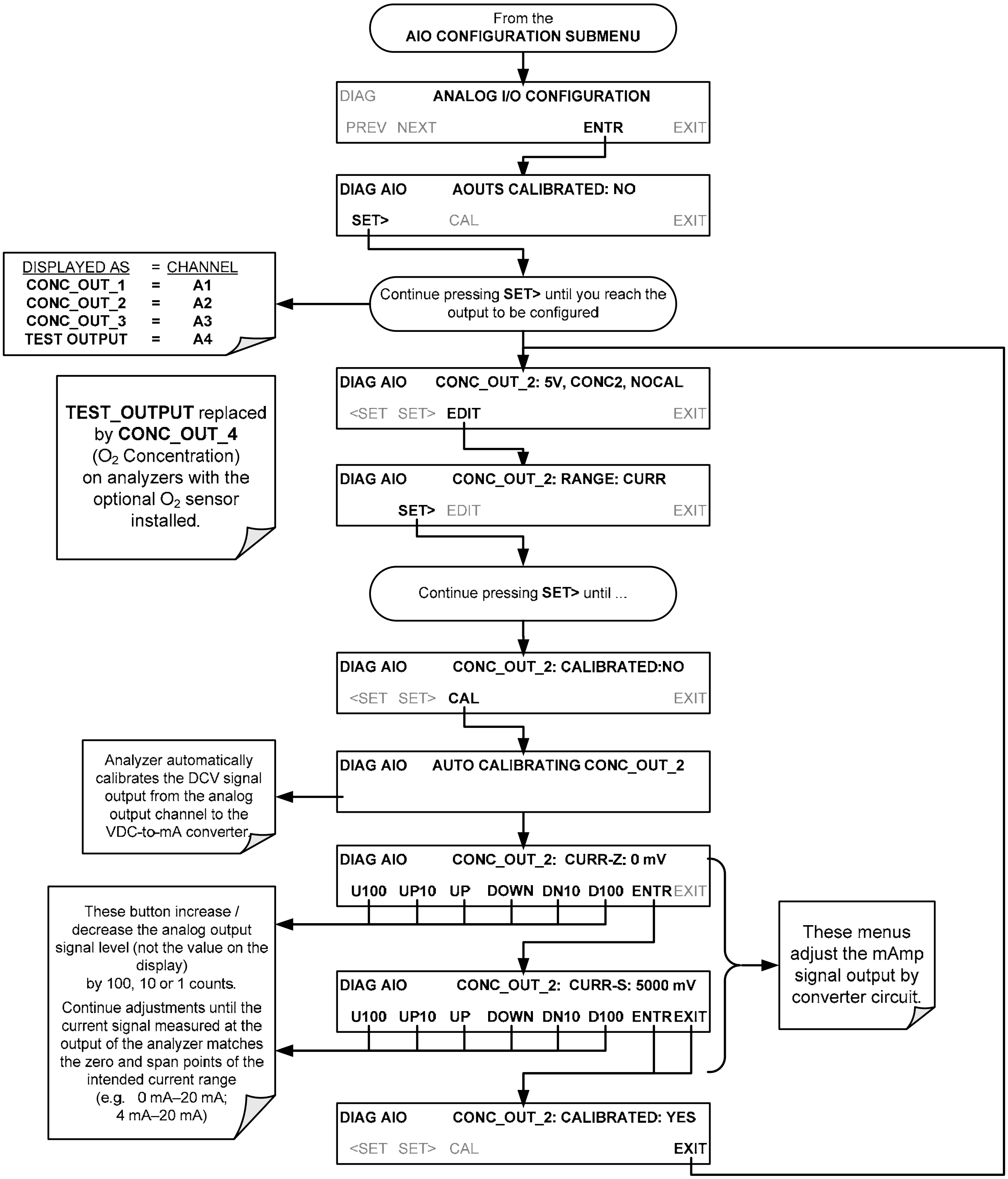


Figure 8-7: Setup for Checking / Calibration Current Output Signal Levels Using an Ammeter

CAUTION
General Safety Hazard
Do not exceed 60 V peak voltage between current loop outputs and instrument ground.

To adjust the zero and span signal levels of the current outputs, select the **ANALOG I/O CONFIGURATION** submenu (see Figure 8-5) then press:



An alternative method for measuring the output of the Current Loop converter is to connect a 250 ohm ±1% resistor across the current loop output in lieu of the current meter (see Figure 3-8 for pin assignments and diagram of the analog output connector). This allows the use of a voltmeter connected across the resistor to measure converter output as VDC or mVDC.

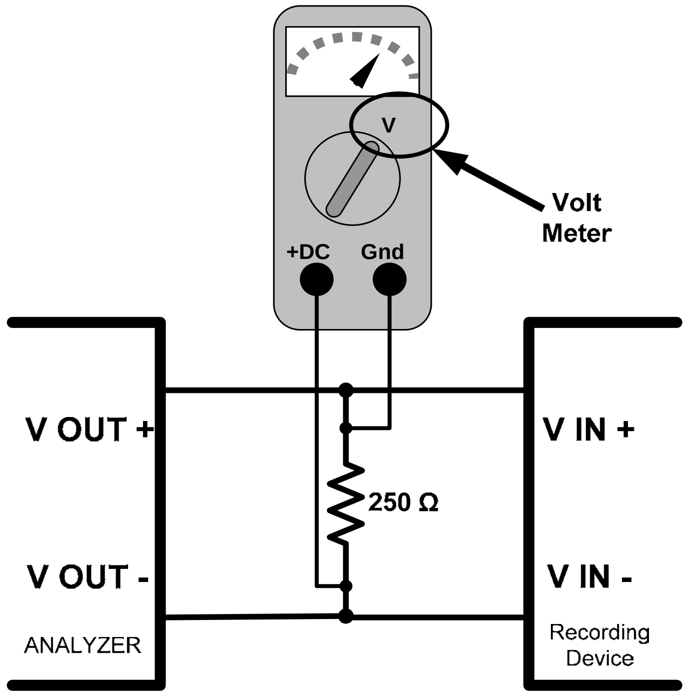


Figure 8-8: Alternative Setup Using 250Ω Resistor for Checking Current Output Signal Levels

In this case, follow the procedure above but adjust the output for the following values:

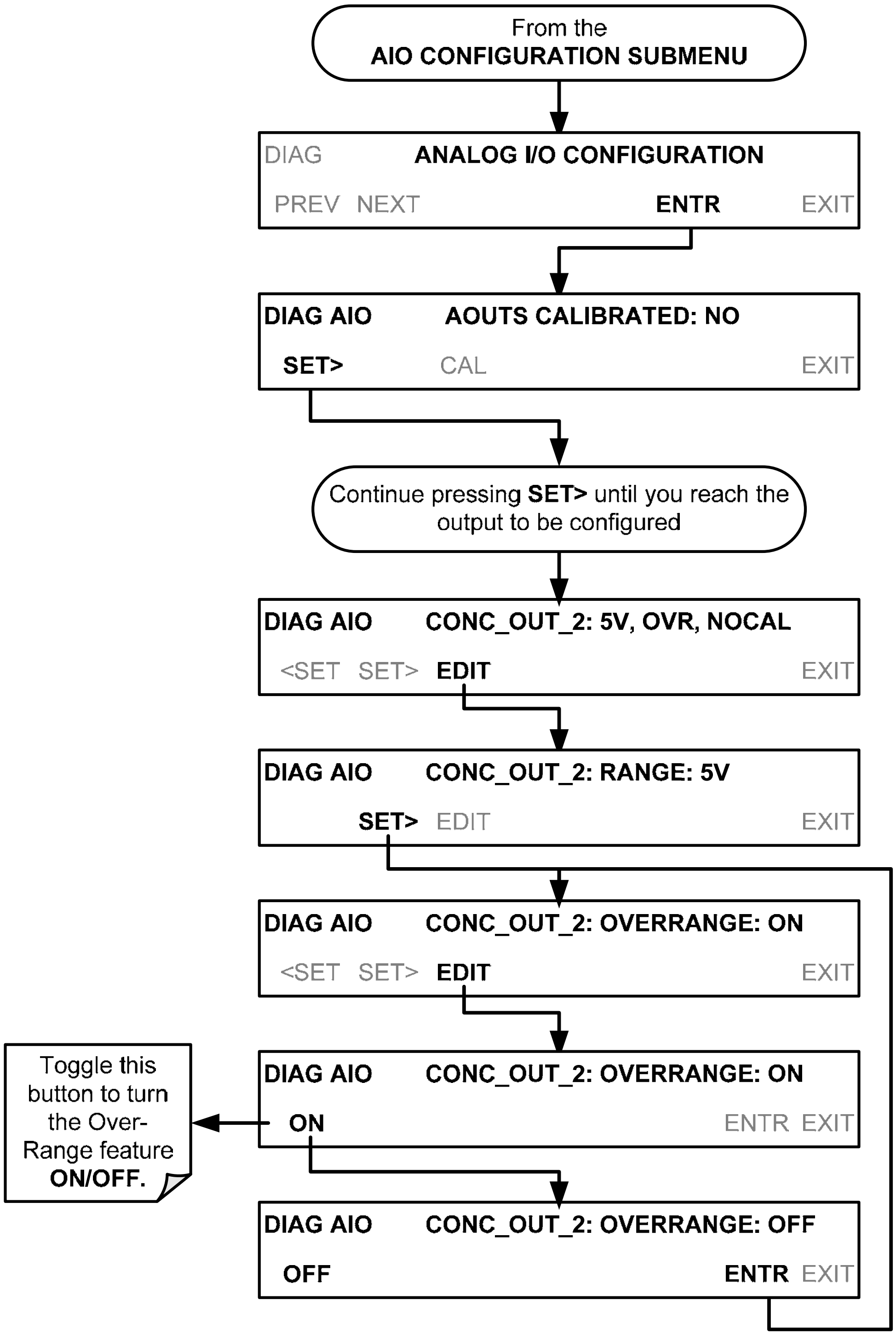
Table 8-9: Current Loop Output Check

% FS	Voltage across Resistor for 2-20 mA	Voltage across Resistor for 4-20 mA
0	500 mVDC	1000 mVDC
100	5000 mVDC	5000 mVDC

8.4.4. TURNING AN ANALOG OUTPUT OVER-RANGE FEATURE ON/OFF

In its default configuration, a ± 5% over-range is available on each of the T200's analog outputs. This over-range can be disabled if your recording device is sensitive to excess voltage or current.

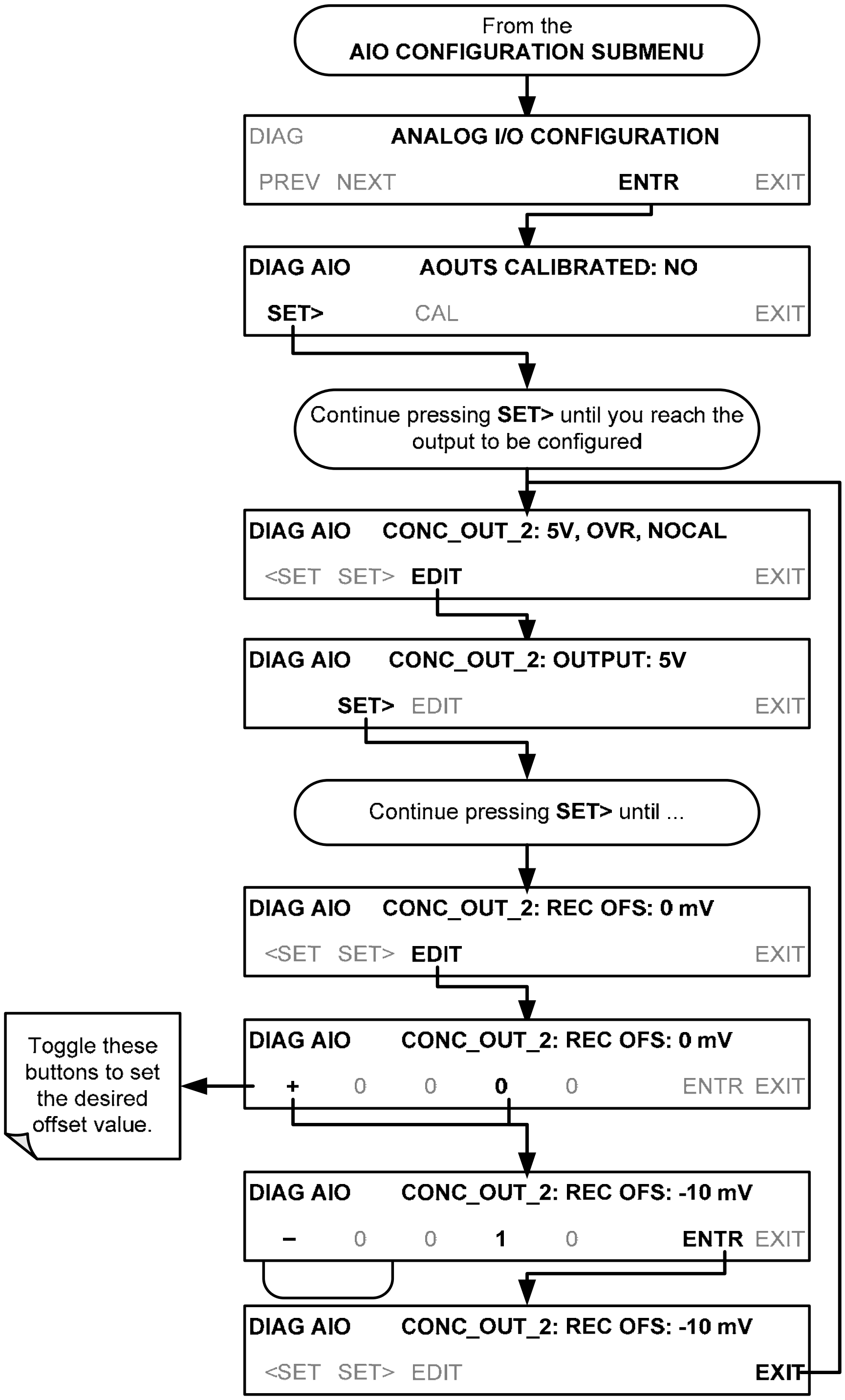
To turn the over-range feature on or off, select the **ANALOG I/O CONFIGURATION** submenu (see Figure 8-5) then press:



8.4.5. ADDING A RECORDER OFFSET TO AN ANALOG OUTPUT

Some analog signal recorders require that the zero signal be significantly different from the baseline of the recorder in order to record slightly negative readings from noise around the zero point. This can be achieved in the T200 by defining a zero offset, a small voltage (e.g., 10% of span).

To add a zero offset to a specific analog output channel, select the **ANALOG I/O CONFIGURATION** submenu (see Figure 8-5) then press:



8.4.6. SELECTING A TEST CHANNEL FUNCTION FOR OUTPUT A4

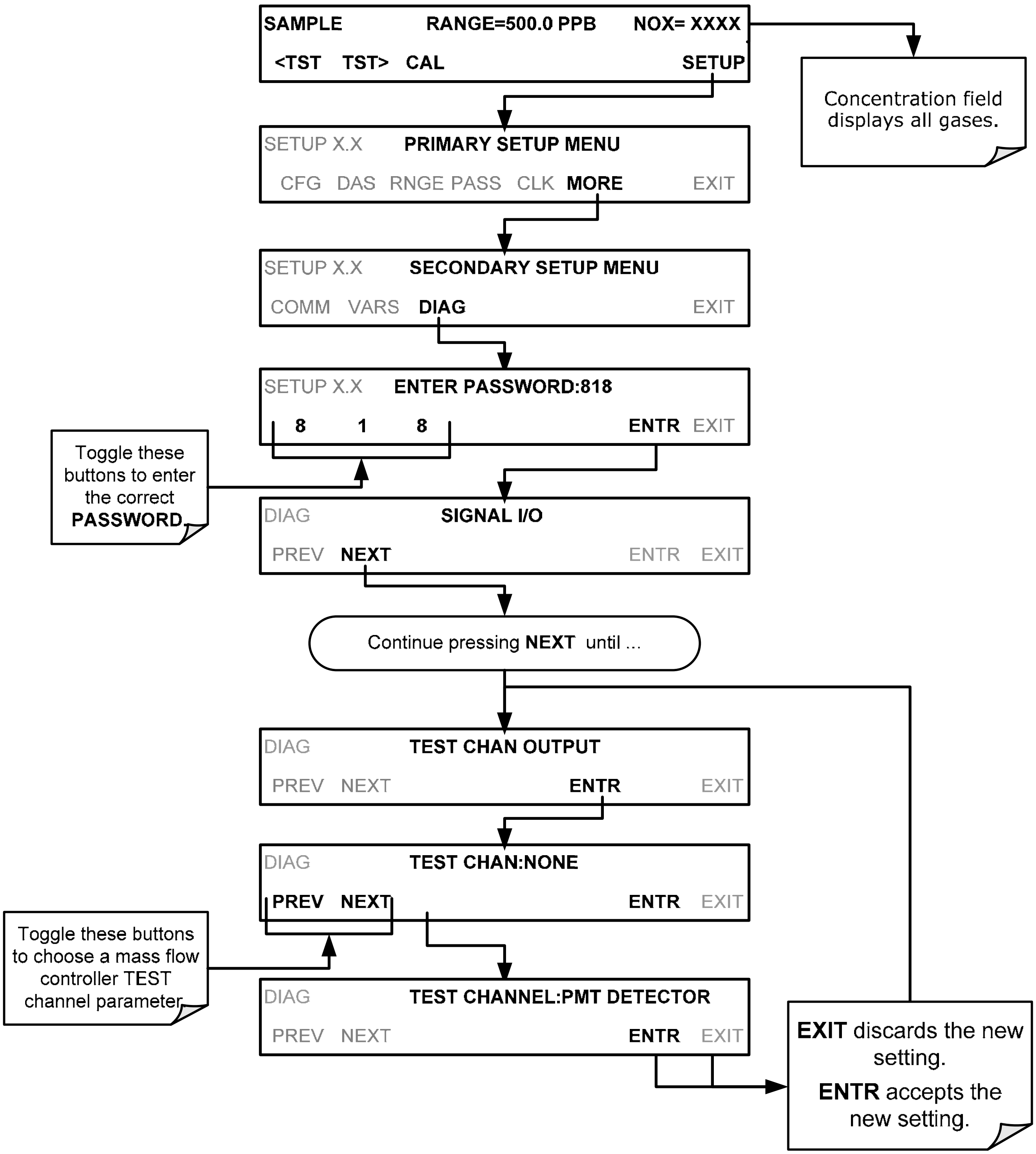
The test functions available to be reported are listed in Table 8-10:

Table 8-10: Test Channels Functions available on the T200's Analog Output

TEST CHANNEL	DESCRIPTION	ZERO	FULL SCALE
NONE	*TEST CHANNEL IS TURNED OFF*		
PMT DETECTOR	The output of the PMT detector converted to a 0 to 5 VDC scale.	**0 mV**	**5000 mV** [1]
OZONE FLOW	The flow rate of O_3 through the analyzer as measured by the O_3 flow sensor.	**0 cm^3/min**	**1000 cm^3/min**
SAMPLE FLOW	The calculated flow rate for sample gas through the analyzer.	**0 cm^3/min**	**1000 cm^3/min**
SAMPLE PRESSURE	The pressure of the sample gas measured upstream of the Auto Zero Valve.	**0 Hg-In-A**	**40 "Hg-In-A**
RCELL PRESSURE	The pressure of gas inside the reaction cell of the sensor module.	**0 Hg-In-A**	**40 Hg-In-A**
RCELL TEMP	The temperature of gas inside the reaction cell of the sensor module.	**0 °C**	**70 °C**
IZS TEMP	The temperature of the permeation tube oven of the optional internal span gas generator.	**0 °C**	**70 °C**
CONV TEMP	The temperature NO_2 → NO converter.	**0 °C**	**500 °C**
PMT TEMP	The temperature inside PMT.	**0 °C**	**50 °C**
BOX TEMP	The temperature inside the T200's chassis.	**0 °C**	**70 °C**
HVPS VOLTAGE	Represents the output voltage of the PMT's high voltage power supply.	**0 mV**	**5000 mV** [1]

Once a function is selected, the instrument not only begins to output a signal on the analog output, but also adds **TEST** to the list of test functions viewable via the front panel display.

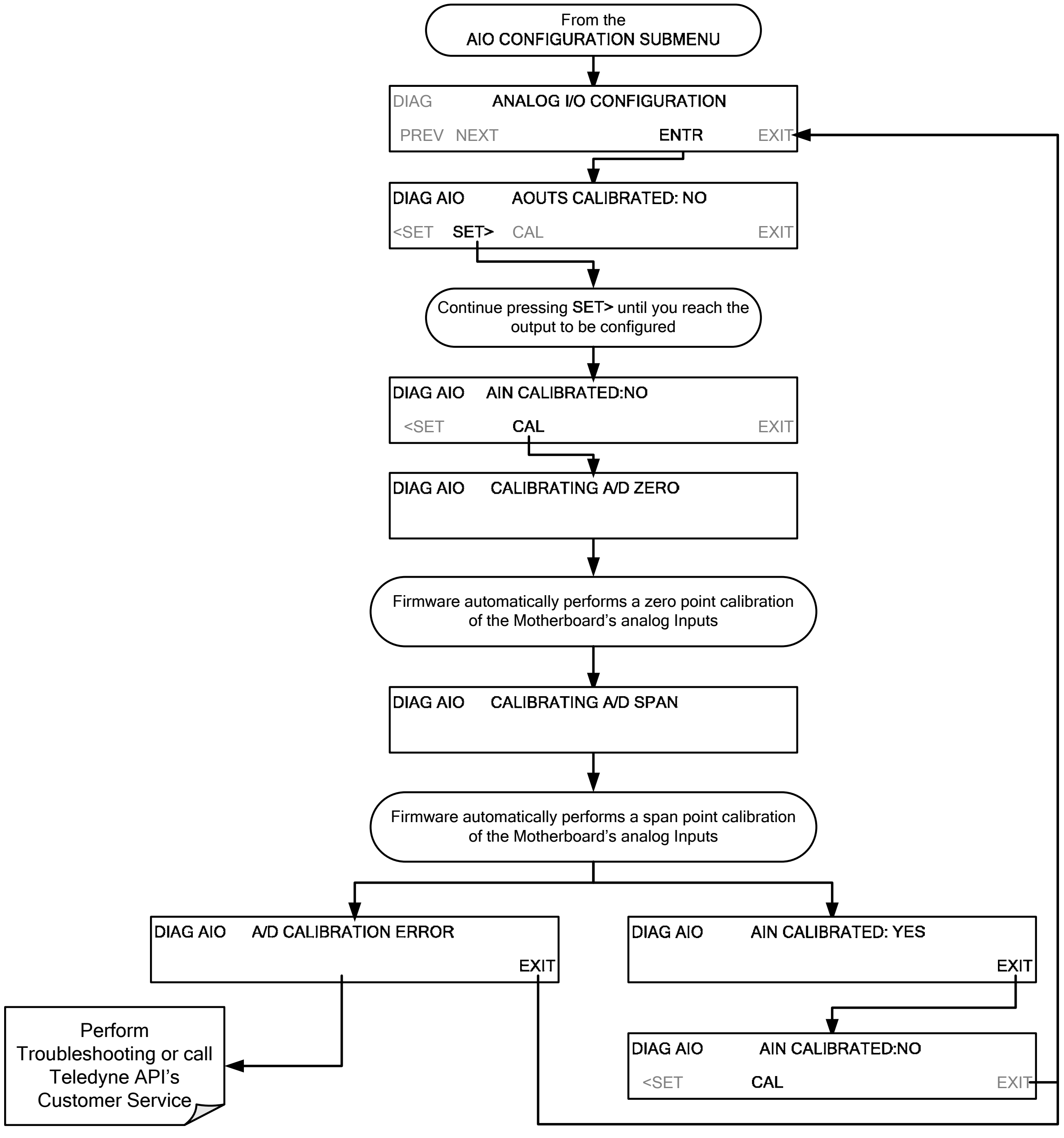
To activate the **TEST** Channel and select a function, press:



8.4.7. AIN CALIBRATION

This is the submenu to conduct a calibration of the T200 analyzer's analog inputs. This calibration should only be necessary after major repair such as a replacement of CPU, motherboard or power supplies.

To perform an analog input calibration, select the **ANALOG I/O CONFIGURATION** submenu (see Figure 8-5) then press:



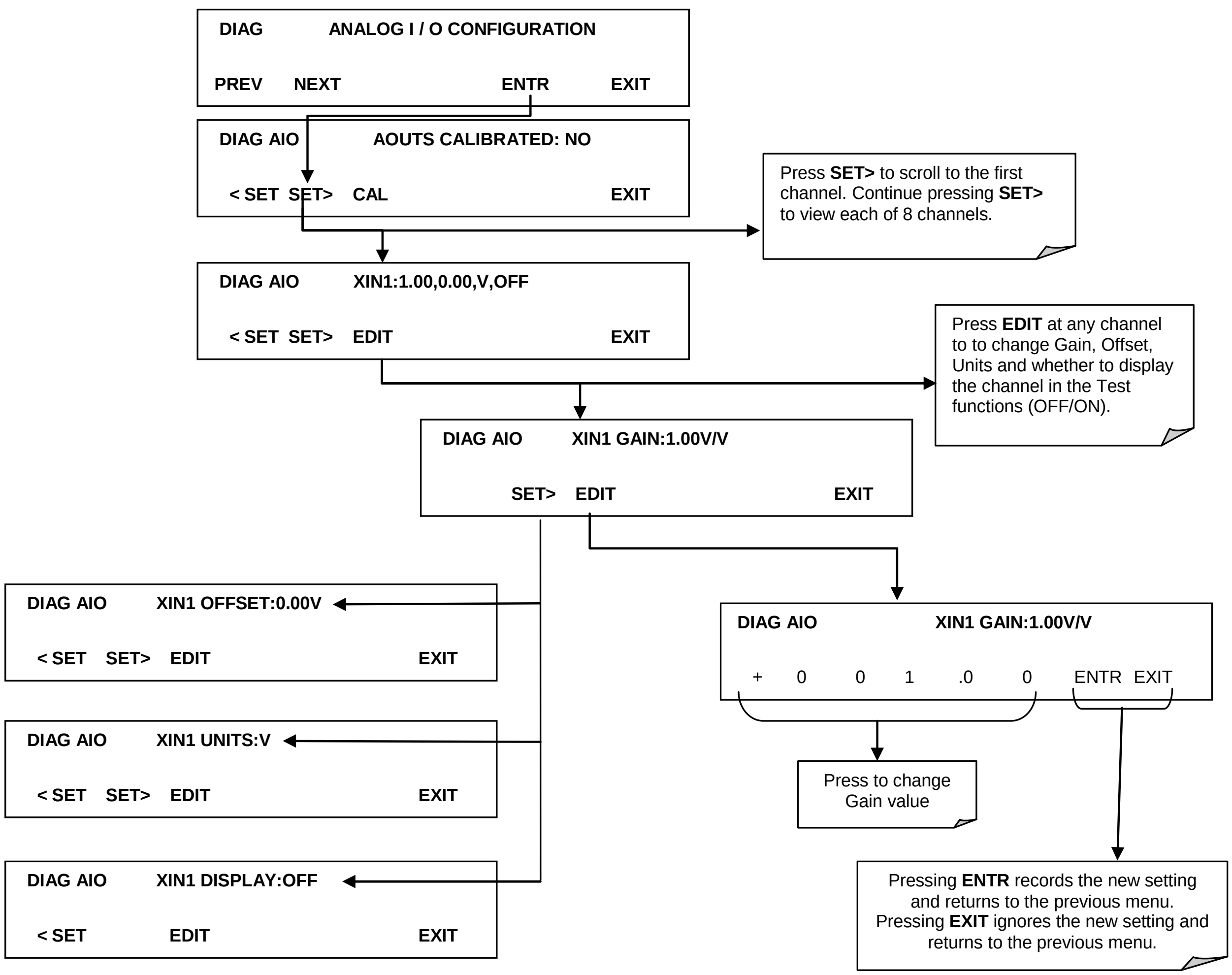
8.4.8. EXTERNAL ANALOG INPUTS (XIN1…XIN8) OPTION CONFIGURATION

To configure the analyzer's optional external analog inputs, define for each channel**:**

- gain (number of units represented by 1 volt)
- offset (volts)
- engineering units to be represented in volts (each press of the touchscreen button scrolls the list of alphanumeric characters from A-Z and 0-9)
- whether to display the channel in the Test functions

These parameters can also be captured in the internal Data Acquisition System (DAS); refer to Appendix A for Analog-In DAS parameters.

To adjust settings for the Analog Inputs option parameters press:



9. REMOTE OPERATION

9.1. USING THE ANALYZER'S COMMUNICATION PORTS

The T200 is equipped with an Ethernet port, a USB port and two serial communication ports accessible via two DB-9 connectors on the back panel of the instrument. The COM1 connector (labeled **RS232**) is a male DB-9 connector and the **COM2** is a female DB9 connector.

Both RS-232 ports operate similarly and give the user the ability to communicate with, issue commands to, and receive data from the analyzer through an external computer system or terminal.

- The RS-232 port (used as COM1) can also be configured to operate in single or RS-232 multidrop mode (see Section 5.6.3 and 9.2).
- The COM2 port can be configured for standard RS-232 operation or half-duplex RS-485 communication (See Section 5.6.3 and 9.3). If configured for RS-485 communication, the rear panel USB port is disabled.

9.1.1. USB PORT COMMUNICATION

The USB comm port may be used only when the COM2 port is not being used except during Multidrop operation. To use the USB port for connection to a personal computer (PC), the baud rates for both the instrument and the PC must match. Elect to change either one to match the other. To view/change the instrument's baud rate, see Section 9.1.4 (USB is COM2 in the Communications menu.).

9.1.2. RS-232 DTE AND DCE COMMUNICATION

RS-232 was developed for allowing communications between data terminal equipment (DTE) and data communication equipment (DCE). Basic data terminals always fall into the DTE category whereas modems are always considered DCE devices.

Electronically, the difference between the DCE and DTE is the pin assignment of the Data Receive and Data Transmit functions.

- DTE devices receive data on pin 2 and transmit data on pin 3.
- DCE devices receive data on pin 3 and transmit data on pin 2.

A switch located below the serial ports on the rear panel allows the user to switch between DTE (for use with data terminals) or DCE (for use with modems). Since computers can be either DTE or DCE, check your computer to determine which mode to use.

9.1.3. COMM PORT DEFAULT SETTINGS AND CONNECTOR PIN ASSIGNMENTS

Received from the factory, the analyzer is set up to emulate an RS-232 DCE device.

- **RS-232 (COM1)**: RS-232 (fixed) DB-9 male connector.
  - **Baud rate**: 115,200 bits per second (baud).
  - **Data Bits**: 8 data bits with 1 stop bit.
  - **Parity**: None.
- **COM2**: RS-232 (configurable to RS 485), DB-9 female connector.
  - **Baud rate**:19200 bits per second (baud).

- **Data Bits**: 8 data bits with 1 stop bit.
- **Parity**: None.

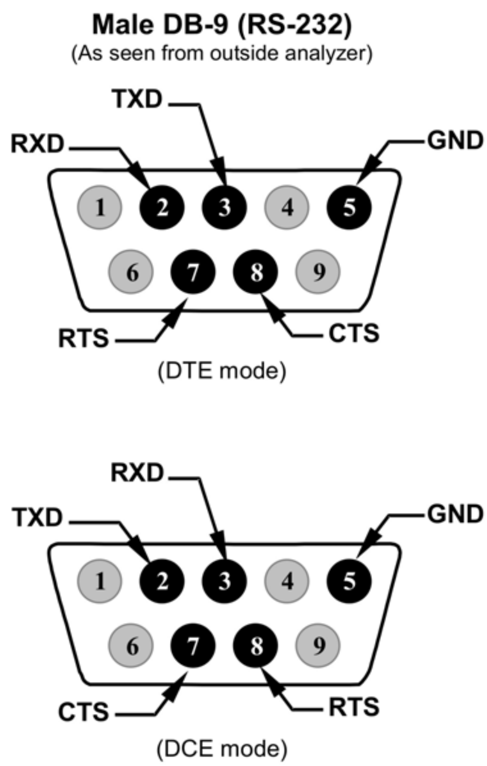


Figure 9-1: Default Pin Assignments for Back Panel COMM Port connectors (RS-232 DCE & DTE)

The signals from these two connectors are routed from the motherboard via a wiring harness to two 10-pin connectors on the CPU card, J11 and J12 (Figure 9-2).

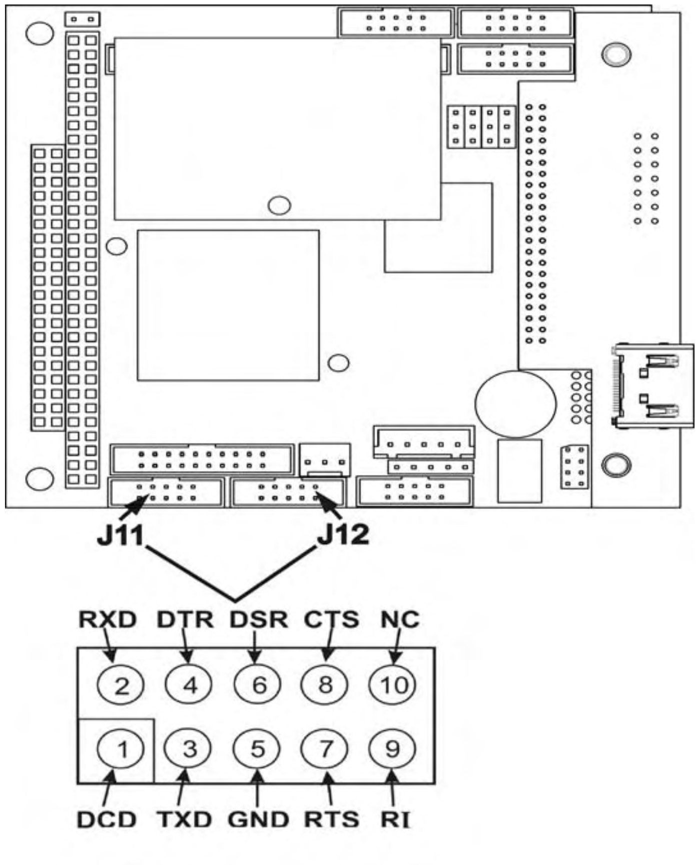


Figure 9-2: Default Pin Assignments for CPU COMM Port connector (RS-232).

Teledyne API offers two mating cables, one of which should be applicable for your use.

- P/N WR000077, a DB-9 female to DB-9 female cable, 6 feet long. Allows connection of the serial ports of most personal computers. Also available as OPT 60.
- P/N WR000024, a DB-9 female to DB-25 male cable. Allows connection to the most common styles of modems (e.g. Hayes-compatible) and code activated switches.

Both cables are configured with straight-through wiring and should require no additional adapters.

NOTE

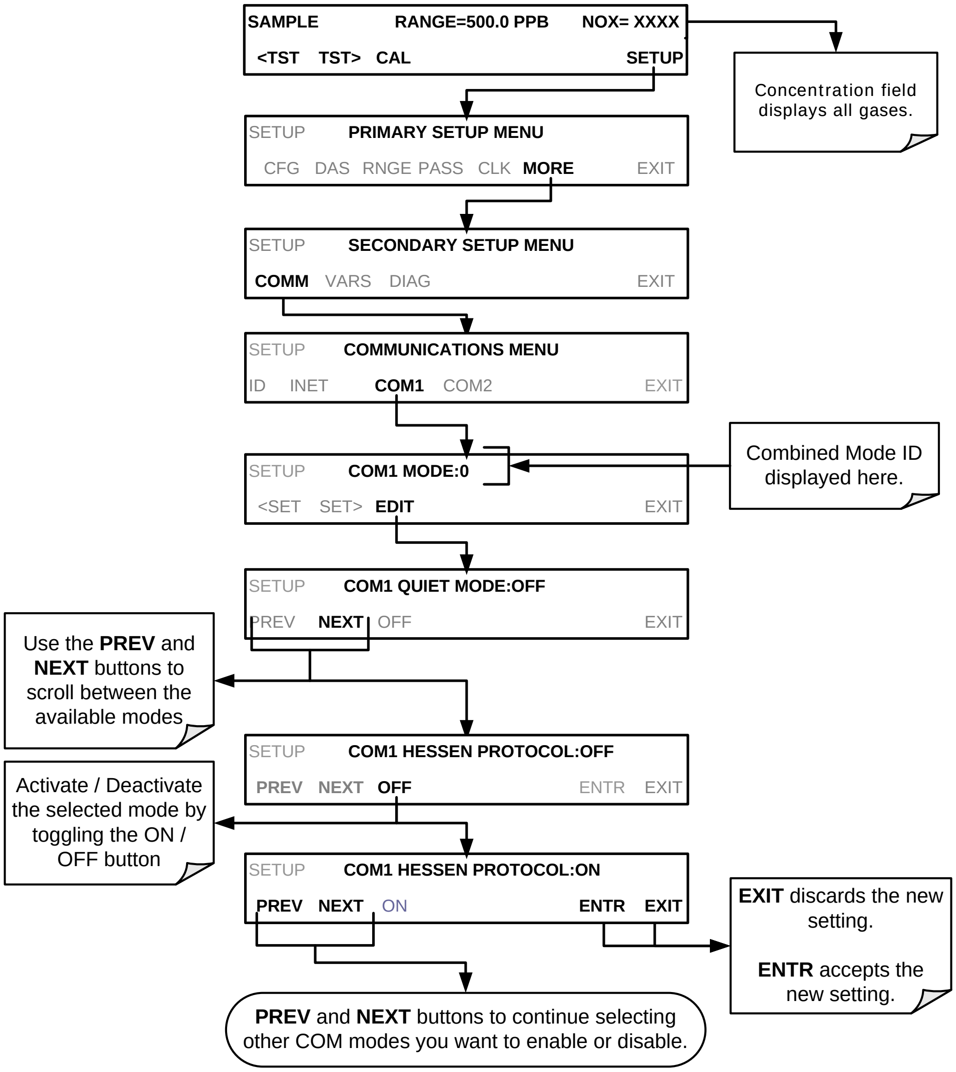
Cables that appear to be compatible because of matching connectors may incorporate internal wiring that makes the link inoperable. Check cables acquired from sources other than Teledyne API for pin assignments before using.

To assist in properly connecting the serial ports to either a computer or a modem, there are activity indicators just above the RS-232 port. Once a cable is connected between the analyzer and a computer or modem, both the red and green LEDs should be on.

- If the lights are not lit, locate the small switch on the rear panel to switch it between DTE and DCE modes.
- If both LEDs are still not illuminated, ensure that the cable properly constructed.

9.1.4. COMM PORT BAUD RATE

To select the baud rate of either one of the COMM Ports (use COM2 to view/configure USB port), press:



9.1.5. COMM PORT COMMUNICATION MODES

Each of the analyzer's serial ports can be configured to operate in a number of different modes, listed in Table 9-1. As modes are selected, the analyzer sums the mode ID numbers and displays this combined number on the front panel display. For example, if quiet mode (01), computer mode (02) and Multi-Drop-Enabled mode (32) are selected, the analyzer would display a combined **MODE ID** of **35**.

Table 9-1: COMM Port Communication Modes

MODE[1]	ID	DESCRIPTION
QUIET	**1**	Quiet mode suppresses any feedback from the analyzer (such as warning messages) to the remote device and is typically used when the port is communicating with a computer program where such intermittent messages might cause communication problems. Such feedback is still available but a command must be issued to receive them.
COMPUTER	**2**	Computer mode inhibits echoing of typed characters and is used when the port is communicating with a computer operated control program.
HESSEN PROTOCOL	**16**	The Hessen communications protocol is used in some European countries. T-API P/N 02252 contains more information on this protocol.
E, 8, 1	**8192**	When turned on this mode switches the **COMM** port settings from ● **NO PARITY;** 8 data bits; 1 stop bit to **EVEN PARITY**; 8 data bits; 1 stop bit.
E, 7, 1	**2048**	When turned on this mode switches the **COMM** port settings from ● **NO PARITY**; 8 data bits; 1 stop bit to **EVEN PARITY**; 7 data bits; 1 stop bit.
RS-485	**1024**	Configures the **COM2** Port for RS-485 communication. RS-485 mode has precedence over multidrop mode if both are enabled. Also, configuring for RS-485 disables the rear panel USB port.
SECURITY	**4**	When enabled, the serial port requires a password before it will respond (see Section 9.1.8.5). The only command that is active is the help screen (? CR).
MULTIDROP PROTOCOL	**32**	Multidrop protocol allows a multi-instrument configuration on a single communications channel. Multidrop requires the use of instrument IDs.
ENABLE MODEM	**64**	Enables to send a modem initialization string at power-up. Asserts certain lines in the RS-232 port to enable the modem to communicate.
ERROR CHECKING[2]	**128**	Fixes certain types of parity errors at certain Hessen protocol installations.
XON/XOFF HANDSHAKE[2]	**256**	Disables XON/XOFF data flow control also known as software handshaking.
HARDWARE HANDSHAKE	**8**	Enables CTS/RTS style hardwired transmission handshaking. This style of data transmission handshaking is commonly used with modems or terminal emulation protocols as well as by Teledyne Instrument's APICOM software.
HARDWARE FIFO[2]	**512**	Disables the **HARDWARE FIFO** (First In – First Out). When FIFO is enabled, it improves data transfer rate for that COMM port.
COMMAND PROMPT	**4096**	Enables a command prompt when in terminal mode.

[1] Modes are listed in the order in which they appear in the **SETUP → MORE → COMM → COM[1 OR 2] → MODE** menu

[2] The default setting for this feature is **ON.** Do not disable unless instructed to by Teledyne API's Customer Service personnel.

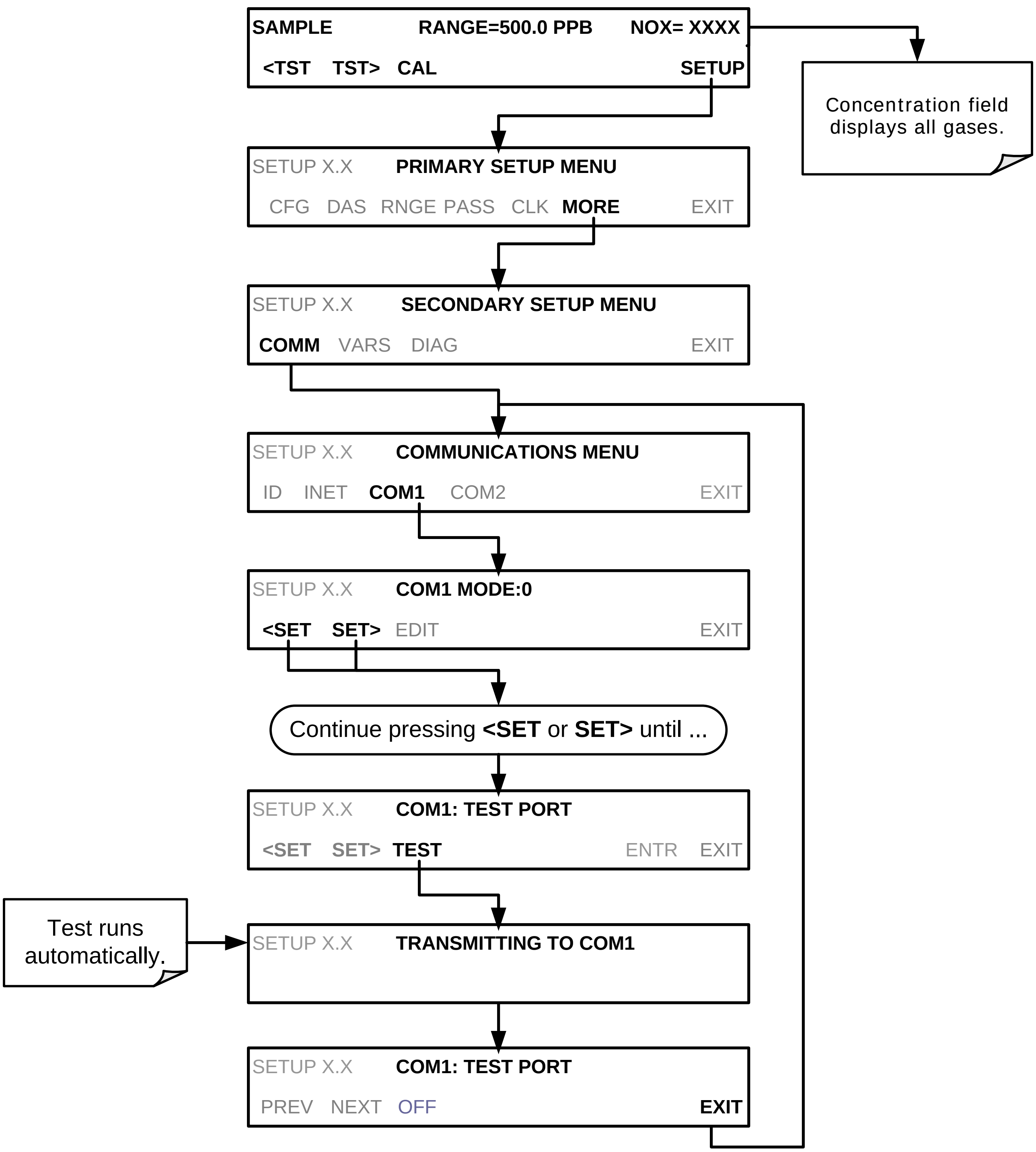
Note

Communication Modes for each COMM port must be configured independently.

9.1.6. COMM PORT TESTING

The serial ports can be tested for correct connection and output in the COMM menu. This test sends a string of 256 ‘w’ characters to the selected COMM port. While the test is running, the red LED on the rear panel of the analyzer should flicker.

To initiate the test press the following button sequence:



9.1.7. MACHINE ID

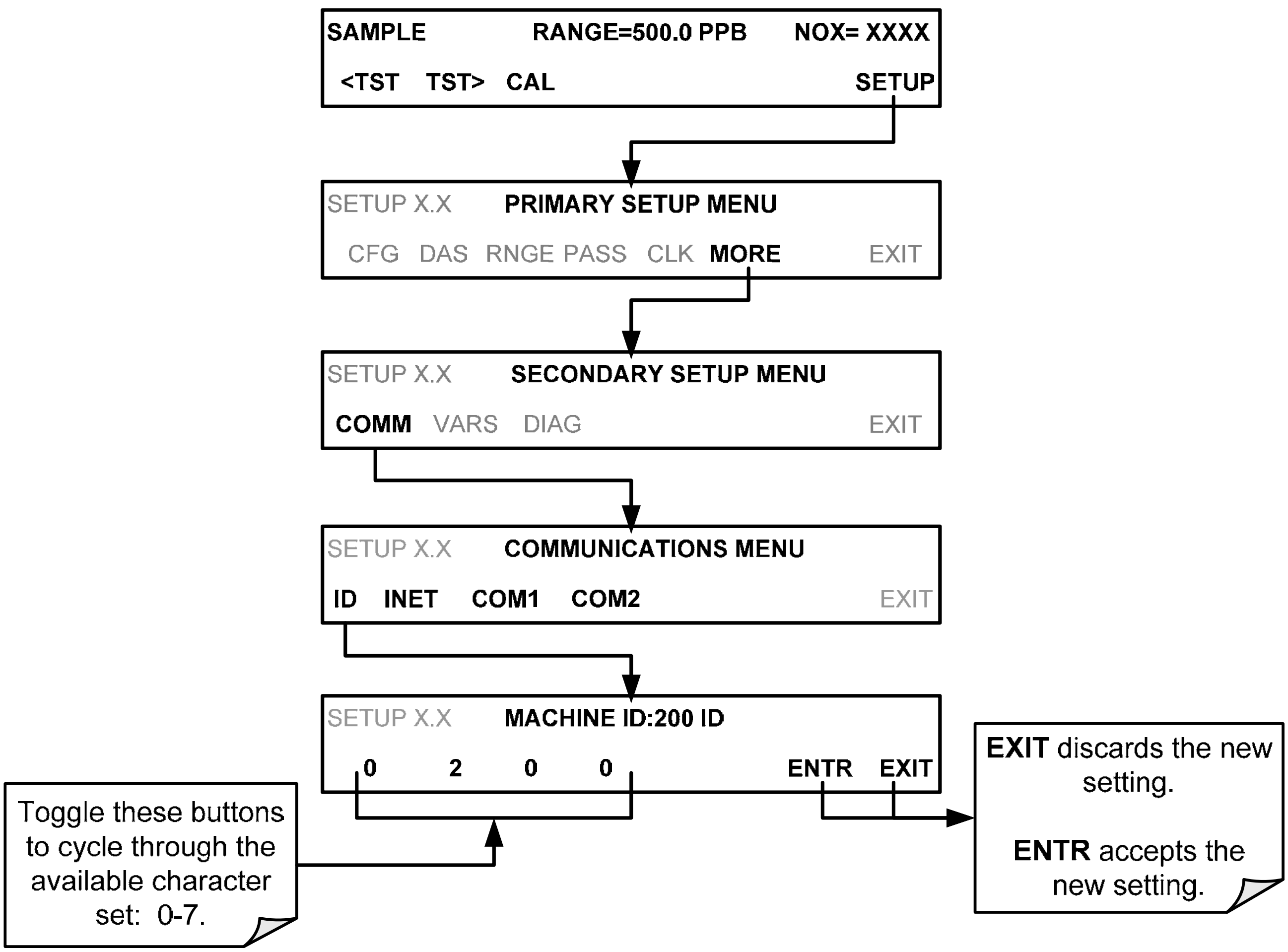
Each type of Teledyne API's analyzer is configured with a default **ID** code. The default **ID** code for all T200 analyzers is **200**.

The **ID** number is only important if more than one analyzer is connected to the same communications channel such as when several analyzers are:

- On the same Ethernet LAN (See Section 9.4);
- In a RS-232multidrop chain (See Section 9.2) or;
- Operating over a RS-485 network (See Section 9.3).

If two analyzers of the same model type are used on one channel, the **ID** codes of one or both of the instruments need to be changed.

To edit the instrument's ID code, press:



The ID can also be used for to identify any one of several analyzers attached to the same network but situated in different physical locations.

9.1.8. TERMINAL OPERATING MODES

The T200 can be remotely configured, calibrated or queried for stored data through the serial ports. As terminals and computers use different communication schemes, the analyzer supports two communicate modes specifically designed to interface with these two types of devices.

- Computer mode is used when the analyzer is connected to a computer with a dedicated interface program.
- Interactive mode is used with a terminal emulation program such as HyperTerminal or a “dumb” computer terminal. The commands that are used to operate the analyzer in this mode are listed in Table 9-2.

9.1.8.1. Help Commands in Terminal Mode

Table 9-2: Terminal Mode Software Commands

COMMAND	Function
Control-T	Switches the analyzer to terminal mode (echo, edit). If mode flags 1 & 2 are OFF, the interface can be used in interactive mode with a terminal emulation program.
Control-C	Switches the analyzer to computer mode (no echo, no edit).
CR (carriage return)	A carriage return is required after each command line is typed into the terminal/computer. The command will not be sent to the analyzer to be executed until this is done. On personal computers, this is achieved by pressing the ENTER button.
BS (backspace)	Erases one character to the left of the cursor location.
ESC (escape)	Erases the entire command line.
?[ID] CR	This command prints a complete list of available commands along with the definitions of their functionality to the display device of the terminal or computer being used. The ID number of the analyzer is only necessary if multiple analyzers are on the same communications line, such as the multi-drop setup.
Control-C	Pauses the listing of commands.
Control-P	Restarts the listing of commands.

9.1.8.2. Command Syntax

Commands are not case-sensitive and all arguments within one command (i.e. ID numbers, key words, data values, etc.) must be separated with a space character.

All Commands follow the syntax:

X [ID] COMMAND <CR>

Where

X	is the command type (one letter) that defines the type of command. Allowed designators are listed in Table 9-3 and Appendix A-6.
[ID]	is the machine identification number (Section 9.1.7). Example: the Command "? 200" followed by a carriage return would print the list of available commands for the revision of software currently installed in the instrument assigned ID Number 200.
COMMAND	is the command designator: This string is the name of the command being issued (LIST, ABORT, NAME, EXIT, etc.). Some commands may have additional arguments that define how the command is to be executed. Press ? <CR> or refer to Appendix A-6 for a list of available command designators
<CR>	is a carriage return. All commands must be terminated by a carriage return (usually achieved by pressing the ENTER button on a computer).

Table 9-3: Teledyne API's Serial I/O Command Types

COMMAND	COMMAND TYPE
C	Calibration
D	Diagnostic
L	Logon
T	Test measurement
V	Variable
W	Warning

9.1.8.3. Data Types

Data types consist of integers, hexadecimal integers, floating-point numbers, Boolean expressions and text strings.

- Integer data are used to indicate integral quantities such as a number of records, a filter length, etc. They consist of an optional plus or minus sign, followed by one or more digits. For example, +1, -12, 123 are all valid integers.
- Hexadecimal integer data are used for the same purposes as integers. They consist of the two characters "0x," followed by one or more hexadecimal digits (0-9, A-F, a-f), which is the 'C' programming language convention. No plus or minus sign is permitted. For example, 0x1, 0x12, 0x1234abcd are all valid hexadecimal integers.
- Floating-point numbers are used to specify continuously variable values such as temperature set points, time intervals, warning limits, voltages, etc. They consist of an optional plus or minus sign, followed by zero or more digits, an optional decimal point and zero or more digits. (At least one digit must appear before or after the decimal point.) Scientific notation is not permitted. For example, +1.0, 1234.5678, -0.1, 1 are all valid floating-point numbers.
- Boolean expressions are used to specify the value of variables or I/O signals that may assume only two values. They are denoted by the key words ON and OFF.
- Text strings are used to represent data that cannot be easily represented by other data types, such as data channel names, which may contain letters and numbers. They consist of a quotation mark,

followed by one or more printable characters, including spaces, letters, numbers, and symbols, and a final quotation mark. For example, “a”, “1”, “123abc”, and “()[]<>” are all valid text strings. It is not possible to include a quotation mark character within a text string.

- Some commands allow you to access variables, messages, and other items. When using these commands, you must type the entire name of the item; you cannot abbreviate any names.

9.1.8.4. Status Reporting

Reporting of status messages as an audit trail is one of the three principal uses for the RS-232 interface (the other two being the command line interface for controlling the instrument and the download of data in electronic format). You can effectively disable the reporting feature by setting the interface to quiet mode (Section 9.1.5, Table 9-1).

Status reports include warning messages, calibration and diagnostic status messages. Refer to Appendix A-3 for a list of the possible messages, and this for information on controlling the instrument through the RS-232 interface.

General Message Format

All messages from the instrument (including those in response to a command line request) are in the format:

X DDD:HH:MM [Id] MESSAGE<CRLF>

Where:

X	is a command type designator, a single character indicating the message type, as shown in the Table 9-3.
DDD:HH:MM	is the time stamp, the date and time when the message was issued. It consists of the Day-of-year (DDD) as a number from 1 to 366, the hour of the day (HH) as a number from 00 to 23, and the minute (MM) as a number from 00 to 59.
[ID]	is the analyzer ID, a number with 1 to 4 digits.
MESSAGE	is the message content that may contain warning messages, test measurements, variable values, etc.
<CRLF>	is a carriage return / line feed pair, which terminates the message.

The uniform nature of the output messages makes it easy for a host computer to parse them into an easy structure. Keep in mind that the front panel display does not give any information on the time a message was issued, hence it is useful to log such messages for troubleshooting and reference purposes. Terminal emulation programs such as HyperTerminal can capture these messages to text files for later review.

9.1.8.5. COMM Port Password Security

In order to provide security for remote access of the T200, a **LOGON** feature can be enabled to require a password before the instrument will accept commands. This is done by turning on the **SECURITY MODE** (Mode 4, Section 9.1.5). Once the **SECURITY MODE** is enabled, the following items apply.

- A password is required before the port will respond or pass on commands.
- If the port is inactive for one hour, it will automatically logoff, which can also be achieved with the **LOGOFF** command.
- Three unsuccessful attempts to log on with an incorrect password will cause subsequent logins to be disabled for 1 hour, even if the correct password is used.
- If not logged on, the only active command is the '?' request for the help screen.
- The following messages will be returned at logon:
- **LOGON SUCCESSFUL** - Correct password given.
- **LOGON FAILED** - Password not given or incorrect.
- **LOGOFF SUCCESSFUL** - Connection terminated successfully.

To log on to the T200 analyzer with **SECURITY MODE** feature enabled, type:

LOGON 940331

940331 is the default password. To change the default password, use the variable **RS232_PASS** issued as follows:

V RS232_PASS=NNNNNN

Where N is any numeral between 0 and 9.

9.1.9. REMOTE ACCESS BY MODEM

The T200 can be connected to a modem for remote access. This requires a cable between the analyzer's COMM port and the modem, typically a DB-9F to DB-25M cable (available from Teledyne API with P/N WR0000024).

Once the cable has been connected, check to ensure that:

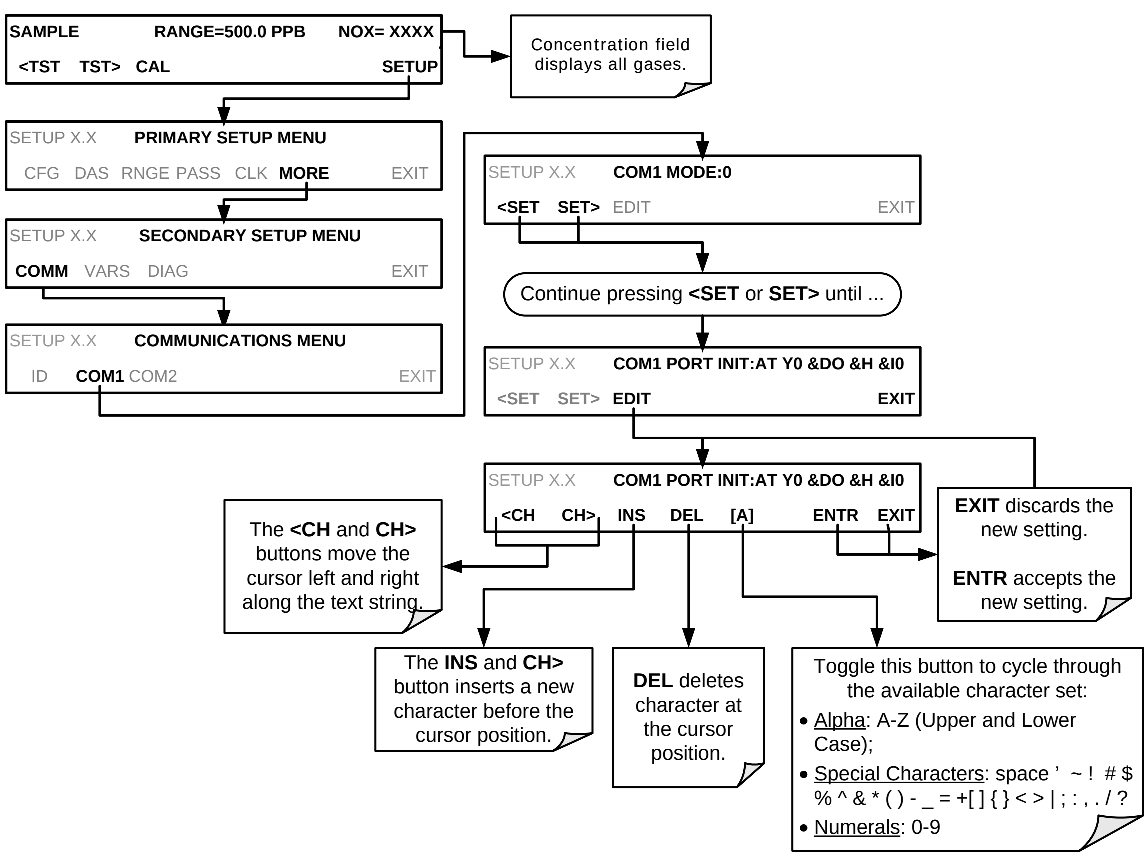
- The DTE-DCE is in the DCE position.
- The T200 COMM port is set for a baud rate that is compatible with the modem,
- The Modem is designed to operate with an 8-bit word length with one stop bit.
- The **MODEM ENABLE** communication mode is turned **ON** (Mode 64, see Section 9.1.5).

Once this is completed, the appropriate setup command line for your modem can be entered into the analyzer. The default setting for this feature is

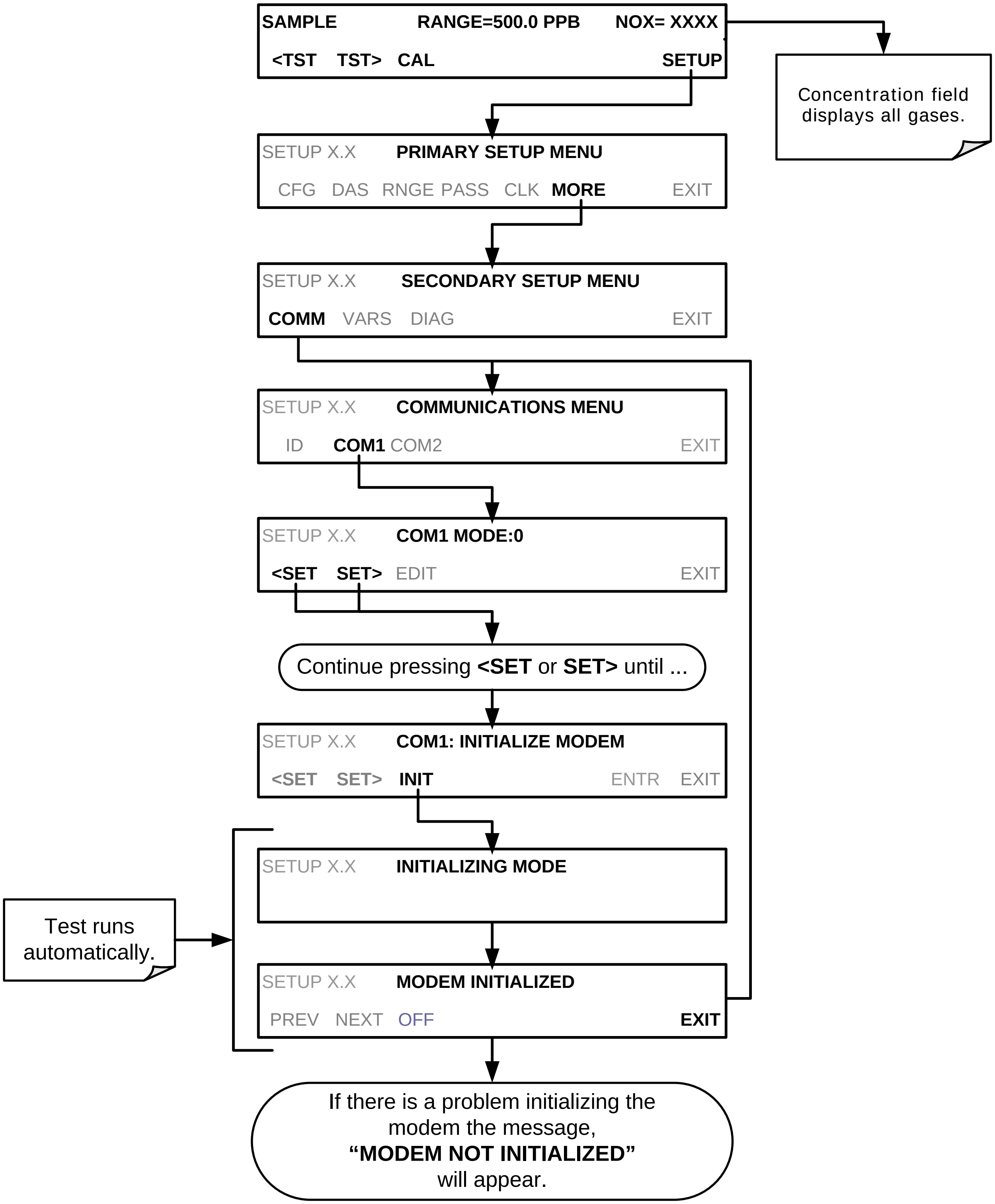
AT Y0 &D0 &H0 &I0 S0=2 &B0 &N6 &M0 E0 Q1 &W0

This string can be altered to match your modem's initialization and can be up to 100 characters long.

To change this setting press:



To initialize the modem press:



9.2. MULTIDROP RS-232 SET UP

When the RS-232 Multidrop option is installed, the instrument designated as last in the chain must be terminated. This requires installing a shunt between two pins on the multidrop printed circuit assembly (PCA) inside the instrument. Step-by-step instructions follow.

Note that because the RS-232 Multidrop option uses both the RS232 and COM2 DB9 connectors on the analyzer's rear panel to connect the chain of instruments, COM2 port is no longer available for separate RS-232 or RS-485 operation.

CAUTION – Risk of Instrument Damage and Warranty Invalidation

Printed circuit assemblies (PCAs) are sensitive to electro-static discharges too small to be felt by the human nervous system. Damage resulting from failure to use ESD protection when working with electronic assemblies will void the instrument warranty.

See *A Primer on Electro-Static Discharge* section in this manual for more information on preventing ESD damage.

To install shunt in the last analyzer:

1. With **NO power** to the instrument, remove its top cover and lay the rear panel open for access to the multidrop PCA, which is seated on the CPU.
2. On the multidrop PCA's JP2 connector, use the shunt provided to jumper Pins 21 ↔ 22 as indicated in Figure 9-3.

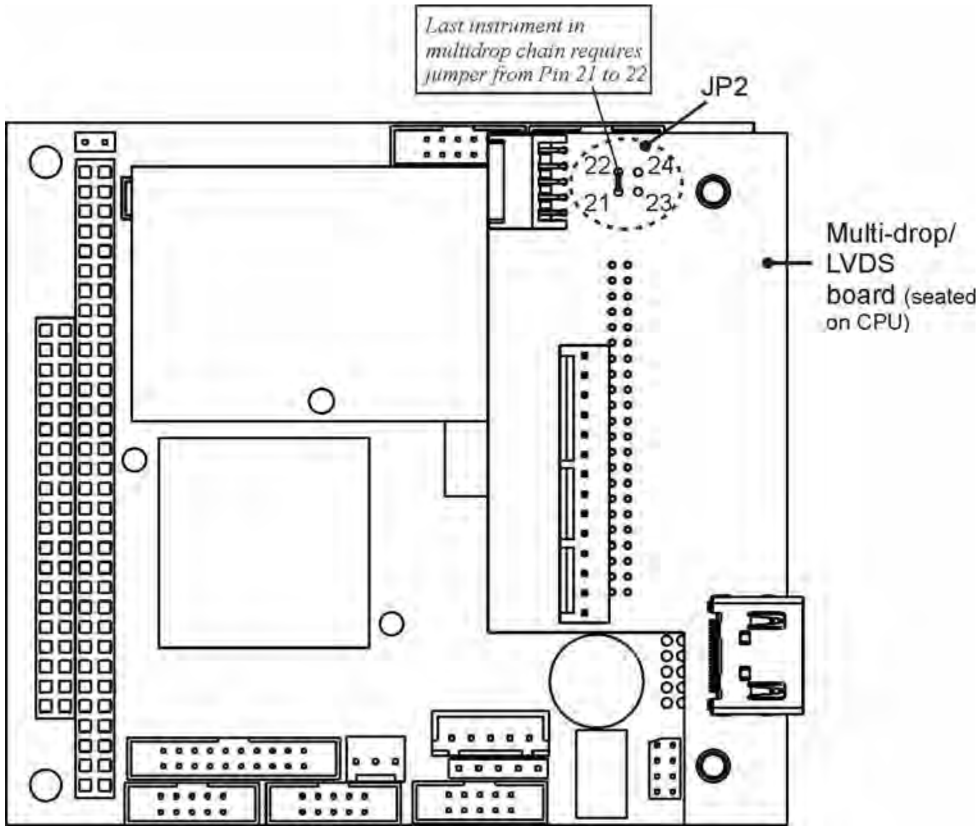


Figure 9-3: JP2 Pins 21-22 on RS-232-Multidrop PCA

3. Close the instrument.
4. Referring to Figure 9-4 use straight-through DB9 male → DB9 female cables to interconnect the host RS232 port to the first analyzer's RS232 port; then from the first analyzer's COM2 port to the second analyzer's RS232 port; from the second analyzer's COM2 port to the third analyzer's RS232 port, etc., connecting in this fashion up to eight analyzers, subject to the distance limitations of the RS-232 standard.
5. BEFORE communicating from the host, power ON the instruments and check that the Machine ID code is unique for each (see Section 9.1.7). On the front panel menu, use SETUP>MORE>COMM>ID. Note that the default ID is typically the model number; to change the 4-digit identification number, press the button of the digit to be changed).

NOTE

Teledyne API recommends setting up the first link, between the Host and the first instrument and testing it before setting up the rest of the chain.

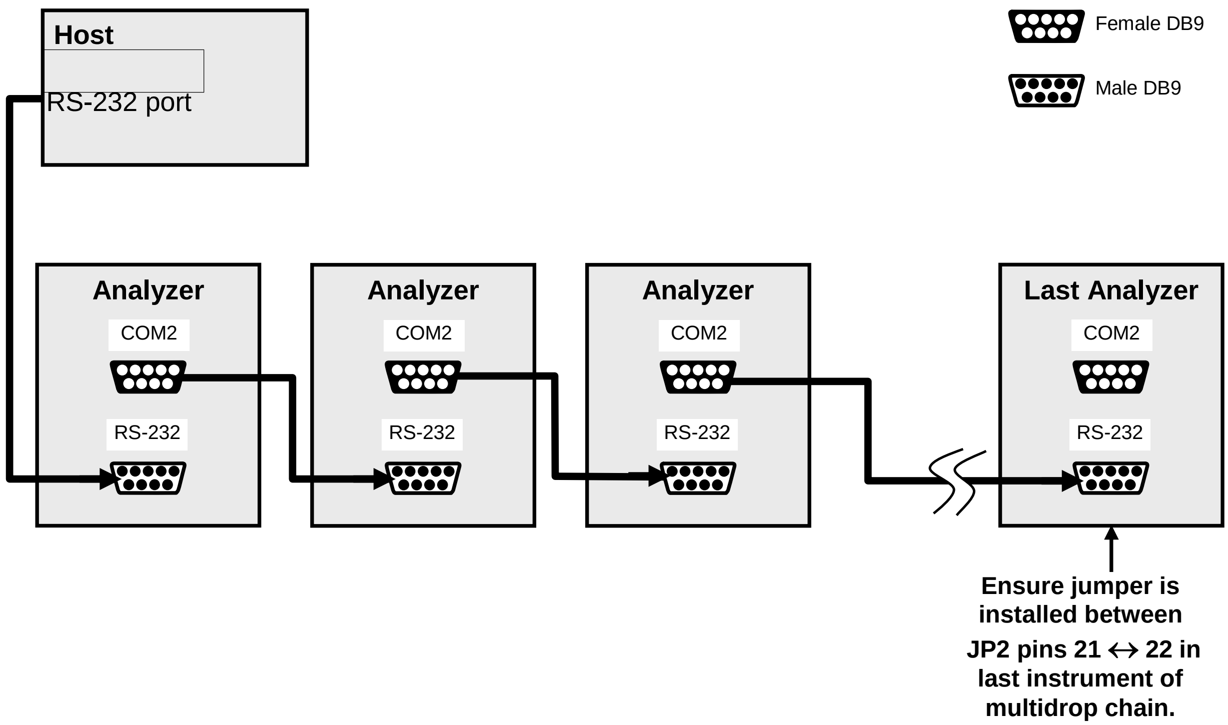


Figure 9-4: RS-232-Multidrop PCA Host/Analyzer Interconnect Diagram

9.3. RS-485 COMMUNICATION

As delivered from the factory, **COM2** is configured for RS-232 communications. This port can be reconfigured for operation as a non-isolated, half-duplex RS-485 port. Using COM2 for RS-485 communication will disable the USB port. To reconfigure this port for RS-485 communication, please contact the factory.

9.4. REMOTE ACCESS VIA THE ETHERNET

When using the Ethernet interface, the analyzer can be connected to any standard 10BaseT or 100BaseT Ethernet network via low-cost network hubs, switches or routers. The interface operates as a standard TCP/IP device on port 3000. This allows a remote computer to connect through the network to the analyzer using APICOM, terminal emulators or other programs.

The Ethernet connector has two LEDs that are on the connector itself, indicating its current operating status.

Table 9-4: Ethernet Status Indicators

LED	FUNCTION
amber (link)	On when connection to the LAN is valid.
green (activity	Flickers during any activity on the LAN.

The analyzer is shipped with DHCP enabled by default. This allows the instrument to be connected to a network or router with a DHCP server. The instrument will automatically be assigned an IP address by the DHCP server (Section 9.4.1). This configuration is useful for quickly getting an instrument up and running on a network. However, for permanent Ethernet connections, a static IP address should be used. Section 9.4.2 below details how to configure the instrument with a static IP address.

9.4.1. CONFIGURING THE ETHERNET INTERFACE USING DHCP

The Ethernet for your T200 uses Dynamic Host Configuration Protocol (DHCP) to configure its interface with your LAN automatically. This requires your network servers also to be running DHCP. The analyzer will do this the first time you turn the instrument on after it has been physically connected to your network. Once the instrument is connected and turned on, it will appear as an active device on your network without any extra set up steps or lengthy procedures.

NOTE

It is a good idea to check the INET settings the first time you power up your analyzer after it has been physically connected to the LAN/Internet to ensure that the DHCP has successfully downloaded the appropriate information from you network server(s).

The Ethernet configuration properties are viewable via the analyzer’s front panel display.

Table 9-5: LAN/Internet Configuration Properties

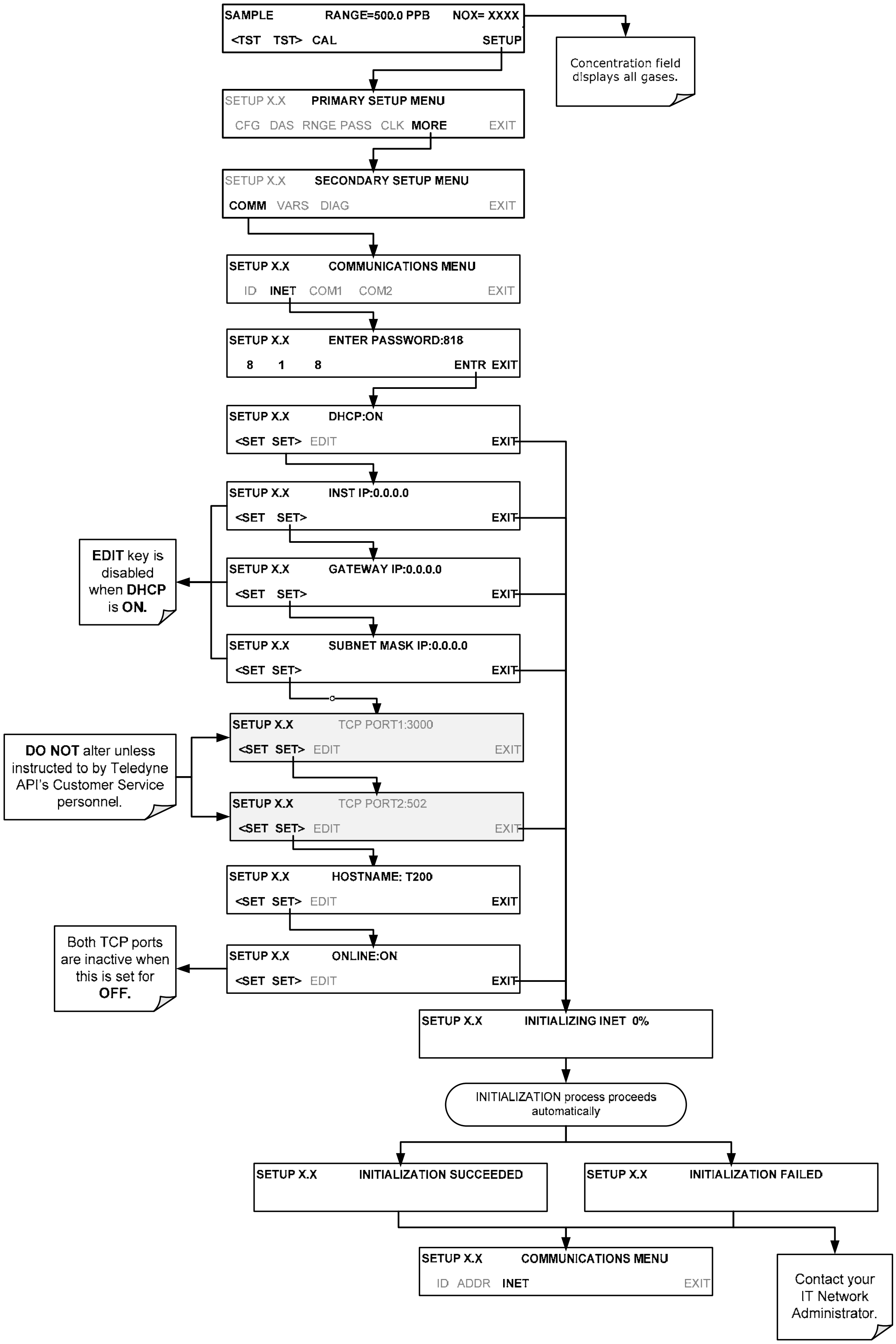
PROPERTY	DEFAULT STATE	DESCRIPTION
DHCP	ON	This displays whether the DHCP is turned ON or OFF. Press EDIT and toggle ON for automatic configuration after first consulting network administrator. (
INSTRUMENT IP ADDRESS		This string of four packets of 1 to 3 numbers each (e.g. 192.168.76.55.) is the address of the analyzer itself.
GATEWAY IP ADDRESS	0.0.0.0	Can only be edited when DHCP is set to OFF. A string of numbers very similar to the Instrument IP address (e.g. 192.168.76.1.) that is the address of the computer used by your LAN to access the Internet.
SUBNET MASK	0.0.0.0	Can only be edited when DHCP is set to OFF. Also a string of four packets of 1 to 3 numbers each (e.g. 255.255.252.0) that identifies the LAN to which the device is connected. All addressable devices and computers on a LAN must have the same subnet mask. Any transmissions sent to devices with different subnets are assumed to be outside of the LAN and are routed through the gateway computer onto the Internet.
TCP PORT[1]	3000	This number defines the terminal control port by which the instrument is addressed by terminal emulation software, such as Internet or Teledyne API's APICOM.
HOST NAME	[initially blank]	The name by which your analyzer will appear when addressed from other computers on the LAN or via the Internet. To change, see Section 9.4.3.
[1] Do not change the setting for this property unless instructed to by Teledyne API's Customer Service personnel.		

NOTE

If the gateway IP, instrument IP and the subnet mask are all zeroes (e.g. "0.0.0.0"), the DCHP was not successful in which case you may have to configure the analyzer's Ethernet properties manually.

See your network administrator.

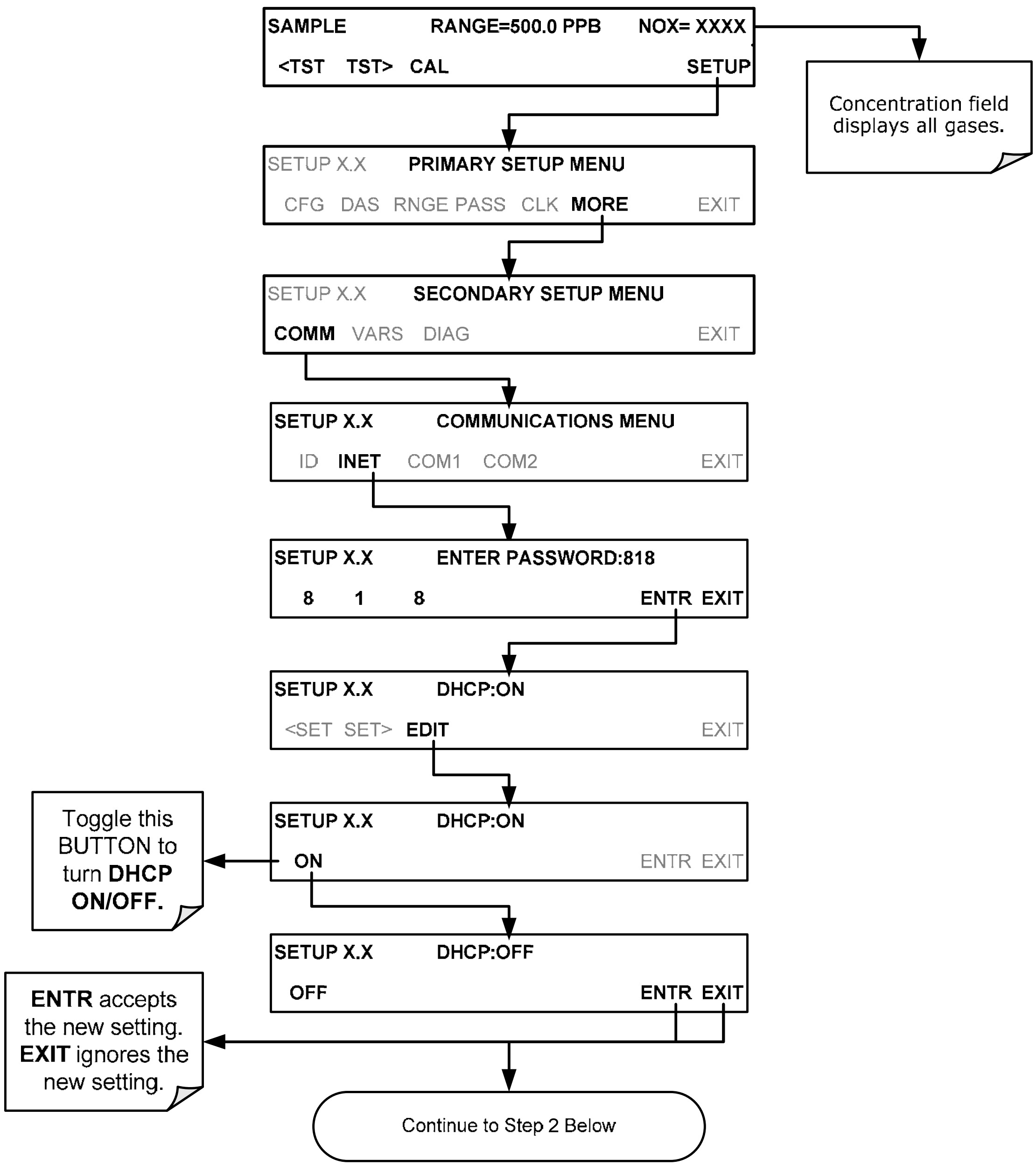
To view the above properties listed in Table 9-5, press:



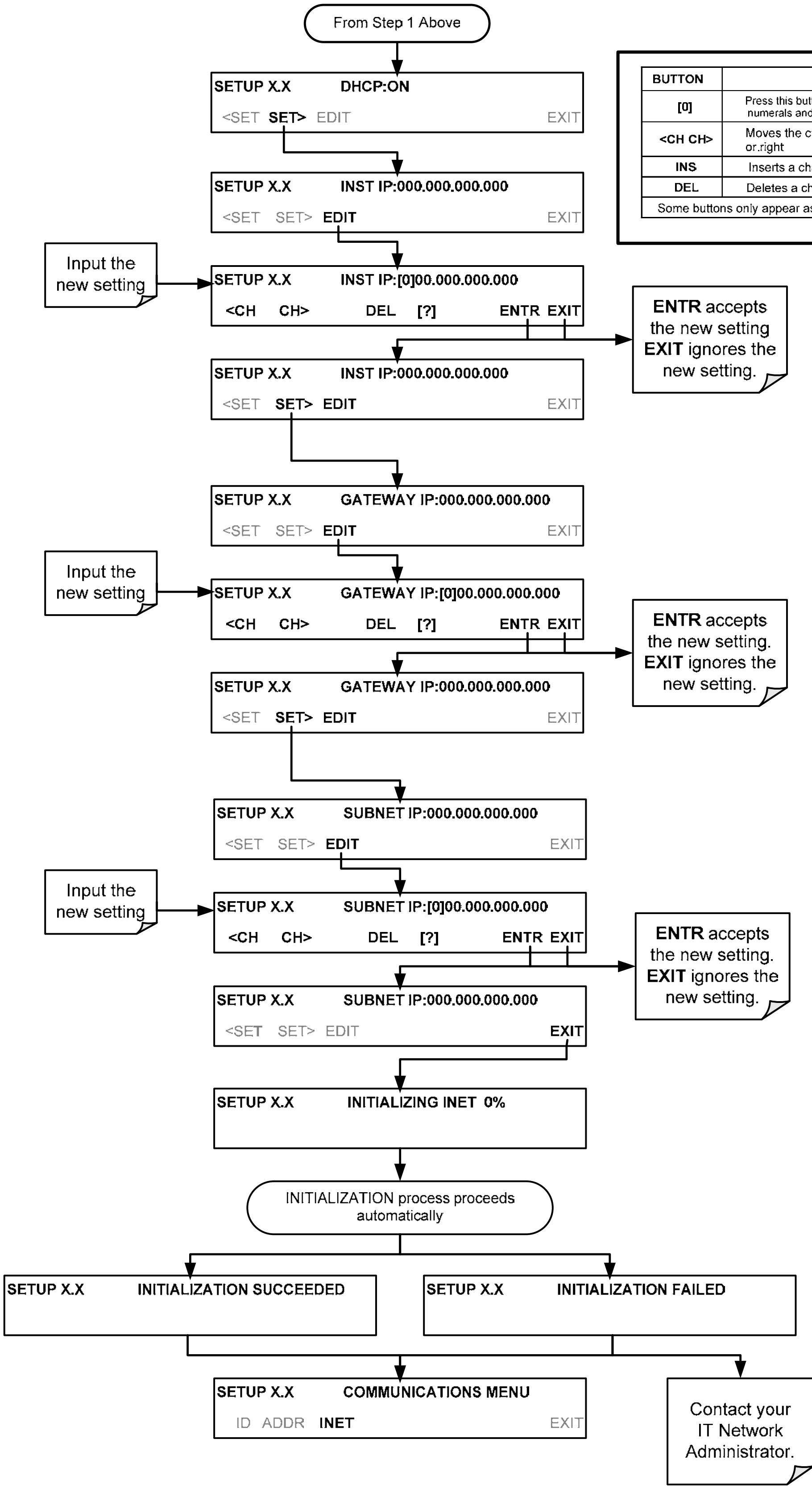
9.4.2. MANUALLY CONFIGURING THE ETHERNET (STATIC IP ADDRESS)

To configure Ethernet communication manually:

1. Connect a cable from the analyzer's Ethernet port to a Local Area Network (LAN) or Internet port.
2. From the analyzer's front panel touchscreen, access the Communications Menu as shown below, turning DHCP mode to OFF.



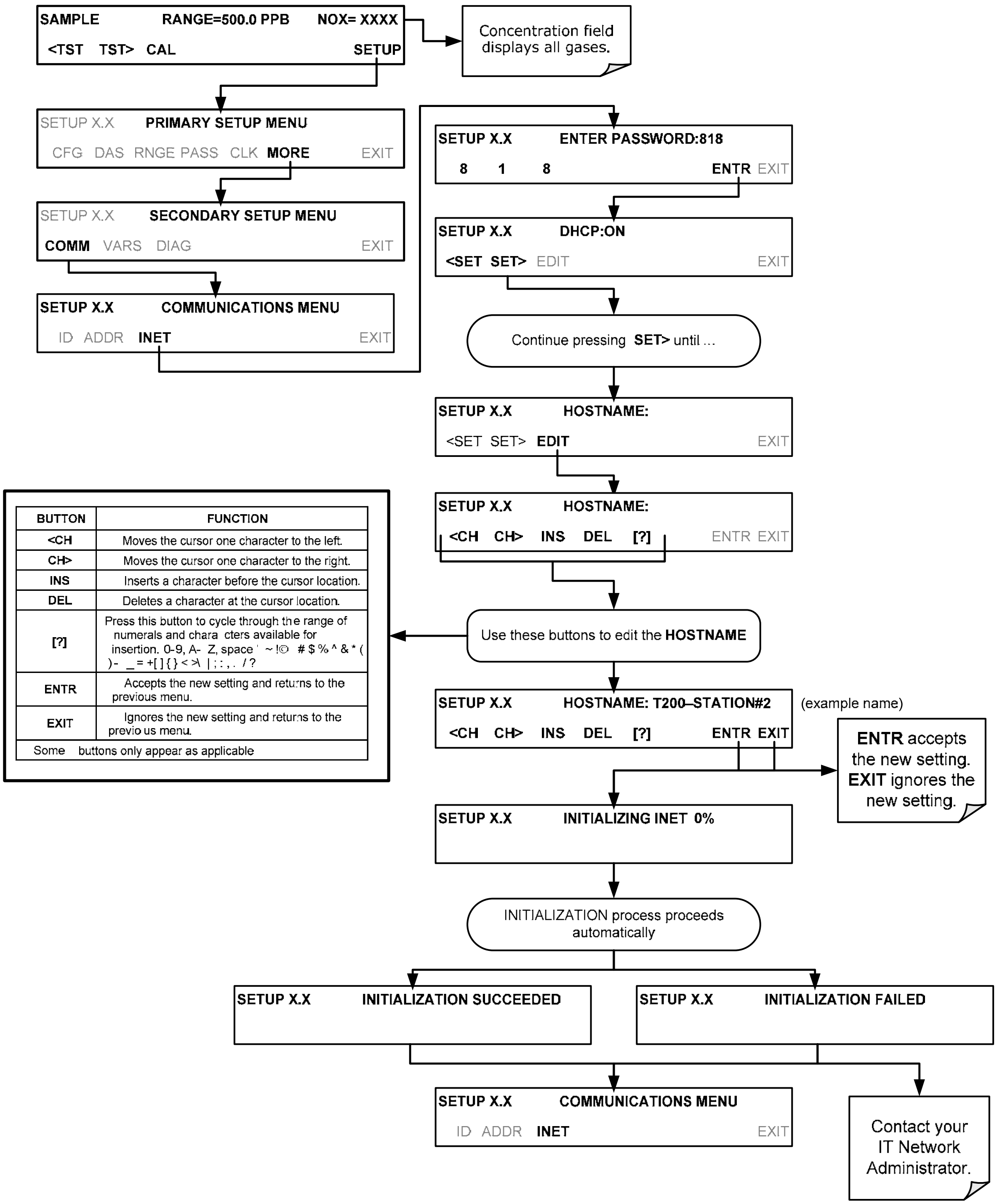
Next, refer to Section 9.4 for the Ethernet configuration settings and configure the **INSTRUMENT IP**, **GATEWAY IP** and **SUBNET MASK** addresses by pressing:



BUTTON	FUNCTION
[0]	Press this button to cycle through the range of numerals and available characters ("0 – 9" & " . ")
<CH CH>	Moves the cursor one character to the left or right
INS	Inserts a character before the cursor location.
DEL	Deletes a character at the cursor location.
Some buttons only appear as applicable.	

9.4.3. CHANGING THE ANALYZER'S HOSTNAME

The **HOSTNAME** is the name by which the analyzer appears on your network. The initial default Hostname is blank. To change this name (particularly if you have more than one T200 analyzer on your network, where each must have a different Hostname), press:



BUTTON	FUNCTION
<CH	Moves the cursor one character to the left.
CH>	Moves the cursor one character to the right.
INS	Inserts a character before the cursor location.
DEL	Deletes a character at the cursor location.
[?]	Press this button to cycle through the range of numerals and characters available for insertion. 0-9, A-Z, space ' ~ !© # $ % ^ & * ( ) - _ = +[ ] { } < >\ | ; : , . / ?
ENTR	Accepts the new setting and returns to the previous menu.
EXIT	Ignores the new setting and returns to the previous menu.
Some buttons only appear as applicable	

9.5. USING THE T200 WITH A HESSEN PROTOCOL NETWORK

9.5.1. GENERAL OVERVIEW OF HESSEN PROTOCOL

The Hessen protocol is a multidrop protocol, in which several remote instruments are connected via a common communications channel to a host computer. The remote instruments are regarded as slaves of the host computer. The remote instruments are unaware that they are connected to a multidrop bus and never initiate Hessen protocol messages. They only respond to commands from the host computer and only when they receive a command containing their own unique ID number.

The Hessen protocol is designed to accomplish two things: to obtain the status of remote instruments, including the concentrations of all the gases measured; and to place remote instruments into zero or span calibration or measure mode. Teledyne API's implementation supports both of these principal features.

The Hessen protocol is not well defined; therefore, while Teledyne-API's application is completely compatible with the protocol itself, it may be different from implementations by other companies.

NOTE

The following sections describe the basics for setting up your instrument to operate over a Hessen Protocol network.

For more detailed information as well as a list of host computer commands and examples of command and response message syntax, download the *Manual Addendum for Hessen Protocol* from the Teledyne API's web site: http://www.teledyne-api.com/manuals/index.asp .

9.5.2. HESSEN COMM PORT CONFIGURATION

Hessen protocol requires the communication parameters of the T200's COMM ports to be set differently than the standard configuration as shown in the table below.

Table 9-6: RS-232 Communication Parameters for Hessen Protocol

PARAMETER	STANDARD	HESSEN
Baud Rate	300 – 19200	1200
Data Bits	8	7
Stop Bits	1	2
Parity	None	Even
Duplex	Full	Half

To change the baud rate of the T200's COMM ports, See Section 9.1.4.

To change the rest of the COMM port parameters listed in the table above, see Section 9.1.5 and Table 9-1.

Note

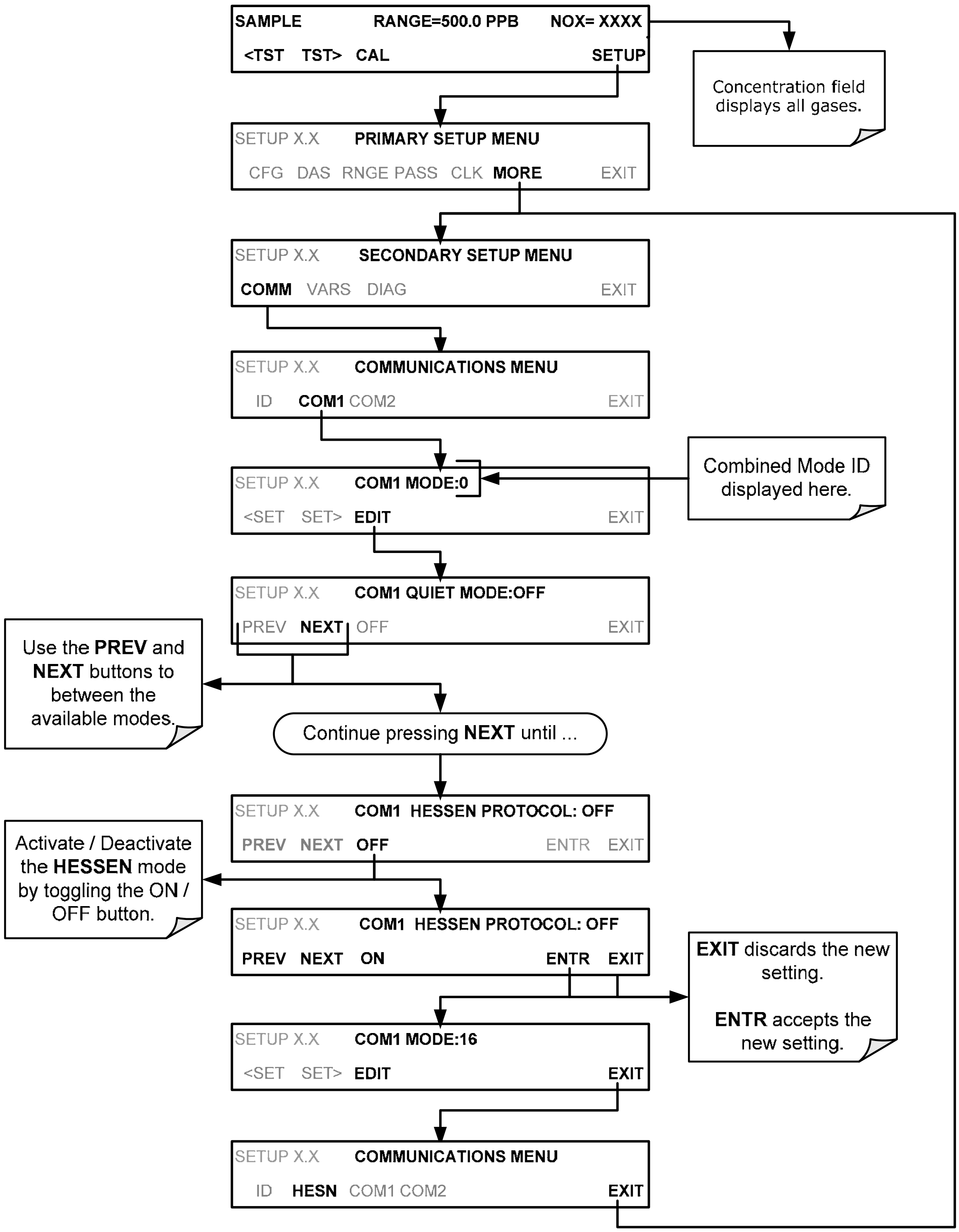
Ensure that the communication parameters of the host computer are also properly set.

Also, the instrument software has a 200 ms latency period before it responds to commands issued by the host computer. This latency should present no problems, but you should be aware of it and not issue commands to the instrument too frequently.

9.5.3. ACTIVATING HESSEN PROTOCOL

Once the COMM port has been properly configured, the next step in configuring the T200 in order to operate over a Hessen protocol network is to activate the Hessen mode for COMM ports and configure the communication parameters for the port(s) appropriately.

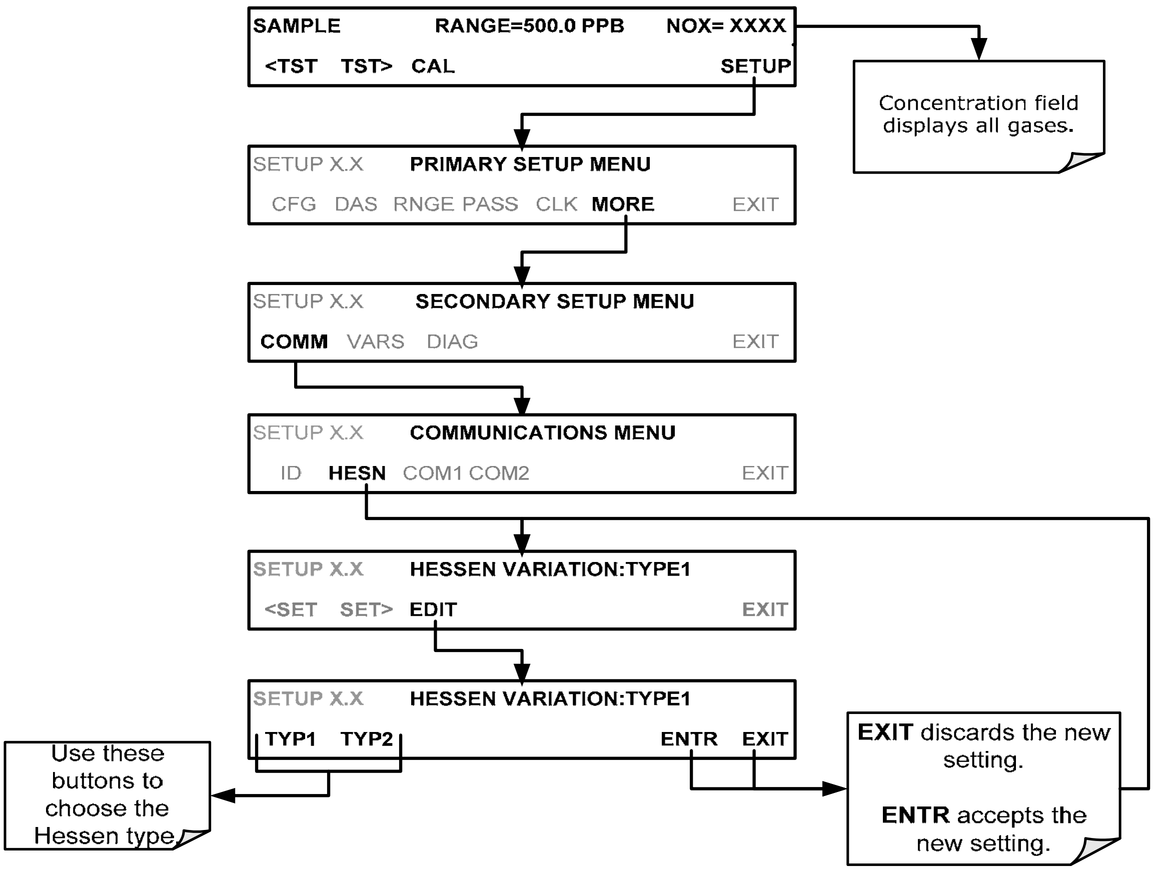
To activate the Hessen Protocol, press:



9.5.4. SELECTING A HESSEN PROTOCOL TYPE

Currently there are two versions of Hessen Protocol in use. The original implementation, referred to as **TYPE 1**, and a more recently released version, **TYPE 2** that has more flexibility when operating with instruments that can measure more than one type of gas. For more specific information about the difference between **TYPE 1** and **TYPE 2** download the *Manual Addendum for Hessen Protocol* from the Teledyne API's web site: http://www.teledyne-api.com/manuals/.

To select a Hessen Protocol Type press:



NOTE
While Hessen Protocol Mode can be activated independently for COM1 and COM2, the TYPE selection affects both Ports.

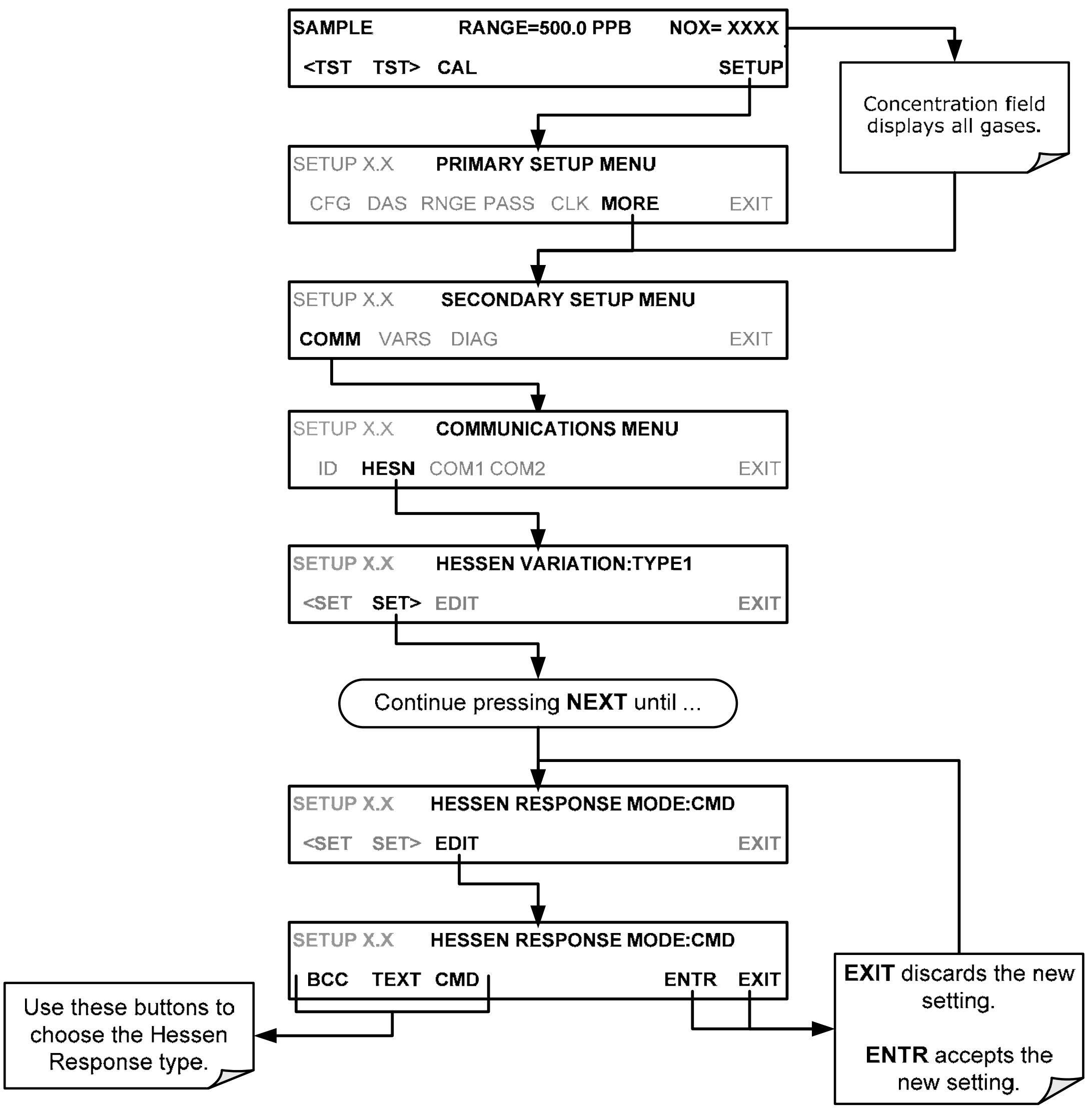
9.5.5. SETTING THE HESSEN PROTOCOL RESPONSE MODE

The Teledyne API's implementation of Hessen Protocol allows the user to choose one of several different modes of response for the analyzer.

Table 9-7: Teledyne API's Hessen Protocol Response Modes

MODE ID	MODE DESCRIPTION
CMD	This is the Default Setting. Reponses from the instrument are encoded as the traditional command format. Style and format of responses depend on exact coding of the initiating command.
BCC	Responses from the instrument are always delimited with <STX> (at the beginning of the response, <ETX> (at the end of the response followed by a 2 digit Block Check Code (checksum), regardless of the command encoding.
TEXT	Responses from the instrument are always delimited with <CR> at the beginning and the end of the string, regardless of the command encoding.

To Select a Hessen response mode, press:



9.5.6. HESSEN PROTOCOL GAS LIST ENTRIES

9.5.6.1. Gas List Entry Format and Definitions

The T200 analyzer keeps a list of available gas types. Each entry in this list is of the following format.

[GAS TYPE],[RANGE],[GAS ID],[REPORTED]

WHERE:

GAS TYPE = The type of gas to be reported (e.g. NO_x, NO and NO_2 etc.).

RANGE = The concentration range for this entry in the gas list. This feature permits the user to select which concentration range will be used for this gas list entry. The T200 analyzer has two ranges: **RANGE1** or LOW & **RANGE2** or HIGH (See Section 7.4.4).

- 0 - The HESSEN protocol to use whatever range is currently active.
- 1 - The HESSEN protocol will always use **RANGE1** for this gas list entry
- 2 - The HESSEN protocol will always use **RANGE2** for this gas list entry
- 3 - Not applicable to the T200 analyzer.

GAS ID = An identification number assigned to a specific gas. The T200 analyzer is a multiple gas instrument that measures NO_x, NO and NO_2. Their ID numbers are as follows:

NO_x 211
NO 212
NO_2 213

REPORT = States whether this list entry is to be reported or not reported when ever this gas type or instrument is polled by the HESSEN network. If the list entry is not to be reported this field will be blank. It's default gas list consists of only reads:

NOX, 0, 211, REPORTED
NO, 0, 212, REPORTED
NO2, 0, 213, REPORTED

These default settings cause the instrument to report the concentration value of the currently active range. If you wish to have just concentration value stored for a specific range, this list entry should be edited or additional entries should be added to the list.

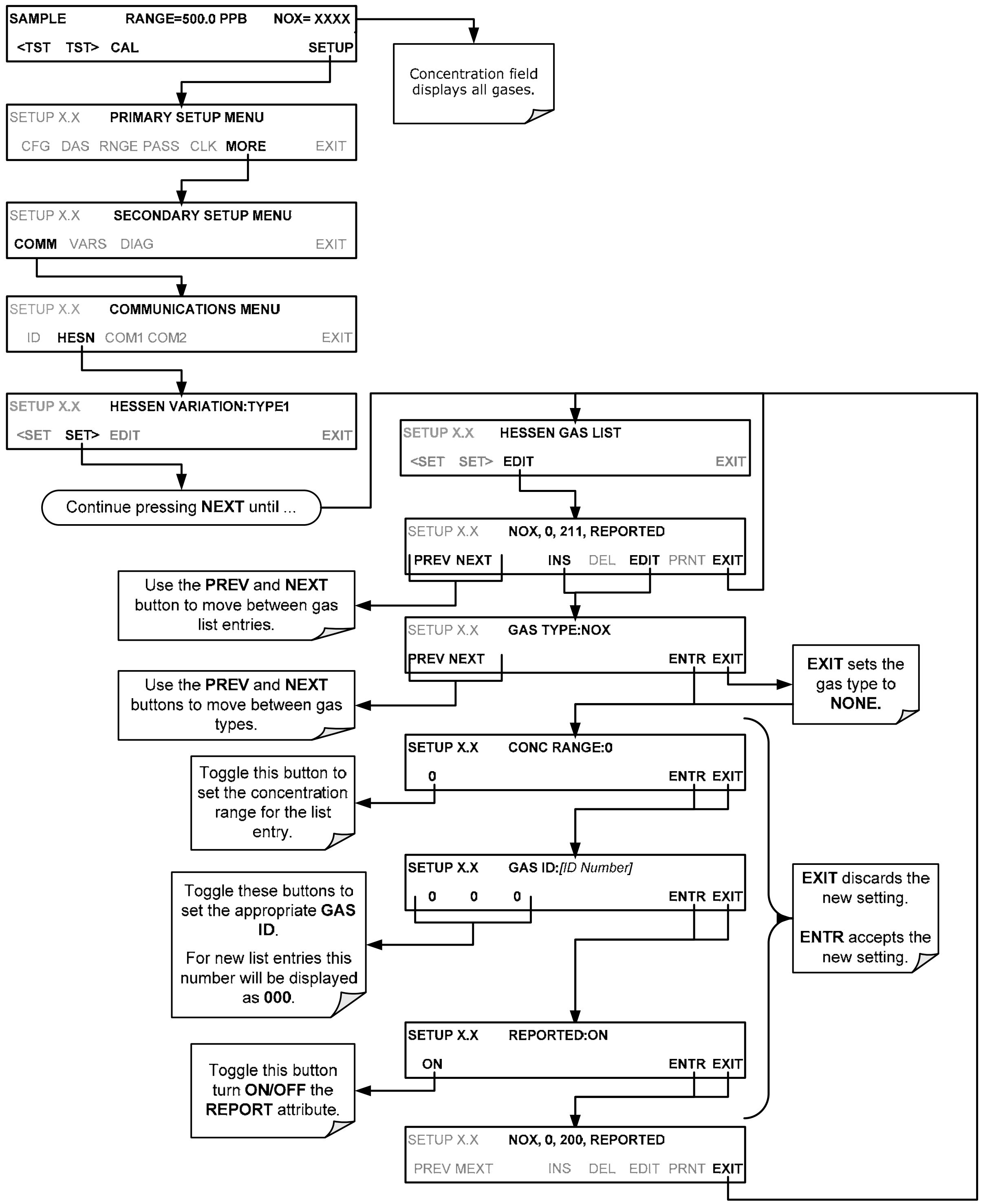
EXAMPLE: Changing the above NO_x gas list entry to read:

NOX, 2, 211, REPORTED

Would only record the last NO_x reading that occurred while **RANGE2** (HIGH) range was active.

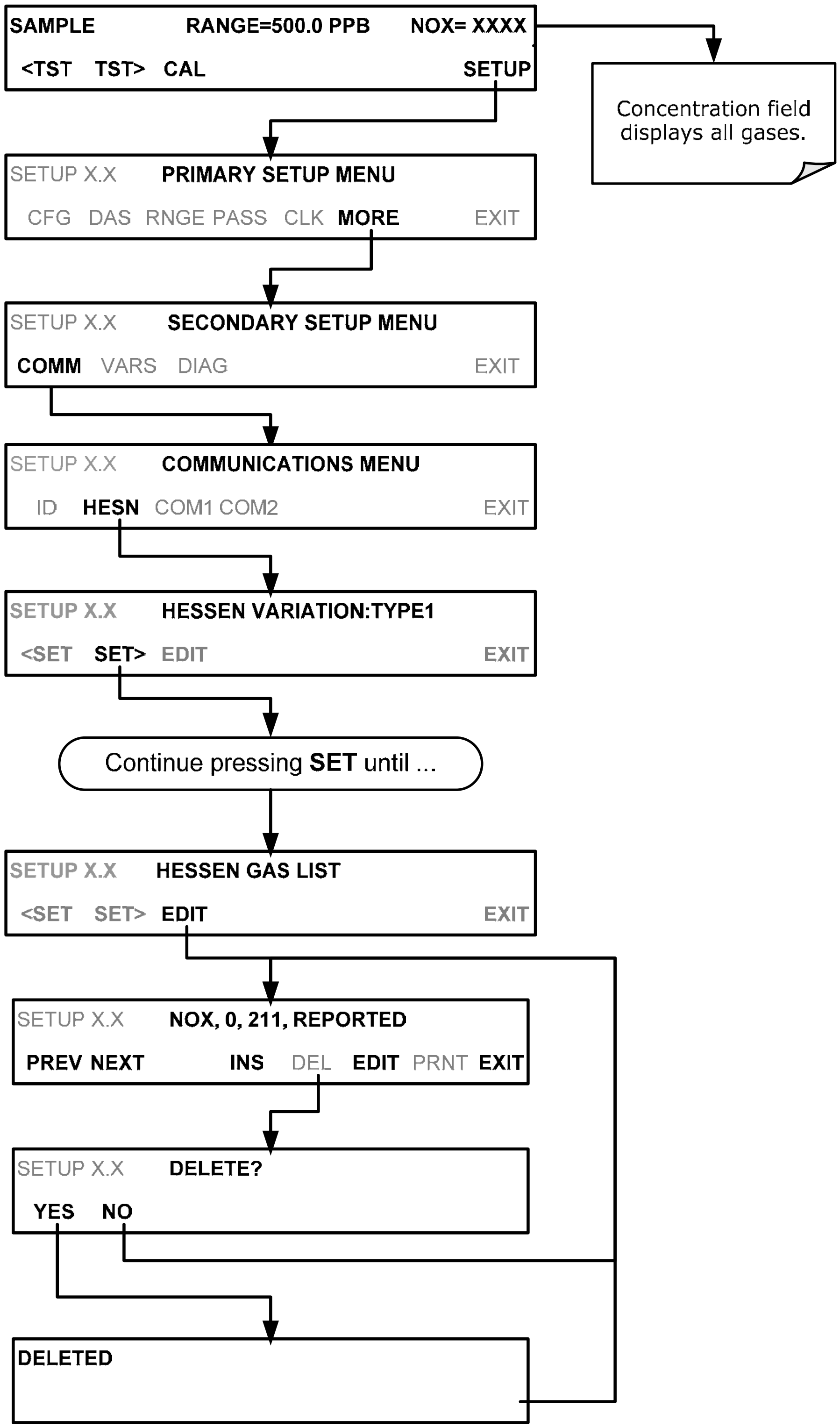
9.5.6.2. Editing or Adding HESSEN Gas List Entries

To add or edit an entry to the Hessen Gas List, press:



9.5.6.3. Deleting HESSEN Gas List Entries

To delete an entry from the Hessen Gas list, press:



9.5.7. SETTING HESSEN PROTOCOL STATUS FLAGS

Teledyne API's' implementation of Hessen protocols includes a set of status bits that the instrument includes in responses to inform the host computer of its condition. Each bit can be assigned to one operational and warning message flag. The default settings for these bit/flags are:

Table 9-8: Default Hessen Status Flag Assignments

STATUS FLAG NAME	DEFAULT BIT ASSIGNMENT
WARNING FLAGS	
SAMPLE FLOW WARNING	0001
OZONE FLOW WARNING	0002
RCEL PRESS WARN	0004
BOX TEMP WARNING	0008
RCELL TEMP WARNING	0010
IZS TEMP WARNING[1]	0020
PMT TEMP WARN	0040
CONV TEMP WARNING	0080
INVALID CONC	8000
OPERATIONAL FLAGS	
In **MANUAL** Calibration Mode	0200
In **ZERO** Calibration Mode	0400
In **SPAN** Calibration Mode	0800
In **WARMUP** Mode	1000
UNITS OF MEASURE FLAGS	
UGM	0000
MGM	2000
PPB	4000
PPM	6000
SPARE/UNUSED BITS	0100
UNASSIGNED FLAGS (0000)	
MANIFOLD TEMPERATURE[2]	**HVPS WARNING**
OZONE GEN OFF	**FRONT PANEL WARN**
SYSTEM RESET	**ANALOG CAL WARNING**
RELAY BOARD WARNING	**CANNOT DYN ZERO**
REAR BOARD NOT DETECTED	**CANNOT DYN SPAN**
AUTOZERO WARNING	**Instrument is in MP CAL mode**

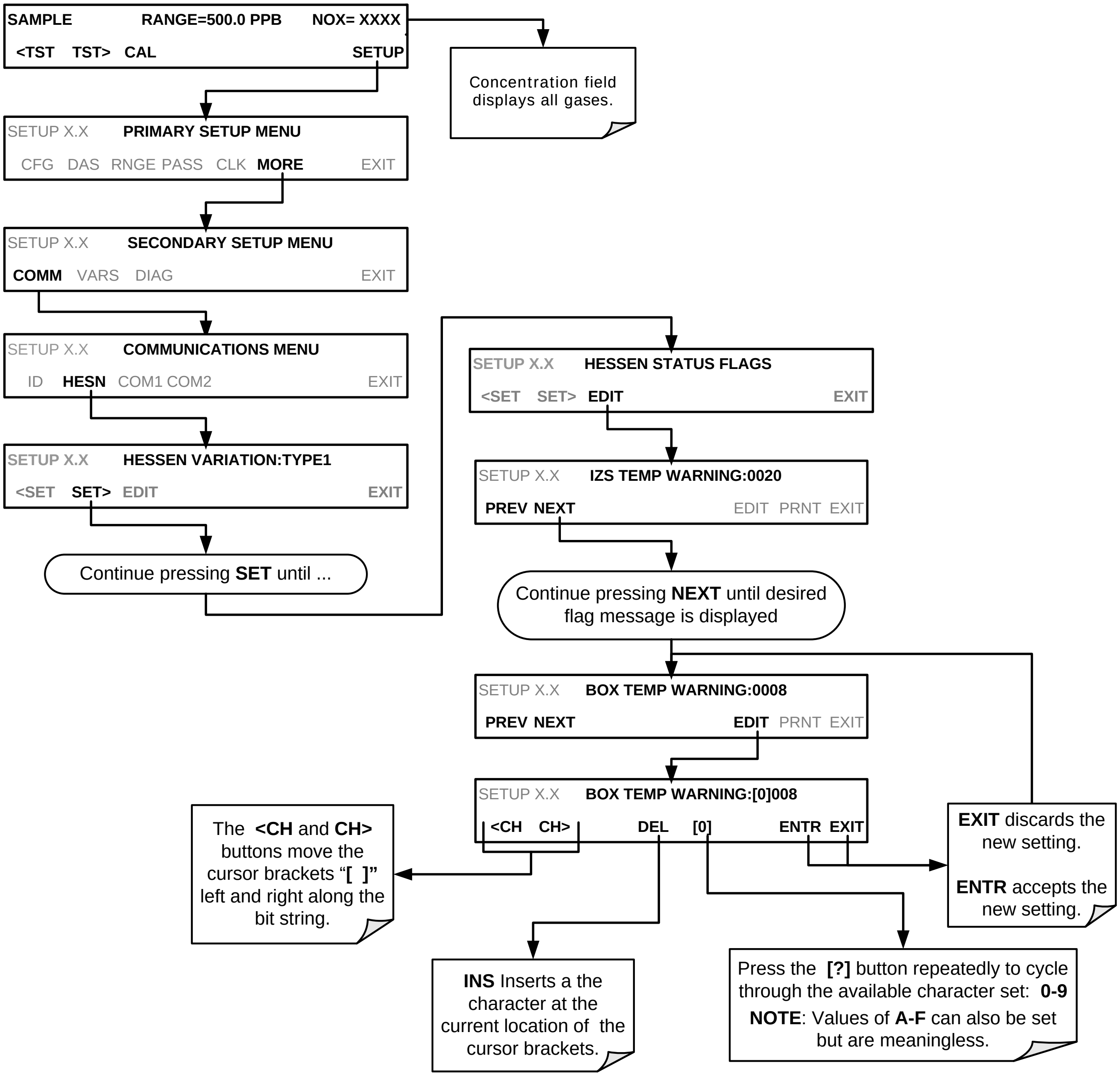
[1] Only applicable if the optional internal span gas generator is installed.

[2] Only applicable if the T200 is equipped with an oxygenator option.

[3] It is possible to assign more than one flag to the same Hessen status bit. This allows the grouping of similar flags, such as all temperature warnings, under the same status bit.

Be careful not to assign conflicting flags to the same bit as each status bit will be triggered if any of the assigned flags is active.

To assign or reset the status flag bit assignments, press:



9.5.8. INSTRUMENT ID CODE

The T200 analyzer is programmed with a default ID code of **200**.

Each instrument on a Hessen Protocol network must have a unique ID code. If more than one T200 analyzer is on the Hessen network, you will have to change this code for all but one of the T200 analyzer’s on the Hessen network (see Section 9.1.7).

9.6. APICOM REMOTE CONTROL PROGRAM

APICOM is an easy-to-use, yet powerful interface program that allows the user to access and control any of Teledyne API's' main line of ambient and stack-gas instruments from a remote connection through direct cable, modem or Ethernet. Running APICOM, a user can:

- Establish a link from a remote location to the T200 through direct cable connection via RS-232 modem or Ethernet.
- View the instrument's front panel and remotely access all functions that could be accessed when standing in front of the instrument.
- Remotely edit system parameters and set points.
- Download, view, graph and save data for predictive diagnostics or data analysis.
- Check on system parameters for troubleshooting and quality control.

APICOM is very helpful for initial setup, data analysis, maintenance and troubleshooting. Figure 9-5 shows an example of APICOM's main interface, which emulates the look and functionality of the instruments actual front panel.

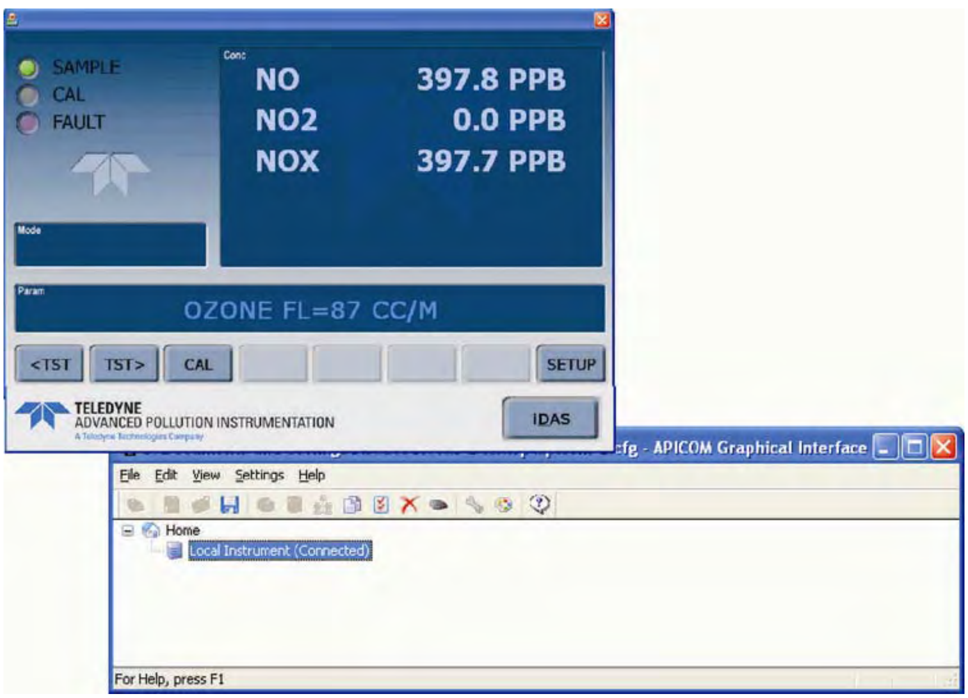


Figure 9-5: APICOM Remote Control Program Interface

NOTE

APICOM is included free of cost with the analyzer and the latest versions can also be downloaded for free at http://www.teledyne-api.com/manuals/.

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10. T200 CALIBRATION PROCEDURES

This section contains a variety of information regarding the various methods for calibrating a T200 NO_x Analyzer as well as other supporting information. For information on EPA protocol calibration, please refer to Section 11. This section is organized as follows:

SECTION 10.1 – BEFORE CALIBRATION

This section contains general information you should know before about calibrating the analyzer.

SECTION 10.2 – MANUAL CALIBRATION CHECKS AND CALIBRATION OF THE T200 ANALYZER IN ITS BASE CONFIGURATION

This section describes:

- The procedure for checking the calibrating of the T200 and calibrating the instrument with no zero/span valves installed or if installed, not operating. It requires that zero air and span gas be installed through the **SAMPLE** port.
- Instructions for selecting the reporting range to be calibrated when the T200 analyzer is set to operate in either the **IND** or **AUTO** reporting range modes.

SECTION 10.3 – MANUAL CALIBRATION WITH THE INTERNAL SPAN GAS GENERATOR

This section describes:

- The procedure for manually checking the calibration of the instrument with optional internal span gas generator installed.
- The procedure for manually calibrating the instrument using the optional internal span gas generator.

– This practice is not approved by the US EPA.

SECTION 10.4 – MANUAL CALIBRATION AND CAL CHECKS WITH THE VALVE OPTIONS INSTALLED

This section describes:

- The procedure for manually checking the calibration of the instrument with optional zero/span valves option installed.
- The procedure for manually calibrating the instrument with zero/span valves and operating.
- Instructions on activating the zero/span valves via the control in contact closures of the analyzers external digital I/O.

SECTION 10.5 – AUTOMATIC ZERO/SPAN CAL/CHECK (AUTOCAL)

This section describes the procedure for using the AutoCal feature of the analyzer to check or calibrate the instrument.

- The AutoCal feature requires that either the zero/span valve option or the internal span gas generator option be installed and operating.

SECTION 10.6 – CALIBRATION QUALITY ANALYSIS

- This section describes how to judge the effectiveness of a recently performed calibration.

SECTION 10.7 – GAS FLOW CALIBRATION

This section describes how to adjust the gas flow calculations made by the CPU based on pressure and flow sensor readings.

NOTE

Throughout this Section are various diagrams showing pneumatic connections between the T200 and various other pieces of equipment such as calibrators and zero air sources.

These diagrams are only intended to be schematic representations of these connections and do not reflect actual physical locations of equipment and fitting location or orientation.

Contact your regional EPA or other appropriate governing agency for more detailed recommendations.

10.1. BEFORE CALIBRATION

The calibration procedures in this section assume that the range mode, analog range and units of measure have already been selected for the analyzer. If this has not been done, please do so before continuing (see Section 7.4.4 for instructions)

NOTE

If any problems occur while performing the following calibration procedures, refer to Section 14.1 for troubleshooting tips.

10.1.1. REQUIRED EQUIPMENT, SUPPLIES, AND EXPENDABLES

Calibration of the T200 NO_x Analyzer requires:

- Zero-air source.
- Span gas source.
- Gas lines - all gas line materials should be stainless steel or Teflon-type (PTFE or FEP).
  - High concentration NO gas transported over long distances may require stainless steel to avoid oxidation of NO due to O_2 diffusing into the tubing.
- A recording device such as a strip-chart recorder and/or data logger (optional).
- For electronic documentation, the internal data acquisition system (DAS) can be used.

10.1.2. CALIBRATION GASES

10.1.2.1. Zero Air

Zero air or zero calibration gas is defined as a gas that is similar in chemical composition to the measured medium but without the gas to be measured by the analyzer.

For the T200, this means zero air should be devoid of NO, NO_2, CO_2, NH_3 or H_2O vapor.

NOTE

Moderate amounts of NH_3 and H_2O can be removed from the sample gas stream by installing the optional sample gas dryer/scrubber (see Section 6.5).

- If your application is not a measurement in ambient air, the zero calibration gas should be matched to the composition of the gas being measured.
- Pure nitrogen (N_2) could be used as a zero gas for applications where NO_X is measured in nitrogen.
- If your analyzer is equipped with an external zero air scrubber option, it is capable of creating zero air from ambient air.

For analyzers without the external zero air scrubber, a zero air generator such as the Teledyne API's M701 can be used. Please visit the company website for more information.

If your analyzer is equipped with an external zero air scrubber option, it is capable of creating zero air from ambient air.

- If your application is not a measurement in ambient air, the zero calibration gas should be matched to the composition of the gas being measured.
- Pure nitrogen could be used as a zero gas for applications where NO_X is measured in nitrogen.

10.1.2.2. Span Gas

Calibration gas is a gas specifically mixed to match the chemical composition of the type of gas being measured at near full scale of the desired reporting range. To measure NO_X with the T200 NO_X analyzer, it is recommended that you use a span gas with an NO concentration equal to 80% of the measurement range for your application

EXAMPLE:

- If the application is to measure NOX in ambient air between 0 ppm and 500 ppb, an appropriate span gas would be 400 ppb.
- If the application is to measure NOX in ambient air between 0 ppm and 1000 ppb, an appropriate span gas would be 800 ppb.

We strongly recommend that span calibration is carried out with NO span gas. Alternatively it is possible to use NO_2 gas in a gas phase titration (GPT) calibration system (see Section 11.5).

Even though NO gas mixed into in nitrogen gas (N_2) could be used as a span gas, the matrix of the balance gas is different and may cause interference problems or yield incorrect calibrations.

- The same applies to gases that contain high concentrations of other compounds (for example, CO_2 or H_2O).

NOTE

The span gas should match all concentrations of all gases of the measured medium as closely as possible.

Cylinders of calibrated NO_x and NO gas traceable to NIST-standards specifications (also referred to as EPA protocol calibration gases or Standard Reference Materials) are commercially available. For a list of these gases see Table 3-8).

10.1.2.3. Span Gas for Multipoint Calibration

Some applications, such as EPA monitoring, require a multipoint calibration where span gases of different concentrations are needed. We recommend using an NO gas of higher concentration combined with a gas dilution calibrator such as a Teledyne API's Model 700E. For more information see Section 3.6.1.3 and Section 11.

10.1.2.4. NO_2 Permeation Tubes

Teledyne API offers an optional internal span gas generator that utilizes an NO_2 permeation tube as a span gas source. The accuracy of these devices is only about ±5%.

Whereas this may be sufficient for quick, daily calibration checks, we recommend using certified NO gases for accurate calibration.

NOTE

The use of permeation tubes is not approved by the US EPA as calibration sources for performing actual calibration of the analyzers used in EPA mandated monitoring.

CAUTION!

High amounts of NO_2 will progressively build up unless you remove the perm tube during periods of non-operation.

10.1.3. DATA RECORDING DEVICES

A strip chart recorder, data acquisition system or digital data acquisition system should be used to record data from the serial or analog outputs of the T200.

- If analog readings are used, the response of the recording system should be checked against a NIST traceable voltage source or meter.
- Data recording devices should be capable of bi-polar operation so that negative readings can be recorded.

For electronic data recording, the T200 provides an internal data acquisition system (DAS), which is described in detail in Section 8.1.

APICOM, a remote control program, is also provided as a convenient and powerful tool for data handling, download, storage, quick check and plotting (see Section 9.6).

10.1.4. NO_2 CONVERSION EFFICIENCY (CE)

In order for the NO_2 converter to function properly, oxygen must be present in the sample stream. In addition, to ensure accurate operation of the T200, it is important to check the NO_2 conversion efficiency (CE) periodically and to update this value as necessary.

-
- See Section 14.7.10 for instruction on checking or calculating the current NO_2 → NO converter efficiency using T200's onboard firmware.
- See Section 14.7.11 for instruction on checking or calculating the current NO_2 → NO converter efficiency using a simplified Gas Phase Titration Method.

10.2. MANUAL CALIBRATION CHECKS AND CALIBRATION OF THE T200 ANALYZER IN ITS BASE CONFIGURATION

ZERO/SPAN CALIBRATION CHECKS VS. ZERO/SPAN CALIBRATION

Pressing the ENTR button during the following procedure resets the stored values for OFFSET and SLOPE and alters the instrument's Calibration.

This should ONLY BE DONE during an actual calibration of the T200.

NEVER press the ENTR button if you are only checking calibration.

10.2.1. SETUP FOR BASIC CALIBRATION CHECKS AND CALIBRATION OF THE T200 ANALYZER.

Connect the sources of zero air and span gas as shown below in one of the following ways:.

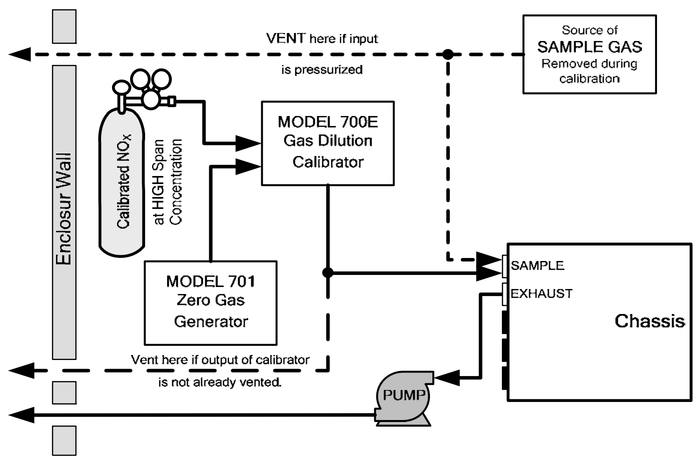


Figure 10-1: Set up for Manual Calibrations/Checks of T200's in Base Configuration w/ a Gas Dilution Calibrator

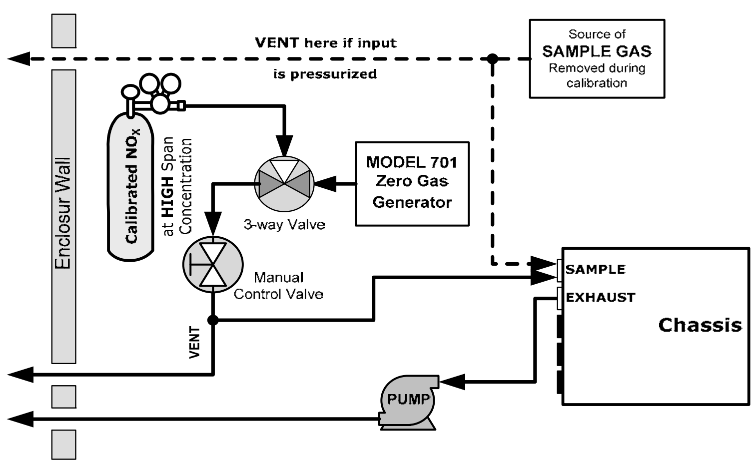
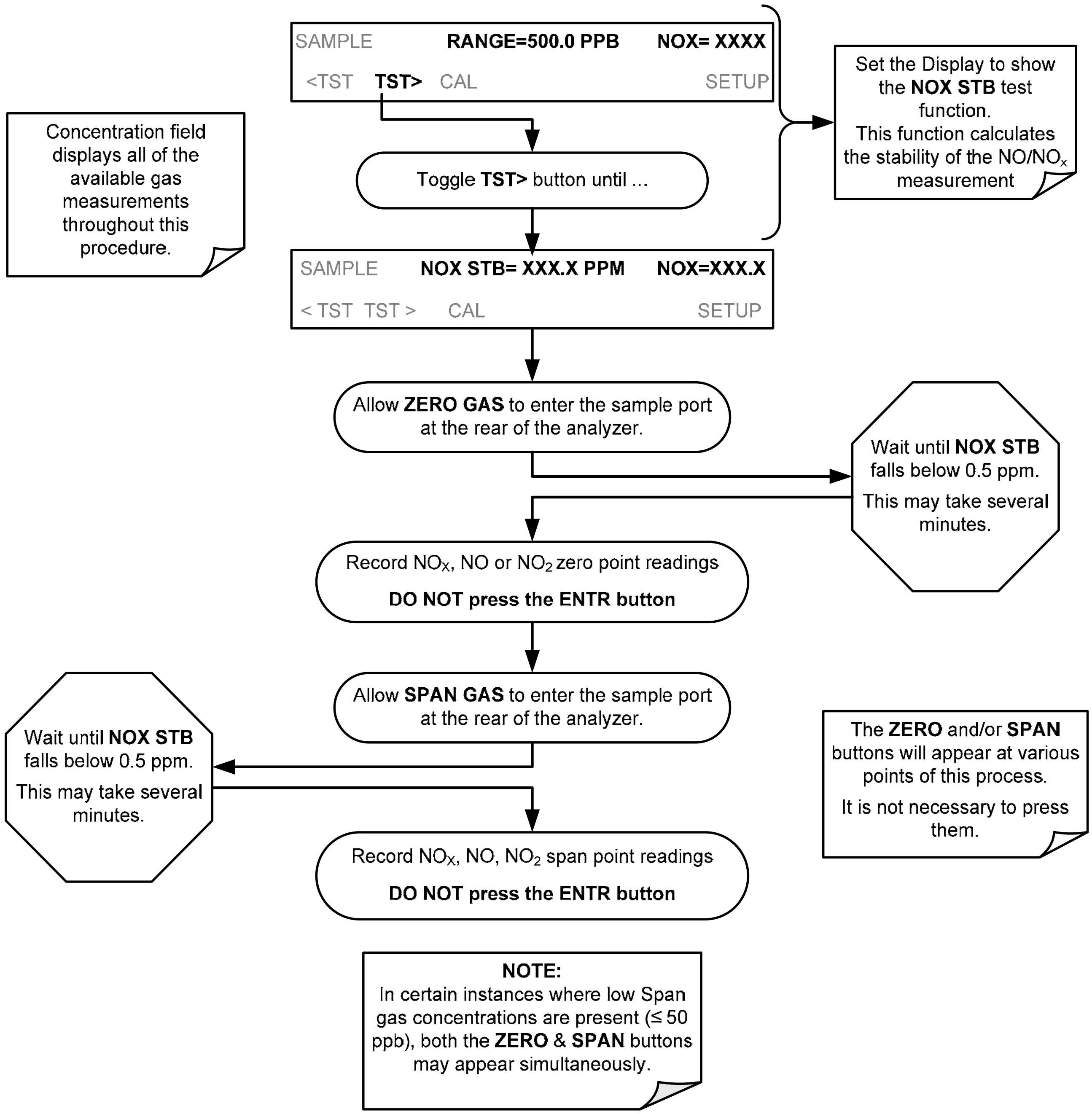


Figure 10-2: Set up for Manual Calibrations/Checks of T200's in Base Configuration w/ Bottled Gas

10.2.2. PERFORMING A BASIC MANUAL CALIBRATION CHECK



NOTE

If the ZERO or SPAN buttons are not displayed, the measurement made is out of the allowable range allowed for a reliable calibration.

See Section 13 for troubleshooting tips.

10.2.3. PERFORMING A BASIC MANUAL CALIBRATION

The following section describes the basic method for manually calibrating the T200 NO_X analyzer.

If the analyzer's reporting range is set for the **AUTO** range mode, a step will appear for selecting which range is to be calibrated (**LOW** or **HIGH**). Each of these two ranges **MUST** be calibrated separately.

10.2.3.1. Setting the expected Span Gas concentration

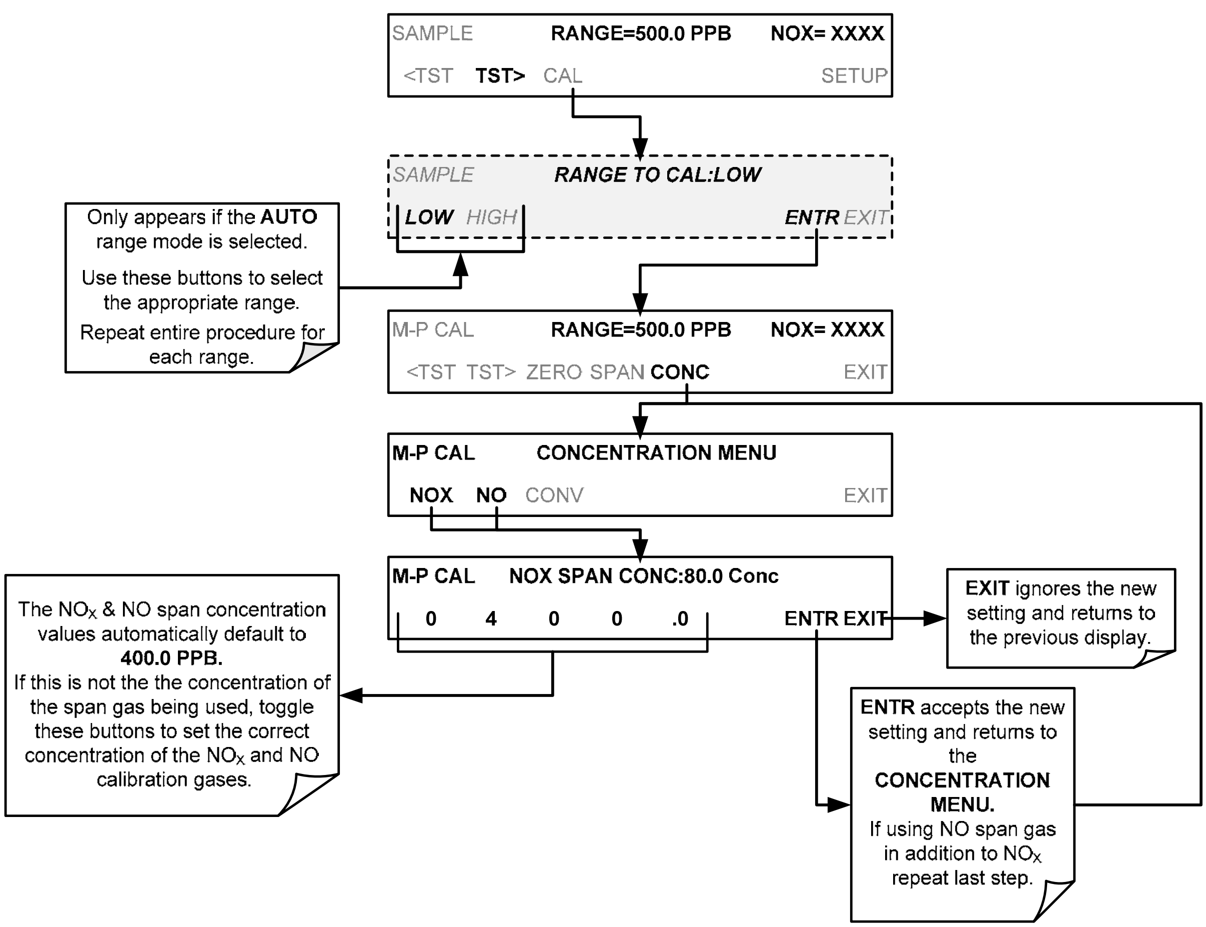
NOTE

The expected concentrations for both NO_x and NO are usually set to the same value unless the conversion efficiency is not equal to 1.000 or not entered properly in the conversion efficiency setting.

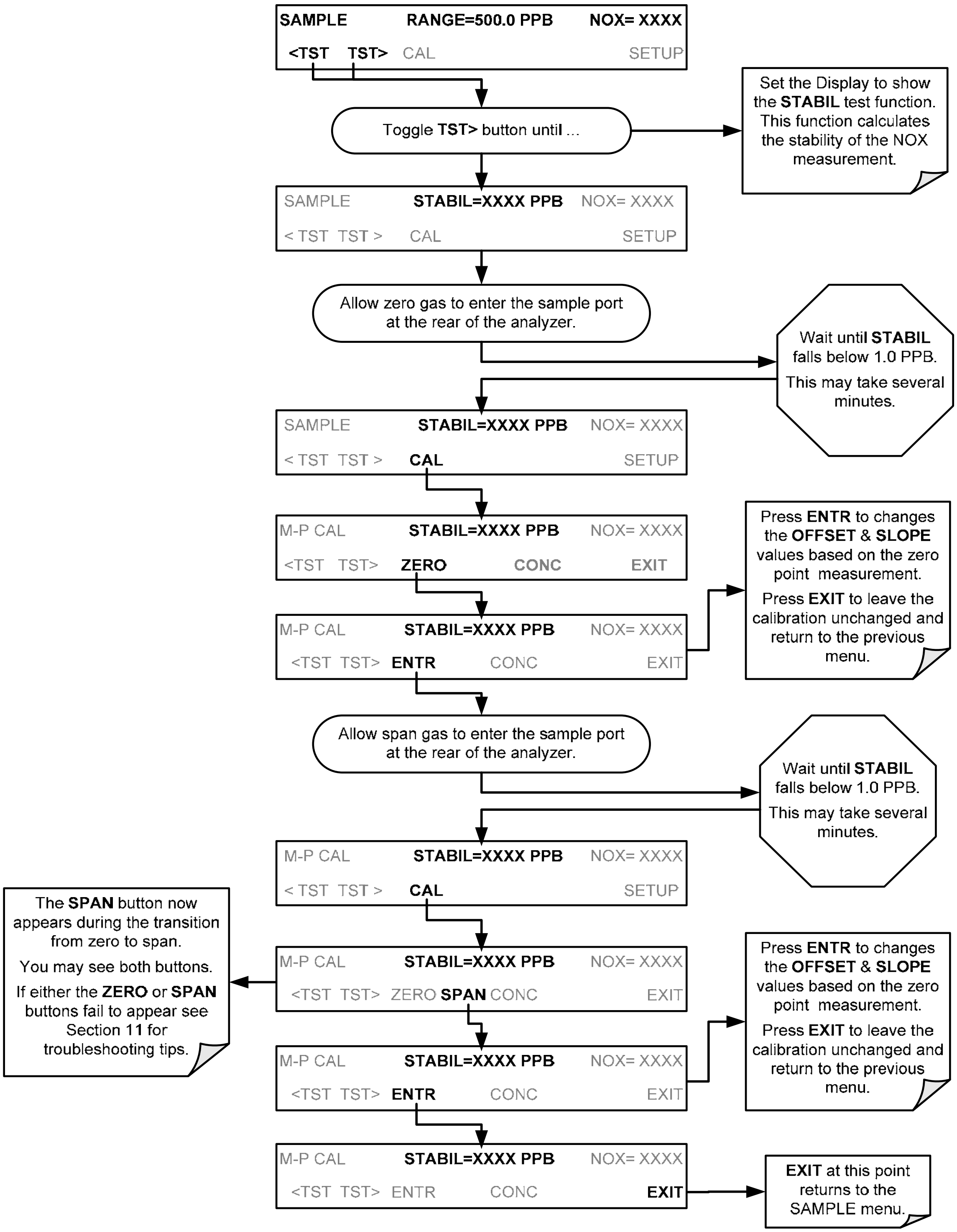
When setting expected concentration values, consider impurities in your span gas source (e.g. NO often contains 1-3% NO_2 and vice versa).

The NO and NO_x span gas concentrations should be 80% of range of concentration values likely to be encountered in your application. The default factory reporting range setting is 500 ppb and the default span gas concentration is 40.0 ppb.

To set the span gas concentration, press:



10.2.3.2. Zero/Span Point Calibration Procedure



NOTE

If the ZERO or SPAN buttons are not displayed, the measurement made during is out of the allowable range allowed for a reliable calibration. See Section 13 for troubleshooting tips.

10.3. MANUAL CALIBRATION WITH THE INTERNAL SPAN GAS GENERATOR

NOTE
The internal span gas generator's NO_2 permeation tube has a limited accuracy of about ±5%. This may be sufficient for informal calibration checks it is not approved by the US EPA as a calibration source.

10.3.1. PERFORMING A PRECISION MANUAL CALIBRATION WITH THE INTERNAL SPAN GAS GENERATOR

While the T200 can be calibrated using the internal span gas generators permeation tube as a span gas source, it is still necessary to perform a precision calibration of the instrument using more accurate zero and span gas standards that the internal generator can provide.

This precise calibration is required if your application is under the US EPA's oversight.

Also, in order to use the permeation tube output as a calibration source, it is necessary to know the concentration of the span gas that is produced. This measurement requires that a precise calibration of the T200 be performed just prior.

- To perform a precision calibration of the T200, connect external sources of zero air and calibrated span gas (see Section 10.1.2 for more information) as shown below:

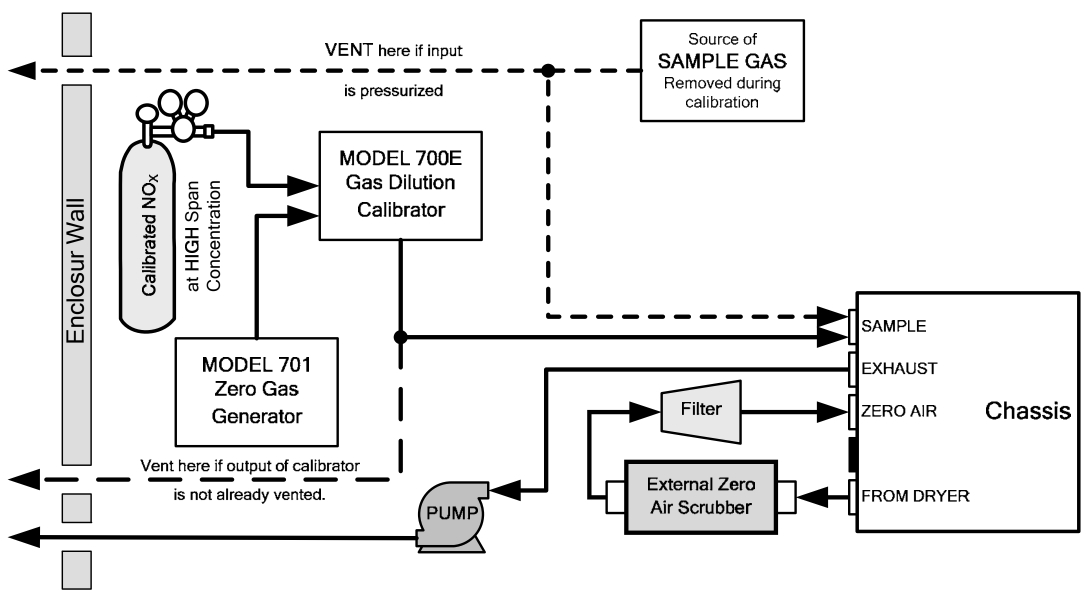


Figure 10-3: Pneumatic Connections for Precision Calibration of an T200 with the Internal Span Gas Generator

- Follow the procedures described in Section 10.2.3.

NOTE
Even though the CALZ and CALS buttons will be visible, DO NOT USE THEM. Pressing the CAL Z or CALS button will cause the instrument to use the internal zero air and span gas.
Instead Press the CAL button. This will cause the analyzer to use the external calibration gas sources.

10.3.2. SETUP FOR CALIBRATION WITH THE INTERNAL SPAN GENERATOR

Connect the sources of zero air and span gas as shown in Figure 10-4.

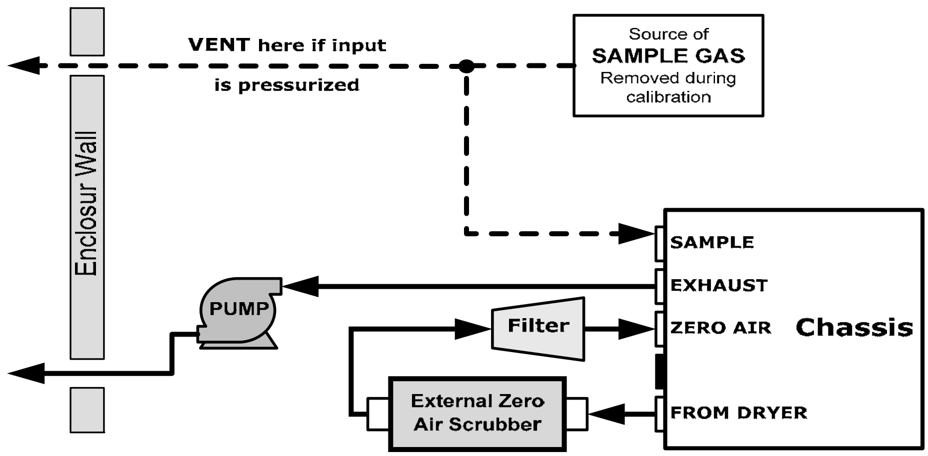


Figure 10-4: Pneumatic Connections for Manual Calibration/Checks with the Internal Span Gas Generator

10.3.3. CAL ON NO_2 FEATURE

When using the IZS option to calibrate the T200, the analyzer's **CAL_ON_NO2** feature must be turned on. This feature enables a continuous zero gas flow across the IZS permeation tube and through the NO_2 converter. It also programs the analyzer to use the NO output from the NO_2 converter to calibrate the span value of both NO and NO_X.

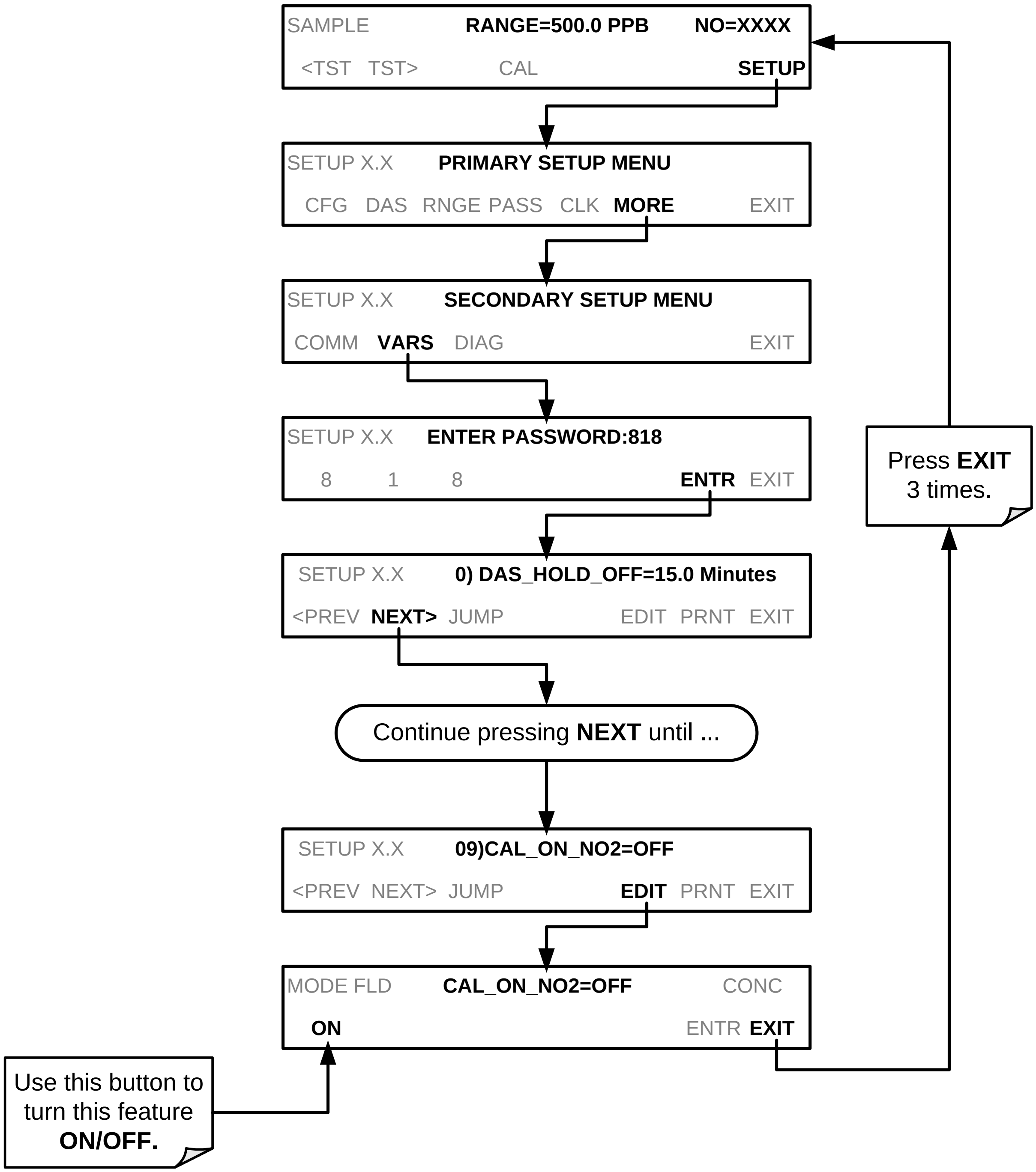
This feature should only be enabled when a span calibration or calibration check is performed. While **CAL_ON_NO2** is enabled, the NO_2 concentration will always be reported as zero. This is because the gas is continuously routed through the NO_2 converter and the analyzer's firmware simulates calibration with NO gas.

Table 10-1: IZS Option Valve States with CAL_ON_NO2 Turned ON

Valve	Condition	Valve Port Connections
Sample/Cal	Open to zero/span valve	1 → 2
Zero/Span	Open to SPAN GAS inlet	1 → 2
NO/NO_x Valve	Open to NO_2 converter	1 → 2
Auto Zero Valve	Cycles normally	N/A

Since the instrument sees the same concentration of NO during both NO and NO_X cycles, it reports an NO_2 concentration of zero.

TO turn the **CAL_ON_NO$_2$** feature **ON/OFF**, press,



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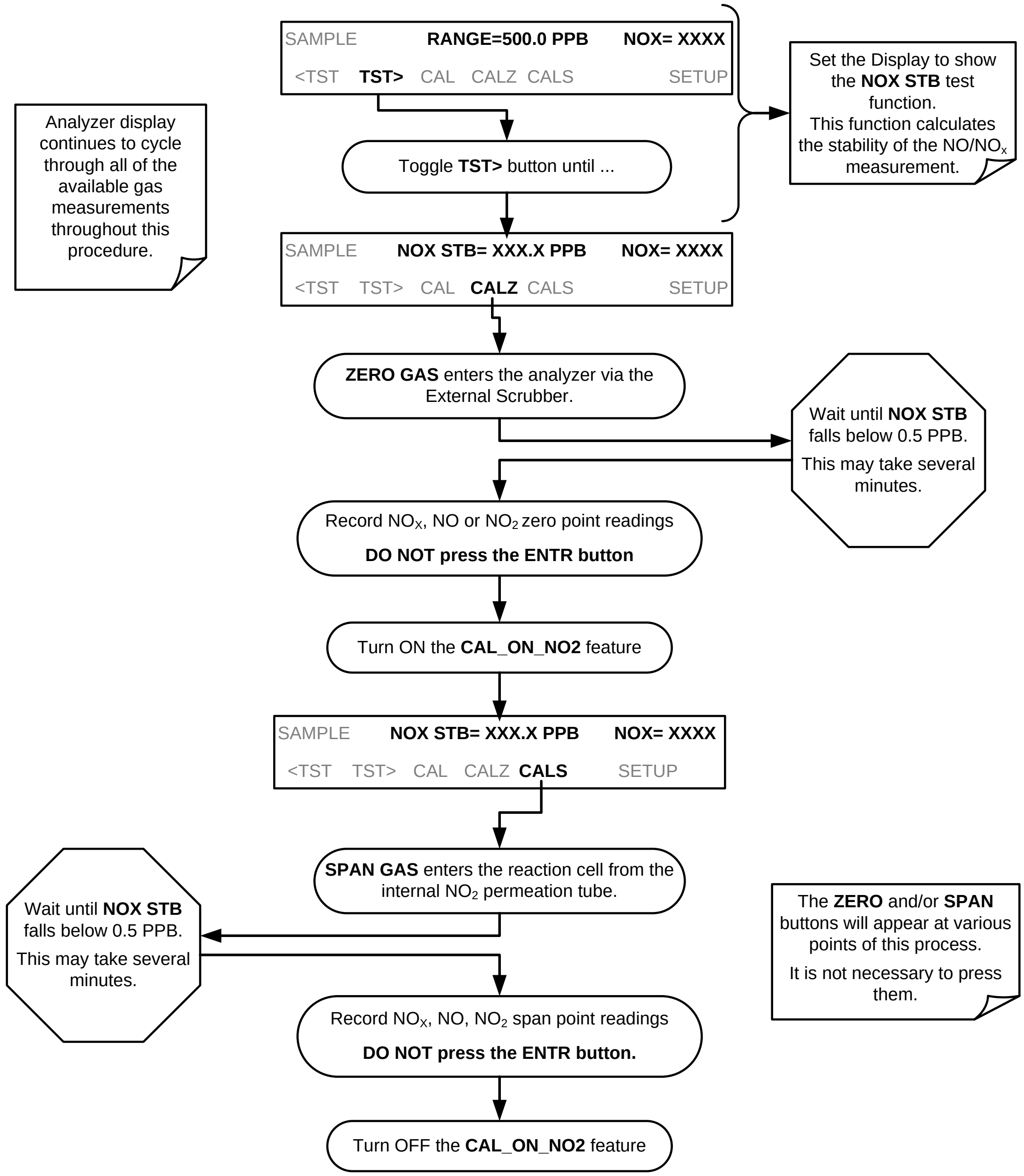
10.3.4. PERFORMING A MANUAL CALIBRATION CHECK WITH THE INTERNAL SPAN GAS GENERATOR



NOTE

If the ZERO or SPAN buttons are not displayed, the measurement made during is out of the allowable range allowed for a reliable calibration.

See Section 13 for troubleshooting tips.

10.3.5. PERFORMING A MANUAL CALIBRATION WITH THE INTERNAL SPAN GAS GENERATOR

If the analyzer's reporting range is set for the **AUTO** range mode, a step will appear for selecting which range is to be calibrated (**LOW** or **HIGH**). Each of these two ranges **MUST** be calibrated separately.

10.3.5.1. Setting the Expected Span Gas concentration

NOTE

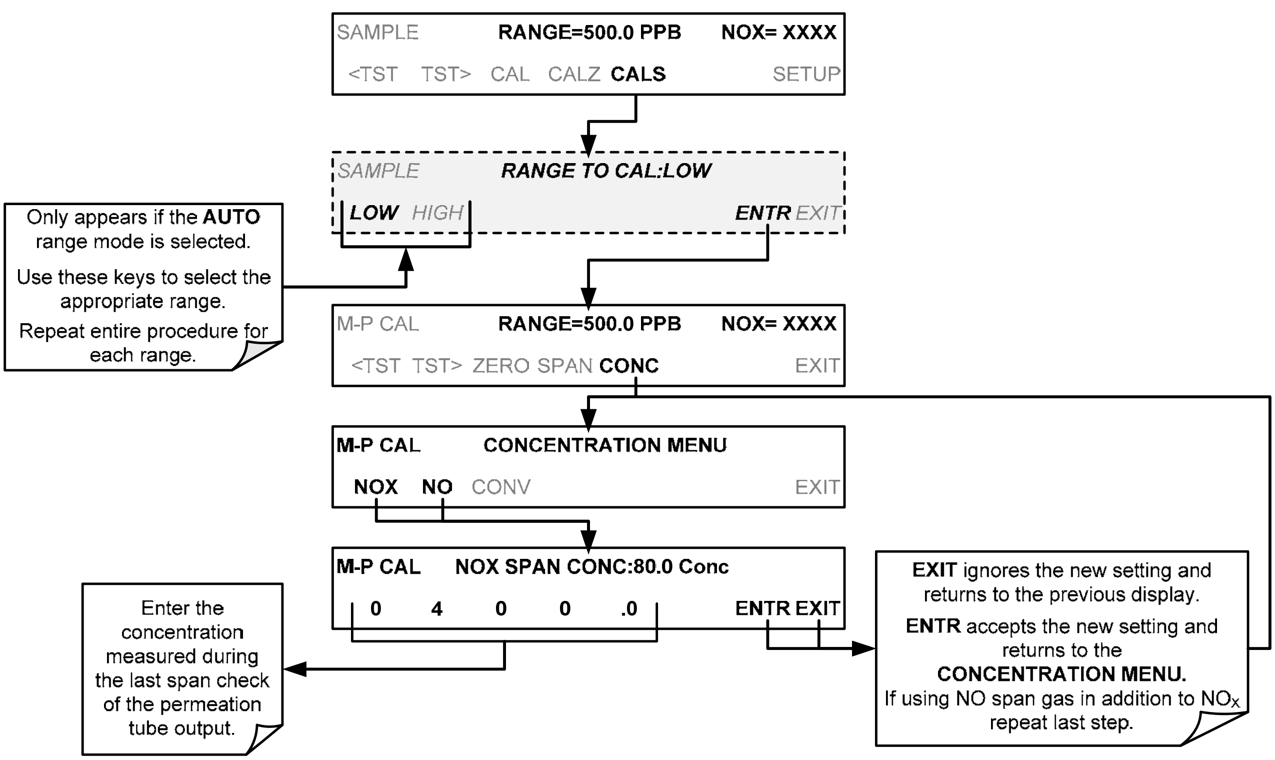
The expected concentrations for both NO_x and NO are usually set to the same value unless the conversion efficiency is not equal to 1.000 or not entered properly in the conversion efficiency setting.

When setting expected concentration values, consider impurities in your span gas source (e.g. NO often contains 1-3% NO_2 and vice versa).

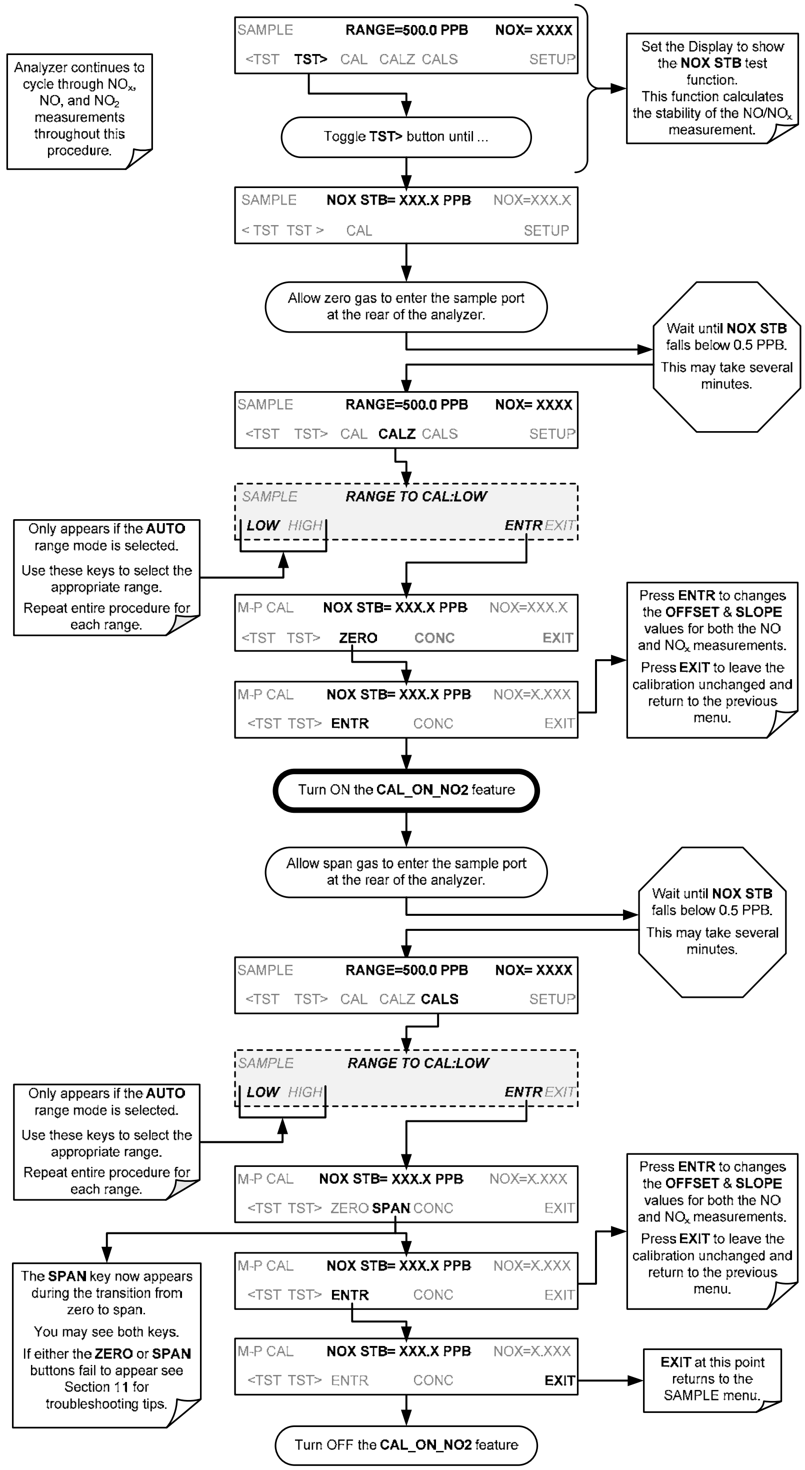
When calibrating the instrument using the internal permeation tube as a span gas source, it is necessary to know, as close as possible, what the concentration of the gas being output by the tube. To determine this value:

1. Perform a precision calibration of the instrument as describes in Section 10.3.1.
2. Perform a calibration check as described in Section 10.3.4.
   - Record the value displayed for NO/NO_2 during the span check portion of the procedure.
   - This will be the concentration value used in subsequent calibrations using the internal span gas source.
   - It is a good idea to measure the permeation tube output once every 4 to 6 months.
3. Ensure that the reporting range span point is set for a value at least 10% higher than the measured value of the permeation tube output

To set the span gas concentration, press:



10.3.5.2. Zero/Span Point Calibration Procedure with Internal Span Gas Generator



NOTE

If the ZERO or SPAN buttons are not displayed, the measurement made during is out of the allowable range allowed for a reliable calibration. See Section 13 for troubleshooting tips.

10.4. MANUAL CALIBRATION AND CAL CHECKS WITH THE VALVE OPTIONS INSTALLED

There are a variety of valve options available on the T200 for handling calibration gases (see Section 6 for descriptions of each).

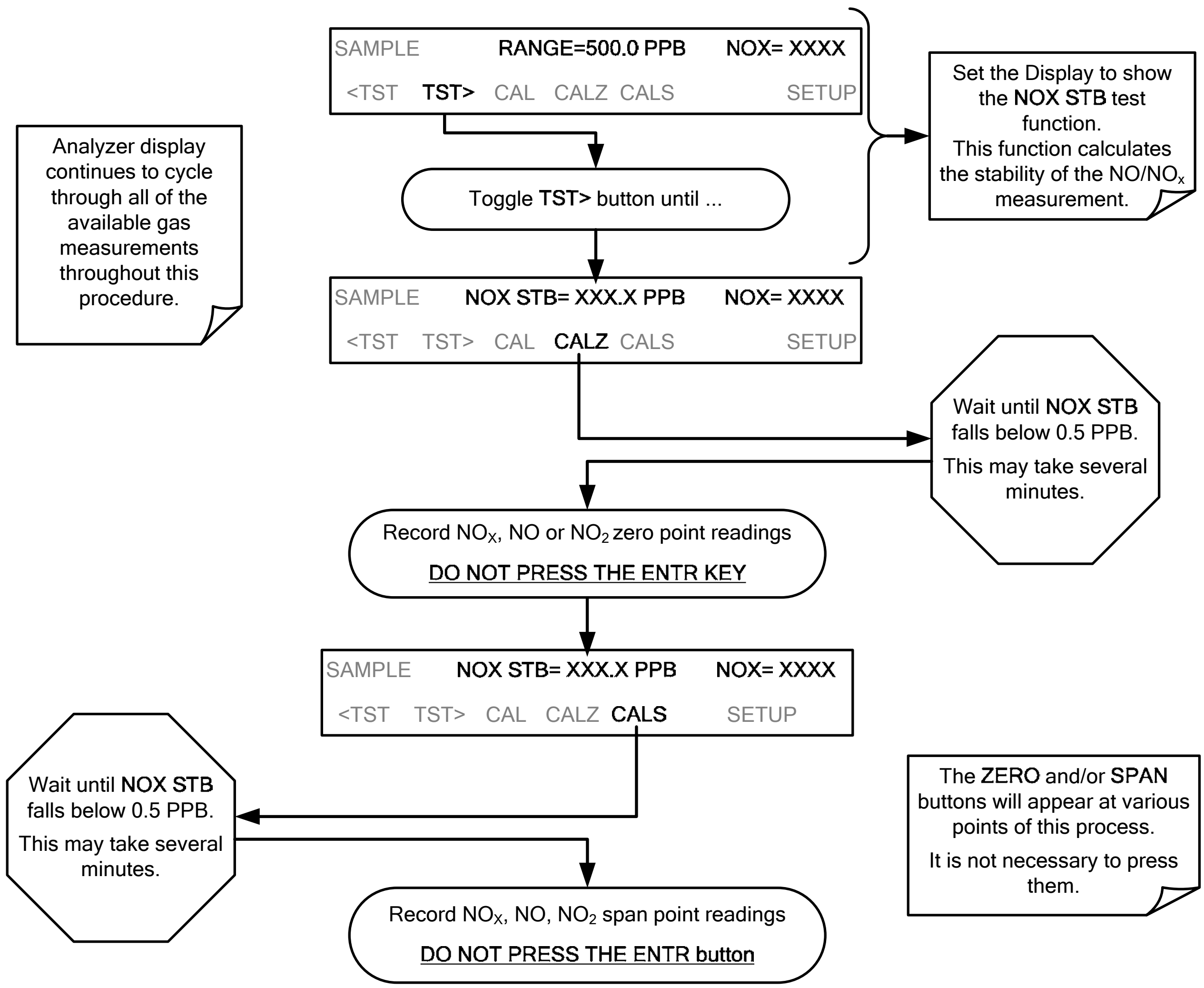
Generally performing calibration checks and zero/span point calibrations on analyzers with these options installed is similar to the methods discussed in the previous sections of this Section. The primary differences are:

- On instruments with Z/S valve options, zero air and span gas is supplied to the analyzer through other gas inlets besides the sample gas inlet.
- The zero and span calibration operations are initiated directly and independently with dedicated buttons (**CALZ** & **CALS**).

10.4.1. SETUP FOR CALIBRATION USING VALVE OPTIONS

Each of the various calibration valve options requires a different pneumatic setup that is dependent on the exact nature and number of valves present. Refer to the following diagrams for information on each or these valve sets.

10.4.2. MANUAL CALIBRATION CHECKS WITH VALVE OPTIONS INSTALLED



10.4.3. MANUAL CALIBRATION USING VALVE OPTIONS

The following section describes the basic method for manually calibrating the T200 NO_X analyzer.

If the analyzer's reporting range is set for the **AUTO** range mode, a step will appear for selecting which range is to be calibrated (**LOW** or **HIGH**). Each of these two ranges **MUST** be calibrated separately.

10.4.3.1. Setting the Expected Span Gas Concentration

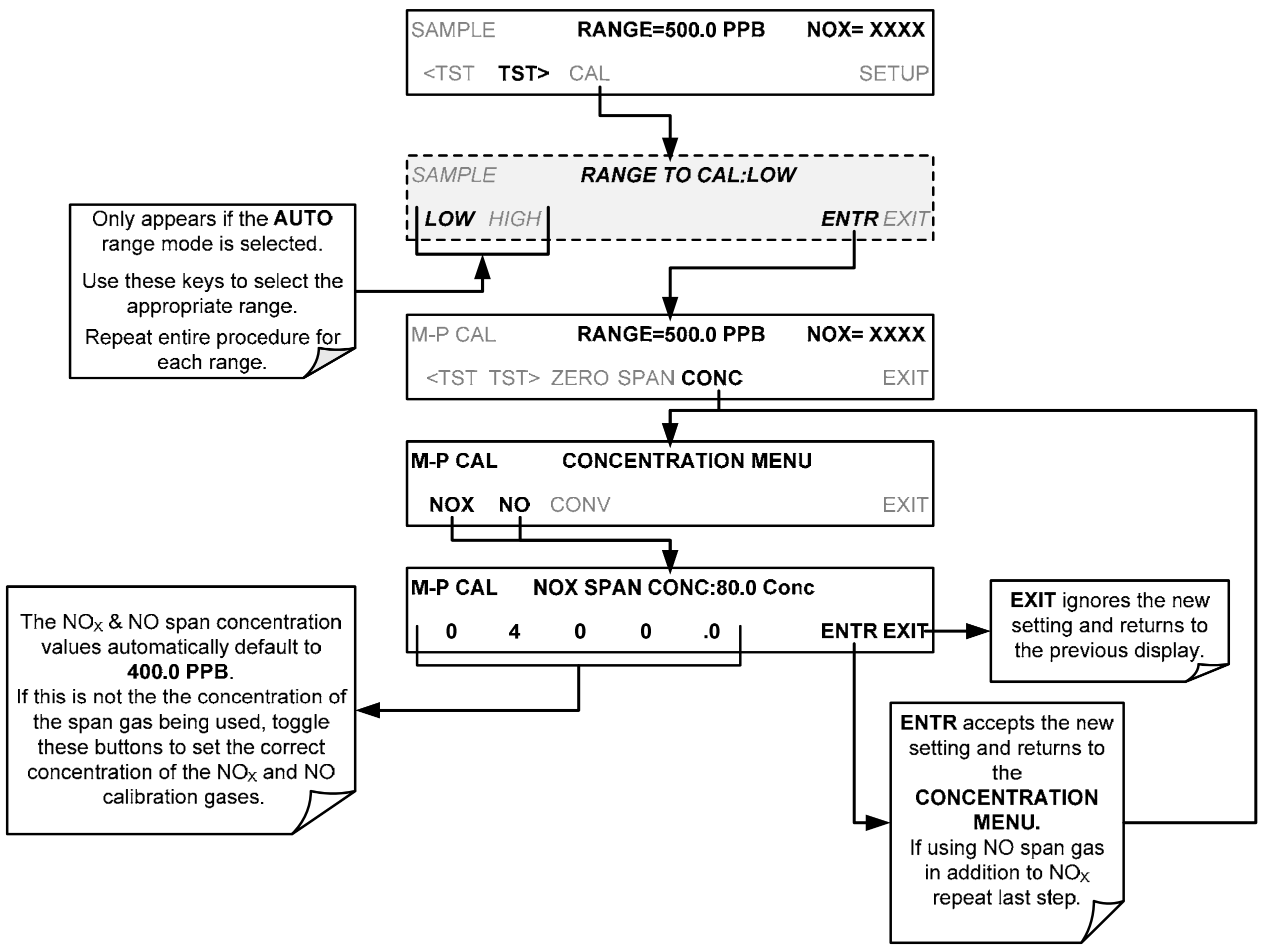
NOTE

The expected concentrations for both NO_x and NO are usually set to the same value unless the conversion efficiency is not equal to 1.000 or not entered properly in the conversion efficiency setting.

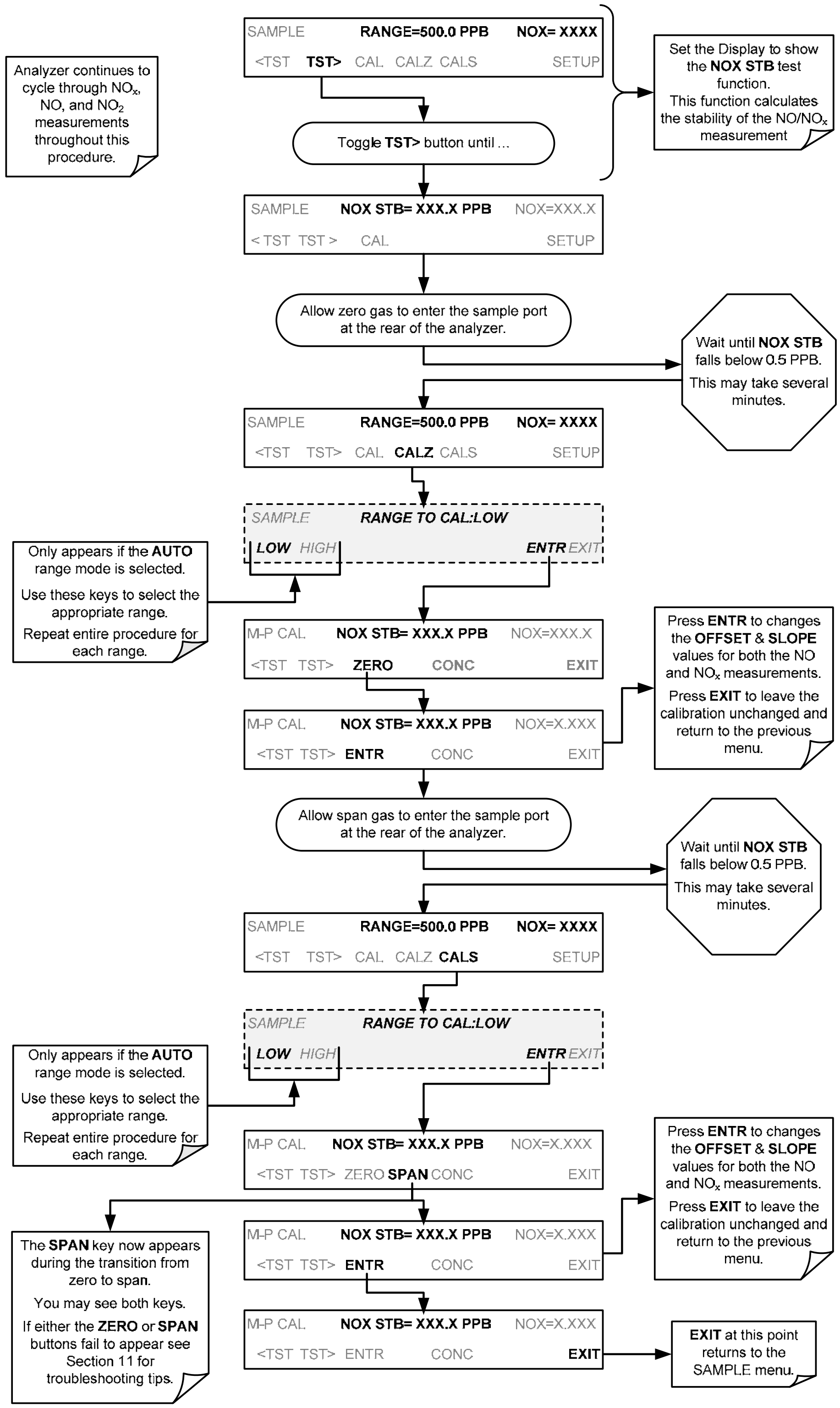
When setting expected concentration values, consider impurities in your span gas source (e.g. NO often contains 1-3% NO_2 and vice versa).

The NO and NO_x span gas concentrations should be 80% of range of concentration values likely to be encountered in your application. The default factory reporting range setting is 500 ppb and the default span gas concentration is 400.0 ppb.

To set the span gas concentration, press:



10.4.3.2. Zero/Span Point Calibration Procedure



NOTE

If the ZERO or SPAN buttons are not displayed, the measurement made during is out of the allowable range allowed for a reliable calibration. See Section 13 for troubleshooting tips.

10.4.3.3. Use of Zero/Span Valve with Remote Contact Closure

Contact closures for controlling calibration and calibration checks are located on the rear panel **CONTROL IN** connector. Instructions for setup and use of these contacts are found in Section 3.5.5.

When the contacts are closed for at least 5 seconds, the instrument switches into zero, low span or high span mode and the internal zero/span valves will be automatically switched to the appropriate configuration.

- The remote calibration contact closures may be activated in any order.
- It is recommended that contact closures remain closed for at least 10 minutes to establish a reliable reading.
- The instrument will stay in the selected mode for as long as the contacts remain closed.

If contact closures are being used in conjunction with the analyzer's AutoCal (see Section 10.5) feature and the AutoCal attribute "**CALIBRATE"** is enabled, the T200 will not re-calibrate the analyzer UNTIL when the contact is opened. At this point, the new calibration values will be recorded before the instrument returns to **SAMPLE** mode.

If the AutoCal attribute "**CALIBRATE"** is disabled, the instrument will return to **SAMPLE** mode, leaving the instrument's internal calibration variables unchanged.

10.5. AUTOMATIC ZERO/SPAN CAL/CHECK (AUTOCAL)

The AutoCal system allows unattended periodic operation of the Z**ERO/SPAN** valve options by using the T200's internal time of day clock. AutoCal operates by executing **SEQUENCES** programmed by the user to initiate the various calibration modes of the analyzer and open and close valves appropriately. It is possible to program and run up to three separate sequences (**SEQ1**, **SEQ2** and **SEQ3**). Each sequence can operate in one of three modes, or be disabled.

Table 10-2: AUTOCAL Modes

MODE NAME	ACTION
DISABLED	Disables the Sequence.
ZERO	Causes the Sequence to perform a Zero calibration/check.
ZERO-SPAN	Causes the Sequence to perform a Zero point calibration/check followed by a Span point calibration/check.
SPAN	Causes the Sequence to perform a Span concentration calibration/check only.

For each mode, there are seven parameters that control operational details of the **SEQUENCE**. They are:

Table 10-3: AutoCal Attribute Setup Parameters

ATTRIBUTE	ACTION
TIMER ENABLED	Turns on the Sequence timer.
STARTING DATE	Sequence will operate after Starting Date.
STARTING TIME	Time of day sequence will run.
DELTA DAYS	Number of days to skip between each Sequence execution. • If set to 7, for example, the AutoCal feature will be enabled once every week on the same day.
DELTA TIME	Number of hours later each "Delta Days" Sequence is to be run. • If set to 0, the sequence will start at the same time each day. **Delta Time** is added to **Delta Days** for the total time between cycles. • This parameter prevents the analyzer from being calibrated at the same daytime of each calibration day and prevents a lack of data for one particular daytime on the days of calibration
DURATION	Number of minutes the sequence operates. • This parameter needs to be set such that there is enough time for the concentration signal to stabilize. • The STB parameter shows if the analyzer response is stable at the end of the calibration. • This parameter is logged with calibration values in the DAS.
CALIBRATE	Enable to do a calibration – Disable to do a cal check only. • This setting must be OFF for analyzers used in US EPA applications and with internal span gas generators installed and functioning.
RANGE TO CAL	LOW calibrates the low range, HIGH calibrates the high range. Applies only to auto and remote range modes; this property is not available in single and independent range modes.

NOTE

The CALIBRATE attribute (formerly called "dynamic calibration") must always be set to OFF for analyzers used in US EPA controlled applications that have internal span gas generators option installed.

Calibration of instruments used in US EPA related applications should only be performed using external sources of zero air and span gas with an accuracy traceable to EPA or NIST standards and supplied through the analyzer's sample port.

The following example sets sequence #2 to do a zero-span calibration every other day starting at 1:00 AM on September 4, 2008, lasting 15 minutes, without calibration. This will start ½ hour later each iteration.

Table 10-4: Example AutoCal Sequence

MODE AND ATTRIBUTE	VALUE	COMMENT
SEQUENCE	2	Define Sequence #2
MODE	ZERO-SPAN	Select Zero and Span Mode
TIMER ENABLE	ON	Enable the timer
STARTING DATE	Sept. 4, 2008	Start after Sept 4, 2008
STARTING TIME	1:00 AM	First Span starts at 1:00AM
DELTA DAYS	2	Do Sequence #2 every other day
DELTA TIME	00:30	Do Sequence #2 ½ hr later each day
DURATION	15.0	Operate Span valve for 15 min
CALIBRATE	OFF	Calibrate at end of Sequence

NOTES

The programmed STARTING_TIME must be a minimum of 5 minutes later than the real time clock for setting real time clock (See Section 7.4.3).

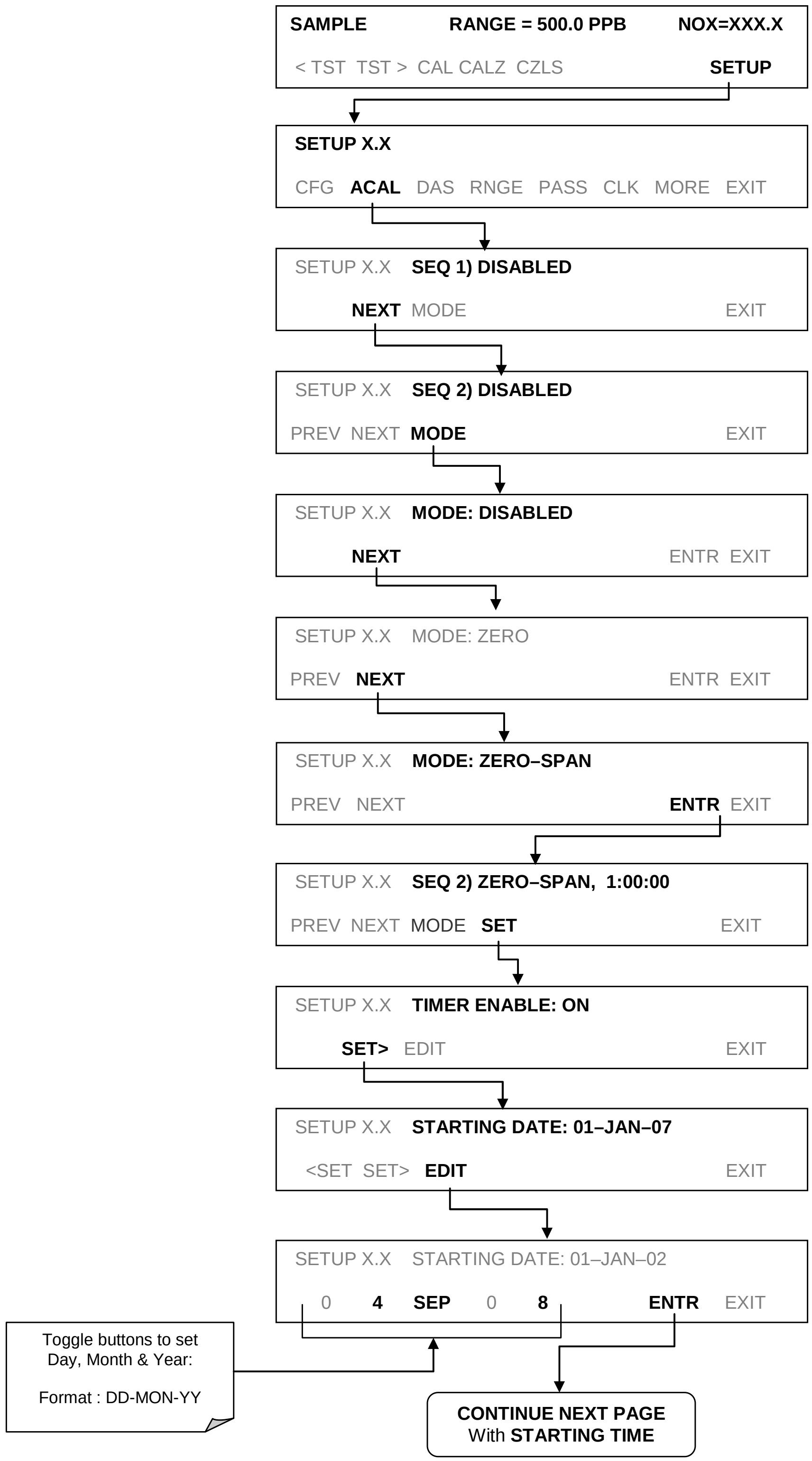
Avoid setting two or more sequences at the same time of the day. Any new sequence that is initiated whether from a timer, the COMM ports or the contact closure inputs will override any sequence that is in progress.

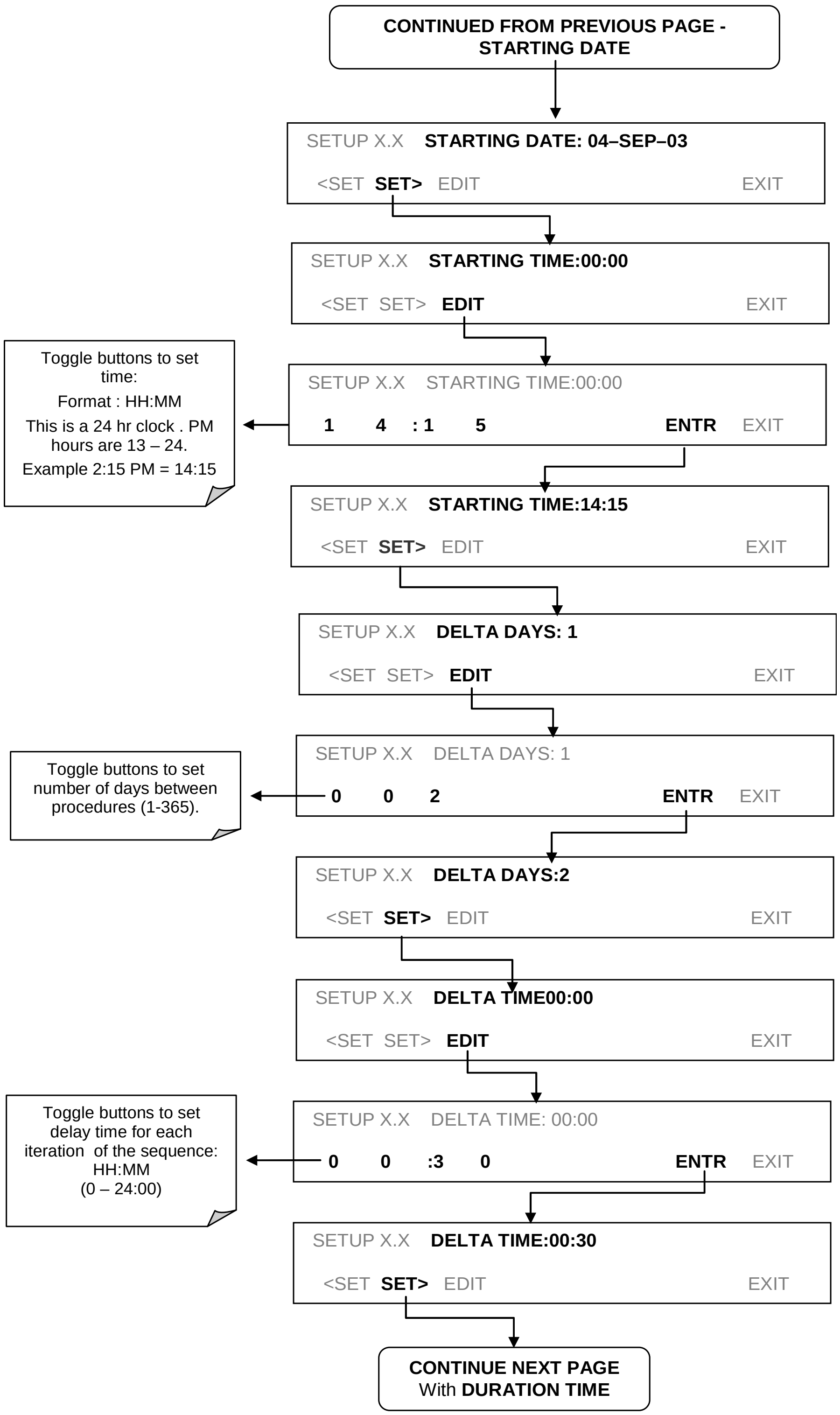
The CALIBRATE attribute must always be set to OFF on analyzers with IZS Options installed and functioning.

Calibrations should ONLY be performed using external sources of Zero Air and Span Gas whose accuracy is traceable to EPA standards.

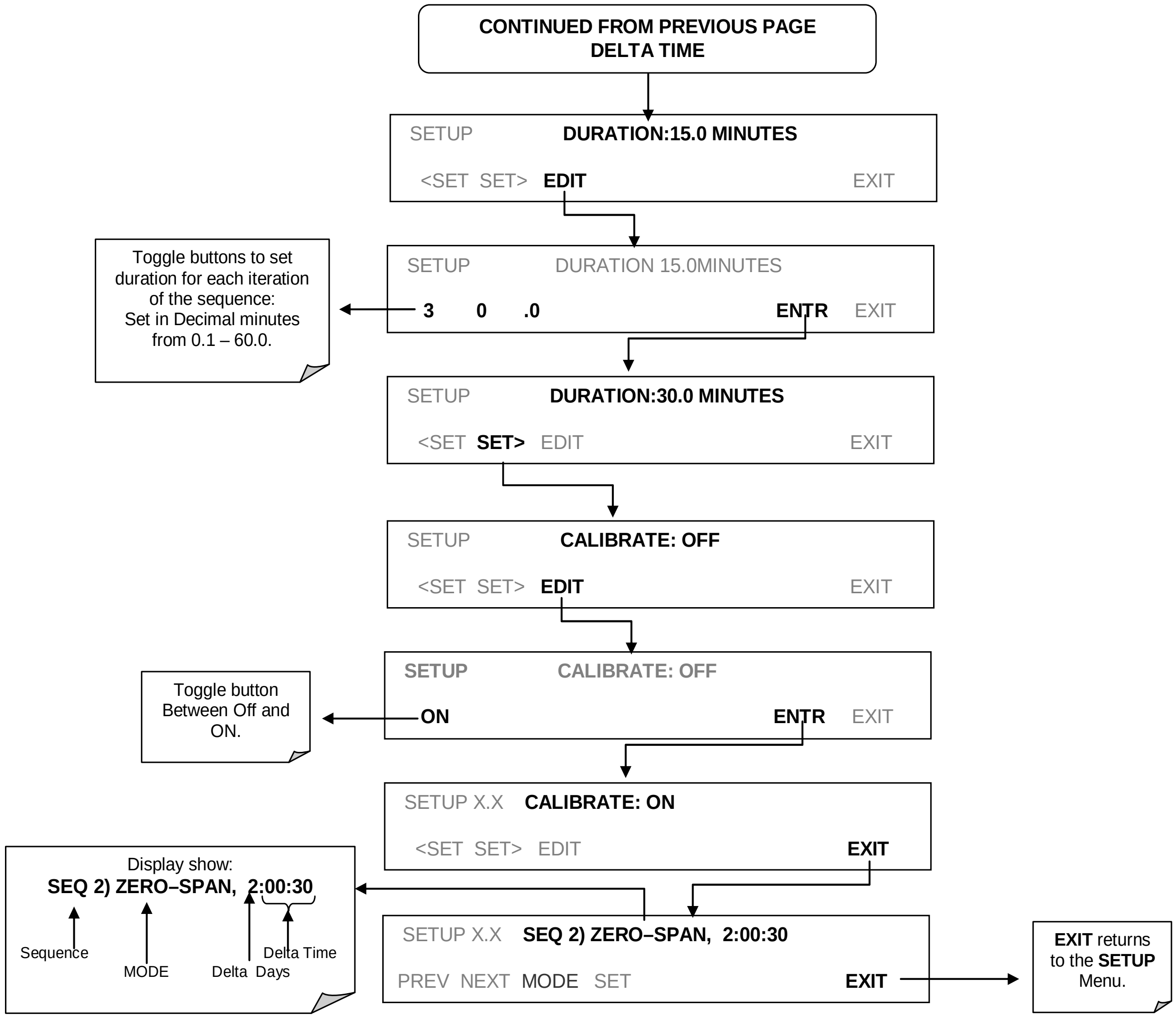
10.5.1. SETUP → ACAL: PROGRAMMING AND AUTO CAL SEQUENCE

To program the example sequence shown in Table 10-4, press:





CONTINUED FROM PREVIOUS PAGE - STARTING DATE
SETUP X.X STARTING DATE: 04–SEP–03
<SET SET> EDIT EXIT
SETUP X.X STARTING TIME:00:00
<SET SET> EDIT EXIT
Toggle buttons to set time:
Format : HH:MM
This is a 24 hr clock . PM hours are 13 – 24.
Example 2:15 PM = 14:15
SETUP X.X STARTING TIME:00:00
1 4 :1 5 ENTR EXIT
SETUP X.X STARTING TIME:14:15
<SET SET> EDIT EXIT
SETUP X.X DELTA DAYS: 1
<SET SET> EDIT EXIT
Toggle buttons to set number of days between procedures (1-365).
SETUP X.X DELTA DAYS: 1
0 0 2 ENTR EXIT
SETUP X.X DELTA DAYS:2
<SET SET> EDIT EXIT
SETUP X.X DELTA TIME00:00
<SET SET> EDIT EXIT
Toggle buttons to set delay time for each iteration of the sequence: HH:MM
(0 – 24:00)
SETUP X.X DELTA TIME: 00:00
0 0 :3 0 ENTR EXIT
SETUP X.X DELTA TIME:00:30
<SET SET> EDIT EXIT
CONTINUE NEXT PAGE
With DURATION TIME



NOTE

If at any time an illegal entry is selected (Example: Delta Days > 367) the ENTR button will disappear from the display.

10.6. CALIBRATION QUALITY ANALYSIS

After completing one of the calibration procedures described above, it is important to evaluate the analyzer's calibration **SLOPE** and **OFFSET** parameters. These values describe the linear response curve of the analyzer, separately for NO and NO_X. The values for these terms, both individually and relative to each other, indicate the quality of the calibration.

To perform this quality evaluation, you will need to record the values of the following test functions (see Section 7.2.1), all of which are automatically stored in the DAS channel **CALDAT** for data analysis, documentation and archival.

NO OFFS

NO SLOPE

NOX OFFS

NOX SLOPE

Ensure that these parameters are within the limits listed in Table 10-5 and frequently compare them to those values on the *Final Test and Validation Data Sheet (P/N 04490)* that came attached to your manual, which should not be significantly different.

- If they are, refer to the troubleshooting Section 13.

Table 10-5: Calibration Data Quality Evaluation

Function	Minimum Value	Optimum Value	Maximum Value
NOX SLOPE	-0.700	1.000	1.300
NO SLOPE	-0.700	1.000	1.300
NOX OFFS	-20.0 mV	0.0 mV	150.0 mV
NO OFFS	-20.0 mV	0.0 mV	150.0 mV

The default DAS configuration records all calibration values in channel CALDAT as well as all calibration check (zero and span) values in its internal memory.

- Up to 200 data points are stored for up 4 years of data (on weekly calibration checks) and a lifetime history of monthly calibrations.
- Review these data to see if the zero and span responses change over time.
- These channels also store the STB figure (standard deviation of NO_X concentration) to evaluate if the analyzer response has properly leveled off during the calibration procedure.
- Finally, the CALDAT channel also stores the converter efficiency for review and documentation.

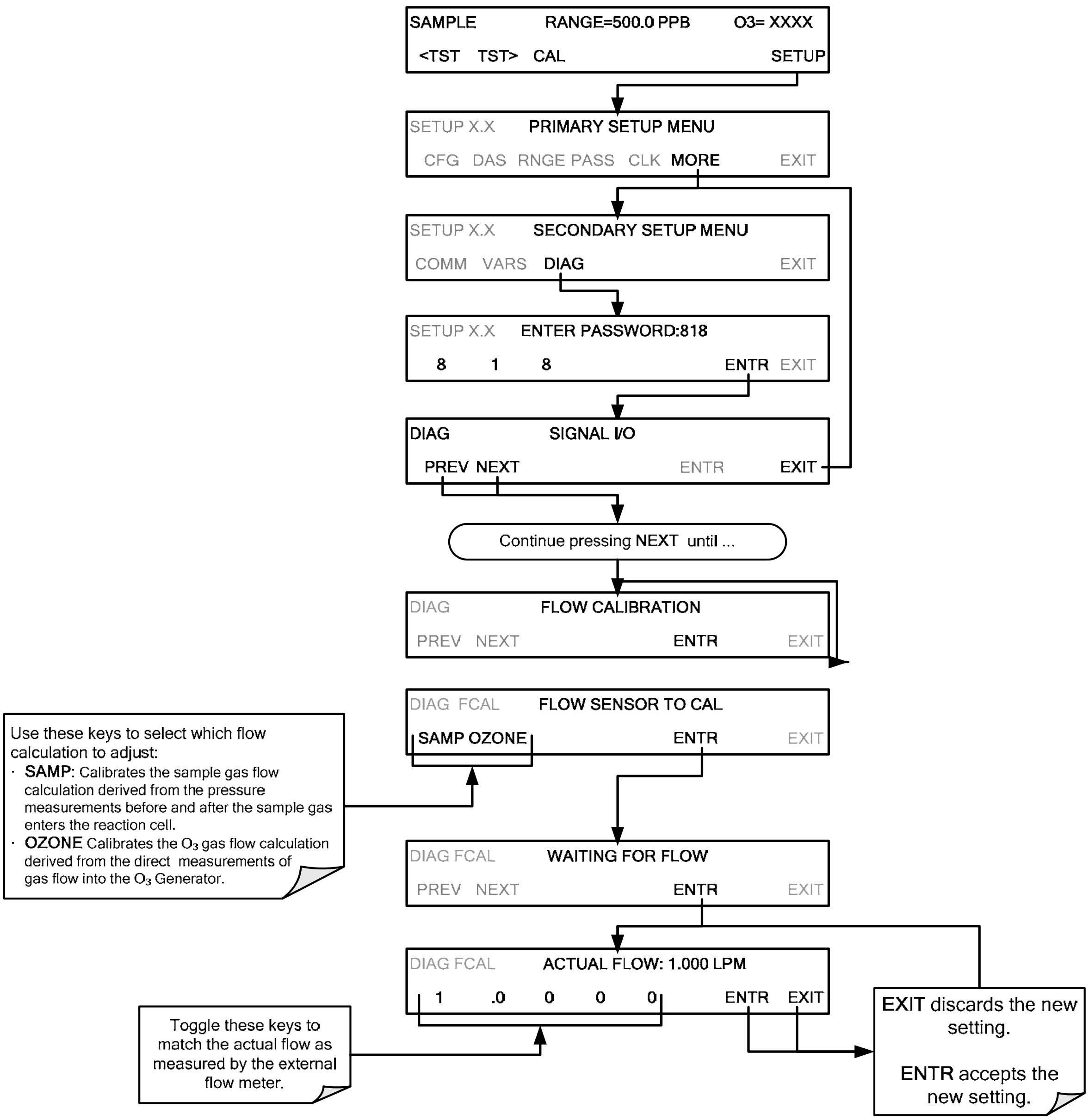
10.7. GAS FLOW CALIBRATION

Rate of sample gas and O_3 flow through the T200 is a key part of the NO_x, NO and NO_2 concentration calculations. The **FLOW CALIBRATION** submenu located under the DIAG menu allows the calibration/ adjustment of these calculations.

NOTE

A separate flow meter is required for the procedure.

To calibrate the flow of gas calculations made by the CPU, press.



: .

11. EPA PROTOCOL CALIBRATION

To ensure high quality, accurate measurements at all times, the T200 analyzer must be calibrated prior to use. A quality assurance program centered on this aspect and including attention to the built-in warning features of the analyzer, periodic inspection, regular zero/span checks, regular evaluation of test parameters for predictive diagnostics and data analysis and routine maintenance of the instrument are paramount to achieving this goal.

The US EPA strongly recommends that you obtain a copy of the publication Quality Assurance Handbook for Air Pollution Measurement Systems (abbreviated, Q.A. Handbook Volume II); USEPA Order Number: EPA454R98004; or NIST Order Number: PB99-129876.

This manual can be purchased from:

- EPA Technology Transfer Network (http://www.epa.gov/ttn/amtic)
- National Technical Information Service (NTIS, http://www.ntis.gov/)

Special attention should be paid to Section 2.3 of the handbook[8] which covers the measurement of NO_2. Specific regulations regarding the use and operation of ambient NO_x analyzers can be found in Reference 1 at the end of this Section.

If the T200 is used for EPA compliance monitoring, it must be calibrated in accordance with the instructions in this section.

A bibliography and references relating to NO_2 monitoring are listed in Section 11.10.

11.1. T200 CALIBRATION – GENERAL GUIDELINES

In general, calibration is the process of adjusting the gain and offset of the T200 against a standard with certified, traceable concentration. The reliability of data derived from the analyzer depends primarily upon its state of calibration.

In this section, the term dynamic calibration is used to express a multipoint check against known standards and involves introducing gas samples of known concentration into the instrument in order to adjust the instrument to a predetermined sensitivity and to produce a calibration relationship. This relationship is derived from the instrumental response to successive samples of different known concentrations. As a minimum, three reference points and a zero point are recommended to define this relationship. The instrument(s) supplying the zero air and Span calibration gases used must themselves be calibrated and that calibration must be traceable to an EPA/ NIST primary standard (see Section 2.0.7 of the Q.A. Handbook and Table 3-8 of this instruction manual)

All monitoring systems are subject to some drift and variation in internal parameters and cannot be expected to maintain accurate calibration over long periods of time. Therefore, it is necessary to dynamically check the calibration relationship on a predetermined schedule. Zero and span checks must be used to document that the data remain within control limits. These checks are also used in data reduction and validation. The internal data acquisition system of the T200 allows to store all calibration checks (as well as full calibrations) over long periods of time for documentation.

- Table 11-1 summarizes the initial quality assurance activities for calibrating equipment.
- Table 11-2 contains a matrix for the actual, dynamic calibration procedure.

Calibrations should be carried out at the field monitoring site. The analyzer should be in operation for at least several hours (preferably overnight) before calibration so that it is fully warmed up and its operation has stabilized. During the calibration, the T200:

- Should be in the **CAL** mode,
- The test atmosphere should be supplied through all components used during normal ambient sampling and through as much of the ambient air inlet system as is practicable.
- If the instrument will be used on more than one range, it should be calibrated separately on each applicable range.
- Details of documentation, forms and procedures should be maintained with each analyzer and also in a central backup file as described in Section 12 of the Quality Assurance Handbook.
- Personnel, equipment and reference materials used in conducting audits must be independent from those normally used in calibrations and operations.

11.2. CALIBRATION EQUIPMENT, SUPPLIES, AND EXPENDABLES

The measurement of NO_x, NO and NO_2 in ambient air requires a certain amount of basic sampling equipment and supplemental supplies. These include, but are not limited to, the following:

Table 11-1: Activity Matrix for EPA Calibration Equipment and Supplies

Equipment/ Supplies	Acceptance Limits	Frequency And Method of Measurement	Action If Requirements Are Not Met
Recorder	Compatible with output signal of analyzer; min chart width of 150 mm (6 in) is recommended	Check upon receipt	Return equipment to supplier
Sample line and manifold	Constructed of PTFE, glass or stainless steel	Check upon receipt	Return equipment to supplier
Calibration equipment	Meets guidelines and Section 2.3.2 of Q. A. Handbook	See Section 2.3.9 of Q. A. Handbook	Return equipment/ supplies to supplier or take corrective action
Working standard NO cylinder gas	Traceable to NIST-SRM SRM. Meets limits in traceability protocol for accuracy and stability. Section 2.0.7 of Q. A. Handbook	Analyzed against NIST-SRM; see protocol in Section 2.0.7, Q.A. Handbook	Obtain new working standard and check for traceability
Recording forms	Develop standard forms	N/A	Revise forms as appropriate
Audit equipment	Cannot be the same as used for calibration	System must be checked out against known standards	Locate problem and correct or return to supplier

When purchasing these materials, a logbook should be maintained as a reference for future procurement needs and as a basis for future fiscal planning.

11.2.1. SPARE PARTS AND EXPENDABLE SUPPLIES

In addition to the basic equipment described in the Q.A. Handbook, it is necessary to maintain an inventory of spare parts and expendable supplies. Section 13 describes the parts that require periodic replacement and the frequency of replacement. Appendix B contains a list of spare parts and kits of expendables supplies.

11.2.2. CALIBRATION GAS AND ZERO AIR SOURCES

11.2.2.1. Zero Air

Devices that condition ambient air by drying and removal of pollutants are available on the commercial market such as the Teledyne API M701 zero air generator.

11.2.2.2. Span Gas

NO and NO_x calibration gases supplied either directly from pressurized bottles of calibrated gas of different concentrations (see Table 3-8 or from a single source of high concentration gas then mixed to create various lower concentrations. In the latter case, we recommend using a gas dilution calibrator such as a Teledyne API M700E.

In ALL cases, the gases and instrument(s) used must be calibrated and that calibration must be traceable to an EPA/NIST primary standard.

11.2.3. DATA RECORDING DEVICE

Either a strip chart recorder, data acquisition system, digital data acquisition system should be used to record the data from the T200 RS-232 port or analog outputs. If analog readings are being used, the response of that system should be checked against a NIST referenced voltage source or meter. Data recording device should be capable of bi-polar operation so that negative readings can be recorded. Strip chart recorder should be at least 6" (15 cm) wide.

11.2.4. RECORD KEEPING

Record keeping is a critical part of all quality assurance programs. Standard forms similar to those that appear in this manual should be developed for individual programs. Three things to consider in the development of record forms are:

- Does the form serve a necessary function?
- Is the documentation complete?
- Will the forms be filed in such a manner that they can easily be retrieved when needed?

11.3. CALIBRATION FREQUENCY

A system of Level 1 and Level 2 zero/span checks is recommended (see Section 11.4). Level 1 zero and span checks should be conducted at least every two weeks. Level 2 checks should be conducted in between the Level 1 checks at a frequency determined by the user. Span concentrations for both levels should be between 70 and 90% of the reporting range.

To ensure accurate measurements of the NO, NO_X, and NO_2 concentrations, calibrate the analyzer at the time of installation, and recalibrate it:

- No later than three months after the most recent calibration or performance audit that indicated the analyzer calibration to be acceptable.
- An interruption of more than a few days in analyzer operation.
- Any repairs which might affect its calibration.
- Physical relocation of the analyzer.
- Any other indication (including excessive zero or span drift) of possible significant inaccuracy of the analyzer.

Following any of the activities listed above, the zero and span should be checked to determine if a calibration is necessary. If the analyzer zero and span drifts exceed the calibration limits in Section 12 of the Q.A. Handbook[6], a calibration should be performed.

11.4. LEVEL 1 CALIBRATIONS VERSUS LEVEL 2 CHECKS

All monitoring instruments are subject to some drift and variation in internal parameters and cannot be expected to maintain accurate calibration over long periods of time the EPA requires a schedule of periodic checks of the analyzer's calibration be implemented. Zero and span checks must be used to document that the data remains within required limits. These checks are also used in data reduction and system validation.

A Level 1 Span check is used to document that the T200 is within control limits and must be conducted every 2 weeks. A Level 2 Span Check is to be conducted between the Level 1 Checks on a schedule to be determined by the user.

Table 11-2: Definition of Level 1 and Level 2 Zero and Span Checks

LEVEL 1 ZERO AND SPAN CALIBRATION	LEVEL 2 ZERO AND SPAN CHECK
A Level 1 zero and span calibration is a simplified, two-point analyzer calibration used when analyzer linearity does not need to be checked or verified. (Sometimes when no adjustments are made to the analyzer, the Level 1 calibration may be called a zero/span check, in which case it must not be confused with a Level 2 zero/span check.) Since most analyzers have a reliably linear or near-linear output response with concentration, they can be adequately calibrated with only two concentration standards (two-point concentration). Furthermore, one of the standards may be zero concentration, which is relatively easily obtained and need not be certified. Hence, only one certified concentration standard is needed for the two-point (Level 1) zero and span calibration. Although lacking the advantages of the multipoint calibration, the two-point zero and span calibration--because of its simplicity--can be (and should be) carried out much more frequently. Also, two-point calibrations are easily automated. Frequency checks or updating of the calibration relationship with a two-point zero and span calibration improves the quality of the monitoring data by helping to keep the calibration relationship more closely matched to any changes (drifts) in the analyzer response.	A Level 2 zero and span check is an "unofficial" check of an analyzer's response. It may include dynamic checks made with uncertified test concentrations, artificial stimulation of the analyzer's detector, electronic or other types of checks of a portion of the analyzer, etc. Level 2 zero and span checks are not to be used as a basis for analyzer zero or span adjustments, calibration updates, or adjustment of ambient data. They are intended as quick, convenient checks to be used between zero and span calibrations to check for possible analyzer malfunction or calibration drift. Whenever a Level 2 zero or span check indicates a possible calibration problem, a Level 1 zero and span (or multipoint) calibration should be carried out before any corrective action is taken. If a Level 2 zero and span check is to be used in the quality control program, a "reference response" for the check should be obtained immediately following a zero and span (or multipoint) calibration while the analyzer's calibration is accurately known. Subsequent Level 2 check responses should then be compared to the most recent reference response to determine if a change in response has occurred. For automatic Level 2 zero and span checks, the first scheduled check following the calibration should be used for the reference response. It should be kept in mind that any Level 2 check that involves only part of the analyzer's system cannot provide information about the portions of the system not checked and therefore cannot be used as a verification of the overall analyzer calibration.

In addition, an independent precision check between 0.08 and 0.10 ppm must be carried out at least once every two weeks. Table 11-1 summarizes the quality assurance activities for routine operations. A discussion of each activity appears in the following sections.

To provide for documentation and accountability of activities, a checklist should be compiled and then filled out by the field operator as each activity is completed.

For information on shelter and sample inlet system, an in-depth study is in Field Operations Guide for Automatic Air Monitoring Equipment, Publication No. APTD-0736, PB 202-249 and PB 204-650, U.S. Environmental Protection Agency, Office of Air Programs, October 1972

11.5. GAS PHASE TITRATION (GPT)

11.5.1. GPT PRINCIPLE OF OPERATION

Gas phase titration (GPT) is recommended during calibration of the T200. Those using a NO_2 permeation tube should refer to the CFR[1].

The principle of GPT is based on the rapid gas phase reaction between NO and O_3 that produces stoichiometric quantities of NO_2 as shown by the following equation:

Equation 11-1

$$NO + O_3 \longrightarrow NO_2 + O_2 + h\nu$$

- Given that the O_3 concentration is known for this reaction, the resultant concentration of NO_2 can be determined. Ozone is added to excess NO in a dynamic calibration system as shown in Figure 11-1, and the NO channel of the chemiluminescence analyzer detects the changes in NO concentration.
- After the addition of O_3, the observed decrease in NO concentration on the calibrated NO channel is equivalent to the concentration of NO_2 produced.
- The amount of generated NO_2 may be varied by adding varying amounts of O_3 from a stable O_3 generator.
- All zero air used in this procedure should conform to the requirements stated in Section 11.2 .

Dynamic calibration systems based on this principle are commercially available, or may be assembled by the user. A recommended calibration system is described in the Federal Register CFR[1].

11.5.2. GPT CALIBRATOR CHECK PROCEDURE

It has been empirically determined that the NO-O_3 reaction is complete (<1% residual O_3) if the NO concentration in the reaction cell (ppm) multiplied by the residence time (min.) of the reactants in the chamber is >2.75 ppm min. The theory behind the development of this equation is in the Federal Register[1]. The following procedures and equations should be used to determine whether an existing GPT calibration system will meet required conditions for a specific calibration.

For calibrators that have known pre-set flow rates, use equations Equation 11-6 and Equation 11-7 below to verify the required conditions.

If the calibrator does not meet specifications, follow the complete procedure to determine what flow modifications must be made.

1. Select an NO standard gas that has a nominal concentration in the range of 50 to 100 ppm.
   - Determine the exact concentration $[NO]_{STD}$ by referencing against an NIST-SRM SRM, as discussed in the Q.A. Handbook.
2. Determine the volume (cm^3) of the calibrator reaction cell (V_{RC}). If the actual volume is not known, estimate the volume by measuring the approximate dimensions of the chamber and using an appropriate formula.
3. Determine the required minimum total flow output (F_T) :

Equation 11-2

$$F_T = \text{analyzer flow demand } (cm^3/min) \times 110/100$$

   - If more than one analyzer is to be calibrated at the same time, multiply F_T by the number of analyzers.

4. Calculate the NO concentration $[NO]_{OUT}$ needed to approximate 90% of the URL of the NO_2 analyzer to be calibrated:

Equation 11-3

$$[NO]_{OUT} = \text{URL of analyzer (ppm)} \times 90/100$$

5. Calculate the NO flow (F_{NO}) required to generate the NO concentration $[NO]_{OUT}$:

Equation 11-4

$$F_{NO} = \frac{[NO]_{OUT} \, x \, F_T}{[NO]_{STD}}$$

6. Calculate the required flow through the ozone generator (F_O):

Equation 11-5

$$F_o = \sqrt{\frac{[NO]_{STD} \; X \; F_{NO} \; X \; V_{RC}}{2.75 \; ppm - \text{min}}} - F_{NO}$$

7. Verify that the residence time (t_R) in the reaction cell is <2 min:

Equation 11-6

$$t_R = \frac{V_{RC}}{F_O + F_{NO}} \leq 2 \, \text{min}$$

8. Verify that the dynamic parameter specification (P_R) of the calibrator's reaction cell is >2.75 ppm-min:

Equation 11-7

$$P_R = [NO]_{STD} \times \frac{F_{NO}}{F_O + F_{NO}} \times \frac{V_{RC}}{F_O + F_{NO}} \geq 2.75$$

NOTE
If t_r is >2 minutes or if P_R is <2.75 ppm min, changes in flow conditions (F_T, F_O, F_{NO}) or in the reaction cell volume (V_{RC}), or both will have to be made, and t_r and P_R will have to be recalculated.

9. After equations 8-5 and 8-6 are satisfied, calculate the diluent air flow (F_D):

Equation 11-8

$$F_D = F_T - F_O - F_{NO}$$

11.5.2.1. Example GPT Calculation

The following is an example calculation that can be used to determine whether an existing GPT calibrator will meet the required conditions for a specific calibration. For this example, it is assumed that only the volume of the reaction cell, V_{RC}, and the concentration of the NO standard, $[NO]_{STD}$, are known. All flow settings (F_{NO}, F_O, F_T, and F_D) will be calculated. In many uses, these flow settings are known and need only to be substituted in Equations 8-5 and 8-6 to verify the required conditions. Before doing any calculations, the URL and flow demand of the analyzer being calibrated must be known. Operating parameters are determined from the operations manual:

- Upper range limit = 0.5 ppm, and
- Flow demand = 500 cm3/min.
- Volume of calibrator reaction cell is determined by physical measurement: VRC = 180 cm3
- The concentration of the NO standard gas to be used is determined by reference against an NIST-SRM SRM (Section 2.0.7, Q.A. Handbook):

$$[NO]_{STD} = 50.5 \text{ ppm}$$

Determine the minimum total flow (F_T) required at the output manifold:

$$F_T = 500 \text{ cm}^3/\text{min } (110/100) = 550 \text{ cm}^3/\text{min}$$

Because low flows are difficult to control and measure, it is often advantageous to set a higher total flow than needed. In this example, we will set F_T to 2750 cm^3/min.

Determine the highest NO concentration, $[NO]_{OUT}$, required at the output manifold,:

$$[NO]_{OUT} = 0.5 \text{ ppm } (90/100) = 0.45 \text{ ppm}$$

Calculate the NO flow (F_{NO}) required to generate the NO concentration $[NO]_{OUT}$:

$$F_{NO} = \frac{0.45\,ppm \times 2750\ cm^3/\min}{50.5\,ppm} = 24.5\ cm^3/\min$$

Calculate the required flow rate through ozone generator (F_O):

$$F_O = \sqrt{\frac{50.5\ ppm\ x\ 24.5\ cm^3/min\ x\ 180\ cm^3}{2.75\ ppm - min}} - 24.5\ cm^3/min$$

$$= \sqrt{80984 cm^6/min^2} - 24.5 cm^3/min = 260\ cm^3/min$$

Verify that the residence time (t_R) in the reaction cell is <2 min:

$$t_R = \frac{180\,cm^3}{260\,cm^3/\min + 24.5\,cm^3/\min} = 0.63\min$$

Verify the dynamic parameter specification (P_R) of the calibrator reaction cell:

$$P_R = 50.5\,ppm \times \frac{24\,cm^3/\min}{260\,cm^3/\min + 24.5\,cm^3/\min} \times \frac{180\,cm^3}{260\,cm^3/\min + 24.5\,cm^3/\min} = 2.75\,ppm-\min$$

Calculate the diluent airflow (F_D) required at the mixing chamber:

$$F_D = 2750\ cm^3/min - 260\ cm^3/min - 24.5\ cm^3/min = 2465.5\ cm^3/min$$

11.6. GPT MULTIPOINT CALIBRATION PROCEDURE

The procedure for calibration of chemiluminescence NO_x analyzers by GPT is specified in the Federal Register.[1] This section applies the general procedure to the specific case of the T200.

Calibration must be performed with a calibrator that meets all conditions specified in the Q.A. Handbook.

NOTE

The user should be sure that all flow meters are calibrated under the conditions of use against a reliable standard.

All volumetric flow rates should be corrected to 25° C (78°F) and 760 mm (29.92 in.) Hg. Calibrations of flow meters are discussed in the QA Handbook, Vol. II, Part 1, Appendix 12[6].

Gas Phase Titration (GPT) requires the use of the NO channel of the analyzer to determine the amount of NO_2 generated by titration. Therefore it is necessary to calibrate and determine the linearity of the NO channel before proceeding with the NO_2 calibration. It is also necessary to calibrate the NO_x channel. This can be done simultaneously with the NO calibration. During the calibration the T200 should be operating in its normal sampling mode, and the test atmosphere should pass through all filters, scrubbers, conditioners, and other components used during normal ambient sampling and as much of the ambient air inlet system as is practicable. All operational adjustments to the T200 should be completed prior to the calibration.

11.6.1. SET UP FOR GPT MULTIPOINT CALIBRATION OF THE T200

The following T200 features must be activated or set before calibration.

- Calibrate the NO_2 → NO converter (see Section 10.1.4).
- Set the reporting ranges for Independent mode (see Section 7.4.4.6).
- Turn ON the automatic temperature/pressure compensation feature (see Section 8.2).
- Set the units of measure to ppb (see Section 7.4.4.8).

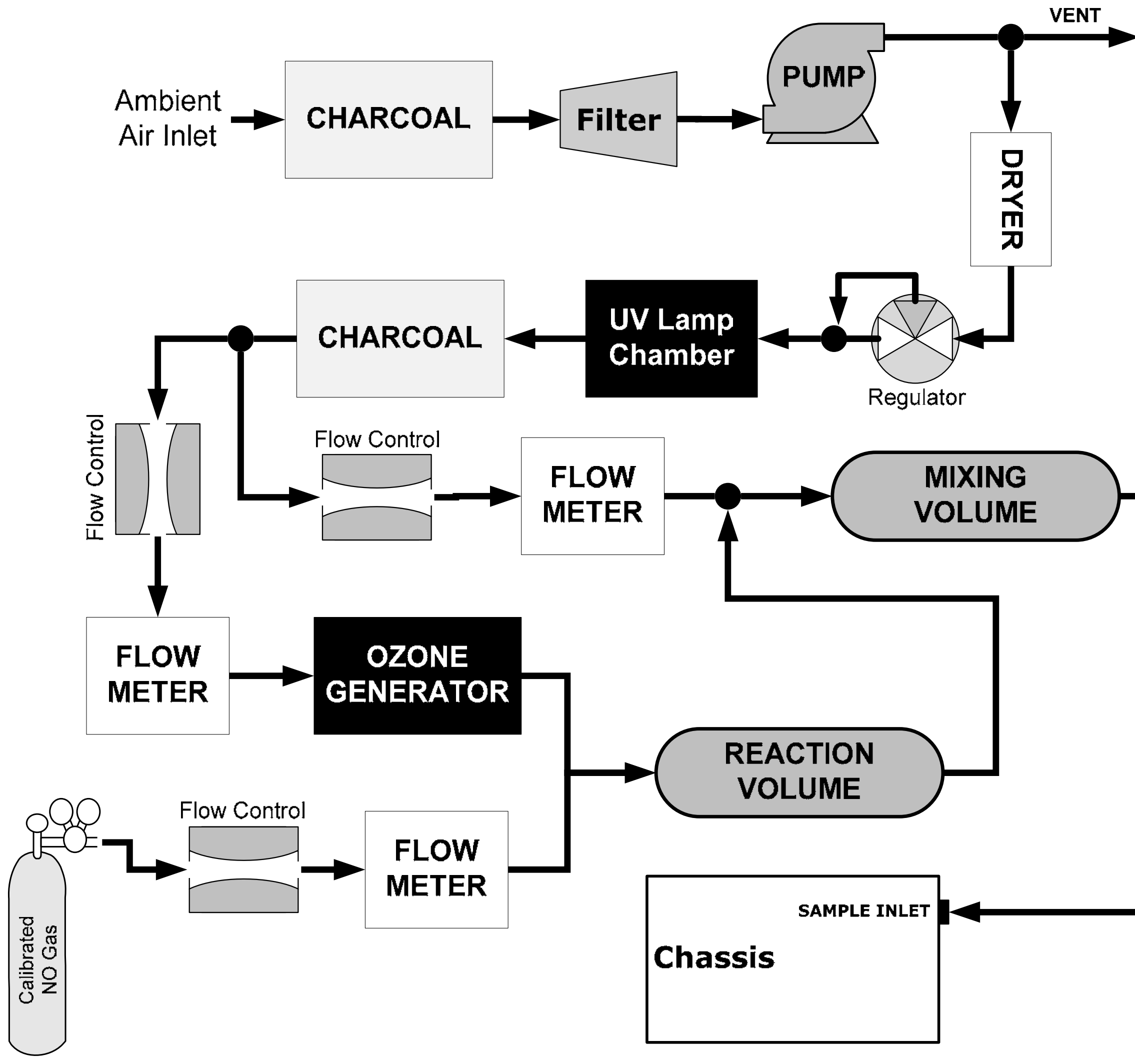


Figure 11-1: GPT Calibration System

NOTE
The analyzer should be calibrated on the same range used for monitoring.
Ensure that the GPT calibration system can supply the range of concentrations at a sufficient flow over the whole range of concentrations that will be encountered during calibration.

11.6.2. ZERO CALIBRATION

The zero point calibration procedure is identical to that described in Sections 10.1, 10.2, 10.4 or 10.5.

11.6.3. SPAN CALIBRATION

1. Adjust the NO concentration to approximately 80% of the URL of the NO channel.
   - The expected NO and NO_X span concentrations can be determined by measuring the cylinder and diluent flows and computing the resulting concentrations.
   - If there is any NO_2 impurity in the NO standard gas it should be taken into account when the NO_X concentration is entered during the NO/NO_X channel calibration.
   - This is done by ADDING the impurity concentration to the NO concentration to get the NO_X concentration for calibration. Calculate the exact NO and NO_X concentrations as follows:

Equation 11-9

$$[NO]_{OUT} = \frac{F_{NO} \times [NO]_{STD}}{F_T}$$

2. Enter the respective concentrations using the procedure in Section 7.3. The expected span concentrations need not be re-entered each time a calibration is performed unless they are changed.
3. Enter the expected NO_X and NO span gas concentrations:
4. Sample the generated concentration until the NO and the NO_X responses have stabilized.
5. Span the instrument by the following the same method as 10.1, 10.3 or 10.5.
   - The analog voltage output should measure 80% of the voltage range selected. (e.g. 4.00 VDC if 0-5V output is selected.)
   - The readings on the front panel display should be equal to the expected NO and NO_X concentrations.

NOTE

See the Troubleshooting Section 13 if there are problems.

Also see the Calibration Quality Check procedure Section 10.6.

6. After the zero and the 80% upper range limit points have been set, generate five approximately evenly spaced calibration points between zero and 80% upper range limit without further adjustment to the instrument.
7. Allow the instrument to sample these intermediate concentrations for about 10 minutes each and record the instrument NO and NO_X responses.
8. Plot the analyzer NO and NO_X responses versus the corresponding calculated concentrations to obtain the calibration relationships.
   - Determine the straight line of best fit (y = mx + b) determined by the method of least squares.
9. After the best-fit line has been drawn for the NO and the NO_X calibrations, determine whether the analyzer response is linear.
   - To be considered linear, no calibration point should differ from the best-fit line by more than 2% of full scale.

11.7. GPT NO_2 CHECK

The T200 computes the NO_2 concentration by subtracting the NO from the NO_X concentration. Unlike analog instruments, this difference is calculated by the T200's internal computer software. It is extremely unlikely that the NO_2 concentration will be in error. Therefore this procedure is a confirmation that the NO_2 subtraction algorithm in the computer is operating correctly.

NOTE
Do not make any adjustments to the instrument during this procedure.

1. Generate an NO concentration near 90% of the upper range limit.
   - Dilution air and O_3 generator air flows should be the same as used in the calculation of specified conditions of the dynamic parameter according to Section 11.5.
2. Sample this NO concentration until the NO and NO_X responses stabilize. Record the NO and NO_x concentrations.
3. Turn **ON** and adjust the O_3 generator in the calibrator to produce sufficient O_3 to decrease the NO concentration to about 10% of full scale.
   - This will be equivalent to 80% of the URL of the NO_2 channel. After the analyzer responses stabilize, record the resultant NO, NO_X, and NO_2 concentrations.

NOTE
If the NO_X reading should drop to less than 96% of its starting value during this step, it indicates the NO_2 converter is in need of troubleshooting or replacement. See Section 14.7.10 for further details.

4. While maintaining all other conditions, adjust the ozone generator to obtain several other concentrations of NO_2 evenly spaced between the 80% URL point and the zero point. Record the NO, NO_X, and NO_2 concentrations for each additional point.

5. Calculate the resulting NO_2 concentrations as follows:

Equation 11-10

$$[NO_2]_{OUT} = [NO]_{ORIG} - [NO]_{REM} + \frac{F_{NO} * [NO_2]_{IMP}}{F_T}$$

Where $[NO]_{ORIG}$ is the NO concentration before the GPT ozone is turned on, and $[NO]_{REM}$ is the NO remaining after GPT.

Plot the NO_2 concentration output by the instrument on the y-axis against the generated NO_2 $[NO_2]_{OUT}$ on the x-axis. The plot should be a straight line within the ± 2% linearity criteria given for the NO_x and NO channels. If the plot is not linear the most likely cause is that the converter needs replacing. See Section 10.1.4 on NO_2 converter efficiency.

11.8. OTHER QUALITY ASSURANCE PROCEDURES

Precision is determined by a one-point check at least once every two weeks. Accuracy is determined by a three-point audit once each quarter.

Essential to quality assurance are scheduled checks for verifying the operational status of the monitoring system. The operator should visit the site at least once each week. Every two weeks a Level 1 zero and span check must be made on the analyzer. Level 2 zero and span checks should be conducted at a frequency desired by the user. Definitions of these terms are given in Table 11-2.

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11.8.1. SUMMARY OF QUALITY ASSURANCE CHECKS

The following items should be checked on a regularly scheduled basis to assure high quality data from the T200. See Table 11-3 for a summary of activities; also the QA Handbook should be checked for specific procedures.

Table 11-3: Activity Matrix for Data Quality

Characteristic	Acceptance Limits	Frequency and Method of Measurement	Action if Requirements are not Met
Shelter temperature	Mean temperature between 22°C and 28°C (72° and 82° F), daily fluctuations not greater than ± 2°C	Check thermograph chart weekly for variations greater than ± 2°C (4°F)	Mark strip chart for the affected time period. Repair or adjust temperature control.
Sample introduction system	No moisture, foreign material, leaks, obstructions; sample line connected to manifold	Weekly visual inspection	Clean, repair, or replace as needed.
Recorder	Adequate ink & paper Legible ink traces Correct chart speed and range Correct time	Weekly visual inspection	Replenish ink and paper supply. Adjust time to agree with clock; note on chart.
Analyzer operational settings	TEST measurements at nominal values T200 in SAMPLE mode	Weekly visual inspection	Adjust or repair as needed.
Analyzer operational check	Zero and span within tolerance limits as described in Section 12 of the Q.A. Handbook[6]	Level 1 zero/span every 2 weeks; Level 2 between Level 1 checks at frequency desired by user	Find source of error and repair. After corrective action, re-calibrate analyzer.
Precision check	Assess precision as described in Sections 15&18 of the Q.A. Handbook[6]	Every 2 weeks, Subsection 3.4.3 (Ibid.)	Calc, report precision, Section 12 of the Q.A. Handbook[6].

11.8.2. SHORT CALIBRATION CHECKS

A system of Level 1 and Level 2 zero/span checks (Table 11-2) is recommended. These checks must be conducted in accordance with the specific guidance given in Section 12 of the Q.A. Handbook[6]. Level 1 zero and span checks must be conducted every two weeks. Level 2 checks should be conducted in between the Level 1 checks at a frequency desired by the user. Span concentrations for both levels should be between 70 and 90% of the measurement range.

Zero and span data are to be used to:

- Provide data to allow analyzer adjustment for zero and span drift;
- Provide a decision point on when to calibrate the analyzer;
- Provide a decision point on invalidation of monitoring data.

These items are described in detail in Sections 15 & 18 of the Q.A. Handbook[6]. Refer to Section 13 of this manual if the instrument is not within the allowed margins. We recommend using APICOM and the DAS for analysis and documentation of zero/span check data.

11.8.3. ZERO/SPAN CHECK PROCEDURES

The Zero and span calibration can be checked in a variety of different ways. They include:

- Manual zero/span checks can be done from the front panel touchscreen. The procedure is in Section 10.2.2 of this manual.
- Automatic zero/span checks can be performed every night. See Section 10.5 of this manual for setup and operation procedures.
- Zero/Span checks through remote contact closure can be initiated through remote contact closures on the rear panel. See Section 10.4.3.3 of this manual.
- Zero/span checks can also be controlled through the RS-232 port. See Section 9 of this manual for more details on setting up and using the analyzer's RS-232 port.

11.8.4. PRECISION CHECK

A periodic check is used to assess the data for precision. A one-point precision check must be carried out at least once every 2 weeks on each analyzer at an NO_2 concentration between 0.08 and 0.10 ppm.

- The analyzer must be operated in its normal sampling mode, and the precision test gas must pass through all filters, scrubbers, conditioners, and other components used during normal ambient sampling.
- The standards from which precision check test concentrations are obtained must be traceable to NIST-SRM SRM. Those standards used for calibration or auditing may be used.

11.8.4.1. Precision Check Procedure

Connect the analyzer to a precision gas that has an NO_2 concentration between 0.08 and 0.10 ppm. An NO_2 precision gas may be generated by either GPT or a NO_2 permeation tube. If a precision check is made in conjunction with a zero/span check, it must be made prior to any zero or span adjustments.

- Allow the analyzer to sample the precision gas until a stable trace is obtained.
- Record this value.

- NO and NO_X precision checks should also be made if those data are being reported. Information from the check procedure is used to assess the precision of the monitoring data; see in Section 12 of the Q.A. Handbook[6] for procedures for calculating and reporting precision.

11.9. CERTIFICATION OF WORKING STANDARDS

The NO content of the NO working standard must be periodically assayed against NIST-traceable NO or NO_2 standards. Any NO_2 impurity in the cylinder must also be assayed. Certification of the NO working standard should be made on a quarterly basis or more frequently, as required. Procedures are outlined below for certification against NO traceable standard which is the simplest and most straightforward procedure.

To assure data of desired quality, two considerations are essential:

- The measurement process must be in statistical control at the time of the measurement and;
- Any systematic errors, when combined with the random variation in the measurement process, must result in a suitably small uncertainty.

Evidence of good quality data includes documentation of the quality control checks and the independent audits of the measurement process by recording data on specific forms or on a quality control chart and by using materials, instruments, and measurement procedures that can be traced to appropriate standards of reference.

To establish traceability, data must be obtained routinely by repeated measurements of standard reference samples (primary, secondary, and/or working standards). More specifically, working calibration standards must be traceable to standards of higher accuracy.

11.9.1.1. Certification Procedures of Working Standards

This procedure requires the use of calibrated NO gas traceable to an NIST-SRM SRM and the gas phase titration calibration procedure (Section 11.5) to calibrate the NO, NO_X, and NO_2 responses of the analyzer. Also the efficiency of the analyzer's NO_2 converter must be determined (Section 10.1.4).

Generate several NO concentrations by diluting the NO working standard. Use the nominal NO cylinder concentration, $[NO]_{NOM}$, to calculate the diluted concentrations. Plot the analyzer NO response (in ppm) versus the nominal diluted NO concentration and determine the slope, S_{NOM}. Calculate the NO concentration of the working standard $[NO]_{STD}$ from:

Equation 11-11

$$[NO]_{STD} = [NO]_{NOM} \times S_{NOM}$$

A more detailed procedure is presented in Reference 1.

11.9.1.2. Other Methods of Establishing Traceability

Methods of establishing traceability are:

- Using a NO working standard traced to NIST NO_2 standard.
- Using a NO_2 working standard traced to NIST NO_2 standard.
- Using a NO_2 working standard traced to NIST NO standard.

NOTE

If the NO_2 impurity in the NO cylinder, $[NO_2]_{imp}$ is greater than the 1 ppm value allowed in the calibration procedure, check that the NO delivery system is not the source of contamination before discarding the NO standard.

For further information on calibration by GPT and NO_2 permeation devices, refer to part 50 of Section 1, Title 40 CFR, Appendix F Reference 13 of that Appendix.

11.10. REFERENCES

1. Environmental Protection Agency, Title 40, Code of Federal Regulations, Part 50, Appendix F, Measurement Principle and Calibration Procedure for the Measurement of Nitrogen Dioxide in the Atmosphere (Gas Phase Chemiluminescence), Federal Register, 41 (232), 52688-52692, December 1976 (as amended at 48 FR 2529, Jan 20, 1983).

2. Ellis, Elizabeth C. Technical Assistance Document for the Chemiluminescence Measurement of Nitrogen Dioxide, U.S. Environmental Protection Agency, Research Triangle Park, NC. 83 pages, December 1975. Available online at http://www.epa.gov/ttn/amtic/files/ambient/criteria/reldocs/4-75-003.pdf.

3. Environmental Protection Agency, Title 40, Code of Federal Regulations, Part 58, Appendix A, Measurement Principle and Calibration Procedure for the Measurement of Nitrogen Dioxide in the Atmosphere (Gas Phase Chemiluminescence), Federal Register, 41 (232), 52688-52692, December 1976 (as amended at 48 FR 2529, Jan 20, 1983).

4. Mavrodineanu, R., and Gills, T. E., Standard Reference Materials: Summary of Gas Cylinder and Permeation Tube Standard Reference Materials Issued by the National Bureau of Standards, Document SP260-108, May 1987.
   And: Taylor, J. K., Standard Reference Materials: Handbook for SRM Users, Document number SP260-100, February 1993. Available online at:
   http://patapsco.nist.gov/srmcatalog/sp_publications/publications.htm

5. Quality Assurance Handbook for Air Pollution Measurement Systems - Volume I, "A Field Guide to Environmental Quality Assurance," EPA-600/R-94/038a, April 1994. Available online at: http://www.epa.gov/ttn/amtic/qabook.html.

6. Quality Assurance Handbook for Air Pollution Measurement Systems - Volume II, Ambient Air Specific Methods. EPA-600/4-77/027a, December 1986. US EPA Order Number: 454R98004, available at the National Technical Information Service (NTIS), 5285 Port Royal Rd Springfield, VA 22151. Portions are also available at: http://www.epa.gov/ttn/amtic/qabook.html.

7. Environmental Protection Agency, Title 40, Code of Federal Regulations, Part 58, Appendix B, Measurement Principle and Calibration Procedure for the Measurement of Nitrogen Dioxide in the Atmosphere (Gas Phase Chemiluminescence), Federal Register, 41 (232), 52688-52692, December 1976 (as amended at 48 FR 2529, Jan 20, 1983).

8. Quality Assurance Guidance Document. Reference Method for the Determination of Nitrogen Dioxide in the Atmosphere (Chemiluminescence). Draft document, 58 pages, February 2002. Office of Air Quality Planning and Standards, Research Triangle Park NC 27711, draft document available at http://www.epa.gov/ttn/amtic/qabook.html. Guidelines about the measurement of NO_2 in this document replace those in the old QA Handbook and should be consulted as the latest reference.

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PART III
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TECHNICAL INFORMATION

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12. THEORY OF OPERATION

The T200 Nitrogen Oxides Analyzer is a microprocessor controlled instrument that determines the concentration of nitric oxide (NO), total nitrogen oxides (NO_X, the sum of NO and NO_2) and nitrogen dioxide (NO_2) in a sample gas drawn through the instrument.

- It requires that sample and calibration gases be supplied at ambient atmospheric pressure in order to establish a constant gas flow through the reaction cell where the sample gas is exposed to ozone (O_3), initiating a chemical reaction that gives off light (hv).
- The instrument measures the amount of chemiluminescence to determine the amount of NO in the sample gas.
- A catalytic-reactive converter converts NO_2 in the sample gas to NO which, along with the NO present in the sample is reported as NO_X. NO_2 is calculated as the difference between NO_X and NO.

Calibration of the instrument is performed in software and usually does not require physical adjustments to the instrument. During calibration, the microprocessor measures the sensor output signal when gases with known amounts of NO or NO_2 are supplied and stores these results in memory. The microprocessor uses these calibration values along with the signal from the sample gas and data of the current temperature and pressure of the gas to calculate a final NO_X concentration.

The concentration values and the original information from which it was calculated are stored in the unit's internal data acquisition system (DAS Section 8.1) and are reported to the user through a vacuum fluorescence display or several output ports.

12.1. MEASUREMENT PRINCIPLE

12.1.1. CHEMILUMINESCENCE CREATION IN THE T200 REACTION CELL

The T200's measures the amount of NO present in a gas by detecting the chemiluminescence which occurs when nitrogen oxide (NO) is exposed to ozone (O_3). This reaction is a two-step process:

- In the first step, one molecule of NO and one molecule of O_3 collide and chemically react to produce one molecule of oxygen (O_2) and one molecule of nitrogen dioxide (NO_2). Some of the NO_2 molecules created by this reaction retain excess energy from the collision and exist in an excited state, where one of the electrons of the NO_2 molecule resides in a higher energy state than normal (denoted by an asterisk in the following equation).

Equation 12-1

$$NO + O_3 \rightarrow NO_2^* + O_2$$

- The second step occurs because the laws of thermodynamics require that systems seek the lowest stable energy state available, therefore the excited NO_2 molecule quickly returns to its ground state, releasing the excess energy. This release takes the form of a quantum of light ($h\nu$). The distribution of wavelengths for these quanta range between 600 and 3000 nm, with a peak at about 1200 nm.

Equation 12-2

$$NO_2^* \rightarrow NO_2 + h\nu_{1200nm}$$

All things being constant (temperature, pressure, amount of ozone present, etc.), the relationship between the amount of NO present in the reaction cell and the amount of light emitted from the reaction is very linear. If more

NO is present, more IR light is produced. By measuring the amount of IR light produced with a sensor sensitive in the near-infrared spectrum (see Figure 12-2) the amount of NO present can be determined.

In addition, sometimes the excited NO_2 collides with other gaseous molecules in the reaction cell chamber or even the molecules of the reaction cell walls and transfers its excess energy to this collision partner (represented by *M* in the equation 12-3 below) without emitting any light at all. In fact, by far the largest portion of the excited NO_2 returns to the ground state this way, leaving only a few percent yield of usable chemiluminescence.

Equation 12-3

$$NO_2^* + M \rightarrow NO_2 + M$$

The probability of a collision between the NO_2^* molecule and a collision partner *M* increases proportionally with the reaction cell pressure. This non-radiating collision with the NO_2^* molecules is usually referred to as *third body quenching*, an unwanted process further described in Section 12.1.5.2.

Even under the best conditions only about 20% of the NO_2 that is formed by the reaction described in equation 12-1 is in the excited state. In order to maximize chemiluminescence, the reaction cell is maintained at reduced pressure (thereby reducing the amount of available collision partners) and is supplied with a large, constant excess of ozone (about 3000-5000 ppm) from the internal ozone generator.

12.1.2. CHEMILUMINESCENCE DETECTION IN THE T200 REACTION CELL

12.1.2.1. The Photo Multiplier Tube (PMT)

The T200 uses a special kind of vacuum tube, called a photo-multiplier tube (PMT), to detect the amount of light created by the NO and O_3 reaction in the reaction cell.

Photons enter the PMT and strike a negatively charged photo cathode causing it to emit electrons. These electrons are accelerated by an applied high voltage and multiplied through a sequence of similar acceleration steps (dynodes) until a useable current signal is generated (see Section 12.5 for a more detailed description). The more light present (in this case photons given off by the chemiluminescent reaction described above), the more current is produced. Therefore the more NO present in the reaction cell the more current is produced by the PMT.

The current produced by the PMT is converted to a voltage and amplified by the preamplifier board and then communicated to the T200's CPU via the A→ D converter circuitry on the analyzer.

12.1.2.2. Optical Filter

A high pass optical filter, only transparent to wavelengths of light above 645nm, placed between the reaction cell and the PMT (see Figure 12-1) in conjunction with the response characteristics of the PMT creates a very narrow window of wavelengths of light to which the T200 will respond.

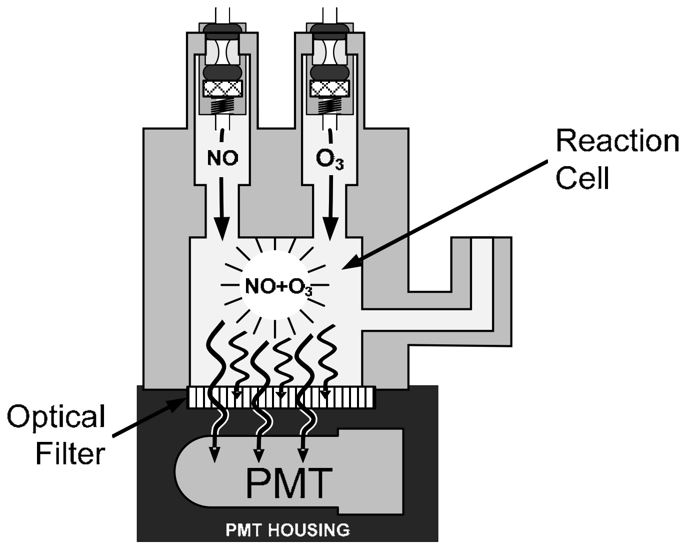


Figure 12-1: Reaction Cell with PMT Tube and Optical Filter

The narrowness of this band of sensitivity allows the T200 to ignore extraneous light and radiation that might interfere with the T200's measurement. For instance, some oxides of sulfur can also be chemiluminescent emitters when in contact with O_3 but give off light at much shorter wavelengths (usually around 260nm to 480nm).

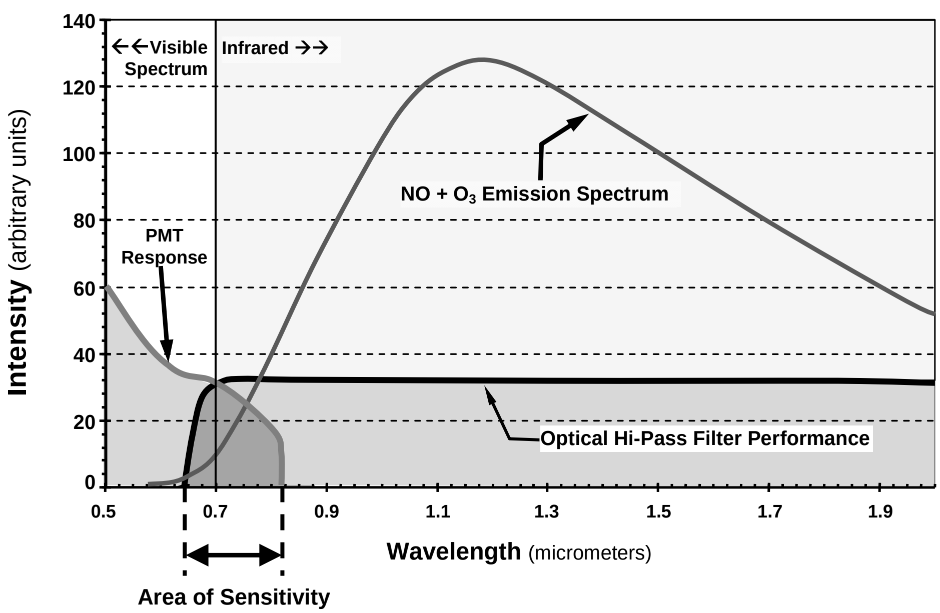


Figure 12-2: T200 Sensitivity Spectrum

12.1.3. NO_X AND NO_2 DETERMINATION

The only gas that is actually measured by the T200 is NO. NO_2, and therefore NO_x (which is defined here as the sum of NO and NO_2 in the sample gas), contained in the gas is not detected because NO_2 does not react with O_3 to create chemiluminescence.

In order to measure the concentration of NO_2, and therefore the concentration of NO_x, the T200 periodically switches the sample gas stream so that the pump pulls it through a special converter cartridge filled with molybdenum (Mo, "moly") chips that are heated to a temperature of 315°C.

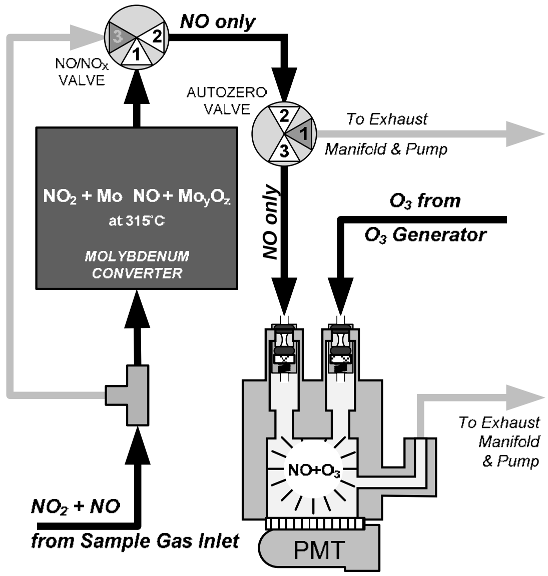


Figure 12-3: $NO_2 \rightarrow$ NO Conversion

The heated molybdenum reacts with NO_2 in the sample gas and produces a NO gas and a variety of molybdenum.

Equation 12-4

$$xNO_2 + yMo \rightarrow xNO + M_yO_z \quad (at\ 315°C)$$

Once the NO_2 in the sample gas has been converted to NO, it is routed to the reaction cell where it undergoes the chemiluminescence reaction described in Equation 12-1 and Equation 12-2.

By converting the NO_2 in the sample gas into NO, the analyzer can measure the total NO_X) content of the sample gas (i.e. the NO present + the converted NO_2 present). By switching the sample gas stream in and out of the "moly" converter every 6 - 10 seconds, the T200 analyzer is able to quasi-continuously measure both the NO and the total NO_X content.

Finally, the NO_2 concentration is not directly measured but calculated by subtracting the known NO content of the sample gas from the known NO_X content.

12.1.4. AUTO ZERO

Inherent in the operation of any PMT is a certain amount of noise. This is due to a variety of factors such as black body infrared radiation given off by the metal components of the reaction cell, unit to unit variations in the PMT units and even the constant universal background radiation that surrounds us at all times. In order to reduce this amount of noise and offset, the PMT is kept at a constant 7° C (45° F) by a Thermo-Electric Cooler (TEC).

While this intrinsic noise and offset is significantly reduced by cooling the PMT, it is not eradicated. To determine how much noise remains, once every minute for about 8 seconds the T200 diverts the sample gas flow directly to the vacuum manifold without passing the reaction cell.

During this time, only O_3 is present in the reaction cell, effectively turning off the chemiluminescence reaction. Once the chamber is completely dark, the T200 records the output of the PMT and keeps a running average of these **AZERO** values. This average offset value is subtracted from the raw PMT readings while the instrument is measuring NO and NO_X to arrive at an Auto Zero corrected reading.

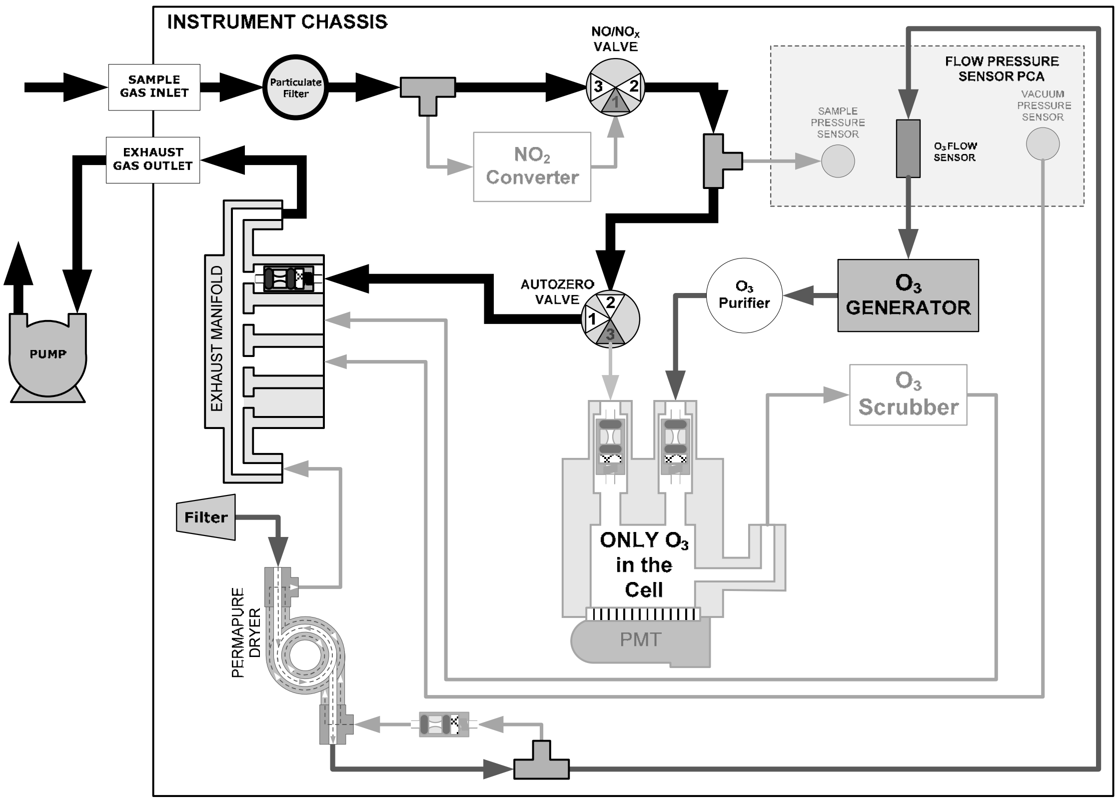


Figure 12-4: Pneumatic Flow During the Auto Zero Cycle

12.1.5. MEASUREMENT INTERFERENCES

It should be noted that the chemiluminescence method is subject to interferences from a number of sources. The T200 has been successfully tested for its ability to reject interference from most of these sources. Table 12-1 list the most common types of interferents that could affect the performance of your T200.

12.1.5.1. Direct Interference

Some gases can directly alter the amount of light detected by the PMT due to chemiluminescence in the reaction cell. This can either be a gas that undergoes chemiluminescence by reacting with O_3 in the reaction cell or a gas that reacts with other compounds and produces excess NO upstream of the reaction cell.

12.1.5.2. Third Body Quenching

As described by Equation 12-3, other molecules in the reaction cell can collide with the excited NO_2^*, causing the excited NO_2^* to return to its ground state without releasing a photon of light. This is known as third party quenching.

Quenching is an unwanted phenomenon and the extent to which it occurs depends on the properties of the collision partner.

- Larger, more polarized molecules such as H_2O and CO_2 are the most significant quenching interferents of NO chemiluminescence.

  - The influence of water vapor on the T200 measurement can be eliminated with an optional, internal sample gas dryer (see Section 6.5).
  - The interference of varying CO_2 amounts at low concentrations (less that 0.5%) is negligible.
  - In cases with excessively high CO_2 concentrations (larger than 0.5%), the effect can be calibrated out by using calibration gases with a CO_2 content equal to the measured air.
  - Only very high and highly variable CO_2 concentrations will then cause a measurable interference. For those applications, it is recommended to use other analyzer models. Please consult Teledyne API's Sales Department or our website (see Section 14.9).
- Smaller less polar and electronically “harder” molecules such as N_2 and O_2 can cause interference of this type as well, however, the concentrations of N_2 and O_2 are virtually constant in ambient air measurements, hence provide a constant amount of quenching that is accounted for in the calibration of the instrument .

12.1.5.3. Light Leaks

The T200 sensitivity curve includes a small portion of the visible light spectrum (see Figure 12-2), therefore it is important to ensure that the reaction cell is completely sealed with respect to light. To ensure this:

- All pneumatic tubing leading into the reaction cell is opaque in order to prevent light from entering the cell.
- Light penetration is prevented by stainless steel filters and orifices.

Table 12-1: List of Interferents

Gas	Interference Type	Rejection Method
CO_2	Dilution: Viscosity of CO_2 molecules causes them to collect in aperture of Critical Flow Orifice altering flow rate of NO.	If high concentrations of CO_2 are suspected, special calibration methods must be performed to account for the affects of the CO_2. Contact Teledyne API's Customer Service Department (see Section 14.9) for details.
	3rd Body Quenching: CO_2 molecules collide with NO_2^* molecules absorbing excess energy kinetically and preventing emission of photons.	
SO_X	Some SO_X variants can also initiate a chemiluminescence reaction upon exposure to O_3 producing excess light.	Wavelengths of light produced by chemiluminescence of SO_X are screened out by the Optical Filter.
	Chemically reacts with NH_3, O_2 and H_2O in O_3 generator to create $(NH_3)_2SO_4$ (ammonium sulfate) and NH_3NO_2 (ammonium nitrate) which form opaque white deposits on optical filter window. Also forms highly corrosive HNO_3 (Nitric Acid)	Most of the ammonium sulfate and ammonium nitrate produced is removed from the sample gas by an air purifier located between the O_3 Generator and the reaction cell.
	3rd Body quenching: SO_X molecules collide with NO_2^* molecules absorbing excess energy kinetically and preventing emission of photons.	If high concentrations of SO_X are suspected, special calibration methods must be performed to account for the affects of the SO_2. Contact Teledyne API's Customer Service Department (see Section 14.9) for details.
H_2O	3rd Body quenching: H_2O molecules collide with NO_2^* molecules absorbing excess energy kinetically and preventing emission of light.	Analyzer's operating in high humidity areas must have some drying applied to the sample gas (see Section 6.5 for more details).
	Water also reacts with NH_3 and SO_X in the O_3 generator to create $(NH_3)_2SO_4$ (ammonium sulfate) and NH_3NO_2 (ammonium nitrate) which form opaque white deposits on the optical filter window. This also forms highly corrosive HNO_3 (nitric acid)	Water is effectively removed from the O_3 gas stream by the Perma Pure® Dryer (Section 12.2.3.2 for more details). We offer several Perma Pure® dryers for the sample stream (see Section 6.5 for more details).
NH_3	Direct Interference: NH_3 is converted to H_2O and NO by the NO_2 converter. Excess NO reacts with O_3 in the reaction cell creating a chemiluminescence artifact.	If a high concentration of NH_3 is suspected, steps must be taken to remove the NH_3 from the sample gas prior to its entry into the NO_2 converter (see Section 6.5 for more details).
	NH_3 also reacts with H_2O, O_2 and SO_X in the O_3 generator to create $(NH_3)_2SO_4$ (ammonium sulfate) and NH_3NO_2 (ammonium nitrate) which form opaque white deposits on optical filter window. Also forms highly corrosive HNO_3 (nitric acid).	The Perma Pure® dryer built into the T200 is sufficient for removing typical ambient concentration levels of NH_3.

12.1.5.4. Reaction Cell Temperature Control

The stability of the chemiluminescence reaction between NO and O_3 can be affected by changes in the temperature and pressure of the O_3 and sample gases in the reaction cell. In order to reduce temperature effects, the reaction cell is maintained at a constant 50° C, just above the high end of the instrument's operation temperature range.

Two AC heaters, one embedded into the bottom of the reaction cell, the other embedded directly above the chamber's exhaust fitting, provide the heat source. These heaters operate off of the instrument's main AC power and are controlled by the CPU through a power relay on the relay board (see Section 12.3.4.4).

A thermistor, also embedded in the bottom of the reaction cell, reports the cell's temperature to the CPU through the thermistor interface circuitry of the motherboard (see Section 12.3.3.3).

12.2. PNEUMATIC OPERATION

NOTE

The sample gas is the most critical flow path in the analyzer. At any point before and in the reaction cell, the integrity of the sample gas cannot be compromised. Therefore, it is important that the sample airflow system is both leak tight and not pressurized over ambient pressure.

Regular leak checks should be performed on the analyzer as described in the maintenance schedule,

Table 13-2. Procedures for correctly performing leak checks can be found in Section 13.3.12.

12.2.1. SAMPLE GAS FLOW

NOTE

In this section of the manual vacuum readings are given in inches of mercury absolute (In-Hg-A). This pressure value is referenced against zero (a perfect vacuum).

The gas flow for the T200 is created by a pump that is pneumatically downstream from the rest of the instrument's components. This is either:

- An external pump pneumatically connected to the analyzer's exhaust port located on the rear panel. This is the most common configuration for the T200 (see Figure 12-5), or;
- An optional internal pump pneumatically connected between the vacuum manifold and the exhaust outlet. (see Figure 12-6).

In either case the pump creates a vacuum of approximately 5 in-Hg-A at one standard liter/minute, which is provided to various pneumatic components by a vacuum manifold located just in front of the rear panel (see Figure 3-5).

Gas flow is created by keeping the analyzer's sample gas inlet near ambient pressure, usually by means of a small vent installed in the sample line at the inlet, in effect pulling the gas through the instrument's pneumatic systems.

By placing the pump downstream from the analyzer's reaction cell, several problems are avoided.

- First, the pumping process heats and compresses the sample air complicating the measurement process.
- Additionally, certain physical parts of the pump itself are made of materials that might chemically react with the sample gas.
- Finally, in certain applications where the concentration of the target gas might be high enough to be hazardous, maintaining a negative gas pressure relative to ambient means that should a minor leak occur, no sample gas would be pumped into the atmosphere surrounding the analyzer.

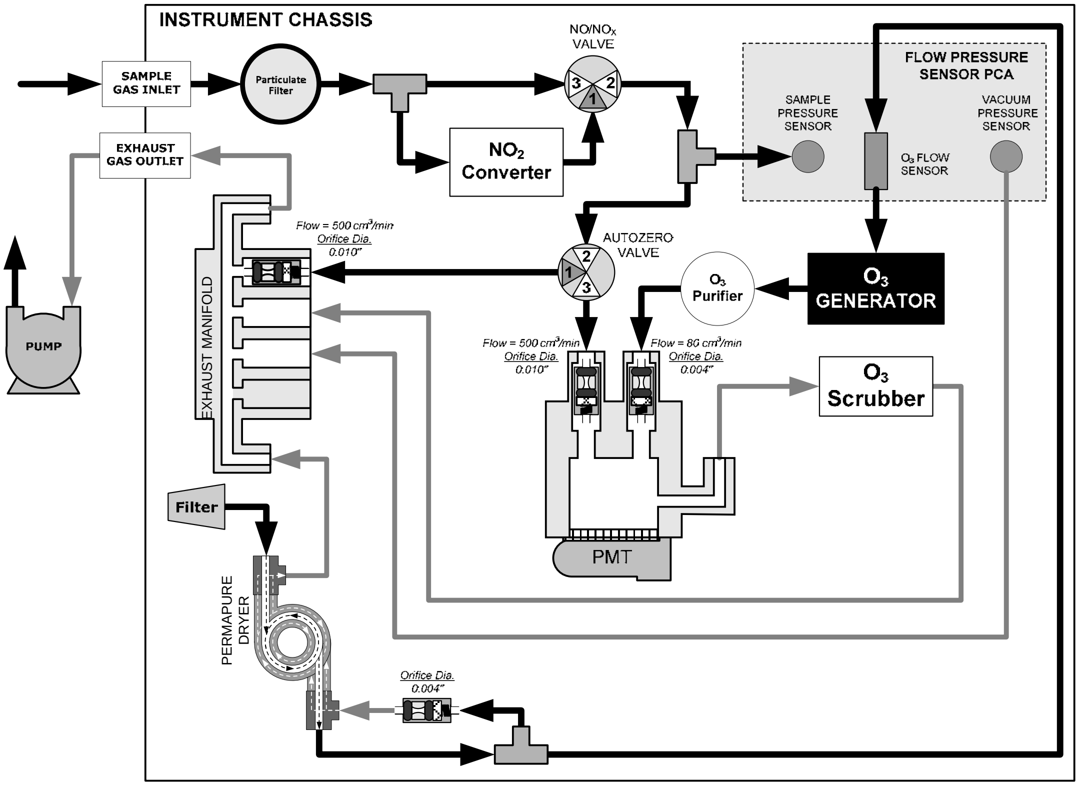


Figure 12-5: Internal Gas Flow for Basic T200 with External Pump

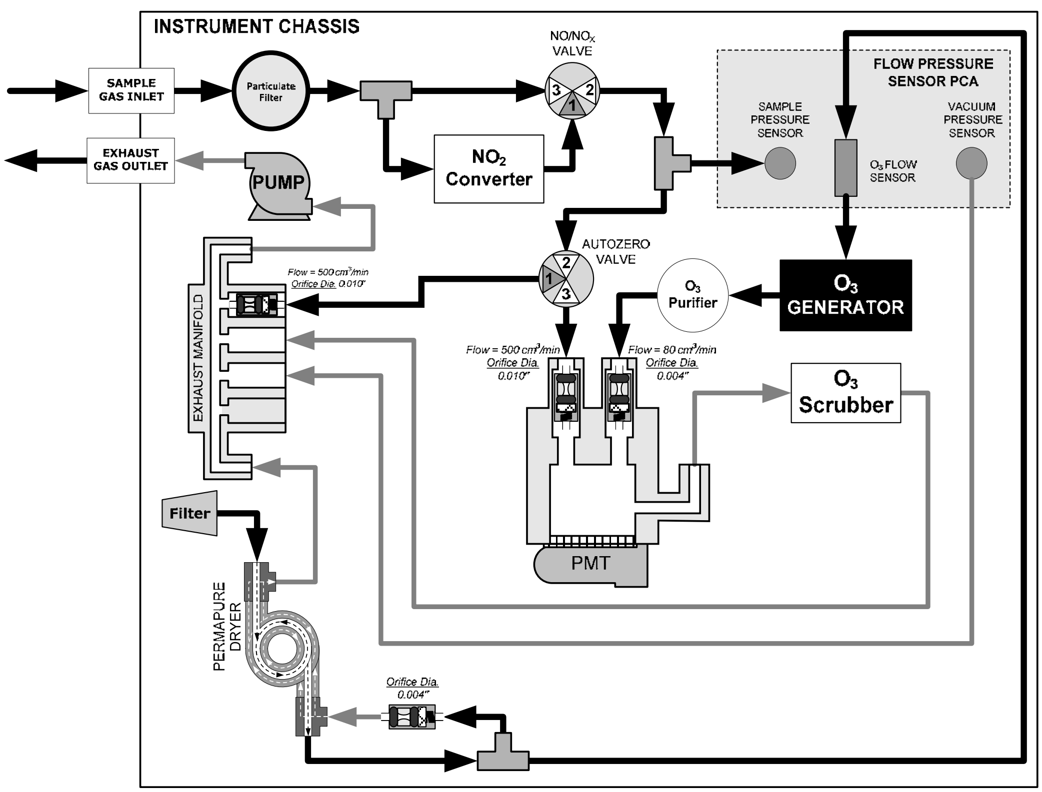


Figure 12-6: Basic Internal Gas Flow for Basic T200 with Internal Pump

12.2.1.1. Vacuum Manifold

The vacuum created by the analyzer's pump is supplied to all of the gas streams for the T200 analyzer through the vacuum manifold (also called the exhaust manifold).

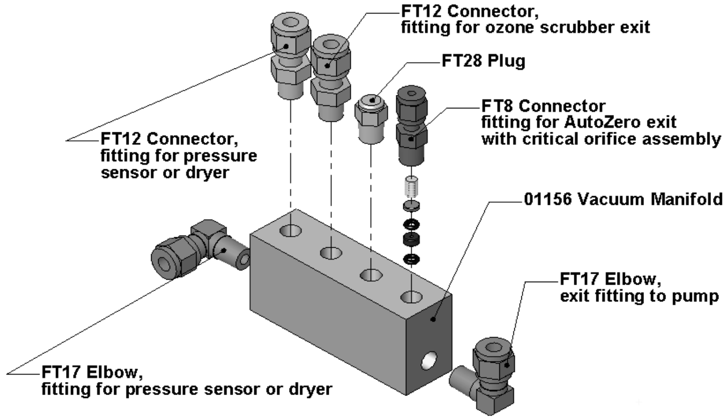


Figure 12-7: Vacuum Manifold, Standard Configuration

Configurations will vary depending on the optional equipment that is installed. For example:

- An T200 with the optional internal span gas generator installed will add another FT8 connector and orifice assembly to the manifold where the FT28 fitting is shown in the above drawing.
- An optional sample gas dryer will add a Tee-fitting so that two ¼" tubes can be connected to the same port.

12.2.1.2. Sample Gas Flow Valves and Routing

As discussed in Section 12.1, the measurement of NO_x, NO and NO_2 requires that the sample gas flow cycles through different routes that include and exclude various scrubbers and converters. There are several valves that perform this function:

- The NO/NO_X valve directs the sample gas either directly to the reaction cell or through the unit's NO_2 converter, alternating every ~8 sec.
- The Auto Zero valve directs the sample gas stream to completely bypass the reaction cell for dark noise measurement once every minute, which is then subtracted as a measurement offset from the raw concentration signal.

Table 12-2: T200 Valve Cycle Phases

Phase	NO/ NO_X Valve Status	Auto Zero Valve Status	Time Index	Activity	Figure
NO Measure	Open to Auto Zero valve	Open to reaction cell	0 - 2 s	Wait period (NO dwell time). Ensures reaction cell has been flushed of previous gas.	Figure 12-3
			2 - 4 s	Analyzer measures chemiluminescence in reaction cell.	
NO_X Measure	Open to NO_2 converter	Open to reaction cell	4 – 6 s	Wait period (NO_X dwell time). Ensures reaction cell has been flushed of previous gas.	Figure 12-3
			6 – 8 s	Analyzer measures NO + O_3 chemiluminescence in reaction cell.	
Cycle repeats every ~8 seconds					
Auto Zero	Open to Auto Zero valve	Open to vacuum manifold	0 – 4 s	Wait period (AZERO dwell time). Ensures reaction cell has been flushed of sample gas and chemi-luminescence reaction is stopped.	Figure 12-4
			4 - 6 s	Analyzer measures background noise without sample gas	
Cycle repeats every minute					

12.2.2. FLOW RATE CONTROL - CRITICAL FLOW ORIFICES

Sample gas flow in the T200 analyzer is created via the use of several flow control assemblies (see Figure 12-8 for an example) located in various places in the gas streams of the instrument. These assemblies consist of:

- A critical flow orifice.
- Two o-rings: Located just before and after the critical flow orifice, the o-rings seal the gap between the walls of assembly housing and the critical flow orifice.
- A Sintered Filter.
- A spring: Applies mechanical force needed to form the seal between the o-rings, the critical flow orifice and the assembly housing.

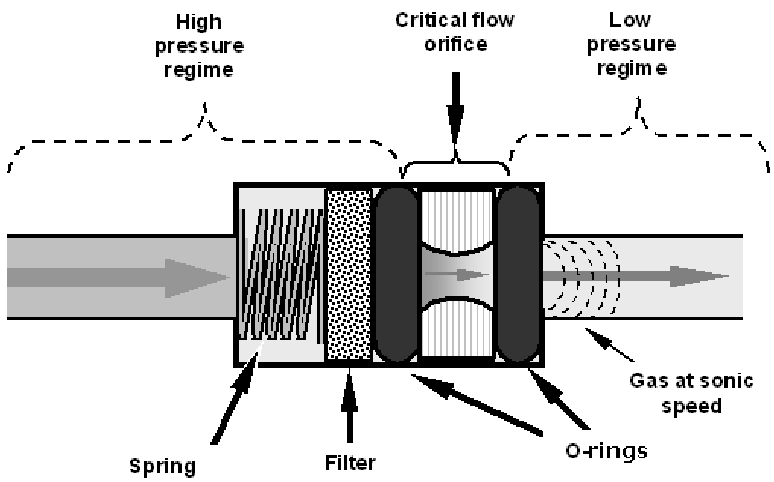


Figure 12-8: Flow Control Assembly & Critical Flow Orifice

12.2.2.1. Critical Flow Orifice

The most important component of each flow control assembly is the critical flow orifice. Critical flow orifices are a simple means to regulate stable gas flow rates. They operate without moving parts by taking advantage of the laws of fluid dynamics. By restricting the flow of gas through the orifice, a pressure differential is created. This pressure differential, created by the analyzer's external pump, draws the gas through the orifice.

As the pressure on the downstream side of the orifice (the pump side) continues to drop, the speed that the gas flows though the orifice continues to rise. Once the ratio of upstream pressure to downstream pressure is greater than 2:1, the velocity of the gas through the orifice reaches the speed of sound. As long as that ratio stays at least 2:1, the gas flow rate is unaffected by any fluctuations, surges, or changes in downstream pressure because such variations only travel at the speed of sound themselves and are therefore cancelled out by the sonic shockwave at the downstream exit of the critical flow orifice.

The actual flow rate of gas through the orifice (volume of gas per unit of time), depends on the size and shape of the aperture in the orifice. The larger the hole, the more gas molecules (moving at the speed of sound) pass through the orifice.

In addition to controlling the gas flow rates into the reaction cell, the two critical flow orifices at the inlets of the reaction cell also maintain an under-pressure inside it, effectively reducing the number of molecules in the chamber and the corresponding incidence of third body quenching (see Section 12.1.5.2) and therefore increasing the chemiluminescence yield.

- The T200 reaches its peak sensitivity at about 2 in-Hg-A, below which the sensitivity drops due to there being too few molecules present and a corresponding decrease in chemiluminescence.

12.2.2.2. Locations and Descriptions of Critical Flow Orifices Inside the T200

The T200 uses several of the following critical flow orifices (Figure 12-9) to create and maintain the proper flow rate of gas through its various components. (Please note that not all features displayed in Figure 12-9 are standard components of T200 analyzers).

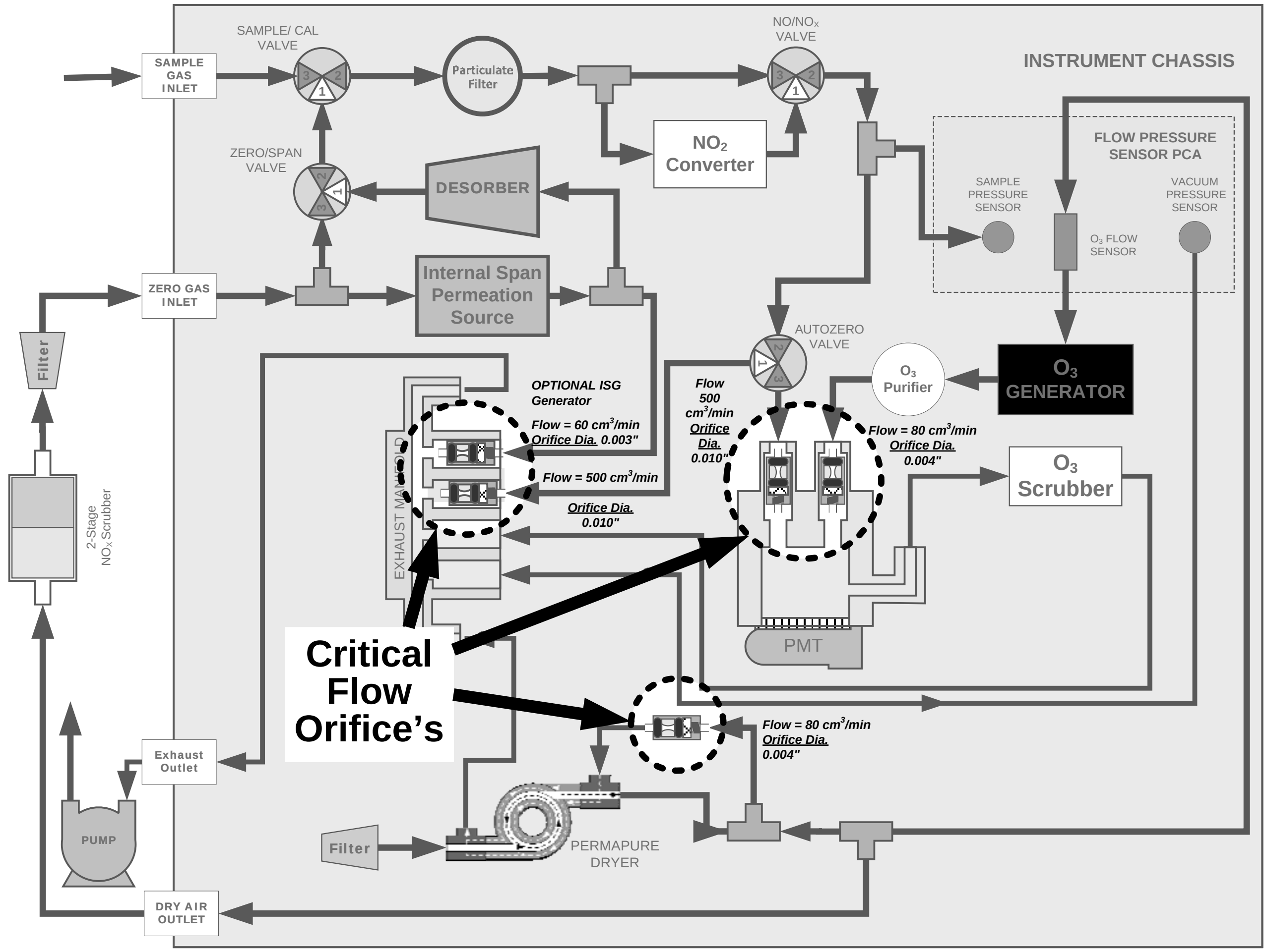


Figure 12-9: Location of Flow Control Assemblies & Critical Flow Orifices

Table 12-3: T200 Gas Flow Rates

Location	Purpose	Orifice Diameter	Flow rate (nominal)
Sample gas inlet of reaction cell	Controls rate of flow of sample gas into the reaction cell.	0.010" (0.25 mm)	500 cm³/min
O_3 supply inlet of reaction cell	Controls rate of flow of ozone gas into the reaction cell.	0.004" (0.10 mm)	80 cm³/min
Dry air return of Perma Pure® dryer	Controls flow rate of dry air return / purge air of the dryer.	0.004" (0.10 mm)	80 cm³/min
Vacuum manifold, Auto Zero port.	Controls rate of sample gas flow when bypassing the reaction cell during the Auto Zero cycle.	0.010" (0.25 mm)	500 cm³/min
Vacuum manifold, Internal span gas generator exhaust port	Controls rate of flow of zero purge gas through the optional Internal span gas generator when it is installed.	0.003" (0.10 mm)	60 cm³/min

The necessary 2:1 ratios across the critical flow orifices is largely exceeded by the pumps supplied with the analyzer which are designed to accommodate a wide range of possible variability in atmospheric pressure and age related degradation of the pump itself. Once the pump does degrade the ratio between sample and vacuum pressures may fall to less than 2:1. At this point, the instrument will display an invalid sample flow rate measurement (**XXXX**).

NOTE

The diameter of a critical flow orifice may change with temperature because of expansion of the orifice material and, hence, the most crucial critical flow orifices in the T200 (those controlling the sample gas and O_3 flow into the cell itself) are located in the reaction cell where they can be maintained at a constant temperature.

12.2.3. OZONE GAS GENERATION AND AIR FLOW

The excess ozone needed for reaction with NO in the reaction cell is generated inside the analyzer because of the instability and toxicity of ozone. Besides the ozone generator itself, this requires a dry air supply and filtering of the gas before it is introduced into the reaction cell.

Due to its toxicity and aggressive chemical behavior, O_3 must also be removed from the gas stream before it can be vented through the exhaust outlet.

CAUTION

GENERAL SAFETY HAZARD

Ozone (O_3) is a toxic gas.

Obtain a Material Safety Data Sheet (MSDS) for this gas. Read and rigorously follow the safety guidelines described there.

Always ensure that the plumbing of the O_3 generation and supply system is maintained and leak-free.

12.2.3.1. The O_3 Generator

The T200 uses a dual-dielectric, Corona Discharge (CD) tube for creating its O_3, which is capable of producing high concentrations of ozone efficiently and with low excess heat (see Figure 12-10). The primary component of the generator is a glass tube with hollow walls of which the outermost and innermost surfaces are coated with electrically conductive material.

Air flows through the glass tube, between the two conductive coatings, in effect creating a capacitor with the air and glass acting as the dielectric. The layers of glass also separate the conductive surfaces from the air stream to prevent reaction with the O_3. As the capacitor charges and discharges, electrons are created and accelerated across the air gap and collide with the O_2 molecules in the air stream splitting them into elemental oxygen.

Some of these oxygen atoms recombine with O_2 to O_3. The quantity of ozone produced is dependent on factors such as the voltage and frequency of the alternating current applied to the CD cells. When enough high-energy electrons are produced to ionize the O_2 molecules, a light emitting, gaseous plasma is formed, which is commonly referred to as a corona, hence the name corona discharge generator.

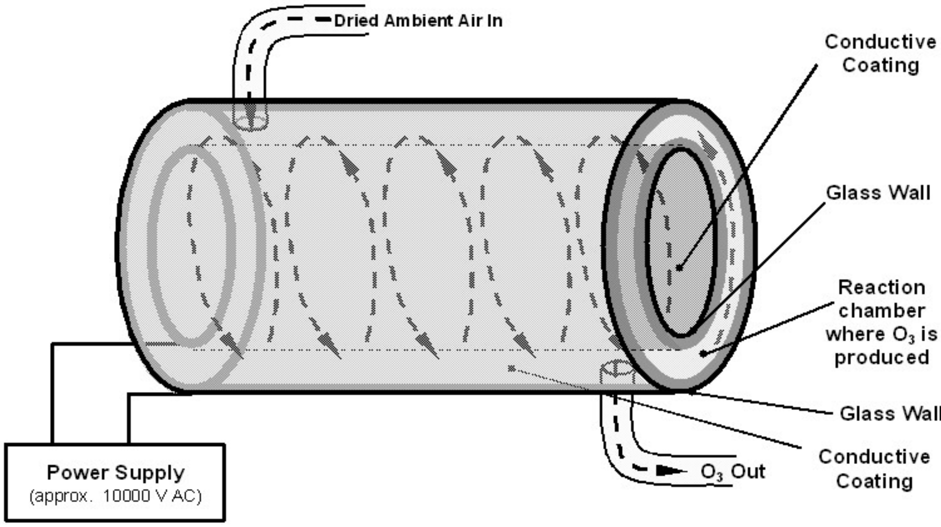


Figure 12-10: Ozone Generator Principle

12.2.3.2. Ozone Generator Dry Air Supply

Ambient air usually contains enough water vapor to greatly diminishes the yield of ozone produced by the ozone generator. Water also reacts with chemicals inside the O_3 Generator to produce caustic substances such as ammonium sulfate or highly corrosive nitric acid that will damage the optical filter located between the reaction cell and the PMT.

To prevent this, the air supply for the O_3 generator is dried using a special Perma Pure® single tube permeation dryer. The dryer consists of a single tube of Nafion® that is mounted within an outer, flexible plastic tube. Nafion® is a co-polymer that absorbs water very well but not most other chemicals. As gas flows through the inner Nafion® tube, water vapor is absorbed into the membrane walls. The absorbed water is transported through the membrane wall and evaporated into the dry purge gas flowing through the outer tube, countercurrent to the gas in the inner tube.

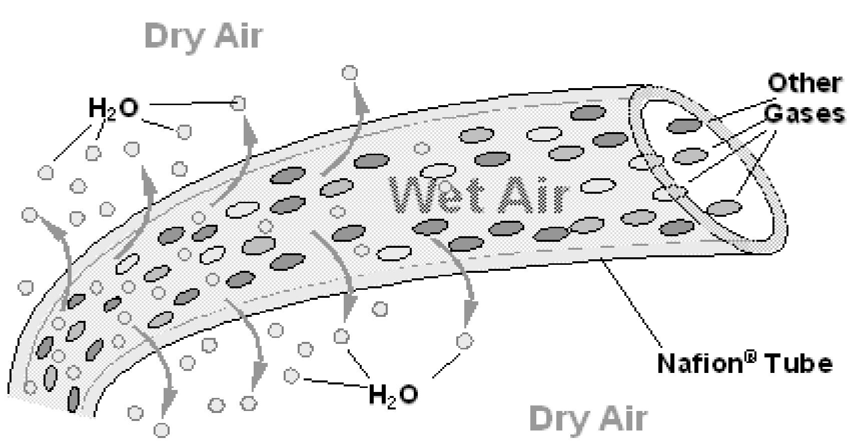


Figure 12-11: Semi-Permeable Membrane Drying Process

The process by which the water vapor molecules are collected and transported through Nafion® material is called per-evaporation and is driven by the humidity gradient between the inner and outer tubes as well as the flow rates and pressure difference between inner and outer tubing. Unlike micro-porous membrane permeation, which transfers water through a relatively slow diffusion process, per-evaporation is a simple kinetic reaction. Therefore, the drying process occurs quickly, typically within milliseconds.

Because this chemical reaction is based on hydrogen bonds between the water molecule and the Nafion® material most other chemical components of the gas to be dried are usually unaffected. Specifically, the gases of interest for the T200, NO and NO_2, do not get absorbed and pass the dryer unaltered.

On the other hand, other small polar gases that are capable of hydrogen bonds such as ammonia (NH_3) can be absorbed this way, too. This is an advantage since gases such as NH_3 can cause interference for the measurement of NO_x, NO and NO_2 (see Table 12-1).

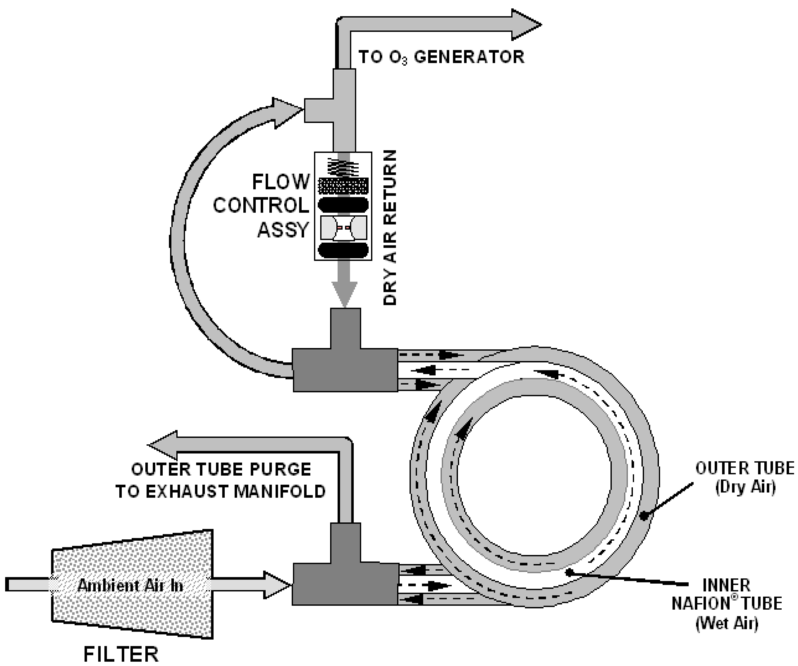


Figure 12-12: T200 Perma Pure® Dryer

To provide a dry purge gas for the outer side of the Nafion tube, the T200 returns some of the dried air from the inner tube to the outer tube. This means that any time the analyzer is turned on after having been OFF for 30 minutes or more, the humidity gradient between the inner and outer tubes is not very large and the dryer's efficiency is low. Since it takes a certain amount of time for the humidity gradient to become large enough for the Perma Pure® Dryer operate efficiently, in such cold start cases the O_3 Generator is not turned on until 30 minutes has passed in order to ensure that it is not operating until its air supply is properly dry. During this 30 minute duration the O3 GEN OVERRIDE menu displays "TMR" on the front panel screen.

NOTE

When rebooting the instrument within less than 30 minutes of power-down, the generator is turned on immediately.

The Perma Pure® Dryer used in the T200 is capable of adequately drying ambient air to a dew point of ≤ -5˚C (~4000 ppm residual H_2O) at a flow rate of 1 standard liter per minute (slpm) or down to ≤ -15˚C (~1600 ppm residual H_2O) at 0.5 slpm. The Perma Pure® Dryer is also capable of removing ammonia from the sample gas up to concentrations of approximately 1 ppm.

12.2.3.3. Ozone Supply Air Filter

The T200 uses ambient air as the supply gas for the O_3 generator and may produce a variety of byproducts. Small amounts of water, ammonia and various sulfur oxides can combine to create ammonium sulfate, ammonium nitrate, nitric acid and other compounds. Whereas sulfates and nitrates can create powdery residues inside the reaction cell causing sensitivity drift, nitric acid is a very aggressive compound, which can deteriorate the analyzer's components. In order to remove these chemical byproducts from the O_3 gas stream, the output of the O_3 generator flows through a special filter between the generator and the reaction cell.

The small amount of NO_X produced in the generator (from the reaction of O_2 or O_3 and N_2 in the air) will not affect the T200's ability to measure NO_x, NO and NO_2 as it is accounted for and removed from the concentration calculations by the analyzer's Auto Zero feature (see Section 12.1.4).

12.2.3.4. Ozone Scrubber

Even though ozone is unstable and typically reacts to form O_2, the break-down is not quite fast enough to ensure that it is completely removed from the exhaust gas stream of the T200 by the time the gas exits the analyzer. Due to the high toxicity and reactivity of O_3, a highly efficient catalytic converter scrubs or converts all of the O_3 from the gas exiting the reaction cell. The conversion process is very safe. It only converts ozone to oxygen and does not produce any toxic or hazardous gases.

The O_3 scrubber is located just inside the NO_2 converter. As this is a true catalytic converter, there are no maintenance requirements as would be required for charcoal-based scrubbers.

A certain amount of fine, black dust may exit the catalyst, particularly if the analyzer is subjected to sudden pressure drops (for example, when disconnecting the running pump without letting the analyzer properly and slowly equilibrate to ambient pressure). To prevent the dust from entering the reaction cell or the pump, the scrubber is equipped with a quartz wool filter material.

12.2.4. PNEUMATIC SENSORS

NOTE
The T200 displays all pressures in inches of mercury absolute (in-Hg-A), i.e. absolute pressure referenced against zero (a perfect vacuum).

The T200 uses three pneumatic sensors to verify the flow and pressure levels of its gas streams. They are located on a printed circuit assembly, called the pneumatic pressure/flow sensor board, located just behind the sensor assembly. The measurements made by these sensors are used for a variety of important calculations and diagnostics.

12.2.4.1. Sample Pressure Sensor

An absolute pressure transducer connected to the input of the NO/NO_X valve is used to measure the pressure of the sample gas before it enters the analyzer's reaction cell.

- In conjunction with the measurement made by the vacuum pressure sensor, this "upstream" measurement is used to compute the sample gas sample flow rate and to validate the critical flow condition (2:1 pressure ratio) through the sample gas critical flow orifice (Section 12.2.2).
- If the Temperature/Pressure Compensation (TPC) feature is turned on (Section 12.9.2), the output of this sensor is also used to supply pressure data for that calculation.
- The actual pressure value is viewable through the analyzer's front panel display as the test function **SAMP**.

- The flow rate of the sample gas is displayed as **SAMP FLW** and the **SIGNAL I/O** function **SAMPLE_PRESSURE**.

12.2.4.2. Vacuum Pressure Sensor

An absolute pressure transducer connected to the exhaust manifold is used to measure the pressure downstream from and inside the instrument's reaction cell.

- The output of the sensor is used by the CPU to calculate the pressure differential between the gas upstream of the reaction cell and the gas downstream from it and is also used as the main diagnostic for proper pump operation.
- If the ratio between the upstream pressure and the downstream pressure falls below 2:1, a warning message (**SAMPLE FLOW WARN**) is displayed on the analyzer's front panel (see Section 7.2.2) and the sample flow rate will display **XXXX** instead of an actual value.
- If this pressure exceeds 10 in-Hg-A, an **RCEL PRESS WARN** is issued, even though the analyzer will continue to calculate a sample flow up to ~14 in Hg.
- If the Temperature/Pressure Compensation (TPC) feature is turned on (see Section 12.9.2), the output of this sensor is also used to supply pressure data for that calculation.
- This measurement is viewable through the analyzer's front panel as the test function **RCEL** and the **SIGNAL I/O** function **RCELL_PRESSURE**.

12.2.4.3. Sample Gas Flow Calculation

Sample gas flow in the T200 analyzer is not a directly measured value, but is rather calculated based on the measured pressure differential across the sample gas critical flow orifice. Specifically, the upstream reading of the sample pressure sensor is compared to the downstream pressure reading of the vacuum pressure sensor and this differential is used, by the analyzer's CPU, to derive the gas flow rate through the reaction cell.

- The results of this calculation are viewable from the instruments front panel via the test function **SAMP FLW.**
- Since this is a calculated value and not a measured reading there is no corresponding **SIGNALI/O** function.

12.2.4.4. O_3 Supply Air Flow Sensor

In contrast to the sample gas flow, the ozone flow is measured with a mass flow sensor, which is mounted on the flow/pressure sensor PCA just behind the PMT sensor assembly. Pneumatically, it lies between the Perma Pure® dryer and the O_3. This mass flow sensor has a full scale range of 0-1000 cm^3/min and can be calibrated through software to its span point (Section 10.7).

Since the flow value displayed on the front panel is an actual measurement (and not a calculated value), short term variability in the measurement may be higher than that of the sample flow, which is based on a calculation from (more stable) differential pressures. On the other hand, any sustained drift, i.e. long-term change, in the ozone flow rate may usually indicate a flow problem.

This information is used to validate the O_3 gas flow rate.

- If the flow rate exceeds ±15% of the nominal flow rate (80 cm^3/min), a warning message **OZONE FLOW WARNING** is displayed on the analyzer's front panel (see Section 7.2.2) and the O_3 generator is turned off.
  - A second warning, **OZONE GEN OFF** is also displayed.
- This flow measurement is viewable through instrument's front panel display as the test function **OZONE FL** and the **SIGNAL I/O** function **OZONE_FLOW**.

As with all other test parameters, we recommend to monitor the ozone flow over time for predictive diagnostics and maintenance evaluation.

12.3. ELECTRONIC OPERATION

12.3.1. OVERVIEW

Figure 12-13 shows a block diagram of the major electronic components of the analyzer.

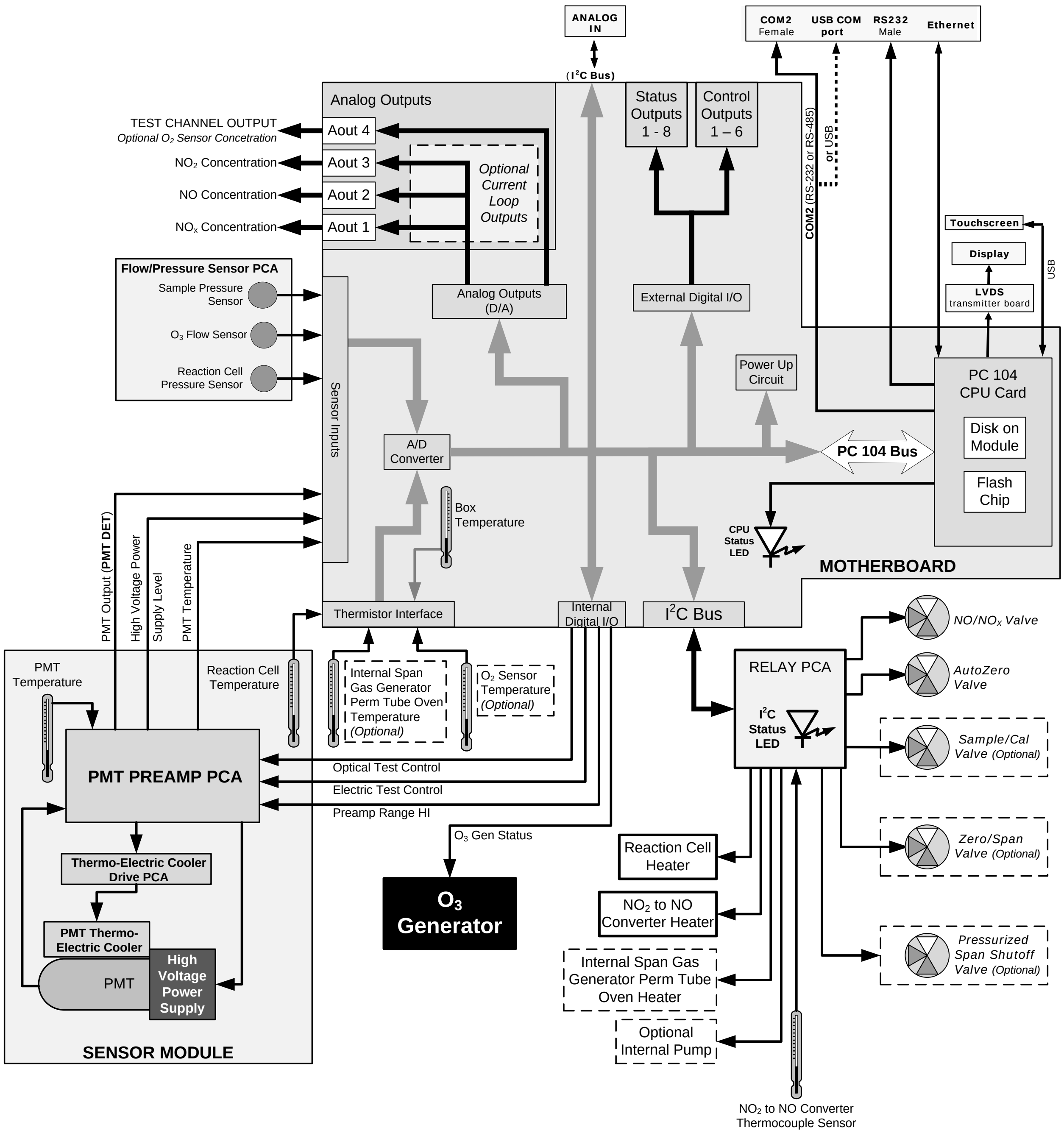


Figure 12-13: T200 Electronic Block Diagram

The core of the analyzer is a microcomputer/central processing unit (CPU) that controls various internal processes, interprets data, makes calculations, and reports results using specialized firmware developed by Teledyne API. It communicates with the user as well as receives data from and issues commands to a variety of peripheral devices via a separate printed circuit assembly onto which the CPU is mounted: the motherboard.

The motherboard is directly mounted to the inside rear panel and collects data, performs signal conditioning duties and routes incoming and outgoing signals between the CPU and the analyzer's other major components.

Data are generated by the sensor module which outputs an analog signal corresponding to the amount of chemiluminescence present in the reaction cell. This signal is converted into digital data by a unipolar, analog-to-digital converter, located on the motherboard.

A variety of sensors report the physical and operational status of the analyzer's major components, again through the signal processing capabilities of the motherboard. These status reports are used as data for the various concentration calculations and as trigger events for certain warning messages and control commands issued by the CPU. This information is stored in memory by the CPU and in most cases can be viewed by the user via the front panel display.

The CPU issues commands via a series of relays and switches (also over the I^2C bus) located on a separate printed circuit assembly, called the relay PCA, to control the function of key electromechanical devices such as heaters and valves. It also issues some commands directly to the Sensor module (e.g. initiate Electric Test or Optical Test).

By controlling the state of various valves the CPU directs the flow of sample gas through the various gas paths of the analyzer (NO measurement path; NO_x measurement path; Auto Zero Path). Based on which path is active, the CPU interprets the sensor output to derive raw data representing concentrations for NO_x, NO and zero (dark condition), accesses the operational data stored in memory then calculates final concentrations for NO_x, NO and NO_2.

The CPU communicates with the user and the outside world in several ways:

- Through the analyzer's front panel LCD touch-screen interface
- Through the serial I/O channels
- Various analog voltage and current outputs
- Several sets of Digital I/O channels
- Ethernet

12.3.2. CPU

The unit's CPU card, installed on the motherboard located inside the rear panel, is a low power (5 VDC, 720mA max), high performance, Vortex86SX-based microcomputer running Windows CE. Its operation and assembly conform to the PC 104 specification.

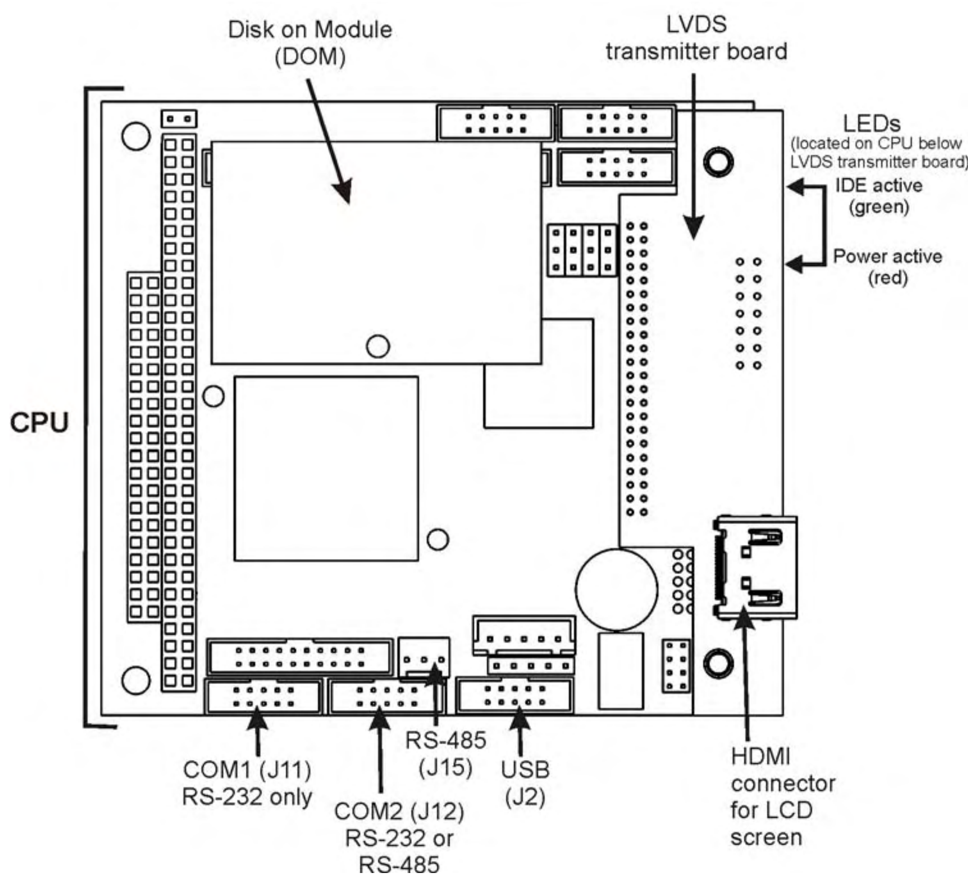


Figure 12-14: CPU Board

The CPU includes two types of non-volatile data storage: a Disk-on-Module (DOM) and an embedded flash chip.

DISK-ON-MODULE

The DOM is a 44-pin IDE flash drive with storage capacity to 128 MB. It is used to store the computer's operating system, the Teledyne API firmware, and most of the operational data generated by the analyzer's internal data acquisition system (DAS).

FLASH CHIP

This non-volatile, embedded flash chip includes 2MB of storage for calibration data as well as a backup of the analyzer configuration. Storing these key data on a less heavily accessed chip significantly decreases the chance of data corruption.

In the unlikely event that the flash chip should fail, the analyzer will continue to operate with just the DOM. However, all configuration information will be lost, requiring that the unit be recalibrated.

12.3.3. MOTHERBOARD

This PCA provides a multitude of functions including, A/D conversion, digital input/output, PC-104 to I^2C translation, temperature sensor signal processing and is a pass through for the RS-232 and RS-485 signals.

12.3.3.1. A to D Conversion

Analog signals, such as the voltages received from the analyzers various sensors, are converted into digital signals that the CPU can understand and manipulate by the analog to digital converter (A/D). Under the control of the CPU, this functional block selects a particular signal input and then coverts the selected voltage into a digital word.

The A/D consists of a Voltage-to-Frequency (V-F) converter, a Programmable Logic Device (PLD), three multiplexers, several amplifiers and some other associated devices. The V-F converter produces a frequency proportional to its input voltage. The PLD counts the output of the V-F during a specified time, and sends the result of that count, in the form of a binary number, to the CPU.

The A/D can be configured for several different input modes and ranges but in the T200 it is used in unipolar mode with a +5V full scale. The converter includes a 1% over and under-range. This allows signals from –0.05V to +5.05V to be fully converted.

For calibration purposes, two reference voltages are supplied to the A/D converter: Reference ground and +4.096 VDC. During calibration, the device measures these two voltages, outputs their digital equivalent to the CPU. The CPU uses these values to compute the converter's offset and slope and uses these factors for subsequent conversions. See Section 8.4.7 for instructions on performing this calibration.

12.3.3.2. Sensor Inputs

The key analog sensor signals are coupled to the A/D through the master multiplexer from two connectors on the motherboard. 100K terminating resistors on each of the inputs prevent cross talk from appearing on the sensor signals.

PMT DETECTOR OUTPUT: The PMT detector output from the PMT preamplifier is used in the computation of the NO, NO_X and NO_2 concentrations displayed on the front panel display and reported through the instrument's analog outputs and COMM ports.

- This information is available in several forms:
- As a raw voltage signal via the test function **PMTDET** and the SIGNAL I/O function **PMT_SIGNAL**, or;
- Normalized for temperature, pressure and auto-zero offset via the front panel test function **NORM PMT**.
- It is recorded by the DAS system in the following parameters:
  - **PMTDET** – The same as the test function **PMT DET**.
  - **RAWNOX** – The raw PMT output when the instrument is measuring NO_X.
  - **RAW NO** – The raw PMT output when the instrument is measuring NO.

HIGH VOLTAGE POWER SUPPLY LEVEL: The PMT high voltage is based on the drive voltage from the preamplifier board. It is digitized and sent to the CPU where it is used to calculate the voltage setting of the HVPS.

- The value of this signal is viewable via the front panel test function **HVPS** and the SIGNAL I/O function **HVPS_VOLTAGE**.
- It is recorded by the DAS system as the parameter **HVPS**.

PMT TEMPERATURE: The PMT temperature is measured with a thermistor inside the PMT cold block. Its signal is amplified by the PMT temperature feedback circuit on the preamplifier board and is digitized and sent to the CPU where it is used to calculate the current temperature of the PMT.

- The value of this signal is viewable via the front panel test function **PMT TEMP** and the SIGNAL I/O function **PMT_TEMP**.
- It is recorded by the DAS system as the parameter **PMTTMP**.

SAMPLE GAS PRESSURE SENSOR: This sensor, located on the flow/pressure sensor PCA, measures the gas pressure in the sample chamber upstream of the sample gas stream flow control assembly. Its functions are described in Section 12.2.4.1.

- The value of this signal is viewable via the front panel test function **SAMP** and the SIGNAL I/O function **SAMPLE_PRESSURE**.
- It is recorded by the DAS system as the parameter **SMPPRS**.

VACUUM PRESSURE SENSOR: This sensor, also located on the flow/pressure sensor PCA, is pneumatically located downstream from the reaction cell and measures the pressure of the gas mixture inside the reaction cell . Its functions are described in Section 12.2.4.2.

- The value of this signal is viewable via the front panel test function **RCEL** and the SIGNAL I/O function **RCEL_PRESSURE**.
- It is recorded by the DAS system as the parameter **RCPRES**.

O_3 FLOW SENSOR: This sensor, located on the flow/pressure sensor PCA, measures the flow rate of the O_3 gas stream as it is supplied to the reaction cell. Its functions are described in Section 12.2.4.4.

- The value of this signal is viewable via the front panel test function **OZONE FLOW** and the SIGNAL I/O function **OZONE_FLOW**.
- It is recorded by the DAS system as the parameter **O3FLOW**.

12.3.3.3. Thermistor Interface

This circuit provides excitation, termination and signal selection for several negative coefficient, thermistor temperature sensors located inside the analyzer. They are:

REACTION CELL TEMPERATURE SENSOR: The reaction cell temperature sensor is a thermistor embedded in the reaction cell manifold. This temperature is used by the CPU to control the reaction cell heating circuit and as a parameter in the temperature/pressure compensation algorithm.

- The value of this signal is viewable via the front panel test function **RCEL TEMP** and the SIGNAL I/O function **RCELL_TEMP**.
- It is recorded by the DAS system as the parameter **RCTEMP**.

BOX TEMPERATURE SENSOR: A thermistor is attached to the motherboard. It measures the analyzer's inside temperature. This information is stored by the CPU and can be viewed by the user for troubleshooting purposes through the front panel display. It is also used as part of the NO, NO_x and NO_2 calculations when the instrument's Temperature/Pressure Compensation feature is enabled.

- The value of this signal is viewable via the front panel test function **BOX TEMP** and the SIGNAL I/O function **BOX_TEMP**.
- It is recorded by the DAS system as the parameter **BOXTMP**.

INTERNAL SPAN GAS GENERATOR OVEN_temperature: This thermistor reports the temperature of the optional internal span gas generator's NO_2 permeation source to the CPU as part of a control loop that keeps the tube at a high constant temperature (necessary to ensure that the permeation rate of NO_2 is constant). It is stored and reported as test function **IZS TEMP**.

- The value of this signal is viewable via the front panel test function **IZS TEMP** and the SIGNAL I/O function **IZS_TEMP**.
- It is recorded by the DAS system as the parameter **IZTEMP**.

NOTE

There are two thermistors that monitor the temperature of the PMT assembly.

One is imbedded in the cold block of the PMT's TEC. Its signal is conditioned by the PMT preamplifier PCA and reported to the CPU via the motherboard (see Section 12.3.3.2).

The second is located on the PMT Preamplifier PCA and is used only as a reference for the preamplifier circuitry. Its output is neither reported nor stored.

12.3.3.4. Analog Outputs

The analyzer comes equipped with four analog outputs. On the instrument's rear panel analog connector (see Figure 3-4), they are labeled **A1**, **A2**, **A3** and **A4**.

- CONCENTRATION OUTPUTS: Outputs labeled **A1**, **A2** and **A3** carry the concentration signals of NO_X, NO and NO_2, respectively. A variety of scaling measurement and electronic factors apply to these signals.
  - See Section 7.4.4 for information on setting the reporting range type and measurement range scaling factors for these output channels.
  - See Sections 8.4.3 for instructions calibrating and scaling the electronic output of these channels.
- TEST OUTPUT: The fourth analog output, labeled **A4** is special. It can be set by the user (see Section 8.4.6) to carry the current signal level of most of the parameters accessible through the **TEST** menu of the unit's software.

In its standard configuration, the T200 comes with all four of these channels set up to output a DC voltage. However, 4-20mA current loop drivers can be purchased for the first three of these outputs, **A1, A2** and **A3**.

OUTPUT LOOP-BACK: All of the functioning analog outputs are connected back to the A/D converter through a Loop-back circuit. This permits the voltage outputs to be calibrated by the CPU without need for any additional tools or fixtures (see Section 8.4.3.2).

12.3.3.5. External Digital I/O

This external digital I/O performs two functions.

- STATUS OUTPUTS: Logic-Level voltages (0-5 VDC) are output through an optically isolated 8-pin connector located on the rear panel of the analyzer (see Figure 3-4). These outputs convey good/bad and on/off information about certain analyzer conditions. They can be used to interface with certain types of programmable devices.

  For information on setting up the status outputs (see Section 3.5.4).
- CONTROL INPUTS: By applying 5V DC power to these digital inputs from an external source such as a PLC or Data logger zero point and span point calibrations can be remotely initiated. .

  For information on setting up the status inputs (see Section 3.5.5).

12.3.3.6. Internal Digital I/O

There are several internal digital control signals that are generated by the motherboard under CPU control and used to control subsystems of the analyzer.

ELECTRICAL TEST CONTROL: When the CPU sets this control signal to high (**ON**) the electric test feature (**ETEST**) is initiated (see Section 8.3).

- The **ETEST** can be initiated by following the procedure in Section 14.7.12.3, or by setting the SIGNAL I/O Function **ELEC_TEST** to **ON**.

OPTICAL TEST (OTEST) CONTROL: When the CPU sets this control signal to high (**ON**) the optical test feature is initiated (see Section 8.3).

- The **OTEST** can be initiated by following the procedure in 14.7.12.2, or by setting the SIGNAL I/O Function **OPTIC_TEST** to **ON**.

PMT PREAMPLIFIER RANGE CONTROL: The CPU uses this control switch the instrument between its LOW and HIGH physical ranges (see Section 7.4.4.1).

- The instrument can be forced into its HIGH physical range setting the SIGNAL I/O function **PREAMP_RANGE_HI** to **ON**.

O_3 GEN STATUS: The CPU uses this control signal to turn the O_3 generator **ON/OFF** by setting it to HIGH/LOW respectively. The CPU turns **OFF** the O_3 generator if there is if there is no or low air flow to it as measured by the O_3 flow sensor or if the instrument has been turned off for more than 30 minutes.

- The O_3 generator can be manually turned **ON/OFF** by using the **OZONE GENERATOR OVERIDE** feature (See Section 14.7.15.1) or by setting the SIGNAL I/O function **O3GEN_STATUS** to **ON** or **OFF**.

NOTE

Any I/O signals changed while in the SIGNAL I/O menu will remain in effect ONLY until SIGNAL I/O menu is exited.

The analyzer regains control of these signals upon exit and returns them to their normal value/setting.

12.3.3.7. I^2C Data Bus

I^2C is a two-way, clocked, bi-directional digital serial I/O bus that is used widely in commercial and consumer electronic systems. A transceiver on the Motherboard converts data and control signals from the PC-104 bus to I^2C format. The data is then fed to the relay board, optional analog input board and valve driver board circuitry.

12.3.3.8. Power-Up Circuit

This circuit monitors the +5V power supply during start-up and sets the analog outputs, external digital I/O ports, and I^2C circuitry to specific values until the CPU boots and the instrument software can establish control.

12.3.4. RELAY PCA

The CPU issues commands via a series of relays and switches located on a separate printed circuit assembly, called the relay PCA, to control the function of key electromechanical devices such as heaters and valves. The relay PCA receives instructions in the form of digital signals over the I^2C bus, interprets these digital instructions and activates its various switches and relays appropriately.

The relay PCA is located in the right-rear quadrant of the analyzer and is mounted vertically on the backside of the same bracket as the instrument's DC power supplies.

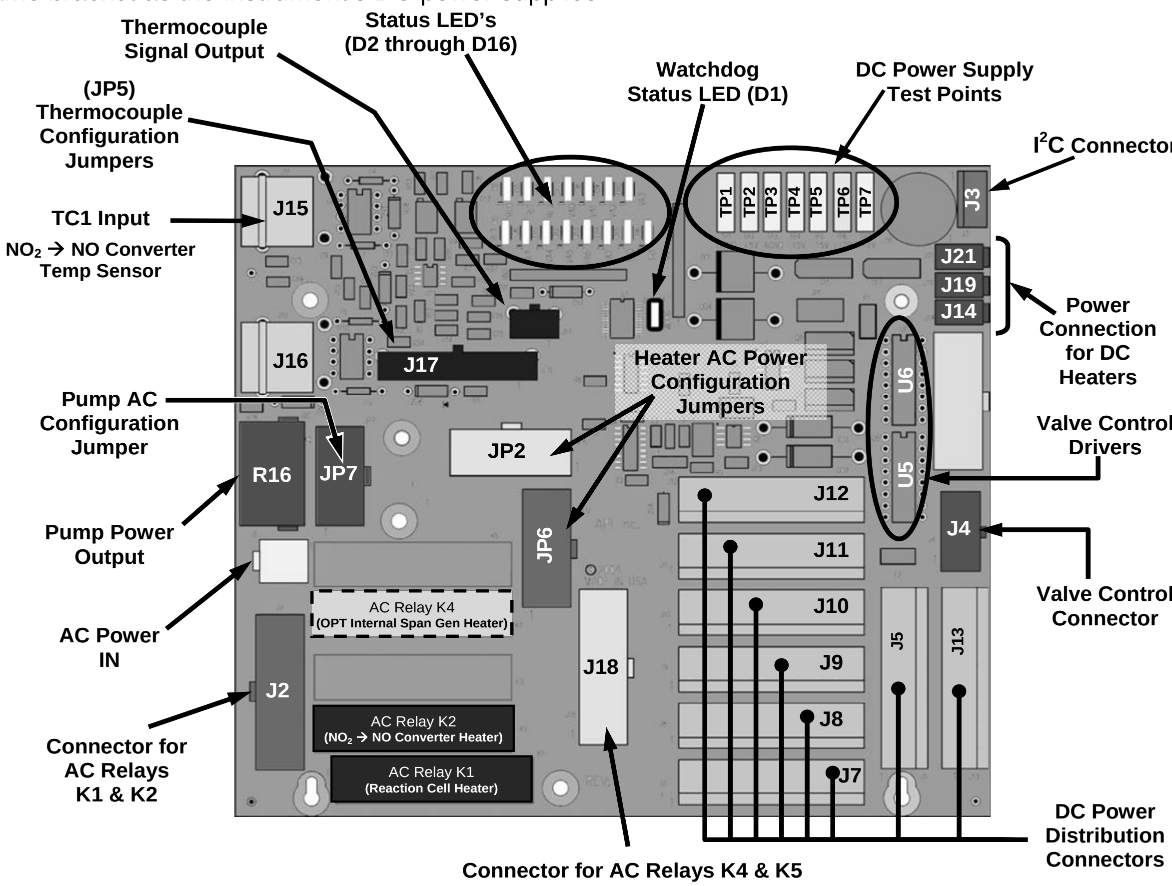


Figure 12-15: Relay PCA Layout (P/N 045230100)

CAUTION

ELECTRICAL SHOCK HAZARD

Only those relays actually required by the configuration of the T200 are populated.

A protective retainer plate is installed over the ac power relay to keep them securely seated in their sockets and prevent accidental contact with those sockets that are not populated see Figure 12-16).

Never remove this retainer while the instrument is plugged in and turned on. The contacts of the AC relay sockets beneath the shield carry high AC voltages even when no relays are present.

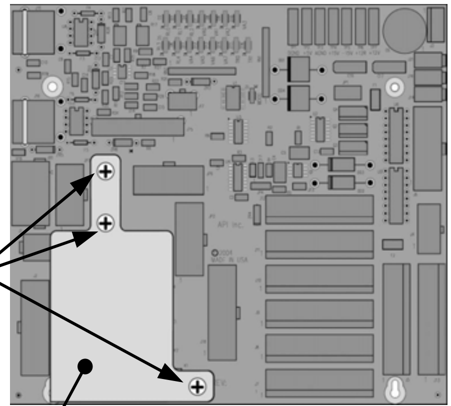


Figure 12-16: Relay PCA P/N 045230100 with AC Relay Retainer in Place

12.3.4.1. Status LED's

Eight LED's are located on the Analyzer's relay PCA to show the current status on the various control functions performed by the relay PCA (see Figure 12-17). They are:

Table 12-4: Relay PCA Status LED's

LED	Color	Function	Status When Lit (Energized State)	Status When Unlit (Default State)
D1	Red	Watchdog Circuit	Cycles **ON/OFF** every 3 Seconds under direct control of the analyzer's CPU.	
D2	Yellow	Reaction Cell Heater	Heating	Not Heating
D3	Yellow	NO_2 → NO Converter Heater	Heating	Not Heating
D4	SPARE			
D5[1]	Yellow	Internal Span Gas Generator Perm Tube Oven Heater	Heating	Not Heating
D6	SPARE			
D7	Green	Zero/Span Valve	Valve **OPEN** to span gas flow	Valve **OPEN** to zero gas flow
D8	Green	Sample/Cal Valve	Valve **OPEN** to calibration gas flow	Valve **OPEN** to sample gas flow
D9	Green	Auto Zero Valve	Sample gas flow **BYPASSES** the reaction cell	Sample gas flow is routed **THROUGH** the reaction cell
D10	Green	NO/NO_x Valve	Gas flow routed **THROUGH** NO_2 → NO converter	Gas Flow **BYPASSES** NO_2 → NO converter
D11[2]	Green	Dual Span Gas Select Valve	Valve **OPEN** to **SPAN 1** gas inlet	Valve **OPEN** to **SPAN2** inlet
D12[3]	Green	Pressurized Span Shutoff Valve	Span gas flow **SHUTOFF**	Span gas flow **OPEN**
D13[4]	Green	Pressurized Zero Shutoff Valve	Zero gas flow **SHUTOFF**	Zero gas flow **OPEN**
D14 - 16	SPARE			

[1] Only active when the optional internal span gas generator is installed.
[2] Only active when the dual pressurized span option is installed.
[3] Only active when one of the pressurized span gas options is installed.
[4] Only active when one the pressurized zero gas option is installed.

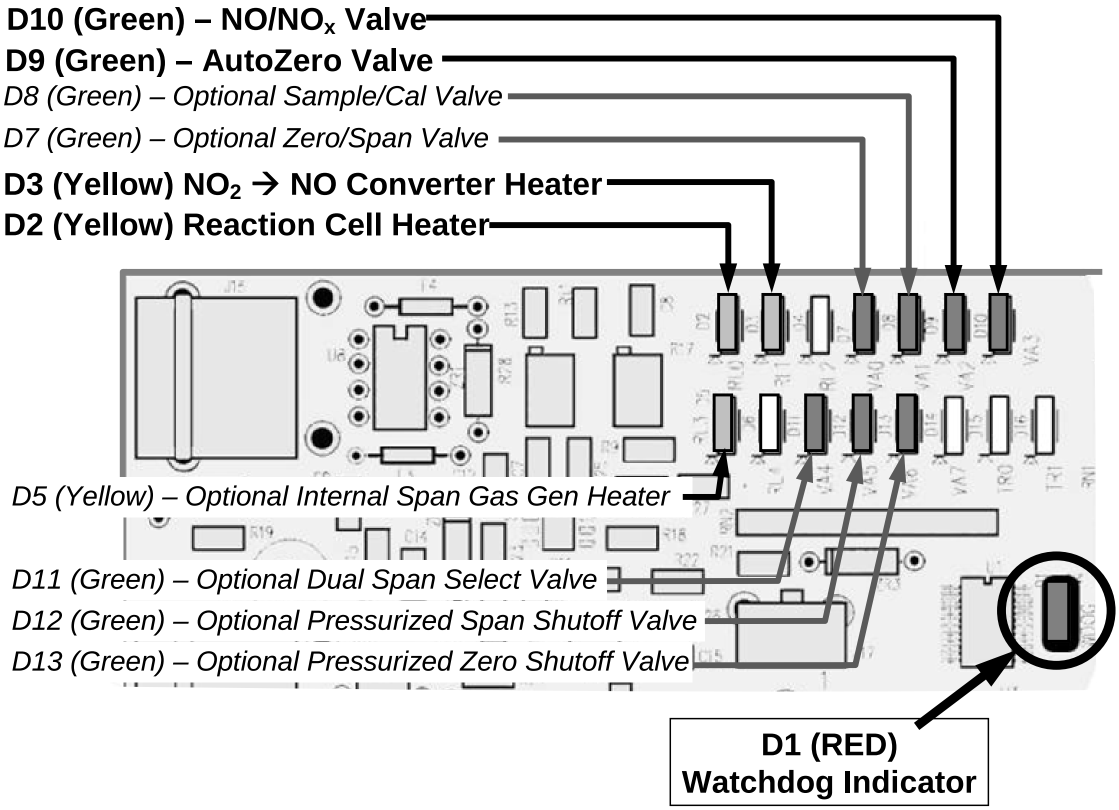


Figure 12-17: Status LED Locations – Relay PCA

12.3.4.2. Watchdog Circuitry

The most important of the status LED's on the relay board is the red I^2C bus watch-dog LED. It is controlled directly by the analyzer's CPU over the I^2C bus. Special circuitry on the relay PCA watches the status of D1. Should this LED ever stay ON or OFF for 30 seconds, indicating that the CPU or I^2C bus has stopped functioning, this Watchdog Circuit automatically shuts all valves and turns off all heaters.

12.3.4.3. Valve Control

The relay board also hosts two valve driver chips, each of which can drive up four valves. The main valve assembly in the T200 is the NO/NO_X - Auto-zero solenoid valve component mounted right in front of the NO_2 converter housing (see Figure 3-5).

- These two valves are actuated with 12 V supplied from the relay board and under the control of the CPU through the I^2C bus.

Additional valves sets also controlled by the CPU via the I^2C bus and the relay PCA can be included in the T200 (see Section 6 for descriptions of these valve sets).

12.3.4.4. Heater Control

For a variety of reasons such as, efficiency of certain chemical reactions, stabilization of sample gas temperature and pressure, etc., various subcomponents of the T200 are heated/cooled.

Two types of sensors are used to gather temperature data for the CPU:

THERMISTORS: These are used in areas where the temperature control point is at or near ambient temperature (e.g. the reaction cell temperature, internal chassis temperate).

- Thermistors change resistance as they heat up and cool down. A DC signal is sent from the Mother board of a sent voltage and current. As the thermistor changes resistance, the returning voltage rises and falls in direct relationship to the change in temperature.
- The output signal from the thermistors is received by the motherboard, converted into digital data which is forwarded to the CPU.

THERMOCOUPLES: These are used where the target temperature is high such as the NO_2 → NO converter.

- Thermocouples generate DC voltage that rises and falls as the thermocouple heats up and cools down.
- This DC signal interpreted, conditioned and amplified by the Relay PCA then transmitted to the motherboard where it is also converted into digital data and forwarded to the CPU.

All of the heaters used in the T200 are AC powered which are turned ON/OFF by AC Relays located on the relay PCA in response to commands issued by the CPU.

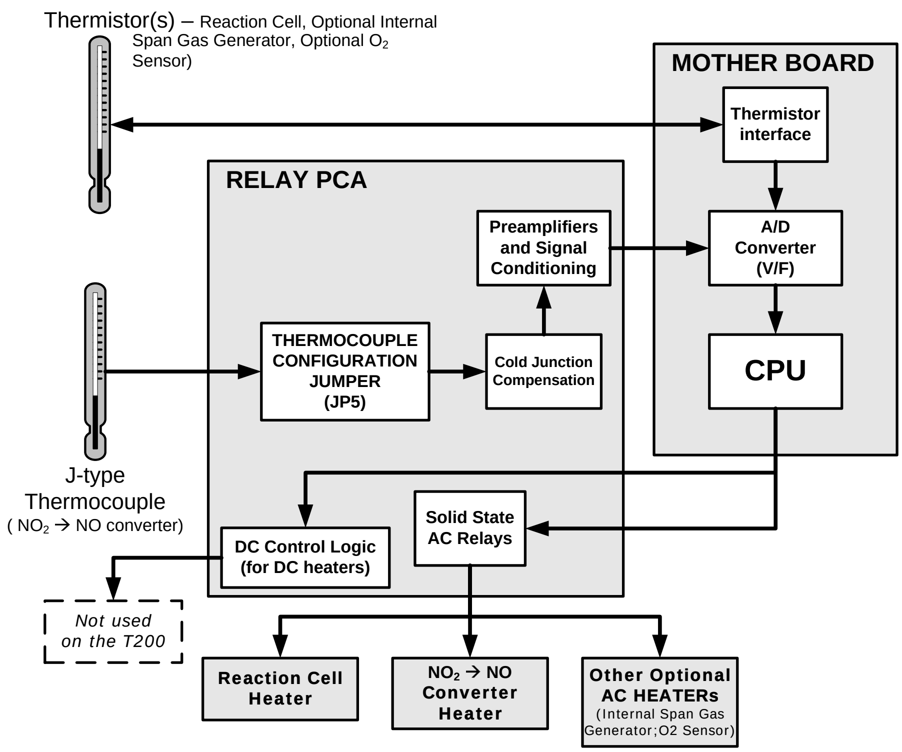


Figure 12-18: Heater Control Loop Block Diagram.

NOTE

The PMT temperature is maintained by a separate control loop that does not involve the relay PCA (see Section 12.5.2).

12.3.4.5. Thermocouple Inputs and Configuration Jumper (JP5)

Although the relay PCA supports two thermocouple inputs, the current T200 analyzers only utilize one. It is used to sense the temperature of the NO_2 → NO converter.

- This single thermocouple input is plugged into the TC1 input (J15).
- TC2 (J16) is currently not used (see Figure 12-15 for location of J15 and J16).

The type and operating parameters of this thermocouple are set using a jumper plug (JP5).

The default configuration for this thermocouple is:

- Type-K
- Temperature compensated for Type-K
- Isolated

Table 12-5: Thermocouple Configuration Jumper (JP5) Pin-Outs

TC INPUT	JUMPER PAIR	DESCRIPTION	FUNCTION
TC1	**1 – 11**	**Gain Selector**	Selects preamp gain factor for J or K TC **OUT = K TC gain factor;** *IN = J TC gain factor*
	2 – 12	*Output Scale Selector*	*Selects preamp gain factor for J or K TC* *OUT = 10 mV / °C; IN = 5 mV / °C*
	3 – 13	*Type J Compensation*	*When present, sets Cold Junction Compensation for J type Thermocouple*
	4 – 14	**Type K Compensation**	When present, sets Cold Junction Compensation for K type Thermocouple
	5 – 15	**Termination Selector**	Selects between Isolated and grounded TC **IN = Isolate TC;** *OUT = Grounded TC*
TC2	*NOT USED*		

CAUTION – Avoid Damaging Instrument

The correct Thermocouple Type must be used if there is ever the need for replacement. If in doubt please consult Teledyne API Customer Service.

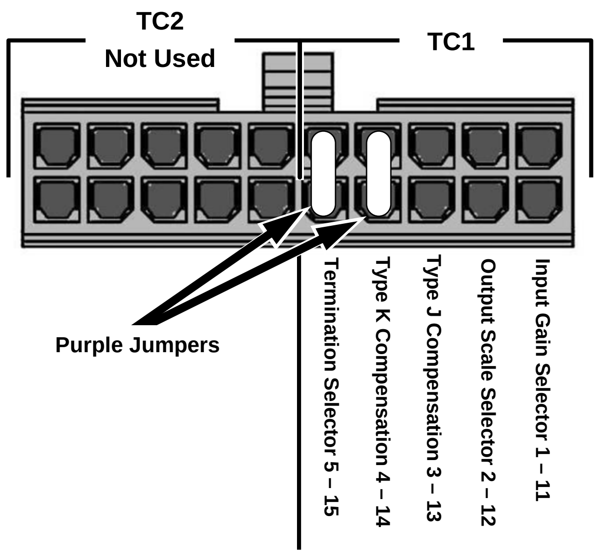


Figure 12-19: Thermocouple Configuration Jumper (JP5) Pin-Outs

12.4. SENSOR MODULE, REACTION CELL

The T200 sensor assembly consists of several subassemblies, each with different tasks:

- The Photo Multiplier Tube (PMT) detects the intensity of the light from the chemiluminescence reaction between NO and O_3 in the reaction cell. It outputs a current signal that varies in relationship with the amount of light in the reaction cell.
- The PMT Preamplifier PCA converts the current output by the PMT into a voltage and amplifies it to a signal strong enough to be usable by the motherboard's A → D converter.

  It also supplies the drive voltage and gain adjustment for the PMT's High Voltage Power Supply (HVPS)
- The Thermo-Electric Cooler (TEC) controls the temperature of the PMT to ensure the accuracy and stability of the measurements.

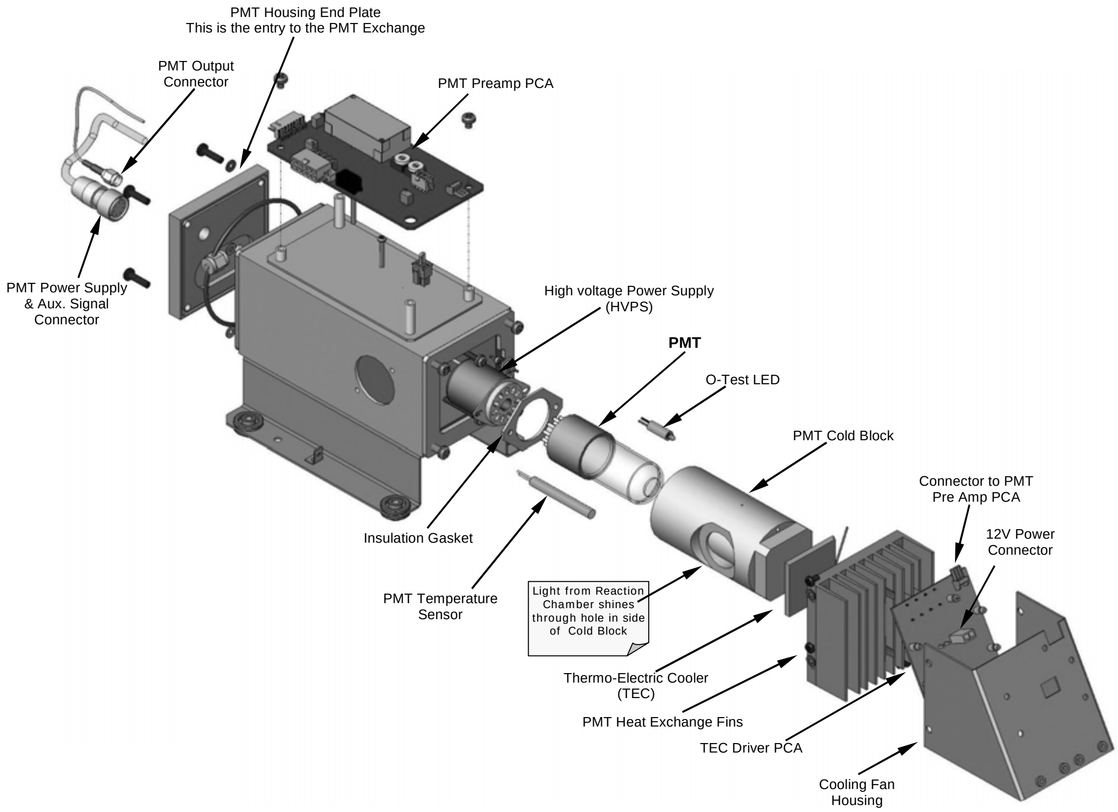


Figure 12-20: T200 Sensor Module Assembly

12.5. PHOTO MULTIPLIER TUBE (PMT)

The T200 uses a photo multiplier tube (PMT) to detect the amount of chemiluminescence created in the Reaction Cell.

A typical PMT is a vacuum tube containing a variety of specially designed electrodes. Photons from the reaction are filtered by an optical high-pass filter, enter the PMT and strike a negatively charged photo cathode causing it to emit electrons. A high voltage potential across these focusing electrodes directs the electrons toward an array of high voltage dynodes.

The dynodes in this electron multiplier array are designed so that each stage multiplies the number of emitted electrons by emitting multiple, new electrons. The greatly increased number of electrons emitted from one end of electron multiplier are collected by a positively charged anode at the other end, which creates a useable current signal. This current signal is amplified by the preamplifier board and then reported to the motherboard.

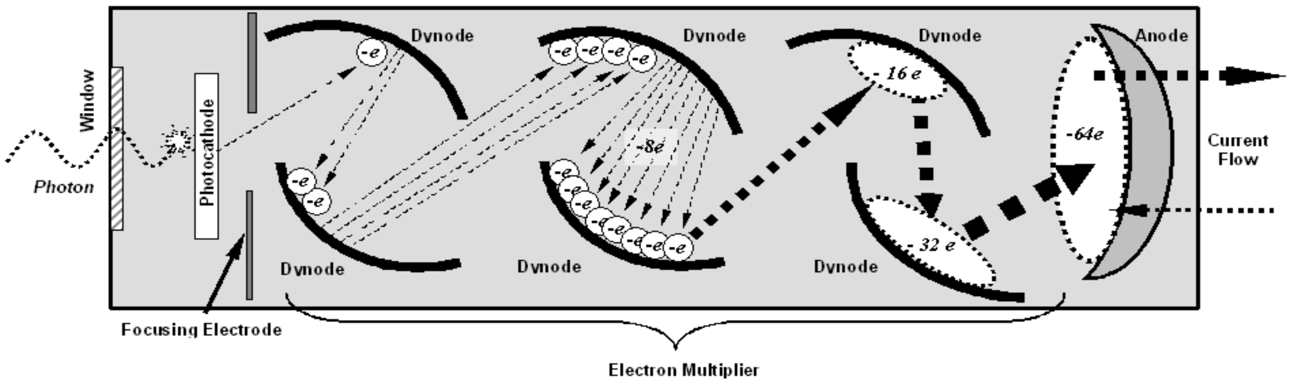


Figure 12-21: Basic PMT Design

A significant performance characteristic of the PMT is the voltage potential across the electron multiplier. The higher the voltage, the greater the number of electrons emitted from each dynode of the electron multiplier, in effect, making the PMT more sensitive and responsive to smaller variations in light intensity but also more noisy (this is referred to as “dark noise”).

- The gain voltage of the PMT used in the T200 is usually set between 400 V and 800 V.
- This parameter is viewable through the front panel as test function **HVPS** (see Section 7.2.1).
- For information on when and how to set this voltage, see Section 14.8.4.

The PMT is housed inside the PMT module assembly (see Figure 12-20). This assembly also includes the high voltage power supply required to drive the PMT, an LED used by the instrument’s optical test function, a thermistor that measures the temperature of the PMT and various components of the PMT cooling system including the TEC.

12.5.1. PMT PREAMPLIFIER

The PMT preamplifier board provides a variety of functions:

- It amplifies the PMT signal into a useable analog voltage **(PMTDET)** that can be processed by the motherboard into a digital signal to be used by the CPU to calculate the NO, NO_2 and NO_x concentrations of the gas in the sample chamber.
- It supplies the drive voltage for the HVPS.
- It includes the circuitry for switching between the two physical ranges.
- It amplifies the signal output by the PMT temperature sensor and feeds it back to the thermoelectric cooler driver PCA. This amplified signal is also sent to the Motherboard to be digitized and forwarded to the CPU. It is viewable via the front panel as the test function **PMT TEMP**.
- It provides means for adjusting the electronic signal output from the PMT by:
  - Adjusting this voltage directly the sensitivity of the PMT’s dynode array and therefore the strength of the signal output by the PMT through the use of two hexadecimal switches.
  - Directly adjusting the gain of the output signal.

NOTE

These adjustments should only be performed when encountering problems with the software calibration that cannot be rectified otherwise. See Section 14.8.4 for more information about this hardware calibration.

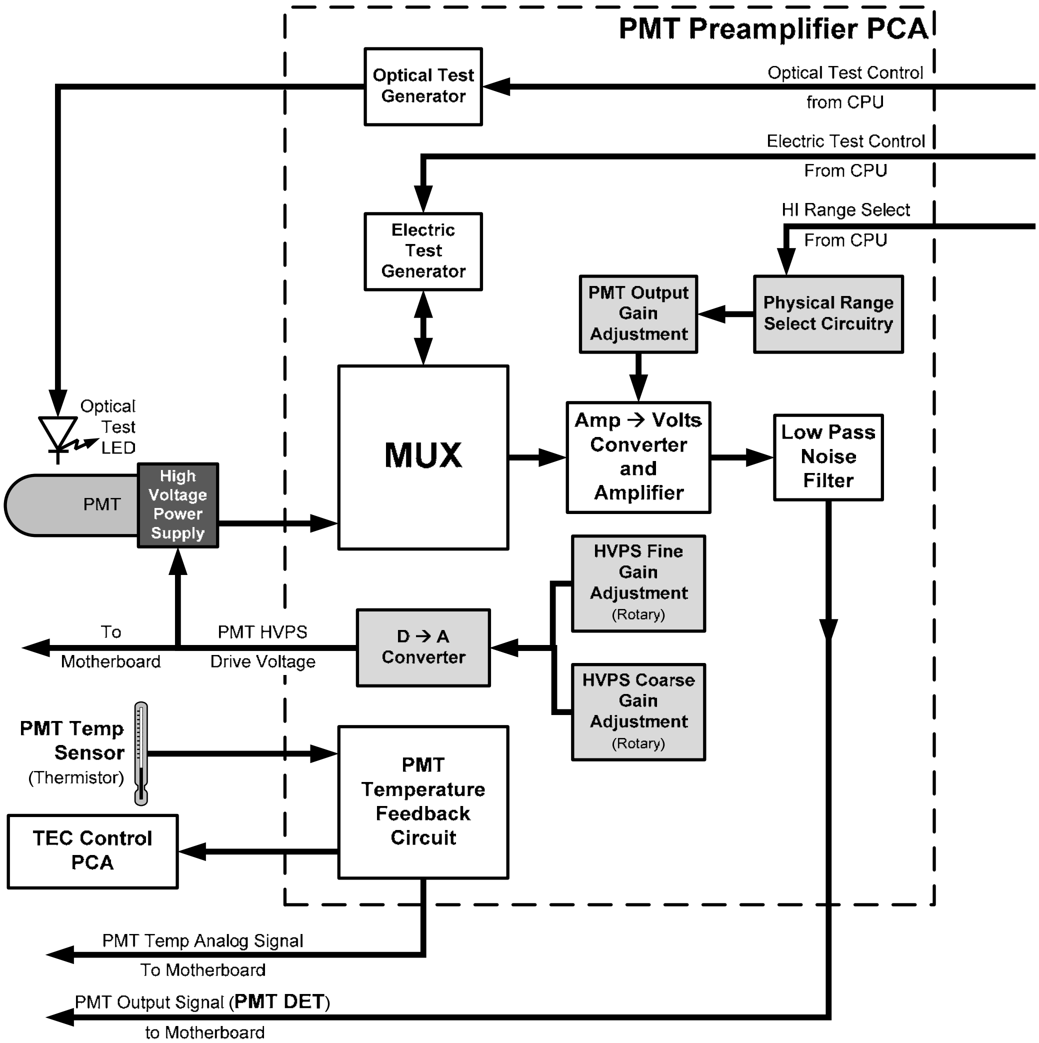


Figure 12-22: PMT Preamp Block Diagram

The PMT preamplifier PCA also operates two different tests used to calibrate and check the performance of the sensor module.

- The electrical test (**ETEST**) circuit generates a constant, electronic signal intended to simulate the output of the PMT (after conversion from current to voltage). By bypassing the detector's actual signal, it is possible to test most of the signal handling and conditioning circuitry on the PMT preamplifier board. See section 14.7.12.3 for instructions on performing this test.
- The optical test (**OTEST**) feature causes an LED inside the PMT cold block to create a light signal that can be measured with the PMT. If zero air is supplied to the analyzer, the entire measurement capability of the sensor module can be tested including the PMT and the current to voltage conversion circuit on the PMT preamplifier board. See Section 14.7.12.2 for instructions on performing this test.

12.5.2. PMT COOLING SYSTEM

The performance of the analyzer's PMT is significantly affected by temperature. Variations in PMT temperature are directly reflected in the signal output of the PMT. Also the signal to noise ratio of the PMT output is radically influenced by temperature as well. The warmer the PMT is, the noisier its signal becomes until the noise renders the concentration signal useless.

To alleviate this problem a special cooling system exists utilizing a type of electronic heat pump called a thermo-electric cooler (TEC). A TEC is a solid-state active heat pump which transfers heat from a heat absorbing "cool" side to a heat releasing "hot" side via a series of DC powered semiconductor junctions. The effectiveness of the pump at moving heat away from the cold side is reliant on the amount of current flowing through the semiconductor junctions and how well the heat from the hot side can be removed.

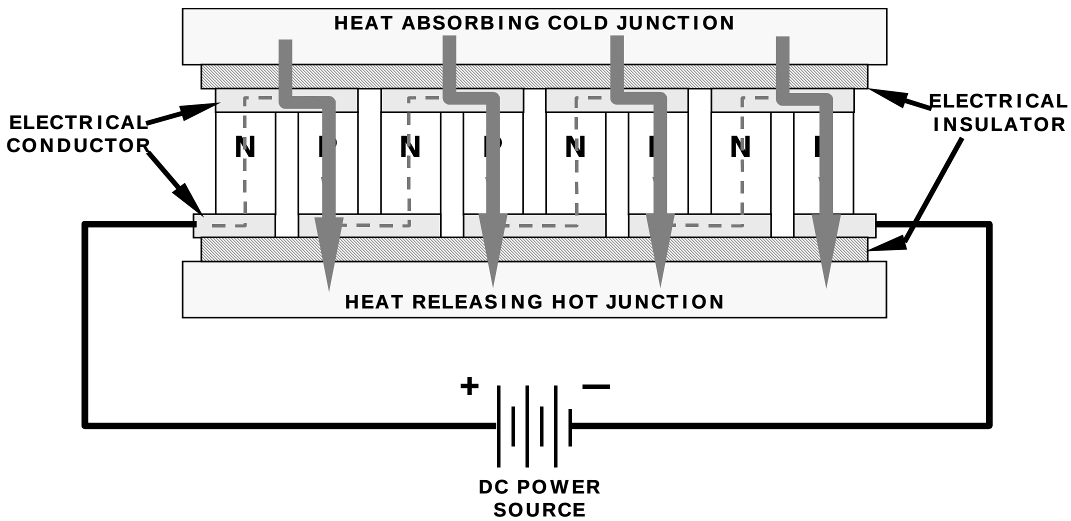


Figure 12-23: Typical Thermo-Electric Cooler

In the case of the T200, the current flow is controlled by the TEC Control PCA which adjusts the amount of current applied to the TEC based on the temperature sensed by a thermistor embedded in the PMT's cold block. The higher the temperature of the PMT, the more current is pumped through the TEC. The "hot" side of the TEC is cooled by a constant flow of ambient air that is directed across a set of heat sinks by a fan.

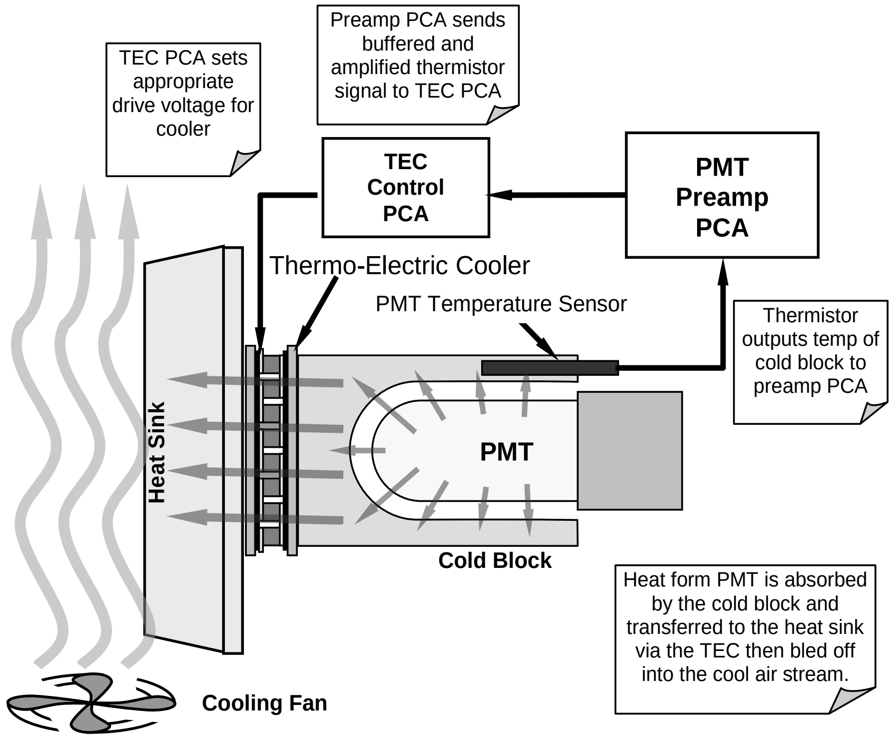


Figure 12-24: PMT Cooling System Block Diagram

The target temperature at which the TEC system keeps the PMT is approximately 8.0ºC. Arriving at this temperature may take up to 30 minutes after the instrument is turned on.

The actual temperature of the PMT can be viewed via the front panel as the test function **PMT TEMP** (see Section 7.2.1).

12.5.2.1. TEC Control Board

The TEC control PCA is located on the sensor housing assembly, under the slanted shroud, next to the cooling fins and directly above the cooling fan. Using the amplified PMT temperature signal from the PMT preamplifier board (see Section 10.4.5), it sets the drive voltage for the thermoelectric cooler. The warmer the PMT gets, the more current is passed through the TEC causing it to pump more heat to the heat sink.

- A red LED located on the top edge of this circuit board indicates that the control circuit is receiving power.
- Four test points are also located at the top of this assembly.
- For the definitions and acceptable signal levels of these test points see 14.7.14.

12.6. PNEUMATIC SENSOR BOARD

The flow and pressure sensors of the T200 are located on a printed circuit assembly just behind the PMT sensor. Refer to Section 14.7.6.1 for a figure and on how to test this assembly. The signals of this board are supplied to the motherboard for further signal processing. All sensors are linearized in the firmware and can be span calibrated from the front panel.

12.7. POWER SUPPLY/CIRCUIT BREAKER

The analyzer operates on 100 VAC, 115 VAC or 230 VAC power at either 50 Hz or 60Hz. Individual instruments are set up at the factory to accept any combination of these five attributes.

Power enters the analyzer through a standard International Electrotechnical Commission (IEC) 320 power receptacle located on the rear panel of the instrument. From there it is routed through the **ON/OFF** Switch located in the lower right corner of the front panel. AC Line power is stepped down and converted to DC power by two DC power supplies.

- One supplies +12 VDC (5 A), for the PMT's thermoelectric cooler, fans and as well as the various gas stream valves (both standard and optional).
- A second supply provides +5 VDC (3 A) and ±15 VDC (1.5/0.5 A) for logic and analog circuitry as well as the power for the O_3 generator.

All AC and DC Voltages are distributed via the relay PCA.

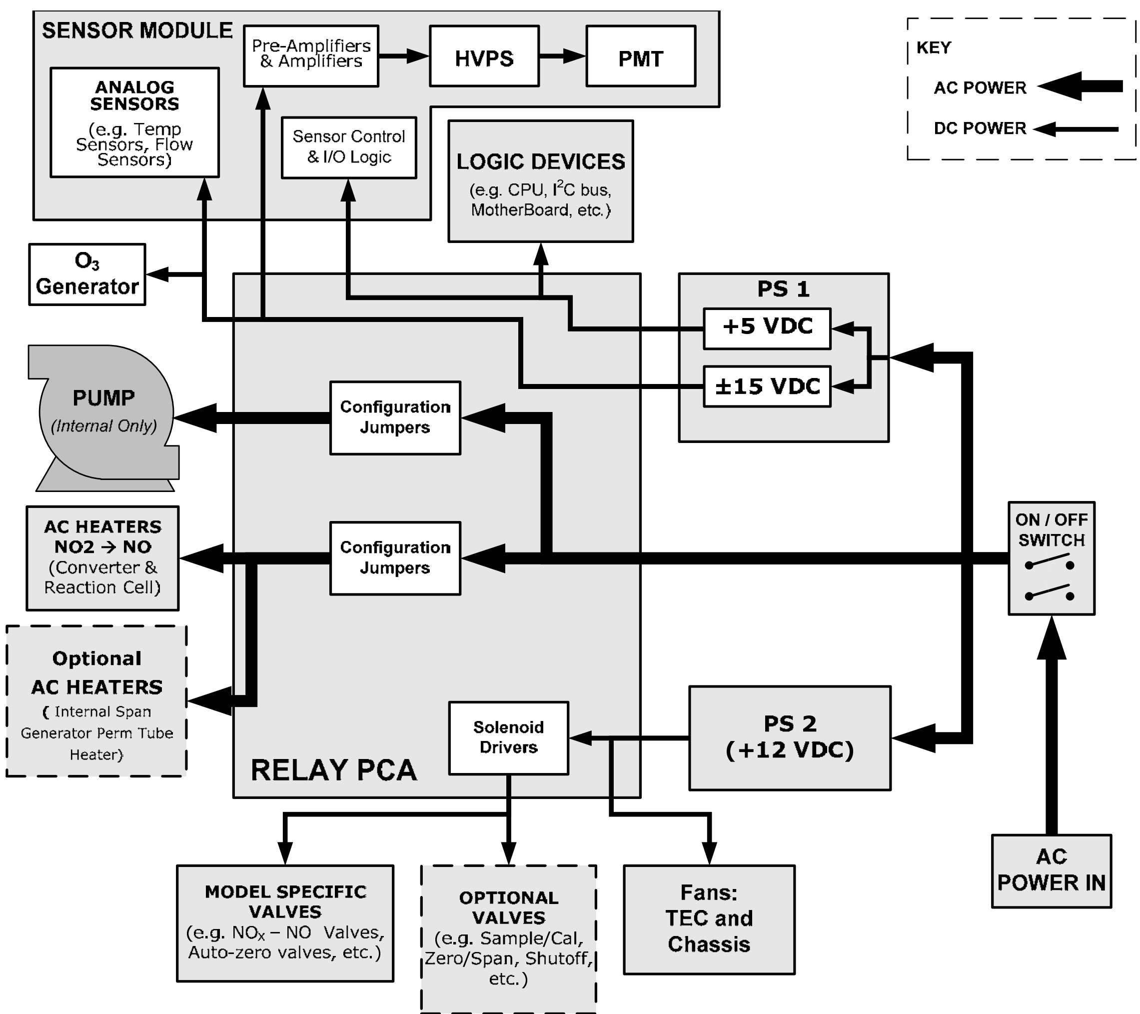
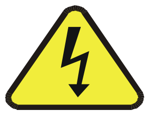


Figure 12-25: Power Distribution Block Diagram

12.7.1. AC POWER SWITCH/CIRCUIT BREAKER

A 6.75 amp circuit breaker is built into the **ON/OFF** switch. In case of a wiring fault or incorrect supply power, the circuit breaker will automatically turn off the analyzer.

- Under normal operation, the T200 draws about 1.5 A at 115 V and 2.0 A during start-up.



WARNING

ELECTRICAL SHOCK HAZARD

Should the AC power circuit breaker trip, investigate and correct the condition causing this situation before turning the analyzer back on.

12.7.2. AC POWER CONFIGURATION

The T200 analyzer's digital components will operate with any of the specified power regimes. As long as instrument is connected to 100-120 VAC or 220-240 VAC at either 50 or 60 Hz,. Internally, the status LEDs located on the Relay PCA, Motherboard and CPU should turn on as soon as the power is supplied.

However, some of the analyzer's non-digital components, such as the various internal pump options or the AC powered heaters for the NO_2 → NO converter the reaction cell and some of the T200's must be properly configured for the type of power being supplied to the instrument.

Configuration of the power circuits is set using several jumper sets located on the instruments relay PCA.

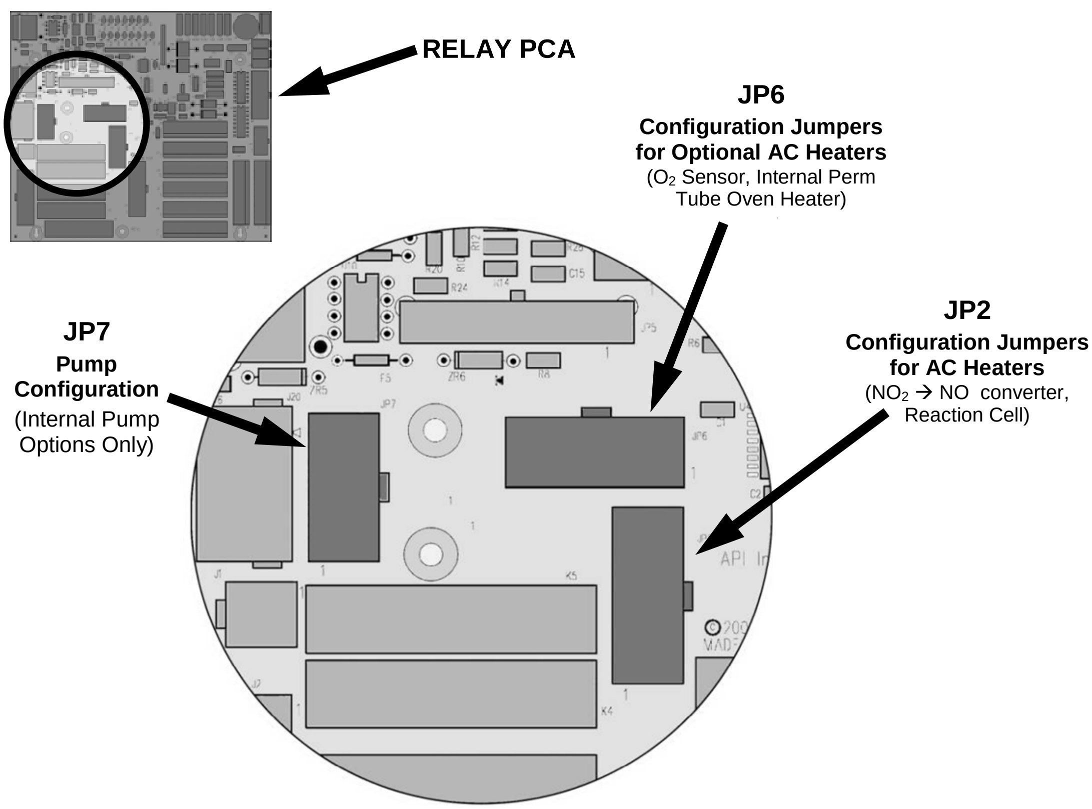


Figure 12-26: Location of AC power Configuration Jumpers

12.7.2.1. AC Configuration – Internal Pump (JP7)

If your T200 includes an internal pump the following table, jumper set JP7 is used to configure the power supplied to it as shown in Figure 12-27.

Table 12-6: AC Power Configuration for Internal Pumps (JP7)

LINE POWER	LINE FREQUENCY	JUMPER COLOR	FUNCTION	JUMPER BETWEEN PINS
110VAC 115 VAC	60 HZ	WHITE	Connects pump pin 3 to 110 / 115 VAC power line	2 to 7
			Connects pump pin 3 to 110 / 115 VAC power line	3 to 8
			Connects pump pins 2 & 4 to Neutral	4 to 9
	50 HZ[1]	BLACK	Connects pump pin 3 to 110 / 115 VAC power line	2 to 7
			Connects pump pin 3 to 110 / 115 VAC power line	3 to 8
			Connects pump pins 2 & 4 to Neutral	4 to 9
220VAC 240 VAC	60 HZ	BROWN	Connects pump pins 3 and 4 together	1 to 6
			Connects pump pin 1 to 220 / 240VAC power line	3 to 8
	50 HZ[1]	BLUE	Connects pump pins 3 and 4 together	1 to 6
			Connects pump pin 1 to 220 / 240VAC power line	3 to 8

[1] A jumper between pins 5 and 10 may be present on the jumper plug assembly, but has no function on the Model T200.

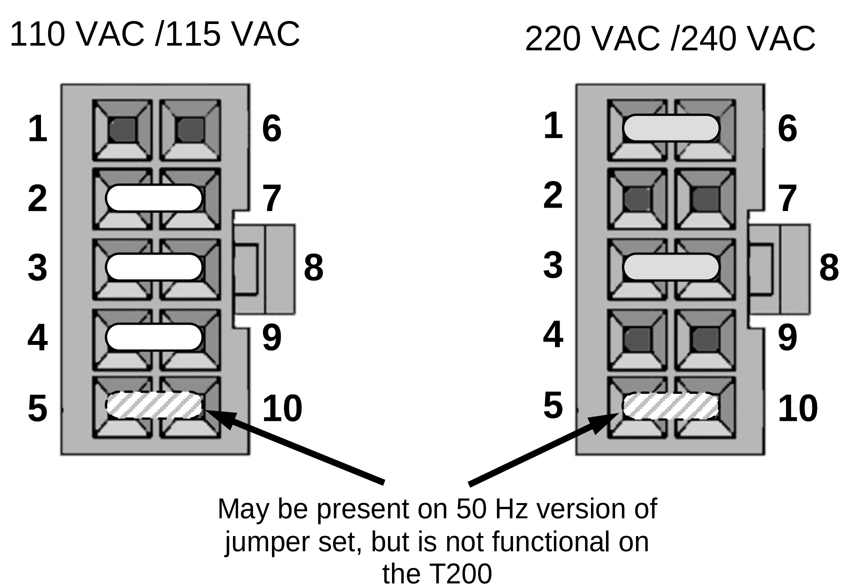


Figure 12-27: Pump AC Power Jumpers (JP7)

12.7.2.2. AC Configuration – Standard Heaters (JP2)

Power configuration for the AC the standard heaters is set using Jumper set JP2 (see Figure 12-28 for the location of JP2).

Table 12-7: Power Configuration for Standard AC Heaters (JP2)

LINE VOLTAGE	JUMPER COLOR	HEATER(S)	JUMPER BETWEEN PINS	FUNCTION
110 VAC / 115 VAC 50Hz & 60 Hz	**WHITE**	Reaction Cell / Sample Chamber Heaters	1 to 8	Common
			2 to 7	Neutral to Load
			4 to 9	Neutral to Load
		Moly Converter	3 to 10	Common
			4 to 9	Neutral to Load
			6 to 11	Neutral to Load
220 VAC / 240 VAC 50Hz & 60 Hz	**BLUE**	Reaction Cell / Sample Chamber Heaters	1 to 7	Load
		Moly Converter	3 to 9	Load

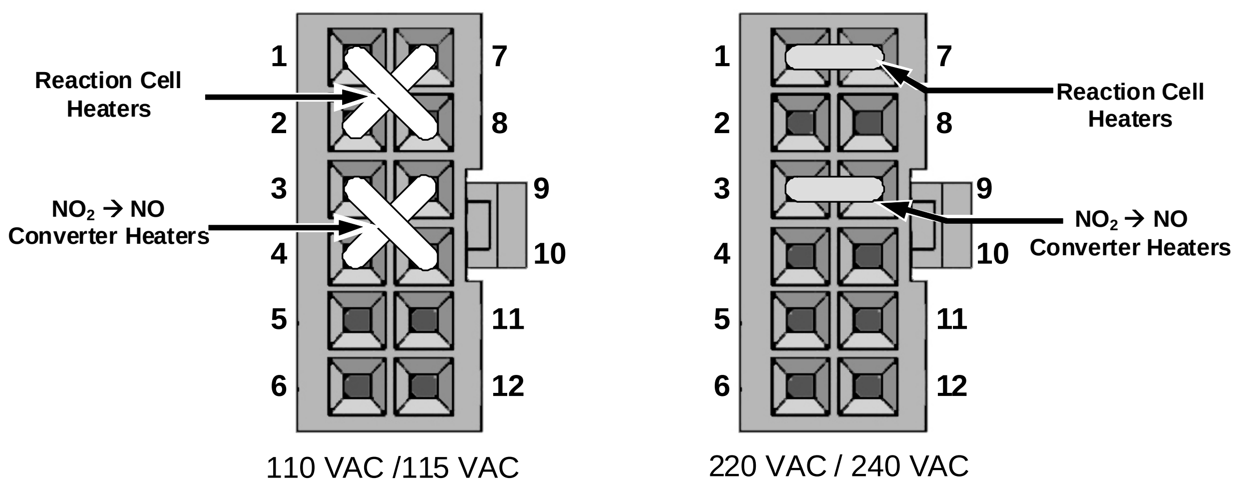


Figure 12-28: Typical Set Up of AC Heater Jumper Set (JP2)

12.7.2.3. AC Configuration – Heaters for Option Packages (JP6)

The IZS valve option includes an AC heaters that maintain an optimum operating temperature for key components of those options. Jumper set JP6 is used to connect the heaters associated with those options to AC power. Since these heaters work with either 110/155 VAC or 220/240 VAC, there is only one jumper configuration.

Table 12-8: Power Configuration for Optional Heaters (JP6)

JUMPER COLOR	HEATER(S)	JUMPER BETWEEN PINS	FUNCTION
RED	Internal Permeation Tube Oven Heater	1 to 8	Common
		2 to 7	Neutral to Load

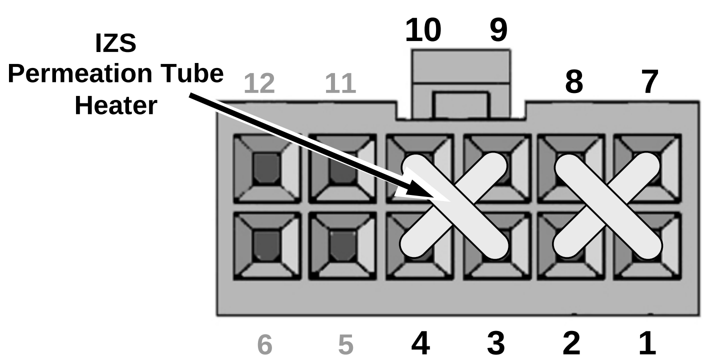


Figure 12-29: Typical Jumper Set (JP2) Set Up of Heaters

12.8. FRONT PANEL TOUCHSCREEN/DISPLAY INTERFACE

Users can input data and receive information directly through the front panel touchscreen display. The LCD display is controlled directly by the CPU board. The touchscreen is interfaced to the CPU by means of a touchscreen controller that connects to the CPU via the internal USB bus and emulates a computer mouse.

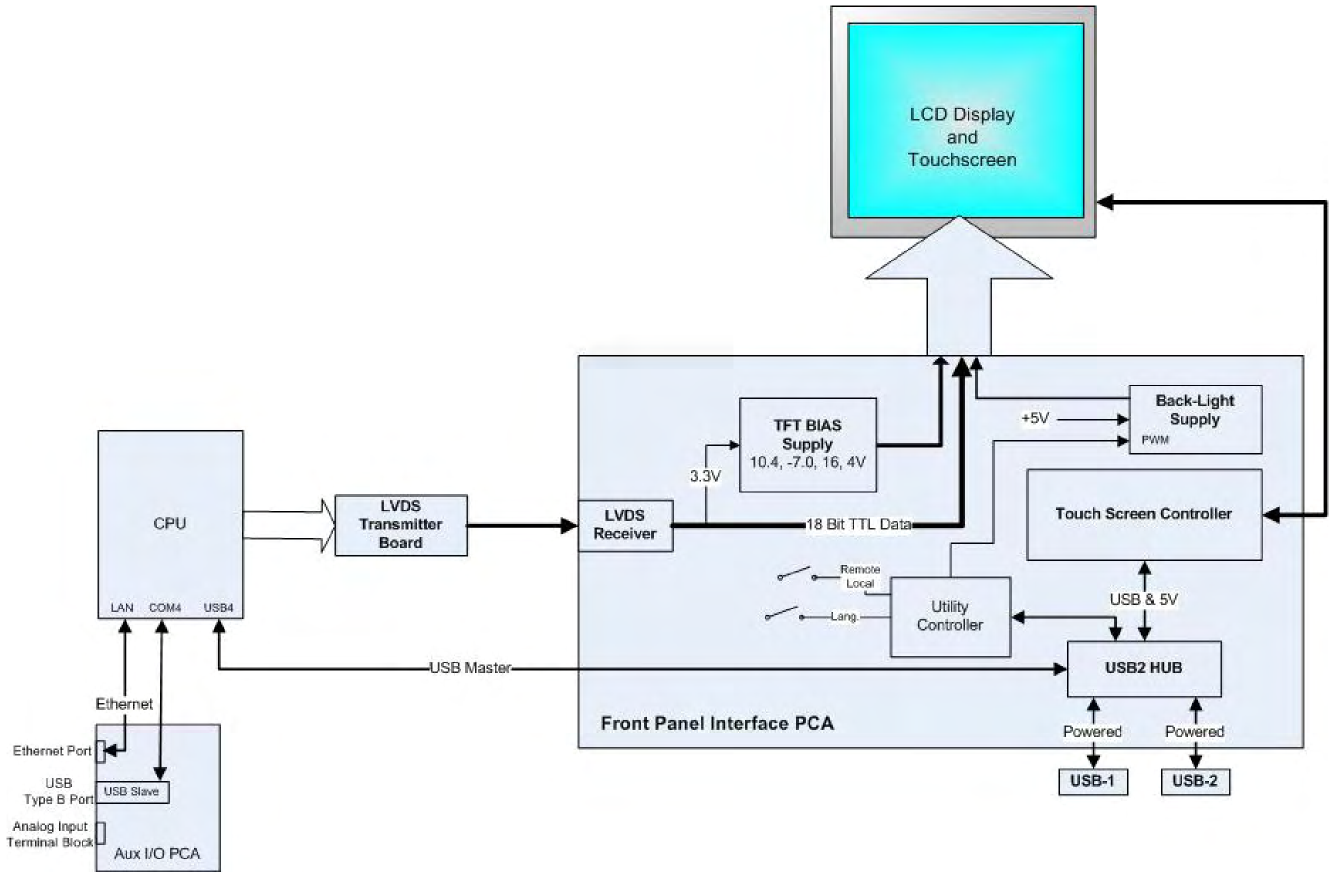


Figure 12-30: Front Panel and Display Interface Block Diagram

12.8.1. 9.6.1. LVDS TRANSMITTER BOARD

The LVDS (low voltage differential signaling) transmitter board converts the parallel display bus to a serialized, low voltage, differential signal bus in order to transmit the video signal to the LCD interface PCA.

12.8.2. FRONT PANEL TOUCHSCREEN/DISPLAY INTERFACE PCA

The front panel interface PCA controls the various functions of the display and touchscreen. For driving the display it provides connection between the CPU video controller and the LCD display module. This PCA also contains:

- power supply circuitry for the LCD display module
- a USB hub that is used for communications with the touchscreen controller and the two front panel USB device ports
- the circuitry for powering the display backlight

12.9. SOFTWARE OPERATION

The T200 NO_x Analyzer has a high performance, VortexX86-based microcomputer running WINDOWS CE. Inside the WINDOWS CE shell, special software developed by Teledyne API interprets user commands via the various interfaces, performs procedures and tasks, stores data in the CPU's various memory devices and calculates the concentration of the sample gas.

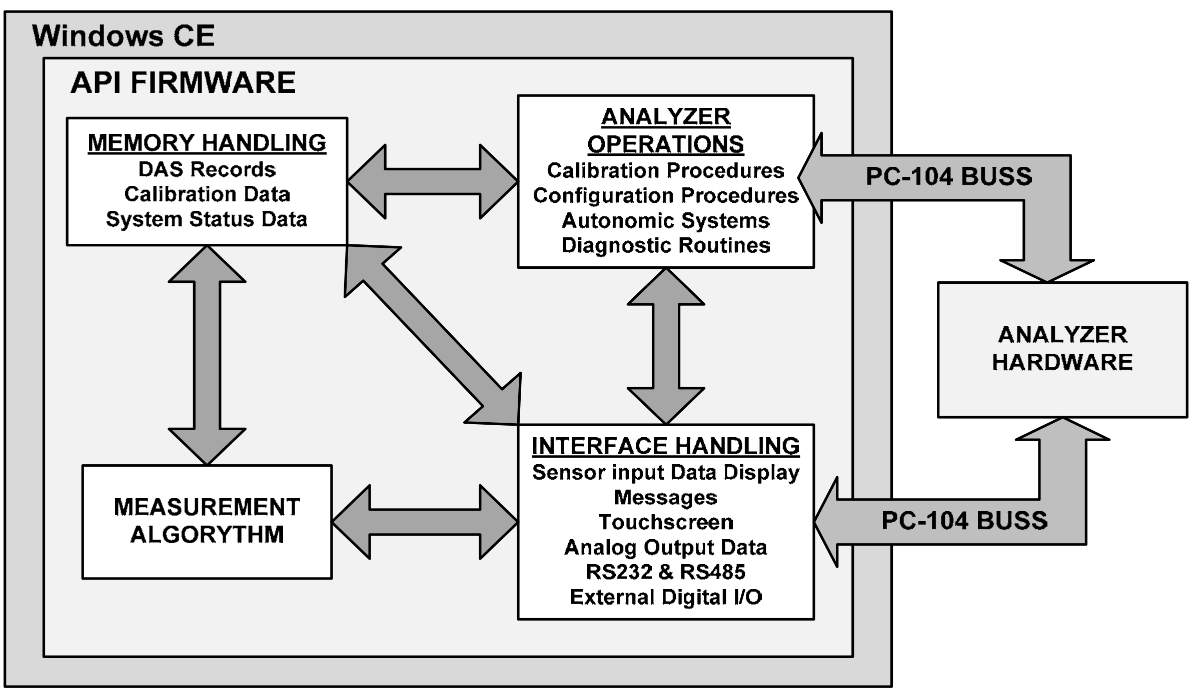


Figure 12-31: Basic Software Operation

12.9.1. ADAPTIVE FILTER

The T200 NO_X analyzer software processes sample gas concentration data through a built-in adaptive filter. Unlike other analyzers that average the output signal over a fixed time period, the T200 averages over a defined number of samples, with samples being about 8 seconds apart (reflecting the switching time of 4 s each for NO and NO_X). This technique is known as boxcar filtering. During operation, the software may automatically switch between two different filters lengths based on the conditions at hand.

During constant or nearly constant concentrations, the software, by default, computes an average of the last 42 samples, or approximately 5.6 minutes. This provides smooth and stable readings and averages out a considerable amount of random noise for an overall less noisy concentration reading.

If the filter detects rapid changes in concentration the filter reduces the averaging to only 6 samples or about 48 seconds to allow the analyzer to respond more quickly. Two conditions must be simultaneously met to switch to the short filter. First, the instantaneous concentration must differ from the average in the long filter by at least 50 ppb. Second, the instantaneous concentration must differ from the average in the long filter by at least 10% of the average in the long filter

12.9.2. TEMPERATURE/PRESSURE COMPENSATION (TPC)

The T200 software includes a feature that compensates for some temperature and pressure changes that might affect measurement of NO and NO_X concentrations.

When the TPC feature is enabled (default setting), the analyzer divides the value of the PMT output signal (**PMTDET)** by a value called **TP_FACTOR**. **TP_FACTOR** is calculated according to the following equation.

$$TP\_Factor = A\left[\frac{BOX\_TEMP(K)}{298(K)}\right] \times A\left[\frac{RCELL\_TEMP(K)}{323(K)}\right] \times A\left[\frac{C3 \times \ln(RCELL("Hg)) + C2}{C3 \times \ln(5("Hg)) + C2}\right] \times A\left[\frac{SAMP("Hg)}{29.92("Hg)}\right]$$

Where:

***C2 = RCELL_PRESS_CONST2* and has a default value of 3.2;**

***C3 = RCELL_PRESS_CONST3* and has a default value of –0.8.**

$$A = 1 + [(\frac{7("Hg)}{rcell\_pressure("Hg)} - 1) \times RCPRESS\_TPC\_GAIN]$$

The four parameters used to compute TP_FACTOR are:

- **BOX TEMP**: The temperature inside the analyzer's case measured in K. This is typically about 5 K higher than room temperature.
- **RCELL TEMP**: The temperature of the reaction cell, measured in K.
- **RCEL**: The pressure of the gas in the vacuum manifold, measured in in-Hg-A.
- **SAMP**: The pressure of the sample gas before it reaches the reaction cell, measured in in-Hg-A. This measurement is ~1 in-Hg-A lower than atmospheric pressure.

Note that, as **RCEL TEMP, BOX TEMP, RCELL** and **SAMP** pressure increase, the value of **TP_FACTOR** increases and, hence, the **PMTDET** value decreases. These adjustments are meant to counter-act changes in the concentrations caused by these parameters.

- The current value of all four of these measurements are viewable as **TEST FUNCTIONS** through the instrument's front panel display (see Section 7.2.1).
- The preset gain parameters are set at the factory and may vary from analyzer to analyzer. The TPC feature is enabled or disabled by setting the value of the variable **TPC_ENABLE** (see Section 8.2).

12.9.3. CALIBRATION - SLOPE AND OFFSET

Calibration of the analyzer is performed exclusively in software. During instrument calibration, (see Sections 10 and 11) the user enters expected values for zero and span via the front panel touchscreen control and commands the instrument to make readings of calibrated sample gases for both levels.

- The readings taken are adjusted, linearized and compared to the expected values.
- With this information, the software computes values for instrument slope and offset and stores these values in memory for use in calculating the NO_x, NO and NO_2 concentrations of the sample gas.

The instrument slope and offset values recorded during the last calibration can be viewed via the instruments front panel (see Section 7.2.1).

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13. MAINTENANCE SCHEDULE & PROCEDURES

For the most part, the T200 analyzer is maintenance free. However it is recommended that a minimal number of simple procedures be performed regularly to ensure that the T200 continues to operate accurately and reliably over its lifetime. In general, the exterior can be wiped down with a lightly damp cloth; avoid spraying anything directly onto any part of the analyzer.

Repairs and troubleshooting are covered in Section 13 .

13.1. PREDICTING FAILURES USING THE TEST FUNCTIONS

Predictive diagnostic functions including failure warnings and alarms built into the analyzer's firmware allow the user to determine when repairs are necessary.

The Test Functions can also be used to predict failures by looking at how their values change over time. Initially it may be useful to compare the state of these Test Functions to the values recorded on the printed record of the *Final Test and Validation Data Sheet*, P/N 04490.

The following table can be used as a basis for taking action as these values change with time. The internal data acquisition system (DAS) is a convenient way to record and track these changes. Use APICOM to download and review this data from a remote location.

Table 13-1: Predictive Uses for Test Functions

<table>
<tr><th>FUNCTION</th><th>EXPECTED</th><th>ACTUAL</th><th>INTERPRETATION & ACTION</th></tr>
<tr><td rowspan="2">RCEL
(pressure)</td><td rowspan="2">Constant to within ± 0.5 in-Hg-A</td><td>Fluctuating</td><td>Developing leak in pneumatic system. Check for leaks.</td></tr>
<tr><td>Slowly increasing</td><td>Pump performance is degrading. Rebuild pump when pressure is above 10 in-Hg-A.</td></tr>
<tr><td rowspan="3">SAMP
(pressure)</td><td rowspan="3">Constant within atmospheric changes</td><td>Fluctuating</td><td>Developing leak in pneumatic system. Check for leaks.</td></tr>
<tr><td>Slowly increasing</td><td>Flow path is clogging up. Replace orifice filters.</td></tr>
<tr><td>Slowly decreasing</td><td>Developing leak in pneumatic system to vacuum (developing valve failure). Check for leaks.</td></tr>
<tr><td>OZONE FL</td><td>Constant to within ± 15</td><td>Slowly decreasing</td><td>Flow path is clogging up. Replace orifice filters.</td></tr>
<tr><td rowspan="4">AZERO</td><td rowspan="4">Constant within ±20 of check-out value</td><td rowspan="4">Significantly increasing</td><td>Developing AZERO valve failure. Replace valve.</td></tr>
<tr><td>PMT cooler failure. Check cooler, circuit, and power supplies.</td></tr>
<tr><td>Developing light leak.</td></tr>
<tr><td>O_3 air filter cartridge is exhausted. Change chemical.</td></tr>
<tr><td>NO_2
(Concentration)</td><td>Constant for constant concentrations</td><td>Slowly decreasing signal for same concentration</td><td>Converter efficiency may be degrading. Replace converter components.</td></tr>
<tr><td rowspan="3">NO_2
with IZS Option installed
(Concentration)</td><td rowspan="3">Constant response from day to day</td><td rowspan="2">Decreasing over time</td><td>Change in instrument response. Low level (hardware) calibrate the sensor.</td></tr>
<tr><td>Degradation of IZS permeation tube. Change permeation tube.</td></tr>
<tr><td>Heavily fluctuating from day to day</td><td>Ambient changes in moisture are affecting the performance. Add a dryer to the zero air inlet.</td></tr>
<tr><td>NO
(Concentration)</td><td>Constant for constant concentration</td><td>Decreasing over time</td><td>Drift of instrument response; clean RCEL window. Check for flow leaks or irregularities.</td></tr>
</table>

NOTE

It is recommended that the above functions be checked weekly.

13.2. MAINTENANCE SCHEDULE

Table 13-2 shows a typical maintenance schedule for the T200. Please note that in certain environments (i.e. dusty, very high ambient pollutant levels) some maintenance procedures may need to be performed more often than shown.

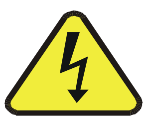
NOTE

A span and zero calibration check (see CAL CHECK REQ'D Column of Table T200 Maintenance Schedule) must be performed following some of the maintenance procedures listed below.

To perform a CHECK of the instrument's Zero or Span Calibration follow the same steps as described in Section 10.3.

DO NOT press the ENTR button at the end of each operation. Pressing the ENTR button resets the stored values for OFFSET and SLOPE and alters the instruments Calibration.

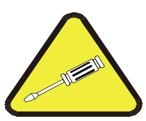
Alternately, use the Auto cal feature described in Section 10.5 with the CALIBRATE attribute set to OFF.



CAUTION

ELECTRICAL SHOCK HAZARD

Risk of electrical shock. Disconnect power before performing any of the following operations that require entry into the interior of the analyzer.



CAUTION

QUALIFIED PERSONNEL

The operations outlined in this chapter are to be performed by qualified maintenance personnel only.

Table 13-2: T200 Maintenance Schedule

ITEM	ACTION	FREQ	CAL CHECK REQ'D	DATE PERFORMED									
TEST functions	Review and evaluate	Weekly	No										
Particulate filter	Change particle filter	Weekly	No										
Zero/span check	Evaluate offset and slope	Weekly	**No**										
Zero/span calibration	Zero and span calibration	Every 3 months	**Yes**										
External zero air scrubber (optional)	Exchange chemical	Every 3 months	No										
External dryer (optional)	Replace chemical	When indicator color changes	No										
Ozone filter	Change chemical	Annually	**Yes**										
Reaction cell window	Clean	Annually or as necessary	**Yes**										
DFU filters	Change particle filter	Annually	No										
Pneumatic sub-system	Check for leaks in gas flow paths	Annually or after repairs involving pneumatics	Yes if a leak is repaired										
Reaction cell O-rings & sintered filters	Replace	Annually	**Yes**										
PMT Sensor Hardware Calibration	Low-level hardware calibration	On PMT/ preamp changes or if slope is outside of 1.0±0.3	**Yes**										
Pump	Rebuild head	when RCEL pressure exceeds 10 in-Hg-A (at sea level)	**Yes**										
Inline Exhaust Scrubber	Replace	Annually	No										
NO_2 converter	Replace converter	Every 3 years or if conversion efficiency drops below 96%	**Yes**										
Desiccant bags	Replace	Any time PMT housing is opened for maintenance	n/a										

13.3. MAINTENANCE PROCEDURES

The following procedures are to be performed periodically as part of the standard maintenance of the T200.

13.3.1. REPLACING THE SAMPLE PARTICULATE FILTER

The particulate filter should be inspected often for signs of plugging or contamination. We recommend that when you change the filter; handle it and the wetted surfaces of the filter housing as little as possible. Do not touch any part of the housing, filter element, PTFE retaining ring, glass cover and the o-ring with your bare hands. Teledyne API recommends using gloves or PTFE coated tweezers or similar handling to avoid contamination of the sample filter assembly.

To change the filter:

1. Turn OFF the analyzer to prevent drawing debris into the instrument.
2. Open the T200's hinged front panel and unscrew the retaining ring on the filter assembly.

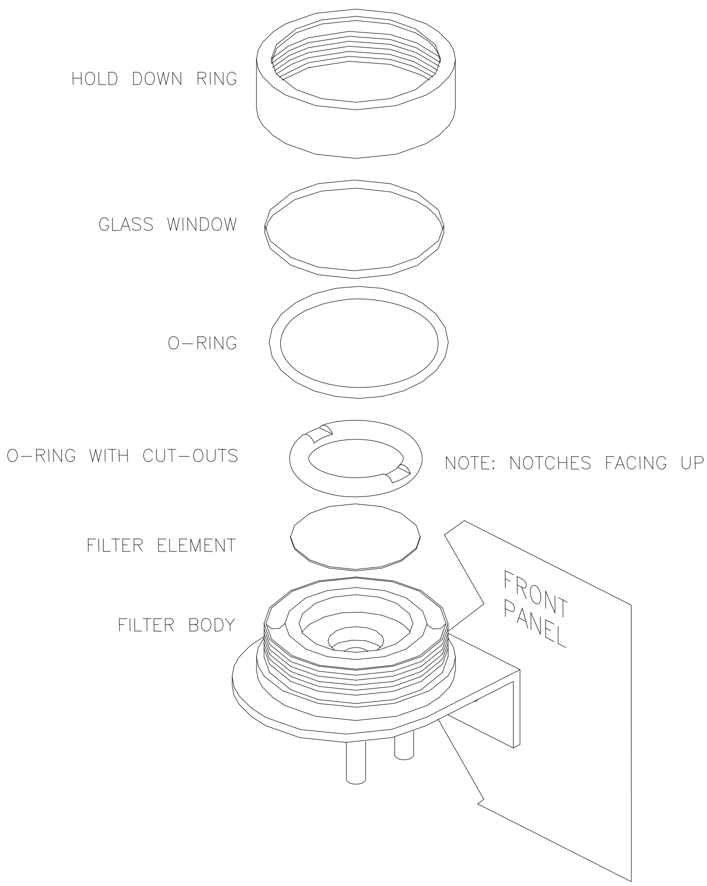


Figure 13-1 Replacing the Particulate Filter

3. Carefully remove the retaining ring, PTFE o-ring, glass filter cover and filter element.
4. Replace the filter, being careful that the element is fully seated and centered in the bottom of the holder.
5. Reinstall the PTFE o-ring with the notches up; the glass cover, then screw on the retaining ring and hand tighten. Inspect the seal between the edge of filter and the o-ring to assure a proper seal.
6. Restart the Analyzer.

13.3.2. CHANGING THE O_3 DRYER PARTICULATE FILTER

The air for the O_3 generator passes through a Perma Pure© dryer, which is equipped with a small particulate filter at its inlet. This filter prevents dust from entering the Perma Pure© dryer and degrading the dryer's performance over time. Change the filter according to the service interval in

Table 13-2 as follows:

1. Before starting the procedure, check and write down the average **RCEL** pressure and the **OZONE FLOW** values.
2. Turn off the analyzer, unplug the power cord and remove the cover.
3. Unscrew the nut around the port of the filter using two 5/8" wrenches.

NOTE

Ensure to use proper wrenches.

Hold the main dryer fitting with a 5/8" wrench to ensure that it does not turn against the Perma Pure© dryer.

Performing this procedure improperly or with incorrect tools creates a risk of causing a significant leak.

4. Take off the old filter element and replace it with a suitable equivalent (Teledyne API P/N FL-3).

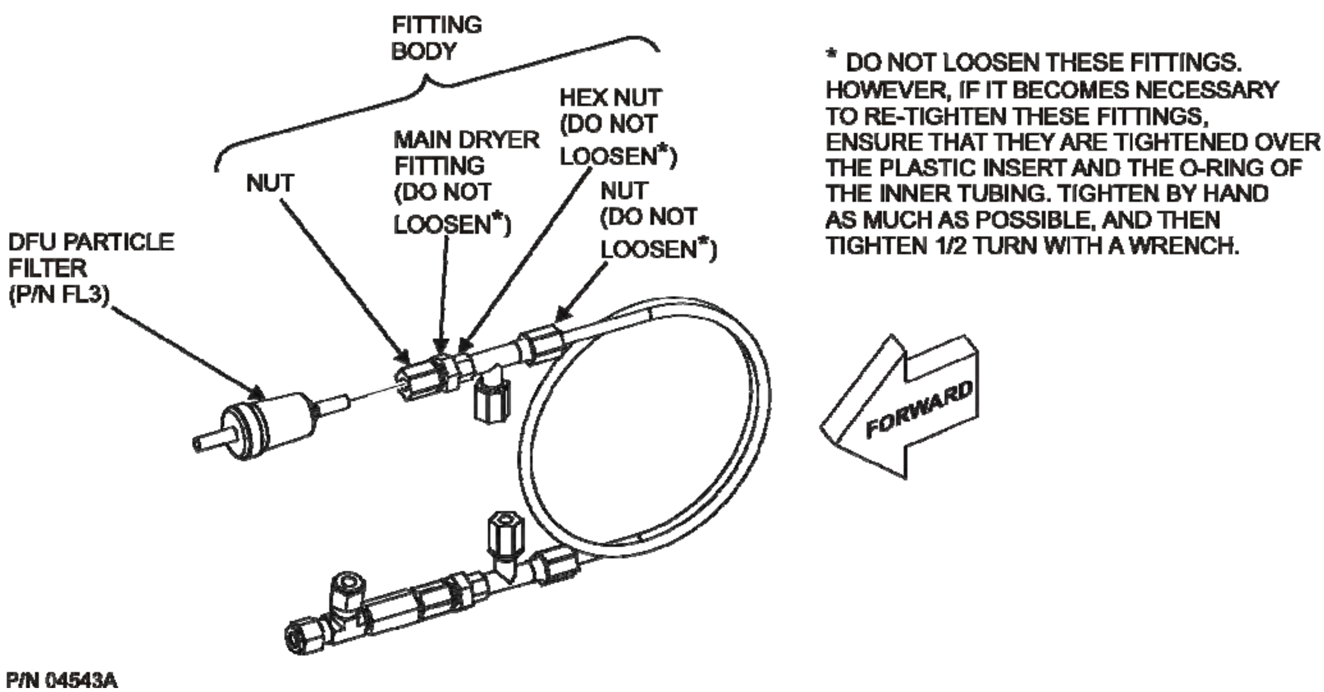


Figure 13-2: Particle Filter on O_3 Supply Air Dryer

5. Holding the main dryer fitting steady with a 5/8" wrench and tighten the nut with your hands.
   - If necessary use a second wrench but do not over-tighten the nut.
6. Replace the cover, plug in the power cord and restart the analyzer.
7. Check the O_3 flow rate; it should be around 80 cm^3/min ± 15.
8. Check the **RCEL** pressure.
   - It should be the same value as before.
9. Refer to Section 13.3.12 to leak check after installing the new DFU particle filter.

13.3.3. CHANGING THE OZONE FILTER CHEMICAL

The O_3 filter is located next to the O_3 generator (see Figure 3-5) and cleans the O_3 stream from solid and liquid contaminants that are created inside the O_3 generator. The content of the filter cartridge needs periodical exchange according to

Table 13-2. A rebuild kit is available from the factory (see Appendix B of this manual lists the part numbers).

To change the filter chemical, follow these steps:

1. Turn of power to the analyzer and pump. Remove the analyzer cover and locate the O_3 filter in the front of the analyzer next to the O_3 generator.
2. Use a 7/16" wrench to remove both pieces of 1/8" male nut with tubing from the NPT fittings.

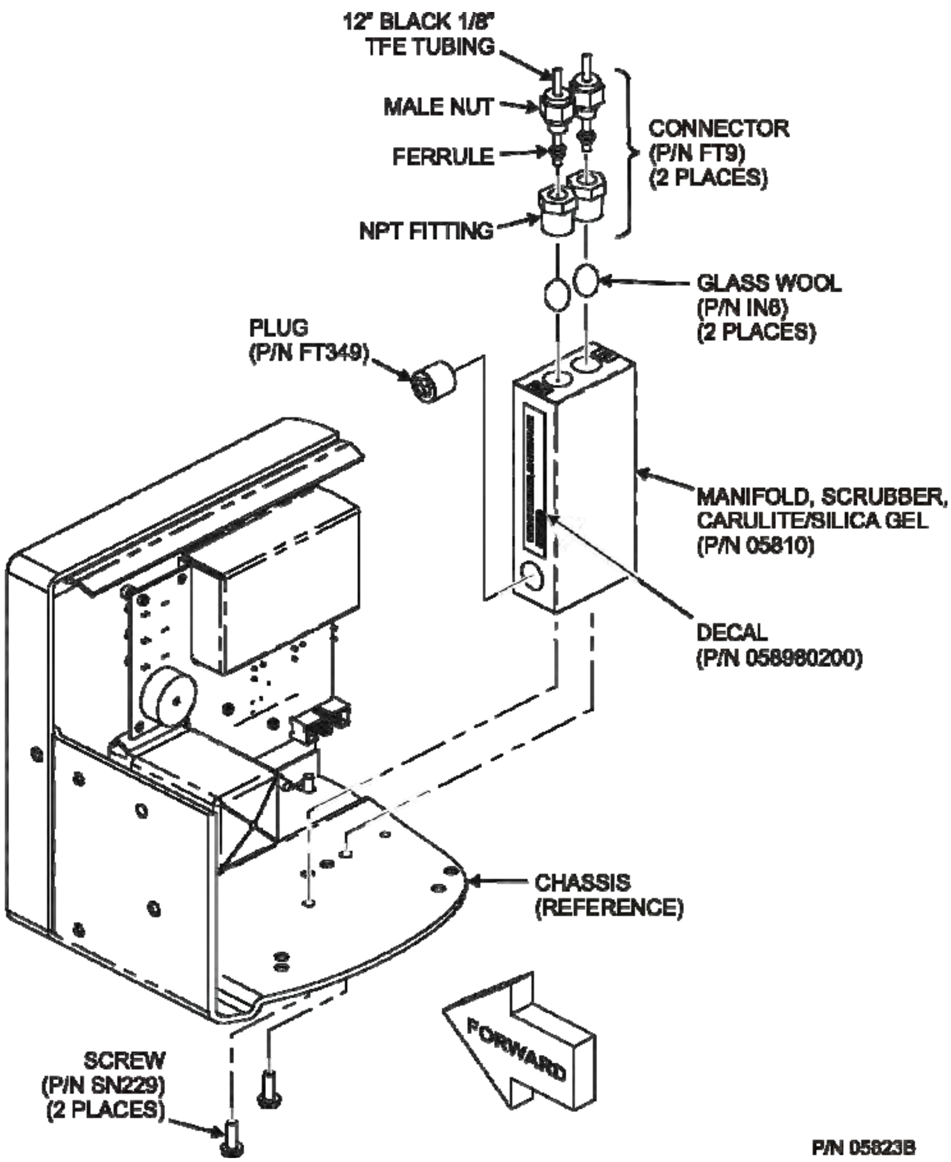


Figure 13-3: Ozone Filter Unit

3. Remove the integrated screws with a Phillips screw driver and remove the scrubber manifold from the chassis.
4. Using a 9/16" wrench, remove both fittings from the cartridge.
5. Discard the glass wool.
6. Pour the contents of the scrubber manifold onto a sheet of white paper. If necessary, remove the plug to ensure that all the contents are poured out.
    - Notice any discoloration of the contents, which is usually white and slightly transparent.
    - The amount of discolored chemical (usually with yellow tint) may give you an indication of the lifetime of the chemical in your application.

The maintenance cycle of this item is dependent on ambient moisture, sub-micron particle load and other factors and may differ from that shown in

Table 13-2.

7. Discard the used silica gel desiccant without touching it. It may contain nitric acid, which is a corrosive and highly irritating substance.

CAUTION

GENERAL SAFETY HAZARD

Immediately wash your hands after contact.

.

8. Using a small powder funnel, fill the cartridge with about 10 g new silica gel desiccant (Teledyne API P/N CH43) so that it is level on both legs of the cartridge.
    - Slight vibration is required to settle the chemical into the cartridge and achieve tightest packing, which increases performance and lifetime of the filter.
    - Ensure that the level of the chemical does not protrude farther than the first two threads of the NPT fitting.

NOTE
Use only genuine, pre-conditioned Teledyne API's refill kits for this procedure.
Do not leave this material uncovered for more than a few seconds, as it will absorb contaminants from ambient air!

9. Seal the silica gel desiccant with 1 cm^3 of glass wool on each well.
    - Ensure that the plug is large enough and compressed into the cartridge so that the chemical is securely held in place.
10. Add new Teflon tape (P/N HN000036) to the NPT fittings.
11. Screw the NPT fittings back into the scrubber manifold.
12. Screw the cartridge back onto the chassis; orientation is not important.
13. Evaluate the ferrules on the tubing.
    - If the ferrules are too old, we recommend replacing them with new ferrules.
14. Reconnect the tubing using 7/16" and 9/16" wrenches.
    - Do not over-tighten the fittings.
15. If the service interval for this item has been exceeded, it may also be necessary to clean the reaction cell as described in Section 13.3.9.
16. Leak check the system using the pressurized approach described in Section 13.3.12.

- If necessary, tighten the fittings some more but do not over-tighten.

17. Restart the analyzer and pump and continue operation.

NOTE

ONLY USE TELEDYNE API'S REFILL KITS!

Teledyne API's refill kits have been properly conditioned to prevent a significant increase of the T200's Auto Zero value which can cause large negative offsets on that may take 2-3 weeks to disappear.

Always store unused refill material is a cool dry place.

18. Re-calibrate the analyzer after one hour (Section 10).
    - If Auto Zero is high, you may have to wait day until calibration.

13.3.4. MAINTAINING THE EXTERNAL SAMPLE PUMP (PUMP PACK)

13.3.4.1. Rebuilding the Pump

The sample pump head periodically wears out and must be replaced when the **RCEL** pressure exceeds 10 in-Hg-A (at sea level, adjust this value accordingly for elevated locations).

- A pump rebuild kit is available from the factory. Refer to the label on the pump for the part number. Instructions and diagrams are included in the kit.
- A flow and leak check after rebuilding the sample pump is recommended.
- A span check and re-calibration after this procedure is necessary as the response of the analyzer changes with the **RCEL** pressure.

13.3.4.2. Replacing the Scrubber

CAUTION!

Do NOT attempt to change the contents of the inline exhaust scrubber cartridge; change the entire cartridge.

1. Through the SETUP>MORE>DIAG menu turn OFF the OZONE GEN OVERRIDE. Wait 10 minutes to allow pump to pull room air through scrubber before proceeding to step 2.
2. Disconnect exhaust line from analyzer.
3. Turn off (unplug) analyzer sample pump.
4. Disconnect tubing from (NOx or charcoal) scrubber cartridge.
5. Remove scrubber from system.
6. Dispose of according to local laws.
7. Install new scrubber into system.
8. Reconnect tubing to scrubber and analyzer.
9. Turn on pump.
10. Through the SETUP menu (per Step 1 above) turn ON the OZONE GEN OVERRIDE.

13.3.5. CHANGING THE PUMP DFU FILTER

The exhaust air from the analyzer passes a small particle filter (Dry Filter Unit (*DFU* - filter), P/N FL3) before entering the pump. It should be replaced when:

- It becomes visibly dirty or;

The pressure differential between the test functions **SAMP** and **RCEL** increases significantly.

13.3.5.1. Procedure for Replacing Filters on External Pumps

1. Power down the analyzer and pump.
2. For internally mounted filters, skip the next two steps.
3. Remove the analyzer exhaust tube from the dust filter.
4. Remove the particle filter from the pump by pushing the white plastic ring into the fitting and pulling the filter out of the fitting.
    - If necessary, use needle-nose pliers to pry the filter out of the fittings.
5. Push a new filter into the pump fitting and ensure that the arrow on the filter points towards the pump.
6. Push the exhaust tubing onto the filter. Skip the next two steps.
7. For internally mounted filters at the inside rear panel, remove the chassis and locate the filter between the vacuum manifold and the exhaust port fitting.
8. Disconnect the clear tubing from the filter body and change the filter with the arrow pointing against the gas flow. To remove the hose clamps, slide the two clamp ends in opposite directions with a needle-nose pliers until the clamp comes apart. Reconnect the tubing by using the same or new clamps and pushing tightening them until a good seal is achieved.
9. Restart the pump and clear any error warnings from the front panel display.
10. After about 5 minutes, check the RCEL pressure reading and ensure that it is similar to its value before changing the filter but less than 10 in-Hg-A.

13.3.5.2. Procedure for Replacing Filters on Internal Pumps

1. Power down the analyzer and pump.
2. Remove the chassis top and locate the filter between the vacuum manifold and the exhaust port fitting.
3. Disconnect the clear tubing from the filter body and change the filter with the arrow pointing against the gas flow.
4. To remove the hose clamps, slide the two clamp ends in opposite directions with a needle-nose pliers until the clamp comes apart.
5. Reconnect the tubing by using the same or new clamps and pushing tightening them until a good seal is achieved.
6. Restart the pump and clear any error warnings from the front panel display.
7. After about 5 minutes, check the **RCEL** pressure reading and ensure that it is similar to its value before changing the filter (but less than 10 in-Hg-A).

13.3.6. CHANGING THE INTERNAL SPAN GAS GENERATOR PERMEATION TUBE

1. Turn off the analyzer, unplug the power cord and remove the cover.
2. Locate the permeation tube (see Figure 3-5) oven in the rear left of the analyzer.
3. Remove the top layer of insulation if necessary.
4. Unscrew the black aluminum cover of the oven (3 screws) using a medium Phillips-head screw driver.
    - Leave the fittings and tubing connected to the cover.

5. Remove the old permeation tube and replace it with the new tube.
    - Ensure that the tube is placed into the larger of two holes and that the open permeation end of the tube (plastic) is facing up.
6. Re-attach the cover with three screws.
    - Ensure that the sealing O-ring is properly in place and;
    - That the three screws are tightened evenly.
7. Replace the analyzer cover, plug the power cord back in and turn on the analyzer.
8. Carry out a span check to see if the new permeation device works properly (see Section 10.3.4).
9. The permeation rate may need several days to stabilize.

WARNING

DO NOT LEAVE INSTRUMENT TURNED OFF FOR MORE THAN 8 HOURS WITHOUT REMOVING THE PERMEATION TUBE. DO NOT SHIP THE INSTRUMENT WITHOUT REMOVING THE PERMEATION TUBE. THE TUBE CONTINUES TO EMIT NO_2, EVEN AT ROOM TEMPERATURE AND WILL CONTAMINATE THE ENTIRE INSTRUMENT.

13.3.7. CHANGING THE EXTERNAL ZERO AIR SCRUBBER (OPT 86C)

The external zero air scrubber that is included with several of the T200's optional calibration valve packages contains two chemicals:

- Pink Purafil© (P/N CH 9)that converts NO in the ambient air to NO_2, and;
- Black, charcoal (P/N CH 1) that absorbs the NO_2 thereby creating zero air.

These chemicals need to be replaced periodically (see Table 13-2) or as needed.

CAUTION!

The following procedures apply only to the External Zero Air Scrubber and NOT to the inline exhaust scrubber cartridge that is part of the pump pack assembly.

NOTE

This procedure can be carried out while the instrument is running, however ensure that the analyzer is not in ZERO calibration mode.

1. Locate the scrubber on the outside rear panel; Figure 13-4 shows the exploded assembly.
2. Remove the old scrubber by disconnecting the 1/4" plastic tubing from the DFU particle filter using 9/16" and 1/2" wrenches.
3. Remove the DFU particle filter from the cartridge using 9/16" wrenches.
4. Unscrew the top of the scrubber canister and discard the Purafil© and charcoal contents.
    - Ensure to abide to local laws about discarding these chemicals.
    - The rebuild kit (listed in Appendix B) comes with a Material and Safety Data Sheet, which contains more information on these chemicals.
5. It is not necessary to remove the insert from the barrel, but if removed, perform the following procedure:

   - Coat the threads of the insert with epoxy (Teledyne API P/N CH32).
   - Hand tighten insert to barrel.
6. It is not necessary to remove the nylon tube fitting from the insert, but if removed, apply Teflon tape (Teledyne API P/N HW36) to the threads of the nylon tube fitting before installing on the insert.
7. Refill the scrubber with charcoal at the bottom and the Purafil© chemical at the top.
   - Use three, white retainer pads to separate the chemicals as shown Figure 13-4
8. Replace the screw-top cap and tighten the cap; hand-tighten only.
9. If necessary, replace the filter with a new unit and discard the old. See Section 13.3.7.1.
   - The bottom retainer pad should catch most of the dust, the filter should not be visibly dirty (on the inside).
10. Replace the scrubber assembly into its clips on the rear panel.
11. Reconnect the plastic tubing to the fitting of the DFU particle filter.
12. Adjust the scrubber cartridge such that it does not protrude above or below the analyzer in case the instrument is mounted in a rack.
    - If necessary, squeeze the clips for a tighter grip on the cartridge.

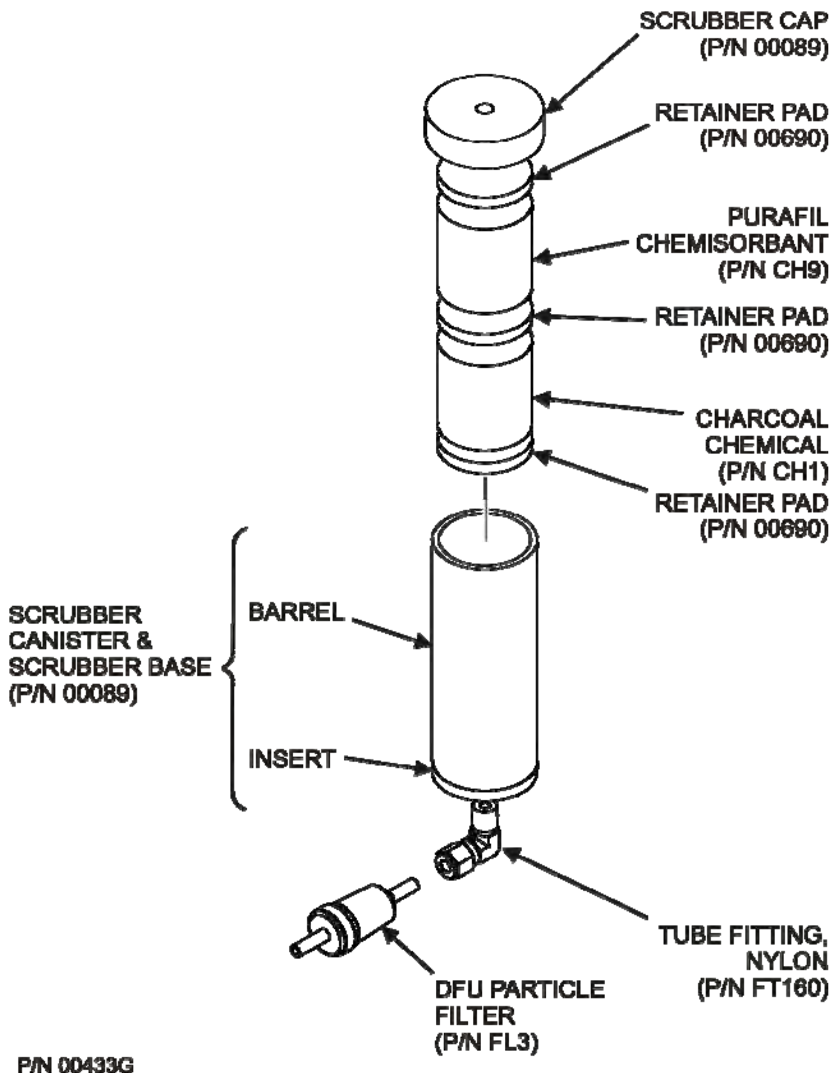


Figure 13-4: Zero Air Scrubber Assembly

13.3.7.1. Changing the External Scrubber's DFU Filter

There is also a DFU filter on the inlet of the external zero air scrubber that is included in several of the optional calibration valve packages.

To change this filter:

1. Disconnect the tube and fitting from one end and remove the filter from the scrubber canister.
2. Insert a new filter and reattach the tubing.
3. Ensure that the small arrow embedded on the filter points in flow direction, i.e., to analyzer.

13.3.8. CHANGING THE NO_2 CONVERTER

The NO_2 converter is located in the center of the instrument, Figure 3-5 for the location, and Figure 13-5 for the assembly.

The converter is designed for replacement of the cartridge only; the heater with built-in thermocouple is to be reused.

NOTE

Wear gloves prior to changing the NO_2 Converter to ensure that the fiberglass insulation does not come into contact with your skin.

1. Turn off the analyzer power.
2. Remove the instrument cover and allow the converter to cool.
3. Remove the converter assembly cover as well as the Moly insulation (top layer and corner cut out layers) until the Moly converter assembly can be seen.

CAUTION

HOT SURFACE HAZARD

The converter operates at 315º C. Severe burns can result if the assembly is not allowed to cool.

Do not handle the assembly until it is at room temperature. This may take several hours

4. Remove the tube fittings from the Moly converter assembly.
5. Disconnect the power and the thermocouple from the Moly converter assembly.
6. Unscrew the steel cable clamp (for the power leads) from the converter housing with a Phillips-head screw driver.
7. Remove the Moly converter assembly (converter cartridge and band heater) from the converter housing.
   - Make a note of the orientation of the tubes relative to the heater cartridge.
8. Unscrew the band heater and loosen it.
9. Remove the old converter cartridge.

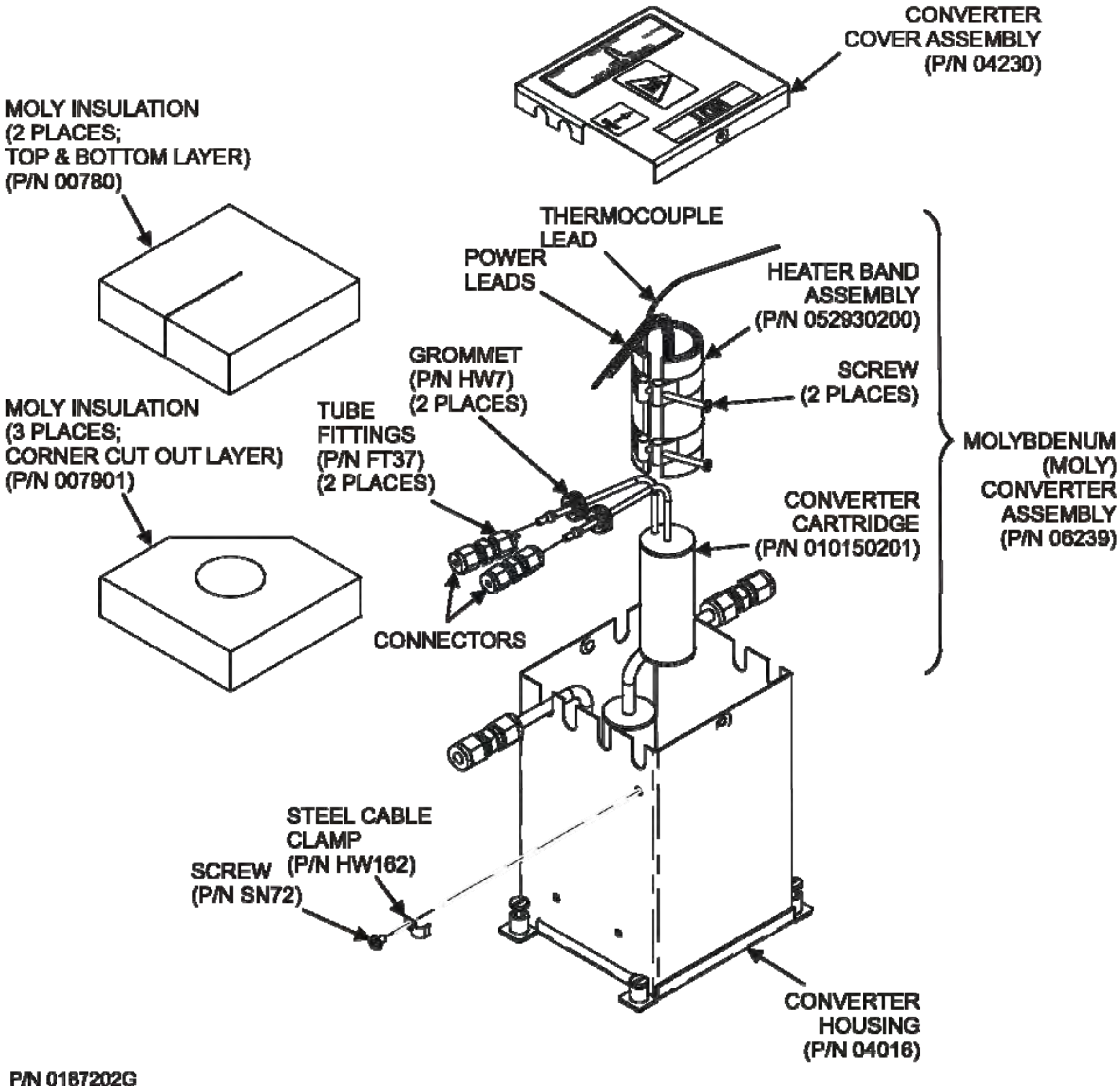


Figure 13-5: NO_2 Converter Assembly

10. Wrap the band heater around the new replacement converter cartridge and tighten the screws using a high-temperature anti-seize agent (Teledyne API P/N CH42) such as copper paste.
    - Ensure to use proper alignment of the heater with respect to the converter tubes.
11. Replace the Moly converter assembly by routing the cables through the holes in the converter housing and reconnecting them properly.
12. Reconnect the steel cable clamp around the power leads for safe operation.
13. Reattach the tube fittings to the converter and replace the Moly insulation (top layer and corner cut out layers).
14. Reinstall the converter assembly cover.
15. Reinstall the instrument cover and power up the analyzer.
16. Allow the converter to burn-in for 24 hours, and then recalibrate the instrument.

13.3.9. CLEANING THE REACTION CELL

A dirty reaction cell will cause excessive noise, drifting zero or span values, low response or a combination of all. To clean the reaction cell, it is necessary to remove it from the sensor housing.

1. Turn off the instrument power and vacuum pump. Refer to Figure 13-6 for the following procedure.
2. Disconnect the black 1/4" exhaust tube and the 1/8" sample and ozone air tubes from the reaction cell. Disconnect the heater/thermistor cable.
3. Remove two screws (Teledyne API P/N SN144) and two washers holding the reaction cell to the PMT housing and lift the cell and manifold out.

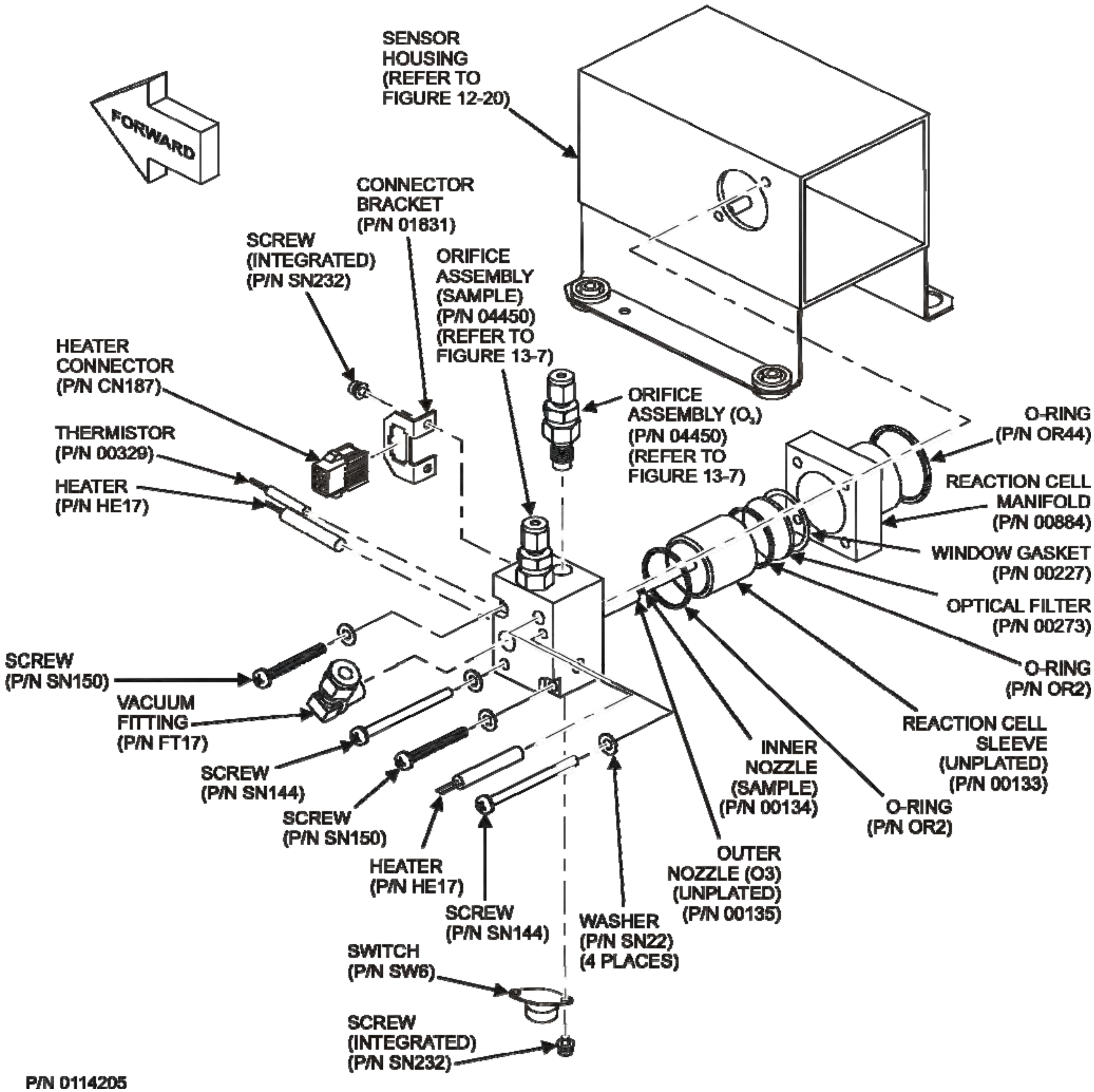


Figure 13-6: Reaction Cell Assembly

4. Remove two screws (Teledyne API P/N SN150) and two washers.
5. The reaction cell will separate into two halves, the stainless steel manifold assembly and the black plastic reaction cell with window gasket, stainless steel reaction cell sleeve, optical filter and O-rings.
6. The reaction cell (both plastic part and stainless steel sleeve) and optical filter should be cleaned with Distilled Water (DI - Water) and a clean tissue, and dried thereafter.
7. Usually it is not necessary to clean the sample and ozone flow orifices since they are protected by sintered filters.
   - If tests show that cleaning is necessary, refer to Section 13.3.10 on how to clean the critical flow orifice.
8. Do not remove the sample and ozone nozzles. They are Teflon threaded and require a special tool for reassembly. If necessary, the manifold with nozzles attached can be cleaned in an ultrasonic bath.
9. Reassemble in proper order and re-attach the reaction cell to the sensor housing. Reconnect pneumatics and heater connections, then re-attach the pneumatic sensor assembly and the cleaning procedure is complete.
10. After cleaning the reaction cell, it is also recommended to exchange the ozone supply air filter chemical as described in Section 13.3.3.
11. After cleaning, the analyzer span response may drop 10 - 15% in the first 10 days as the reaction cell window conditions. This is normal and does not require another cleaning.

13.3.10. REPLACING CRITICAL FLOW ORIFICES

There are several critical flow orifices installed in the T200 (see Figure 12-9 for a pneumatic location of each orifice). Despite the fact that these flow restrictors are protected by sintered stainless steel filters, they can, on occasion, clog up, particularly if the instrument is operated without sample filter or in an environment with very fine, sub-micron particle-size dust.

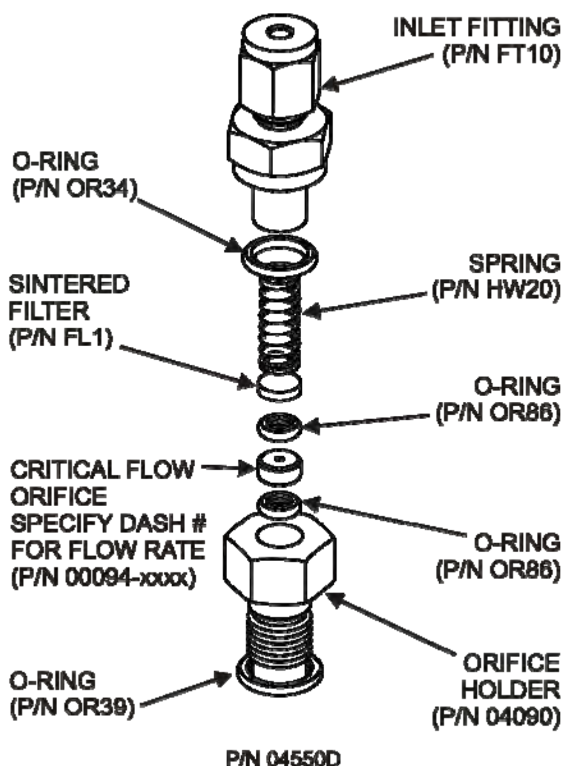


Figure 13-7: Critical Flow Orifice Assembly

To clean or replace a critical flow orifice:

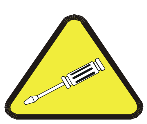
1. Turn off power to the instrument and vacuum pump.
2. Remove the analyzer cover and locate the reaction cell (Figure 13-5 and Figure 13-6).
3. Unscrew the 1/8” sample and ozone air tubes from the reaction cell.
4. For orifices on the reaction cell (Figure 13-6): Unscrew the orifice holder with a 9/16” wrench.
   - This part holds all components of the critical flow assembly as shown in Figure 13-7.
   - Appendix B contains a list of spare part numbers.
5. For orifices in the vacuum manifold: the assembly is similar to the one shown in Figure 13-7, except:
   - Without the orifice holder, P/N 04090, and bottom O-ring, P/N OR34 and;
   - With an NPT fitting in place of the FT 10 fitting.
6. After taking off the connecting tube, unscrew the NPT fitting.
7. Take out the components of the assembly:
   - A spring
   - A sintered filter
   - Two O-rings and the orifice

NOTE
For the vacuum manifold only, you may need to use a scribe or pressure from the vacuum port to get the parts out of the manifold.

8. Discard the two O-rings and the sintered filter and install new ones.
9. Reassemble the parts as shown in low Orifice Assembly
10.
11. To clean or replace a critical flow o the critical flow orifice assembly into the reaction cell manifold or the vacuum manifold.
12. Reconnect all tubing, power up the analyzer and pump. After a warm-up period of 30 minutes, carry out a leak test as described in Section 13.3.12.

13.3.11. CHECKING FOR LIGHT LEAKS

When re-assembled or operated improperly, the T200 can develop small gaps around the PMT, which let stray light from the analyzer surrounding into the PMT housing. To find such light leaks, follow the procedures below.



CAUTION
QUALIFIED PERSONNEL
This procedure can only be carried out with the analyzer running and its cover removed.
This procedure should only be carried out by qualified personnel.

1. Scroll the front panel display to show then test function to **PMT**.
2. Supply zero gas to the analyzer.
3. With the instrument still running, carefully remove the analyzer cover.

CAUTION

ELECTRICAL SHOCK HAZARD

Take extra care not to touch any of the inside wiring with the metal cover or your body.

Do not drop screws or tools into a running analyzer!

4. Shine a powerful flashlight or portable incandescent light at the inlet and outlet fitting and at all of the joints of the reaction cell as well as around the PMT housing.
   - The PMT value should not respond to the light, the PMT signal should remain steady within its usual noise floor.
5. If there is a PMT response to the external light, symmetrically tighten the reaction cell mounting screws or replace the 1/4" vacuum tubing with new, black PTFE tubing (this tubing will fade with time and become transparent).

NOTE

Often, light leaks are also caused by O-rings being left out of the assembly.

6. Carefully replace the analyzer cover. If tubing was changed, carry out a leak check.

NOTE

If the black PMT housing end plate for the Sensor Assembly is removed, ensure to replace the 5 desiccant bags inside the housing.

13.3.12. CHECKING FOR PNEUMATIC LEAKS

CAUTION

TECHNICAL INFORMATION

Do not exceed 15 psi when pressurizing the system during either Simple or Detailed checks.

13.3.12.1. Simple Vacuum Leak and Pump Check

Leaks are the most common cause of analyzer malfunction. This section presents a simple leak check, whereas the next section details a more thorough procedure. The method described here is easy, fast and detects, but does not locate, most leaks. It also verifies the sample pump condition.

1. Turn the analyzer ON, and allow at least 30 minutes for flows to stabilize.
2. Cap the sample inlet port (cap must be wrench-tight).
3. After several minutes, when the pressures have stabilized, note the SAMP (sample pressure) and the RCEL (vacuum pressure) readings.
   - If both readings are equal to within 10% and less than 10 in-Hg-A, the instrument is free of large leaks.
   - It is still possible that the instrument has minor leaks.
   - If both readings are < 10 in-Hg-A, the pump is in good condition.
   - A new pump will create a pressure reading of about 4 in-Hg-A (at sea level).

13.3.12.2. Detailed Pressure Leak Check

If a leak cannot be located by the above procedure, obtain a leak checker similar to Teledyne API's P/N 01960, which contains a small pump, shut-off valve, and pressure gauge to create both over-pressure and vacuum. Alternatively, a tank of pressurized gas, with the two stage regulator adjusted to ≤ 15 psi, a shutoff valve and pressure gauge may be used.

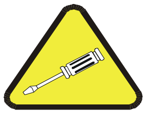
CAUTION
TECHNICAL INFORMATION

Once tube fittings have been wetted with soap solution under a pressurized system, do not apply or reapply vacuum as this will cause soap solution to be sucked into the instrument, contaminating inside surfaces.

Turn OFF power to the instrument and remove the instrument cover.

1. Install a leak checker or a tank of gas (compressed, oil-free air or nitrogen) as described above on the sample inlet at the rear panel.
2. Disconnect the pump tubing on the outside rear panel and cap the pump port.
    - If IZS or zero/span valves are installed, disconnect the tubing from the zero and span gas ports and plug them (Figure 3-3).
    - Cap the DFU particle filter on the Perma Pure dryer.
3. Pressurize the instrument with the leak checker or tank gas, allowing enough time to fully pressurize the instrument through the critical flow orifice.
    - Check each tube connection (fittings, hose clamps) with soap bubble solution, looking for fine bubbles.
    - Once the fittings have been wetted with soap solution, do not reapply vacuum as it will draw soap solution into the instrument and contaminate it.
    - **Do not exceed 15 psi pressure.**
4. If the instrument has the zero and span valve option, the normally closed ports on each valve should also be separately checked.
    - Connect the leak checker to the normally closed ports and check with soap bubble solution.
5. If the analyzer is equipped with an IZS Option Connect the leak checker to the Dry Air inlet and check with soap bubble solution.
6. Once the leak has been located and repaired, the leak-down rate of the indicated pressure should be less than 1 in-Hg-A (0.4 psi) in 5 minutes after the pressure is turned off.
7. Clean surfaces from soap solution, reconnect the sample and pump lines and replace the instrument cover.
8. Restart the analyzer.

13.3.12.3. Performing a Sample Flow Check



CAUTION
TECHNICAL INFORMATION

Use a separate, calibrated flow meter capable of measuring flows between 0 and 1000 cm³/min to measure the gas flow rate though the analyzer. Do not use the built in flow measurement viewable from the front panel of the instrument.

This value is only calculated, not measured.

Sample flow checks are useful for monitoring the actual flow of the instrument, as the front panel display shows only a calculated value. A decreasing, actual sample flow may point to slowly clogging pneumatic paths, most likely critical flow orifices or sintered filters. To perform a sample flow check:

1. Disconnect the sample inlet tubing from the rear panel SAMPLE port.
2. Attach the outlet port of a flow meter to the sample inlet port on the rear panel.
   - Ensure that the inlet to the flow meter is at atmospheric pressure.
3. The sample flow measured with the external flow meter should be 500 cm³/min ± 10%.
   - If a combined sample/ozone air Perma Pure dryer is installed (optional equipment), the flow will be 640 cm³/min ± 10% (500 cm³/min for the sample and 80 cm³/min for the ozone generator supply air and 60 cm³/min for the purge flow).
4. Low flows indicate blockage somewhere in the pneumatic pathway.

14. GENERAL TROUBLESHOOTING & REPAIR

This section contains a variety of methods for identifying the source of performance problems with the analyzer. Also included in this section are procedures that are used in repairing the instrument.

NOTE

QUALIFIED PERSONNEL

The operations outlined in this chapter must be performed by qualified maintenance personnel only.

CAUTION

GENERAL SAFETY HAZARD

- **Risk of electrical shock. Some operations need to be carried out with the instrument open and running.**
- **Exercise caution to avoid electrical shocks and electrostatic or mechanical damage to the analyzer.**
- **Do not drop tools into the analyzer or leave those after your procedures.**
- **Do not shorten or touch electric connections with metallic tools while operating inside the analyzer.**
- **Use common sense when operating inside a running analyzer.**

14.1. GENERAL TROUBLESHOOTING

The T200 Nitrogen oxide analyzer has been designed so that problems can be rapidly detected, evaluated and repaired. During operation, it continuously performs diagnostic tests and provides the ability to evaluate its key operating parameters without disturbing monitoring operations.

A systematic approach to troubleshooting will generally consist of the following five steps:

1. Note any **WARNING MESSAGES** and take corrective action as necessary.
2. Examine the values of all TEST functions and compare them to factory values. Note any major deviations from the factory values and take corrective action.
3. Use the internal electronic status LEDs to determine whether the electronic communication channels are operating properly.
    - Verify that the DC power supplies are operating properly by checking the voltage test points on the relay PCA.
    - Note that the analyzer's DC power wiring is color-coded and these colors match the color of the corresponding test points on the relay PCA.
4. SUSPECT A LEAK FIRST!
    - Customer service data indicate that the majority of all problems are eventually traced to leaks in the internal pneumatics of the analyzer or the diluent gas and source gases delivery systems.
    - Check for gas flow problems such as clogged or blocked internal/external gas lines, damaged seals, punctured gas lines, a damaged / malfunctioning pumps, etc.
5. Follow the procedures defined in Section 3.7.3 to confirm that the analyzer's vital functions are working (power supplies, CPU, relay PCA, touchscreen, PMT cooler, etc.).

- See Figure 3-5 or the general layout of components and sub-assemblies in the analyzer.
- See the wiring interconnect diagram and interconnect list in Appendix D.

14.1.1. FAULT DIAGNOSIS WITH WARNING MESSAGES

The most common and/or serious instrument failures will result in a warning message being displayed on the front panel. Table 14-1 lists warning messages, along with their meaning and recommended corrective action.

It should be noted that if more than two or three warning messages occur at the same time, it is often an indication that some fundamental sub-system (power supply, relay PCA, motherboard) has failed rather than an indication of the specific failures referenced by the warnings.

The analyzer will alert the user that a Warning Message is active by flashing the FAULT LED and displaying the Warning message in the Param field along with the **CLR** button (press to clear Warning message). The **MSG** button displays if there is more than one warning in queue or if you are in the TEST menu and have not yet cleared the message. The following display/touch screen examples provide an illustration of each:

The analyzer will also alert the user via the Serial I/O COMM port(s).

To view or clear the various warning messages press:

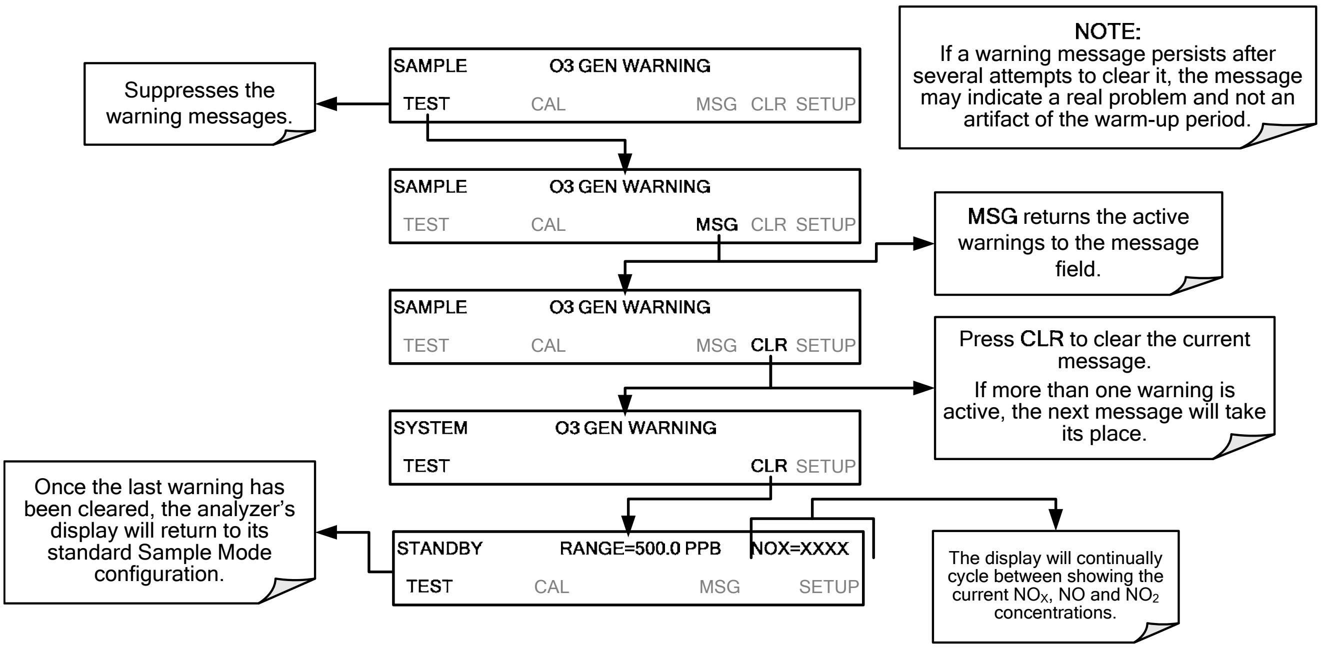


Table 14-1: Front Panel Warning Messages

WARNING	FAULT CONDITION	POSSIBLE CAUSES
AZERO WARN XXX.X MV	Auto-zero reading above 200 mV. Value shown in message indicates auto-zero reading at time warning was displayed.	• AZERO valve not working • Valve control driver failed • Bad Relay PCA • Failed +12 VDC power supply • Gas leak across AZERO Valve ports • Dirty Reaction Cell • O_3 flow problem to RCELL
BOX TEMP WARNING	Box Temp is < 7°C or > 48°C.	• Box Temperature typically runs ~7°C warmer than ambient temperature • Poor/blocked ventilation to the analyzer • Stopped Exhaust-Fan • Ambient Temperature outside of specified range
CANNOT DYN SPAN	Dynamic Span operation failed.	• Measured concentration value is too high or low • Concentration Slope value to high or too low
CANNOT DYN ZERO	Dynamic Zero operation failed.	• Measured concentration value is too high • Concentration Offset value to high
CONFIG INITIALIZED	Configuration and Calibration data reset to original Factory state.	• Failed Disk on Chip • User erased data
CONV TEMP WARNING	NO_2 → NO Converter temperature < 305°C or > 325°C.	• Heater configured for wrong voltage type • Failed converter Temperature Sensor • Relay controlling the Heater is not working • Failed Relay Board
DATA INITIALIZED	Data Storage in DAS was erased.	• Failed Disk-on-Chip • User cleared data.
HVPS WARNING	High voltage power supply output outside of warning limits specified by *HVPS_SET* variable.	• No +15 VDC power supply to Preamplifier PCA • Drive voltage not adjusted properly • Failed PMT Preamplifier PCA • Dirty reaction cell • Bad pneumatic flow
IZS TEMP WARNING	Permeation tube oven temperature is < 45°C or > 55°C.	• Heater configured for wrong voltage type • Failed permeation tube Temperature Sensor • Relay controlling the Heater is not working • Failed Relay Board
OZONE FLOW WARNING	O_3 flow rate is < 50 cc/min or > 150 cc/min.	• Failed Sample Pump • Blocked O_3 dryer • Blocked inlet/outlet to O_3 purifier • Dirty O_3 dryer DFU • Leak downstream of RCELL • Failed O_3 Flow Sensor
OZONE GEN OFF	Ozone generator is off. This is the only warning message that automatically clears itself. It clears itself when the ozone generator is turned on.	• O_3 generator override is turned ON. • Electrical connection between motherboard and generator is faulty. • Bad +15VDC power supply
PMT TEMP WARNING	Sample temperature is < 5°C or > 12°C.	• PMT fan not operating • Failed PMT Temperature Sensor • TEC not functioning • Failed PMT Preamp PCA

WARNING	FAULT CONDITION	POSSIBLE CAUSES
RCELL PRESS WARN	Sample Pressure is <15 in-Hg or > 35 in-Hg Normally 29.92 in-Hg at sea level decreasing at 1 in-Hg per 1000 ft of altitude (with no flow – pump disconnected).	If Sample Pressure is < 15 in-HG: • Blocked Particulate Filter • Blocked Sample Inlet/Gas Line • Failed Pressure Senor/circuitry If Sample Pressure is > 35 in-HG: • Bad Pressure Sensor/circuitry • Pressure too high at Sample Inlet.
RCELL TEMP WARNING	RCELL temperature is < 45°C or > 55°C.	• Heater configured for wrong voltage type • Failed RCELL Temperature Sensor • Relay controlling the heater is not working • Failed Relay Board • I^2C Bus
REAR BOARD NOT DET	Motherboard not detected on power up.	• This WARNING only appears on Serial I/O COMM Port(s) Front Panel Display will be frozen, blank or will not respond. • Failure of Motherboard
RELAY BOARD WARN	The CPU cannot communicate with the Relay Board.	• I^2C Bus failure • Failed Relay Board • Loose connectors/wiring
SAMPLE FLOW WARN	Sample flow rate is < 350 cc/min or > 600 cc/min.	• Failed Sample Pump • Blocked Sample Inlet/Gas Line • Dirty Particulate Filter • Leak downstream of RCELL Critical Flow Orifice • Failed Sample Pressure Sensor • Failed Vacuum Pressure Sensor
SYSTEM RESET	The computer has rebooted.	• This message occurs at power on. • If it is confirmed that power has not been interrupted: • Failed +5 VDC power • Fatal Error caused software to restart • Loose connector/wiring

NOTE

A failure of the analyzer's CPU, motherboard or power supplies can result in any or ALL of the above messages.

14.1.2. FAULT DIAGNOSIS WITH TEST FUNCTIONS

Besides being useful as predictive diagnostic tools, the test functions viewable from the analyzers front panel can be used to isolate and identify many operational problems when combined with a thorough understanding of the analyzers Theory of Operation (see Section 12).

The acceptable ranges for these test functions are listed in the "Nominal Range" column of the analyzer *Final Test and Validation Data Sheet* (P/N 04490) shipped with the instrument. Values outside these acceptable ranges indicate a failure of one or more of the analyzer's subsystems. Functions whose values are still within acceptable ranges but have significantly changed from the measurement recorded on the factory data sheet may also indicate a failure.

A worksheet has been provided in Appendix C to assist in recording the value of these test functions.

NOTE

A value of "XXXX" displayed for any of these TEST functions indicates an OUT OF RANGE reading.

NOTE

Sample Pressure measurements are represented in terms of ABSOLUTE pressure because this is the least ambiguous method reporting gas pressure.

Absolute atmospheric pressure is about 29.92 in-Hg-A at sea level. It decreases about 1 in-Hg per 1000 ft gain in altitude. A variety of factors such as air conditioning systems, passing storms, and air temperature, can also cause changes in the absolute atmospheric pressure.

Table 14-2: Test Functions - Indicated Failures

TEST FUNCTION	INDICATED FAILURE(S)
NO_x STB	Unstable concentrations; leaks
SAMPLE Fl	Leaks; clogged critical flow orifice
OZONE FL	Leaks; clogged critical flow orifice
PMT	Calibration off; HVPS problem; no flow (leaks)
NORM PMT	Auto Zero too high
AZERO	Leaks; malfunctioning NO, NO_x or Auto Zero valve; O_3 air filter cartridge exhausted
HVPS	Calibration off; preamp board circuit problems
RCELL TEMP	Malfunctioning heater; relay board communication (I^2C bus); relay burnt out
BOX TEMP	Environment out of temperature operating range; broken thermistor
PMT TEMP	TEC cooling circuit broken; relay board communication (I^2C bus); 12 V power supply
IZS TEMP (option)	Malfunctioning heater; relay board communication (I^2C bus); relay burnt out
MOLY TEMP	Malfunctioning heater; disconnected or broken thermocouple; relay board communication (I^2C bus); relay burnt out; incorrect AC voltage configuration
RCEL (pressure)	Leak; malfunctioning valve; malfunctioning pump; clogged flow orifices
SAMP (pressure)	Leak; malfunctioning valve; malfunctioning pump; clogged flow orifices; sample inlet overpressure
NOX SLOPE	HVPS out of range; low-level (hardware) calibration needs adjustment; span gas concentration incorrect; leaks
NOX OFFset	Incorrect span gas concentration; low-level calibration off
NO SLOPE	HVPS out of range; low-level calibration off; span gas concentration incorrect; leaks
NO OFFSet	Incorrect span gas concentration; low-level calibration off
Time of Day	Internal clock drifting; move across time zones; daylight savings time?

14.1.3. DIAG → SIGNAL I/O: USING THE DIAGNOSTIC SIGNAL I/O FUNCTION

The signal I/O diagnostic mode allows access to the digital and analog I/O in the analyzer. Some of the digital signals can be controlled through the touchscreen. These signals, combined with a thorough understanding of the instruments Theory of Operation (see Section 12), are useful for troubleshooting in three ways:

- The technician can view the raw, unprocessed signal level of the analyzer's critical inputs and outputs.
- Many of the components and functions that are normally under algorithmic control of the CPU can be manually exercised.
- The technician can directly control the signal level Analog and Digital Output signals.

This allows the technician to observe systematically the effect of directly controlling these signals on the operation of the analyzer. Following is an example of how to use the Signal I/O menu to view the raw voltage of an input signal or to control the state of an output voltage or control signal.

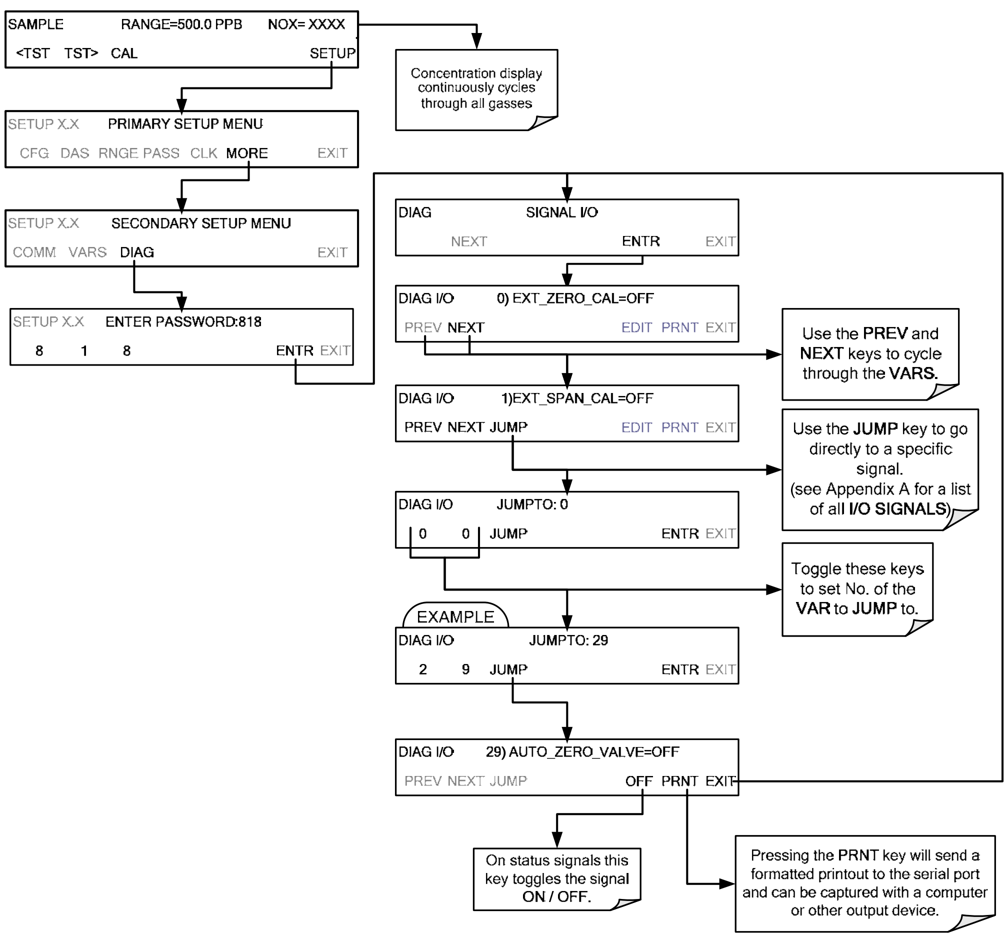


Figure 14-1: Example of Signal I/O Function

> **NOTE**
>
> **Any I/O signals changed while in the signal I/O menu will remain in effect ONLY until signal I/O menu is exited. The Analyzer regains control of these signals upon exit.**
>
> **See Appendix A-4 for a complete list of the parameters available for review under this menu.**

14.2. USING THE ANALOG OUTPUT TEST CHANNEL

The signals available for output over the T200's analog output channel can also be used as diagnostic tools. See Section 8.4 for instruction on activating the analog output and selecting a function.

Table 14-3: Test Channel Outputs as Diagnostic Tools

TEST CHANNEL	DESCRIPTION	ZERO	FULL SCALE	CAUSES OF EXTREMELY HIGH / LOW READINGS
PMT DETECTOR	The output of the PMT detector converted to a 0 to 5 VDC scale.	**0 mV**	**5000 mV**	• Failed PMT • PMT Temperature too High/Low • Bad PMT Preamp PCA • Failed HVPS • Misadjusted HVPS drive Voltage • Light Leak in reaction cell
OZONE FLOW	The flow rate of O_3 through the analyzer as measured by the O_3 flow sensor	**0 cm^3/min**	**1000 cm^3/min**	• Check for Gas Flow problems in the O_3 gas lines.
SAMPLE FLOW	The calculated flow rate for sample gas through the analyzer.	**0 cm^3/min**	**1000 cm^3/min**	• Check for Gas Flow problems in the sample gas lines.
SAMPLE PRESSURE	The pressure of the sample gas measured upstream of the Auto Zero Valve	**0 In-Hg-A**	**40 In-Hg-A**	• Check for Gas Flow problems in the sample gas lines.
RCELL PRESSURE	The pressure of gas inside the reaction cell of the sensor module	**0 In-Hg-A**	**40 In-Hg-A**	• Check for Gas Flow problems in all gas lines.
RCELL TEMP	The temperature of gas inside the reaction cell of the sensor module	**0 °C**	**70 °C**	• Same as **RCELL TEMP WARNING** in Table 14-1.
IZS TEMP	The temperature of the permeation tube oven of the optional internal span gas generator.	**0 °C**	**70 °C**	• Same as **IZS TEMP WARNING** in Table 14-1.
CONV TEMP	The temperature NO_2 → NO converter	**0 mV**	**5000 mV**	• Same as **CONV TEMP WARNING** in Table 14-1.
PMT TEMP	The temperature inside PMT	**0 °C**	**50 °C**	• Same as **PMT TEMP WARNING** in Table 14-1.
BOX TEMP	The temperature inside the T200's chassis	**0 °C**	**70 °C**	• Same as **BOX TEMP WARNING** in Table 14-1.
HVPS VOLTAGE	Represents the output voltage of the PMT's high voltage power supply	**0 mV**	**5000 mV**	• Same as **HVPSWARNING** in Table 14-1.

14.3. USING THE INTERNAL ELECTRONIC STATUS LEDS

Several LEDs are located inside the instrument to assist in determining if the analyzer's CPU, I^2C bus and Relay PCA are functioning properly.

14.3.1. CPU STATUS INDICATOR

DS5, a red LED, that is located on upper portion of the motherboard, just to the right of the CPU board, flashes when the CPU is running the main program loop. After power-up, approximately 30 – 60 seconds, DS5 should flash on and off. If characters are written to the front panel display but DS5 does not flash then the program files have become corrupted, contact Teledyne API's Customer Service Department (see Section 14.9) because it may be possible to recover operation of the analyzer. If after 30 – 60 seconds, neither DS5 is flashing nor have any characters been written to the front panel display then the CPU is bad and must be replaced.

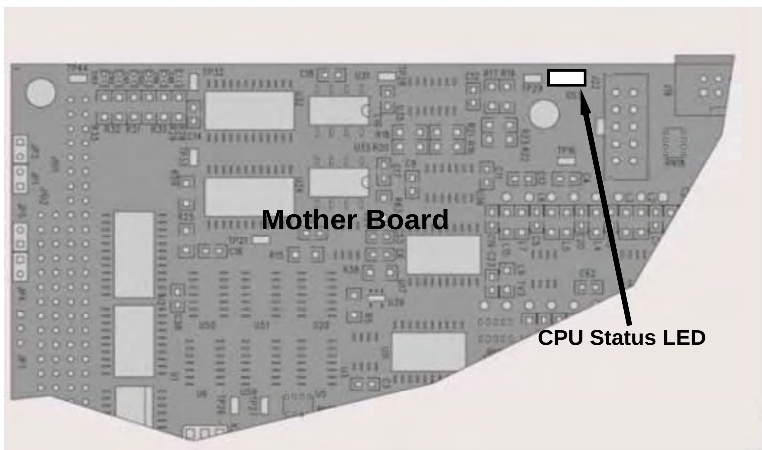


Figure 14-2: CPU Status Indicator

14.3.2. RELAY PCA STATUS LEDS

There are sixteen LEDs located on the Relay PCA. Some are not used on this model.

14.3.2.1. I^2C Bus Watchdog Status LEDs

The most important is D1 (see , which indicates the health of the I^2C bus).

Table 14-4: Relay PCA Watchdog LED Failure Indications

LED	Function	Fault Status	Indicated Failure(s)
D1 (Red)	I^2C bus Health (Watchdog Circuit)	Continuously ON or Continuously OFF	Failed/Halted CPU Faulty Motherboard, Touchscreen or Relay PCA Faulty Connectors/Wiring between Motherboard, Touchscreen or Relay PCA Failed/Faulty +5 VDC Power Supply (PS1)

If D1 is blinking, then the other LEDs can be used in conjunction with **DIAG** Menu Signal I/O to identify hardware failures of the relays and switches on the Relay PCA.

14.3.2.2. Relay PCA Status LED s

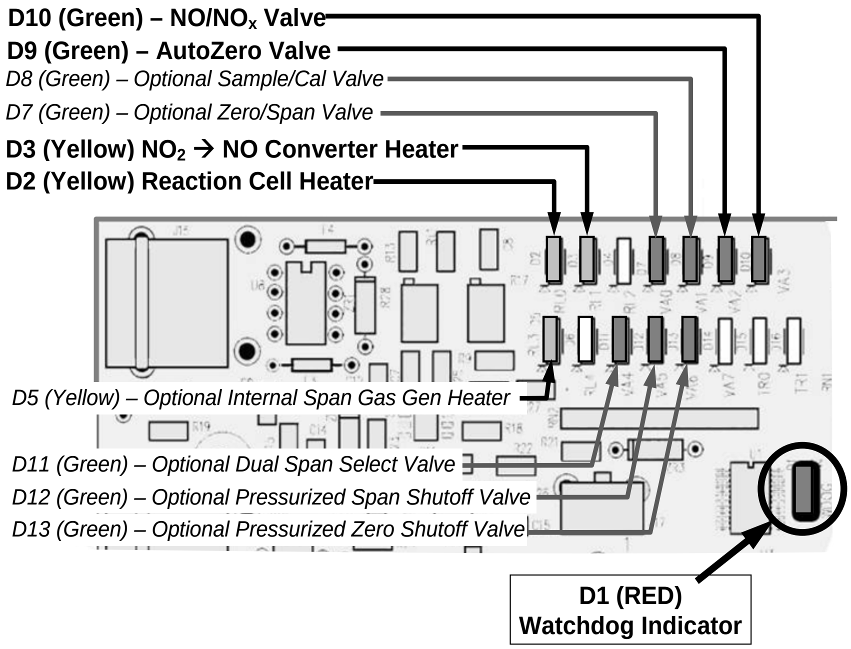


Figure 14-3: Relay PCA Status LEDS Used for Troubleshooting

Table 14-5: Relay PCA Status LED Failure Indications

LED	COLOR	FUNCTION	FAULT STATUS	INDICATED FAILURE(S)
LED ROW 1				
D2	Yellow	Reaction Cell heater	Continuously ON or OFF	Heater broken, thermistor broken
D3	Yellow	NO_2 converter heater	Continuously ON or OFF	Heater broken, thermocouple broken
D7	Green	Zero/Span valve status	Continuously ON or OFF	Valve broken or stuck, valve driver chip broken
D8	Green	Sample/Cal valve status	Continuously ON or OFF	Valve broken or stuck, valve driver chip broken
D9	Green	Auto-zero valve status	Continuously ON or OFF	Valve broken or stuck, valve driver chip broken
D10	Green	NO/NO_x valve status	Continuously ON or OFF	Valve broken or stuck, valve driver chip broken
LED ROW 2				
D5	Yellow	Internal span gas generator perm tube heater	Continuously ON or OFF	Heater broken, thermistor broken
D11	Green	Dual span select valve	Continuously ON or OFF	Valve broken or stuck, valve driver chip broken
D12	Green	Pressurized Span shutoff valve	Continuously ON or OFF	Valve broken or stuck, valve driver chip broken
D13	Green	Pressurized Zero shutoff valve	Continuously ON or OFF	Valve broken or stuck, valve driver chip broken
D14- 16	Green	Spare	N/A	N/A

14.4. GAS FLOW PROBLEMS

The T200 has two main flow paths, the sample flow and the flow of the ozone supply air. With IZS or zero/span valve option installed, there is a third (zero air) and a fourth (span gas) flow path, but either one of those is only controlled by critical flow orifices and not displayed on the front panel or stored to the DAS.

- Flow is too high
- Flow is greater than zero, but is too low, and/or unstable
- Flow is zero (no flow)

When troubleshooting flow problems, it is essential to confirm the actual flow rate without relying on the analyzer's flow display. The use of an independent, external flow meter to perform a flow check as described in Section 13.3.12 is essential. Refer to the pneumatic flow diagrams in Section 6 as needed for reference.

14.4.1. ZERO OR LOW FLOW PROBLEMS

14.4.1.1. Sample Flow is Zero or Low

The T200 does not actually measure the sample flow but rather calculates it from a differential pressure between sample and vacuum manifold. On flow failure, the unit will display a **SAMPLE FLOW WARNING** on the front panel display and the respective test function reports **XXXX** instead of a value "0". This message applies to both a flow rate of zero as well as a flow that is outside the standard range (350-600 cm^3/min).

If the analyzer displays **XXXX** for the sample flow, confirm that the external sample pump is operating and configured for the proper AC voltage.

- Whereas the T200 can be internally configured for two different power regimes (100-120 V and 220-240 V, either 50 or 60 Hz), the external pump is physically different for each of three power regimes (100 V / 50 Hz, 115 V / 60 Hz and 230 V / 50 Hz).
- If the pump is not running, use an AC Voltmeter to ensure that the pump is supplied with the proper AC power. If AC power is supplied properly, but the pump is not running, replace the pump.

NOTE
Sample and vacuum pressures mentioned in this chapter refer to operation of the analyzer at sea level. Pressure values need to be adjusted for elevated locations, as the ambient pressure decreases by about 1 in-Hg per 300 m / 1000 ft.

- If the pump is operating but the unit reports a **XXXX** gas flow, do the following three steps:
- Check for actual sample flow.
    - To check the actual sample flow, disconnect the sample tube from the sample inlet on the rear panel of the instrument.
    - Ensure that the unit is in basic **SAMPLE** mode.
    - Place a finger over the inlet and see if it gets sucked in by the vacuum or, more properly, use a flow meter to measure the actual flow.
    - If there is proper flow of around 450-550 cm^3/min, contact customer service.
    - If there is no flow or low flow, continue with the next step.
- Check pressures.

- Check that the sample pressure is at or around 28 in-Hg-A at sea level (adjust as necessary when in elevated location, the pressure should be about 1” below ambient atmospheric pressure) and that the **RCEL** pressure is below 10 in-Hg-A.
- The T200 will calculate a sample flow up to about 14 in-Hg-A **RCEL** pressure but a good pump should always provide less than 10 in.
- If both pressures are the same and around atmospheric pressure, the pump does not operate properly or is not connected properly. The instrument does not get any vacuum.
- If both pressures are about the same and low (probably under 10 in-Hg-A, or ~20” on sample and 15” on vacuum), there is a cross-leak between sample flow path and vacuum, most likely through the Perma Pure dryer flow paths. See troubleshooting the Perma Pure dryer later in this chapter.
- If the sample and vacuum pressures are around their nominal values (28 and <10 in-Hg-A, respectively) and the flow still displays **XXXX**, carry out a leak check as described in Section 13.3.12.
- If gas flows through the instrument during the above tests but goes to zero or is low when it is connected to zero air or span gas, the flow problem is not internal to the analyzer but likely caused by the gas source such as calibrators/generators, empty gas tanks, clogged valves, regulators and gas lines.
- If an IZS or Zero/Span valve option is installed in the instrument, press **CALZ** and **CALS**. If the sample flow increases, suspect a bad Sample/Cal valve.
- If none of these suggestions help, carry out a detailed leak check of the analyzer as described in Section 13.3.12.2.

14.4.1.2. Ozone Flow is Zero or Low

If there is zero or a low (<50 cm³/min) ozone flow, the unit displays an **OZONE FLOW WARNING** message on the front panel and a value between 0.0 and 50 cm³/min for the actual ozone flow as measured by the internal mass flow meter. In this case, carry out the following steps:

- Check the actual flow rate through the ozone dryer by using an external flow meter to the inlet port of the dryer.
    - This inlet port is inside the analyzer at the end of the plastic particle filter (Section 13.3.2 for illustration).
    - If there is nominal flow (about 160 cm³/min from 80 cm³/min O_3 flow and 80 cm³/min purge flow), consult customer service as there is a problem with the firmware or electronics.
- If the actual flow is low or zero, check if the pump operates properly. The RCEL pressure should be below 10 in-Hg-A at sea level.
    - If it is above 10”, rebuild the pump (Section 13.3.4.1). Check the spare parts list in Appendix B on how to order pump rebuild kits.
- Check if the particle filter is clogged.
    - Briefly remove the particle filter to see if this improves the flow.
    - Be very cautious when handling the Perma Pure dryer fittings (see Section 13.3.2 on proper handling instructions).
    - If the filter is clogged, replace it with a new unit.
    - If taking off this filter does not solve the problem, continue to the next step.
    - Do not leave the Perma Pure dryer without filter for more than a few seconds, as you may draw in dust, which will reduce the performance of the dryer.
- A leak between the flow meter and the reaction cell (where the flow-determining critical orifice is located) may cause a low flow (the system draws in ambient air through a leak after the flow meter).

- Check for leaks as described in Section 13.3.12.
- Repair the leaking fitting, line or valve and re-check.

- The most likely cause for zero or low ozone flow is a clogged critical flow orifice or sintered filter within the orifice assembly.
  - The orifice that sets the ozone flow is located on the reaction cell.
  - Check the actual ozone flow by disconnecting the tube from the reaction cell and measuring the flow going into the cell.

– If this flow is correct (~80 cm^3/min), the orifice works properly.

– If this flow is low, replace the sintered filter.

- The orifice holder assembly allows a quick and easy replacement of the filter (see Section 13.3.5 on for replacement procedures).
- Appendix B lists a spare part kit with a complete orifice assembly that allows a quick replacement with minimum instrument down-time.

14.4.1.3. High Flow

Flows that are significantly higher than the allowed operating range (typically ±10-11% of the nominal flow) should not occur in the T200 unless a pressurized sample, zero or span gas is supplied to the inlet ports.

- Ensure to vent excess pressure and flow just before the analyzer inlet ports.

When supplying sample, zero or span gas at ambient pressure, a high flow would indicate that one or more of the critical flow orifices are physically broken (very unlikely case), allowing more than nominal flow, or were replaced with an orifice of wrong specifications.

- If the flows are within 15% higher than normal, we recommend measuring and recalibrating the flow electronically using the procedure in Section 10, followed by a regular review of these flows over time to see if the new setting is retained properly.
- Also, check the flow assembly o-rings and replace as needed.

14.4.1.4. Sample Flow is Zero or Low but Analyzer Reports Correct Flow

Note that the T200 analyzer can report a correct flow rate even if there is no or a low actual sample flow through the reaction cell.

- The sample flow on the T200 is only calculated from the sample pressure and critical flow condition is verified from the difference between sample pressure and vacuum pressure.
- If the critical flow orifice assembly is partially or completely clogged, both the sample and vacuum pressures are still within their nominal ranges (the pump keeps pumping, the sample port is open to the atmosphere), but there is no flow possible through the reaction cell.

Although measuring the actual flow is the best method, in most cases, this fault can also be diagnosed by evaluating the two pressure values.

- Since there is no longer any flow, the sample pressure should be equal to ambient pressure, which is about 1 in-Hg-A higher than the sample pressure under normal operation.
- The reaction cell pressure, on the other hand, is significantly lower than under normal operation, because the pump no longer has to remove 500 cm^3/min of sample gas and evacuates the reaction cell much better.
- Those two indicators, taken together with a zero or low actual flow, indicate a clogged sample orifice.

The T200 features a new orifice holder, which makes switching sample and ozone flow orifices very easy, refer to Section 13.3.10 on how to change the sample orifices and Appendix B for part numbers of these assemblies.

Again, monitoring the pressures and flows regularly will reveal such problems, because the pressures would slowly or suddenly change from their nominal, mean values. Teledyne API recommends to review all test data once per week and to do an exhaustive data analysis for test and concentration values once per month, paying particular attention to sudden or gradual changes in all parameters that are supposed to remain constant, such as the flow rates.

14.5. CALIBRATION PROBLEMS

14.5.1. NEGATIVE CONCENTRATIONS

Negative concentration values can be caused for several reasons:

- A slight, negative signal is normal when the analyzer is operating under zero gas and the signal is drifting around the zero calibration point.
    - This is caused by the analyzer's zero noise and may cause reported concentrations to be negative for a few seconds at a time down to -20 ppb, but should randomly alternate with similarly high, positive values.
    - The T200 has a built-in Auto Zero function, which should take care of most of these deviations from zero, but may yield a small, residual, negative value.
    - If larger, negative values persist continuously, check if the Auto Zero function was accidentally turned off using the remote variables in Appendix A-2.
    - In this case, the sensitivity of the analyzer may be drifting negative.
- A corruption of the Auto Zero filter may also cause negative concentrations.
    - If a short, high noise value was detected during the Auto Zero cycle, that higher reading will alter the Auto Zero filter value.
    - As the value of the Auto Zero filter is subtracted from the current PMT response, it will produce a negative concentration reading.
    - High Auto Zero readings can be caused by
    - a leaking or stuck Auto Zero valve (replace the valve),
    - by an electronic fault in the preamplifier causing it to have a voltage on the PMT output pin during the Auto Zero cycle (replace the preamplifier),
    - by a reaction cell contamination causing high background (>40 mV) PMT readings (clean the reaction cell),
    - by a broken PMT temperature control circuit, allowing high zero offset (repair the faulty PMT cooler). After fixing the cause of a high Auto Zero filter reading, the T200 will take 15 minutes for the filter to clear itself, or
    - by an exhausted chemical in the ozone scrubber cartridge (see Section 13.3.3).
- Calibration error is the most likely explanation for negative concentration values.
    - If the zero air contained some NO or NO_2 gas (contaminated zero air or a worn-out zero air scrubber) and the analyzer was calibrated to that concentration as "zero", the analyzer may report negative values when measuring air that contains little or no NO_x.
    - The same problem occurs, if the analyzer was zero-calibrated using zero gas that is contaminated with ambient air or span gas (cross-port leaks or leaks in supply tubing or user not waiting long enough to flush pneumatic systems).
- If the response offset test functions for NO (**NO OFFS**) or NO_X (**NOX OFFS**) are greater than 150 mV, a reaction cell contamination is indicated.
- Clean the reaction cell in accordance to Section 13.3.9.

14.5.2. NO RESPONSE

If the instrument shows no response (display value is near zero) even though sample gas is supplied properly and the instrument seems to perform correctly.

- Carry out an electrical test with the ELECTRICAL TEST procedure in the diagnostics menu, see Section 14.7.12.3.
  - If this test produces a concentration reading, the analyzer's electronic signal path is correct.
- Carry out an optical test using the OPTIC TEST procedure in the diagnostics menu, see Section 14.7.12.2.
  - If this test results in a concentration signal, then the PMT sensor and the electronic signal path are operating properly.
  - If the T200 passes both ETEST and OTEST, the instrument is capable of detecting light and processing the signal to produce a reading.
  - Therefore, the problem must be in the pneumatics or the ozone generator.
- Check if the ozone generator is turned on.
  - Usually, the analyzer issues a warning whenever the ozone generator is turned off.
  - Go to **SETUP-MORE-DIAG-ENTR**, then scroll to the **OZONE GEN OVERRIDE** and see if it shows ON.
  - – If it shows OFF, turn it ON and **EXIT** the **DIAG** menu.
  - – If this is done and the ozone flow is correct, the analyzer should be properly supplied with ozone unless the generator itself is broken.
- Confirm the lack of response by supplying NO or NO_2 span gas of about 80% of the range value to the analyzer.
- Check the sample flow and ozone flow rates for proper values.
- Check for disconnected cables to the sensor module.
- If NO_2 signal is zero while NO signal is correct, check the NO/NO_X valve and the NO_2 converter for proper operation.

14.5.3. UNSTABLE ZERO AND SPAN

Leaks in the T200 or in the external gas supply and vacuum systems are the most common source of unstable and non-repeatable concentration readings.

- Check for leaks in the pneumatic systems as described in Section 13.3.12.
- Consider pneumatic components in the gas delivery system outside the T200 such as a change in zero air source (ambient air leaking into zero air line or a worn-out zero air scrubber) or a change in the span gas concentration due to zero air or ambient air leaking into the span gas line.
- Once the instrument passes a leak check, do a flow check (this chapter) to ensure that the instrument is supplied with adequate sample and ozone air.
- Confirm the sample pressure, sample temperature, and sample flow readings are correct and steady.
- Verify that the sample filter element is clean and does not need to be replaced.

14.5.4. INABILITY TO SPAN - NO SPAN BUTTON (CALS)

In general, the T200 will not display certain buttons whenever the actual value of a parameter is outside of the expected range for that parameter. If the calibration menu does not show a **SPAN** button when carrying out a span calibration, the actual concentration must be outside of the range of the expected span gas concentration, which can have several reasons.

- Verify that the expected concentration is set properly to the actual span gas concentration in the CONC sub-menu.
- Confirm that the NO_x span gas source is accurate.
    - This can be done by comparing the source with another calibrated analyzer, or by having the NO_x source verified by an independent traceable photometer.
- Check for leaks in the pneumatic systems as described in Section 13.3.12.
    - Leaks can dilute the span gas and, hence, the concentration that the analyzer measures may fall short of the expected concentration defined in the CONC sub-menu.
- If the low-level, hardware calibration has drifted (changed PMT response) or was accidentally altered by the user, a low-level calibration may be necessary to get the analyzer back into its proper range of expected values.
    - One possible indicator of this scenario is a slope or offset value that is outside of its allowed range (0.7-1.3 for slope, -20 to 150 for offsets). See Section 14.8.4 on how to carry out a low-level hardware calibration.

14.5.5. INABILITY TO ZERO - NO ZERO BUTTON (CALZ)

In general, the T200 will not display certain buttons whenever the actual value of a parameter is outside of the expected range for that parameter. If the calibration menu does not show a ZERO button when carrying out a zero calibration, the actual gas concentration must be significantly different from the actual zero point (as per last calibration), which can have several reasons.

- Confirm that there is a good source of zero air. If the IZS option is installed, compare the zero reading from the IZS zero air source to a zero air source using NOX-free air. Check any zero air scrubber for performance. It may need to be replaced (Section 13.3.7).
- Check to ensure that there is no ambient air leaking into zero air line. Check for leaks in the pneumatic systems as described in Section 13.3.12.

14.5.6. NON-LINEAR RESPONSE

The T200 was factory calibrated to a high level of NO and should be linear to within 1% of full scale. Common causes for non-linearity are:

- Leaks in the pneumatic system.
    - Leaks can add a constant of ambient air, zero air or span gas to the current sample gas stream, which may be changing in concentrations as the linearity test is performed.
    - Check for leaks as described in Section 13.3.12.
- The calibration device is in error.
    - Check flow rates and concentrations, particularly when using low concentrations.
    - If a mass flow calibrator is used and the flow is less than 10% of the full scale flow on either flow controller, you may need to purchase lower concentration standards.

- The standard gases may be mislabeled as to type or concentration.
  - Labeled concentrations may be outside the certified tolerance.
- The sample delivery system may be contaminated.
  - Check for dirt in the sample lines or reaction cell.
- Calibration gas source may be contaminated (NO_2 in NO gas is common).
- Dilution air contains sample or span gas.
- Ozone concentration too low because of wet air in the generator.
  - Generator system needs to be cleaned and dried with dry supply air.
  - Check the Perma Pure dryer for leaks.
  - This mostly affects linearity at the low end.
- Ozone stream may be contaminated with impurities.
  - An exhausted ozone filter chemical will let compounds such as HNO_3 and ammonia derivatives break through to the reaction cell.
  - Check the contents of the ozone filter cartridge and replace as necessary.
  - This also will affect linearity mostly at the low level.
- Sample inlet may be contaminated with NOX exhaust from this or other analyzers.
  - Verify proper venting of the pump exhaust.
- Span gas overflow is not properly vented and creates a back-pressure on the sample inlet port.
  - Also, if the span gas is not vented at all and does not supply enough sample gas, the analyzer may be evacuating the sample line.
  - Ensure to create and properly vent excess span gas.
- Diffusion of oxygen into Teflon-type tubing over long distances.
  - PTFE or related materials can act as permeation devices. In fact, the permeable membrane of NO_2 permeation tubes is made of PTFE.
  - When using very long supply lines (> 1 m) between high concentrations span gases and the dilution system, oxygen from ambient air can diffuse into the line and react with NO to form NO_2.
    - This reaction is dependent on NO concentration and accelerates with increasing NO concentration, hence, affects linearity only at high NO levels.
    - Using stainless steel for long span gas supply lines avoids this problem.

14.5.7. DISCREPANCY BETWEEN ANALOG OUTPUT AND DISPLAY

If the concentration reported through the analog outputs does not agree **w**ith the value reported on the front panel, you may need to recalibrate the analog outputs.

- This becomes more likely when using a low concentration or low analog output range.
- Analog outputs running at 0.1 V full scale should always be calibrated manually.
- See Section 8.4.3 for a detailed description of this procedure.

14.5.8. DISCREPANCY BETWEEN NO AND NO_X SLOPES

If the slopes for NO and NO_X are significantly different after software calibration (more than 1%), consider the following three problems:

- NO_2 impurities in the NO calibration gas. NO gases often exhibit NO_2 on the order of 1-2% of the NO value.
  - This will cause differences in the calibration slopes. If the NO_2 impurity in NO is known, it can easily be accounted for by setting the expected values for NO and NO_2 accordingly to different values, e.g., 448 ppb NO and 450 ppb NO_X.
  - This problem is worse if NO gas is stored in a cylinder with balance air instead of balance gas nitrogen or large amounts of nitrous oxide (N_2O).
  - The oxygen in the air slowly reacts with NO to yield NO_2, increasing over time.
- The expected concentrations for NO and NO_X in the calibration menu are set to different values.
  - If a gas with 100% pure NO is used, this would cause a bias.
  - See Section 10.2.3.1 on how to set expected concentration values.
- The converter efficiency parameter has been set to a value not equal to 1.000 even though the conversion efficiency is 1.0.
  - The actual conversion efficiency needs to match the parameter set in the CAL menu.
  - See Section 10.1.4 for more information on this feature.

An instrument calibration with the IZS option (and expected concentrations set to the same amount) will always yield identical slopes for NO and NO_X, as the instrument measures only NO_X and assumes NO to be the same (with NO_2 being zero).

14.6. OTHER PERFORMANCE PROBLEMS

Dynamic problems (i.e. problems that only manifest themselves when the analyzer is monitoring sample gas) can be the most difficult and time consuming to isolate and resolve. The following section provides an itemized list of the most common dynamic problems with recommended troubleshooting checks and corrective actions.

14.6.1. EXCESSIVE NOISE

Excessive noise levels under normal operation usually indicate leaks in the sample supply or the analyzer itself. Ensure that the sample or span gas supply is leak-free and carry out a detailed leak check as described earlier in this chapter.

Another possibility of excessive signal noise may be the preamplifier board, the high voltage power supply and/or the PMT detector itself.

  - Contact the factory on troubleshooting these components.

14.6.2. SLOW RESPONSE

If the analyzer starts responding too slow to any changes in sample, zero or span gas, check for the following:

- Dirty or plugged sample filter or sample lines.
- Sample inlet line is too long.
- Leaking NO/NO_X valve. Carry out a leak check.

- Dirty or plugged critical flow orifices. Check flows, pressures and, if necessary, change orifices (Section 13.3.10).
- Wrong materials in contact with sample - use glass, stainless steel or Teflon materials only. Porous materials, in particular, will cause memory effects and slow changes in response.
- Dirty reaction cell. Clean the reaction cell.
- Insufficient time allowed for purging of lines upstream of the analyzer. Wait until stability is low.
- Insufficient time allowed for NO or NO_2 calibration gas source to become stable. Wait until stability is low.
- NO_2 converter temperature is too low. Check for proper temperature.

14.6.3. AUTO ZERO WARNINGS

Auto Zero warnings occur if the signal measured during an Auto Zero cycle is higher than 200 mV.

NOTE

The Auto-Zero warning displays the value of the Auto Zero reading when the warning occurs.

- If this value is higher than 150 mV, check that the Auto Zero valve is operating properly.
  - To do so, use the **SIGNAL I/O** functions in the **DIAG** menu to toggle the valve on and off.
  - Listen if the valve is switching, see if the respective LED on the relay board is indicating functionality.
- Scroll the **TST** functions until **PMT** is displayed and observe the PMT value change between the two valve states.
  - If the valve is operating properly, you should be able to hear it switch (once a minute under normal operation or when manually activated from the **SIGNAL I/O** menu):
    - the PMT value should drop from span gas reading (e.g., 800-900 mV at 400 ppb NO) to less than 150 mV and;
    - the LED on the relay board should light up when the valve is activated.
  - If the PMT value drops significantly but not to less than 150 mV, the valve is probably leaking across its ports.
    - In this case, replace the valve.
  - If the PMT value does not change at all, the valve is probably not switching at all.
    - Check the power supply to the valve (12 V to the valve should turn on and off when measured with a voltmeter).

NOTE

It takes only a small leak across the ports of the valve to show excessive Auto Zero values when supplying high concentrations of span gas.

Another reason for high (although not necessarily out-of-range) values for Auto Zero could be the ozone air filter cartridge, if its contents have been exhausted and needs to be replaced.

- This filter cartridge chemicals that can cause chemiluminescence and, if saturated, these chemicals can break through to the reaction cell, causing an erroneously high Auto Zero value (background noise).

A dirty reaction cell can cause high Auto Zero values.

- Clean the reaction cell according to Section 13.3.9.

Finally, a high **HVPS** voltage value may cause excess background noise and a high **AZERO** value.

- The HVPS value changes from analyzer to analyzer and could show nominal values between 450 and 800 V.
- Check the low-level hardware calibration of the preamplifier board and, if necessary, recalibrate exactly as described in Section 14.8.4 in order to minimize the **HVPS**.

14.7. SUBSYSTEM CHECKOUT

The preceding sections of this manual discussed a variety of methods for identifying possible sources of failures or performance problems within the analyzer. In most cases this included a list of possible causes and, in some cases, quick solutions or at least a pointer to the appropriate sections describing them. This section describes how to determine if a certain component or subsystem is actually the cause of the problem being investigated.

14.7.1. AC MAIN POWER

The T200 analyzer's electronic systems will operate with any of the specified power regimes. As long as system is connected to 100-120 VAC or 220-240 VAC at either 50 or 60 Hz it will turn on and after about 30 seconds show a front panel display.

- Internally, the status LEDs located on the Relay PCA, Motherboard and CPU should turn on as soon as the power is supplied.
- If they do not, check the circuit breaker built into the ON/OFF switch on the instruments front panel.
- If the instrument is equipped with an internal pump, it will begin to run. If it does not:
    - Verify that the pump power configuration plug is properly wired (see Section 12.7.2.1 and Figure 12-27)
    - If the configuration plug is set for 230 VAC and the instrument is plugged into 115 VAC or 100 VAC the sample pump will not start.
- If the configuration plug is set for 115 or 100 VAC and the unit is plugged into a 230 VAC circuit, the circuit breaker built into the ON/OFF Switch on the front panel will trip to the OFF position immediately after power is switched on.
- T200's without internal pumps that are configured for 230 V will still turn on at 115 V, but the heaters may burn out or not heat up fast enough.

CAUTION

ELECTRICAL SHOCK HAZARD

Should the AC power circuit breaker trip, investigate and correct the condition causing this situation before turning the analyzer back on.

14.7.2. DC POWER SUPPLY

If you have determined that the analyzer's AC mains power is working, but the unit is still not operating properly, there may be a problem with one of the instrument's switching power supplies. The supplies can have two faults, namely no DC output, and noisy output.

To assist tracing DC Power Supply problems, the wiring used to connect the various printed circuit assemblies and DC Powered components and the associated test points on the relay PCA follow a standard color-coding scheme as defined in the following table.

Table 14-6: DC Power Test Point and Wiring Color Codes

NAME	TEST POINT#	COLOR	DEFINITION
DGND	1	Black	Digital ground
+5V	2	Red	
AGND	3	Green	Analog ground
+15V	4	Blue	
-15V	5	Yellow	
+12R	6	Purple	12 V return (ground) line
+12V	7	Orange	

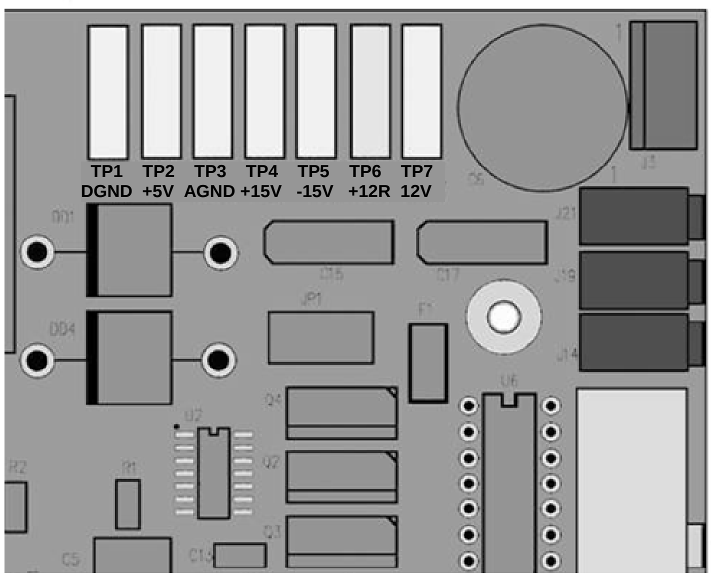


Figure 14-4: Location of DC Power Test Points on Relay PCA

A voltmeter should be used to verify that the DC voltages are correct per the values in the table below, and an oscilloscope, in AC mode, with band limiting turned on, can be used to evaluate if the supplies are producing excessive noise (> 100 mV p-p).

Table 14-7: DC Power Supply Acceptable Levels

POWER SUPPLY	VOLTAGE	CHECK RELAY BOARD TEST POINTS				MIN V	MAX V
		FROM Test Point		TO Test Point			
		NAME	#	NAME	#		
PS1	+5	DGND	1	+5	2	+4.85	+5.25
PS1	+15	AGND	3	+15	4	+13.5	+16.0

PS1	-15	AGND	3	-15V	5	-13.5	-16.0
PS1	AGND	AGND	3	DGND	1	-0.05	+0.05
PS1	Chassis	DGND	1	Chassis	N/A	-0.05	+0.05
PS2	+12	+12V Ret	6	+12V	7	+11.8	+12.5
PS2	DGND	+12V Ret	6	DGND	1	-0.05	+0.05

14.7.3. I^2C BUS

Operation of the I^2C bus can be verified by observing the behavior of D1 on the relay PCA & D2 on the Valve Driver PCA. Assuming that the DC power supplies are operating properly, the I^2C bus is operating properly if D1 on the relay PCA and D2 of the Valve Driver PCA are flashing

There is a problem with the I^2C bus if both D1 on the relay PCA and D2 of the Valve Driver PCA are ON/OFF constantly.

14.7.4. LCD/DISPLAY MODULE

TOUCHSCREEN INTERFACE

Assuming that there are no wiring problems and that the DC power supplies are operating properly, the display screen should light and show the splash screen and other indications of its state as the CPU goes through its initialization process.

14.7.5. RELAY PCA

The Relay PCA can be most easily checked by observing the condition of the status LEDs on the Relay PCA (see Section 14.3.2), and using the **SIGNAL I/O** submenu under the **DIAG** menu (see Section 14.1.3) to toggle each LED **ON** or **OFF.**

If D1 on the Relay PCA is flashing and the status indicator for the output in question (Heater power, Valve Drive, etc.) toggles properly using the Signal I/O function, then the associated control device on the Relay PCA is bad.

Several of the control devices are in sockets and can be easily replaced. The table below lists the control device associated with a particular function.

Table 14-8: Relay PCA Control Devices

FUNCTION	CONTROL DEVICE	SOCKETED
All valves	U5	Yes
Reaction Cell Heater	K1	Yes
NO_2 → NO Converter heater	K2	Yes
Permeation Tube Heater for Optional Internal Span Gas Generator	K4	Yes

14.7.6. MOTHERBOARD

14.7.6.1. Test Channel / Analog Outputs Voltage

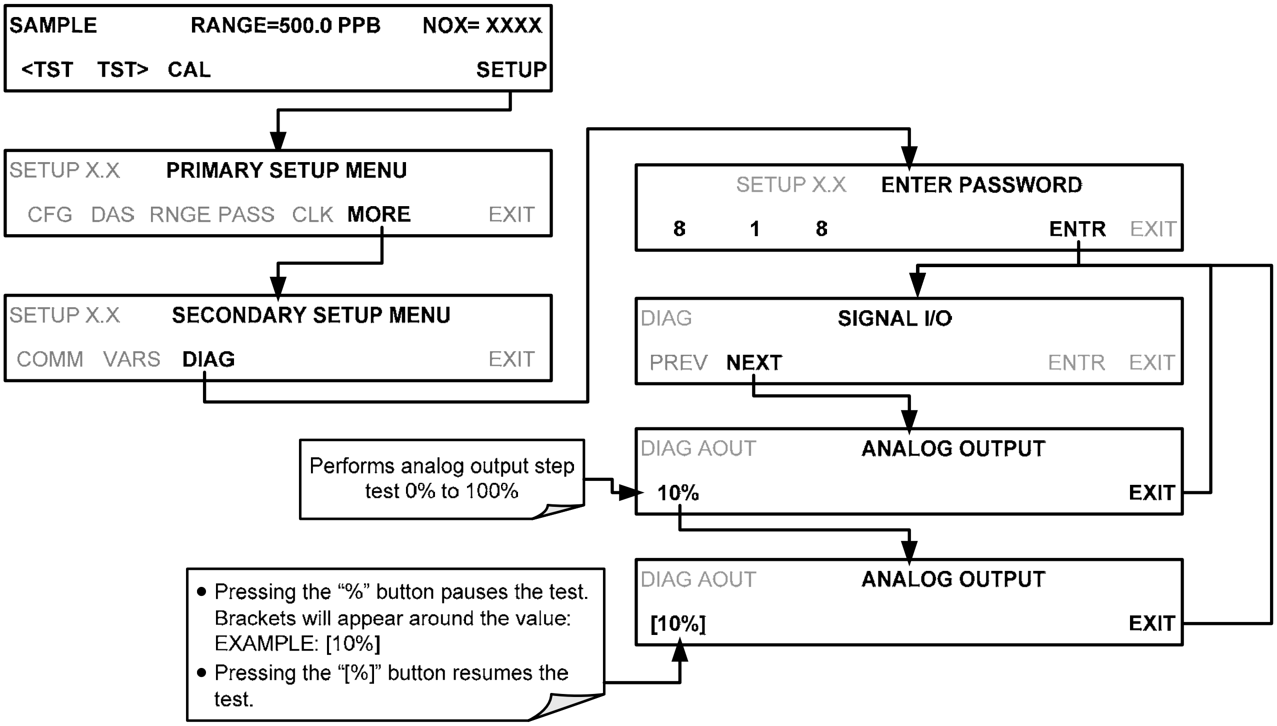
The **ANALOG OUTPUT** submenu, located under the **SETUP → MORE → DIAG** menu is used to verify that the T200 analyzer's three analog outputs are working properly. The test generates a signal on all three outputs simultaneously as shown in the following table:

Table 14-9: Analog Output Test Function - Nominal Values Voltage Outputs

		FULL SCALE OUTPUT OF VOLTAGE RANGE (see Section 8.4.2)			
		100MV	**1V**	**5V**	**10V***
STEP	**%**	**NOMINAL OUTPUT VOLTAGE**			
1	0	0	0	0	0
2	20	20 mV	0.2	1	2
3	40	40 mV	0.4	2	4
4	60	60 mV	0.6	3	6
5	80	80 mV	0.8	4	8
6	100	100 mV	1.0	5	10
*** For 10V output, increase the Analog Output Calibration Limits (AOUT CAL LIM in the DIAG>Analog I/O Config menu) to 4% (offset limit) and 20% (slope limit).**					

For each of the steps the output should be within 1% of the nominal value listed in the table below except for the 0% step, which should be within 0mV ±2 to 3 mV. Ensure you take into account any offset that may have been programmed into channel (See Section 8.4.5).

If one or more of the steps fails to be within these ranges, it is likely that there has been a failure of the either or both of the Digital-to-Analog Converters (DACs) and their associated circuitry on the motherboard. To perform the test connect a voltmeter to the output in question and perform an analog output step test as follows:



14.7.6.2. A/D Functions

The simplest method to check the operation of the A-to-D converter on the motherboard is to use the Signal I/O function under the **DIAG** menu to check the two A/D reference voltages and input signals that can be easily measured with a voltmeter.

1. Use the Signal I/O function (see Section 14.1.3 and Appendix A) to view the value of **REF_4096_MV** and **REF_GND**.
    - If both are within 3 mV of nominal (4096 and 0), and are stable, ±0.2 mV then the basic A/D is functioning properly. If not then the motherboard is bad.
2. Choose a parameter in the Signal I/O function list (see Section 14.1.3) such as **OZONE_FLOW .**
    - Compare this voltages at its origin (see the interconnect drawing and interconnect list in Appendix D) with the voltage displayed through the signal I/O function.
    - If the wiring is intact but there is a large difference between the measured and displayed voltage (±10 mV) then the motherboard is bad.

14.7.6.3. Status Outputs

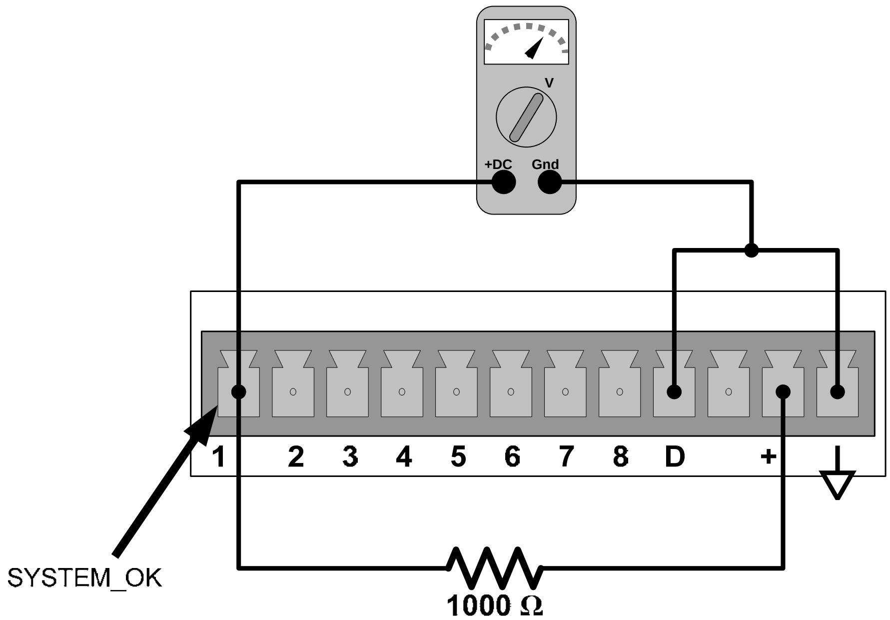


Figure 14-5: Typical Set Up of Status Output Test

To test the status output electronics:

1. Connect a jumper between the “D" pin and the “▽” pin on the status output connector.
2. Connect a 1000 ohm resistor between the “+” pin and the pin for the status output that is being tested.
3. Connect a voltmeter between the “▽” pin and the pin of the output being tested.
4. Under the DIAG→ Signal I/O menu (see Section 14.1.3), scroll through the inputs and outputs until you get to the output in question.
5. Alternately, turn on and off the output noting the voltage on the voltmeter.
   - It should vary between 0 volts for ON and 5 volts for OFF.

Table 14-10: Status Outputs Check

PIN (LEFT TO RIGHT)	STATUS
1	**ST_SYSTEM_OK**
2	**ST_CONC_VALID**
3	**ST_HIGH_RANGE**
4	**ST_ZERO_CAL**
5	**ST_SPAN_CAL**
6	**ST_DIAG_MODE**
7	*Not Used on T200*
8	**ST_O2_CAL**

14.7.6.4. Control Inputs

The control input bits can be tested by applying a trigger voltage to an input and watching changes in the status of the associated function under the **SIGNAL I/O** submenu:

EXAMPLE: to test the "**A**" control input:

1. Under the **DIAG→** Signal I/O menu (see Section 14.1.3), scroll through the inputs and outputs until you get to the output named **EXT_ZERO_CAL**.
2. Connect a jumper from the "+" pin on the appropriate connector to the "U" on the same connector.
3. Connect a second jumper from the "▽" pin on the connector to the "A" pin.
4. The status of **EXT_ZERO_CAL** should change to read "ON".
5. Connect a second jumper from the "▽" pin on the connector to the "B" pin.
6. The status of **EXT_ZERO_CAL** should change to read "ON".

Table 14-11: T200 Control Input Pin Assignments and Corresponding Signal I/O Functions

INPUT	CORRESPONDING I/O SIGNAL
A	EXT_ZERO_CAL
B	EXT_SPAN_CAL1
C, D, E& F	NOT USED

14.7.7. PRESSURE / FLOW SENSOR ASSEMBLY

The flow and pressure sensors of the T200 are located on a PCA just behind the PMT sensor (see Figure 3-5) can be checked with a Voltmeter.

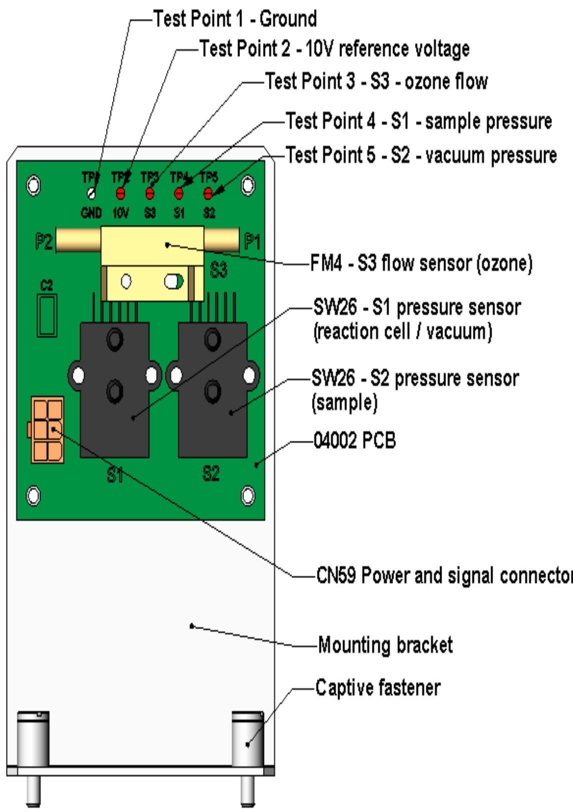


Figure 14-6: Pressure / Flow Sensor Assembly

The following procedure assumes that the wiring is intact and that the motherboard and power supplies are operating properly:

14.7.7.1. Basic PCA Operation Check:

- Measure the voltage between TP2 and TP1 C1 it should be 10 VDC ± 0.25 VDC. If not then the board is bad. Replace the PCA.

14.7.7.2. Sample Pressure Sensor Check:

1. Measure the pressure on the inlet side of S1 with an external pressure meter.
2. Measure the voltage across TP4 and TP1.
   - The expected value for this signal should be:

$$\text{Expected mVDC} = \left(\frac{\text{Pressure}}{30.0_{\text{Hg-In-A}}} \times 4660_{\text{mvDC}}\right) + 250_{\text{mvDC}} \quad \pm 10\%_{\text{rdg}}$$

EXAMPLE: If the measured pressure is 20 Hg-in-A, the expected voltage level between TP4 and TP1 would be between 2870 mVDC and 3510 mVDC.

EXAMPLE: If the measured pressure is 25 Hg-in-A, the expected voltage level between TP4 and TP1 would be between 3533 mVDC and 4318 mVDC.

- If this voltage is out of range, then either pressure transducer S1 is bad, the board is bad or there is a pneumatic failure preventing the pressure transducer from sensing the absorption cell pressure properly. Replace the PCA.

14.7.7.3. Vacuum Pressure Sensor Check

- Measure the pressure on the inlet side of S2 with an external pressure meter.
- Measure the voltage across TP5 and TP1.
  - Evaluate the reading in the same manner as for the sample pressure sensor.

14.7.7.4. O_3 Flow Sensor Check

- Measure the voltage across TP3 and TP1.
  - With proper flow (80 cc^3/min through the O_3 generator), this should be approximately 2V ± 0.25 (this voltage will vary with altitude).
  - With flow stopped (photometer inlet disconnected or pump turned OFF) the voltage should be approximately 1V.
  - If the voltage is incorrect, the flow sensor S3 is bad, the board is bad (replace the PCA) or there is a leak upstream of the sensor.

14.7.8. CPU

There are two major types of CPU board failures, a complete failure and a failure associated with the Disk On Module (DOM). If either of these failures occurs, contact the factory.

For complete failures, assuming that the power supplies are operating properly and the wiring is intact, the CPU is faulty if on power-on, the watchdog LED on the motherboard is not flashing.

In some rare circumstances, this failure may be caused by a bad IC on the motherboard, specifically U57, the large, 44 pin device on the lower right hand side of the board. If this is true, removing U57 from its socket will allow the instrument to start up but the measurements will be invalid.

If the analyzer stops during initialization (the front panel display shows a fault or warning message), it is likely that the DOM, the firmware or the configuration and data files have been corrupted.

14.7.9. RS-232 COMMUNICATIONS

14.7.9.1. General RS-232 Troubleshooting

Teledyne API's analyzers use the RS-232 communications protocol to allow the instrument to be connected to a variety of computer-based equipment. RS-232 has been used for many years and as equipment has become more advanced, connections between various types of hardware have become increasingly difficult. Generally, every manufacturer observes the signal and timing requirements of the protocol very carefully.

Problems with RS-232 connections usually center around 4 general areas:

- Incorrect cabling and connectors. See Section 9.1.3 for connector and pin-out information.
- The BAUD rate and protocol are incorrectly configured. See Section 9.1.4.
- If a modem is being used, additional configuration and wiring rules must be observed. See Section 9.1.9
- Incorrect setting of the DTE – DCE Switch is set correctly. See Section 9.1.1

- Verify that cable (P/N 03596) that connects the serial COMM ports of the CPU to J12 of the motherboard is properly seated.

14.7.9.2. Troubleshooting Analyzer/Modem or Terminal Operation

These are the general steps for troubleshooting problems with a modem connected to a Teledyne API's analyzer.

1. Check cables for proper connection to the modem, terminal or computer.
2. Check to ensure that the DTE-DCE is in the correct position as described in Section 9.1.1.
3. Check to ensure that the set up command is correct (see Section 9.1.9).
4. Verify that the Ready to Send (RTS) signal is at logic high. The T200 sets pin 7 (RTS) to greater than 3 volts to enable modem transmission.
5. Ensure that the BAUD rate, word length, and stop bit settings between modem and analyzer match. See Section 9.1.4.
6. Use the RS-232 test function to send “w” characters to the modem, terminal or computer. See Section 9.1.6.
7. Get your terminal, modem or computer to transmit data to the analyzer (holding down the space bar is one way); the green LED should flicker as the instrument is receiving data.
8. Ensure that the communications software or terminal emulation software is functioning properly.

NOTE

Further help with serial communications is available in a separate manual “RS-232 Programming Notes” Teledyne API's P/N 01350.

14.7.10. NO_2 → NO CONVERTER

Provided that oxygen was present in the Sample stream during operation for the NO_2 converter to function properly, the NO_2 converter assembly can fail in two ways:

- An electrical failure of the band heater and/or the thermocouple control circuit and;
- A performance failure of the converter itself.

14.7.10.1. NO_2 → NO Converter Electrical System

NO_2 converter heater failures can be divided into two possible problems:

- Temperature is reported properly but heater does not heat to full temperature.
  - In this case, the heater is either disconnected or broken or the power relay is broken.
  - Disconnect the heater cable coming from the relay board and measure the resistance between any two of the three heater leads with a multi-meter.
  - The resistance between A and B should be about 1000 Ω.
  - That between A and C should be the same as between B and C, about 500 Ω each.
  - If any of these resistances is near zero or without continuity, the heater is broken.
- Temperature reports zero or overload (near 500° C).
  - This indicates a disconnected or failing thermocouple or a failure of the thermocouple circuit.
  - Check that the thermocouple is connected properly and the wire does not show signs of a broken or kinked pathway.

- If it appears to be properly connected, disconnect the yellow thermocouple plug (marked K) from the relay board and measure the voltage (not resistance) between the two leads with a multi-meter capable of measuring in the low mV range.
- The voltage should be about 12 mV (ignore the sign) at 315° C and about 0 mV at room temperature.
  - Measure the continuity with an Ohm-meter.
- It should read close to zero Ω. If the thermo-couple does not have continuity, it is broken.
- If it reads zero voltage at elevated temperatures, it is broken.

- To test the thermocouple at room temperature, heat up the converter can (e.g., with a heat gun) and see if the voltage across the thermocouple leads changes.
  - If the thermocouple is working properly, the electronic circuit is broken.
  - In any case, consult the factory.

CAUTION!
If the thermocouple is broken, do NOT replace the thermocouple without first consulting the factory; using the wrong Type could cause permanent damage to the instrument. The Type K thermocouple has a red and a yellow wire. If in doubt, consult the factory.

14.7.10.2. NO_2 Conversion Efficiency

The efficiency at which the NO_2 → NO converter changes NO_2 into NO directly effects the accuracy of the T200's NO_x, NO and NO_2 measurements. The T200 firmware includes a Converter Efficiency (CE) gain factor that is multiplied by the NO_2 and NO_X measurements to calculate the final concentrations for each. This gain factor is stored in the analyzer's memory.

The default setting for the NO_2 converter efficiency is 1.0000. Over time, the molybdenum in the NO_2 → NO converter oxidizes and it becomes less efficient at converting NO_2 into NO.

To ensure accurate operation of the T200, it is important to check the NO_2 conversion efficiency periodically and to update this value as necessary.

- For the analyzer to function correctly, the converter efficiency must be between 0.9600 and 1.0200 (96-102% conversion efficiency) as per US-EPA requirements.
- If the converter's efficiency is outside these limits, the NO_2 converter should be replaced.
- The current converter efficiency level is also recorded along with the calibration data in the DAS for documentation and performance analysis (Section 8.1).

14.7.10.3. Calculating / Checking Converter Efficiency

The T200 to automatically calculate the current NO_2 conversion efficiency by comparing a known starting concentration of NO_2 gas to the measured NO output of the converter. There are three steps to performing this operation.

STEP ONE

Supply the analyzer with a known concentration of NO_2 gas, to the analyzer.

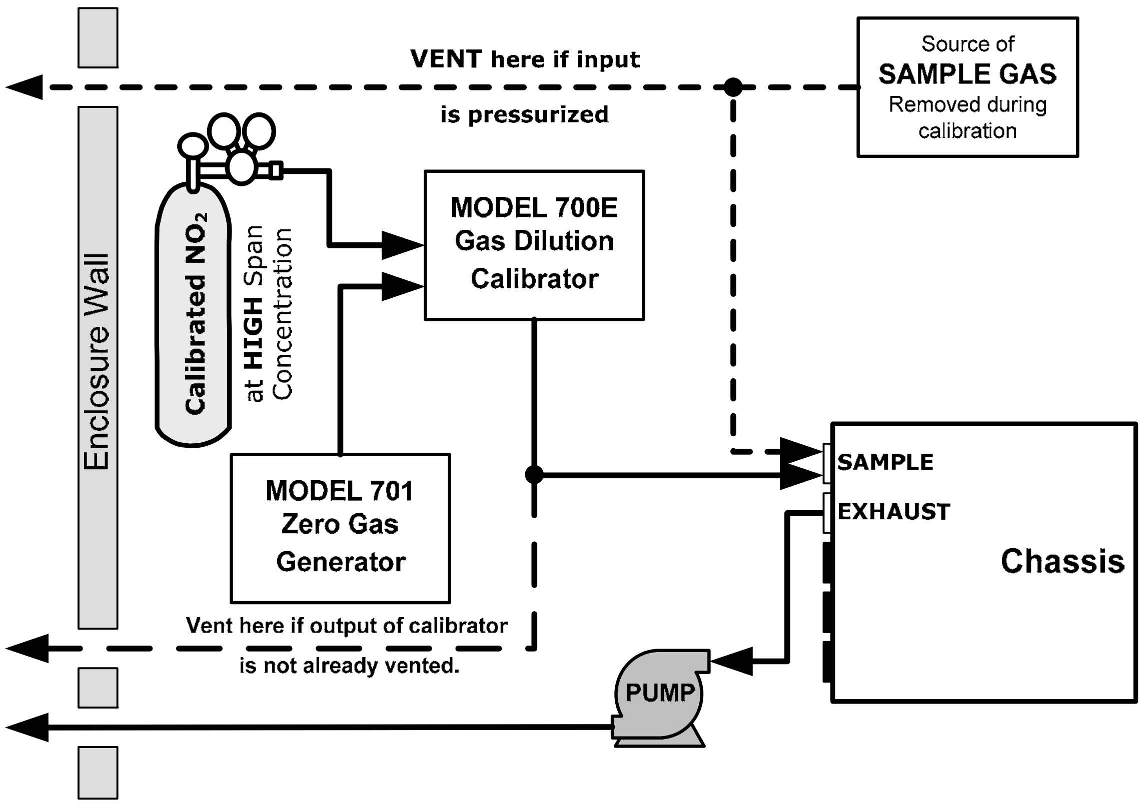
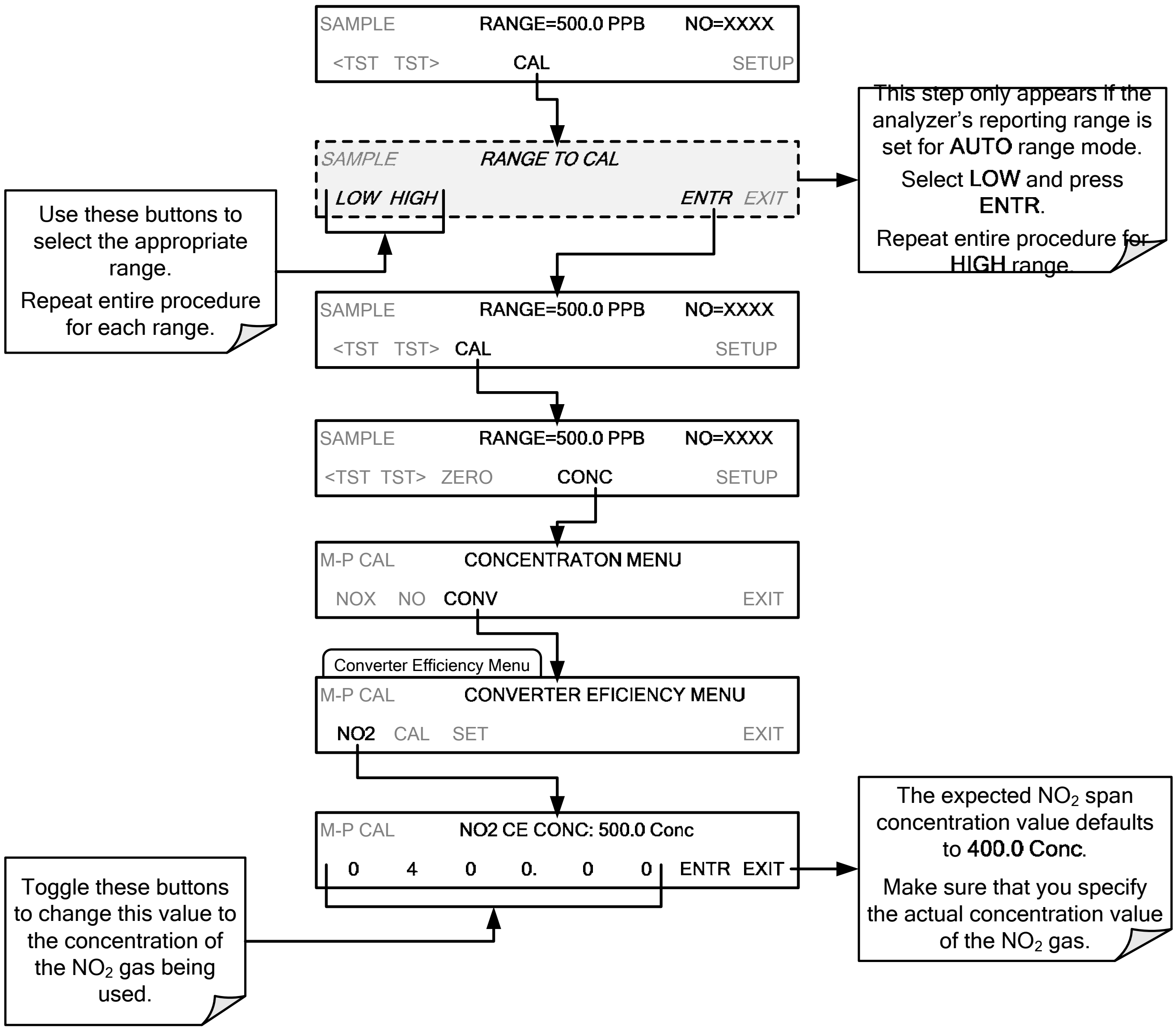


Figure 14-7: Setup for determining NO_2 → NO Efficiency – T200 Base Configuration

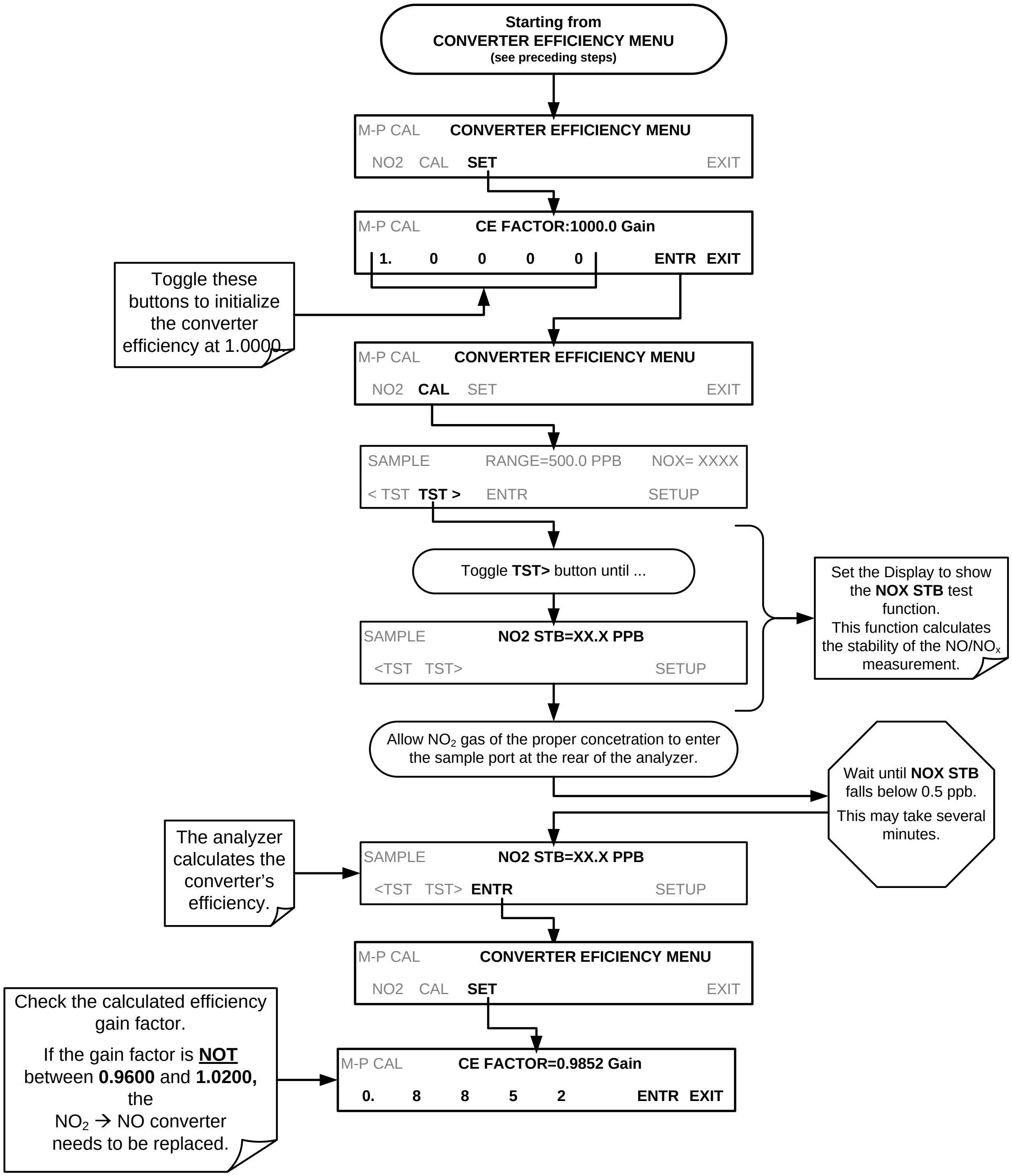
STEP TWO

Input the starting NO_2 concentration value into the T200 by pressing:



STEP THREE

To cause the analyzer to calculate and record the NO_2 → NO converter efficiency, press:



14.7.10.4. Evaluating NO_2 → NO Converter Performance

If the converter appears to have performance problems (conversion efficiency is outside of allowed range of 96-102%), check the following:

- Recalculate the converter efficiency (see previous section)
- Accuracy of NO_2 source (GPT or gas tank standard).
  - NO_2 gas standards are typically certified to only ±2% and often change in concentrations over time. You should get the standard re-certified every year.
  - If you use the GPT calibration, check the accuracy of the ozone source.
- Age of the converter.
  - The NO_2 converter has a limited operating life and may need to be replaced every ~3 years or when necessary (e.g., earlier if used with continuously high NO_2 concentrations).
  - We estimate a lifetime of about 10000 ppm-hours (a cumulative product of the NO_2 concentration times the exposure time to that concentration).
  - This lifetime heavily depends on many factors such as:
    - Absolute concentration (temporary or permanent poisoning of the converter is possible).
    - Sample flow rate and pressure inside the converter.
    - Converter temperature.
    - Duty cycle.
  - This lifetime is only an estimated reference and not a guaranteed lifetime.
- In some cases with excessive sample moisture, the oxidized molybdenum metal chips inside the converter cartridge may bake together over time and restrict air flow through the converter, in which case it needs to be replaced.
  - To avoid this problem, we recommend the use of a sample gas conditioner (Section 6.5).
  - Section 13.3.8 describes how to replace the NO_2 converter cartridge.
- With no NO_2 in the sample gas and a properly calibrated analyzer, the NO reading is negative, while the NO_2 reading remains around zero.
- The converter is destroying NO and needs to be replaced.
- With no NO_2 in the sample gas and a properly calibrated analyzer, the NO_X reading is significantly higher than the actual (gas standard) NO concentration.
- The converter is producing NO_2 and needs to be replaced.

14.7.11. SIMPLIFIED GPT CALIBRATION

This section describes how to determine the NO_2 → NO converter's efficiency using a GPT method where the actual concentration of ozone is not a factor in the accuracy of the calculation.

- This procedure is based on the Code of Federal Regulations, Title 40, Chapter I, subchapter C, Part 50, Appendix F.
- In the following example a reference point of 450 ppb NO gas will be used. This is only an example. Any other reference points within measurement range of the instrument may be used.
- For this procedure use a calibrated O_3 generator, such as a Teledyne API's T700.

> **NOTE**
>
> **There must be a minimum of 10% more NO than O_3 produced.**
>
> **Example, if the Ozone concentration used is 400 ppb then the NO concentration must be used must be 440 ppb or more.**

A PREPARATION

1. Leak check machine to ensure that there are no leaks in the analyzer.
2. Calibrate the instrument at the same NO span gas value as being used in this method.
    - For this example 450 ppb NO span gas
3. If you have input a converter efficiency (CE) factor into the instrument firmware (see 14.7.10.3) other than 100%, change this back to 100% for the duration of this test. (CAL>CONC>CONV>SET).

B DETERMINE THE AMOUNT OF NO OUTGASSED BY THE NO_2 → NO CONVERTER.

1. Bypass the NO_2 → NO converter by placing a short piece of tubing in the gas stream in place of the converter.
2. Perform a straight dilution with 445 ppb NO gas & air as a diluent gas.
3. Input the NO gas into the analyzer.
4. Allow the machine to stabilize & write down the NO_x value on line 2 of GPT data sheet (Section 14.7.11.1).
5. Remove the converter bypass so that the NO gas is flowing through the NO_2 → NO converter
6. Allow the machine to stabilize.
7. Write down your NO_x value on your data sheet on lines 3 AND line 5 of the GPT data sheet.
8. Subtract line 2 from line 3 & write that number down on line 4. Also write the NO value on line 8 of the data sheet.
    - The specification shown on the data sheet is the value that is used by Teledyne API when performing the procedure on new NO_2 → NO converters.
    - Older NO_2 → NO converters might outgas a bit more NO, therefore a slightly wider specification might be in order.
    - If this value is a constant or changes only slightly over time, this is not a problem the machine will calibrate this out.

C PERFORM THE SIMPLIFIED GPT CALCULATION.

1. Generate the same 450 ppb NO gas & input 400 ppb of O_3 (or generate 450 ppb NO & 400 ppb NO_2, if that's what your calibrator says).
2. Allow the instrument to stabilize for 10 minutes.
3. Write down the NO_x value on line 6 & the NO value on line 9.
4. Subtract line 6 from line 6 & put that onto line 7.
5. Subtract line 8 from line 7 & put that onto line 10.
6. Write the number from line 7 into the blank next to letter A on line 11 & put the number from line 10 into the blank next to letter B on line 11.
7. Divide A by B & multiply it by 100.
8. Write this value it into the blank next to letter C on lines 11 and 12.
9. Subtract that value from 100 & write it in the blank next to the letter D on line 12.
10. This is the converter efficiency.
    - This value should be >96%.
    - For CEMS applications, a converter efficiency of <96% might be acceptable, depending on application & the guideline set up by the regulatory agency.
    - In any application, check with your regulatory agency (agencies) to see what the minimum CE factor is before replacing the converter.

14.7.11.1. Simplified GPT Data Sheet

Line #	TEST		RESULT
1	**LEAK-CHECK** (WHEN HOT)		YES / NO
2	NO_x RESPONSE (MOLY BYPASSED)		__________
3	NO_x RESPONSE (MOLY IN-LINE)		__________
4	**OUT-GASSING** (NO – NOX)		__________ (>-5 ppb, <5 ppb)
5	($NO_{x\ ORIG}$)	(NO_x mode, O_3 off)	__________ ppb
6	($NO_{x\ REM}$)	(NO_x mode, O_3 on)	__________ ppb
7	NO_x **LOSS**		__________ (**A**) (<4% of $NO_{x\ ORIG}$: for 450PP 4% is 18 ppb)
8	(NO_{ORIG})	(NO mode, O3 off)	__________ ppb
9	(NO_{REM})	(NO mode, O3 on)	__________ ppb
10	NO_2	__________ (**B**) (>300ppb)	

11 Efficiency LOSS [(**A** / **B**) x 100] = [(____**A** / ____**B**) x 100] = ____**C**%

12 Total Conv Eff [100% – **C**] = 100% - ____**C** = _____**D**% (> 96%)

14.7.12. SENSOR MODULE

14.7.12.1. PMT Sensor

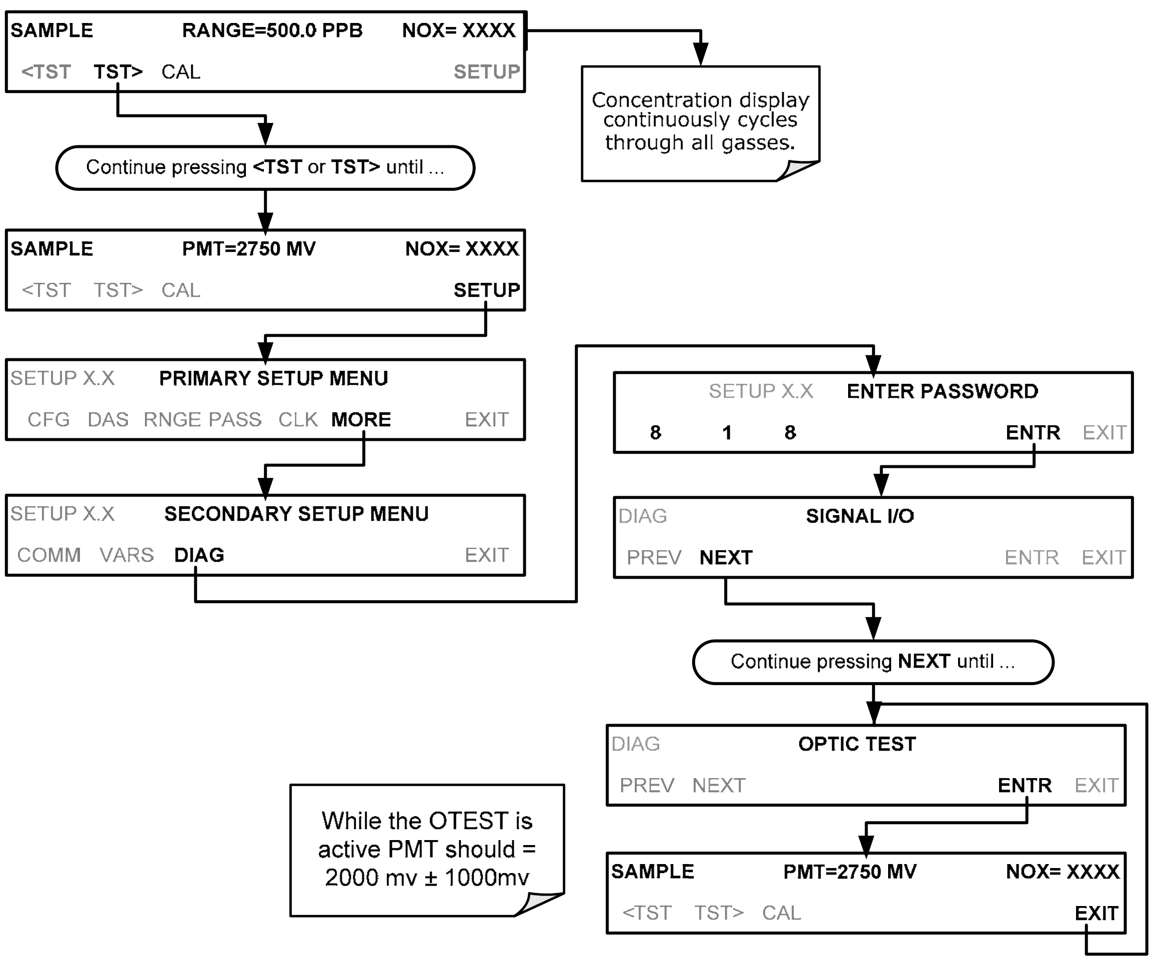
The photo multiplier tube detects the light emitted by the reaction of NO with ozone. It has a gain of about 500000 to 1000000. It is not possible to test the detector outside of the instrument in the field. The basic method to diagnose a PMT fault is to eliminate the other components using **ETEST**, **OTEST** and specific tests for other sub-assemblies.

14.7.12.2. Optics Test

The optic test function tests the response of the PMT sensor by turning on an LED located in the cooling block of the PMT (see Figure 12-20). The analyzer uses the light emitted from the LED to test its photo-electronic subsystem, including the PMT and the current to voltage converter on the pre-amplifier board.

- To ensure that the analyzer measures only the light coming from the LED, the analyzer should be supplied with zero air.
- The optic test should produce a PMT signal of about 2000±1000 mV.

To activate the optics test, press:



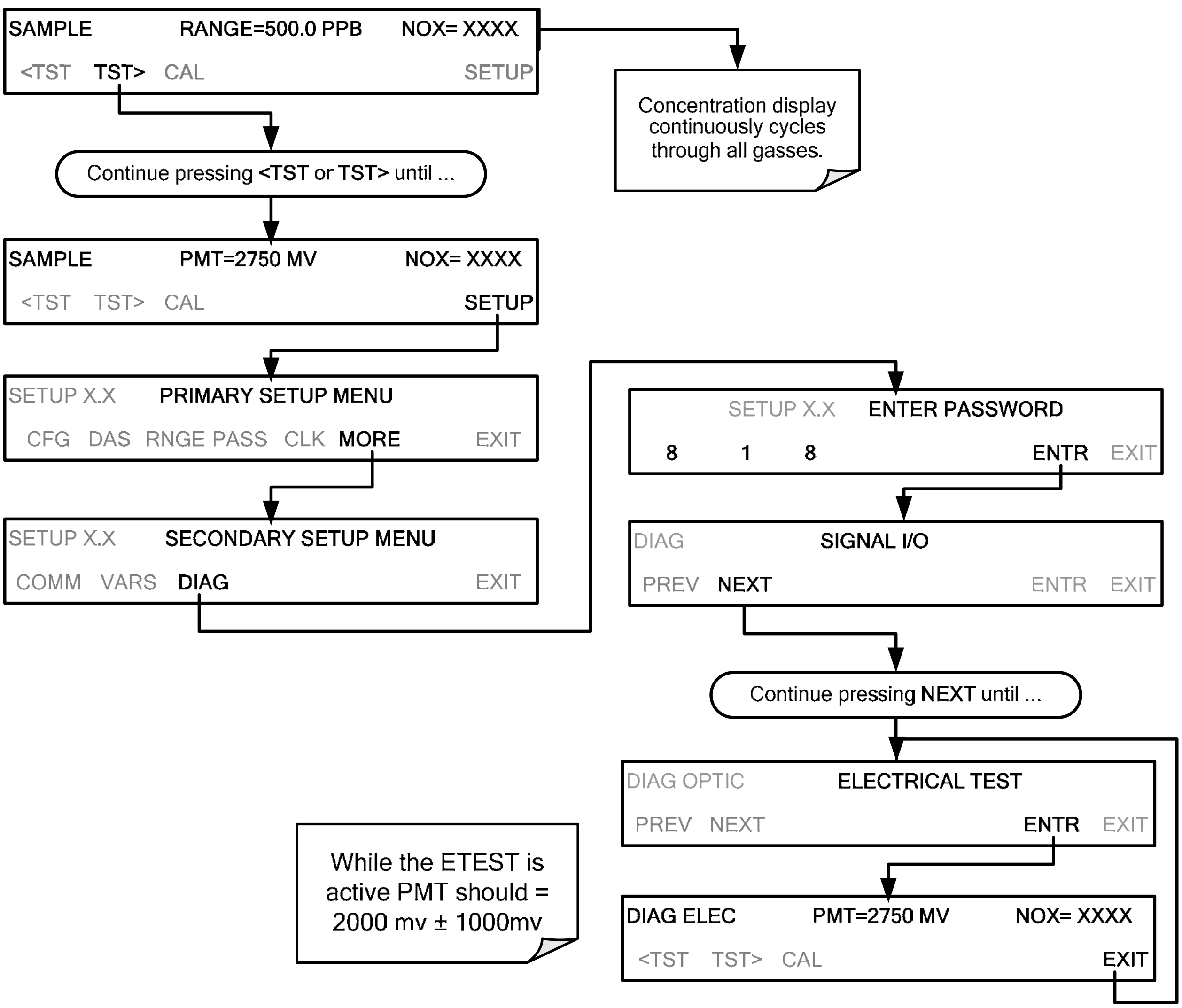
NOTE
This is a coarse test for functionality and not an accurate calibration tool. The resulting PMT signal can vary significantly over time and also changes with low-level calibration.

14.7.12.3. Electrical Test

The electrical test function creates a current, which is substituted for the PMT signal and feeds it into the preamplifier board.

- This signal is generated by circuitry on the pre-amplifier board itself and tests the filtering and amplification functions of that assembly along with the A/D converter on the motherboard.
- It does not test the PMT itself.
- The electrical test should produce a PMT signal of about 2000 ±1000 mV.

To activate the electrical test, press:



14.7.13. PMT PREAMPLIFIER BOARD

To check the correct operation of the preamplifier board, perform an the optics test (OTEST) and an electrical test (ETEST) described in Sections 14.7.12.2 and 14.7.12.3 above.

- If the instrument passes the OTEST but fails the ETEST, the preamplifier board may be faulty or need a hardware calibration.

14.7.13.1. High Voltage Power Supply

The HVPS is located in the interior of the sensor module and is plugged into the PMT tube. It requires 2 voltage inputs.

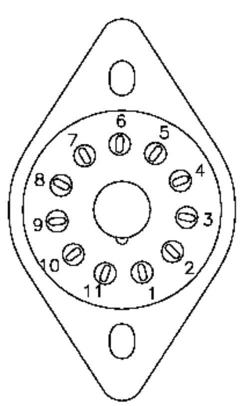
- The first is +15 V, which powers the supply.
- The second is the programming voltage which is generated on the preamplifier board.
- Adjustment of the HVPS is covered in the factory calibration procedure in Section 14.8.4.

This power supply has 10 independent power supply steps, one to each pin of the PMT. The following test procedure below allows you to test each step.

1. Turn off the instrument.
2. Remove the cover and disconnect the 2 connectors at the front of the NO_X sensor module.
3. Remove the end cap from the sensor (4 screws).
4. Remove the HVPS/PMT assembly from the cold block inside the sensor (2 plastic screws).
5. Disconnect the PMT from the HVPS.
6. Re-connect the 7 pin connector to the sensor end cap, and power-up the instrument.
   - Scroll the front panel display to the **HVPS** test parameter.
   - Divide the displayed **HVPS** voltage by 10 and test the pairs of connector points as shown in the figure.
7. Check the overall voltage (should be equal to the **HVPS** value displayed on the front panel and the voltages between each pair of pins of the supply

   EXAMPLE

   If the HVPS signal is 700 V the pin-to-pin voltages should be 70 V.



HVPS PINS	VOLTAGE
11−1	70
1−2	70
2−3	70
3−4	70
4−5	70
5−6	70
6−7	70
7−8	70
8−9	70

8. Turn off the instrument power, and reconnect the PMT, and then reassemble the sensor.
   - If any faults are found in the test, you must obtain a new HVPS as there are no user serviceable parts inside the supply.

14.7.14. PMT TEMPERATURE CONTROL PCA

The TEC control PCA is located on the sensor housing assembly, under the slanted shroud, next to the cooling fins and directly above the cooling fan.

If the red LED located on the top edge of this assembly is not glowing the control circuit is not receiving power. Check the analyzers power supply, the relay board's power distribution circuitry and the wiring connecting them to the PMT temperature control PCA.

TEC CONTROL TEST POINTS

Four test points are also located at the top of this assembly they are numbered left to right start with the T1 point immediately to the right of the power status LED. These test points provide information regarding the functioning of the control circuit.

- To determine the current running through the control circuit, measure the voltage between T1 and T2. Multiply that voltage by 10.
- To determine the drive voltage being supplied by the control circuit to the TEC, measure the voltage between T2 and T3.
    - If this voltage is zero, the TEC circuitry is most likely open.

  Or,

    - If the voltage between T2 and T3 = 0 VDC and the voltage measured between T1 and T2 = 0 VDC there is most likely an open circuit or failed op amp on control PCA itself.
    - If the voltage between T2 and T3 = 0 VDC and the voltage measured between T1 to T2 is some voltage other than 0 VDC, the TEC is most likely shorted.
- T4 is tied directly to ground. To determine the absolute voltage on any one of the other test points make a measurement between that test point and T4.

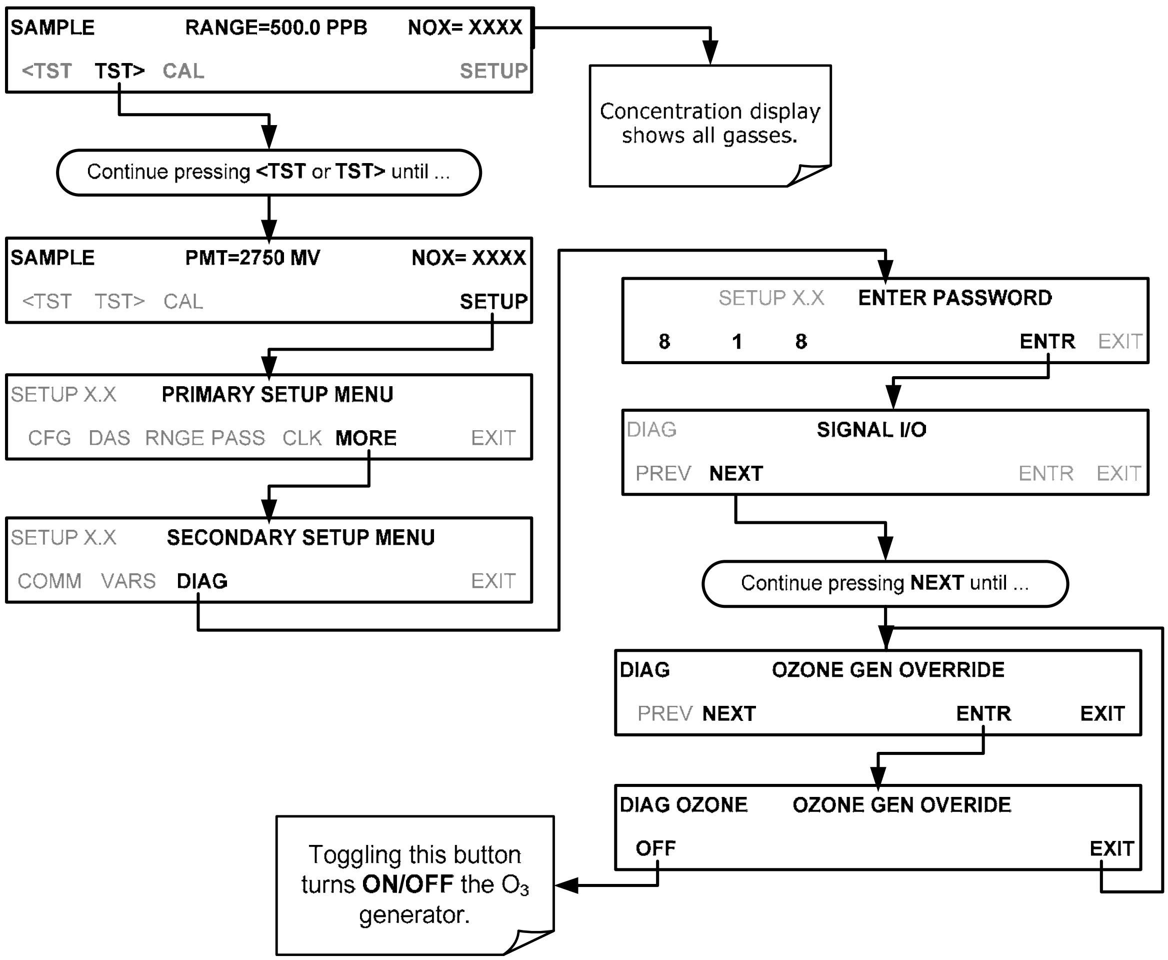
14.7.15. O_3 GENERATOR

The ozone generator can fail in two ways, electronically (printed circuit board) and functionally (internal generator components). Assuming that air is supplied properly to the generator, the generator should automatically turn on 30 minutes after the instrument is powered up or if the instrument is still warm. See Section 12.2.3 for ozone generator functionality. Accurate performance of the generator can only be determined with an ozone analyzer connected to the outlet of the generator. However, if the generator appears to be working properly but the sensitivity or calibration of the instrument is reduced, suspect a leak in the ozone generator supply air.

A leak in the dryer or between the dryer and the generator can cause moist, ambient air to leak into the air stream, which significantly reduces the ozone output. The generator will produce only about half of the nominal O_3 concentration when run with moist, ambient air instead of dried air. In addition, moist supply air will produce large amounts of nitric acid in the generator, which can cause analyzer components downstream of the generator to deteriorate and/or causes significant deposit of nitrate deposits on the reaction cell window, reducing sensitivity and causing performance drift. Carry out a leak check as described earlier in this chapter.

14.7.15.1. O_3 Generator Override

This feature allows the user to manually turn the ozone generator off and on. This should be done before disconnecting the generator, to prevent ozone from leaking out, or after a system restart if the user does not want to wait for 30 minutes during warm-up time. To access this feature press the following buttons: (Also note that the ozone generator does not turn on if the ozone flow conditions are out of specification (e.g., if there is no flow through the system or the pump is broken).



NOTE

This is one of the two settings in the DIAG menu that is retained after you exit the menu.

14.7.16. INTERNAL SPAN GAS GENERATOR AND VALVE OPTIONS

The zero/span valves and Internal span gas generator options need to be enabled in the software (contact the factory on how to do this).

- Check for the physical presence of the valves or the IZS option.
- Check front panel for correct software configuration. When the instrument is in SAMPLE mode, the front panel display should show CALS and CALZ buttons in the second line of the display. The presence of the buttons indicates that the option has been enabled in software. In addition, the IZS option is enabled if the TEST functions show a parameter named IZS TEMP.

The semi-permeable PTFE membrane of the permeation tube is severely affected by humidity. Variations in humidity between day and night are usually enough to yield very variable output results. If the instrument is installed in an air-conditioned shelter, the air is usually dry enough to produce good results. If the instrument is installed in an environment with variable or high humidity, variations in the permeation tube output will be significant. In this case, a dryer for the supply air is recommended (dew point should be –20° C or less).

The permeation tube of the internal span gas generator option is heated with a proportional heater circuit and the temperature is maintained at 50°C ±1°C. Check the front panel display or the **IZS_TEMP** signal voltage using the **SIGNAL I/O** function under the **DIAG** Menu (Section 8.3). At 50° C, the temperature signal from the IZS thermistor should be around 2500 mV.

14.7.17. TEMPERATURE SENSOR

14.7.17.1. Box Temperature Sensor

The box temperature sensor (thermistor) is mounted on the motherboard below the bottom edge of the CPU board when looking at it from the front. It cannot be disconnected to check its resistance.

Box temperature will vary with, but will usually read about 5° C higher than, ambient (room) temperature because of the internal heating zones from the NO_2 converter, reaction cell and other devices.

- To check the box temperature functionality, we recommend checking the **BOX_TEMP** signal voltage using the **SIGNAL I/O** function under the **DIAG** Menu (Section 14.1.3).
- At about 30° C, the signal should be around 1500 mV.
- To check the accuracy of the sensor, use a calibrated external thermometer / temperature sensor to verify the accuracy of the box temperature by:
  - Placing it inside the chassis, next to the thermistor labeled **XT1** (above connector J108) on the motherboard.
  - Compare its reading to the value of the test function **PMT TEMP**.

14.7.17.2. PMT Temperature Sensor Control

The temperature of the PMT should be low and constant. It is more important that this temperature is maintained at a constant level than it is to be a specific temperature.

The PMT cooler uses a Peltier, thermo-electric cooler element supplied with 12 V DC power from the switching power supply PS2. The temperature is controlled by a proportional temperature controller located on the preamplifier board.

- Voltages applied to the cooler element vary from 0.1 to 12 VDC.
- The temperature set point (hard-wired into the preamplifier board) will vary by ±2
- The actual temperature will be maintained to within 0.1° Ç around that set point.

To check the operation of the PMT temperature control system:

1. Turn off the analyzer and let its internal components cool / heat to ambient temperature.
2. Turn on the analyzer.
3. Set the front panel to show the **PMT TEMP** test function (see Section 7.2.1).
   - The temperature should fall steadily to 6-10° C.
   - If the temperature fails to reach this point after 60 minutes, there is a problem in the cooler circuit.
   - If the control circuit on the preamplifier board is faulty, a temperature of –1° Ç will be reported.

14.8. REPAIR PROCEDURES

This section contains some procedures that may need to be performed when a major component of the analyzer requires repair or replacement.

NOTE

Maintenance procedures (e.g., replacement of regularly changed expendables) are discussed in Section 13 (Maintenance Schedule & Procedures are not listed here).

Also, there may be more detailed service notes for some of the below procedures. Contact Teledyne API's Customer Service Department (see Section 14.9).

CAUTION

ELECTRICAL SHOCK HAZARD

Risk of electrical shock.

Unless the procedure being performed requires the instrument be operating, turn it off and disconnect power before opening the analyzer and removing, adjusting or repairing any of its components or subsystems.

CAUTION

QUALIFIED PERSONNEL

The operations outlined in this chapter are to be performed by qualified maintenance personnel only.

14.8.1. DISK-ON-MODULE REPLACEMENT PROCEDURE

NOTE

Servicing of circuit components requires electrostatic discharge protection, i.e. ESD grounding straps, mats and containers. Failure to use ESD protection when working with electronic assemblies will void the instrument warranty. Refer to Section 15 for more information on preventing ESD damage.

Replacing the Disk-on-Module (DOM) will cause loss of all DAS data; it may also cause loss of some instrument configuration parameters unless the replacement DOM carries the exact same firmware version. Whenever changing the version of installed software, the memory must be reset. Failure to ensure that memory is reset can cause the analyzer to malfunction, and invalidate measurements. After the memory is reset, the A/D converter must be re-calibrated, and all information collected in Step 1 below must be re-entered before the instrument will function correctly. Also, zero and span calibration should be performed.

1. Document all analyzer parameters that may have been changed, such as range, auto-cal, analog output, serial port and other settings before replacing the DOM
2. Turn off power to the instrument, fold down the rear panel by loosening the mounting screws.
3. When looking at the electronic circuits from the back of the analyzer, locate the Disk-on-Module in the right-most socket of the CPU board.
4. The DOM should carry a label with firmware revision, date and initials of the programmer.

5. Remove the nylon standoff clip that mounts the DOM over the CPU board, and lift the DOM off the CPU. Do not bend the connector pins.
6. Install the new Disk-on-Module, making sure the notch at the end of the chip matches the notch in the socket.
7. It may be necessary to straighten the pins somewhat to fit them into the socket. Press the chip all the way in.
8. Close the rear panel and turn on power to the machine.
9. If the replacement DOM carries a firmware revision, re-enter all of the setup information.

14.8.2. O_3 GENERATOR REPLACEMENT

The ozone generator is a black, brick-shaped device with printed circuit board attached to its rear and two tubes extending out the right side in the front of the analyzer (see Figure 3-5). The board has a red LED that, when lit, indicates ozone is being generated. To replace the ozone generator:

1. Turn off the analyzer power, remove the power cord and the analyzer cover.
2. Disconnect the 1/8" black tube from the ozone scrubber cartridge and the ¼" clear tube from the plastic extension tube at the brass fitting nearest to the ozone generator.
3. Unplug the electrical connection on the rear side of the brick.
4. Unscrew the two mounting screws that attach the ozone generator to the chassis and take out the entire assembly.
5. If you received a complete replacement generator with circuit board and mounting bracket attached, simply reverse the above steps to replace the current generator.

NOTE

Ensure to carry out a leak check and a recalibration after the analyzer has warmed up for about 60 minutes.

14.8.3. SAMPLE AND OZONE (PERMA PURE®) DRYER REPLACEMENT

The T200 standard configuration is equipped with a dryer for the ozone supply air. An optional dryer is available for the sample stream and a combined dryer for both gas streams can also be purchased. To change one or both of these dryers:

1. Turn off power to the analyzer and pump, remove the power cord and the analyzer cover.
2. Locate the dryers in the center of the instrument, between sensor and NO_2 converter (see Figure 3-5).
   - They are mounted to a bracket, which can be taken out when unscrewing the two mounting screws (if necessary).
3. Disconnect all tubing that extends out of the dryer assembly.
   - Take extra care not to twist any of the white plastic fittings on the dryer.
   - These connect the inner drying tube to the outer purge tube and are delicate. See Sections 13.3.1 and 13.3.2.
4. Note the orientation of the dryer on the bracket.
5. Cut the tie wraps that hold the dryer to the mounting bracket and take out the old dryer.

- If necessary, unscrew the two mounting screws on the bracket and take out the entire assembly.

6. Attach the replacement dryer to the mounting bracket in the same orientation as the old dryer.
7. Fix the dryer to the bracket using new tie wraps.
8. Cut off excess length of the wraps.
9. Put the assembly back into the chassis and tighten the mounting screws.
10. Re-attach the tubes to vacuum manifold, flow meter and/or NO/NO_x valve using at least two wrenches.
    - Take extra care not to twist the dryer's white plastic fittings, as this will result in large leaks that are difficult to trouble-shoot and fix.
11. Carry out a detailed leak check (see Section 13.3.12.2),
12. Close the analyzer.
13. Power up pump and analyzer and re-calibrate the instrument after it stabilizes.

14.8.4. PMT SENSOR HARDWARE CALIBRATION

The sensor module hardware calibration is used in the factory to adjust the slope and offset of the PMT output and to optimize the signal output and HVPS.

- If the instrument's slope and offset values are outside of the acceptable range and all other more obvious causes for this problem have been eliminated, the hardware calibration can be used to adjust the sensor as has been done in the factory.
- This procedure is also recommended after replacing the PMT or the preamplifier board.

To calibrate the PMT preamplifier PCA:

1. Perform a full zero point calibration using zero air (see Section 10).
2. Display the **STB** test function on the front panel :
    - Set it for **NO_STB** (see Section 8.2.1).
3. Locate the preamplifier board (see Figure 3-5).
4. Locate the following components on the preamplifier board (Figure 14-8):
    - HVPS coarse adjustment switch (Range 0-9, then A-F).
    - HVPS fine adjustment switch (Range 0-9, then A-F).
    - Gain adjustment potentiometer (Full scale is 10 turns).
5. Turn the gain adjustment potentiometer 12 turns clockwise or to its maximum setting.
6. Feed NO gas into the analyzer.
    - This should be 90% of the upper limit setting for the T200's reporting range:

    EXAMPLE: if the reporting range is set at 500 ppb, use 450 ppb NO.
7. Wait until the **STB** value is below 0.5 ppb

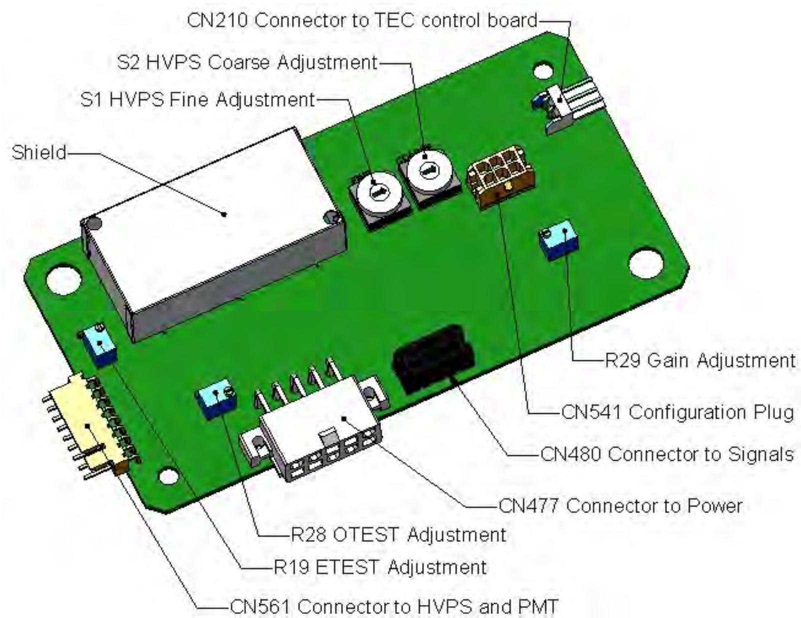


Figure 14-8: Pre-Amplifier Board Layout

8. Scroll to the **NORM PMT** test function on the analyzer's front panel.
9. With the NO gas concentrations mentioned in Step 5 above, the **NORM PMT** value should be 900 mV.
10. Set the HVPS coarse adjustment to its minimum setting (0).
11. Set the HVPS fine adjustment switch to its maximum setting (F).
    - Set the HVPS coarse adjustment switch to the lowest setting that will give you just above the target value for **NORM PMT** signal.
12. Adjust the HVPS fine adjustment such that the **NORM PMT** value is close to the target value.
    - It may be necessary to go back and forth between coarse and fine adjustments if the proper value is at the threshold of the min/max coarse setting.

NOTE
Do not overload the PMT by accidentally setting both adjustment switches to their maximum setting. Start at the lowest setting and increment slowly. Wait 10 seconds between adjustments.

NOTE
During these adjustments, the NORM PMT value will fluctuate as the analyzer continues to switch between NO and NO_X streams as well as between measure and Auto Zero modes.

13. Perform a span point calibration (see Section 10) to normalize the sensor response to its new PMT sensitivity.
14. Review the slope and offset values:
    - The slope values should be 1.000±0.300.
    - The offset values should be approximately 0.0 (-20 to +150 mV is allowed).

14.8.5. REPLACING THE PMT, HVPS OR TEC

The photo multiplier tube (PMT) should last for the lifetime of the analyzer, however, the high voltage power supply (HVPS) or the thermo-electric cooler (TEC) components may fail. Replacing any of these components requires opening the sensor module. This is a delicate assembly and it is recommend that you ensure the PMT, HVPS or TEC modules are, indeed, faulty before unnecessarily opening of the module.

CAUTION
QUALIFIED PERSONNEL

While the PMT or HVPS can be removed through the front panel without un-mounting the entire sensor module, we recommend turning off the instrument, opening its top cover and removing the entire assembly so that further repairs can be carried out at an anti-ESD workstation.

Follow the guidelines defined in Section 15 for preventing electrostatic damage to electronic components.

1. Turn OFF the analyzer and disconnect the power cord.
2. Remove the cover.
3. Disconnect all pneumatic and electrical connections from the sensor assembly.
4. Remove the sensor assembly.
5. If the TEC is to be replaced, remove the reaction cell assembly at this point by unscrewing two holding screws.
   - This is necessary only if the repair being performed involves removing the PMT cold block.

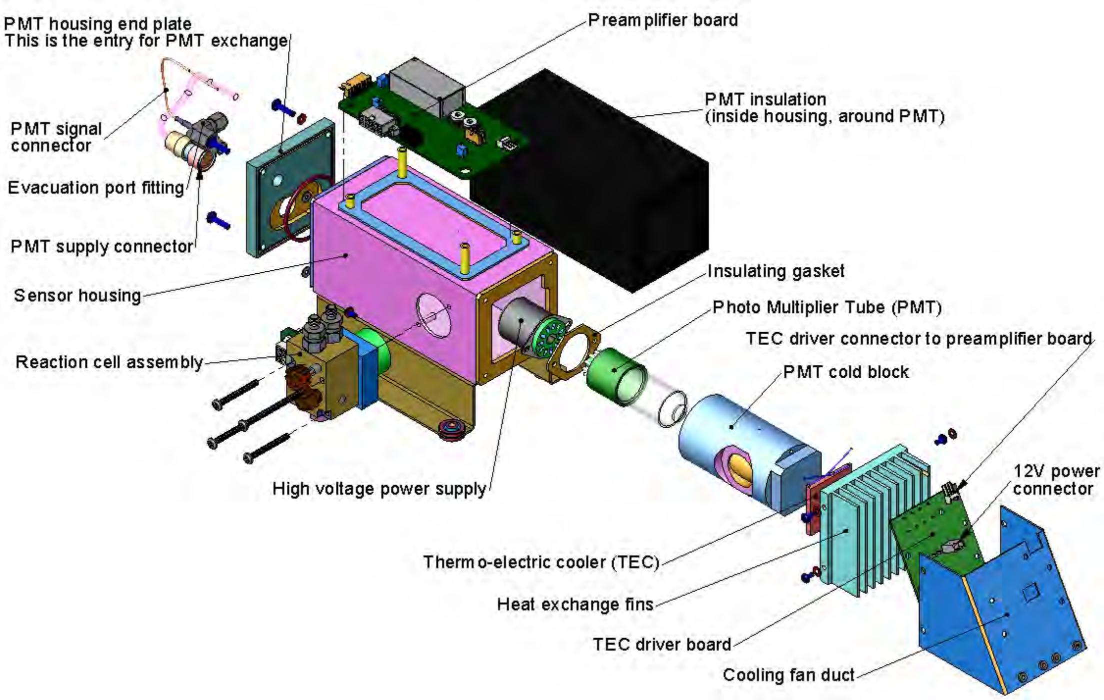


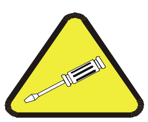
Figure 14-9: T200 Sensor Assembly

6. Remove the two connectors on the PMT housing end plate facing towards the front panel.
7. Remove the end plate itself (4 screws with plastic washers).

NOTE

If the black PMT housing end plate for the Sensor Assembly is removed, ensure to replace the 5 desiccant bags inside the housing.

8. Remove the dryer packages inside the PMT housing.
9. Unscrew the PMT assembly, which is held to the cold block by two plastic screws.
10. Discard the plastic screws and replace with new screws at the end of this procedure (the threads get stripped easily and it is recommended to use new screws).
11. Along with the plate, slide out the OPTIC TEST LED and the thermistor that measures the PMT temperature.
    - Thermistor will be coated with a white, thermal conducting paste.
    - Do not contaminate the inside of the housing with this grease, as it may contaminate the PMT glass tube on re-assembly.
12. Carefully take out the assembly consisting of the HVPS, the gasket and the PMT.
13. Change the PMT or the HVPS or both, clean the PMT glass tube with a clean, anti-static wipe and do not touch it after cleaning.
14. If the cold block or TEC is to be changed:
    - Disconnect the TEC driver board from the preamplifier board, remove the cooler fan duct (4 screws on its side) including the driver board.
    - Disconnect the driver board from the TEC and set the sub-assembly aside.
15. Remove the end plate with the cooling fins (4 screws) and slide out the PMT cold block assembly, which contains the TEC.
16. Unscrew the TEC from the cooling fins and the cold block and replace it with a new unit.
17. Reassemble this TEC subassembly in reverse order.
    - Ensure to use thermal grease between TEC and cooling fins as well as between TEC and cold block and that the side opening in the cold block will face the reaction cell when assembled.
    - Evenly tighten the long mounting screws for good thermal conductivity.



CAUTION
QUALIFIED PERSONNEL

The thermo-electric cooler needs to be mounted flat to the heat sink.

If there is any significant gap, the TEC might burn out. Ensure to apply heat sink paste before mounting it and tighten the screws evenly and cross-wise.

18. Reinsert the TEC subassembly in reverse order.
    - Ensure that the O-ring is placed properly and the assembly is tightened evenly.
19. Insert the LED and thermistor into the cold block, insert new drying packages and carefully replace the end plate by making sure that the O-ring is properly in place.
    - Improperly placed O-rings will cause leaks, which – in turn – cause moisture to condense on the inside of the cooler and likely cause a short in the HVPS.
20. Reinsert the PMT/HVPS subassembly in reverse order.
    - Don’t forget the gasket between HVPS and PMT.
    - Use new plastic screws to mount the PMT assembly on the PMT cold block.
21. Install new silica gel packets (desiccant bags).
22. Reconnect the cables and the reaction cell (evenly tighten these screws).

23. Replace the sensor assembly into the chassis and fasten with four screws and washers.
24. Reconnect all electrical and pneumatic connections.
25. Leak check the system (see Section 13.3.12).
26. Turn ON the analyzer.
27. Verify the basic operation of the analyzer using the ETEST(14.7.12.3) and OTEST features (14.7.12.2) or zero and span gases, then carry out a hardware calibration of the analyzer followed by a zero/span point calibration (See Section 10.4.3.2).

14.8.6. REMOVING / REPLACING THE RELAY PCA FROM THE INSTRUMENT

This is the most commonly used version of the Relay PCA. It includes a bank of solid state AC relays. This version is installed in analyzers where components such as AC powered heaters must be turned ON & OFF.

A retainer plate is installed over the relay to keep them securely seated in their sockets.

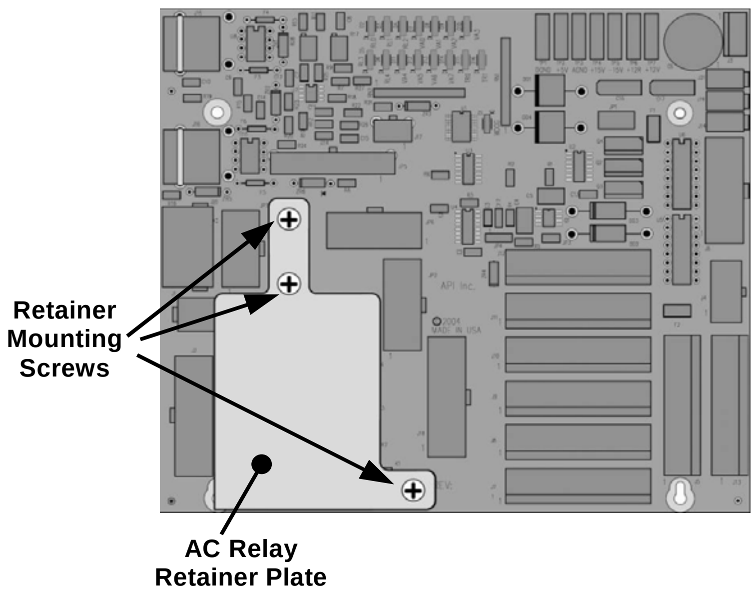


Figure 14-10: Relay PCA with AC Relay Retainer In Place

The Relay retainer plate installed on the relay PCA covers the lower right mounting screw of the relay PCA. Therefore, when removing the relay PCA, the retainer plate must be removed first.

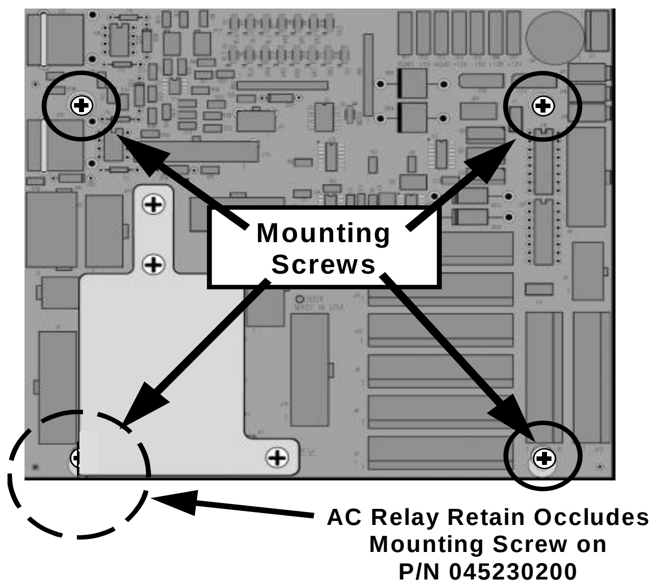


Figure 14-11: Relay PCA Mounting Screw Locations

14.9. TECHNICAL ASSISTANCE

If this manual and its troubleshooting & repair section do not solve your problems, technical assistance may be obtained from:

Teledyne API, Customer Service,
9480 Carroll Park Drive
San Diego, California 92121-5201USA

Toll-free Phone:	800-324-5190
Phone:	858-657-9800
Fax:	858-657-9816
Email:	api-customerservice@teledyne.com
Website:	http://www.teledyne-api.com/

Before you contact Teledyne API's Customer Service, fill out the problem report form in Appendix C, which is also available online for electronic submission at http://www.teledyne-api.com/manuals/.

15. A PRIMER ON ELECTRO-STATIC DISCHARGE

Teledyne API considers the prevention of damage caused by the discharge of static electricity to be extremely important part of making sure that your analyzer continues to provide reliable service for a long time. This section describes how static electricity occurs, why it is so dangerous to electronic components and assemblies as well as how to prevent that damage from occurring.

15.1. HOW STATIC CHARGES ARE CREATED

Modern electronic devices such as the types used in the various electronic assemblies of your analyzer, are very small, require very little power and operate very quickly. Unfortunately, the same characteristics that allow them to do these things also make them very susceptible to damage from the discharge of static electricity. Controlling electrostatic discharge begins with understanding how electro-static charges occur in the first place.

Static electricity is the result of something called triboelectric charging which happens whenever the atoms of the surface layers of two materials rub against each other. As the atoms of the two surfaces move together and separate, some electrons from one surface are retained by the other.

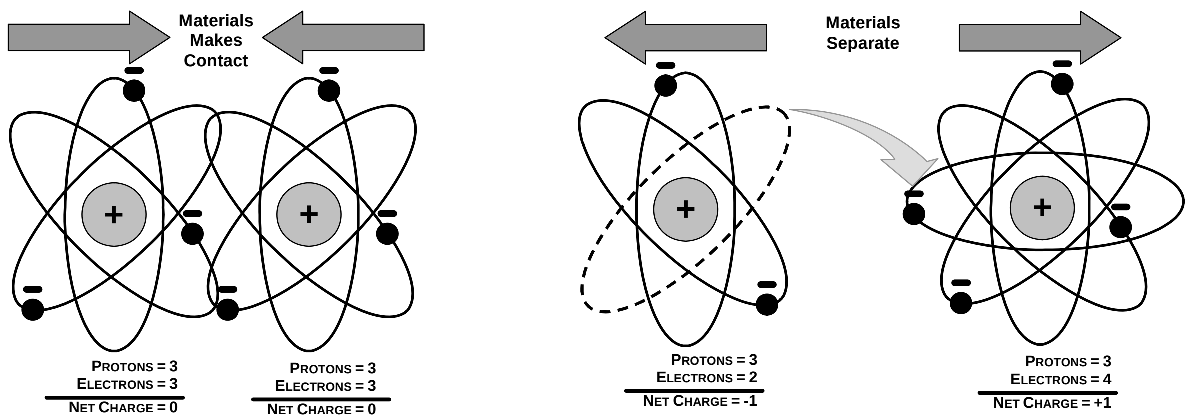


Figure 15-1: Triboelectric Charging

If one of the surfaces is a poor conductor or even a good conductor that is not grounded, the resulting positive or negative charge cannot bleed off and becomes trapped in place, or static. The most common example of triboelectric charging happens when someone wearing leather or rubber soled shoes walks across a nylon carpet or linoleum tiled floor. With each step, electrons change places and the resulting electro-static charge builds up, quickly reaching significant levels. Pushing an epoxy printed circuit board across a workbench, using a plastic handled screwdriver or even the constant jostling of Styrofoam™ pellets during shipment can also build hefty static charges.

Table 15-1: Static Generation Voltages for Typical Activities

MEANS OF GENERATION	65-90% RH	10-25% RH
Walking across nylon carpet	1,500V	35,000V
Walking across vinyl tile	250V	12,000V
Worker at bench	100V	6,000V
Poly bag picked up from bench	1,200V	20,000V
Moving around in a chair padded with urethane foam	1,500V	18,000V

15.2. HOW ELECTRO-STATIC CHARGES CAUSE DAMAGE

Damage to components occurs when these static charges come into contact with an electronic device. Current flows as the charge moves along the conductive circuitry of the device and the typically very high voltage levels of the charge overheat the delicate traces of the integrated circuits, melting them or even vaporizing parts of them. When examined by microscope the damage caused by electro-static discharge looks a lot like tiny bomb craters littered across the landscape of the component's circuitry.

A quick comparison of the values in with the those shown in the , listing device susceptibility levels, shows why *Semiconductor Reliability News* estimates that approximately 60% of device failures are the result of damage due to electro-static discharge.

Table 15-2: Sensitivity of Electronic Devices to Damage by ESD

DEVICE	DAMAGE SUSCEPTIBILITY VOLTAGE RANGE	
	DAMAGE BEGINS OCCURRING AT	CATASTROPHIC DAMAGE AT
MOSFET	10	100
VMOS	30	1800
NMOS	60	100
GaAsFET	60	2000
EPROM	100	100
JFET	140	7000
SAW	150	500
Op-AMP	190	2500
CMOS	200	3000
Schottky Diodes	300	2500
Film Resistors	300	3000
This Film Resistors	300	7000
ECL	500	500
SCR	500	1000
Schottky TTL	500	2500

Potentially damaging electro-static discharges can occur:

- Any time a charged surface (including the human body) discharges to a device. Even simple contact of a finger to the leads of a sensitive device or assembly can allow enough discharge to cause damage. A similar discharge can occur from a charged conductive object, such as a metallic tool or fixture.
- When static charges accumulated on a sensitive device discharges from the device to another surface such as packaging materials, work surfaces, machine surfaces or other device. In some cases, charged device discharges can be the most destructive.
- A typical example of this is the simple act of installing an electronic assembly into the connector or wiring harness of the equipment in which it is to function. If the assembly is carrying a static charge, as it is connected to ground a discharge will occur.
- Whenever a sensitive device is moved into the field of an existing electro-static field, a charge may be induced on the device in effect discharging the field onto the device. If the device is then momentarily grounded while within the electrostatic field or removed from the region of the electrostatic field and grounded somewhere else, a second discharge will occur as the charge is transferred from the device to ground.

15.3. COMMON MYTHS ABOUT ESD DAMAGE

- **I didn't feel a shock so there was no electro-static discharge:** The human nervous system isn't able to feel a static discharge of less than 3500 volts. Most devices are damaged by discharge levels much lower than that.
- **I didn't touch it so there was no electro-static discharge:** Electro Static charges are fields whose lines of force can extend several inches or sometimes even feet away from the surface bearing the charge.
- **It still works so there was no damage**: Sometimes the damages caused by electro-static discharge can completely sever a circuit trace causing the device to fail immediately. More likely, the trace will be only partially occluded by the damage causing degraded performance of the device or worse, weakening the trace. This weakened circuit may seem to function fine for a short time, but even the very low voltage and current levels of the device's normal operating levels will eat away at the defect over time causing the device to fail well before its designed lifetime is reached.

  These latent failures are often the most costly since the failure of the equipment in which the damaged device is installed causes down time, lost data, lost productivity, as well as possible failure and damage to other pieces of equipment or property.
- **Static Charges can't build up on a conductive surface:** There are two errors in this statement.

  Conductive devices can build static charges if they are not grounded. The charge will be equalized across the entire device, but without access to earth ground, they are still trapped and can still build to high enough levels to cause damage when they are discharged.

  A charge can be induced onto the conductive surface and/or discharge triggered in the presence of a charged field such as a large static charge clinging to the surface of a nylon jacket of someone walking up to a workbench.
- **As long as my analyzer is properly installed, it is safe from damage caused by static discharges:** It is true that when properly installed the chassis ground of your analyzer is tied to earth ground and its electronic components are prevented from building static electric charges themselves. This does not prevent discharges from static fields built up on other things, like you and your clothing, from discharging through the instrument and damaging it.

15.4. BASIC PRINCIPLES OF STATIC CONTROL

It is impossible to stop the creation of instantaneous static electric charges. It is not, however difficult to prevent those charges from building to dangerous levels or prevent damage due to electro-static discharge from occurring.

15.4.1. GENERAL RULES

Only handle or work on all electronic assemblies at a properly set up ESD station. Setting up an ESD safe workstation need not be complicated. A protective mat properly tied to ground and a wrist strap are all that is needed to create a basic anti-ESD workstation.

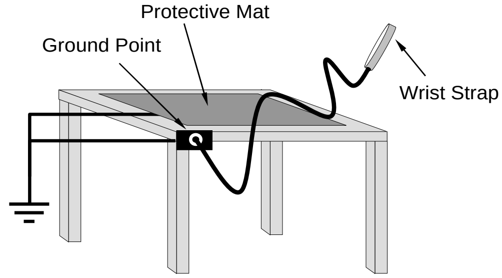


Figure 15-2: Basic anti-ESD Workbench

For technicians that work in the field, special lightweight and portable anti-ESD kits are available from most suppliers of ESD protection gear. These include everything needed to create a temporary anti-ESD work area anywhere.

- **Always wear an Anti-ESD wrist strap when working on the electronic assemblies of your analyzer**. An anti-ESD wrist strap keeps the person wearing it at or near the same potential as other grounded objects in the work area and allows static charges to dissipate before they can build to dangerous levels. Anti-ESD wrist straps terminated with alligator clips are available for use in work areas where there is no available grounded plug.

  Also, anti-ESD wrist straps include a current limiting resistor (usually around one meg-ohm) that protects you should you accidentally short yourself to the instrument's power supply.

- **Simply touching a grounded piece of metal is insufficient**. While this may temporarily bleed off static charges present at the time, once you stop touching the grounded metal new static charges will immediately begin to re-build. In some conditions, a charge large enough to damage a component can rebuild in just a few seconds.

- **Always store sensitive components and assemblies in anti-ESD storage bags or bins:** Even when you are not working on them, store all devices and assemblies in a closed anti-Static bag or bin. This will prevent induced charges from building up on the device or assembly and nearby static fields from discharging through it.

- **Use metallic anti-ESD bags for storing and shipping ESD sensitive components and assemblies rather than pink-poly bags.** The famous, pink-poly bags are made of a plastic that is impregnated with a liquid (similar to liquid laundry detergent) which very slowly sweats onto the surface of the plastic creating a slightly conductive layer over the surface of the bag.

  While this layer may equalizes any charges that occur across the whole bag, it does not prevent the build up of static charges. If laying on a conductive, grounded surface, these bags will allow charges to bleed away but the very charges that build up on the surface of the bag itself can be transferred through the bag by induction onto the circuits of your ESD sensitive device. Also, the liquid impregnating the plastic is eventually used up after which the bag is as useless for preventing damage from ESD as any ordinary plastic bag.

  Anti-Static bags made of plastic impregnated with metal (usually silvery in color) provide all of the charge equalizing abilities of the pink-poly bags but also, when properly sealed, create a Faraday cage that completely isolates the contents from discharges and the inductive transfer of static charges.

  Storage bins made of plastic impregnated with carbon (usually black in color) are also excellent at dissipating static charges and isolating their contents from field effects and discharges.

- **Never use ordinary plastic adhesive tape near an ESD sensitive device or to close an anti-ESD bag.** The act of pulling a piece of standard plastic adhesive tape, such as Scotch® tape, from its roll will generate a static charge of several thousand or even tens of thousands of volts on the tape itself and an associated field effect that can discharge through or be induced upon items up to a foot away.

15.4.2. BASIC ANTI-ESD PROCEDURES FOR ANALYZER REPAIR AND MAINTENANCE

15.4.2.1. Working at the Instrument Rack

When working on the analyzer while it is in the instrument rack and plugged into a properly grounded power supply:

1. Attach you anti-ESD wrist strap to ground before doing anything else.
    - Use a wrist strap terminated with an alligator clip and attach it to a bare metal portion of the instrument chassis.
    - This will safely connect you to the same ground level to which the instrument and all of its components are connected.
2. Pause for a second or two to allow any static charges to bleed away.
3. Open the casing of the analyzer and begin work. Up to this point, the closed metal casing of your analyzer has isolated the components and assemblies inside from any conducted or induced static charges.
4. If you must remove a component from the instrument, do not lay it down on a non-ESD preventative surface where static charges may lie in wait.
5. Only disconnect your wrist strap after you have finished work and closed the case of the analyzer.

15.4.2.2. Working at an Anti-ESD Work Bench

When working on an instrument of an electronic assembly while it is resting on a anti-ESD workbench:

1. Plug you anti-ESD wrist strap into the grounded receptacle of the work station before touching any items on the work station and while standing at least a foot or so away. This will allow any charges you are carrying to bleed away through the ground connection of the workstation and prevent discharges due to field effects and induction from occurring.
2. Pause for a second or two to allow any static charges to bleed away.
3. Only open any anti-ESD storage bins or bags containing sensitive devices or assemblies after you have plugged your wrist strap into the workstation.
    - Lay the bag or bin on the workbench surface.
    - Before opening the container, wait several seconds for any static charges on the outside surface of the container to be bled away by the workstation's grounded protective mat.
4. Do not pick up tools that may be carrying static charges while also touching or holding an ESD sensitive device.
    - Only lay tools or ESD-sensitive devices and assemblies on the conductive surface of your workstation. Never lay them down on any non-ESD preventative surface.
5. Place any static sensitive devices or assemblies in anti-static storage bags or bins and close the bag or bin before unplugging your wrist strap.
6. Disconnecting your wrist strap is always the last action taken before leaving the workbench.

15.4.2.3. Transferring Components from Rack to Bench and Back

When transferring a sensitive device from an installed Teledyne API's analyzer to an Anti-ESD workbench or back:

1. Follow the instructions listed above for working at the instrument rack and workstation.
2. Never carry the component or assembly without placing it in an anti-ESD bag or bin.
3. Before using the bag or container allow any surface charges on it to dissipate:
   - If you are at the instrument rack, hold the bag in one hand while your wrist strap is connected to a ground point.
   - If you are at an anti-ESD workbench, lay the container down on the conductive work surface.
   - In either case wait several seconds.
4. Place the item in the container.
5. Seal the container. If using a bag, fold the end over and fastening it with anti-ESD tape.
   - Folding the open end over isolates the component(s) inside from the effects of static fields.
   - Leaving the bag open or simply stapling it shut without folding it closed prevents the bag from forming a complete protective envelope around the device.
6. Once you have arrived at your destination, allow any surface charges that may have built up on the bag or bin during travel to dissipate:
   - Connect your wrist strap to ground.
   - If you are at the instrument rack, hold the bag in one hand while your wrist strap is connected to a ground point.
   - If you are at a anti-ESD workbench, lay the container down on the conductive work surface.
   - In either case wait several seconds.
7. Open the container.

15.4.2.4. Opening Shipments from Teledyne API's Customer Service

Packing materials such as bubble pack and Styrofoam pellets are extremely efficient generators of static electric charges. To prevent damage from ESD, Teledyne API ships all electronic components and assemblies in properly sealed ant-ESD containers.

Static charges will build up on the outer surface of the anti-ESD container during shipping as the packing materials vibrate and rub against each other. To prevent these static charges from damaging the components or assemblies being shipped ensure that you:

Always unpack shipments from Teledyne API's Customer Service by:

1. Opening the outer shipping box away from the anti-ESD work area.
2. Carry the still sealed ant-ESD bag, tube or bin to the anti-ESD work area.
3. Follow steps 6 and 7 of Section 14.2.3 above when opening the anti-ESD container at the work station.
4. Reserve the anti-ESD container or bag to use when packing electronic components or assemblies to be returned to Teledyne API.

15.4.2.5. Packing Components for Return to Teledyne API's Customer Service.

Always pack electronic components and assemblies to be sent to Teledyne API's Customer Service in anti-ESD bins, tubes or bags.

CAUTION
ESD Hazard

- **DO NOT use pink-poly bags.**
- **NEVER allow any standard plastic packaging materials to touch the electronic component/assembly directly.**
  - **This includes, but is not limited to, plastic bubble-pack, Styrofoam peanuts, open cell foam, closed cell foam, and adhesive tape.**
- **DO NOT use standard adhesive tape as a sealer. Use ONLY anti-ESD tape.**

Never carry the component or assembly without placing it in an anti-ESD bag or bin.

1. Before using the bag or container allow any surface charges on it to dissipate:
   - If you are at the instrument rack, hold the bag in one hand while your wrist strap is connected to a ground point.
   - If you are at an anti-ESD workbench, lay the container down on the conductive work surface.
   - In either case wait several seconds.
2. Place the item in the container.
3. Seal the container. If using a bag, fold the end over and fastening it with anti-ESD tape.
   - Folding the open end over isolates the component(s) inside from the effects of static fields.
   - Leaving the bag open or simply stapling it shut without folding it closed prevents the bag from forming a complete protective envelope around the device.

NOTE

If you do not already have an adequate supply of anti-ESD gags or containers available, Teledyne API's Customer Service department will supply them (see Section 14.9 for contact information).

Follow the instructions listed above for working at the instrument rack and workstation.

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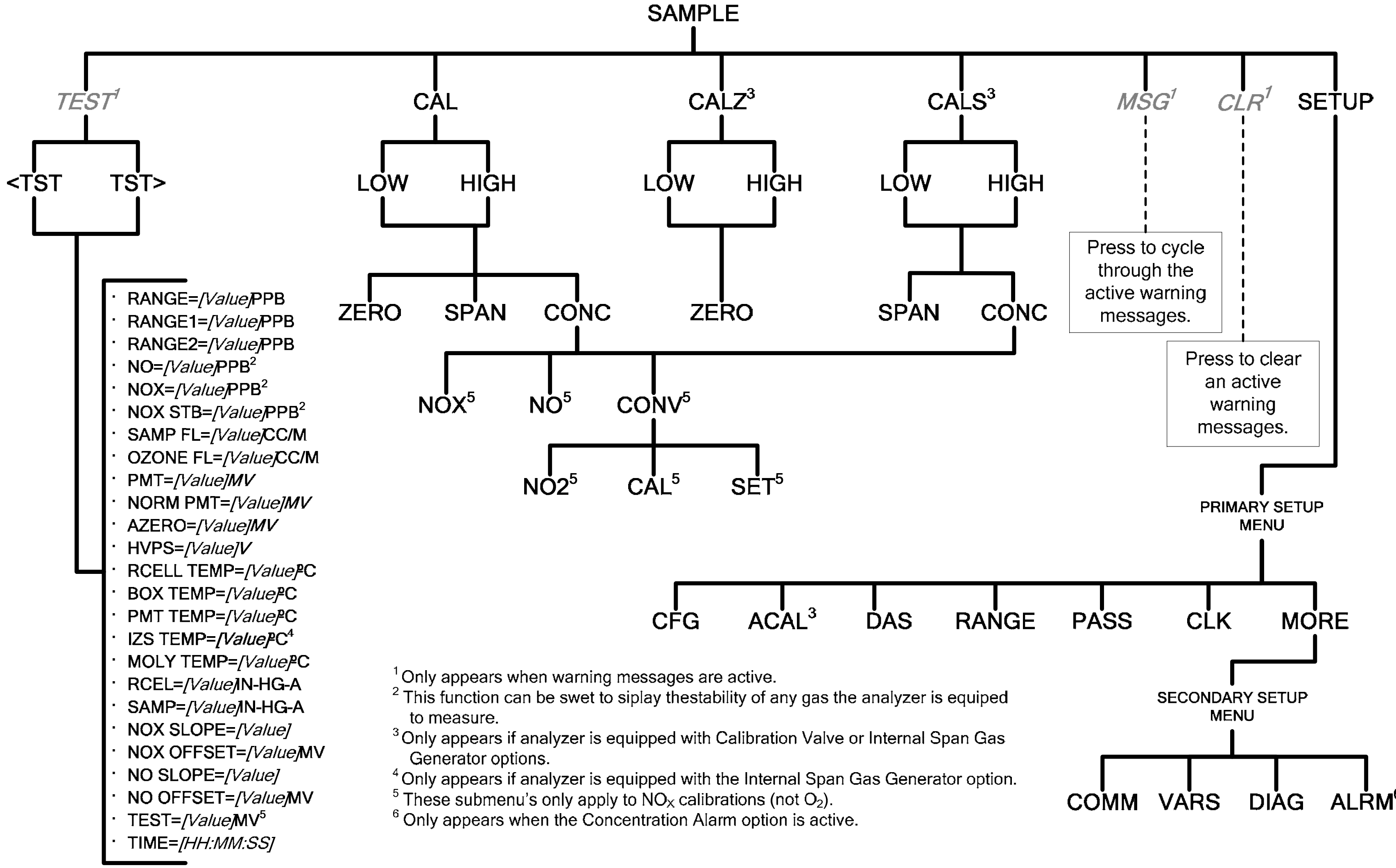
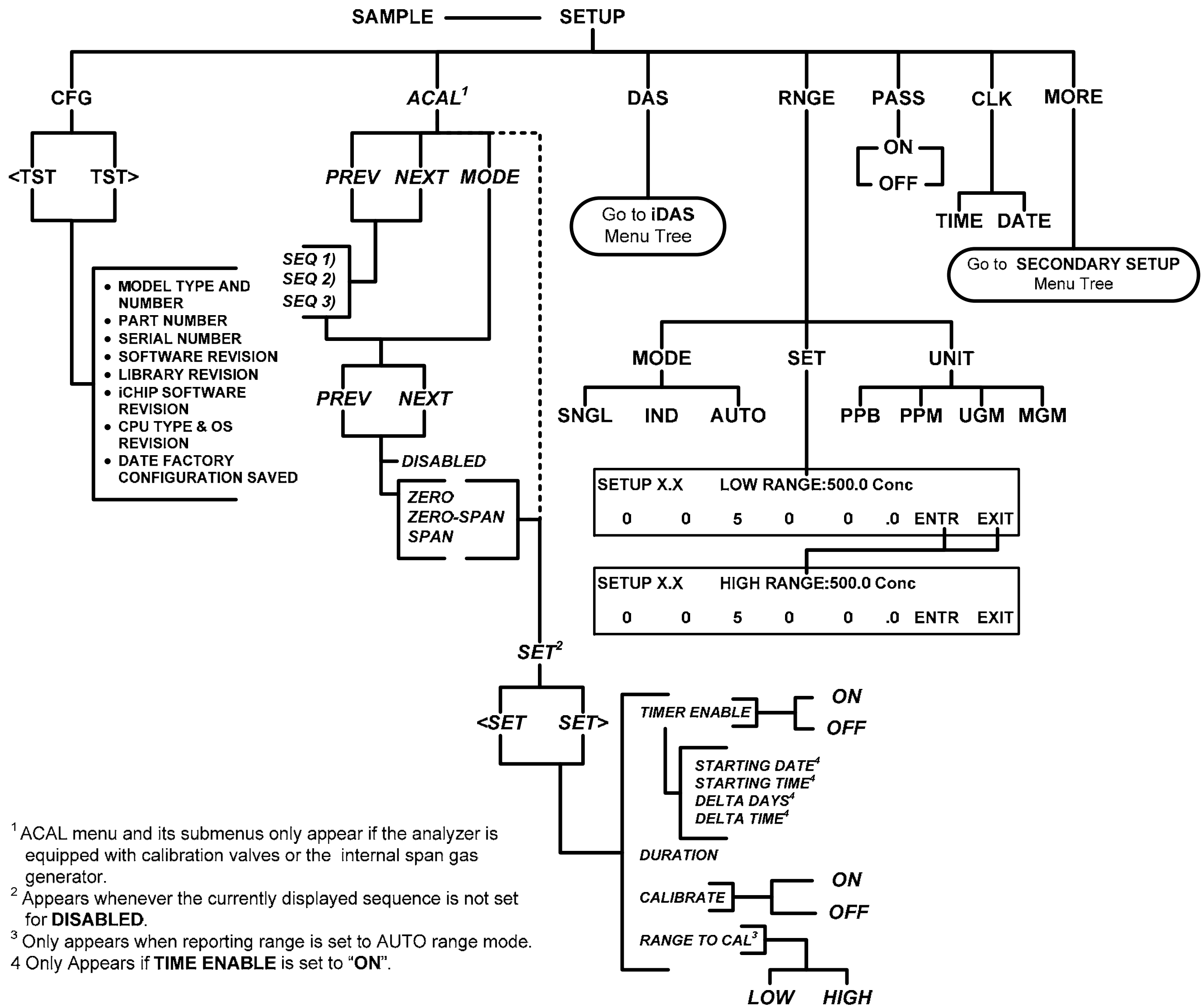
APPENDIX A: Version Specific Software Documentation

APPENDIX A-1: Software Menu Trees and Index, Software Version K.3



[1] Only appears when warning messages are active.
[2] This function can be swet to siplay thestability of any gas the analyzer is equiped to measure.
[3] Only appears if analyzer is equipped with Calibration Valve or Internal Span Gas Generator options.
[4] Only appears if analyzer is equipped with the Internal Span Gas Generator option.
[5] These submenu's only apply to NO_X calibrations (not O_2).
[6] Only appears when the Concentration Alarm option is active.

Figure A-1: Basic Sample Display Menu



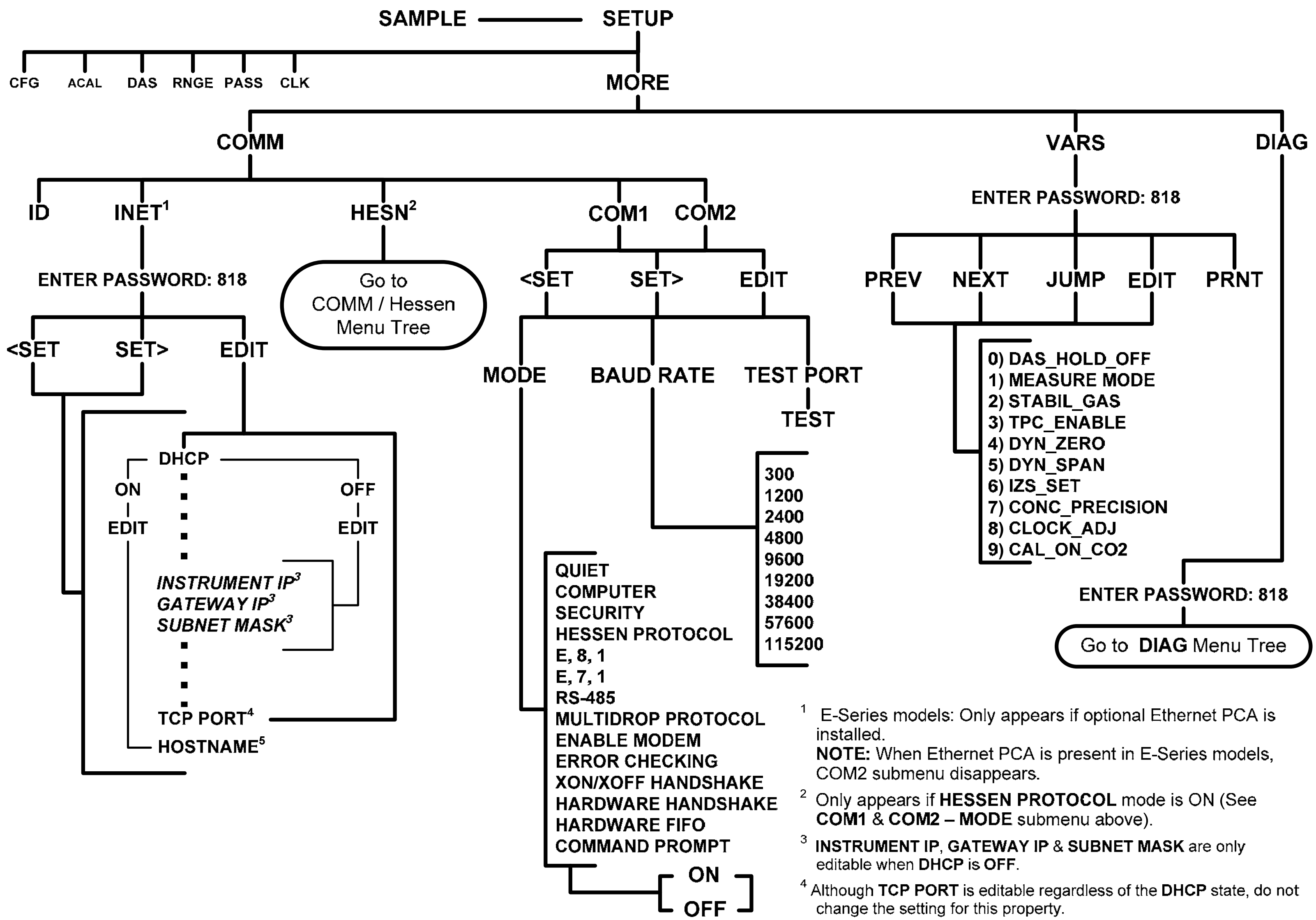
[1] ACAL menu and its submenus only appear if the analyzer is equipped with calibration valves or the internal span gas generator.

[2] Appears whenever the currently displayed sequence is not set for **DISABLED**.

[3] Only appears when reporting range is set to AUTO range mode.

4 Only Appears if **TIME ENABLE** is set to "**ON**".

Figure A-2: Primary Setup Menu (Except DAS)



[1] E-Series models: Only appears if optional Ethernet PCA is installed.
NOTE: When Ethernet PCA is present in E-Series models, COM2 submenu disappears.

[2] Only appears if **HESSEN PROTOCOL** mode is ON (See **COM1** & **COM2 – MODE** submenu above).

[3] **INSTRUMENT IP**, **GATEWAY IP** & **SUBNET MASK** are only editable when **DHCP** is **OFF**.

[4] Although **TCP PORT** is editable regardless of the **DHCP** state, do not change the setting for this property.

[5] **HOST NAME** is only editable when **DHCP** is **ON**.

Figure A-3: Secondary Setup Menu (COMM & VARS)

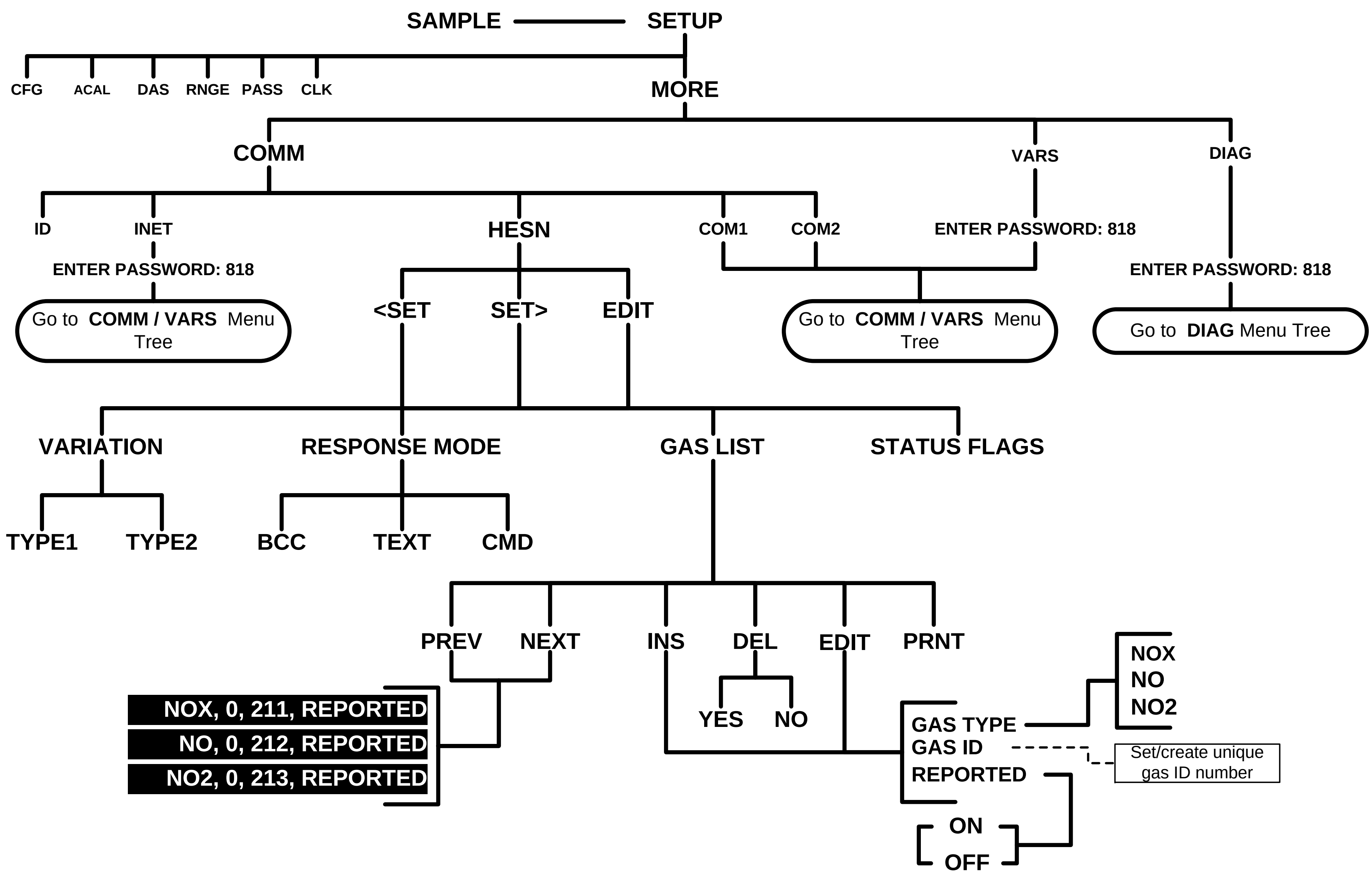
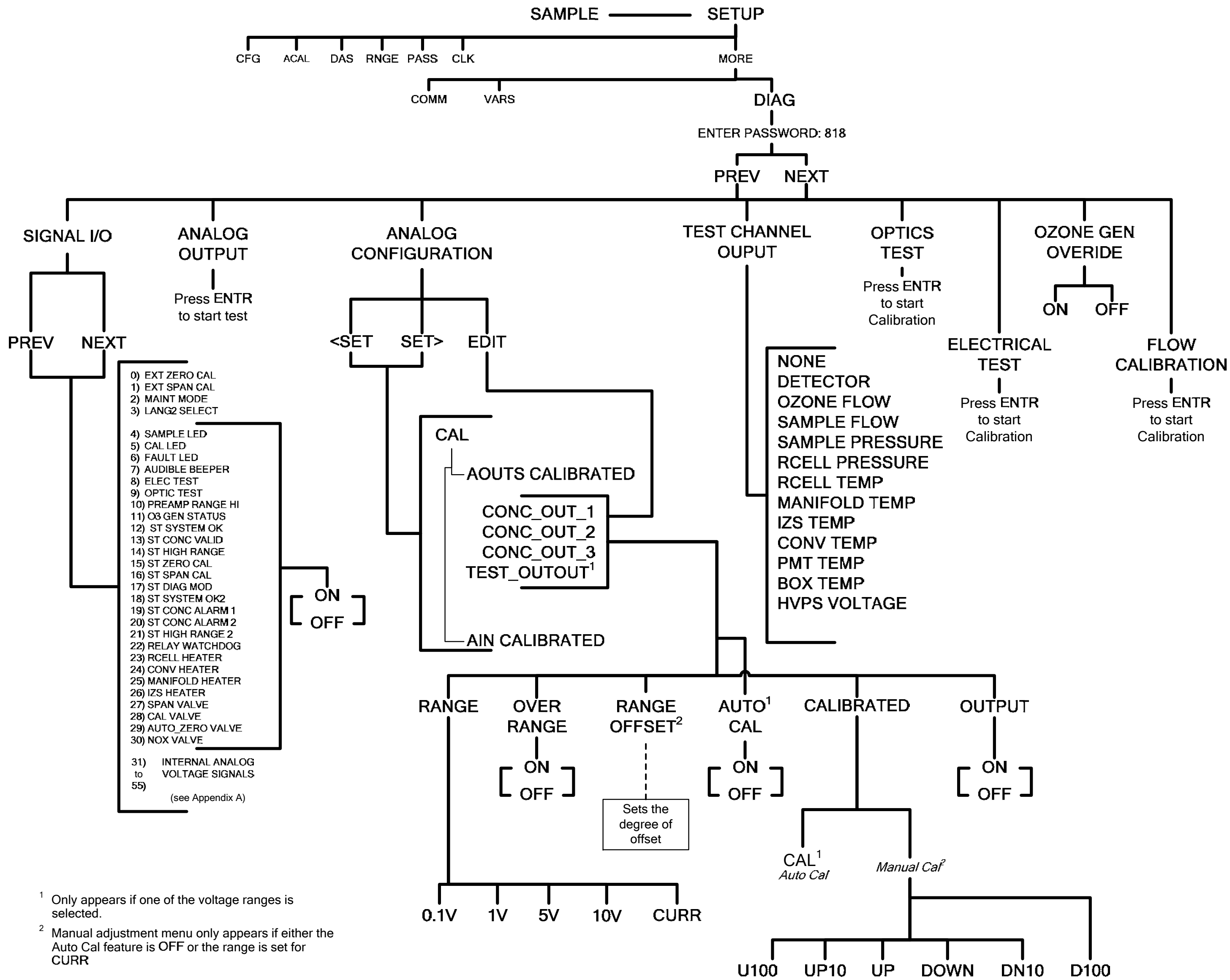


Figure A-4: Secondary Setup Menu (HESSEN)



[1] Only appears if one of the voltage ranges is selected.

[2] Manual adjustment menu only appears if either the Auto Cal feature is OFF or the range is set for CURR

Figure A-5: Secondary Setup Menu (DIAG)

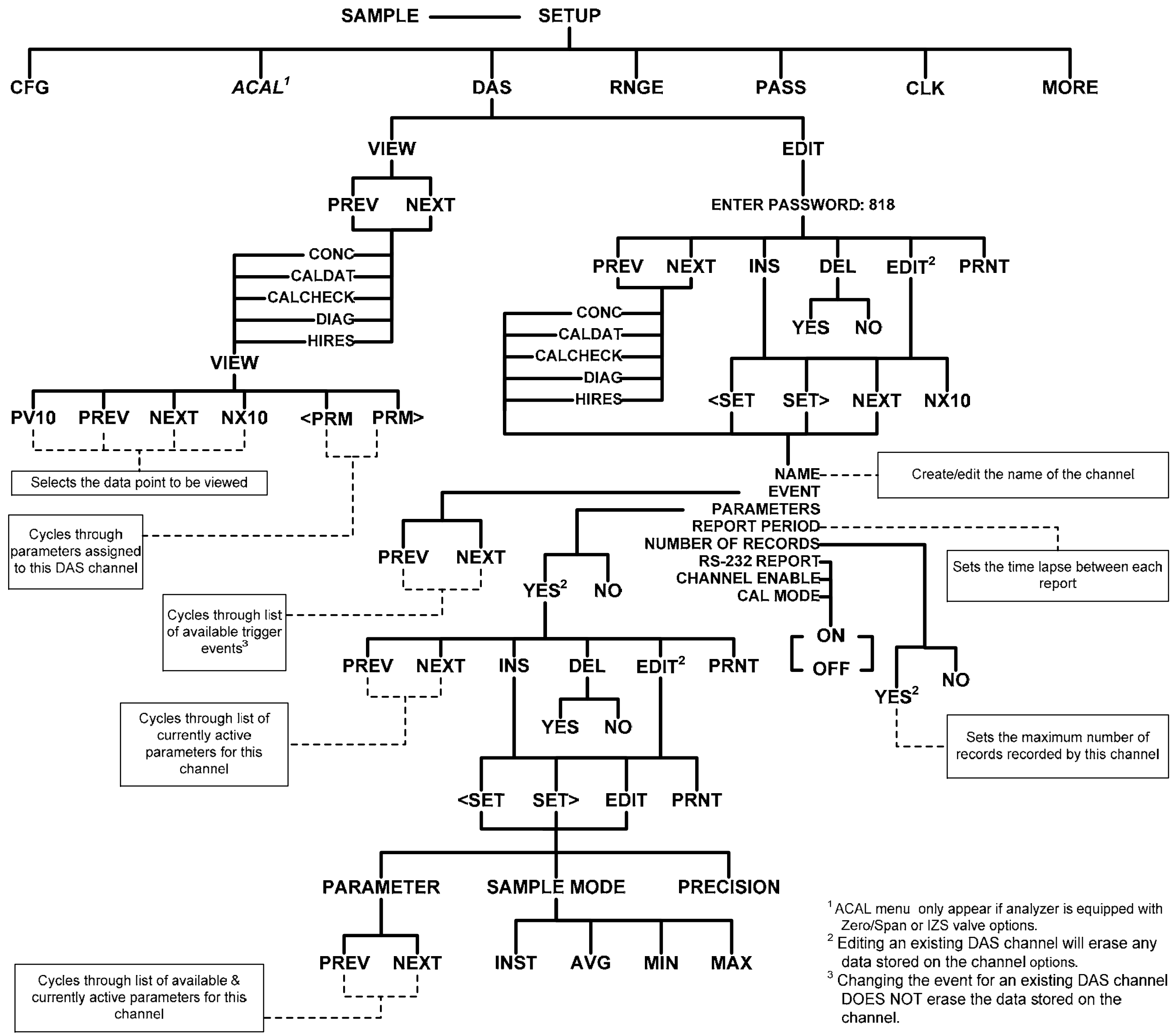


Figure A-6: Internal Data Acquisition (DAS) Menu

APPENDIX A-2: Setup Variables For Serial I/O

Table A-1: T2 Setup Variables, Software Version K.3

Please note that variables listed below under "Setup Variables Available Through serial I/O" should not be changed unless specifically instructed by Teledyne-API customer service or engineering! Changing those variables may cause significant problems with analyzer performance. Only those variables listed under "Setup Variables Available through Front Panel Display And serial I/O" are those see on the front panel display and should be changed by the user if necessary.

Setup Variable	Numeric Units	Default Value	Value Range	Description
Low Access Level Setup Variables (818 password)				
DAS_HOLD_OFF	Minutes	15	0.5–20	Duration of DAS hold off period.
MEASURE_MODE	—	NO-NOX, NOX [8]	NO, NOX, NOX-NO, NON-OX	Gas measure mode. Enclose value in double quotes (") when setting from the RS-232 interface.
STABIL_GAS	—	NOX	NO, NO2, NOX, O2 [14], CO2 [15]	Selects gas for stability measurement. Enclose value in double quotes (") when setting from the RS-232 interface.
TPC_ENABLE	—	ON	OFF, ON	ON enables temperature/ pressure compensation; OFF disables it.
DYN_ZERO	—	OFF	ON, OFF	ON enables remote dynamic zero calibration; OFF disables it.
DYN_SPAN	—	OFF	ON, OFF	ON enables remote dynamic span calibration; OFF disables it.
IZS_SET [3]	ºC	51 Warnings: 50–52	30–70	IZS temperature set point and warning limits.
CONC_PRECISION	—	AUTO [3], 3 [4, 5]	AUTO, 0, 1, 2, 3, 4	Number of digits to display to the right of the decimal point for concentrations on the display. Enclose value in double quotes (") when setting from the RS-232 interface.
STAT_REP_GAS [8]	—	NOX	NO, NO2, NOX, CO2 [15], O2 [14]	Selects gas to report in TAI protocol status message. Enclose value in double quotes (") when setting from the RS-232 interface.

Setup Variable	Numeric Units	Default Value	Value Range	Description
REM_CAL_DURATION [8]	Minutes	20	1–120	Duration of automatic calibration initiated from TAI protocol.
CLOCK_ADJ	Sec./Day	0	-60–60	Time-of-day clock speed adjustment.
CAL_ON_NO2 [3]	—	OFF	ON, OFF	ON enables span calibration on pure NO_2; OFF disables it.
Medium Access Level Setup Variables (929 password)				
LANGUAGE_SELECT	—	ENGL	ENGL, SECD, EXTN	Selects the language to use for the user interface. Enclose value in double quotes (") when setting from the RS-232 interface.
MAINT_TIMEOUT	Hours	2	0.1–100	Time until automatically switching out of software-controlled maintenance mode.
BXTEMP_TPC_GAIN	—	0	0–10	Box temperature compensation attenuation factor.
RCTEMP_TPC_GAIN	—	0	0–10	Reaction cell temperature compensation attenuation factor.
RCPRESS_TPC_GAIN	—	1	0–10	Reaction cell pressure compensation attenuation factor.
SPRESS_TPC_GAIN	—	1	0–10	Sample pressure compensation attenuation factor.
CE_FACTOR1	—	1	0.8–1.2, 0.1–2 [6]	Moly converter efficiency factor for range 1.
CE_FACTOR2	—	1	0.8–1.2, 0.1–2 [6]	Moly converter efficiency factor for range 2.
NEG_NO2_SUPPRESS	—	ON	ON, OFF	ON suppresses negative NO_2 in during switching mode; OFF does not suppress negative NO_2 readings
FILT_SIZE	Samples	42, 10 [4,9]	1–500	Moving average filter size.
SG_FILT_SIZE	Samples	42	1–500	Moving average filter size in single-gas measure modes.
FILT_ADAPT	—	ON	ON, OFF	ON enables adaptive filter; OFF disables it.
FILT_OMIT_DELTA	PPM	0.05 [3], 10 [4], 0.03 [5], 0.8 [9]	0.005–0.1 [3,5], 5–100 [4], 0.1–100 [9]	Absolute change in concentration to omit readings.
FILT_OMIT_PCT	%	10 [3,4], 8 [5]	1–100	Percent change in concentration to omit readings.
FILT_SHORT_DELT	PPM	0.04 [3],	0.005–0.1 [3,5],	Absolute change in

Setup Variable	Numeric Units	Default Value	Value Range	Description
		5 [4], 0.015 [5], 0.5 [9]	5–100 [4], 0.1–100 [9]	concentration to shorten filter.
FILT_SHORT_PCT	%	8 [3,5], 5 [4], 7 [9]	1–100	Percent change in concentration to shorten filter.
FILT_ASIZE	Samples	3, 2 [4], 4 [5]	1–500	Moving average filter size in adaptive mode.
SG_FILT_ASIZE	Samples	6, 4 [5]	1–500	Moving average filter size in adaptive mode, in single-gas measure modes.
FILT_DELAY	Seconds	120 [3], 60 [4], 200 [5], 80 [9]	0–200	Delay before leaving adaptive filter mode.
SG_FILT_DELAY	Seconds	200 [5], 60	0–200	Delay before leaving adaptive filter mode in single-gas measure modes.
CO2_DWELL [15]	Seconds	1	0.1–30	Dwell time before taking each sample.
CO2_FILT_ADAPT [15]	—	ON	ON, OFF	ON enables CO_2 adaptive filter; OFF disables it.
CO2_FILT_SIZE [15]	Samples	48	1–300	CO_2 moving average filter size.
CO2_FILT_ASIZE [15]	Samples	12	1–300	CO_2 moving average filter size in adaptive mode.
CO2_FILT_DELTA [15]	%	2	0.01–10	Absolute CO_2 conc. change to trigger adaptive filter.
CO2_FILT_PCT [15]	%	10	0.1–100	Percent CO_2 conc. change to trigger adaptive filter.
CO2_FILT_DELAY [15]	Seconds	90	0–300	Delay before leaving CO_2 adaptive filter mode.
CO2_DIL_FACTOR [15]	—	1	0.1–1000	Dilution factor for CO_2. Used only if is dilution enabled with *FACTORY_OPT* variable.
O2_DWELL [14]	Seconds	1	0.1–30	Dwell time before taking each sample.
O2_FILT_ADAPT [14]	—	ON	ON, OFF	ON enables O_2 adaptive filter; OFF disables it.
O2_FILT_SIZE [14]	Samples	60	1–500	O_2 moving average filter size in normal mode.
O2_FILT_ASIZE [14]	Samples	10	1–500	O_2 moving average filter size in adaptive mode.
O2_FILT_DELTA [14]	%	2	0.1–100	Absolute change in O_2 concentration to shorten filter.
O2_FILT_PCT [14]	%	2	0.1–100	Relative change in O_2 concentration to shorten filter.

Setup Variable	Numeric Units	Default Value	Value Range	Description
O2_FILT_DELAY [14]	Seconds	20	0–300	Delay before leaving O_2 adaptive filter mode.
O2_DIL_FACTOR [14]	—	1	0.1–1000	Dilution factor for O_2. Used only if is dilution enabled with *FACTORY_OPT* variable.
NOX_DWELL	Seconds	2.5 [3], 4.2 [4], 4 [5], 3.5 [9]	0.1–30	Dwell time after switching valve to NO_X position.
SG_NOX_DWELL	Seconds	4 [5], 1	0.1–30	Dwell time after switching valve to NO_X position in single-gas measure modes.
NOX_SAMPLE	Samples	2	1–30	Number of samples to take in NO_X mode.
SG_NOX_SAMPLE	Samples	2	1–30	Number of samples to take in NO_X mode in single-gas measure modes.
NO_DWELL	Seconds	1.5 [3,5], 4.2 [4], 3.0 [9]	0.1–30	Dwell time after switching valve to NO position.
SG_NO_DWELL	Seconds	1.5 [5], 1	0.1–30	Dwell time after switching valve to NO position in single-gas measure modes.
NO_SAMPLE	Samples	2	1–30	Number of samples to take in NO mode.
SG_NO_SAMPLE	Samples	2	1–30	Number of samples to take in NO mode in single-gas measure modes.
USER_UNITS	—	PPB [3, 5], PPM [4, 9]	PPB [3, 5], PPM [3, 4, 9], UGM [3, 5], MGM [3, 4, 9]	Concentration units for user interface. Enclose value in double quotes (") when setting from the RS-232 interface.
DIL_FACTOR	—	1	1–1000	Dilution factor. Used only if is dilution enabled with *FACTORY_OPT* variable.
AZERO_ENABLE	—	ON, OFF [8]	ON, OFF	ON enables auto-zero; OFF disables it.
AZERO_FREQ	Minutes	1 [3,5], 2 [4]	0–60	Auto-zero frequency.
AZERO_DWELL	Seconds	2 [3], 4 [4], 1.5 [5]	0.1–60	Dwell time after opening auto-zero valve.
AZERO_POST_DWELL	Seconds	2 [3], 4 [4], 1.5 [5]	0–60	Dwell time after closing auto-zero valve.
AZERO_SAMPLE	Samples	2	1–10	Number of auto-zero samples to average.

Setup Variable	Numeric Units	Default Value	Value Range	Description
SG_AZERO_SAMP	Samples	2	1–10	Number of auto-zero samples to average in single-gas measure modes.
AZERO_FSIZE [3,4,6,8]	Samples	15 [3], 8 [4]	1–50	Moving average filter size for auto-zero samples.
AZERO_LIMIT	mV	200 [3], 4000 [5]	0–1000 [3], 0–5000 [5]	Maximum auto-zero offset allowed.
NOX_TARG_ZERO1	Conc	0	-100–999.99	Target NO_X concentration during zero calibration of range 1.
NOX_SPAN1	Conc.	400, 80 [4], 20 [11], 16 [9]	0.01–9999.99	Target NO_X concentration during span calibration of range 1.
NO_TARG_ZERO1	Conc	0	-100–999.99	Target NO concentration during zero calibration of range 1.
NO_SPAN1	Conc.	400, 80 [4], 20 [11], 16 [9]	0.01–9999.99	Target NO concentration during span calibration of range 1.
NO2_SPAN1	Conc.	400, 80 [4], 20 [11], 16 [9]	0.01–9999.99	Target NO_2 concentration during converter efficiency calibration of range 1.
NOX_SLOPE1	PPM/mV	1	0.25–4	NO_X slope for range 1.
NOX_OFFSET1	mV	0	-10000–10000	NO_X offset for range 1.
NO_SLOPE1	PPM/mV	1	0.25–4	NO slope for range 1.
NO_OFFSET1	mV	0	-10000–10000	NO offset for range 1.
NOX_TARG_ZERO2	Conc	0	-100–999.99	Target NO_X concentration during zero calibration of range 2.
NOX_SPAN2	Conc.	400, 80 [4], 20 [11], 16 [9]	0.01–9999.99	Target NO_X concentration during span calibration of range 2.
NO_TARG_ZERO2	Conc	0	-100–999.99	Target NO concentration during zero calibration of range 2.
NO_SPAN2	Conc.	400, 80 [4], 20 [11], 16 [9]	0.01–9999.99	Target NO concentration during span calibration of range 2.

Setup Variable	Numeric Units	Default Value	Value Range	Description
NO2_SPAN2	Conc.	400, 80 [4], 20 [11], 16 [9]	0.01–9999.99	Target NO_2 concentration during converter efficiency calibration of range 2.
NOX_SLOPE2	PPM/mV	1	0.25–4	NO_X slope for range 2.
NOX_OFFSET2	mV	0	-10000–10000	NO_X offset for range 2.
NO_SLOPE2	PPM/mV	1	0.25–4	NO slope for range 2.
NO_OFFSET2	mV	0	-10000–10000	NO offset for range 2.
CO2_TARG_SPAN_CONC [15]	%	12	0.01–100, 0.01–9999.99 [16]	Target CO_2 concentration during span calibration.
CO2_SLOPE [15]	—	1	0.5–5	CO_2 slope.
CO2_OFFSET [15]	%	0	-10–10, -100–100 [16]	CO_2 offset.
O2_TARG_SPAN_CONC [14]	%	20.95	0.1–100	Target O_2 concentration during span calibration.
O2_SLOPE [14]	—	1	0.5–2	O_2 slope.
O2_OFFSET [14]	%	0	-10–10	O_2 offset.
RANGE_MODE	—	SNGL	SNGL, IND, AUTO, REM [4,5]	Range control mode. Enclose value in double quotes (") when setting from the RS-232 interface.
PHYS_RANGE1	PPM	2, 20 [9], 500 [4], 1 [11]	0.1–2500, 5–5000 [9], 5–10000 [4]	Low pre-amp range.
PHYS_RANGE2	PPM	22, 220 [9], 5500 [4], 100 [11]	0.1–2500, 5–5000 [9], 5–10000 [4]	High pre-amp range.
CONC_RANGE1	Conc.	500, 100 [4], 20 [9]	1–20000, 1–10000 [4], 1–500 [9]	D/A concentration range 1 or range for NO_X.
CONC_RANGE2 [1]	Conc.	500, 100 [4], 200 [9]	1–20000, 1–10000 [4], 1–500 [9]	D/A concentration range 2 or range for NO.
CONC_RANGE3 [1]	Conc.	500, 100 [4], 20 [9]	1–20000, 1–10000 [4], 1–500 [9]	D/A concentration range 3 or range for NO_2.
CO2_RANGE [15]	%	15	0.1–500	CO_2 concentration range.
O2_RANGE [14]	%	100	0.1–500	O_2 concentration range.

Setup Variable	Numeric Units	Default Value	Value Range	Description
RCELL_SET	ºC	50 [3,4], 40 [5] Warnings: 45–55 [3,4], 35–45 [5]	30–70	Reaction cell temperature set point and warning limits.
MANIFOLD_SET [5]	ºC	50 [4,6,8], 40 [5] Warnings: 45–55 [4,6,8], 35–45 [5]	30–70	Manifold temperature set point and warning limits.
CONV_TYPE	—	MOLY [3,5, 9], CONV [4], O3KL [6]	NONE, MOLY, CONV, O3KL	Converter type. “CONV” is mini-hicon. Enclose value in double quotes (") when setting from the RS-232 interface. Changing this variable changes *CONV_SET* accordingly.
CONV_SET	ºC	315, 200 [6] Warnings: 305–325, 190–210 [6]	0–800	Converter temperature set point and warning limits.
BOX_SET	ºC	30 Warnings: 7–48	0–70	Nominal box temperature set point and warning limits.
PMT_SET	ºC	7 [3,4], 5 [5] Warnings: 5–12 [3,4], 3–7 [5]	0–40 [3,4], -10–40 [5]	PMT temperature warning limits. Set point is not used.
SFLOW_SET	cc/m	500, 290 [4], 360 [4+14], 250 [9], 320 [9+14] Warnings: 350–600, 200–600 [4,9], 300–700 [4+14, 9+14]	0–1000, 100–1000 [4, 9]	Sample flow warning limits. Set point is not used.
SAMP_FLOW_SLOPE	—	1	0.001–100	Slope term to correct sample flow rate.

Setup Variable	Numeric Units	Default Value	Value Range	Description
OFLOW_SET	cc/m	80, 250 [4, 9] Warnings: 50–150, 200–600 [4, 9]	0–500, 100–1000 [4, 9]	Ozone flow warning limits. Set point is not used.
OZONE_FLOW_SLOPE	—	1	0.001–100	Slope term to correct ozone flow rate.
RCELL_PRESS_CONST2	—	3.6	-99.999–99.999	Reaction cell pressure compensation constant #2.
RCELL_PRESS_CONST3	—	-1.1	-99.999–99.999	Reaction cell pressure compensation constant #3.
PRESS_FILT_SIZE	Samples	3, 30 [5]	1–20, 1–120 [5]	Sample and reaction cell pressure moving average filter size.
PRESS_SAMP_FREQ [5]	Seconds	20	1–120	Sample and reaction cell pressure sampling frequency.
RS232_MODE	—	0	0–65535	RS-232 COM1 mode flags. Add values to combine flags. 1 = quiet mode 2 = computer mode 4 = enable security 16 = enable Hessen protocol [12] 32 = enable multidrop 64 = enable modem 128 = ignore RS-232 line errors 256 = disable XON / XOFF support 512 = disable hardware FIFOs 1024 = enable RS-485 mode 2048 = even parity, 7 data bits, 1 stop bit 4096 = enable command prompt
BAUD_RATE	—	115200	300, 1200, 2400, 4800, 9600, 19200, 38400, 57600, 115200	RS-232 COM1 baud rate. Enclose value in double quotes (") when setting from the RS-232 interface.

Setup Variable	Numeric Units	Default Value	Value Range	Description
MODEM_INIT	—	“AT Y0 &D0 &H0 &I0 S0=2 &B0 &N6 &M0 E0 Q1 &W0”	Any character in the allowed character set. Up to 100 characters long.	RS-232 COM1 modem initialization string. Sent verbatim plus carriage return to modem on power up or manually. Enclose value in double quotes (") when setting from the RS-232 interface.
RS232_MODE2	BitFlag	0, 3 [8]	0–65535	RS-232 COM2 mode flags. *(Same settings as RS232_MODE, plus these when MODBUS option is installed:)* 8192 = enable dedicated MODBUS ASCII protocol 16384 = enable dedicated MODBUS RTU or TCP protocol
BAUD_RATE2	—	19200, 9600 [8]	300, 1200, 2400, 4800, 9600, 19200, 38400, 57600, 115200	RS-232 COM2 baud rate. Enclose value in double quotes (") when setting from the RS-232 interface.
MODEM_INIT2	—	“AT Y0 &D0 &H0 &I0 S0=2 &B0 &N6 &M0 E0 Q1 &W0”	Any character in the allowed character set. Up to 100 characters long.	RS-232 COM2 modem initialization string. Sent verbatim plus carriage return to modem on power up or manually. Enclose value in double quotes (") when setting from the RS-232 interface.
RS232_PASS	Password	940331	0–999999	RS-232 log on password.
MACHINE_ID	ID	200	0–9999	Unique ID number for instrument.
COMMAND_PROMPT	—	“Cmd> ”	Any character in the allowed character set. Up to 100 characters long.	RS-232 interface command prompt. Displayed only if enabled with *RS232_MODE* variable. Enclose value in double quotes (") when setting from the RS-232 interface.

Setup Variable	Numeric Units	Default Value	Value Range	Description
TEST_CHAN_ID	—	NONE	NONE, PMT DE-TECTOR, OZONE FLOW, SAMPLE FLOW, SAMPLE PRESSURE, RCELL PRESSURE, RCELL TEMP, MANIFOLD TEMP, IZS TEMP, CONV TEMP, PMT TEMP, BOX TEMP, HVPS VOLTAGE	Diagnostic analog output ID. Enclose value in double quotes (") when setting from the RS-232 interface.
REMOTE_CAL_MODE [3]	—	LOW	LOW, HIGH, CO2 [15], O2 [14]	Range to calibrate during remote calibration. Enclose value in double quotes (") when setting from the RS-232 interface.
PASS_ENABLE	—	OFF	ON, OFF	ON enables passwords; OFF disables them.
STABIL_FREQ	Seconds	10	1–300	Stability measurement sampling frequency.
STABIL_SAMPLES	Samples	25	2–40	Number of samples in concentration stability reading.
HVPS_SET	Volts	650 [3,5], 550 [4], 600 [9] Warnings: 400–900 [3,5], 400–700 [4], 450–750 [9]	0–2000	High voltage power supply warning limits. Set point is not used.
RCELL_PRESS_SET	In-Hg	6 Warnings: 0.5–15	0–100	Reaction cell pressure warning limits. Set point is not used.
RCELL_CYCLE	Seconds	10	0.5–30	Reaction cell temperature control cycle period.

Setup Variable	Numeric Units	Default Value	Value Range	Description
RCELL_PROP	1/ºC	1	0–10	Reaction cell PID temperature control proportional coefficient.
RCELL_INTEG	—	0.1	0–10	Reaction cell PID temperature control integral coefficient.
RCELL_DERIV	—	0 (disabled)	0–10	Reaction cell PID temperature control derivative coefficient.
MANIFOLD_CYCLE [5]	Seconds	5	0.5–30	Manifold temperature control cycle period.
MANIFOLD_PROP [5]	1/ºC	0.2	0–10	Manifold PID temperature control proportional coefficient.
MANIFOLD_INTEG [5]	—	0.1	0–10	Manifold PID temperature control integral coefficient.
MANIFOLD_DERIV [5]	—	0.5	0–10	Manifold PID temperature control derivative coefficient.
IZS_CYCLE [3]	Seconds	2	0.5–30	IZS temperature control cycle period.
IZS_PROP [3]	1/ºC	1	0–10	IZS temperature PID proportional coefficient.
IZS_INTEG [3]	—	0.03	0–10	IZS temperature PID integral coefficient.
IZS_DERIV [3]	—	0	0–10	IZS temperature PID derivative coefficient.
CO2_CELL_SET [15]	ºC	50 Warnings: 45–55	30–70	CO_2 sensor cell temperature set point and warning limits.
CO2_CELL_CYCLE [15]	Seconds	10	0.5–30	CO_2 cell temperature control cycle period.
CO2_CELL_PROP [15]	—	1	0–10	CO_2 cell PID temperature control proportional coefficient.
CO2_CELL_INTEG [15]	—	0.1	0–10	CO_2 cell PID temperature control integral coefficient.
CO2_CELL_DERIV [15]	—	0 (disabled)	0–10	CO_2 cell PID temperature control derivative coefficient.
STD_O2_CELL_TEMP [14]	ºK	323	1–500	Standard O_2 cell temperature for temperature compensation.
O2_CELL_SET [14]	ºC	50 Warnings: 45–55	30–70	O_2 sensor cell temperature set point and warning limits.
O2_CELL_CYCLE [14]	Seconds	10	0.5–30	O_2 cell temperature control cycle period.
O2_CELL_PROP [14]	—	1	0–10	O_2 cell PID temperature control proportional coefficient.
O2_CELL_INTEG [14]	—	0.1	0–10	O_2 cell PID temperature control integral coefficient.
O2_CELL_DERIV [14]	—	0 (disabled)	0–10	O_2 cell PID temperature control derivative coefficient.
STAT_REP_PERIOD [8]	Seconds	1	0.5–120	TAI protocol status message report period.

Setup Variable	Numeric Units	Default Value	Value Range	Description
SERIAL_NUMBER	—	"00000000 "	Any character in the allowed character set. Up to 100 characters long.	Unique serial number for instrument. Enclose value in double quotes (") when setting from the RS-232 interface.
DISP_INTENSITY	—	HIGH	HIGH, MED, LOW, DIM	Front panel display intensity. Enclose value in double quotes (") when setting from the RS-232 interface.
I2C_RESET_ENABLE	—	ON	OFF, ON	I^2C bus automatic reset enable.
ALARM_TRIGGER [17]	Cycles	3	1–100	Number of times concentration must exceed limit to trigger alarm.
CLOCK_FORMAT	—	"TIME=%H:%M:%S"	Any character in the allowed character set. Up to 100 characters long.	Time-of-day clock format flags. Enclose value in double quotes (") when setting from the RS-232 interface. "%a" = Abbreviated weekday name. "%b" = Abbreviated month name. "%d" = Day of month as decimal number (01 – 31). "%H" = Hour in 24-hour format (00 – 23). "%I" = Hour in 12-hour format (01 – 12). "%j" = Day of year as decimal number (001 – 366). "%m" = Month as decimal number (01 – 12). "%M" = Minute as decimal number (00 – 59). "%p" = A.M./P.M. indicator for 12-hour clock. "%S" = Second as decimal number (00 – 59). "%w" = Weekday as decimal number (0 – 6; Sunday is 0). "%y" = Year without century, as decimal number (00 – 99). "%Y" = Year with century, as decimal number. "%%" = Percent sign.

Setup Variable	Numeric Units	Default Value	Value Range	Description
FACTORY_OPT	—	0, 512 [5,6]	0–65535	Factory option flags. Add values to combine flags. 1 = enable dilution factor 2 = display units in concentration field 4 = zero/span valves installed 8 [18] = low span valve installed 16 [3] = IZS and zero/span valves installed 32 = enable software-controlled maintenance mode 64 = display temperature in converter warning message 128 = enable switch-controlled maintenance mode 256 = not used 512 = enable manifold temperature control 1024 = enable concentration alarms [17] 2048 = enable Internet option 8192 = enable non-zero offset calibration 16384 = enable pressurized zero calibration 32768 = enable pressurized span calibration

[1] Multi-range modes.
[2] Hessen protocol.
[3] T200 and M200E.
[4] T200H and M200EH.
[5] T200U and M200EU.
[6] M200EUP.
[7] "De-tuned" instrument.
[8] TAI protocol
[9] T200M AND M200EM.
[10] User-configurable D/A output option.
[11] SUNLAW special.
[12] Must power-cycle instrument for these options to fully take effect.
[14] O_2 option.
[15] CO_2 option.
[16] CO_2 PPM sensor.
[17] Concentration alarm option.
[18] Low span option.

APPENDIX A-3: Warnings and Test Measurements

Table A-2: Warning Messages, Software Version K.3

Name [1]	Message Text	Description
Warnings		
WSYSRES	SYSTEM RESET	Instrument was power-cycled or the CPU was reset.
WDATAINIT	DATA INITIALIZED	Data storage was erased.
WCONFIGINIT	CONFIG INITIALIZED	Configuration storage was reset to factory configuration or erased.
WNOXALARM1 [9]	NOX ALARM 1 WARN	NO_X concentration alarm limit #1 exceeded
WNOXALARM2 [9]	NOX ALARM 2 WARN	NO_X concentration alarm limit #2 exceeded
WNOALARM1 [9]	NO ALARM 1 WARN	NO concentration alarm limit #1 exceeded
WNOALARM2 [9]	NO ALARM 2 WARN	NO concentration alarm limit #2 exceeded
WNO2ALARM1 [9]	NO2 ALARM 1 WARN	NO_2 concentration alarm limit #1 exceeded
WNO2ALARM2 [9]	NO2 ALARM 2 WARN	NO_2 concentration alarm limit #2 exceeded
WO2ALARM1 [5+9]	O2 ALARM 1 WARN	O_2 concentration alarm limit #1 exceeded
WO2ALARM2 [5+9]	O2 ALARM 2 WARN	O_2 concentration alarm limit #2 exceeded
WCO2ALARM1 [8+9]	CO2 ALARM 1 WARN	CO_2 concentration alarm limit #1 exceeded
WCO2ALARM2 [8+9]	CO2 ALARM 2 WARN	CO_2 concentration alarm limit #2 exceeded
WSAMPFLOW	SAMPLE FLOW WARN	Sample flow outside of warning limits specified by *SFLOW_SET* variable.
WOZONEFLOW	OZONE FLOW WARNING	Ozone flow outside of warning limits specified by *OFLOW_SET* variable.
WOZONEGEN	OZONE GEN OFF	Ozone generator is off. This is the only warning message that automatically clears itself. It clears itself when the ozone generator is turned on.
WRCELLPRESS	RCELL PRESS WARN	Reaction cell pressure outside of warning limits specified by *RCELL_PRESS_SET* variable.
WBOXTEMP	BOX TEMP WARNING	Chassis temperature outside of warning limits specified by *BOX_SET* variable.
WRCELLTEMP	RCELL TEMP WARNING	Reaction cell temperature outside of warning limits specified by *RCELL_SET* variable.
WMANIFOLDTEMP [4]	MANIFOLD TEMP WARN	Bypass or dilution manifold temperature outside of warning limits specified by *MANIFOLD_SET* variable.
WCO2CELLTEMP [8]	CO2 CELL TEMP WARN	CO_2 sensor cell temperature outside of warning limits specified by *CO2_CELL_SET* variable.
WO2CELLTEMP [5]	O2 CELL TEMP WARN	O_2 sensor cell temperature outside of warning limits specified by *O2_CELL_SET* variable.
WIZSTEMP	IZS TEMP WARNING	IZS temperature outside of warning limits specified by *IZS_SET* variable.
WCONVTEMP	CONV TEMP WARNING	Converter temperature outside of warning limits specified by *CONV_SET* variable.
WPMTTEMP	PMT TEMP WARNING	PMT temperature outside of warning limits specified by *PMT_SET* variable.

Name [1]	Message Text	Description
WAUTOZERO	AZERO WRN XXX.X MV	Auto-zero reading above limit specified by *AZERO_LIMIT* variable. Value shown in message indicates auto-zero reading at time warning was displayed.
WHVPS	HVPS WARNING	High voltage power supply output outside of warning limits specified by *HVPS_SET* variable.
WDYNZERO	CANNOT DYN ZERO	Contact closure zero calibration failed while *DYN_ZERO* was set to *ON*.
WDYNSPAN	CANNOT DYN SPAN	Contact closure span calibration failed while *DYN_SPAN* was set to *ON*.
WREARBOARD	REAR BOARD NOT DET	Rear board was not detected during power up.
WRELAYBOARD	RELAY BOARD WARN	Firmware is unable to communicate with the relay board.
WFRONTPANEL [11]	FRONT PANEL WARN	Firmware is unable to communicate with the front panel.
WANALOGCAL	ANALOG CAL WARNING	The A/D or at least one D/A channel has not been calibrated.

[1] The name is used to request a message via the RS-232 interface, as in “T BOXTEMP”.
[2] Engineering firmware only.
[3] Current instrument units.
[4] Factory option.
[5] O_2 option.
[6] User-configurable D/A output option.
[7] Optional.
[8] CO_2 option.
[9] Concentration alarm option.
[10] M200EUP.
[11] Applies to E-Series.

Table A-3: Test Measurements, Software Version K.3

Name [1]	Message Text	Description
Test Measurements		
NONOXCONC	NO=396.5 NOX=396.5 [3]	Simultaneously displays NO and NOX concentrations.
RANGE [not 6]	RANGE=500.0 PPB [3]	D/A range in single or auto-range modes.
RANGE1 [not 6]	RANGE1=500.0 PPB [3]	D/A #1 range in independent range mode.
RANGE2 [not 6]	RANGE2=500.0 PPB [3]	D/A #2 range in independent range mode.
RANGE3 [not 6]	RANGE3=500.0 PPB [3]	D/A #3 range in independent range mode.
STABILITY	NOX STB=0.0 PPB [3] O2 STB=0.0 PCT [5] CO2 STB=0.0 PCT [8]	Concentration stability (standard deviation based on setting of *STABIL_FREQ* and *STABIL_SAMPLES*). Select gas with *STABIL_GAS* variable.
RESPONSE [2]	RSP=8.81(1.30) SEC	Instrument response. Length of each signal processing loop. Time in parenthesis is standard deviation.
SAMPFLOW	SAMP FLW=460 CC/M	Sample flow rate.
OZONEFLOW	OZONE FL=87 CC/M	Ozone flow rate.
PMT	PMT=800.0 MV	Raw PMT reading.
NORMPMT	NORM PMT=793.0 MV	PMT reading normalized for temperature, pressure, auto-zero offset, but not range.
AUTOZERO	AZERO=1.3 MV	Auto-zero offset.
HVPS	HVPS=650 V	High voltage power supply output.
RCELLTEMP	RCELL TEMP=50.8 C	Reaction cell temperature.
BOXTEMP	BOX TEMP=28.2 C	Internal chassis temperature.
REMBOXTEMP [10]	REM BOX TMP=30.1 C	Remote chassis temperature.
PMTTEMP	PMT TEMP=7.0 C	PMT temperature.
MANIFOLDTEMP [4]	MF TEMP=50.8 C	Bypass or dilution manifold temperature.
CO2CELLTEMP [8]	CO2 CELL TEMP=50.8 C	CO_2 sensor cell temperature.
O2CELLTEMP [5]	O2 CELL TEMP=50.8 C	O_2 sensor cell temperature.
IZSTEMP	IZS TEMP=50.8 C	IZS temperature.
CONVTEMP	MOLY TEMP=315.0 C	Converter temperature. Converter type is *MOLY*, *CONV*, or *O3KL*.
SAMPRESTTEMP [10]	SMP RST TMP=49.8 C	Sample restrictor temperature.
RCELLPRESS	RCEL=7.0 IN-HG-A	Reaction cell pressure.
SAMPPRESS	SAMP=29.9 IN-HG-A	Sample pressure.
NOXSLOPE	NOX SLOPE=1.000	NOX slope for current range, computed during zero/span calibration.
NOXOFFSET	NOX OFFS=0.0 MV	NOX offset for current range, computed during zero/span calibration.
NOSLOPE	NO SLOPE=1.000	NO slope for current range, computed during zero/span calibration.
NOOFFSET	NO OFFS=0.0 MV	NO offset for current range, computed during zero/span calibration.

Name [1]	Message Text	Description
NO2	NO2=0.0 PPB [3]	NO_2 concentration for current range.
NO2_1 [7]	NO2_1=0.0 PPB [3]	NO_2 concentration for range #1.
NO2_2 [7]	NO2_2=0.0 PPB [3]	NO_2 concentration for range #2.
NOX	NOX=396.5 PPB [3]	NOX concentration for current range.
NOX_1 [7]	NOX_1=396.5 PPB [3]	NOX concentration for range #1.
NOX_2 [7]	NOX_2=396.5 PPB [3]	NOX concentration for range #2.
NO	NO=396.5 PPB [3]	NO concentration for current range.
NO_1 [7]	NO_1=396.5 PPB [3]	NO concentration for range #1.
NO_2 [7]	NO_2=396.5 PPB [3]	NO concentration for range #2.
CO2RANGE [8, not 6]	CO2 RANGE=100.00 PCT	D/A #4 range for CO_2 concentration.
CO2SLOPE [8]	CO2 SLOPE=1.000	CO_2 slope, computed during zero/span calibration.
CO2OFFSET [8]	CO2 OFFSET=0.000	CO_2 offset, computed during zero/span calibration.
CO2 [8]	CO2=15.0 %	CO_2 concentration.
O2RANGE [5, not 6]	O2 RANGE=100.00 PCT	D/A #4 range for O_2 concentration.
O2SLOPE [5]	O2 SLOPE=1.000	O_2 slope computed during zero/span calibration.
O2OFFSET [5]	O2 OFFSET=0.00 %	O_2 offset computed during zero/span calibration.
O2 [5]	O2=0.00 %	O_2 concentration.
TESTCHAN [5,6,8]	TEST=3627.1 MV	Value output to *TEST_OUTPUT* analog output, selected with *TEST_CHAN_ID* variable.
CLOCKTIME	TIME=10:38:27	Current instrument time of day clock.

[1] The name is used to request a message via the RS-232 interface, as in “T BOXTEMP”.
[2] Engineering firmware only.
[3] Current instrument units.
[4] Factory option.
[5] O_2 option.
[6] User-configurable D/A output option.
[7] Optional.
[8] CO_2 option.
[9] Concentration alarm option.
[10] M200EUP.

APPENDIX A-4: Signal I/O Definitions

Table A-4: Signal I/O Definitions, Software Version K.3

Signal Name	Bit or Channel Number	Description
Internal inputs, U7, J108, pins 9–16 = bits 0–7, default I/O address 322 hex		
	0–7	Spare
Internal outputs, U8, J108, pins 1–8 = bits 0–7, default I/O address 322 hex		
ELEC_TEST	0	1 = electrical test on 0 = off
OPTIC_TEST	1	1 = optic test on 0 = off
PREAMP_RANGE_HI	2	1 = select high preamp range 0 = select low range
O3GEN_STATUS	3	0 = ozone generator on 1 = off
	4–5	Spare
I2C_RESET	6	1 = reset I^2C peripherals 0 = normal
I2C_DRV_RST	7	0 = hardware reset 8584 chip 1 = normal
Control inputs, U11, J1004, pins 1–6 = bits 0–5, default I/O address 321 hex		
EXT_ZERO_CAL	0	0 = go into zero calibration 1 = exit zero calibration
EXT_SPAN_CAL	1	0 = go into span calibration 1 = exit span calibration
EXT_LOW_SPAN [20]	2	0 = go into low span calibration 1 = exit low span calibration
REMOTE_RANGE_HI [21]	3	0 = remote select high range 1 = default range
CAL_MODE_0 [5] CAL_MODE_1 CAL_MODE_2	0 1 2	Three inputs, taken as binary number (CAL_MODE_2 is MSB) select calibration level and range: 0 & 7 = Measure 1 = Zero, range #3 2 = Span, range #3 3 = Zero, range #2 4 = Span, range #2 5 = Zero, range #1 6 = Span, range #1
	4–5	Spare
	6–7	Always 1

Signal Name	Bit or Channel Number	Description
Control inputs, U14, J1006, pins 1–6 = bits 0–5, default I/O address 325 hex		
	0–5	Spare
	6–7	Always 1
Control outputs, U17, J1008, pins 1–8 = bits 0–7, default I/O address 321 hex		
	0–7	Spare
Control outputs, U21, J1008, pins 9–12 = bits 0–3, default I/O address 325 hex		
	0–3	Spare
Alarm outputs, U21, J1009, pins 1–12 = bits 4–7, default I/O address 325 hex		
ST_SYSTEM_OK2 [12]	4	1 = system OK 0 = any alarm condition or in diagnostics mode
MB_RELAY_36 [18]		Controlled by MODBUS coil register
OUT_CAL_MODE [13]		1 = calibration mode 0 = measure mode
ST_CONC_ALARM_1 [17]	5	1 = conc. limit 1 exceeded 0 = conc. OK
MB_RELAY_37 [18]		Controlled by MODBUS coil register
OUT_SPAN_CAL [13]		1 = span calibration 0 = zero calibration
ST_CONC_ALARM_2 [17]	6	1 = conc. limit 2 exceeded 0 = conc. OK
MB_RELAY_38 [18]		Controlled by MODBUS coil register
OUT_PROBE_1 [13]		0 = select probe #1 1 = not selected
ST_HIGH_RANGE2 [19]	7	1 = high auto-range in use (mirrors *ST_HIGH_RANGE* status output) 0 = low auto-range
MB_RELAY_39 [18]		Controlled by MODBUS coil register
OUT_PROBE_2 [13]		0 = select probe #2 1 = not selected

Signal Name	Bit or Channel Number	Description
A status outputs, U24, J1017, pins 1–8 = bits 0–7, default I/O address 323 hex		
ST_SYSTEM_OK	0	0 = system OK 1 = any alarm condition
ST_CONC_VALID	1	0 = conc. valid 1 = conc. filters contain no data
ST_HIGH_RANGE	2	0 = high auto-range in use 1 = low auto-range
ST_ZERO_CAL	3	0 = in zero calibration 1 = not in zero
ST_SPAN_CAL	4	0 = in span calibration 1 = not in span
ST_DIAG_MODE	5	0 = in diagnostic mode 1 = not in diagnostic mode
ST_LOW_SPAN_CAL [20]	6	0 = in low span calibration 1 = not in low span
ST_O2_CAL [11]	7	0 = in O_2 calibration mode 1 = in measure or other calibration mode
B status outputs, U27, J1018, pins 1–8 = bits 0–7, default I/O address 324 hex		
ST_CO2_CAL [15]	0	0 = in CO_2 calibration mode 1 = in measure or other calibration mode
	1–7	Spare
Front panel I^2C keyboard, default I^2C address 4E hex		
MAINT_MODE	5 (input)	0 = maintenance mode 1 = normal mode
LANG2_SELECT	6 (input)	0 = select second language 1 = select first language (English)
SAMPLE_LED	8 (output)	0 = sample LED on 1 = off
CAL_LED	9 (output)	0 = cal. LED on 1 = off
FAULT_LED	10 (output)	0 = fault LED on 1 = off
AUDIBLE_BEEPER	14 (output)	0 = beeper on (for diagnostic testing only) 1 = off

Signal Name	Bit or Channel Number	Description
Relay board digital output (PCF8575), default I^2C address 44 hex		
RELAY_WATCHDOG	0	Alternate between 0 and 1 at least every 5 seconds to keep relay board active
RCELL_HEATER	1	0 = reaction cell heater on 1 = off
CONV_HEATER	2	0 = converter heater on 1 = off
MANIFOLD_HEATER [10]	3	0 = bypass or dilution manifold heater on 1 = off
IZS_HEATER	4	0 = IZS heater on 1 = off
CO2_CELL_HEATER [15]		0 = CO_2 sensor cell heater on 1 = off
O2_CELL_HEATER [11]	5	0 = O_2 sensor cell heater on 1 = off
SPAN_VALVE	6	0 = let span gas in 1 = let zero gas in
ZERO_VALVE [3]		0 = let zero gas in 1 = let sample gas in
CAL_VALVE	7	0 = let cal. gas in 1 = let sample gas in
AUTO_ZERO_VALVE	8	0 = let zero air in 1 = let sample gas in
NOX_VALVE	9	0 = let NO_X gas into reaction cell 1 = let NO gas into reaction cell
NO2_CONVERTER [4]		0 = turn on NO_2 converter (measure NO_x) 1 = turn off NO_2 converter (measure NO)
LOW_SPAN_VALVE [20]	10	0 = let low span gas in 1 = let high span/sample gas in
SPAN_VALVE [3]	11	0 = let span gas in 1 = let sample gas in
NO2_VALVE [16]	12	0 = let NO_2 gas into reaction cell 1 = let NO_X/NO gas into reaction cell
VENT_VALVE [7]		0 = open vent valve 1 = close vent valve
	13–15	Spare

Signal Name	Bit or Channel Number	Description
Rear board primary MUX analog inputs, MUX default I/O address 32A hex		
PMT_SIGNAL	0	PMT detector
HVPS_VOLTAGE	1	HV power supply output
PMT_TEMP	2	PMT temperature
CO2_SENSOR [15]	3	CO_2 concentration sensor
	4	Temperature MUX
	5	Spare
O2_SENSOR [11]	6	O_2 concentration sensor
SAMPLE_PRESSURE	7	Sample pressure
RCELL_PRESSURE	8	Reaction cell pressure
REF_4096_MV	9	4.096V reference from MAX6241
OZONE_FLOW	10	Ozone flow rate
TEST_INPUT_11	11	Diagnostic test input
SAMP_REST_TEMP [4]		Sample restrictor temperature
CONV_TEMP	12	Converter temperature
TEST_INPUT_13	13	Diagnostic test input
	14	DAC loopback MUX
REF_GND	15	Ground reference
Rear board temperature MUX analog inputs, MUX default I/O address 326 hex		
BOX_TEMP	0	Internal box temperature
RCELL_TEMP	1	Reaction cell temperature
IZS_TEMP	2	IZS temperature
CO2_CELL_TEMP [15]		CO_2 sensor cell temperature
	3	Spare
O2_CELL_TEMP [11]	4	O_2 sensor cell temperature
TEMP_INPUT_5	5	Diagnostic temperature input
REM_BOX_TEMP [4]		Remote box temperature
TEMP_INPUT_6	6	Diagnostic temperature input
MANIFOLD_TEMP [10]	7	Bypass or dilution manifold temperature
Rear board DAC MUX analog inputs, MUX default I/O address 327 hex		
DAC_CHAN_1	0	DAC channel 0 loopback
DAC_CHAN_2	1	DAC channel 1 loopback
DAC_CHAN_3	2	DAC channel 2 loopback
DAC_CHAN_4	3	DAC channel 3 loopback

Signal Name	Bit or Channel Number	Description
Rear board analog outputs, default I/O address 327 hex		
CONC_OUT_1	0	Concentration output #1 (NO_X)
DATA_OUT_1 [6]		Data output #1
CONC_OUT_2	1	Concentration output #2 (NO)
DATA_OUT_2 [6]		Data output #2
CONC_OUT_3	2	Concentration output #3 (NO_2)
DATA_OUT_3 [6]		Data output #3
TEST_OUTPUT	3	Test measurement output
CONC_OUT_4 [11, 15]		Concentration output #4 (CO_2 or O_2)
DATA_OUT_4 [6]		Data output #4

[1] Hessen protocol.
[2] T200H and M200EH.
[3] T200U and M200EU.
[4] M200EUP.
[5] Triple-range option.
[6] User-configurable D/A output option.
[7] Pressurized zero/span option.
[8] Dual NO_X option.
[9] MAS special.
[10] Factory option.
[11] O_2 option.
[12] Optional
[13] Probe-select special.
[15] CO_2 option.
[16] NO_2 valve option.
[17] Concentration alarm option.
[18] MODBUS option.
[19] High auto range relay option
[20] Low span option.
[21] Remote range control option

APPENDIX A-5: Trigger Events and DAS Functions

Table A-5: DAS Trigger Events, Software Version K.3

Name	Description
ATIMER	Automatic timer expired
EXITZR	Exit zero calibration mode
EXITLS [1]	Exit low span calibration mode
EXITHS	Exit high span calibration mode
EXITMP	Exit multi-point calibration mode
EXITC2 [4]	Exit CO_2 calibration mode
EXITO2 [3]	Exit O_2 calibration mode
SLPCHG	Slope and offset recalculated
CO2SLC [4]	CO_2 slope and offset recalculated
O2SLPC [3]	O_2 slope and offset recalculated
EXITDG	Exit diagnostic mode
CONC1W [5]	Concentration exceeds limit 1 warning
CONC2W [5]	Concentration exceeds limit 2 warning
AZEROW	Auto-zero warning
OFLOWW	Ozone flow warning
RPRESW	Reaction cell pressure warning
RTEMPW	Reaction cell temperature warning
MFTMPW [2]	Bypass or dilution manifold temperature warning
C2TMPW [4]	CO_2 sensor cell temperature warning
O2TMPW [3]	O_2 sensor cell temperature warning
IZTMPW	IZS temperature warning
CTEMPW	Converter temperature warning
PTEMPW	PMT temperature warning
SFLOWW	Sample flow warning
BTEMPW	Box temperature warning
HVPSW	HV power supply warning

[1] Low span option.
[2] Factory option.
[3] O_2 option.
[4] CO_2 option.
[5] Concentration alarm option.

Table A-6: DAS Functions, Software Version K.3

Name	Description	Units
PMTDET	PMT detector reading	mV
RAWNOX [6]	Raw PMT detector reading for NOX	mV
RAWNO [6]	Raw PMT detector reading for NO	mV
NXSLP1	NO_X slope for range #1	—
NXSLP2	NO_X slope for range #2	—
NXSLP3 [7]	NO_X slope for range #3	—
NOSLP1	NO slope for range #1	—
NOSLP2	NO slope for range #2	—
NOSLP3 [7]	NO slope for range #3	—
NXOFS1	NO_X offset for range #1	mV
NXOFS2	NO_X offset for range #2	mV
NXOFS3 [7]	NO_X offset for range #3	mV
NOOFS1	NO offset for range #1	mV
NOOFS2	NO offset for range #2	mV
NOOFS3 [7]	NO offset for range #3	mV
CO2SLP [5]	CO_2 slope	—
CO2OFS [5]	CO_2 offset	%
O2SLPE [3]	O_2 slope	—
O2OFST [3]	O_2 offset	%
NXZSC1	NO_X concentration for range #1 during zero/span calibration, just before computing new slope and offset	PPB [2]
NXZSC2	NO_X concentration for range #2 during zero/span calibration, just before computing new slope and offset	PPB [2]
NXZSC3 [7]	NO_X concentration for range #3 during zero/span calibration, just before computing new slope and offset	PPB [2]
NOZSC1	NO concentration for range #1 during zero/span calibration, just before computing new slope and offset	PPB [2]
NOZSC2	NO concentration for range #2 during zero/span calibration, just before computing new slope and offset	PPB [2]
NOZSC3 [7]	NO concentration for range #3 during zero/span calibration, just before computing new slope and offset	PPB [2]
N2ZSC1	NO_2 concentration for range #1 during zero/span calibration, just before computing new slope and offset	PPB [2]
N2ZSC2	NO_2 concentration for range #2 during zero/span calibration, just before computing new slope and offset	PPB [2]

Name	Description	Units
N2ZSC3 [7]	NO_2 concentration for range #3 during zero/span calibration, just before computing new slope and offset	PPB [2]
CO2ZSC [5]	CO_2 concentration during zero/span calibration, just before computing new slope and offset	%
O2ZSCN [3]	O_2 concentration during zero/span calibration, just before computing new slope and offset	%
NXCNC1	NO_X concentration for range #1	PPB [2]
NXCNC2	NO_X concentration for range #2	PPB [2]
NXCNC3 [7]	NO_X concentration for range #3	PPB [2]
NOCNC1	NO concentration for range #1	PPB [2]
NOCNC2	NO concentration for range #2	PPB [2]
NOCNC3 [7]	NO concentration for range #3	PPB [2]
N2CNC1	NO_2 concentration for range #1	PPB [2]
N2CNC2	NO_2 concentration for range #2	PPB [2]
N2CNC3 [7]	NO_2 concentration for range #3	PPB [2]
CO2CNC [5]	CO_2 concentration	%
O2CONC [3]	O_2 concentration	%
STABIL	Concentration stability	PPB [2]
AZERO	Auto zero offset (range de-normalized)	mV
O3FLOW	Ozone flow rate	cc/m
RCPRES	Reaction cell pressure	"Hg
RCTEMP	Reaction cell temperature	°C
MFTEMP [1]	Bypass or dilution manifold temperature	°C
C2TEMP [5]	CO_2 sensor cell temperature	°C
O2TEMP [3]	O_2 sensor cell temperature	°C
IZTEMP	IZS block temperature	°C
CNVEF1	Converter efficiency factor for range #1	—
CNVEF2	Converter efficiency factor for range #2	—
CNVEF3 [7]	Converter efficiency factor for range #3	—
CNVTMP	Converter temperature	°C
PMTTMP	PMT temperature	°C
SMPFLW	Sample flow rate	cc/m
SMPPRS	Sample pressure	"Hg
SRSTMP [8]	Sample restrictor temperature	°C
BOXTMP	Internal box temperature	°C
RBXTMP [8]	Remote box temperature	°C
HVPS	High voltage power supply output	Volts
REFGND	Ground reference (REF_GND)	mV

Name	Description	Units
XIN1 [9]	Channel 1 Analog In	
XIN1SLPE [9]	Channel 1 Analog In Slope	
XIN1OFST [9]	Channel 1 Analog In Offset	
XIN2 [9]	Channel 2 Analog In	
XIN2SLPE [9]	Channel 2 Analog In Slope	
XIN2OFST [9]	Channel 2 Analog In Offset	
XIN3 [9]	Channel 3 Analog In	
XIN3SLPE [9]	Channel 3 Analog In Slope	
XIN3OFST [9]	Channel 3 Analog In Offset	
XIN4 [9]	Channel 4 Analog In	
XIN4SLPE [9]	Channel 4 Analog In Slope	
XIN4OFST [9]	Channel 4 Analog In Offset	
XIN5 [9]	Channel 5 Analog In	
XIN5SLPE [9]	Channel 5 Analog In Slope	
XIN5OFST [9]	Channel 5 Analog In Offset	
XIN6 [9]	Channel 6 Analog In	
XIN6SLPE [9]	Channel 6 Analog In Slope	
XIN6OFST [9]	Channel 6 Analog In Offset	
XIN7 [9]	Channel 7 Analog In	
XIN7SLPE [9]	Channel 7 Analog In Slope	
XIN7OFST [9]	Channel 7 Analog In Offset	
XIN8 [9]	Channel 8 Analog In	
XIN8SLPE [9]	Channel 8 Analog In Slope	
XIN8OFST [9]	Channel 8 Analog In Offset	
RF4096	4096 mV reference (REF_4096_MV)	mV
TEST11	Diagnostic test input (TEST_INPUT_11)	mV
TEST13	Diagnostic test input (TEST_INPUT_13)	mV
TEMP5	Diagnostic temperature input (TEMP_INPUT_5)	°C
TEMP6	Diagnostic temperature input (TEMP_INPUT_6)	°C

[1] Factory option.
[2] Current instrument units.
[3] O_2 option.
[4] Optional.
[5] CO_2 option.
[6] Engineering firmware only.
[7] Triple-range option.
[8] M200EUP.
[9] Analog In option, T-Series only.

APPENDIX A-6: Terminal Command Designators

Table A-7: Terminal Command Designators, Software Version K.3

Command	Additional Command Syntax	Description
? [ID]		Display help screen and this list of commands
LOGON [ID]	password	Establish connection to instrument
LOGOFF [ID]		Terminate connection to instrument
T [ID]	SET ALL|name|hexmask	Display test(s)
	LIST [ALL|name|hexmask] [NAMES|HEX]	Print test(s) to screen
	name	Print single test
	CLEAR ALL|name|hexmask	Disable test(s)
W [ID]	SET ALL|name|hexmask	Display warning(s)
	LIST [ALL|name|hexmask] [NAMES|HEX]	Print warning(s)
	name	Clear single warning
	CLEAR ALL|name|hexmask	Clear warning(s)
C [ID]	ZERO|LOWSPAN|SPAN [1|2]	Enter calibration mode
	ASEQ number	Execute automatic sequence
	COMPUTE ZERO|SPAN	Compute new slope/offset
	EXIT	Exit calibration mode
	ABORT	Abort calibration sequence
D [ID]	LIST	Print all I/O signals
	name[=value]	Examine or set I/O signal
	LIST NAMES	Print names of all diagnostic tests
	ENTER name	Execute diagnostic test
	EXIT	Exit diagnostic test
	RESET [DATA] [CONFIG] [exitcode]	Reset instrument
	PRINT ["name"] [SCRIPT]	Print DAS configuration
	RECORDS ["name"]	Print number of DAS records
	REPORT ["name"] [RECORDS=number] [FROM=<start date>][TO=<end date>][VERBOSE|COMPACT|HEX] (Print DAS records)(date format: MM/DD/YYYY(or YY) [HH:MM:SS]	Print DAS records
	CANCEL	Halt printing DAS records
V [ID]	LIST	Print setup variables
	name[=value [warn_low [warn_high]]]	Modify variable
	name="value"	Modify enumerated variable
	CONFIG	Print instrument configuration
	MAINT ON|OFF	Enter/exit maintenance mode
	MODE	Print current instrument mode
	DASBEGIN [<data channel definitions>] DASEND	Upload DAS configuration
	CHANNELBEGIN propertylist CHANNELEND	Upload single DAS channel
	CHANNELDELETE ["name"]	Delete DAS channels

The command syntax follows the command type, separated by a space character. Strings in [brackets] are optional designators. The following key assignments also apply.

Terminal Key Assignments	
ESC	Abort line
CR (ENTER)	Execute command
Ctrl-C	Switch to computer mode
Computer Mode Key Assignments	
LF (line feed)	Execute command
Ctrl-T	Switch to terminal mode

APPENDIX A-7: MODBUS Register Map

MODBUS Register Address (decimal, 0-based)	Description [10]	Units
MODBUS Floating Point Input Registers (32-bit IEEE 754 format; read in high-word, low-word order; read-only)		
0	Instantaneous PMT detector reading	mV
2	NO_X slope for range #1	—
4	NO_X slope for range #2	—
6	NO slope for range #1	—
8	NO slope for range #2	mV
10	NO_X offset for range #1	mV
12	NO_X offset for range #2	mV
14	NO offset for range #1	mV
16	NO offset for range #2	mV
18	NO_X concentration for range #1 during zero/span calibration, just before computing new slope and offset	PPB
20	NO_X concentration for range #2 during zero/span calibration, just before computing new slope and offset	PPB
22	NO concentration for range #1 during zero/span calibration, just before computing new slope and offset	PPB
24	NO concentration for range #2 during zero/span calibration, just before computing new slope and offset	PPB
26	NO_2 concentration for range #1 during zero/span calibration, just before computing new slope and offset	PPB
28	NO_2 concentration for range #2 during zero/span calibration, just before computing new slope and offset	PPB
30	NO_X concentration for range #1	PPB
32	NO_X concentration for range #2	PPB
34	NO concentration for range #1	PPB
36	NO concentration for range #2	PPB
38	NO_2 concentration for range #1	PPB
40	NO_2 concentration for range #2	PPB
42	Concentration stability	PPB
44	Auto zero offset (range de-normalized) Pre React [11]	mV
46	Ozone flow rate	cc/m
48	Reaction cell pressure	"Hg
50	Reaction cell temperature	°C
52	Manifold temperature	°C
54	Converter efficiency factor for range #1	—
56	Converter efficiency factor for range #2	—
58	Converter temperature	°C

MODBUS Register Address (decimal, 0-based)	Description [10]	Units
60	PMT temperature	°C
62	Sample flow rate	cc/m
64	Sample pressure	"Hg
66	Internal box temperature	°C
68	High voltage power supply output	Volts
70	Ground reference (REF_GND)	mV
72	4096 mV reference (REF_4096_MV)	mV
74	Diagnostic test input (TEST_INPUT_13)	mV
76	Diagnostic temperature input (TEMP_INPUT_6)	°C
78	IZS temperature	°C
80 [9]	Sample restrictor temperature	°C
82 [9]	Remote box temperature	°C
80	Diagnostic test input (TEST_INPUT_11)	mV
82	Diagnostic temperature input (TEMP_INPUT_5)	°C
84 [1]	Raw PMT detector reading for NO_X	mV
86 [1]	Raw PMT detector reading for NO	mV
100 [3]	NO_X slope for range #3	—
102 [3]	NO slope for range #3	mV
104 [3]	NO_X offset for range #3	mV
106 [3]	NO offset for range #3	mV
108 [3]	NO_X concentration for range #3 during zero/span calibration, just before computing new slope and offset	PPB
110 [3]	NO concentration for range #3 during zero/span calibration, just before computing new slope and offset	PPB
112 [3]	NO_2 concentration for range #3 during zero/span calibration, just before computing new slope and offset	PPB
114 [3]	NO_X concentration for range #3	PPB
116 [3]	NO concentration for range #3	PPB
118 [3]	NO_2 concentration for range #3	PPB
120 [3]	Converter efficiency factor for range #3	—
200 [5]	O_2 concentration	%
202 [5]	O_2 concentration during zero/span calibration, just before computing new slope and offset	%
204 [5]	O_2 slope	—
206 [5]	O_2 offset	%
208 [5]	O_2 sensor cell temperature	°C
300 [6]	CO_2 concentration	%
302 [6]	CO_2 concentration during zero/span calibration, just before computing new slope and offset	%
304 [6]	CO_2 slope	—

MODBUS Register Address (decimal, 0-based)	Description [10]	Units
306 [6]	CO_2 offset	%
308 [6]	CO_2 sensor cell temperature	°C
MODBUS Floating Point Holding Registers (32-bit IEEE 754 format; read/write in high-word, low-word order; read/write)		
0	Maps to *NOX_SPAN1* variable; target conc. for range #1	Conc. units
2	Maps to *NO_SPAN1* variable; target conc. for range #1	Conc. units
4	Maps to *NOX_SPAN2* variable; target conc. for range #2	Conc. units
6	Maps to *NO_SPAN2* variable; target conc. for range #2	Conc. units
100 [3]	Maps to *NOX_SPAN3* variable; target conc. for range #3	Conc. units
102 [3]	Maps to *NO_SPAN3* variable; target conc. for range #3	Conc. units
200 [5]	Maps to *O2_TARG_SPAN_CONC* variable; target conc. for range O_2 gas	%
300 [6]	Maps to *CO2_TARG_SPAN_CONC* variable; target conc. for range CO_2 gas	%
MODBUS Discrete Input Registers (single-bit; read-only)		
0	Manifold temperature warning	
1	Converter temperature warning	
2	Auto-zero warning	
3	Box temperature warning	
4	PMT detector temperature warning	
5	Reaction cell temperature warning	
6	Sample flow warning	
7	Ozone flow warning	
8	Reaction cell pressure warning	
9	HVPS warning	
10	System reset warning	
11	Rear board communication warning	
12	Relay board communication warning	
13	Front panel communication warning	
14	Analog calibration warning	
15	Dynamic zero warning	
16	Dynamic span warning	
17	Invalid concentration	
18	In zero calibration mode	
19	In span calibration mode	
20	In multi-point calibration mode	
21	System is OK (same meaning as *SYSTEM_OK* I/O signal)	
22	Ozone generator warning	

MODBUS Register Address (decimal, 0-based)	Description [10]	Units
23	IZS temperature warning	
24 [8]	In low span calibration mode	
25 [7]	NO concentration alarm limit #1 exceeded	
26 [7]	NO concentration alarm limit #2 exceeded	
27 [7]	NO_2 concentration alarm limit #1 exceeded	
28 [7]	NO_2 concentration alarm limit #2 exceeded	
29 [7]	NO_X concentration alarm limit #1 exceeded	
30 [7]	NO_X concentration alarm limit #2 exceeded	
200 [5]	Calibrating O_2 gas	
201 [5]	O_2 sensor cell temperature warning	
202 [5+7]	O_2 concentration alarm limit #1 exceeded	
203 [5+7]	O_2 concentration alarm limit #2 exceeded	
300 [6]	Calibrating CO_2 gas	
301 [6]	CO_2 sensor cell temperature warning	
302 [6+7]	CO_2 concentration alarm limit #1 exceeded	
303 [6+7]	CO_2 concentration alarm limit #2 exceeded	
MODBUS Coil Registers (single-bit; read/write)		
0	Maps to relay output signal 36 (*MB_RELAY_36* in signal I/O list)	
1	Maps to relay output signal 37 (*MB_RELAY_37* in signal I/O list)	
2	Maps to relay output signal 38 (*MB_RELAY_38* in signal I/O list)	
3	Maps to relay output signal 39 (*MB_RELAY_39* in signal I/O list)	
20 [2]	Triggers zero calibration of NO_X range #1 (on enters cal.; off exits cal.)	
21 [2]	Triggers span calibration of NO_X range #1 (on enters cal.; off exits cal.)	
22 [2]	Triggers zero calibration of NO_X range #2 (on enters cal.; off exits cal.)	
23 [2]	Triggers span calibration of NO_X range #2 (on enters cal.; off exits cal.)	

[1] Engineering firmware only.

[2] Set *DYN_ZERO* or *DYN_SPAN* variables to *ON* to enable calculating new slope or offset. Otherwise a calibration check is performed.

[3] Triple-range option.

[4] Optional.

[5] O_2 option.

[6] CO_2 option.

[7] Concentration alarm option.

[8] Low span option.

[9] M200EUP.

[10] All NO_X references become NO_y for M200EU_NO_y.

[11] M200EU and M200EU_NO_y.

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APPENDIX B - Spare Parts

Note **Use of replacement parts other than those supplied by T-API may result in non compliance with European standard EN 61010-1.**

Note **Due to the dynamic nature of part numbers, please refer to the Website or call Customer Service for more recent updates to part numbers.**

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T200 Spare Parts List

PN 06847A DCN5809 08/18/2010

Part Number	Description
000940100	ORIFICE, 3 MIL, DILUTION & VACUUM MANIFOLDS & IZS
000940400	ORIFICE, 4 MIL, OZONE FLOW & O2 OPTION
000940600	ORIFICE, 10 MIL, SAMPLE FLOW & DILUTION & VACUUM MANIFOLDS
001330000	SLEEVE, REACTION CELL
001761800	ASSY, FLOW CTL, 90CC, OZONE DRYER
002270100	AKIT, GASKETS, WINDOW, (12 GASKETS = 1)
002730000	CD, FILTER, 665NM (KB)
004330000	ZERO AIR SCRUBBER (NO/NO2)
005960000	KIT, EXPENDABLE, ACTIVATED CHARCOAL (6 LBS)
005970000	KIT, EXPENDABLE, PURAFIL (6 LBS)
008830000	COLD BLOCK (KB)
009690200	AKIT, TFE FLTR ELEM (FL19,100=1) 47mm
009690300	AKIT, TFE FLTR ELEM (FL19, 30=1) 47mm
009810300	ASSY, PUMP PK, 115V/60HZ w/FL34/NO/SO
009810600	ASSY, PUMP PACK, 100V/60HZ w/FL34
009811000	ASSY, PUMP, NOX, 220-240V/50-60HZ FL34
011310000	ASSY, OZONE DRYER W/FLOW CONTROL
011340500	ASSY, SENSOR
011420500	ASSY, NOX REACTION CELL
011630000	HVPS INSULATOR GASKET (KB)
011930000	CD, PMT (R928), NOX, (KB)
013140000	ASSY, COOLER FAN (NOX/SOX)
014030000	AKIT, NOX EXPENDABLES, IZS
014080100	ASSY, HVPS, SOX/NOX
016290000	WINDOW, SAMPLE FILTER, 47MM (KB)
016300800	ASSY, SAMPLE FILTER, 47MM, ANG BKT, 1UM
018720100	ASSY, MOLY CONVERTER, W/O3 DESTRUCTOR
018720200	ASSY, MOLYCON, w/O3 DEST - EXH *
037860000	ORING, TFE RETAINER, SAMPLE FILTER
039700100	HEATER, BAND, TYPE K, DUAL VOLTAGE(KB)
040010000	ASSY, FAN REAR PANEL
040030800	PCA, FLOW/PRESSURE
040400000	ASSY, HEATERS/THERMAL SWITCH, REACTION CELL
040410100	ASSY, VACUUM MANIFOLD
040420200	ASSY, O3 GEN BRK, HIGH-O/P
040900000	ORIFICE HOLDER, REACTION CELL (KB)
041800500	PCA, PMT PREAMP, VR
041920000	ASSY, THERMISTOR, REACTION CELL
042680100	ASSY, VALVE (SS)
043170000	MANIFOLD, RCELL, (KB) *
043420000	ASSY, HEATER/THERM, O2 SEN
044530000	OPTION, O2 SENSOR ASSY,(KB)
044600000	AKIT, SPARES, NOX
044610000	ASSY, VALVES, MOLY/HICON

T200 Spare Parts List

PN 06847A DCN5809 08/18/2010

Part Number	Description
045230200	PCA, RELAY CARD W/RELAYS, E SERIES, S/N'S >467
045500100	ASSY, ORIFICE HOLDER, 4 MIL, OZONE FLOW
045500300	ASSY, ORIFICE HOLDER, 10 MIL, SAMPLE FLOW & DIL MANIFOLD
045500400	ASSY, ORIFICE HOLDER, 3 MIL, DIL MANIFOLD
046030000	KIT, EXPENDABLE, DESSICANT, OZONE FILTER
046480000	ASSY, DILUTION MANIFOLD, (KB)
047150000	AKIT, EXPENDABLES, NOX
048830000	AKIT, EXP KIT, EXHAUST CLNSR, SILCA GEL
049310100	PCA, TEC CONTROL, E SERIES
049760300	ASSY, TC PROG PLUG, MOLY,TYP K, TC1
050610700	CONFIGURATION PLUGS, 115V, M200E
050610900	CONFIGURATION PLUGS, 220-240V, M200E
050611100	CONFIGURATION PLUGS, 100V, M200E
050700200	KIT, RELAY BD NOX CONFIGURATION
051210000	ASSY, OZONE DESTRUCTOR
051990000	ASSY, SCRUBBER, INLINE, PUMP PACK
052820000	ASSY, IZS, HEATER/THERM, NOX
052930200	ASSY, BAND HEATER TYPE K, NOX
055290000	AKIT, PUMP REBUILD, THOMAS 688, SNGL HD
055740000	ASSY, PUMP, NOx PUMP PACK, 115V/60HZ
055740100	ASSY, PUMP, NOx PUMP PACK, 220V/60HZ
055740200	ASSY, PUMP, NOx PUMP PACK, 220V/50HZ
058021100	PCA, E-SERIES MOTHERBD, GEN 5-ICOP (ACCEPTS ACROSSER OR ICOP CPU)
058230000	ASSY, O3 CLEANSER, ALUMINUM
059940000	OPTION, SAMPLE GAS CONDITIONER, NOX*
062390000	ASSY, MOLY GUTS w/WOOL
062420200	PCA, SER INTRFACE, ICOP CPU, E- (OPTION) (USE WITH ICOP CPU 062870000)
064540000	ASSY, PUMP NOX INTERNAL, 115V/60HZ
064540100	ASSY, PUMP NOX INTERNAL, 230V/60HZ
064540200	ASSY, PUMP NOX INTERNAL, 230V/50HZ
066970000	PCA, INTRF. LCD TOUCH SCRN, F/P
067240000	CPU, PC-104, VSX-6154E, ICOP *
067300000	PCA, AUX-I/O BD, ETHERNET, ANALOG & USB
067300100	PCA, AUX-I/O BOARD, ETHERNET
067300200	PCA, AUX-I/O BOARD, ETHERNET & USB
067900000	LCD MODULE, W/TOUCHSCREEN
068240100	DOM, w/SOFTWARE, T200 *
068580000	MANUAL, T200, OPERATORS
068810000	PCA, LVDS TRANSMITTER BOARD
069500000	PCA, SERIAL & VIDEO INTERFACE BOARD
072150000	ASSY. TOUCHSCREEN CONTROL MODULE
CN0000073	POWER ENTRY, 120/60 (KB)
CN0000458	CONNECTOR, REAR PANEL, 12 PIN
CN0000520	CONNECTOR, REAR PANEL, 10 PIN
FL0000001	FILTER, FLOW CONTROL
FL0000003	FILTER, DFU (KB)

T200 Spare Parts List

PN 06847A DCN5809 08/18/2010

Part Number	Description
FM0000004	FLOWMETER (KB)
FT0000010	FITTING, FLOW CONTROL
HW0000005	FOOT, CHASSIS/PUMP PACK
HW0000020	SPRING, FLOW CONTROL
HW0000030	ISOLATOR, SENSOR ASSY
HW0000031	FERRULE, SHOCKMOUNT
HW0000099	STANDOFF, #6-32X.5, HEX SS M/F
HW0000101	ISOLATOR, PUMP PACK
HW0000453	SUPPORT, CIRCUIT BD, 3/16" ICOP
KIT000051	KIT, REACTION CELL REBUILD
KIT000095	AKIT, REPLACEMENT COOLER
KIT000207	KIT, RELAY RETROFIT
KIT000218	KIT, RELAY RETROFIT, MOLY PLUG
KIT000219	AKIT, 4-20MA CURRENT OUTPUT
KIT000231	KIT, RETROFIT, Z/S VALVE
KIT000253	ASSY & TEST, SPARE PS37
KIT000254	ASSY & TEST, SPARE PS38
OP0000030	OXYGEN TRANSDUCER, PARAMAGNETIC
OR0000001	ORING, FLOW CONTROL/IZS
OR0000002	ORING, REACTION CELL SLEEVE
OR0000025	ORING, ZERO AIR SCRUBBER
OR0000027	ORING, COLD BLOCK/PMT HOUSING & HEATSINK
OR0000034	ORING, (USED W/ FT10)
OR0000039	ORING, FLOW CONTROL
OR0000044	ORING, REACTION CELL MANIFOLD
OR0000046	ORING, PERMEATION OVEN
OR0000058	ORING, SAMPLE FILTER
OR0000083	ORING, PMT SIGNAL & OPTIC LED
OR0000086	ORING, 2-006, CV-75 COMPOUND(KB)
OR0000094	ORING, SAMPLE FILTER
PU0000005	PUMP, THOMAS 607, 115V/60HZ (KB)
PU0000011	REBUILD KIT, THOMAS 607(KB)
PU0000052	PUMP, THOMAS 688, 220/240V 50HZ/60HZ
PU0000054	PUMP, THOMAS 688, 100V, 50/60HZ
PU0000083	KIT, REBUILD, PU80, PU81, PU82
RL0000015	RELAY, DPDT, (KB)
SW0000025	SWITCH, POWER, CIRC BREAK, VDE/CE *
SW0000059	PRESSURE SENSOR, 0-15 PSIA, ALL SEN
WR0000008	POWER CORD, 10A(KB)

Recommended Spare Parts Stocking Levels
Models T200 and M200E

(Reference: 04414Q DCN5480)

Recommended Spare Parts Stocking Level: Standard

Part Number	Description	Units				
		1	2-5	6-10	11-20	21-30
011310000	ASSY, DRYER, NOX		1	2	3	4
011930000	CD, PMT (R928), NOX, M200A, M200E(KB)				1	1
014080100	ASSY, HVPS, SOX/NOX				1	1
040010000	ASSY, FAN REAR PANEL, E SERIES	1	1	2	4	4
040030800	PCA, PRESS SENSORS (2X), FLOW, E (NOX)			1	2	3
040400000	ASSY, HEATERS/THERMAL SWITCH, RX CELL	1	1	2	2	3
040420200	ASSY, O3 GEN BRK, M200E, HIGH-O/P					1
041800500	PCA, PMT PREAMP, VR, M200E/EH, (KB)				1	1
042580000	PCA, KEYBOARD, E-SERIES, W/V-DETECT				1	1
044610000	ASSY, VALVES, MOLY/HICON, M200E				1	2
045230200 *	PCA, RELAY CARD, M100E/200E			1	1	2
045500100	ASSY, ORIFICE HOLDER, 4 MIL	1	1	2	2	4
045500300	ASSY, ORIFICE HOLDER, 10 MIL, (NOX)	1	1	2	2	4
058021100	PCA, E-SERIES MOTHERBOARD, GEN 5-I				1	2
059940000	OPTION, SAMPLE GAS CONDITIONER, M200A/E			1	1	2
DS0000025	DISPLAY, E SERIES (KB)				1	1
KIT000095	AKIT, REPLACEMENT COOLER, A/E SERIES		1	2	3	3
062390000	REPLACEMENT, MOLY CONV WELDED CARTRIDGE				1	1
062870000	CPU, PC-104, VSX-6150E, ICOP *(KB)				1	1
KIT000253	KIT, SPARE PS37, E SERIES		1	1	1	2
KIT000254	KIT, SPARE PS38, E SERIES		1	1	1	2
OR0000034	ORING, 2-011V FT10			2	5	10
OR0000044	ORING, 2-125V			2	5	10
OR0000045	ORING, 2-226V			2	5	10
PU0000005 **	PUMP, THOMAS 607, 115V/60HZ (KB)					1
RL0000015	RELAY, DPDT, (KB)	1	1	1	2	3

*** Recommended Spare Parts Stocking Level: To Upgrade from P/N 039550200 to P/N 045230200**

Part Number	Description	Units				
		1	2-5	6-10	11-20	21-30
KIT000208	M200E RELAY RETRO, GNDED HICON			1	1	2

**** Recommended Spare Parts Stocking Level: For Pumps with 50 Hz**

Part Number	Description	Units				
		1	2-5	6-10	11-20	21-30
PU0000006	PUMP, THOMAS 607, 115V/50HZ (KB)					1

Recommended Spare Parts Stocking Level: For O_2 Option Installed

Part Number	Description	Units				
		1	2-5	6-10	11-20	21-30
FM0000004	FLOWMETER (KB)			1	2	3

Recommended Spare Parts Stocking Level: For IZS, ZS Option Installed

Part Number	Description	Units				
		1	2-5	6-10	11-20	21-30
042680100	ASSY, VALVE (SS), M200E		1	2	2	4

M200E/EM/EH Expendables Kit
T200, T200H/M, M200E, M200EH/EM
(Reference: 04715D DCN5179)

Part Number	Description	Quantity	
		M200E	M200EM/EH
		"00"	"01"
018080000	KIT, DESSICANT BAGGIES (12)	1	1
002270100	KIT, WINDOW GASKET (12)	1	1
009690300	KIT, TFE FILTER ELEMENTS, 47MM, 1UM (30)	1	1
046030000	KIT, CH-43, 3 REFILLS	1	
FL0000001	FILTER, SS	4	4
FL0000003	FILTER, DFU	1	1
HW0000020	SPRING	4	4
OR0000086	ORING, FLOW CONTROL	8	8
OR0000034	ORING, FLOW CONTROL	2	2
OR0000039	ORING, FLOW CONTROL	2	2

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TELEDYNE
ADVANCED POLLUTION INSTRUMENTATION
A Teledyne Technologies Company

CUSTOMER: ______________________ PHONE: ______________________

CONTACT NAME: ______________________ FAX NO. ______________________

SITE ADDRESS: ____

MODEL SERIAL NO.: ______________________ FIRMWARE REVISION: ______________________

1. ARE THERE ANY FAILURE MESSAGES? ____

____

____

PLEASE COMPLETE THE FOLLOWING TABLE: **(NOTE: *DEPENDING ON OPTIONS INSTALLED, NOT ALL TEST PARAMETERS SHOWN BELOW WILL BE AVAILABLE IN YOUR INSTRUMENT*)**
*IF OPTION IS INSTALLED

PARAMETER	RECORDED VALUE	ACCEPTABLE VALUE
RANGE	PPB/PPM	50 PPB TO 20 PPM
NOx STAB	PPB/PPM	≤ 1 PPB WITH ZERO AIR
SAMPLE FLOW	CM^3	500 ± 50
OZONE FLOW	CM^3	80 ± 15
PMT SIGNAL WITH ZERO AIR	MV	-20 TO 150
PMT SIGNAL AT SPAN GAS CONC	MV PPB	0-5000MV 0-20,000 PPB
NORM PMT SIGNAL AT SPAN GAS CONC	MV PPB	0-5000MV 0-20000PPB
AZERO	MV	-20 TO 150
HVPS	V	400 – 900
RCELL TEMP	ºC	50 ± 1
BOX TEMP	ºC	AMBIENT ± 5ºC
PMT TEMP	ºC	7 ± 2ºC
IZS TEMP*	ºC	50 ± 1ºC
MOLY TEMP	ºC	315 ± 5ºC
RCEL PRESS	IN-HG-A	<10
SAMP PRESS	IN-HG-A	AMBIENT ± 1
NOx SLOPE		1.0 ± 0.3
NOx OFFSET		50 TO 150
NO SLOPE		1.0 ± 0.3
NO OFFSET		50 TO 150
ETEST	PMT MV	2000 ± 1000
OTEST	PMT MV	2000 ± 1000
Values are in the Signal I/O		
REF_4096_MV	MV	4096mv ±2mv and Must be Stable
REF_GND	MV	0± 0.5 and Must be Stable

TELEDYNE API CUSTOMER SERVICE
EMAIL: api-customerservice@teledyne.com
PHONE: (858) 657-9800 TOLL FREE: (800) 324-5190 FAX: (858) 657-9816

2. WHAT ARE THE RCELL & SAMPLE PRESSURES WITH THE SAMPLE INLET ON REAR OF MACHINE CAPPED?

   RCELL PRESS -______IN-HG-A **SAMPLE PRESSURE -** _____IN-HG-A

3. WHAT ARE THE FAILURE SYMPTOMS? ____

   ____

   ____

4. WHAT TEST(S) HAVE YOU DONE TRYING TO SOLVE THE PROBLEM? ______________________

   ____

   ____

   ____

   ____

   ____

5. IF POSSIBLE, PLEASE INCLUDE A PORTION OF A STRIP CHART PERTAINING TO THE PROBLEM. CIRCLE PERTINENT DATA.
6. THANK YOU FOR PROVIDING THIS INFORMATION. YOUR ASSISTANCE ENABLES TELEDYNE API TO RESPOND FASTER TO THE PROBLEM THAT YOU ARE ENCOUNTERING.

TELEDYNE API CUSTOMER SERVICE
EMAIL: api-customerservice@teledyne.com
PHONE: (858) 657-9800 TOLL FREE: (800) 324-5190 FAX: (858) 657-9816

APPENDIX D – Wire List and Electronic Schematics

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T200 INTERCONNECT LIST

(Reference: 0691101A)

Revision	Description					Checked	Date	DCN	
A	Initial Release					KV	9/3/2010	5833	

		CONNECTION FROM				CONNECTION TO			
Cable Part #	Signal	Assembly	PN	J/P	Pin	Assembly	PN	J/P	Pin
0364901	**CBL, AC POWER**								
	AC Line	Power Entry	CN0000073		L	Power Switch	SW0000025		L
	AC Neutral	Power Entry	CN0000073		N	Power Switch	SW0000025		N
	Power Grnd	Power Entry	CN0000073			Shield	SW0000025		
	Power Grnd	Power Entry	CN0000073			Chassis			
	AC Line Switched	Power Switch	SW0000025		L	PS2 (+12)	060820000	SK2	1
	AC Neutral Switched	Power Switch	SW0000025		N	PS2 (+12)	060820000	SK2	3
	Power Grnd	Power Entry	CN0000073			PS2 (+12)	060820000	SK2	2
	AC Line Switched	Power Switch	SW0000025		L	PS1 (+5, ±15)	068010000	SK2	1
	AC Neutral Switched	Power Switch	SW0000025		N	PS1 (+5, ±15)	068010000	SK2	3
	Power Grnd	Power Entry	CN0000073			PS1 (+5, ±15)	068010000	SK2	2
	AC Line Switched	Power Switch	SW0000025		L	Relay PCA	045230100	J1	1
	AC Neutral Switched	Power Switch	SW0000025		N	Relay PCA	045230100	J1	3
	Power Grnd	Power Entry	CN0000073			Relay PCA	045230100	J1	2
03829	**CBL, DC POWER TO MOTHERBOARD**								
	DGND	Relay PCA	045230100	P7	1	Motherboard	058021100	P15	1
	+5V	Relay PCA	045230100	P7	2	Motherboard	058021100	P15	2
	AGND	Relay PCA	045230100	P7	3	Motherboard	058021100	P15	3
	+15V	Relay PCA	045230100	P7	4	Motherboard	058021100	P15	4
	AGND	Relay PCA	045230100	P7	5	Motherboard	058021100	P15	5
	-15V	Relay PCA	045230100	P7	6	Motherboard	058021100	P15	6
	+12V RET	Relay PCA	045230100	P7	7	Motherboard	058021100	P15	7
	+12V	Relay PCA	045230100	P7	8	Motherboard	058021100	P15	8
	Chassis Gnd	Relay PCA	045230100	P7	10	Motherboard	058021100	P15	9
04022	**CBL, DC POWER, FANM KEYBOARD, TEC, SENSOR PCA**								
	TEC +12V	TEC PCA	049310100	P1	1	Relay PCA	045230100	P10	8
	TEC +12V RET	TEC PCA	049310100	P1	2	Relay PCA	045230100	P10	7
	DGND	Relay PCA	045230100	P10	1	LCD Interface PCA	066970000	P14	8
	+5V	Relay PCA	045230100	P10	2	LCD Interface PCA	066970000	P14	1
	DGND	LCD Interface PCA	066970000	P14	2	Relay PCA	045230100	P11	1
	+5V	LCD Interface PCA	066970000	P14	3	Relay PCA	045230100	P11	2
	+12V RET	Relay PCA	045230100	P11	7	Chassis fan	040010000	P1	1
	+12V	Relay PCA	045230100	P11	8	Chassis fan	040010000	P1	2
	P/Flow Sensor AGND	Relay PCA	045230100	P11	3	P/Flow Sensor PCA	040030800	P1	3
	P/Flow Sensor +15V	Relay PCA	045230100	P11	4	P/Flow Sensor PCA	040030800	P1	6
	Pressure signal 1	P/Flow Sensor PCA	040030800	P1	2	Motherboard	058021100	P110	6
	Pressure signal 2	P/Flow Sensor PCA	040030800	P1	4	Motherboard	058021100	P110	5
	Flow signal 1	P/Flow Sensor PCA	040030800	P1	5	Motherboard	058021100	P110	4
	Flow signal 2	P/Flow Sensor PCA	040030800	P1	1	Motherboard	058021100	P110	3
	Shield	P/Flow Sensor PCA	040030800	P1	S	Motherboard	058021100	P110	12
	Shield	Motherboard	058021100	P110	9	Relay PCA	045230100	P17	S
	Thermocouple signal 1	Motherboard	058021100	P110	2	Relay PCA	045230100	P17	1
	TC 1 signal DGND	Motherboard	058021100	P110	8	Relay PCA	045230100	P17	2
	Thermocouple signal 2	Motherboard	058021100	P110	1	Relay PCA	045230100	P17	3
	TC 2 signal DGND	Motherboard	058021100	P110	7	Relay PCA	045230100	P17	4
04023	**CBL, I2C, RELAY PCA TO MOTHERBOARD**								
	I2C Serial Clock	Motherboard	058021100	P107	3	Relay PCA	045230100	P3	1
	I2C Serial Data	Motherboard	058021100	P107	5	Relay PCA	045230100	P3	2
	I2C Reset	Motherboard	058021100	P107	2	Relay PCA	045230100	P3	4
	I2C Shield	Motherboard	058021100	P107	6	Relay PCA	045230100	P3	5
04024	**CBL, NOX, ZERO/SPAN, IZS VALVES**								
	Zero/Span valve +12V	Relay PCA	045230100	P4	1	Zero/Span valve	042680100	P1	1
	Zero/Span valve +12V RET	Relay PCA	045230100	P4	2	Zero/Span valve	042680100	P1	2
	Sample valve +12V	Relay PCA	045230100	P4	3	Sample valve	042680100	P1	1
	Sample valve +12V RET	Relay PCA	045230100	P4	4	Sample valve	042680100	P1	2
	AutoZero valve +12V	Relay PCA	045230100	P4	5	AutoZero valve	042680100	P1	1
	AutoZero valve +12V RET	Relay PCA	045230100	P4	6	AutoZero valve	042680100	P1	2
	NONOx valve +12V	Relay PCA	045230100	P4	7	NONOx valve	042680100	P1	1
	NONOx valve +12V RET	Relay PCA	045230100	P4	8	NONOx valve	042680100	P1	2

T200 INTERCONNECT LIST

(Reference: 0691101A)

		CONNECTION FROM				CONNECTION TO			
Cable Part #	Signal	Assembly	PN	J/P	Pin	Assembly	PN	J/P	Pin
0402603	**CBL, IZS & O2 SENSOR HEATERS/THERMISTORS, REACTION CELL & MANIFOLD THERMISTORS**								
	Rcell thermistor A	Reaction cell thermistor	041920000	P1	2	Motherboard	058021100	P27	7
	Rcell thermistor B	Reaction cell thermistor	041920000	P1	1	Motherboard	058021100	P27	14
	IZS thermistor A	Motherboard	058021100	P27	6	IZS thermistor/heater	052820000	P1	2
	IZS thermistor B	Motherboard	058021100	P27	13	IZS thermistor/heater	052820000	P1	3
	IZS heater L	IZS thermistor/heater	052820000	P1	4	Relay PCA	045230100	P18	1
	IZS heater N	IZS thermistor/heater	052820000	P1	1	Relay PCA	045230100	P18	2
	Shield					Relay PCA	045230100	P18	11
	O2 sensor heater	Relay PCA	045230100	P18	6	O2 sensor therm./heater	043420000	P1	4
	O2 sensor heater	Relay PCA	045230100	P18	7	O2 sensor therm./heater	043420000	P1	2
	Shield	Relay PCA	045230100	P18	12	O2 sensor therm./heater	043420000	P1	
	O2 sensor thermistor A	O2 sensor therm./heater	043420000	P1	3	Motherboard	058021100	P27	4
	O2 sensor thermistor B	O2 sensor therm./heater	043420000	P1	1	Motherboard	058021100	P27	11
	Byp/dil. man. thermistor A	Motherboard	058021100	P27	1	Manifold thermistor	043420000	P1	1
	Byp/dil. man. thermistor B	Motherboard	058021100	P27	8	Manifold thermistor	043420000	P1	2
	Configuration jumper intern.	Relay PCA	045230100	P18	3	Relay PCA	045230100	P18	4
	Configuration jumper intern.	Relay PCA	045230100	P18	8	Relay PCA	045230100	P18	9
04027	**CBL, NO2 CONVERTER, REACTION CELL & MANIFOLD HEATERS**								
	Bypass/dil. manifold heater L	Manifold heater 1	044340000	P1	1	Relay PCA	045230100	P2	11
	Bypass/dil. manifold heater N	Manifold heater 1	044340000	P1	2	Relay PCA	045230100	P2	12
	Bypass/dil. manifold heater L	Relay PCA	045230100	P2	11	Manifold heater 2	044340000	P1	1
	Bypass/dil. manifold heater N	Relay PCA	045230100	P2	15	Manifold heater 2	044340000	P1	2
	Moly heater A	Relay PCA	045230100	P2	7	Moly heater A	039700100	P1	1
	Moly heater C	Relay PCA	045230100	P2	6	Moly heater C	039700100	P1	2
	Moly heater B	Relay PCA	045230100	P2	10	Moly heater B	039700100	P1	3
	Configuration jumper intern.	Relay PCA	045230100	P2	13	Relay PCA	045230100	P2	14
	Configuration jumper intern.	Relay PCA	045230100	P2	8	Relay PCA	045230100	P2	9
	Reaction cell heater/switch	Relay PCA	045230100	P2	1	Reaction cell heater 1B	040400000	P1	4
	Reaction cell heater/switch	Relay PCA	045230100	P2	1	Reaction cell heater 2B	040400000	P1	6
	Reaction cell heater/switch	Relay PCA	045230100	P2	2	Reaction cell heater 1A	040400000	P1	3
	Reaction cell heater/switch	Relay PCA	045230100	P2	3	Reaction cell heat switch	040400000	P1	1
	Reaction cell heater/switch	Relay PCA	045230100	P2	4	Reaction cell heat switch	040400000	P1	2
	Reaction cell heater/switch	Relay PCA	045230100	P2	5	Reaction cell heater 2A	040400000	P1	5
04105	**CBL, KEYBOARD, DISPLAY TO MOTHERBOARD**								
	Kbd Interrupt	LCD Interface PCA	066970000	J1	7	Motherboard	058021100	J106	1
	DGND	LCD Interface PCA	066970000	J1	2	Motherboard	058021100	J106	8
	SDA	LCD Interface PCA	066970000	J1	5	Motherboard	058021100	J106	2
	SCL	LCD Interface PCA	066970000	J1	6	Motherboard	058021100	J106	6
	Shld	LCD Interface PCA	066970000	J1	10	Motherboard	058021100	J106	5
04176	**CBL, DC POWER TO RELAY PCA**								
	DGND	Relay PCA	045230100	P8	1	Power Supply Triple	068010000	J1	3
	+5V	Relay PCA	045230100	P8	2	Power Supply Triple	068010000	J1	1
	+15V	Relay PCA	045230100	P8	4	Power Supply Triple	068010000	J1	6
	AGND	Relay PCA	045230100	P8	5	Power Supply Triple	068010000	J1	4
	-15V	Relay PCA	045230100	P8	6	Power Supply Triple	068010000	J1	5
	+12V RET	Relay PCA	045230100	P8	7	Power Supply Single	068020000	J1	3
	+12V	Relay PCA	045230100	P8	8	Power Supply Single	068020000	J1	1
04433	**CBL, PREAMPLIFIER TO RELAY PCA**								
	Preamplifier DGND	Relay PCA	045230100	P9	1	Preamp PCA	041800500	P5	1
	Preamplifier +5V	Relay PCA	045230100	P9	2	Preamp PCA	041800500	P5	2
	Preamplifier AGND	Relay PCA	045230100	P9	3	Preamp PCA	041800500	P5	3
	Preamplifier +15V	Relay PCA	045230100	P9	4	Preamp PCA	041800500	P5	4
	Preamplifier -15V	Relay PCA	045230100	P9	6	Preamp PCA	041800500	P5	6
04437	**CBL, PREAMPLIFIER TO TEC**								
	Preamp TEC drive VREF	Preamp PCA	041800500	J1	1	TEC PCA	049310100	J3	1
	Preamp TEC drive CTRL	Preamp PCA	041800500	J1	2	TEC PCA	049310100	J3	2
	Preamp TEC drive AGND	Preamp PCA	041800500	J1	3	TEC PCA	049310100	J3	3

T200 INTERCONNECT LIST

(Reference: 0691101A)

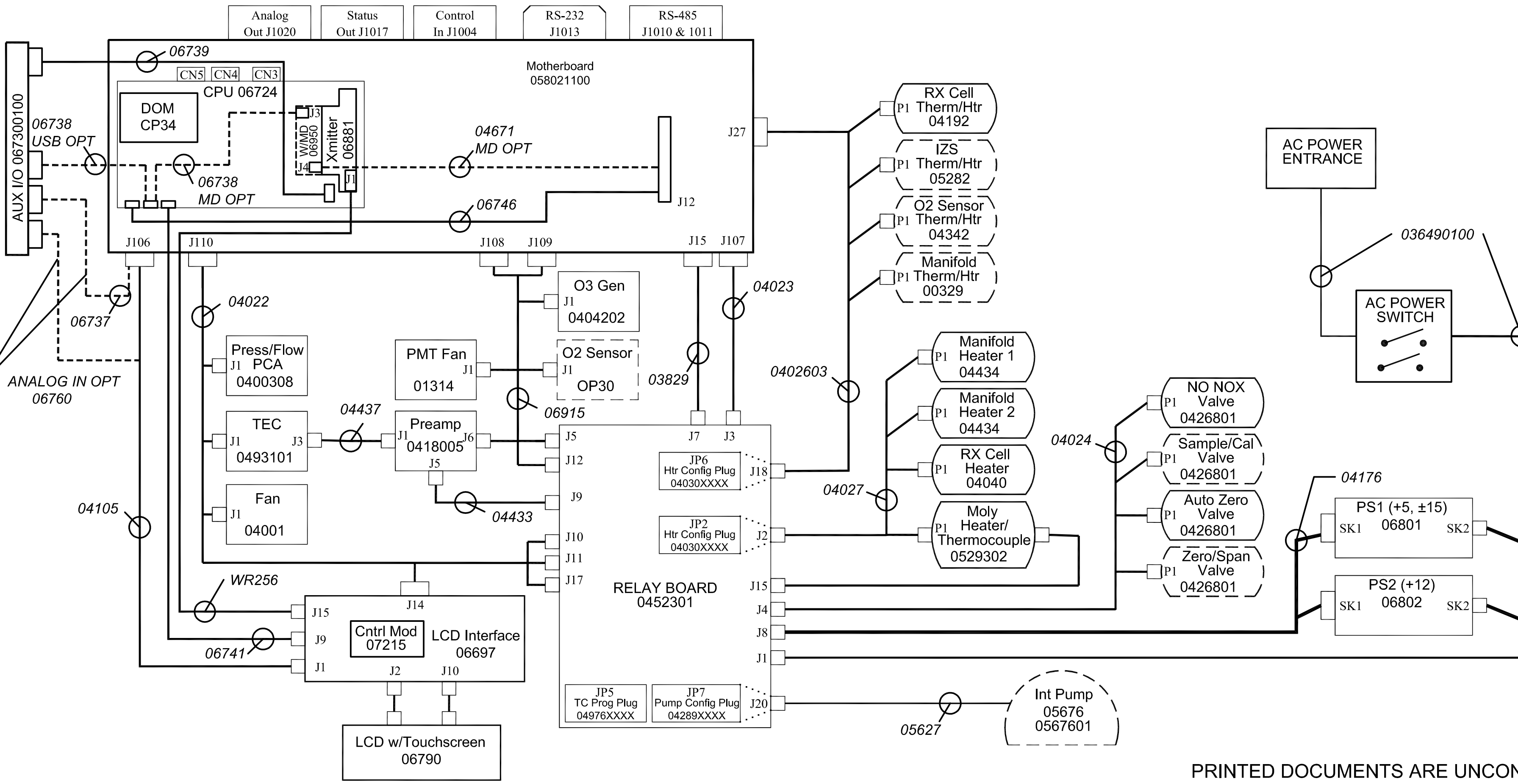
		CONNECTION FROM				CONNECTION TO			
Cable Part #	Signal	Assembly	PN	J/P	Pin	Assembly	PN	J/P	Pin
04671	**CBL, MOTHERBOARD TO XMITTER BD (MULTIDROP OPTION)**								
	GND	Motherboard	058021100	P12	2	Xmitter bd w/Multidrop	069500000	J4	2
	RX0	Motherboard	058021100	P12	14	Xmitter bd w/Multidrop	069500000	J4	14
	RTS0	Motherboard	058021100	P12	13	Xmitter bd w/Multidrop	069500000	J4	13
	TX0	Motherboard	058021100	P12	12	Xmitter bd w/Multidrop	069500000	J4	12
	CTS0	Motherboard	058021100	P12	11	Xmitter bd w/Multidrop	069500000	J4	11
	RS-GND0	Motherboard	058021100	P12	10	Xmitter bd w/Multidrop	069500000	J4	10
	RTS1	Motherboard	058021100	P12	8	Xmitter bd w/Multidrop	069500000	J4	8
	CTS1/485-	Motherboard	058021100	P12	6	Xmitter bd w/Multidrop	069500000	J4	6
	RX1	Motherboard	058021100	P12	9	Xmitter bd w/Multidrop	069500000	J4	9
	TX1/485+	Motherboard	058021100	P12	7	Xmitter bd w/Multidrop	069500000	J4	7
	RS-GND1	Motherboard	058021100	P12	5	Xmitter bd w/Multidrop	069500000	J4	5
	RX1	Motherboard	058021100	P12	9	Xmitter bd w/Multidrop	069500000	J4	9
	TX1/485+	Motherboard	058021100	P12	7	Xmitter bd w/Multidrop	069500000	J4	7
	RS-GND1	Motherboard	058021100	P12	5	Xmitter bd w/Multidrop	069500000	J4	5
06737	**CBL, I2C to AUX I/O (ANALOG IN OPTION)**								
	ATX+	AUX I/O PCA	067300000	J2	1	Motherboard	058021100	J106	1
	ATX-	AUX I/O PCA	067300000	J2	2	Motherboard	058021100	J106	2
	LED0	AUX I/O PCA	067300000	J2	3	Motherboard	058021100	J106	3
	ARX+	AUX I/O PCA	067300000	J2	4	Motherboard	058021100	J106	4
	ARX-	AUX I/O PCA	067300000	J2	5	Motherboard	058021100	J106	5
	LED0+	AUX I/O PCA	067300000	J2	6	Motherboard	058021100	J106	6
	LED1+	AUX I/O PCA	067300000	J2	8	Motherboard	058021100	J106	8
06738	**CBL, CPU COM to AUX I/O (USB OPTION)**								
	RXD1	CPU PCA	067240000	COM1	1	AUX I/O PCA	0673000 or -02	J3	1
	DCD1	CPU PCA	067240000	COM1	2	AUX I/O PCA	0673000 or -02	J3	2
	DTR1	CPU PCA	067240000	COM1	3	AUX I/O PCA	0673000 or -02	J3	3
	TXD1	CPU PCA	067240000	COM1	4	AUX I/O PCA	0673000 or -02	J3	4
	DSR1	CPU PCA	067240000	COM1	5	AUX I/O PCA	0673000 or -02	J3	5
	GND	CPU PCA	067240000	COM1	6	AUX I/O PCA	0673000 or -02	J3	6
	CTS1	CPU PCA	067240000	COM1	7	AUX I/O PCA	0673000 or -02	J3	7
	RTS1	CPU PCA	067240000	COM1	8	AUX I/O PCA	0673000 or -02	J3	8
	RI1	CPU PCA	067240000	COM1	10	AUX I/O PCA	0673000 or -02	J3	10
06738	**CBL, CPU COM to AUX I/O (MULTIDROP OPTION)**								
	RXD	CPU PCA	067240000	COM1	1	Xmitter bd w/Multidrop	069500000	J3	1
	DCD	CPU PCA	067240000	COM1	2	Xmitter bd w/Multidrop	069500000	J3	2
	DTR	CPU PCA	067240000	COM1	3	Xmitter bd w/Multidrop	069500000	J3	3
	TXD	CPU PCA	067240000	COM1	4	Xmitter bd w/Multidrop	069500000	J3	4
	DSR	CPU PCA	067240000	COM1	5	Xmitter bd w/Multidrop	069500000	J3	5
	GND	CPU PCA	067240000	COM1	6	Xmitter bd w/Multidrop	069500000	J3	6
	CTS	CPU PCA	067240000	COM1	7	Xmitter bd w/Multidrop	069500000	J3	7
	RTS	CPU PCA	067240000	COM1	8	Xmitter bd w/Multidrop	069500000	J3	8
	RI	CPU PCA	067240000	COM1	10	Xmitter bd w/Multidrop	069500000	J3	10
06739	**CBL, CPU LAN TO AUX I/O PCA**								
	ATX-	CPU PCA	067240000	LAN	1	AUX I/O PCA	06730XXXX	J2	1
	ATX+	CPU PCA	067240000	LAN	2	AUX I/O PCA	06730XXXX	J2	2
	LED0	CPU PCA	067240000	LAN	3	AUX I/O PCA	06730XXXX	J2	3
	ARX+	CPU PCA	067240000	LAN	4	AUX I/O PCA	06730XXXX	J2	4
	ARX-	CPU PCA	067240000	LAN	5	AUX I/O PCA	06730XXXX	J2	5
	LED0+	CPU PCA	067240000	LAN	6	AUX I/O PCA	06730XXXX	J2	6
	LED1	CPU PCA	067240000	LAN	7	AUX I/O PCA	06730XXXX	J2	7
	LED1+	CPU PCA	067240000	LAN	8	AUX I/O PCA	06730XXXX	J2	8
06741	**CBL, CPU USB to Front Panel**								
	GND	CPU PCA	067240000	USB	8	LCD Interface PCA	066970000	JP9	
	LUSBD3+	CPU PCA	067240000	USB	6	LCD Interface PCA	066970000	JP9	
	LUSBD3-	CPU PCA	067240000	USB	4	LCD Interface PCA	066970000	JP9	
	VCC	CPU PCA	067240000	USB	2	LCD Interface PCA	066970000	JP9	

T200 INTERCONNECT LIST

(Reference: 0691101A)

		CONNECTION FROM				CONNECTION TO			
Cable Part #	Signal	Assembly	PN	J/P	Pin	Assembly	PN	J/P	Pin
06746	**CBL, MB TO 06154 CPU**								
	GND	Motherboard	058021100	P12	2	Shield			
	RX0	Motherboard	058021100	P12	14	CPU PCA	067240000	COM1	1
	RTS0	Motherboard	058021100	P12	13	CPU PCA	067240000	COM1	8
	TX0	Motherboard	058021100	P12	12	CPU PCA	067240000	COM1	4
	CTS0	Motherboard	058021100	P12	11	CPU PCA	067240000	COM1	7
	RS-GND0	Motherboard	058021100	P12	10	CPU PCA	067240000	COM1	6
	RTS1	Motherboard	058021100	P12	8	CPU PCA	067240000	COM2	8
	CTS1/485-	Motherboard	058021100	P12	6	CPU PCA	067240000	COM2	7
	RX1	Motherboard	058021100	P12	9	CPU PCA	067240000	COM2	1
	TX1/485+	Motherboard	058021100	P12	7	CPU PCA	067240000	COM2	4
	RS-GND1	Motherboard	058021100	P12	5	CPU PCA	067240000	COM2	6
	RX1	Motherboard	058021100	P12	9	CPU PCA	067240000	485	1
	TX1/485+	Motherboard	058021100	P12	7	CPU PCA	067240000	485	2
	RS-GND1	Motherboard	058021100	P12	5	CPU PCA	067240000	485	3
06915	**CBL, PREAMP, O2 SENSOR, O3 GEN, FAN, RELAY PCA & MOTHERBOARD**								
	+15V	Relay PCA	045230100	P12	4	Ozone generator	040420200	P1	4
	AGND	Relay PCA	045230100	P12	3	Ozone generator	040420200	P1	5
	+12V	Relay PCA	045230100	P12	8	PMT cooling fan	013140000	P1	1
	+12V RET	Relay PCA	045230100	P12	7	PMT cooling fan	013140000	P1	2
	O3GEN enable signal	Ozone generator	040420200	P1	6	Motherboard	058021100	P108	15
	ETEST	Motherboard	058021100	P108	8	Preamp PCA	041800500	P6	1
	OTEST	Motherboard	058021100	P108	16	Preamp PCA	041800500	P6	2
	PHYSICAL RANGE	Motherboard	058021100	P108	7	Preamp PCA	041800500	P6	4
	PMT TEMP	Preamp PCA	041800500	P6	5	Motherboard	058021100	P109	4
	HVPS	Preamp PCA	041800500	P6	6	Motherboard	058021100	P109	5
	PMT SIGNAL+	Preamp PCA	041800500	P6	7	Motherboard	058021100	P109	6
	AGND	Preamp PCA	041800500	P6	S	Motherboard	058021100	P109	11
	AGND	Motherboard	058021100	P109	9	O2 Sensor (optional)	OP0000030	P1	S
	O2 SIGNAL -	Motherboard	058021100	P109	7	O2 Sensor (optional)	OP0000030	P1	9
	O2 SIGNAL +	Motherboard	058021100	P109	1	O2 Sensor (optional)	OP0000030	P1	10
	DGND	O2 Sensor (optional)	OP0000030	P1	5	Relay PCA	045230100	P5	1
	+5V	O2 Sensor (optional)	OP0000030	P1	6	Relay PCA	045230100	P5	2
WR256	**CBL, TRANSMITTER TO INTERFACE**								
		LCD Interface PCA	066970000	J15		Transmitter PCA	068810000	J1	

REVISIONS				
REV	DESCRIPTION	DATE	DCN	APPROVED
A	INITIAL RELEASE	9/3/10	5833	KV



PRINTED DOCUMENTS ARE UNCONTROLLED

KEY:
1. All part numbers in *Italic* identify cables that are refered to in the accompanying document 069110100
2. All items in Dashed boxes are optional.

THIRD ANGLE PROJECTION

UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN INCHES
TOLERANCES ARE:
FRACTIONS ± 1/32 | DECIMALS ±.03[0.76] ±.010[0.25] | ANGULAR ±0° 30'
DO NOT SCALE DRAWING

TREATMENT: NA
FINISH
SIMILAR TO

CONTRACT: NA

APPROVALS	DATE
DRAWN KV	4/10
CHECK	
CCB	
ISSUED	

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Advanced Pollution Instrumentation
A Teledyne Technologies Company

TITLE: INTERCONNECT DRAWING T200

SIZE	CAGE CODE NO.	DWG. NO.	REV
B	1JZF4	06911	A

SCALE 1/1 | FILE 06911 | SHEET 1 OF 1

VERSION TABLE

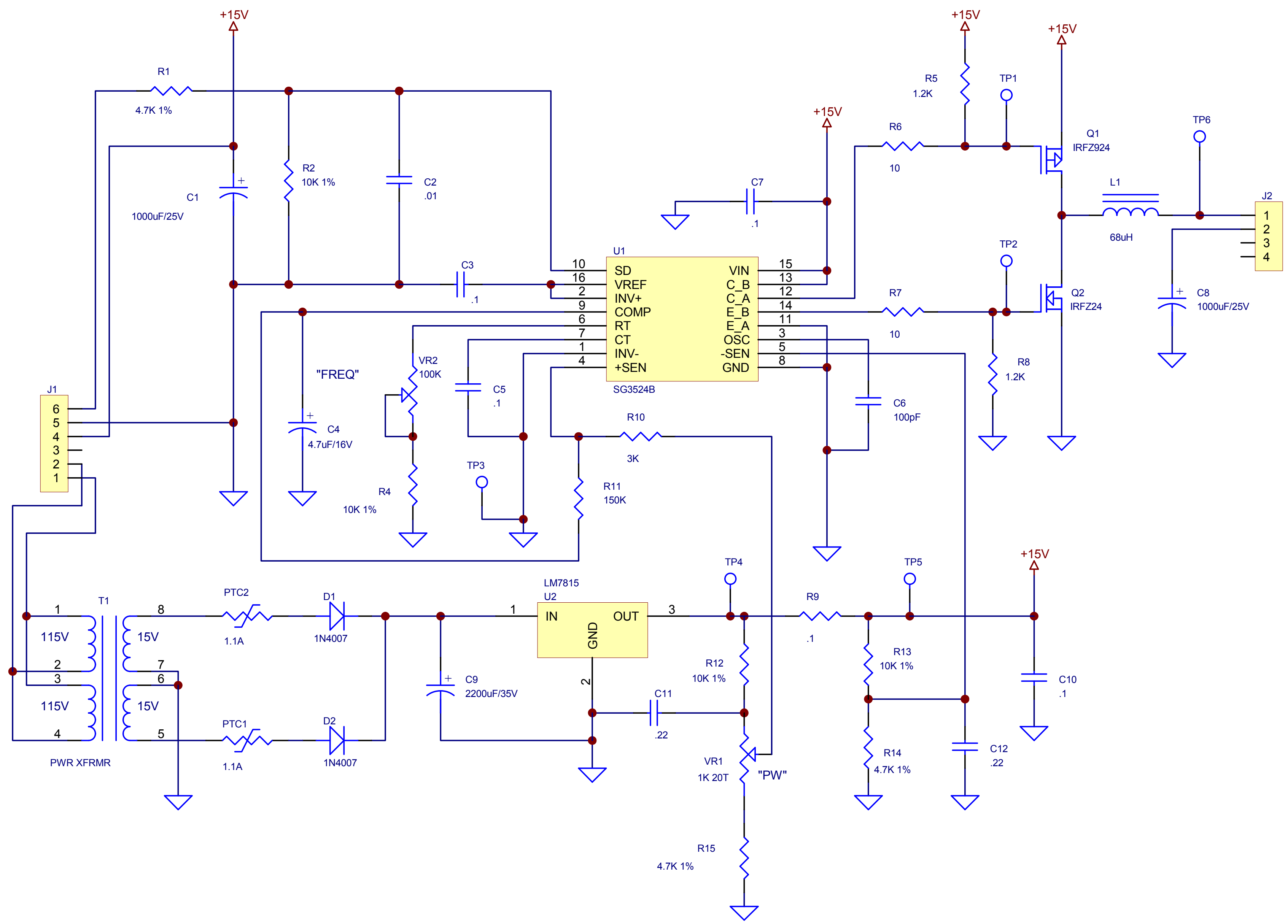
016680000 - CE MARK VERSION
STD PROD. VERSION UP TO 10/99
016680100 - NON CE MARK (OBSOLETE)

016680200 - SUB PS 17 SWITCHER FOR LINEAR SUPPLY
DELETE COMPONENTS
T1, D1, D2, C9, C11, PTC1, PTC2, U2
ADD COMPONENTS
PS1

016680300 - LOW OUTPUT + FIXED FREQ
REPLACE VR2 WITH A WIRE JUMPER
REPLACE R4 WITH RS297 127KOHM

016680400 - HI OUTPUT + FIXED FREQ
REPLACE VR2 WITH A WIRE JUMPER
REPLACE R4 WITH RS13 11 KOHM

016680600 - HI OUTPUT,E SERIES
DELETE COMPONENTS
T1,D1,D2,C9,PTC1,PTC2,U2



10/15/96 REV. D:	Added PTC1,2 secondary overcurrent protection.
11/21/96 REV. E:	Minor cosmetic fixes
10/01/99 REV. F	ADDED VERSION TABLE AT D6

Error : LOGO.BMP file not found.

APPROVALS	DATE
DRAWN	
CHECKED	
APPROVED	

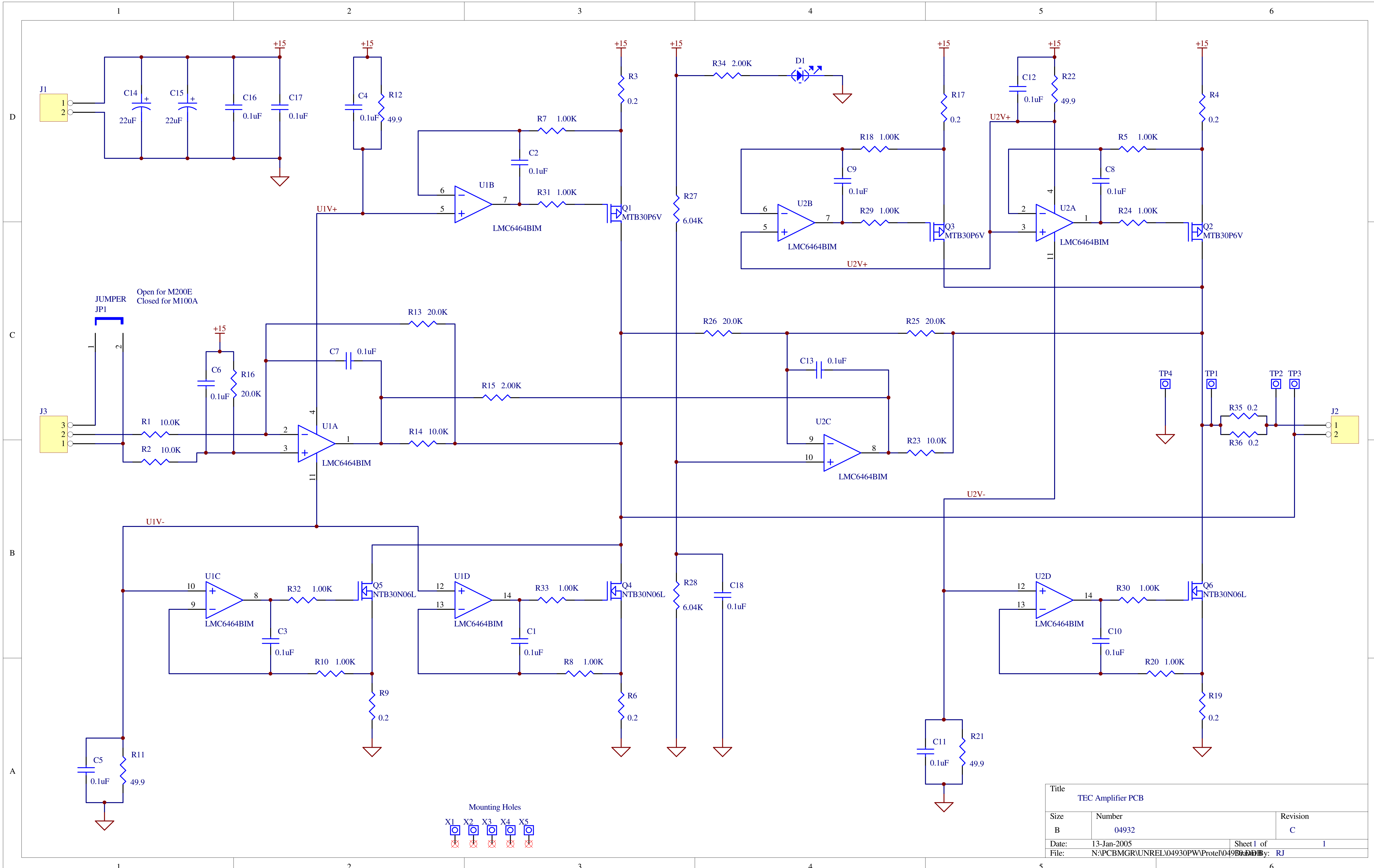
OZON_ GEN

DRIVER

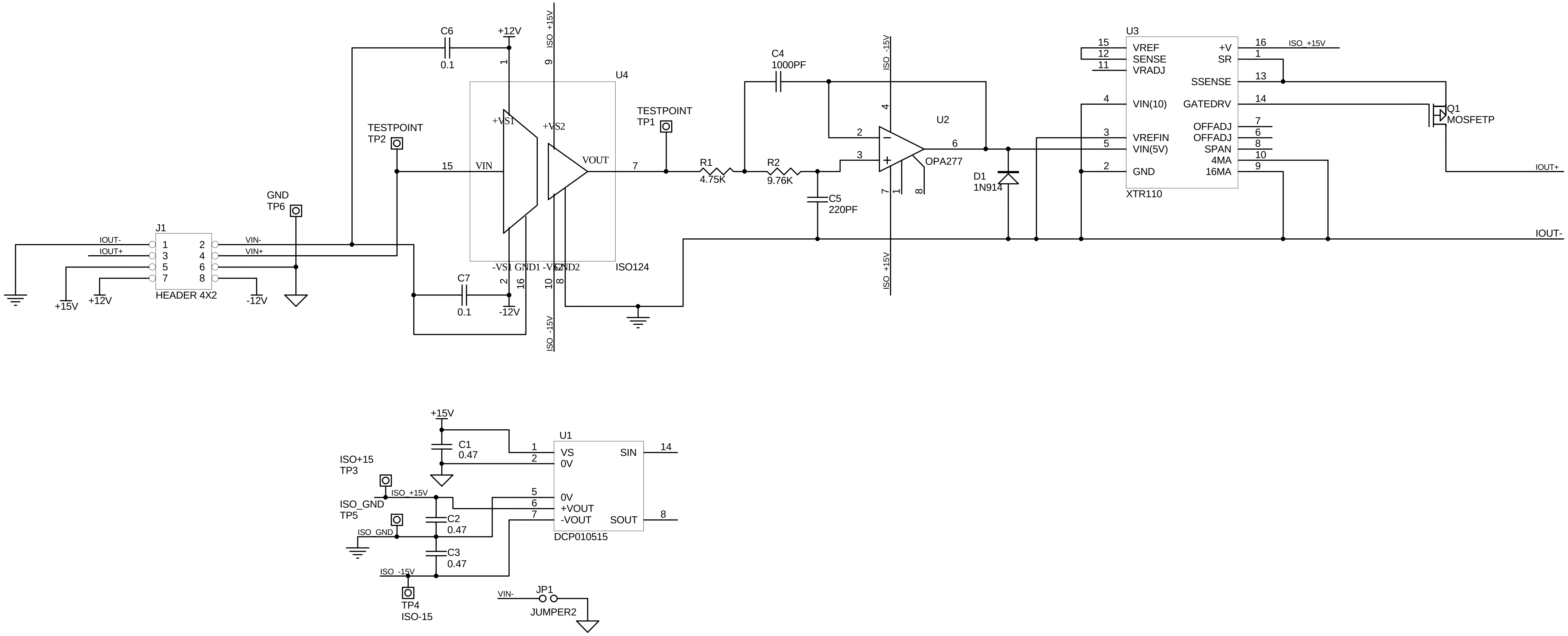
SIZE	DRAWING NO.	REVISION
B	01669	G

LAST MOD. 30-Nov-2006 SHEET 1 of 1

 06858A DCN5847



J1
C14 22uF
C15 22uF
C16 0.1uF
C17 0.1uF
+15
C4 0.1uF
R12 49.9
U1V+
R3 0.2
R7 1.00K
C2 0.1uF
U1B
R31 1.00K
Q1 MTB30P6V
LMC6464BIM
R34 2.00K
D1
R27 6.04K
R17 0.2
R18 1.00K
C9 0.1uF
U2B
R29 1.00K
Q3 MTB30P6V
U2V+
C12 0.1uF
R22 49.9
R4 0.2
R5 1.00K
C8 0.1uF
U2A
R24 1.00K
Q2 MTB30P6V
JUMPER
JP1
Open for M200E
Closed for M100A
R13 20.0K
C7 0.1uF
C6 0.1uF
R16 20.0K
R15 2.00K
J3
R1 10.0K
R2 10.0K
U1A
R14 10.0K
R26 20.0K
R25 20.0K
C13 0.1uF
U2C
R23 10.0K
TP4
TP1
TP2
TP3
R35 0.2
R36 0.2
J2
U1V-
U2V-
U1C
R32 1.00K
Q5 NTB30N06L
C3 0.1uF
R10 1.00K
R9 0.2
U1D
R33 1.00K
Q4 NTB30N06L
C1 0.1uF
R8 1.00K
R6 0.2
R28 6.04K
C18 0.1uF
U2D
R30 1.00K
Q6 NTB30N06L
C10 0.1uF
R20 1.00K
R19 0.2
C11 0.1uF
R21 49.9
C5 0.1uF
R11 49.9
Mounting Holes
X1 X2 X3 X4 X5
Title
TEC Amplifier PCB
Size B
Number 04932
Revision C
Date: 13-Jan-2005
Sheet 1 of 1
File: N:\PCBMGR\UNREL\04930PW\Protel\04930.DDB
Drawn By: RJ



Date	Rev.	Change Description	Engineer
8/9/00	A	INITIAL RELEASE (FROM 03039)	KL

Error : LOGO.BMP file not found.

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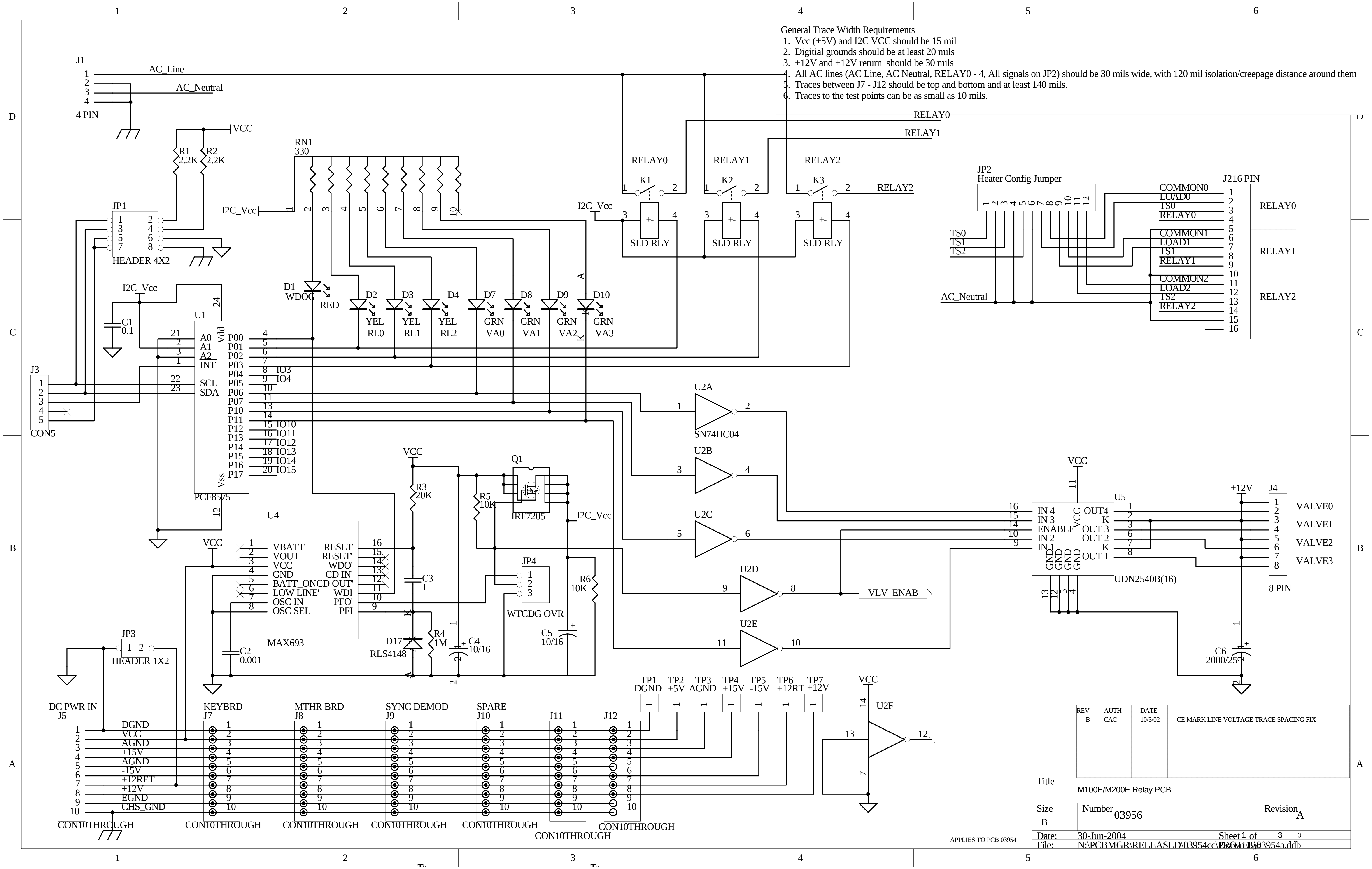
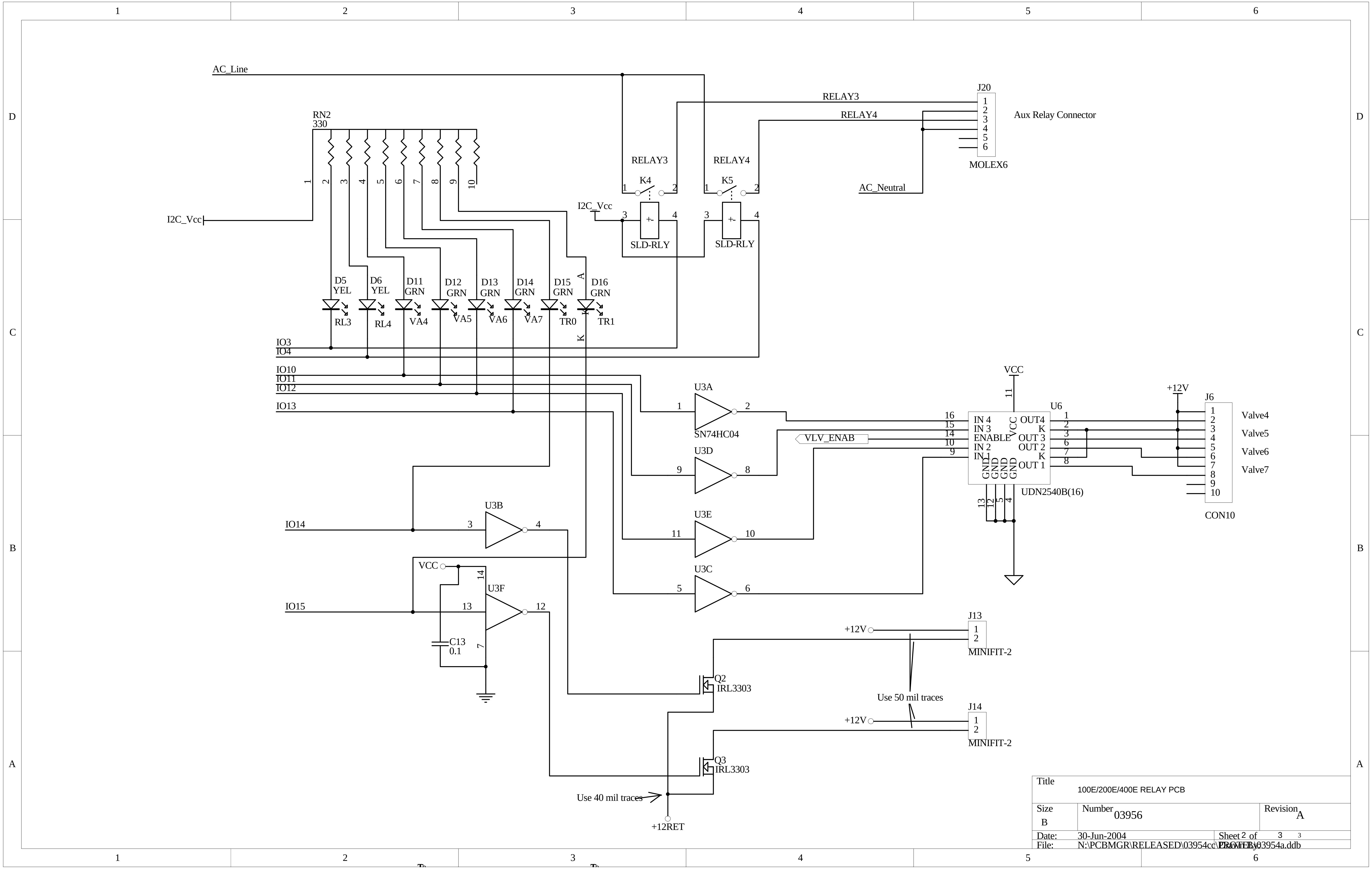
APPROVALS	DATE
DRAWN	
CHECKED	
APPROVED	

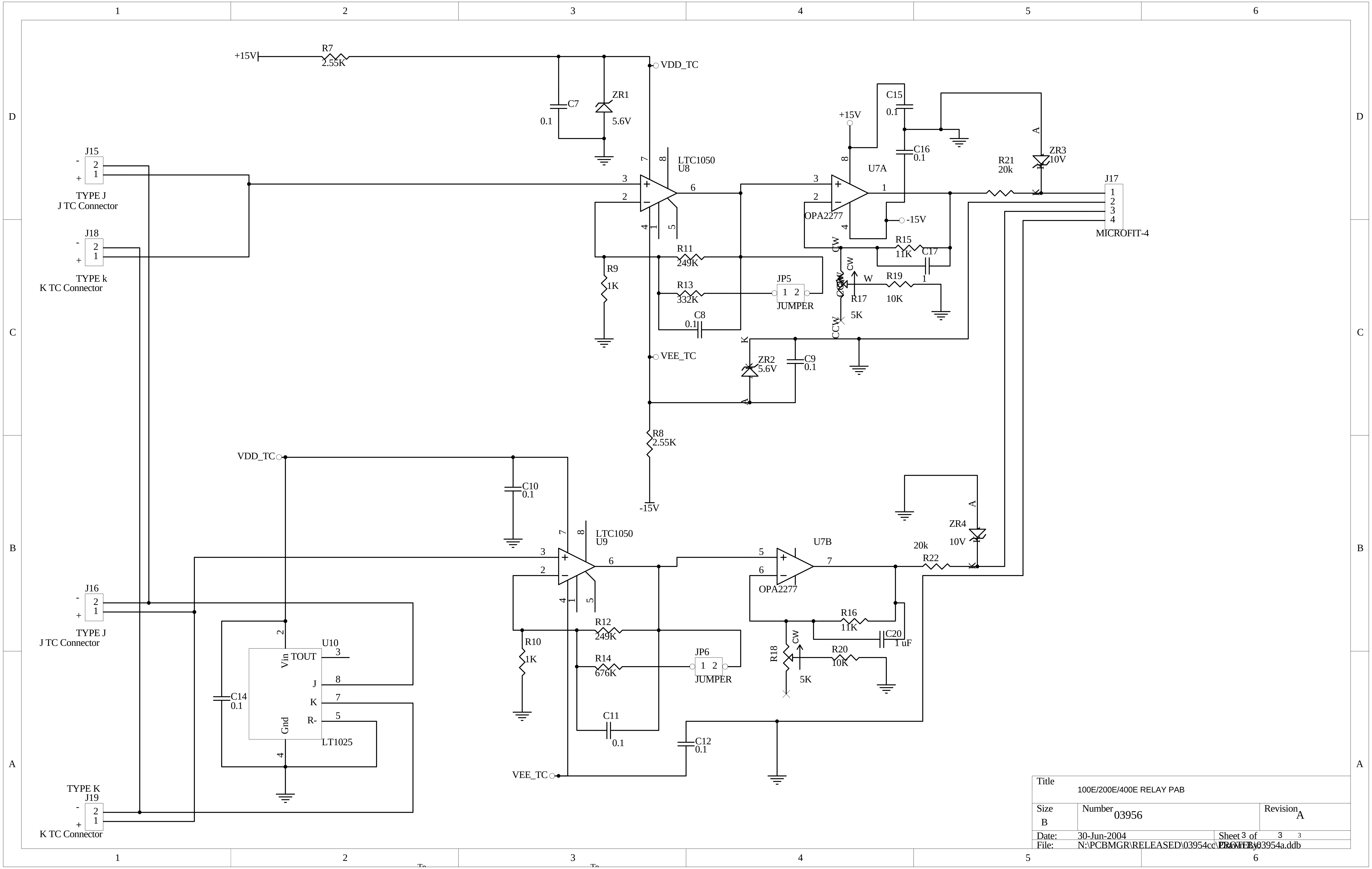
PCA 03631, Isolated 0-20ma, E Series

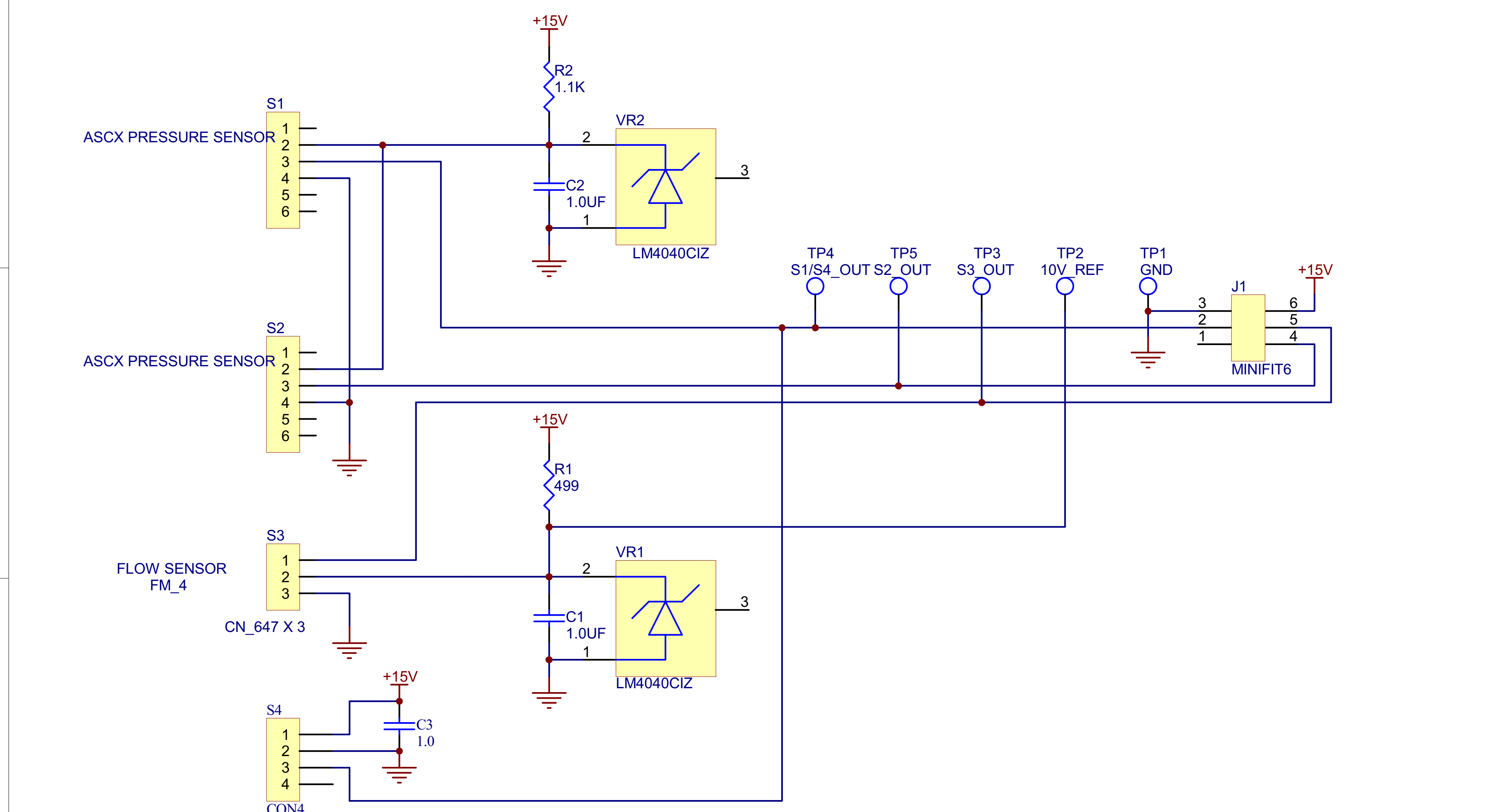
SIZE: B | DRAWING NO.: 03632 | REVISION: A

LAST MOD.: 19-Jul-2002 | SHEET 1 of 1


General Trace Width Requirements
1. Vcc (+5V) and I2C VCC should be 15 mil
2. Digitial grounds should be at least 20 mils
3. +12V and +12V return should be 30 mils
4. All AC lines (AC Line, AC Neutral, RELAY0 - 4, All signals on JP2) should be 30 mils wide, with 120 mil isolation/creepage distance around them
5. Traces between J7 - J12 should be top and bottom and at least 140 mils.
6. Traces to the test points can be as small as 10 mils.
J1
AC_Line
AC_Neutral
4 PIN
VCC
R1 2.2K
R2 2.2K
JP1
HEADER 4X2
RN1 330
I2C_Vcc
RELAY0
RELAY1
RELAY2
K1
K2
K3
SLD-RLY
JP2
Heater Config Jumper
J216 PIN
COMMON0
LOAD0
TS0
COMMON1
LOAD1
TS1
COMMON2
LOAD2
TS2
AC_Neutral
D1 WDOG RED
D2 YEL RL0
D3 YEL RL1
D4 YEL RL2
D7 GRN VA0
D8 GRN VA1
D9 GRN VA2
D10 GRN VA3
C1 0.1
U1
PCF8575
J3
CON5
U2A
SN74HC04
U2B
U2C
U2D
U2E
U2F
VLV_ENAB
Q1
IRF7205
R3 20K
R5 10K
R6 10K
U4
MAX693
VBATT
VOUT
GND
BATT_ONCD
LOW LINE'
OSC IN
OSC SEL
RESET
RESET'
WDO'
CD IN'
CD OUT'
WDI
PFO'
PFI
C2 0.001
C3 1
C4 10/16
C5 10/16
D17 RLS4148
R4 1M
JP4
WTCDG OVR
JP3
HEADER 1X2
U5
UDN2540B(16)
J4
8 PIN
+12V
VALVE0
VALVE1
VALVE2
VALVE3
C6 2000/25
TP1 DGND
TP2 +5V
TP3 AGND
TP4 +15V
TP5 -15V
TP6 +12RT
TP7 +12V
DC PWR IN
J5
DGND
VCC
AGND
+15V
-15V
+12RET
+12V
EGND
CHS_GND
KEYBRD J7
MTHR BRD J8
SYNC DEMOD J9
SPARE J10
J11
J12
CON10THROUGH
REV AUTH DATE
B CAC 10/3/02 CE MARK LINE VOLTAGE TRACE SPACING FIX
Title M100E/M200E Relay PCB
Size B
Number 03956
Revision A
Date: 30-Jun-2004
Sheet 1 of 3
File: N:\PCBMGR\RELEASED\03954cc\PROTEL\03954a.ddb
APPLIES TO PCB 03954


AC_Line
RELAY3
RELAY4
J20
Aux Relay Connector
MOLEX6
AC_Neutral
RN2
330
I2C_Vcc
K4
K5
SLD-RLY
D5 YEL RL3
D6 YEL RL4
D11 GRN VA4
D12 GRN VA5
D13 GRN VA6
D14 GRN VA7
D15 GRN TR0
D16 GRN TR1
IO3
IO4
IO10
IO11
IO12
IO13
IO14
IO15
U3A
SN74HC04
U3B
U3C
U3D
U3E
U3F
VCC
C13
0.1
U6
UDN2540B(16)
IN 4
IN 3
ENABLE
IN 2
IN 1
OUT4
OUT 3
OUT 2
OUT 1
GND
VLV_ENAB
+12V
J6
CON10
Valve4
Valve5
Valve6
Valve7
J13
MINIFIT-2
J14
MINIFIT-2
Q2
IRL3303
Q3
IRL3303
Use 50 mil traces
Use 40 mil traces
+12RET
Title
100E/200E/400E RELAY PCB
Size
B
Number
03956
Revision
A
Date:
30-Jun-2004
Sheet 2 of 3
File:
N:\PCBMGR\RELEASED\03954cc\PROTEL\03954a.ddb
Drawn By:


+15V
R7
2.55K
VDD_TC
C7
0.1
ZR1
5.6V
LTC1050
U8
R11
249K
R9
1K
R13
332K
C8
0.1
VEE_TC
R8
2.55K
-15V
J15
TYPE J
J TC Connector
J18
TYPE k
K TC Connector
C15
0.1
+15V
C16
0.1
U7A
OPA2277
-15V
R15
11K
C17
1
R19
10K
R17
5K
JP5
JUMPER
ZR2
5.6V
C9
0.1
R21
20k
ZR3
10V
J17
MICROFIT-4
VDD_TC
C10
0.1
LTC1050
U9
U7B
OPA2277
ZR4
10V
20k
R22
R12
249K
R10
1K
R14
676K
JP6
JUMPER
R16
11K
C20
1 uF
R18
5K
R20
10K
C11
0.1
C12
0.1
VEE_TC
J16
TYPE J
J TC Connector
U10
LT1025
C14
0.1
TYPE K
J19
K TC Connector
Title
100E/200E/400E RELAY PAB
Size
B
Number
03956
Revision
A
Date:
30-Jun-2004
Sheet 3 of 3
File:
N:\PCBMGR\RELEASED\03954cc\PROTEL\03954a.ddb



TELEDYNE INSTRUMENTS
Advanced Pollution Instrumentation

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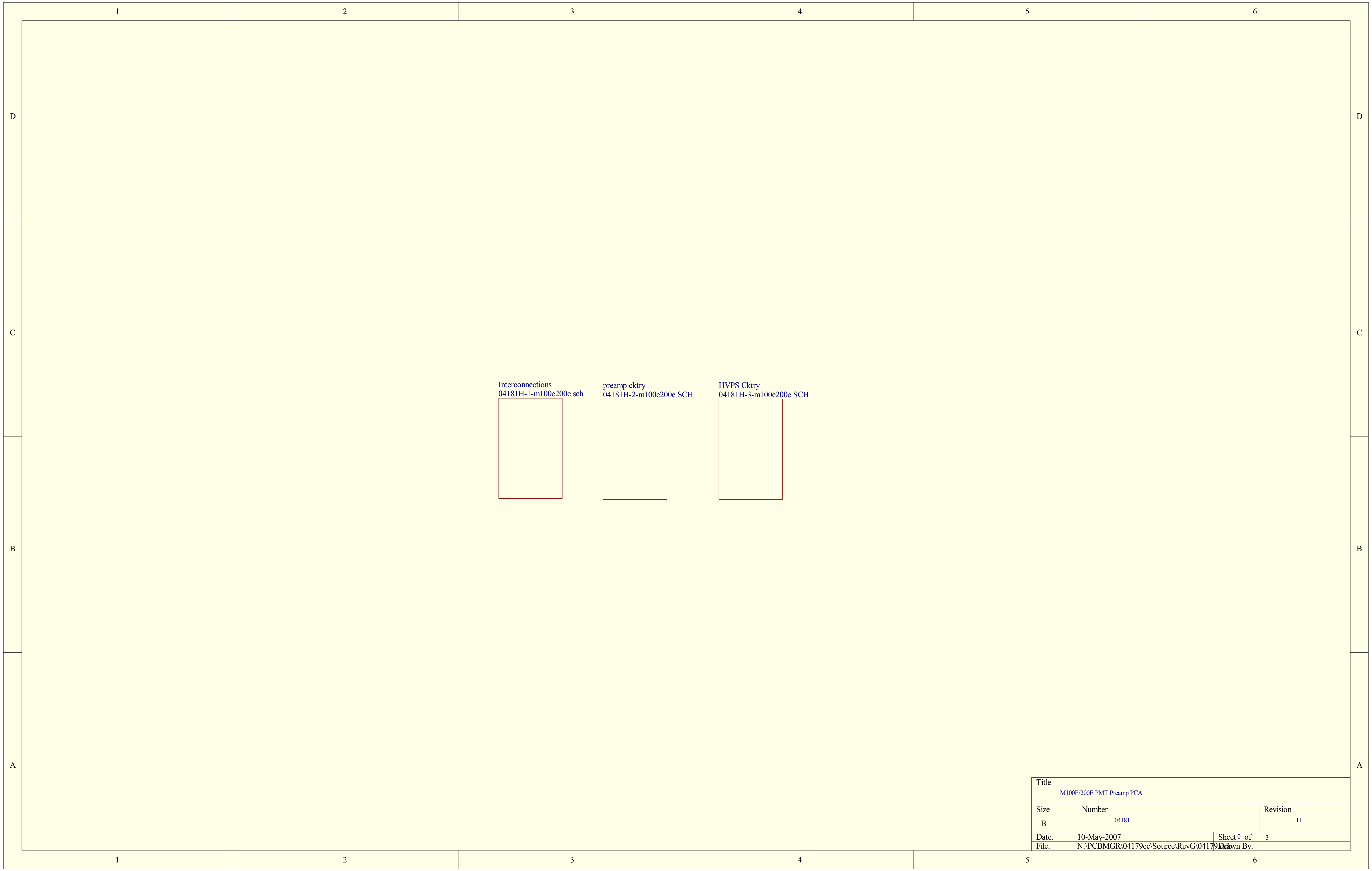
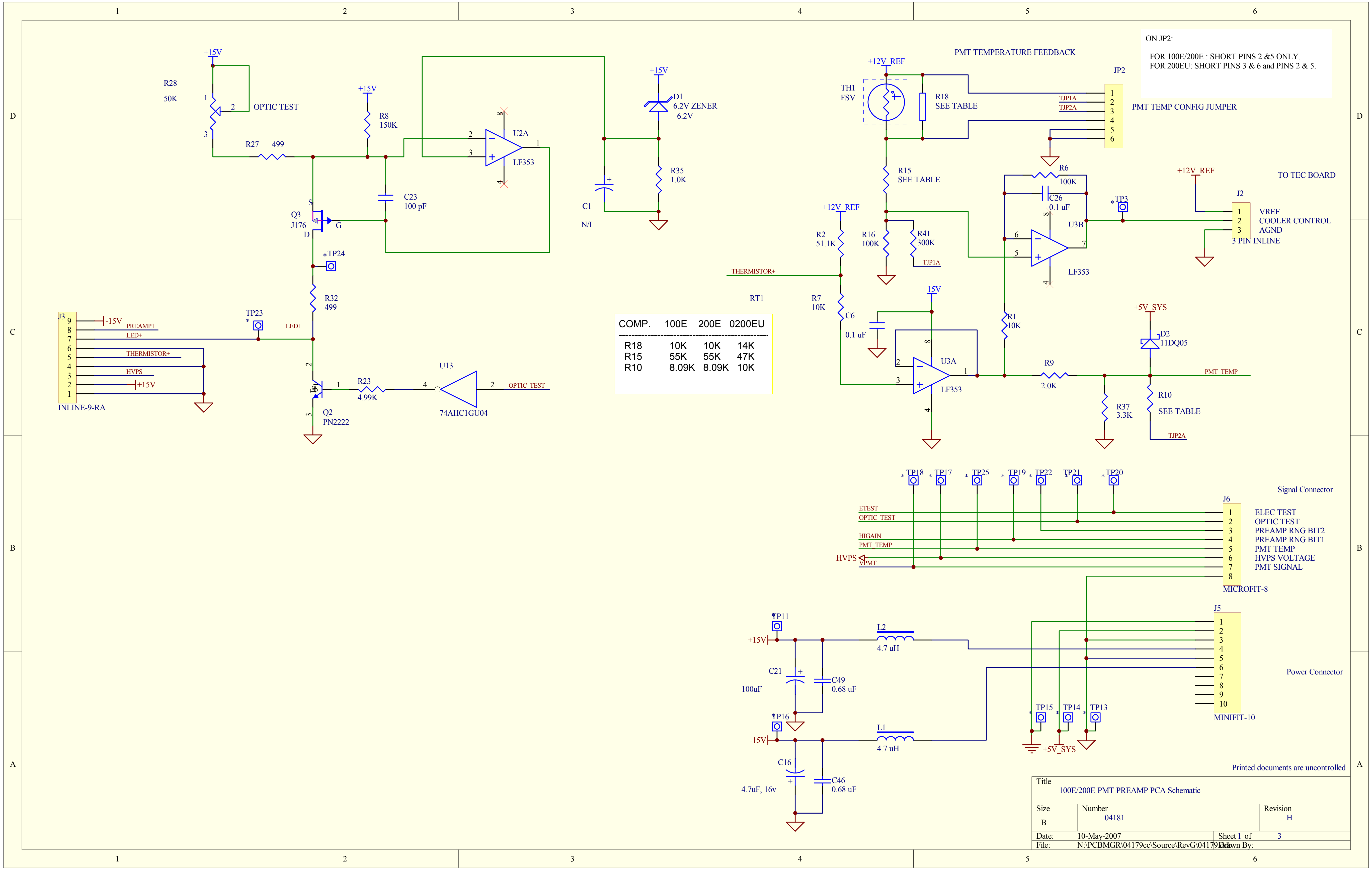
APPROVALS	DATE
DRAWN	
CHECKED	
APPROVED	

SCH, PCA 04003, PRESS/FLOW, 'E' SERIES

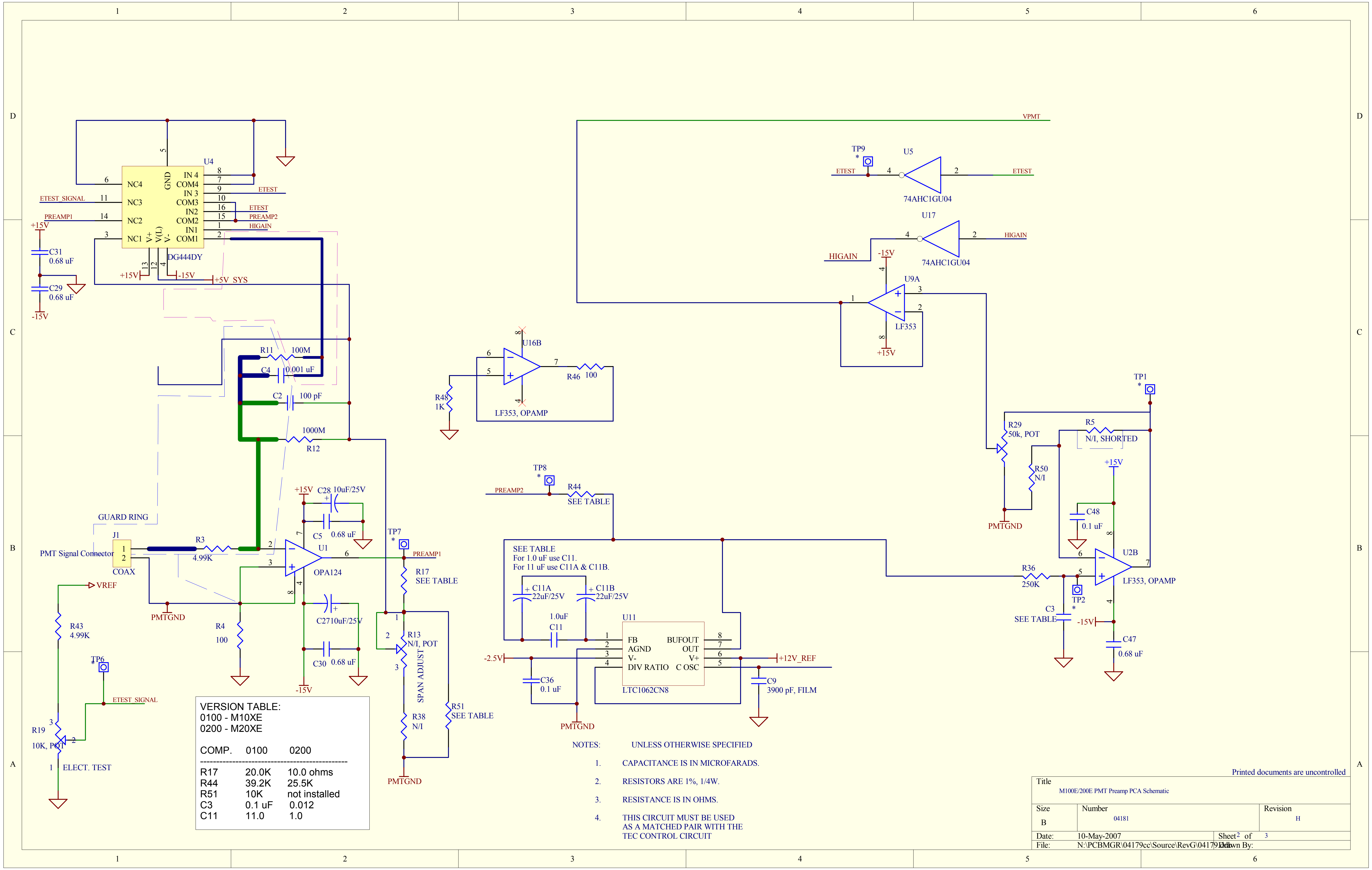
SIZE	DRAWING NO.	REVISION
B	04354	D

LAST MOD. 3-Dec-2007 SHEET 1 of 1


Interconnections
04181H-1-m100e200e.sch
preamp cktry
04181H-2-m100e200e.SCH
HVPS Cktry
04181H-3-m100e200e.SCH
Title
M100E/200E PMT Preamp PCA
Size
B
Number
04181
Revision
H
Date: 10-May-2007
Sheet 0 of 3
File: N:\PCBMGR\04179cc\Source\RevG\04179.ddb
Drawn By:



COMP.	100E	200E	0200EU
R18	10K	10K	14K
R15	55K	55K	47K
R10	8.09K	8.09K	10K



VERSION TABLE:
0100 - M10XE
0200 - M20XE

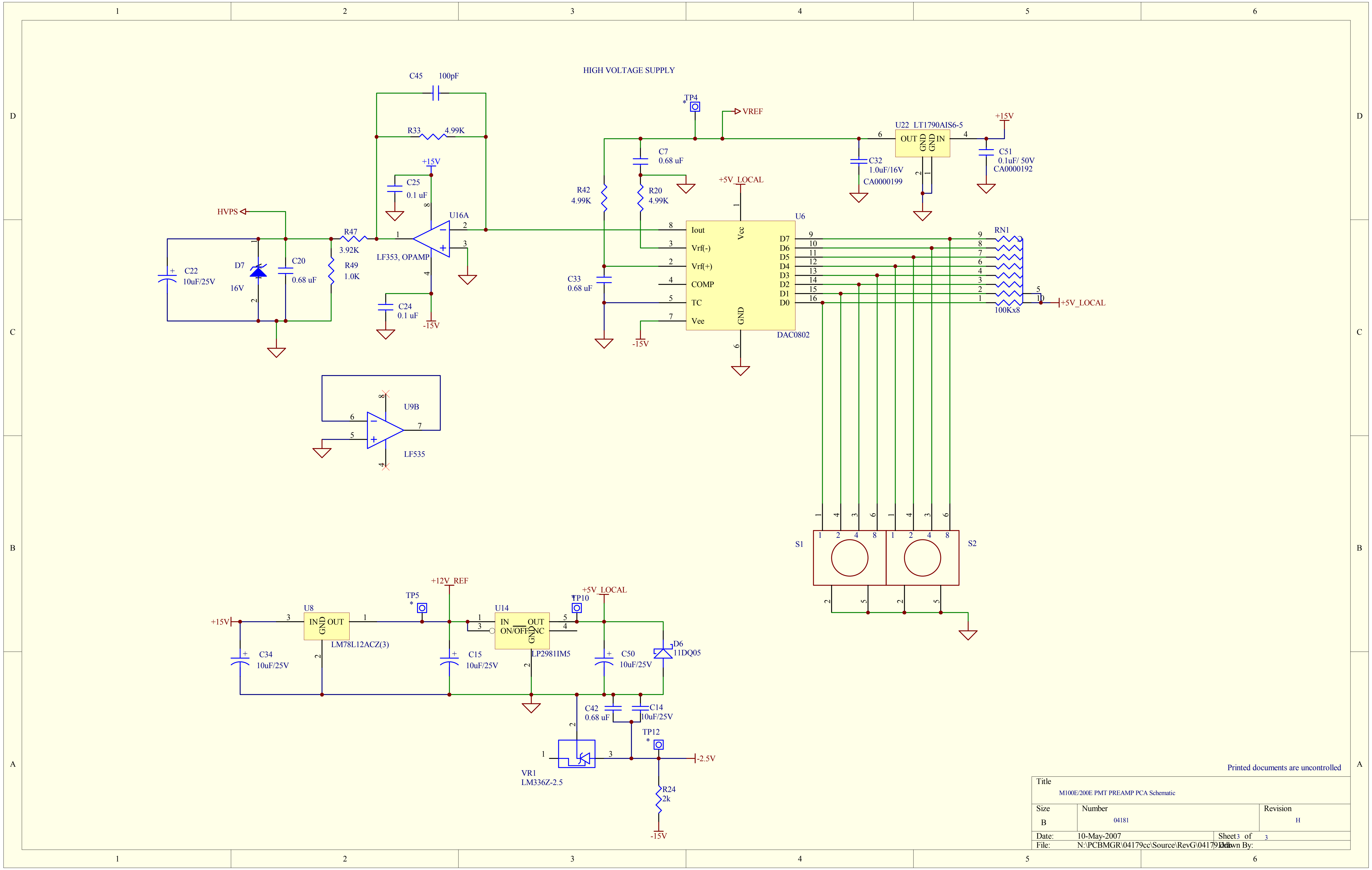
COMP.	0100	0200
R17	20.0K	10.0 ohms
R44	39.2K	25.5K
R51	10K	not installed
C3	0.1 uF	0.012
C11	11.0	1.0

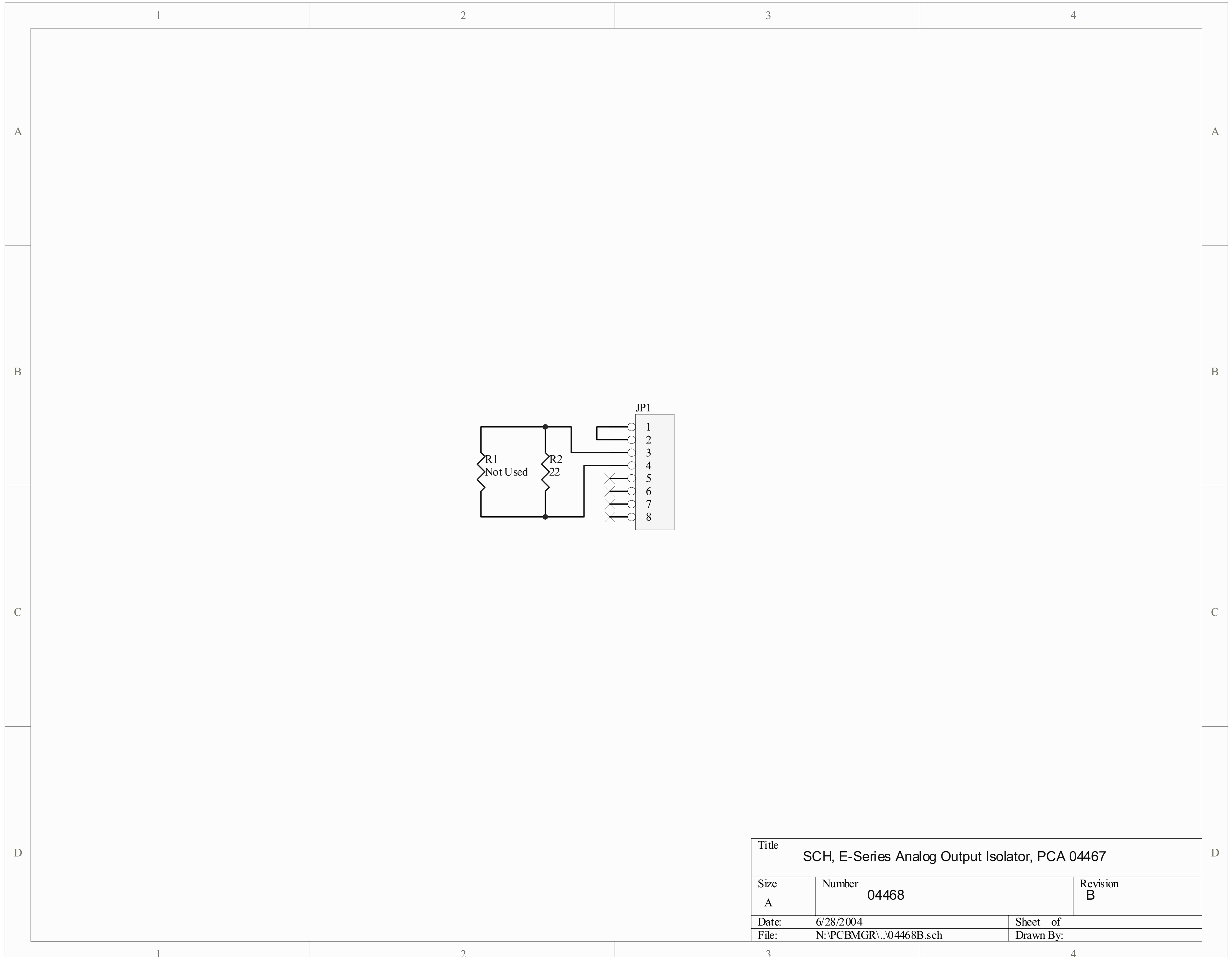
NOTES: UNLESS OTHERWISE SPECIFIED

1. CAPACITANCE IS IN MICROFARADS.
2. RESISTORS ARE 1%, 1/4W.
3. RESISTANCE IS IN OHMS.
4. THIS CIRCUIT MUST BE USED AS A MATCHED PAIR WITH THE TEC CONTROL CIRCUIT

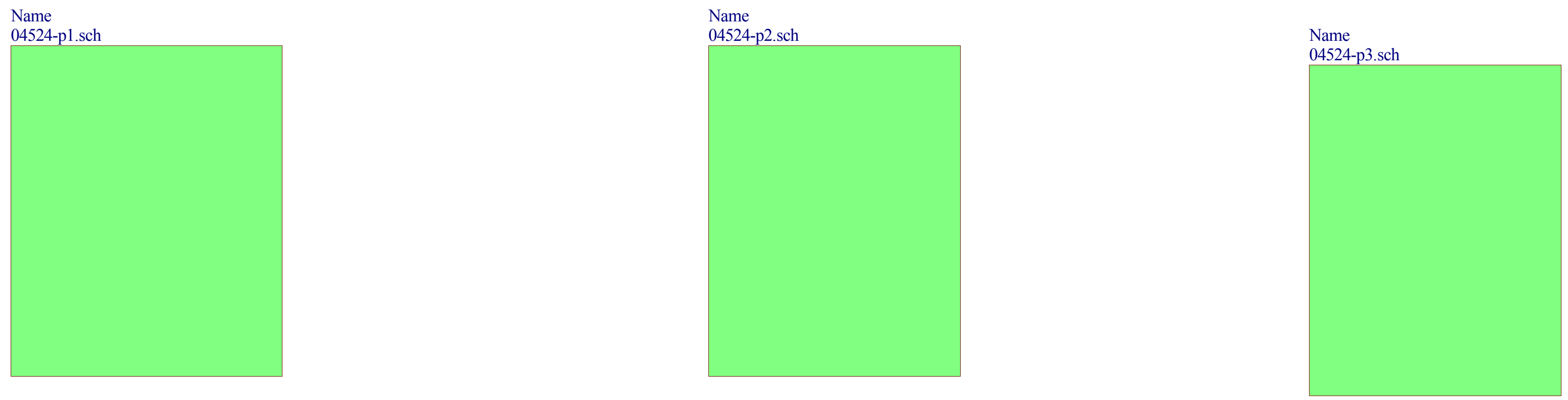
Printed documents are uncontrolled

Title: M100E/200E PMT Preamp PCA Schematic		
Size: B	Number: 04181	Revision: H
Date: 10-May-2007	Sheet 2 of 3	
File: N:\PCBMGR\04179cc\Source\RevG\04179.ddb	Drawn By:	

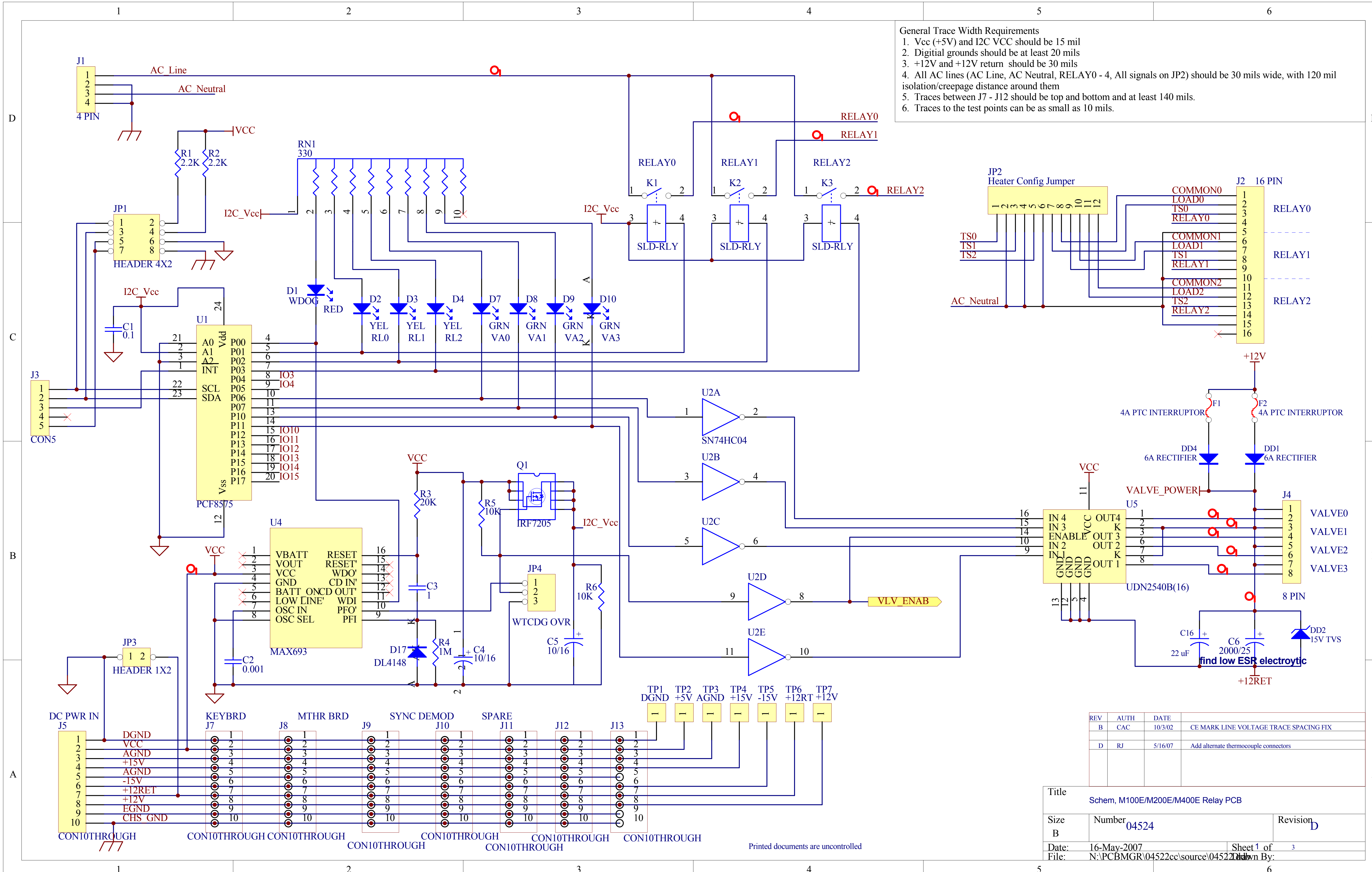

HIGH VOLTAGE SUPPLY
C45 100pF
R33 4.99K
+15V
C25 0.1 uF
U16A
LF353, OPAMP
R47 3.92K
R49 1.0K
HVPS
C22 10uF/25V
D7 16V
C20 0.68 uF
C24 0.1 uF
-15V
TP4
VREF
U22 LT1790AIS6-5
C51 0.1uF/ 50V CA0000192
C32 1.0uF/16V CA0000199
C7 0.68 uF
R42 4.99K
R20 4.99K
+5V_LOCAL
U6
DAC0802
Iout
Vrf(-)
Vrf(+)
COMP
TC
Vee
Vcc
GND
D7 D6 D5 D4 D3 D2 D1 D0
RN1 100Kx8
C33 0.68 uF
U9B
LF535
S1
S2
U8
LM78L12ACZ(3)
C34 10uF/25V
TP5
+12V_REF
C15 10uF/25V
U14
LP2981IM5
+5V_LOCAL
TP10
C50 10uF/25V
D6 11DQ05
C42 0.68 uF
C14 10uF/25V
TP12
-2.5V
VR1 LM336Z-2.5
R24 2k
Printed documents are uncontrolled
Title
M100E/200E PMT PREAMP PCA Schematic
Size B
Number 04181
Revision H
Date: 10-May-2007
Sheet 3 of 3
File: N:\PCBMGR\04179cc\Source\RevG\04179.ddb
Drawn By:

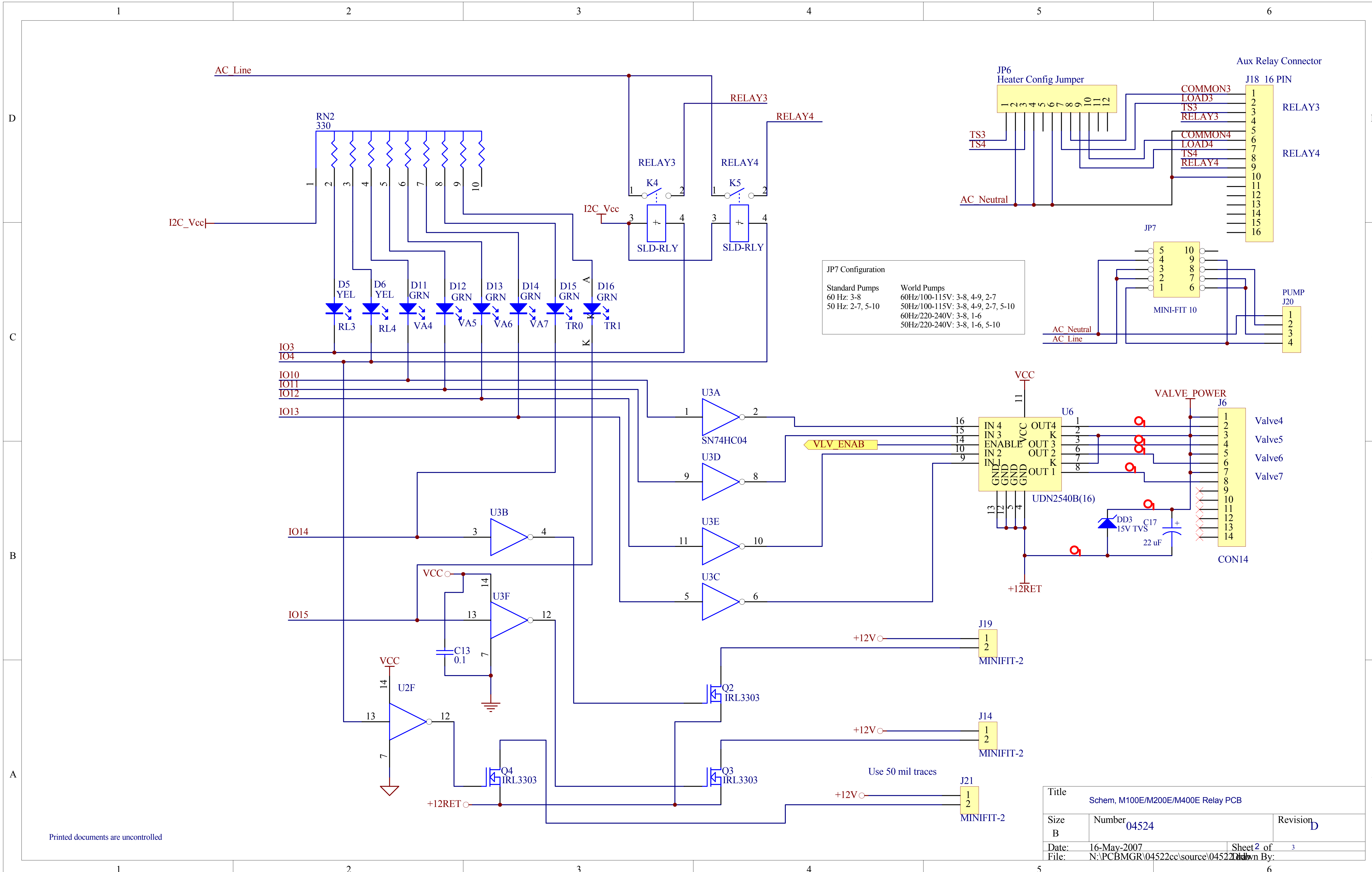


Title	SCH, E-Series Analog Output Isolator, PCA 04467		
Size: A	Number: 04468		Revision: B
Date: 6/28/2004		Sheet of	
File: N:\PCBMGR\..\04468B.sch		Drawn By:	

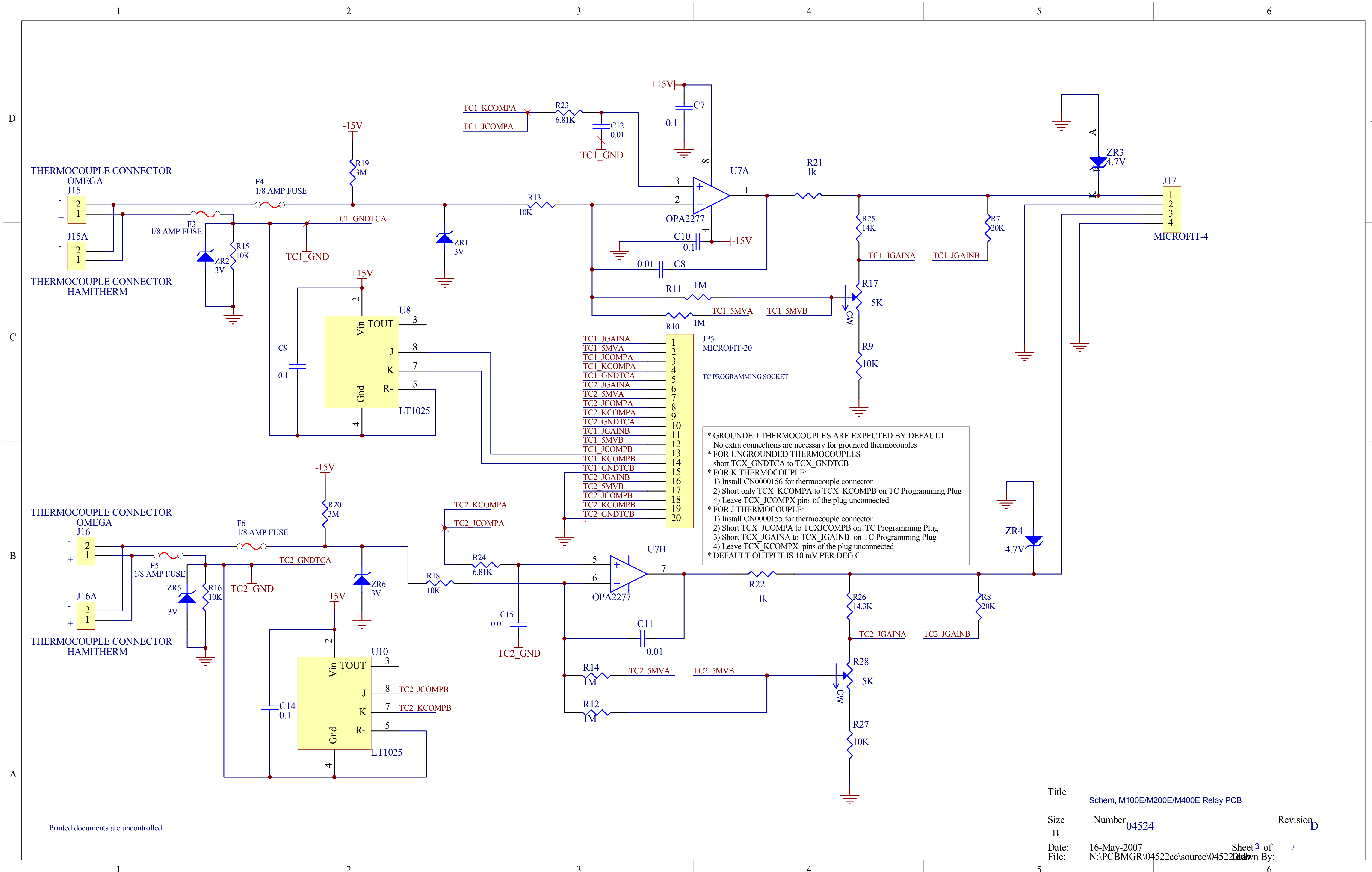


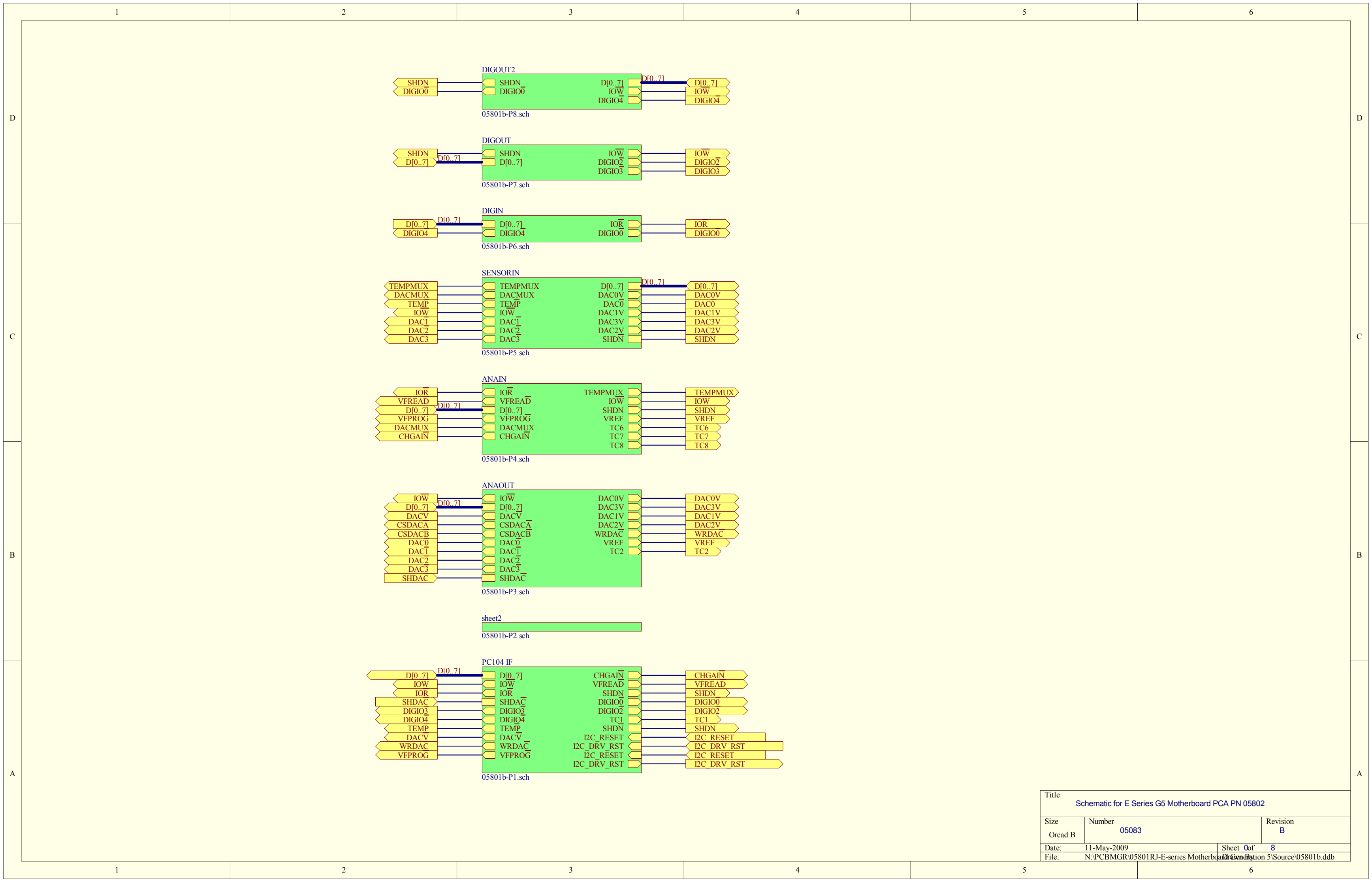
Title	M100E/200E/400E RELAY PCA SCHEMATIC
Size B	Number 04522	Revision D
Date: 16-May-2007	Sheet 0 of 0
File: N:\PCBMGR\04522cc\source\04522.ddb	Drawn By:

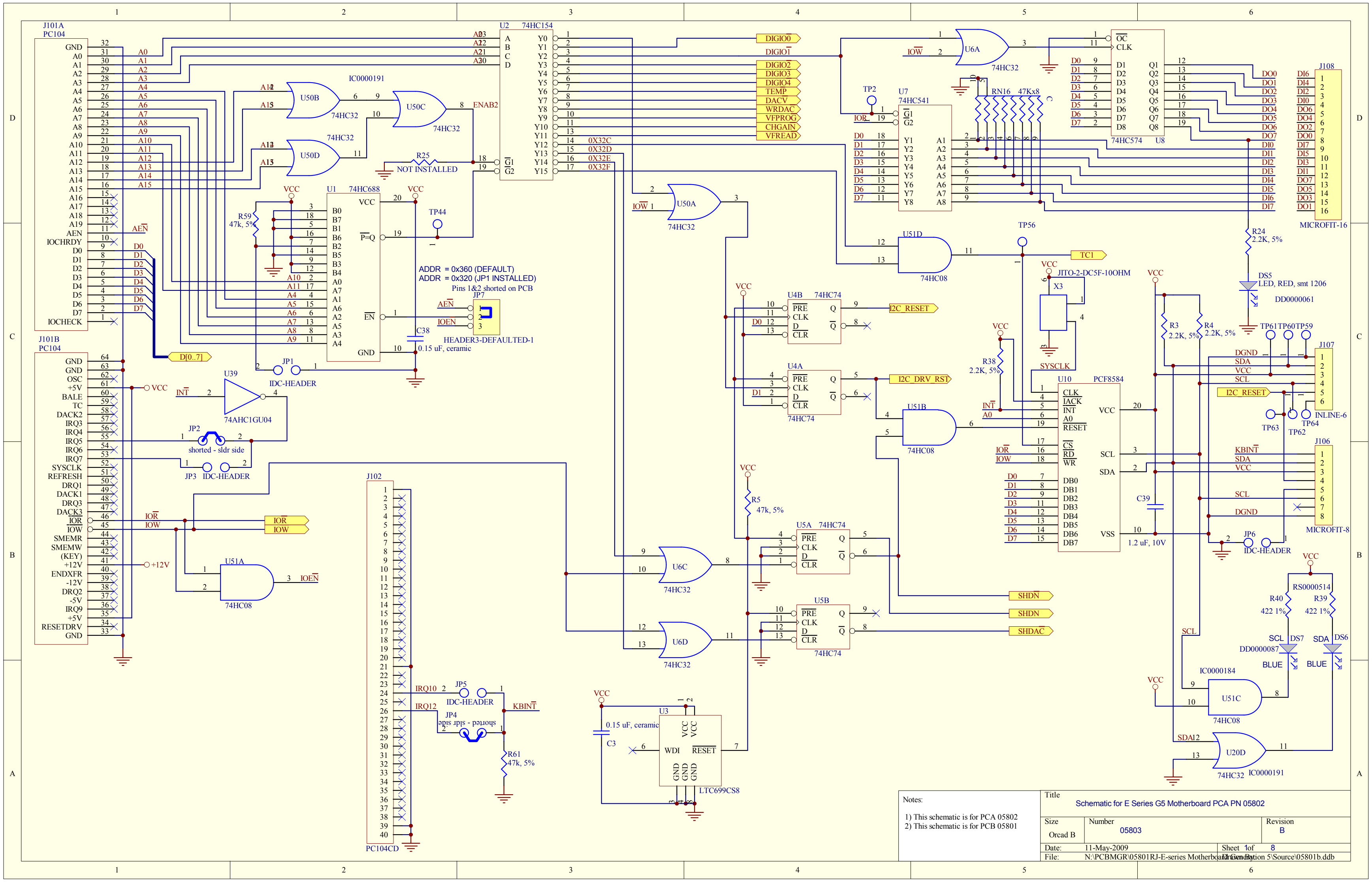

General Trace Width Requirements
1. Vcc (+5V) and I2C VCC should be 15 mil
2. Digitial grounds should be at least 20 mils
3. +12V and +12V return should be 30 mils
4. All AC lines (AC Line, AC Neutral, RELAY0 - 4, All signals on JP2) should be 30 mils wide, with 120 mil isolation/creepage distance around them
5. Traces between J7 - J12 should be top and bottom and at least 140 mils.
6. Traces to the test points can be as small as 10 mils.
J1
AC_Line
AC_Neutral
4 PIN
VCC
R1 2.2K
R2 2.2K
JP1
HEADER 4X2
RN1 330
I2C_Vcc
D1 WDOG RED
D2 YEL RL0
D3 YEL RL1
D4 YEL RL2
D7 GRN VA0
D8 GRN VA1
D9 GRN VA2
D10 GRN VA3
RELAY0
RELAY1
RELAY2
K1
K2
K3
SLD-RLY
JP2 Heater Config Jumper
J2 16 PIN
COMMON0
LOAD0
TS0
COMMON1
LOAD1
TS1
COMMON2
LOAD2
TS2
AC_Neutral
J3
CON5
C1 0.1
U1
PCF8575
A0 A1 A2 INT SCL SDA Vdd Vss
IO3 IO4 IO10 IO11 IO12 IO13 IO14 IO15
U2A
SN74HC04
U2B
U2C
U2D
U2E
VLV_ENAB
+12V
F1 4A PTC INTERRUPTOR
F2 4A PTC INTERRUPTOR
DD4 6A RECTIFIER
DD1 6A RECTIFIER
VALVE_POWER
U5
UDN2540B(16)
IN 4 IN 3 ENABLE IN 2 IN 1 OUT4 K OUT 3 OUT 2 K OUT 1 GND VCC
J4
VALVE0
VALVE1
VALVE2
VALVE3
8 PIN
C16 22 uF
C6 2000/25
find low ESR electroytic
DD2 15V TVS
+12RET
U4
MAX693
VBATT VOUT VCC GND BATT_ON LOW LINE' OSC IN OSC SEL
RESET RESET' WDO' CD IN' CD OUT' WDI PFO' PFI
Q1
IRF7205
R3 20K
R5 10K
R6 10K
C3 1
C4 10/16
C5 10/16
C2 0.001
D17 DL4148
R4 1M
JP4
WTCDG OVR
JP3
HEADER 1X2
DC PWR IN
J5
DGND
VCC
AGND
+15V
AGND
-15V
+12RET
+12V
EGND
CHS_GND
CON10THROUGH
KEYBRD J7
MTHR BRD J8
SYNC DEMOD J9
J10
SPARE J11
J12
J13
TP1 DGND
TP2 +5V
TP3 AGND
TP4 +15V
TP5 -15V
TP6 +12RT
TP7 +12V
REV AUTH DATE
B CAC 10/3/02 CE MARK LINE VOLTAGE TRACE SPACING FIX
D RJ 5/16/07 Add alternate thermocouple connectors
Title Schem, M100E/M200E/M400E Relay PCB
Size B
Number 04524
Revision D
Date: 16-May-2007
Sheet 1 of 3
File: N:\PCBMGR\04522cc\source\04522.ddb
Drawn By:
Printed documents are uncontrolled

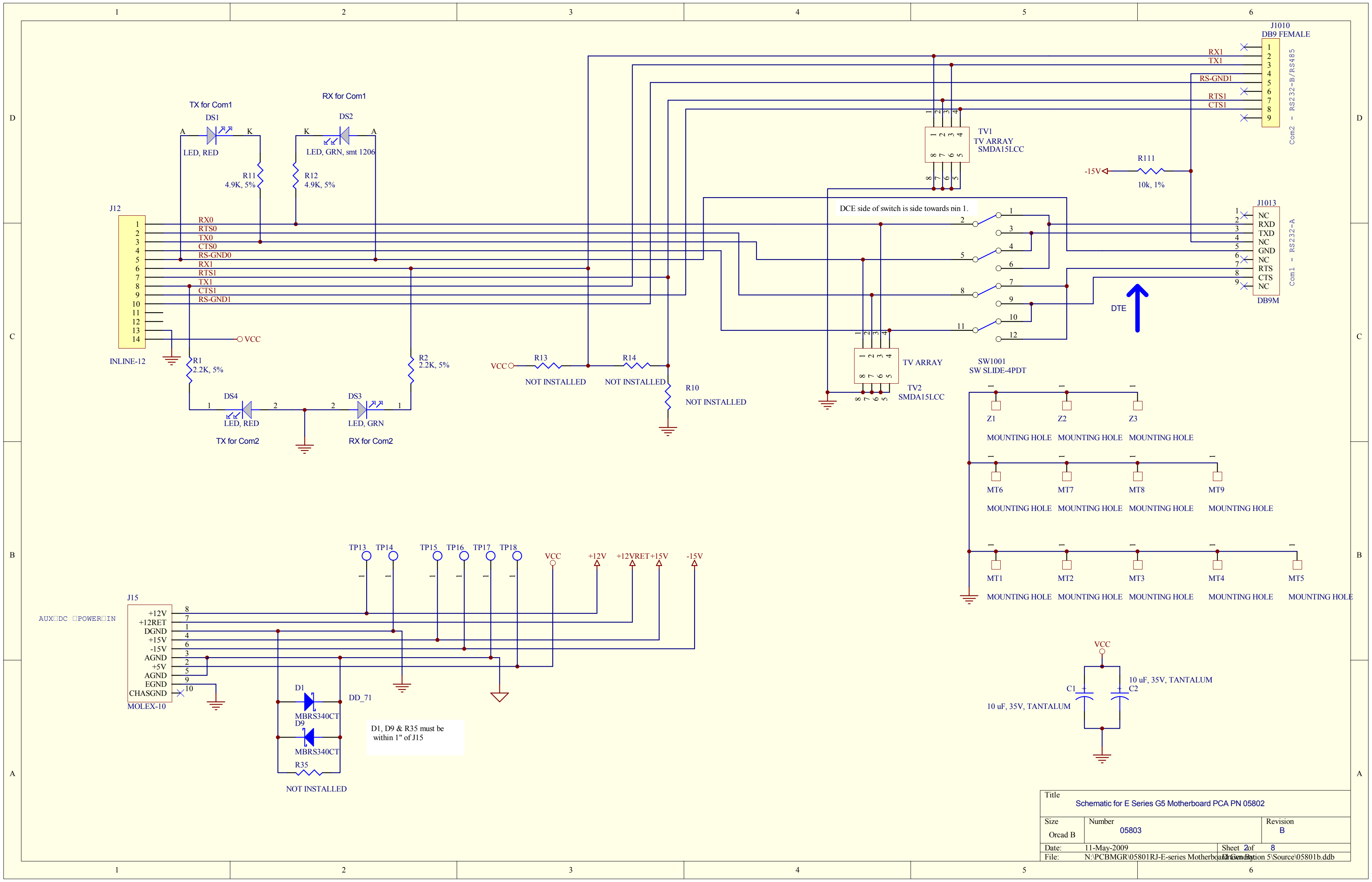


Title	Schem, M100E/M200E/M400E Relay PCB		
Size B	Number 04524		Revision D
Date: 16-May-2007		Sheet 2 of 3	
File: N:\PCBMGR\04522cc\source\04522.ddb		Drawn By:	

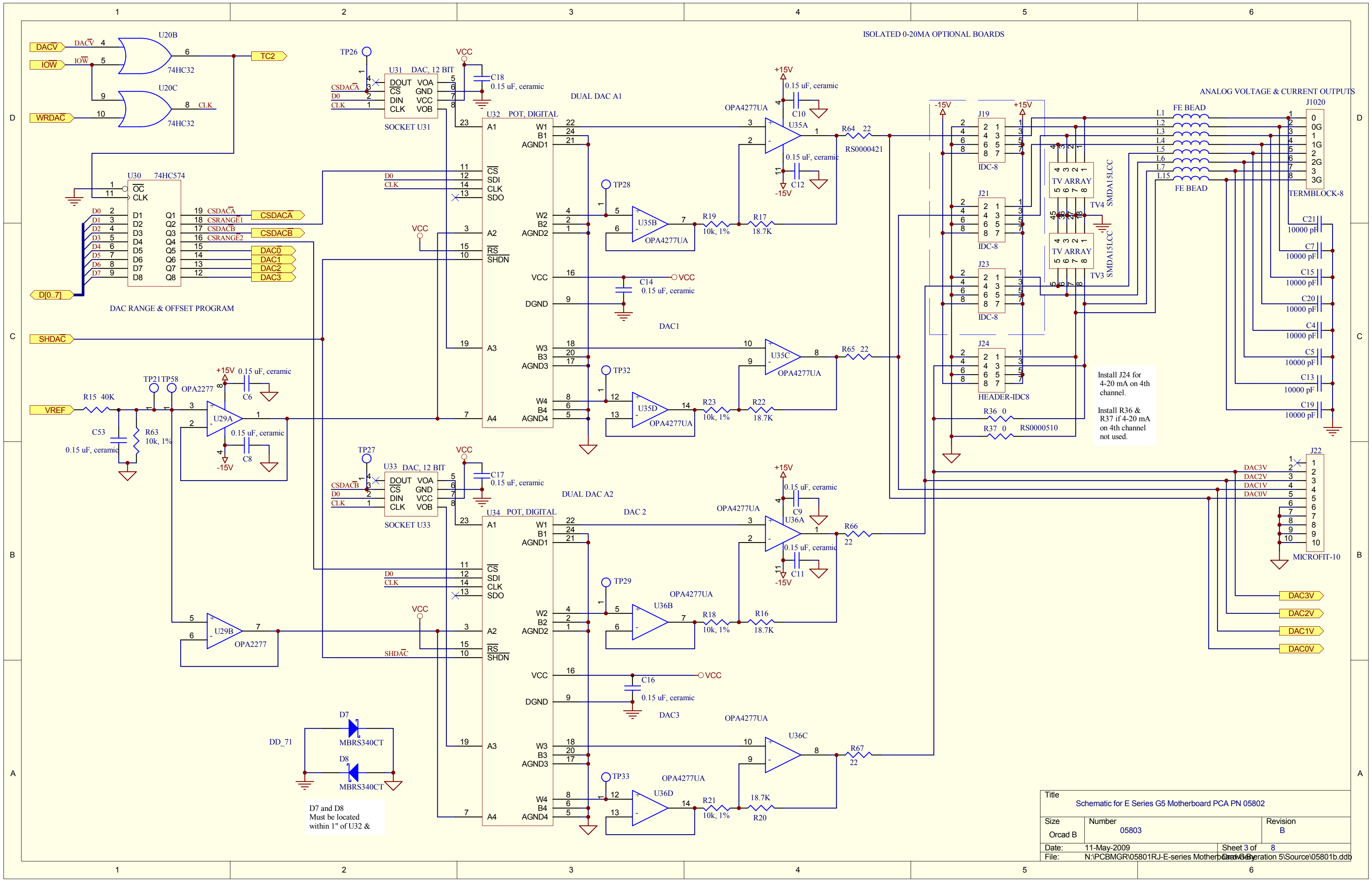

THERMOCOUPLE CONNECTOR
OMEGA
J15
J15A
THERMOCOUPLE CONNECTOR
HAMITHERM
F4
1/8 AMP FUSE
F3
1/8 AMP FUSE
R19
3M
-15V
+15V
ZR1
3V
ZR2
3V
R15
10K
TC1_GNDTCA
TC1_GND
TC1_KCOMPA
TC1_JCOMPA
R23
6.81K
C12
0.01
C7
0.1
R13
10K
U7A
OPA2277
C10
0.1
C8
0.01
R11
1M
R10
1M
TC1_5MVA
TC1_5MVB
R21
1k
R25
14K
R7
20K
TC1_JGAINA
TC1_JGAINB
R17
5K
CW
R9
10K
ZR3
4.7V
J17
MICROFIT-4
U8
LT1025
Vin
TOUT
J
K
R-
Gnd
C9
0.1
JP5
MICROFIT-20
TC PROGRAMMING SOCKET
TC1_JGAINA
TC1_5MVA
TC1_JCOMPA
TC1_KCOMPA
TC1_GNDTCA
TC2_JGAINA
TC2_5MVA
TC2_JCOMPA
TC2_KCOMPA
TC2_GNDTCA
TC1_JGAINB
TC1_5MVB
TC1_JCOMPB
TC1_KCOMPB
TC1_GNDTCB
TC2_JGAINB
TC2_5MVB
TC2_JCOMPB
TC2_KCOMPB
TC2_GNDTCB
* GROUNDED THERMOCOUPLES ARE EXPECTED BY DEFAULT
No extra connections are necessary for grounded thermocouples
* FOR UNGROUNDED THERMOCOUPLES
short TCX_GNDTCA to TCX_GNDTCB
* FOR K THERMOCOUPLE:
1) Install CN0000156 for thermocouple connector
2) Short only TCX_KCOMPA to TCX_KCOMPB on TC Programming Plug
4) Leave TCX_JCOMPX pins of the plug unconnected
* FOR J THERMOCOUPLE:
1) Install CN0000155 for thermocouple connector
2) Short TCX_JCOMPA to TCXJCOMPB on TC Programming Plug
3) Short TCX_JGAINA to TCX_JGAINB on TC Programming Plug
4) Leave TCX_KCOMPX pins of the plug unconnected
* DEFAULT OUTPUT IS 10 mV PER DEG C
THERMOCOUPLE CONNECTOR
OMEGA
J16
J16A
THERMOCOUPLE CONNECTOR
HAMITHERM
F6
1/8 AMP FUSE
F5
1/8 AMP FUSE
R20
3M
ZR5
3V
R16
10K
TC2_GNDTCA
TC2_GND
ZR6
3V
TC2_KCOMPA
TC2_JCOMPA
R24
6.81K
R18
10K
C15
0.01
U7B
OPA2277
C11
0.01
R22
1k
R14
1M
R12
1M
TC2_5MVA
TC2_5MVB
R26
14.3K
R8
20K
TC2_JGAINA
TC2_JGAINB
R28
5K
R27
10K
ZR4
4.7V
U10
LT1025
C14
0.1
TC2_JCOMPB
TC2_KCOMPB
Printed documents are uncontrolled
Title
Schem, M100E/M200E/M400E Relay PCB
Size
B
Number
04524
Revision
D
Date: 16-May-2007
Sheet 3 of 3
File: N:\PCBMGR\04522cc\source\04522.ddb
Drawn By:

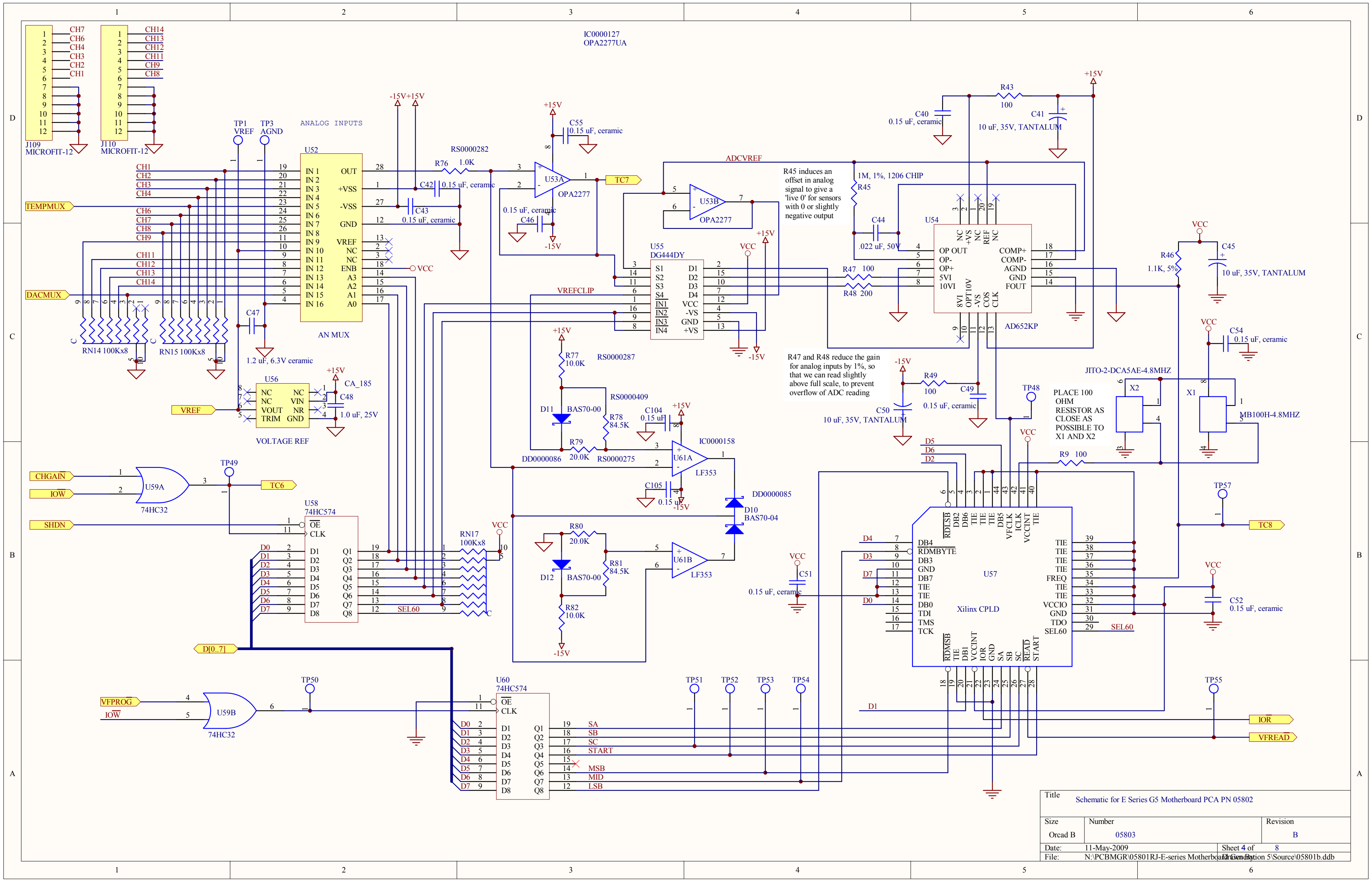

DIGOUT2
05801b-P8.sch
DIGOUT
05801b-P7.sch
DIGIN
05801b-P6.sch
SENSORIN
05801b-P5.sch
ANAIN
05801b-P4.sch
ANAOUT
05801b-P3.sch
sheet2
05801b-P2.sch
PC104 IF
05801b-P1.sch
Title
Schematic for E Series G5 Motherboard PCA PN 05802
Size
Orcad B
Number
05083
Revision
B
Date: 11-May-2009
Sheet 0 of 8
File: N:\PCBMGR\05801RJ-E-series Motherboard Generation 5\Source\05801b.ddb

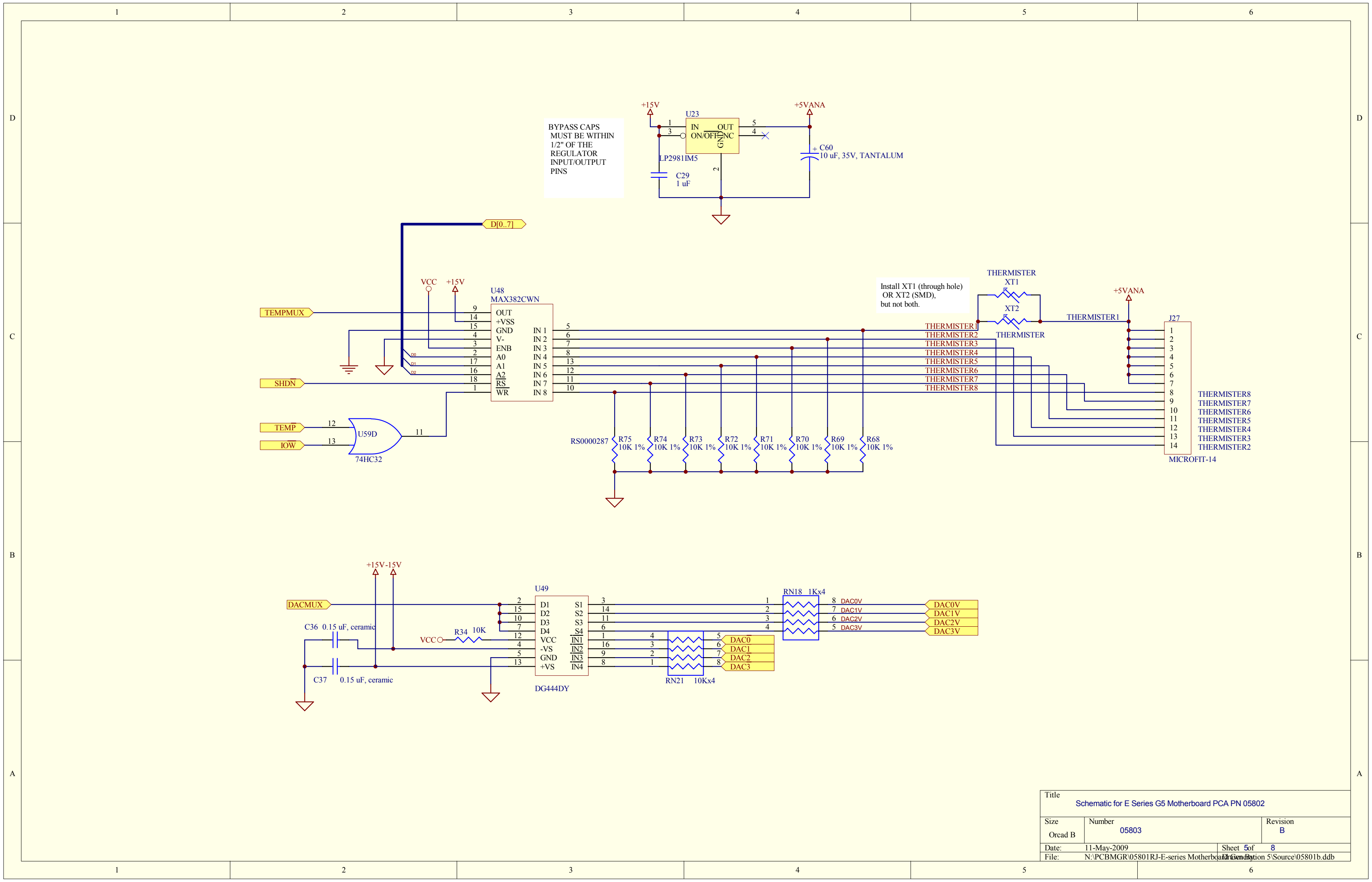

Notes:
1) This schematic is for PCA 05802
2) This schematic is for PCB 05801
Title
Schematic for E Series G5 Motherboard PCA PN 05802
Size
Orcad B
Number
05803
Revision
B
Date: 11-May-2009
Sheet 1 of 8
File: N:\PCBMGR\05801RJ-E-series Motherboard Generation 5\Source\05801b.ddb
ADDR = 0x360 (DEFAULT)
ADDR = 0x320 (JP1 INSTALLED)
Pins 1&2 shorted on PCB
J101A PC104
J101B PC104
J102 PC104CD
U2 74HC154
U1 74HC688
U7 74HC541
U8 74HC574
U10 PCF8584
U3 LTC699CS8
J108 MICROFIT-16
J107 INLINE-6
J106 MICROFIT-8



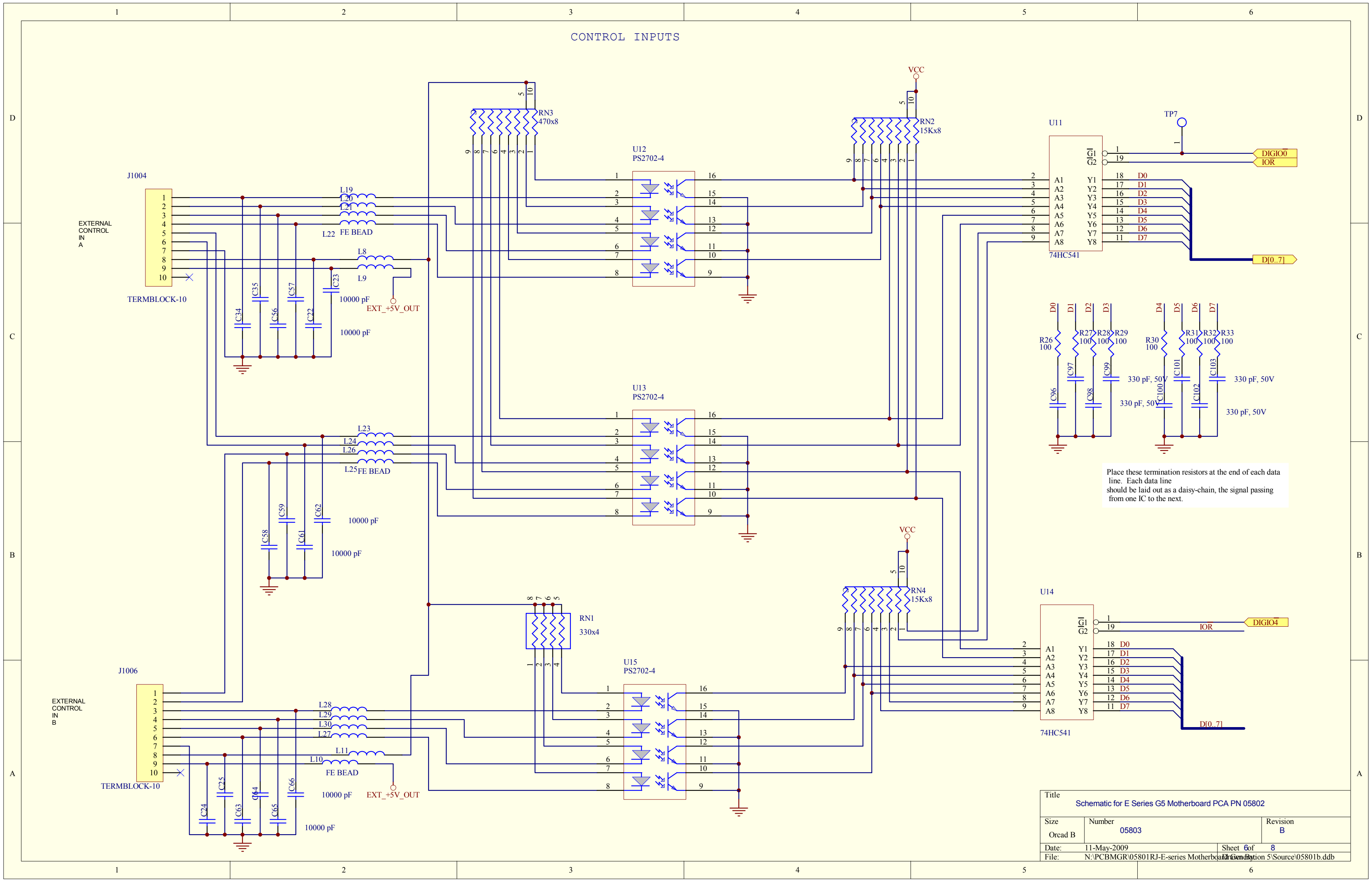
Title		
Schematic for E Series G5 Motherboard PCA PN 05802		
Size: Orcad B	Number: 05803	Revision: B
Date: 11-May-2009	Sheet 2 of 8	
File: N:\PCBMGR\05801RJ-E-series Motherboard Generation 5\Source\05801b.ddb		

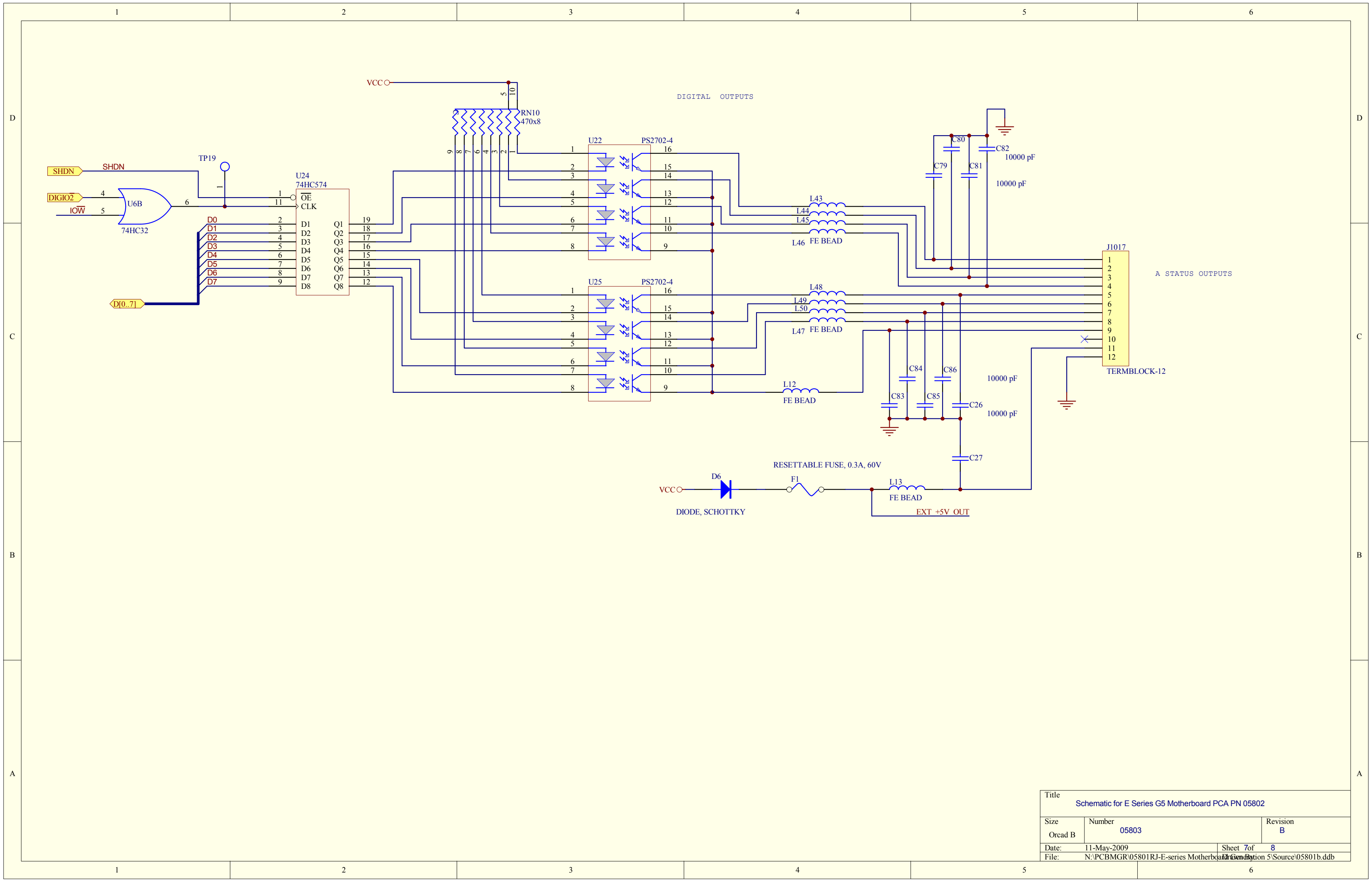

ISOLATED 0-20MA OPTIONAL BOARDS
ANALOG VOLTAGE & CURRENT OUTPUTS
DUAL DAC A1
DUAL DAC A2
DAC RANGE & OFFSET PROGRAM
DAC1
DAC 2
DAC3
SOCKET U31
SOCKET U33
U31 DAC, 12 BIT
U33 DAC, 12 BIT
U32 POT, DIGITAL
U34 POT, DIGITAL
U20B
U20C
74HC32
U30 74HC574
DACV
IOW
WRDAC
TC2
CSDACA
CSDACB
DAC0
DAC1
DAC2
DAC3
D[0..7]
SHDAC
VREF
OPA4277UA
OPA2277
0.15 uF, ceramic
10000 pF
FE BEAD
TV ARRAY
SMDA15LCC
TERMBLOCK-8
J1020
J22
MICROFIT-10
IDC-8
HEADER-IDC8
DAC3V
DAC2V
DAC1V
DAC0V
Install J24 for 4-20 mA on 4th channel.
Install R36 & R37 if 4-20 mA on 4th channel not used.
D7 and D8 Must be located within 1" of U32 &
MBRS340CT
DD_71
Title
Schematic for E Series G5 Motherboard PCA PN 05802
Size
Orcad B
Number
05803
Revision
B
Date: 11-May-2009
Sheet 3 of 8
File: N:\PCBMGR\05801RJ-E-series Motherboard\Generation 5\Source\05801b.ddb


IC0000127
OPA2277UA
ANALOG INPUTS
J109
MICROFIT-12
J110
MICROFIT-12
TEMPMUX
DACMUX
TP1 VREF
TP3 AGND
U52
AN MUX
RS0000282
R76 1.0K
U53A
OPA2277
TC7
C42 0.15 uF, ceramic
C43 0.15 uF, ceramic
C55 0.15 uF, ceramic
C46 0.15 uF, ceramic
U53B
OPA2277
ADCVREF
R45 induces an offset in analog signal to give a 'live 0' for sensors with 0 or slightly negative output
1M, 1%, 1206 CHIP
R45
C40 0.15 uF, ceramic
R43 100
C41 10 uF, 35V, TANTALUM
C44 .022 uF, 50V
U54
AD652KP
R47 100
R48 200
U55
DG444DY
VREFCLIP
RN14 100Kx8
RN15 100Kx8
C47 1.2 uF, 6.3V ceramic
U56
VOLTAGE REF
VREF
CA_185
C48 1.0 uF, 25V
R77 10.0K
RS0000287
RS0000409
D11 BAS70-00
R78 84.5K
C104 0.15 uF
R79 20.0K
RS0000275
DD0000086
IC0000158
U61A LF353
C105 0.15 uF
DD0000085
D10 BAS70-04
R80 20.0K
D12 BAS70-00
R81 84.5K
R82 10.0K
U61B LF353
R47 and R48 reduce the gain for analog inputs by 1%, so that we can read slightly above full scale, to prevent overflow of ADC reading
R49 100
C49 0.15 uF, ceramic
C50 10 uF, 35V, TANTALUM
TP48
PLACE 100 OHM RESISTOR AS CLOSE AS POSSIBLE TO X1 AND X2
JITO-2-DCA5AE-4.8MHZ
X2
X1
MB100H-4.8MHZ
R46 1.1K, 5%
C45 10 uF, 35V, TANTALUM
C54 0.15 uF, ceramic
R9 100
TP57
TC8
CHGAIN
IOW
U59A 74HC32
TP49
TC6
SHDN
U58 74HC574
RN17 100Kx8
SEL60
D[0..7]
U57
Xilinx CPLD
C51 0.15 uF, ceramic
C52 0.15 uF, ceramic
VFPROG
U59B 74HC32
TP50
U60 74HC574
SA
SB
SC
START
MSB
MID
LSB
TP51
TP52
TP53
TP54
TP55
IOR
VFREAD
Title Schematic for E Series G5 Motherboard PCA PN 05802
Size Orcad B
Number 05803
Revision B
Date: 11-May-2009
Sheet 4 of 8
File: N:\PCBMGR\05801RJ-E-series Motherboard Generation 5\Source\05801b.ddb

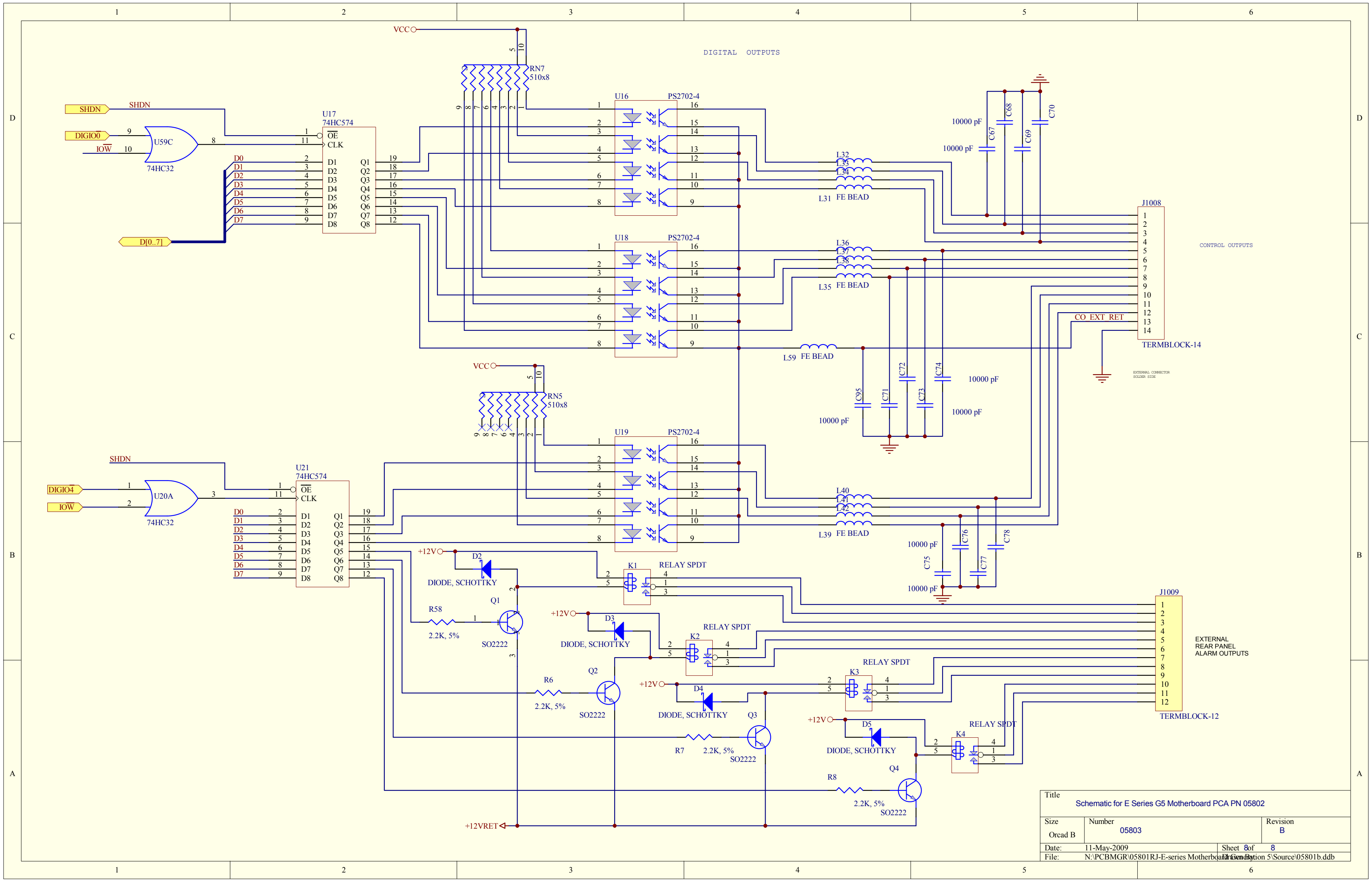


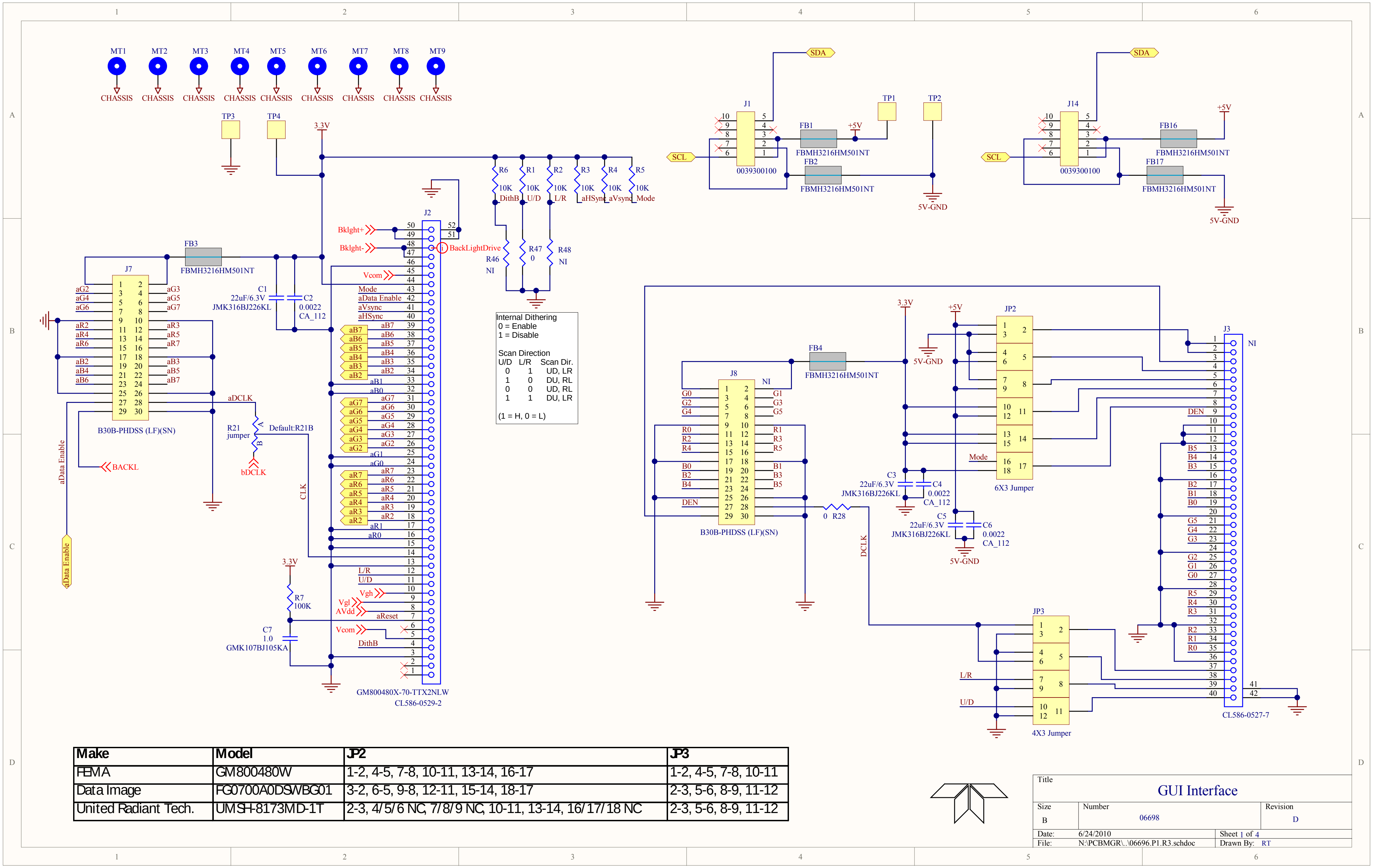
Title	Schematic for E Series G5 Motherboard PCA PN 05802	
Size: Orcad B	Number: 05803	Revision: B
Date: 11-May-2009	Sheet 5 of 8	
File: N:\PCBMGR\05801RJ-E-series Motherboard Generation 5\Source\05801b.ddb		


CONTROL INPUTS
J1004
EXTERNAL CONTROL IN A
TERMBLOCK-10
J1006
EXTERNAL CONTROL IN B
FE BEAD
10000 pF
EXT_+5V_OUT
RN3 470x8
RN2 15Kx8
RN4 15Kx8
RN1 330x4
U12 PS2702-4
U13 PS2702-4
U15 PS2702-4
U11 74HC541
U14 74HC541
VCC
TP7
DIGIO0
IOR
DIGIO4
D[0..7]
330 pF, 50V
Place these termination resistors at the end of each data line. Each data line should be laid out as a daisy-chain, the signal passing from one IC to the next.
Title: Schematic for E Series G5 Motherboard PCA PN 05802
Size: Orcad B
Number: 05803
Revision: B
Date: 11-May-2009
Sheet 6 of 8
File: N:\PCBMGR\05801RJ-E-series Motherboard\Gen 5\Source\05801b.ddb

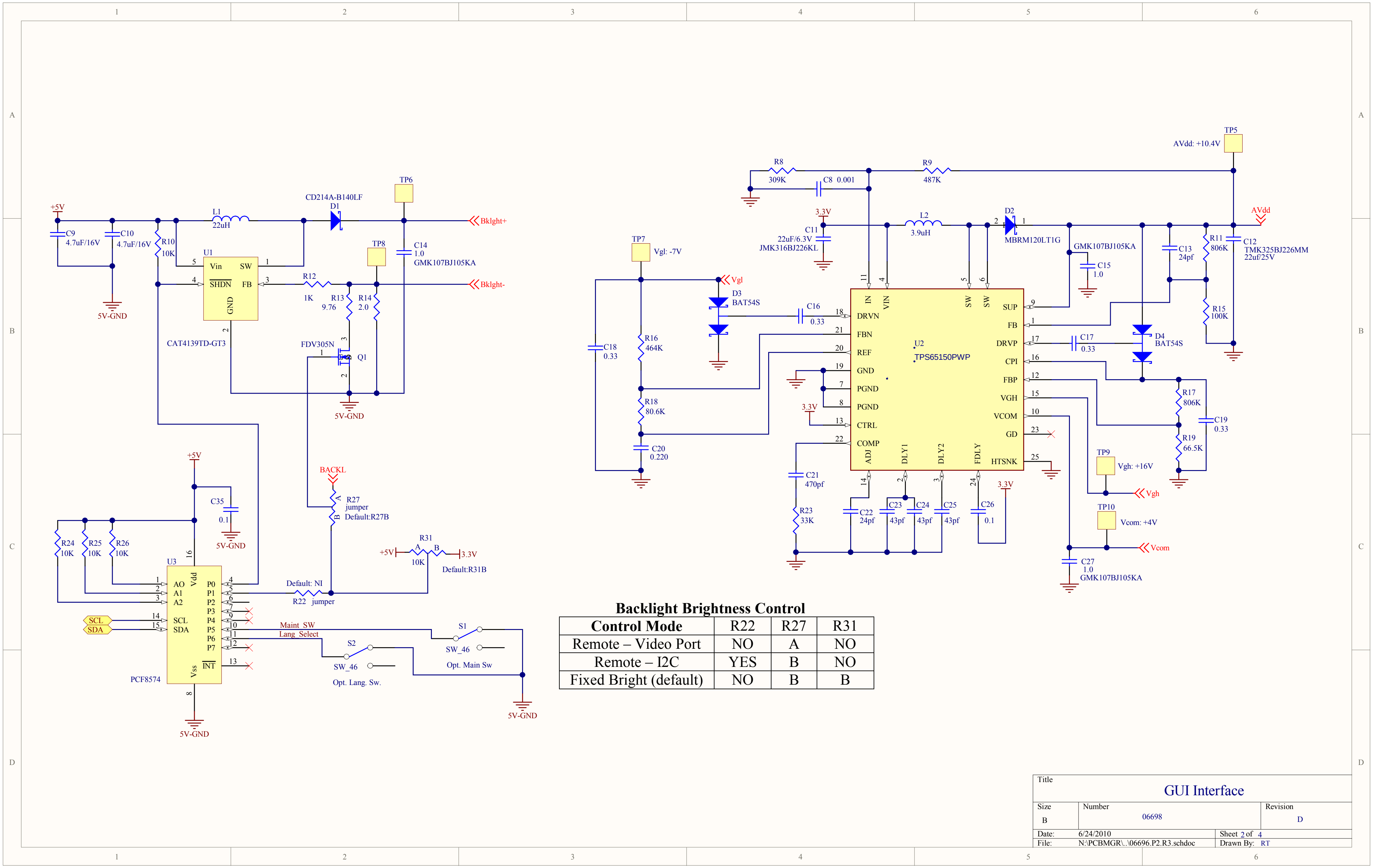


Title	Schematic for E Series G5 Motherboard PCA PN 05802	
Size: Orcad B	Number: 05803	Revision: B
Date: 11-May-2009	Sheet 7 of 8	
File: N:\PCBMGR\05801RJ-E-series Motherboard Generation 5\Source\05801b.ddb		


DIGITAL OUTPUTS
CONTROL OUTPUTS
EXTERNAL REAR PANEL ALARM OUTPUTS
U17 74HC574
U21 74HC574
U59C 74HC32
U20A 74HC32
U16 PS2702-4
U18 PS2702-4
U19 PS2702-4
RN7 510x8
RN5 510x8
J1008 TERMBLOCK-14
J1009 TERMBLOCK-12
CO EXT RET
RELAY SPDT
DIODE, SCHOTTKY
SO2222
2.2K, 5%
FE BEAD
10000 pF
SHDN
DIGIO0
DIGIO4
IOW
D[0..7]
VCC
+12V
+12VRET
Title
Schematic for E Series G5 Motherboard PCA PN 05802
Size
Orcad B
Number
05803
Revision
B
Date: 11-May-2009
Sheet 8 of 8
File: N:\PCBMGR\05801RJ-E-series Motherboard Generation 5\Source\05801b.ddb

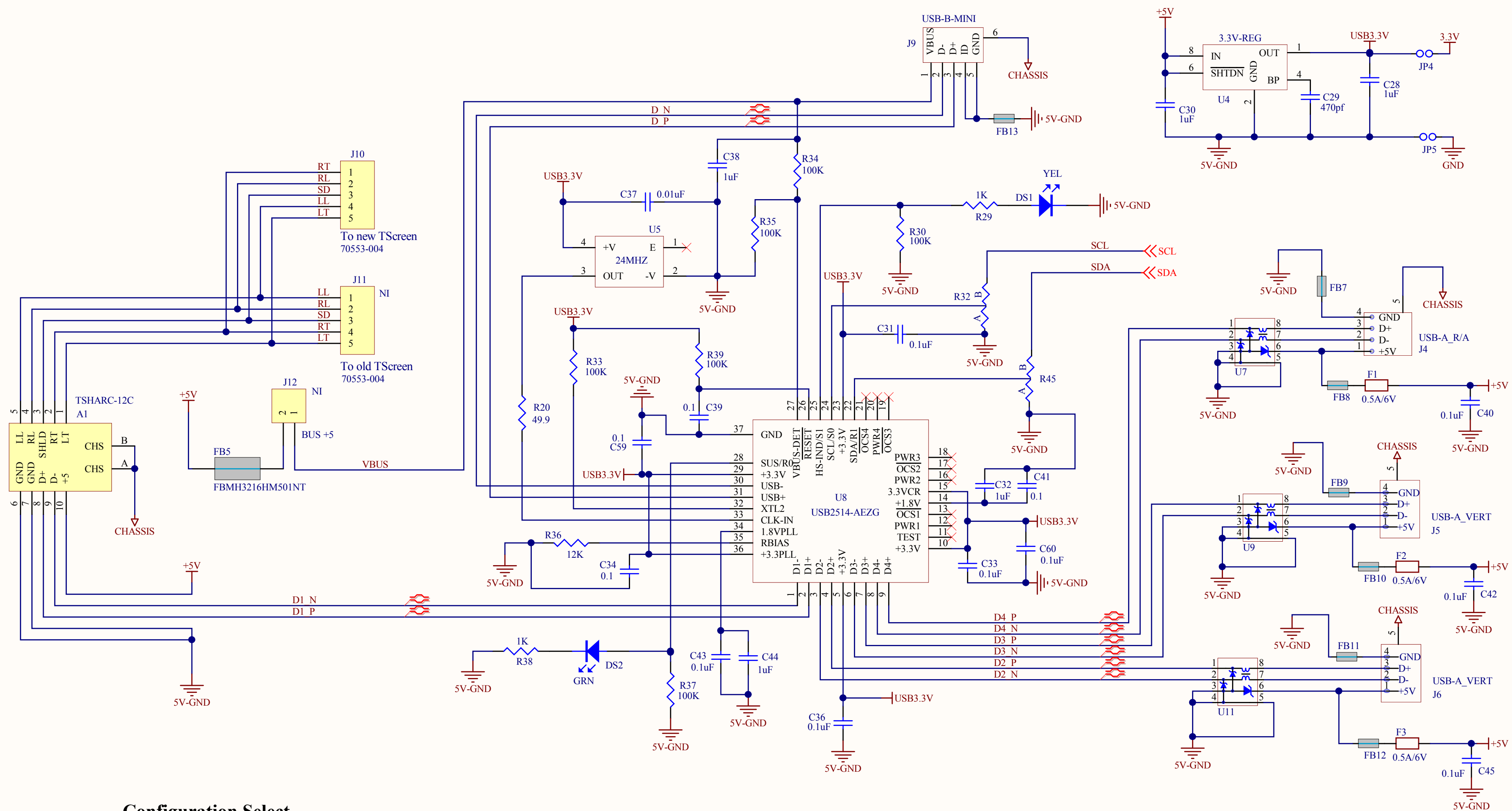


Make	Model	JP2	JP3
FEMA	GM800480W	1-2, 4-5, 7-8, 10-11, 13-14, 16-17	1-2, 4-5, 7-8, 10-11
Data Image	FG0700A0DSWBG01	3-2, 6-5, 9-8, 12-11, 15-14, 18-17	2-3, 5-6, 8-9, 11-12
United Radiant Tech.	UMSH-8173MD-1T	2-3, 4/5/6 NC, 7/8/9 NC, 10-11, 13-14, 16/17/18 NC	2-3, 5-6, 8-9, 11-12



Backlight Brightness Control

Control Mode	R22	R27	R31
Remote – Video Port	NO	A	NO
Remote – I2C	YES	B	NO
Fixed Bright (default)	NO	B	B

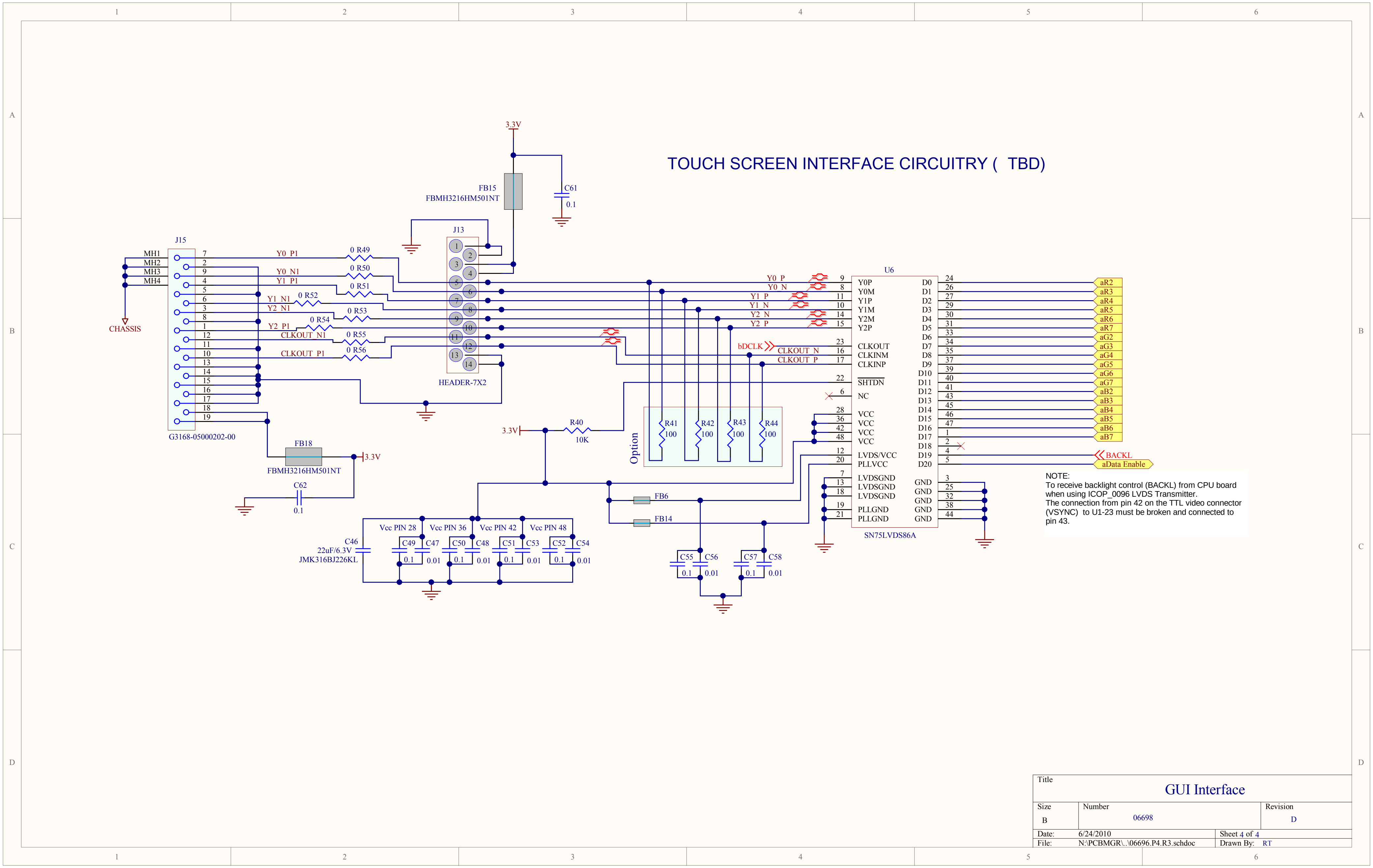


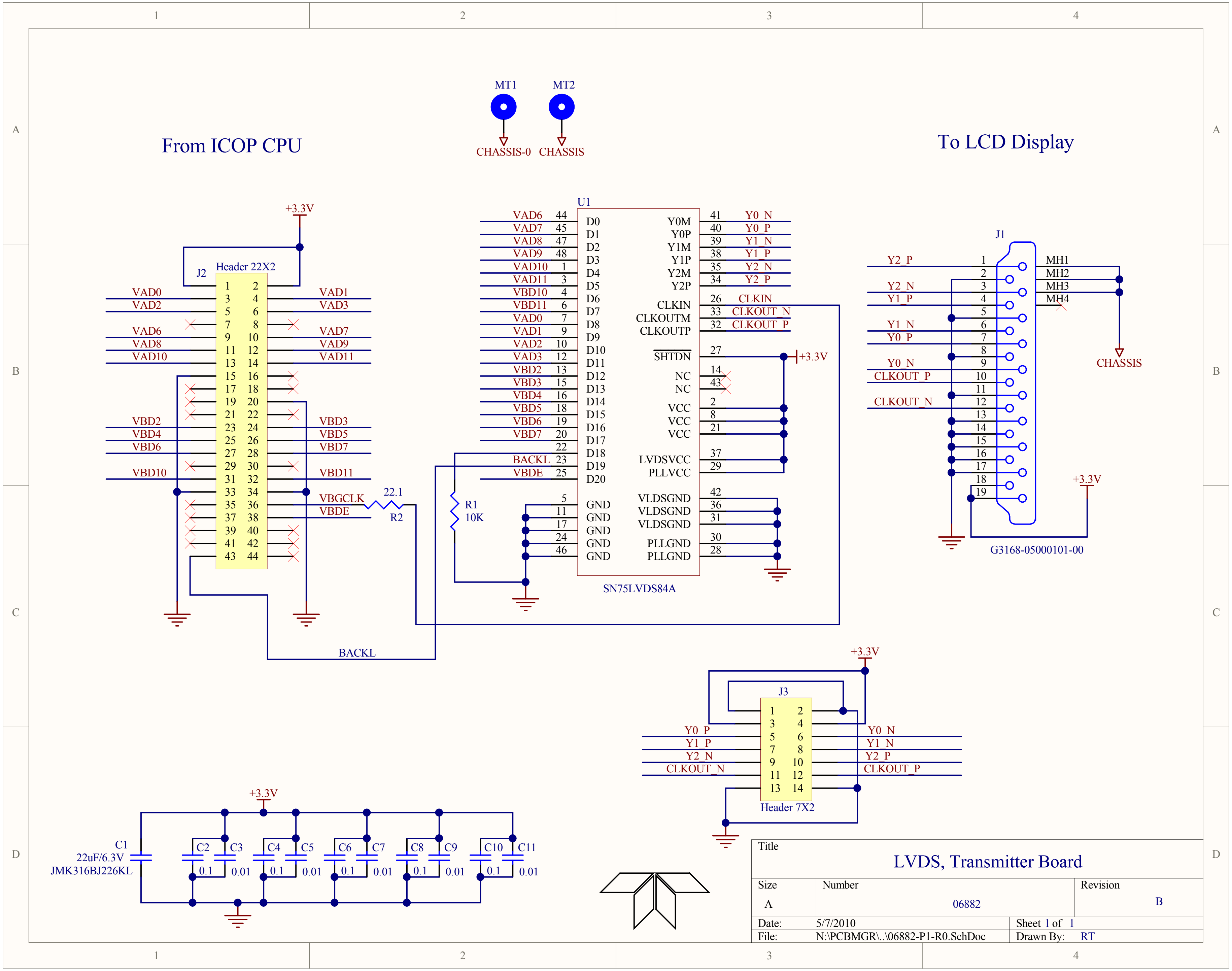
Configuration Select

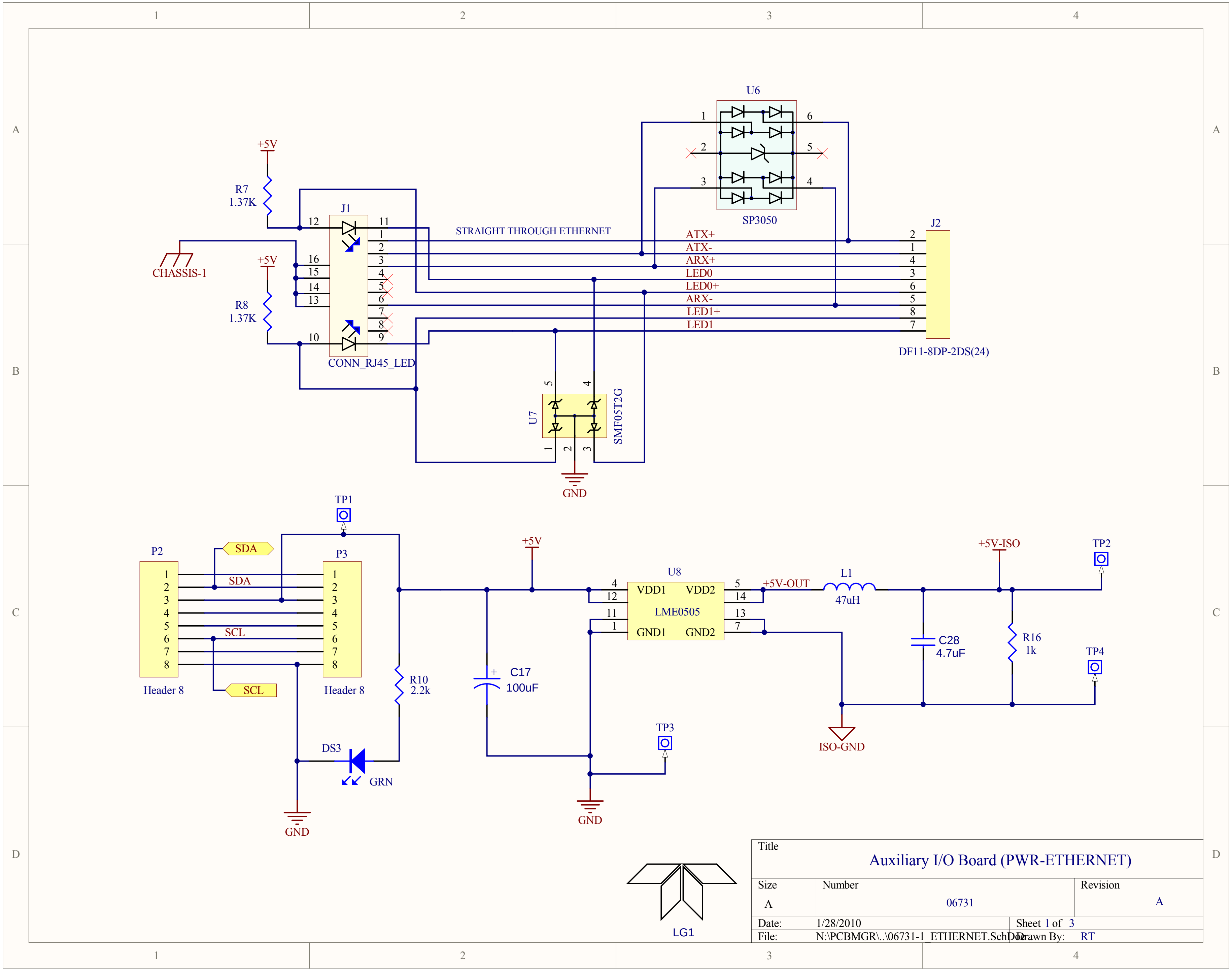
Mode	R32	R45
Default	A	A
MBUS	B	B

Install 100K for A, 0 Ohm for B

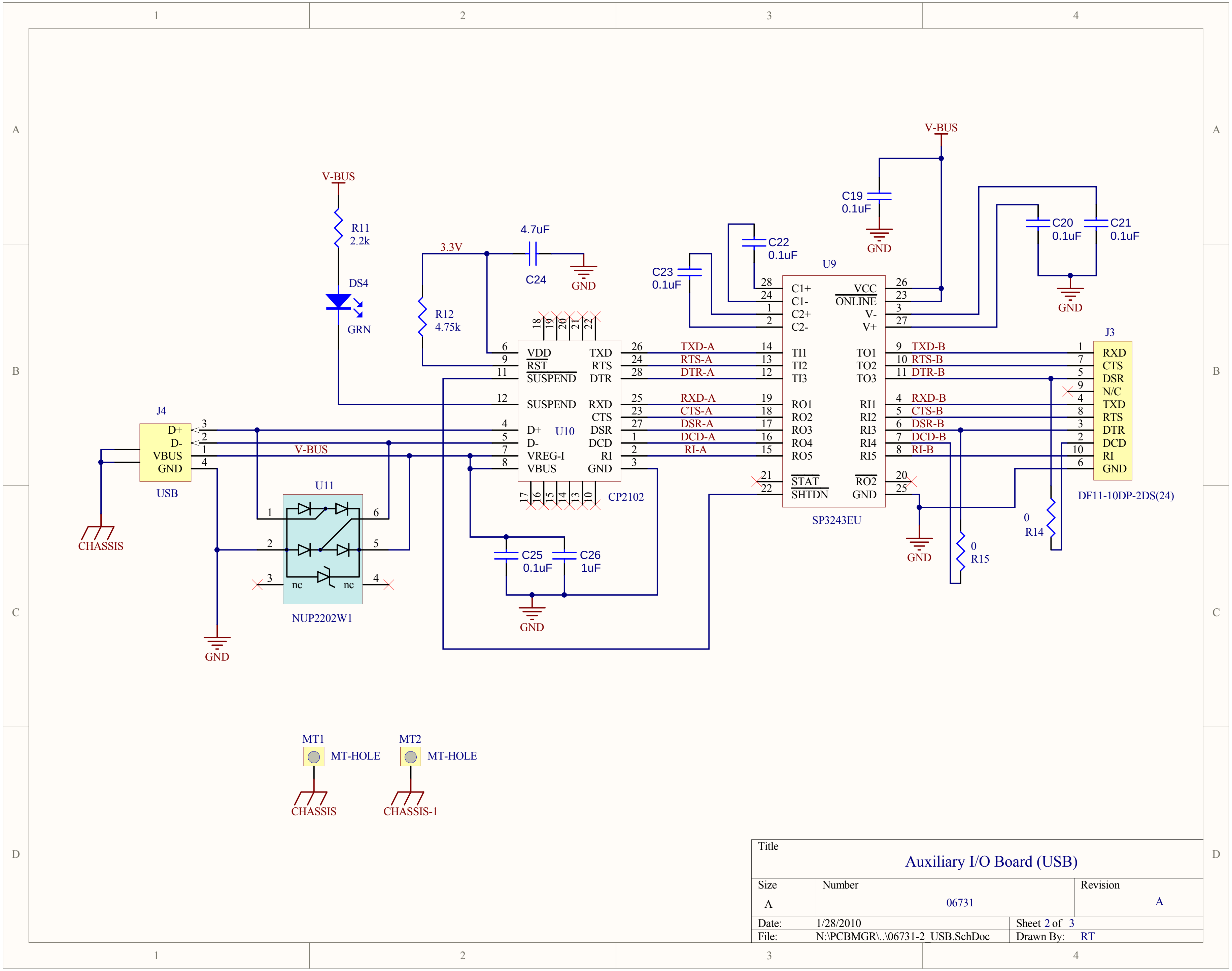
Title	GUI Interface	
Size B	Number 06698	Revision D
Date: 6/24/2010		Sheet 3 of 4
File: N:\PCBMGR\..\06696.P3.R3.schdoc		Drawn By: RT

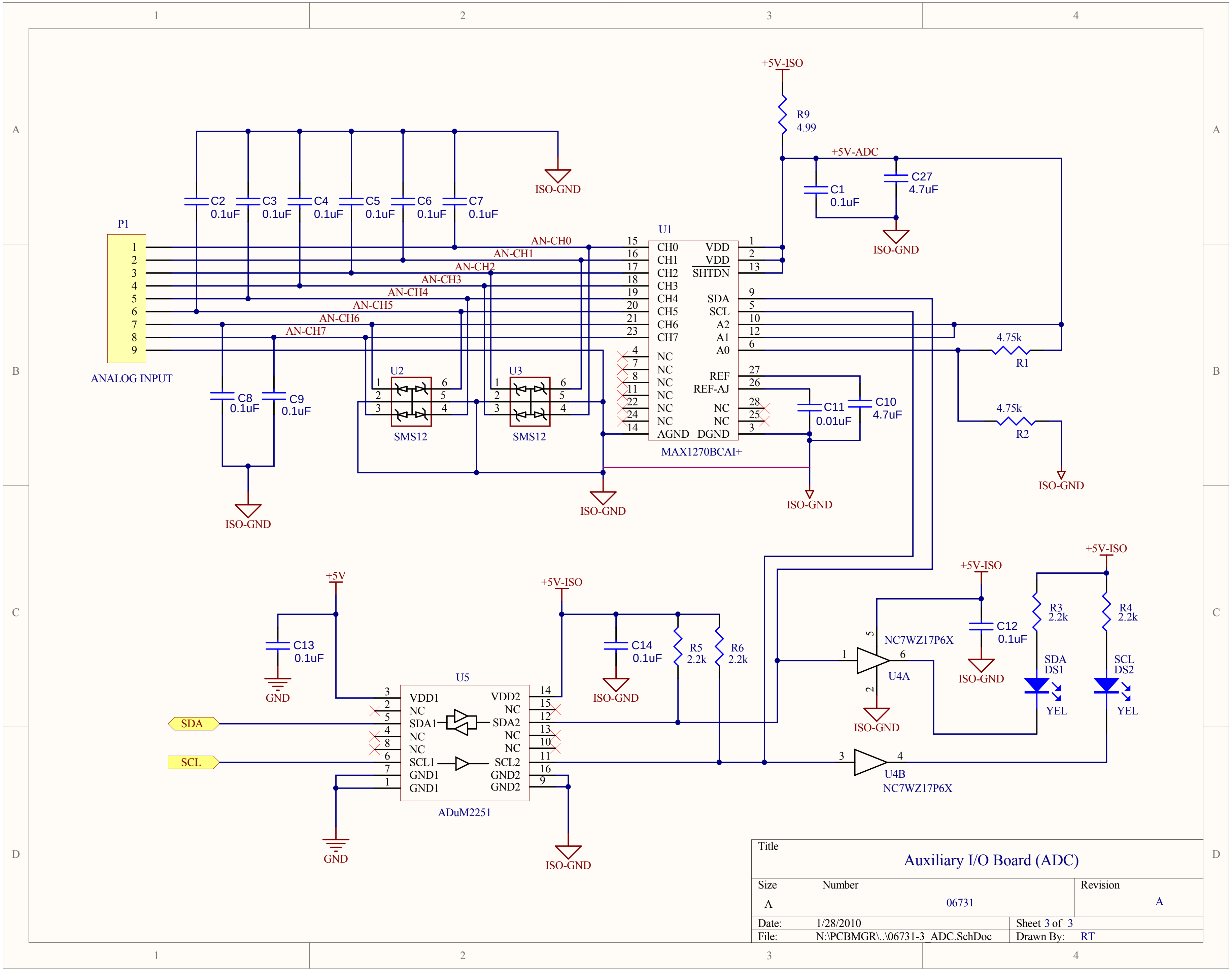

TOUCH SCREEN INTERFACE CIRCUITRY (TBD)
3.3V
FB15
FBMH3216HM501NT
C61
0.1
J13
HEADER-7X2
J15
MH1
MH2
MH3
MH4
CHASSIS
G3168-05000202-00
Y0 P1
Y0 N1
Y1 P1
Y1 N1
Y2 N1
Y2 P1
CLKOUT N1
CLKOUT P1
0 R49
0 R50
0 R51
0 R52
0 R53
0 R54
0 R55
0 R56
FB18
FBMH3216HM501NT
C62
0.1
R40
10K
Option
R41 100
R42 100
R43 100
R44 100
U6
SN75LVDS86A
Y0P
Y0M
Y1P
Y1M
Y2M
Y2P
CLKOUT
CLKINM
CLKINP
SHTDN
NC
VCC
LVDS/VCC
PLLVCC
LVDSGND
PLLGND
GND
Y0 P
Y0 N
Y1 P
Y1 N
Y2 N
Y2 P
bDCLK
CLKOUT N
CLKOUT P
aR2
aR3
aR4
aR5
aR6
aR7
aG2
aG3
aG4
aG5
aG6
aG7
aB2
aB3
aB4
aB5
aB6
aB7
BACKL
aData Enable
FB6
FB14
C46
22uF/6.3V
JMK316BJ226KL
Vcc PIN 28
Vcc PIN 36
Vcc PIN 42
Vcc PIN 48
C49
C47
C50
C48
C51
C53
C52
C54
C55
C56
C57
C58
NOTE:
To receive backlight control (BACKL) from CPU board when using ICOP_0096 LVDS Transmitter.
The connection from pin 42 on the TTL video connector (VSYNC) to U1-23 must be broken and connected to pin 43.
Title
GUI Interface
Size
B
Number
06698
Revision
D
Date: 6/24/2010
Sheet 4 of 4
File: N:\PCBMGR\..\06696.P4.R3.schdoc
Drawn By: RT


From ICOP CPU
To LCD Display
MT1
MT2
CHASSIS-0
CHASSIS
+3.3V
J2
Header 22X2
U1
SN75LVDS84A
J1
G3168-05000101-00
J3
Header 7X2
R1
10K
R2
22.1
BACKL
VBGCLK
VBDE
C1
22uF/6.3V
JMK316BJ226KL
C2
C3
C4
C5
C6
C7
C8
C9
C10
C11
0.1
0.01
Title
LVDS, Transmitter Board
Size
A
Number
06882
Revision
B
Date:
5/7/2010
Sheet 1 of 1
File:
N:\PCBMGR\..\06882-P1-R0.SchDoc
Drawn By:
RT



STRAIGHT THROUGH ETHERNET
U6
SP3050
J1
CONN_RJ45_LED
J2
DF11-8DP-2DS(24)
ATX+
ATX-
ARX+
LED0
LED0+
ARX-
LED1+
LED1
+5V
R7
1.37K
R8
1.37K
CHASSIS-1
U7
SMF05T2G
GND
TP1
P2
P3
Header 8
SDA
SCL
R10
2.2k
DS3
GRN
C17
100uF
U8
LME0505
VDD1
VDD2
GND1
GND2
+5V-OUT
L1
47uH
+5V-ISO
C28
4.7uF
R16
1k
TP2
TP3
TP4
ISO-GND
LG1
Title
Auxiliary I/O Board (PWR-ETHERNET)
Size
A
Number
06731
Revision
A
Date: 1/28/2010
Sheet 1 of 3
File: N:\PCBMGR\..\06731-1_ETHERNET.SchDoc
Drawn By: RT


V-BUS
R11
2.2k
DS4
GRN
3.3V
4.7uF
C24
GND
R12
4.75k
U10
CP2102
VDD
RST
SUSPEND
TXD
RTS
DTR
RXD
CTS
DSR
DCD
RI
GND
D+
D-
VREG-I
VBUS
J4
USB
CHASSIS
U11
NUP2202W1
nc
C25
0.1uF
C26
1uF
U9
SP3243EU
C1+
C1-
C2+
C2-
VCC
ONLINE
V-
V+
TI1
TI2
TI3
TO1
TO2
TO3
RO1
RO2
RO3
RO4
RO5
RI1
RI2
RI3
RI4
RI5
STAT
SHTDN
C19
0.1uF
C20
0.1uF
C21
0.1uF
C22
0.1uF
C23
0.1uF
TXD-A
RTS-A
DTR-A
RXD-A
CTS-A
DSR-A
DCD-A
RI-A
TXD-B
RTS-B
DTR-B
RXD-B
CTS-B
DSR-B
DCD-B
RI-B
J3
DF11-10DP-2DS(24)
N/C
R14
R15
MT1
MT2
MT-HOLE
CHASSIS-1
Title
Auxiliary I/O Board (USB)
Size
A
Number
06731
Revision
A
Date: 1/28/2010
Sheet 2 of 3
File: N:\PCBMGR\..\06731-2_USB.SchDoc
Drawn By: RT


+5V-ISO
R9
4.99
+5V-ADC
C1
0.1uF
C27
4.7uF
ISO-GND
C2
C3
C4
C5
C6
C7
0.1uF
P1
ANALOG INPUT
AN-CH0
AN-CH1
AN-CH2
AN-CH3
AN-CH4
AN-CH5
AN-CH6
AN-CH7
U1
CH0
CH1
CH2
CH3
CH4
CH5
CH6
CH7
NC
AGND
VDD
SHTDN
SDA
SCL
A2
A1
A0
REF
REF-AJ
DGND
MAX1270BCAI+
U2
U3
SMS12
C8
0.1uF
C9
0.1uF
C10
4.7uF
C11
0.01uF
4.75k
R1
R2
+5V
C13
0.1uF
GND
SDA
SCL
U5
VDD1
SDA1
SCL1
GND1
VDD2
SDA2
SCL2
GND2
ADuM2251
C14
0.1uF
R5
2.2k
R6
2.2k
NC7WZ17P6X
U4A
U4B
C12
0.1uF
R3
2.2k
R4
2.2k
SDA
DS1
SCL
DS2
YEL
Title
Auxiliary I/O Board (ADC)
Size
A
Number
06731
Revision
A
Date: 1/28/2010
Sheet 3 of 3
File: N:\PCBMGR\..\06731-3_ADC.SchDoc
Drawn By: RT