TRAINING MANUAL

MODEL 703E / T703
PHOTOMETRIC OZONE CALIBRATOR

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A Teledyne Technologies Company

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TABLE OF CONTENTS

1. PRINCIPLE OF OPERATION

1.1.1. PRINCIPLE OF PHOTOLYTIC O_3 GENERATION

Ozone is a naturally occurring substance that is sometimes called "activated oxygen". It contains three atoms of oxygen (O_3) instead of the usual two found in normal oxygen (O_2) that is essential for life. Because of its relatively short half-life, ozone cannot be bottled and stored for later use and there fore must always be generated on-site by an ozone generator. The two main principles of ozone generation are UV-light and corona discharge. While the corona-discharge method is most common because of its ability to generate very high concentrations (up to 50%), it is inappropriate for calibration needs since the level of fine control over the O_3 concentration is poor. Also, the corona discharge method produces a small amount of NO_2 as a byproduct, which also may be undesirable in a calibration application

The UV-light method is most feasible in calibration application where production of low, accurate concentrations of ozone desired. This method mimics the radiation method that occurs naturally from the sun in the upper atmosphere producing the ozone layer. An ultra-violet lamp inside the generator emits a precise wavelength of UV Light (185ηm). Ambient air is passed over an ultraviolet lamp, which splits some of the molecular oxygen (O_2) in the gas into individual oxygen atoms which attach to other existing oxygen molecules (O_2), forming ozone (O_3).

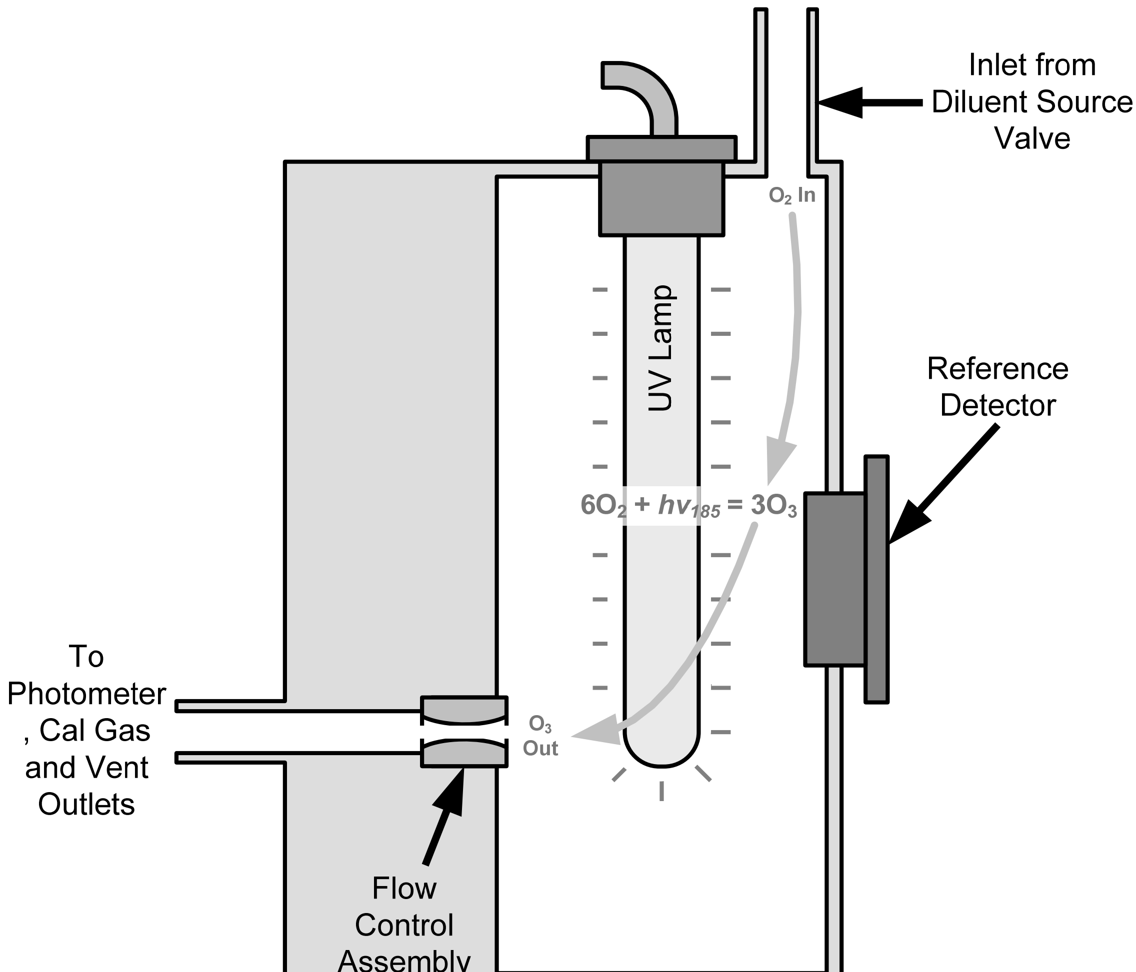


Figure 1-1: O_3 Generator Internal Pneumatics

1.1.2. GENERATOR PNEUMATIC OPERATION

The rate of flow through the O_3 generator is controlled by a flow control assembly located on the Regulator Sub-Assembly in the front of the M703E.

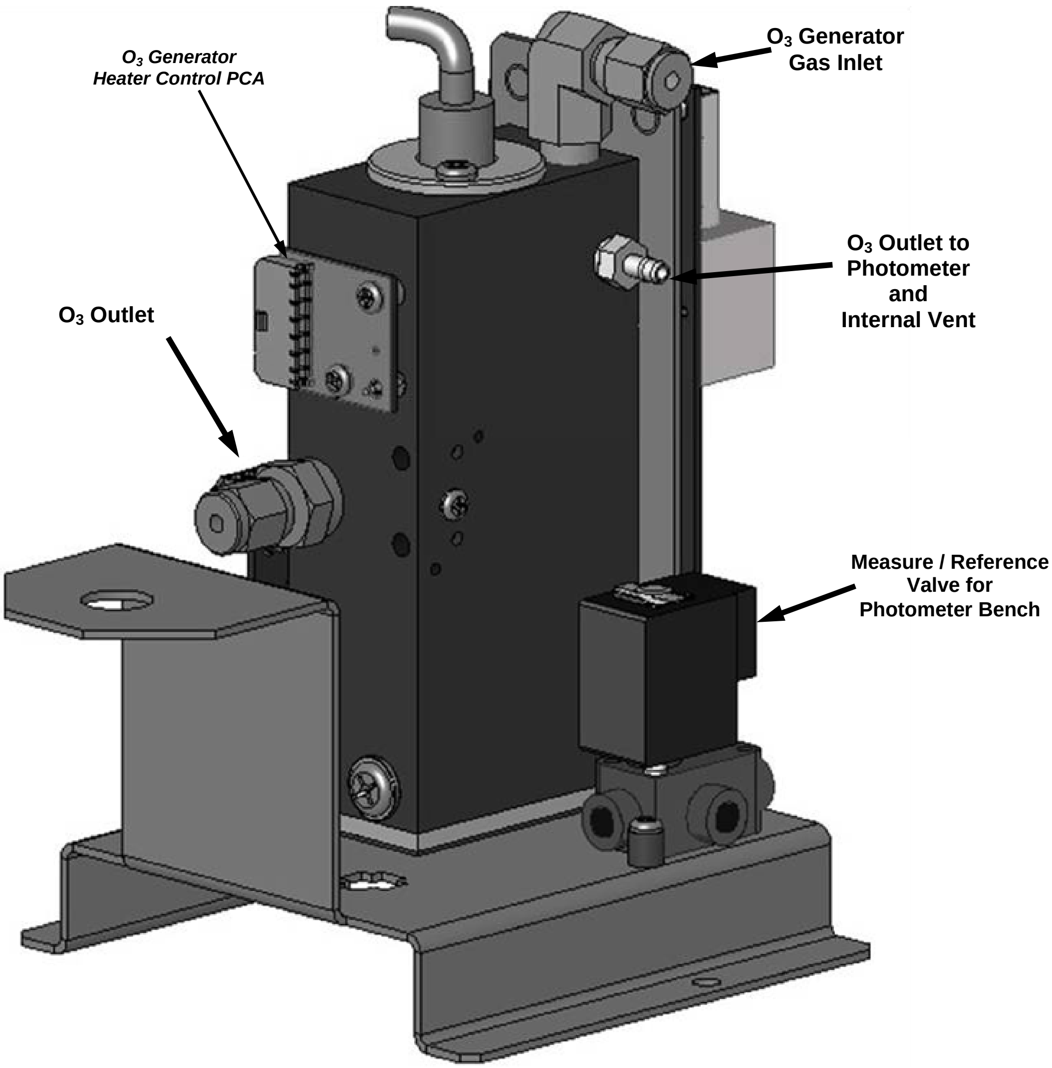


Figure 1-2: O_3 Generator Valve and Gas Fixture Locations

1.1.3. O_3 GENERATOR ELECTRONIC OPERATION

Electronically the O_3 generator and its subcomponents act as peripheral devices operated by the CPU via the motherboard. Sensor signals, such as the UV lamp thermistor are routed to the motherboard, where they are digitized. Digital data is sent by the motherboard to the calibrator's CPU and where required stored in either flash memory or on the CPU's disk-on-chip. Commands from the CPU are sent to the motherboard and forwarded to the various devices via the calibrator's I^2C bus.

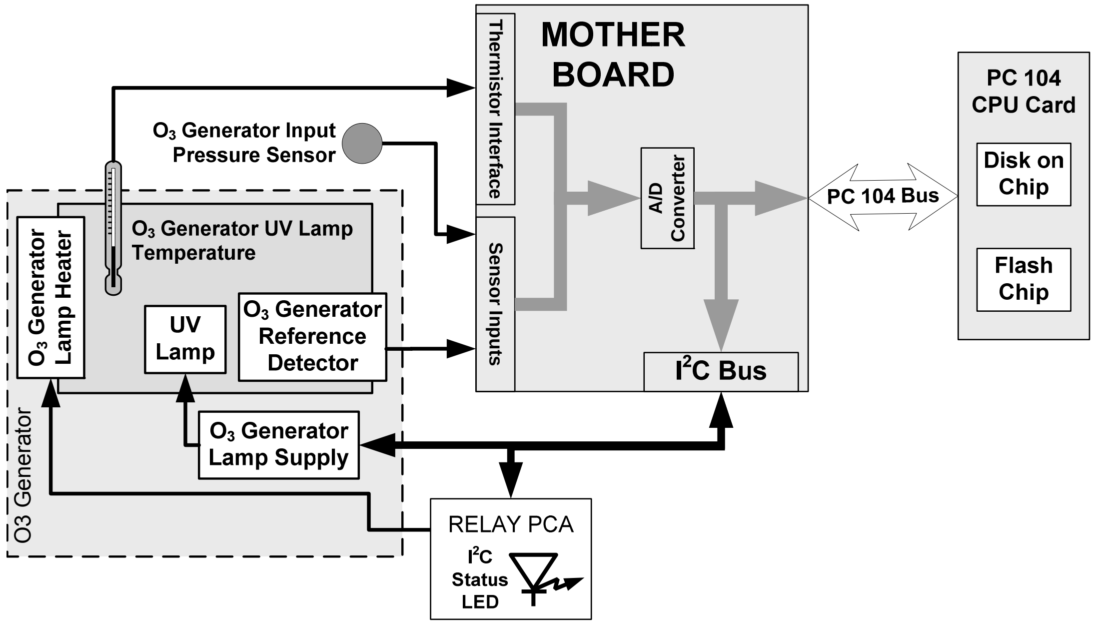


Figure 1-3: **O_3 Generator Electronic Block Diagram**

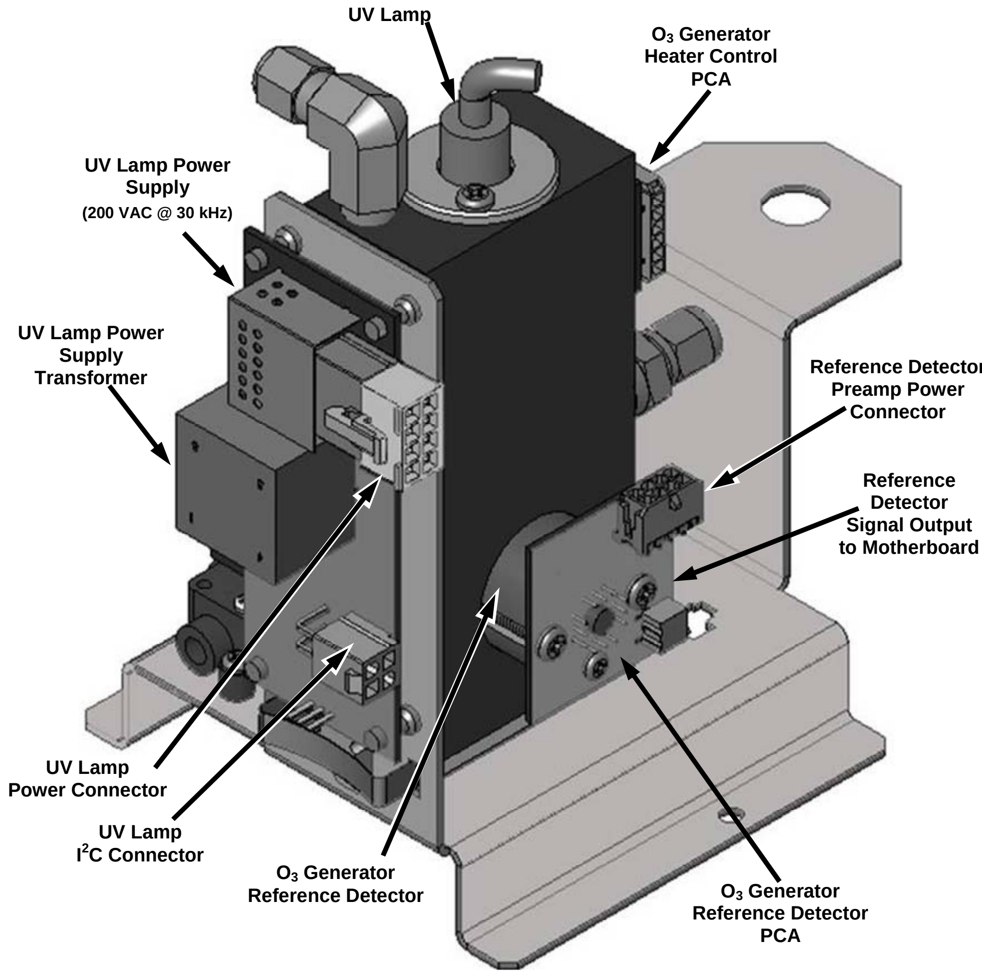


Figure 1-4: O_3 Generator Electronic Components Location

1.1.3.1. O_3 GENERATOR TEMPERATURE CONTROL

In order to operate at peak efficiency the UV lamp of the M703E's O_3 generator is maintained at a constant 48ºC. if the lamp temperature falls below 43ºC or rises above 53ºC a warning is issued by the calibrators CPU.

This temperature is controlled using a thermistor, a heater, and a relay. The location of the thermistor and heater associated with the O_3 generator is shown below:

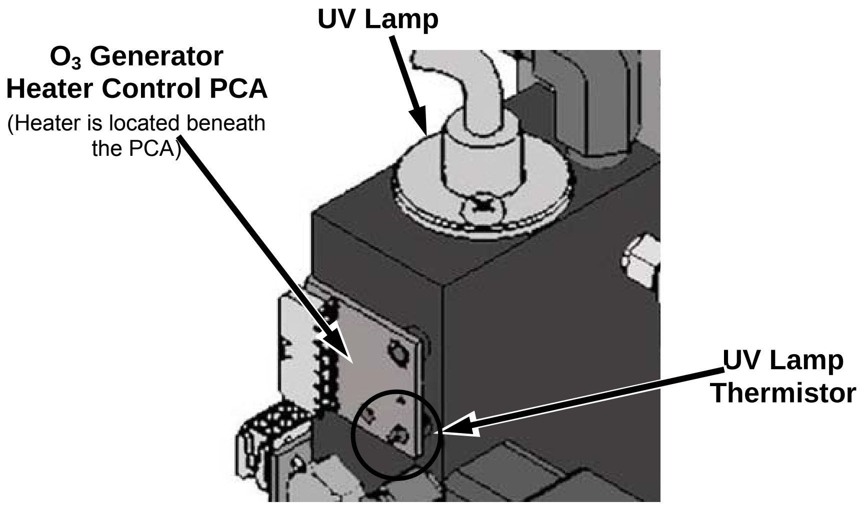


Figure 1-5: O_3 Generator Temperature Thermistor and DC Heater Locations

1.2. PHOTOMETER OPERATION

The Model M703E calibrator's photometer determines the concentration of Ozone (O_3) in a sample gas drawn through it. Sample and calibration gasses must be supplied at ambient atmospheric pressure in order to establish a stable gas flow through the absorption tube where the gas' ability to absorb ultraviolet (UV) radiation of a certain wavelength (in this case 254ηm) is measured.

Gas bearing O_3 and zero air are alternately routed through the photometer's absorption tube. Measurements of the UV light passing through the sample gas with and without O_3 present are made and recorded.

Calibration of the photometer is performed in software and does not require physical adjustments. Two internal variables, a slope and offset are used to adjust the calibration of the photometer.

The CPU uses these calibration values, the UV absorption measurements made on the sample gas in the absorption tube along with data regarding the current temperature and pressure of the gas to calculate a final O_3 concentration.

1.2.1. MEASUREMENT METHOD

1.2.1.1. CALCULATING O_3 CONCENTRATION

The basic principle by which photometer works is called Beer's Law (also referred to as the Beer-Lambert equation). It defines the how light of a specific wavelength is absorbed by a particular gas molecule over a certain distance at a given temperature and pressure. The mathematical relationship between these three parameters for gasses at Standard Temperature and Pressure (STP) is:

Equation 1-1

$$I = I_o e^{-\alpha LC} \qquad \textit{at STP}$$

Where:

I_o is the intensity of the light if there was no absorption.

I is the intensity with absorption.

L is the absorption path, or the distance the light travels as it is being absorbed.

C is the concentration of the absorbing gas. In the case of the Model 703E, Ozone (O_3).

α is the absorption coefficient that tells how well O_3 absorbs light at the specific wavelength of interest.

To solve this equation for **C**, the concentration of the absorbing Gas (in this case O_3), the application of a little algebra is required to rearrange the equation as follows:

Equation 1-2

$$C = \ell n\left(\frac{I_o}{I}\right) \times \left(\frac{1}{\alpha\, L}\right) \quad \text{at STP}$$

Unfortunately, both ambient temperature and pressure influence the density of the sample gas and therefore the number of ozone molecules present in the absorption tube thus changing the amount of light absorbed. In order to account for this effect the following addition is made to the equation:

Equation 1-3

$$C = \ell n\left(\frac{I_o}{I}\right) \times \left(\frac{1}{\alpha\, L}\right) \times \left(\frac{T}{273^o\mathrm{K}} \times \frac{29.92 inHg}{P}\right)$$

Where:

T = sample ambient temperature in degrees Kelvin

P = ambient pressure in inches of mercury

Finally, to convert the result into Parts per Billion (PPB), the following change is made:

Equation 1-4

$$C = \ell n\left(\frac{I_o}{I}\right) \times \left(\frac{10^9}{\alpha\, L}\right) \times \left(\frac{\mathrm{T}}{273^o\mathrm{K}} \times \frac{29.92 inHg}{\mathrm{P}}\right)$$

In a nutshell the M703E photometer:

- Measures each of the above variables: ambient temperature; ambient gas pressure; the intensity of the UV light beam <u>with</u> and <u>without</u> O_3 present;
- Inserts know values for the length of the absorption path and the absorption coefficient, and:
- Calculates the concentration of O_3 present in the sample gas.

1.2.1.2. THE MEASUREMENT / REFERENCE CYCLE

In order to solve the Beer-Lambert equation it is necessary to know the intensity of the light passing through the absorption path both when O_3 is present and when it is not. A valve called the measure/reference valve, physically located on front-left corner of the O_3 generator assembly alternates the gas stream flowing to the photometer between zero air (diluent gas) and the O_3 output from the O_3 generator. This cycle takes about 6 seconds.

Table 1-1: M703E Photometer Measurement / Reference Cycle

TIME INDEX	STATUS
0 sec.	Measure/Reference Valve Opens to the Measure Path.
0 – 2 sec.	Wait Period. Ensures that the Absorption tube has been adequately flushed of any previously present gasses.
2 – 3 Seconds	Analyzer measures the average UV light intensity of O_3 bearing Sample Gas (**I**) during this period.
3 sec.	Measure/Reference Valve Opens to the Reference Path.
3 – 5 sec.	Wait Period. Ensures that the Absorption tube has been adequately flushed of O_3 bearing gas.
5 – 6 Seconds	Analyzer measures the average UV light intensity of Non-O_3 bearing Sample Gas (**I_0**) during this period.
CYCLE REPEAT EVERY 6 SECONDS	

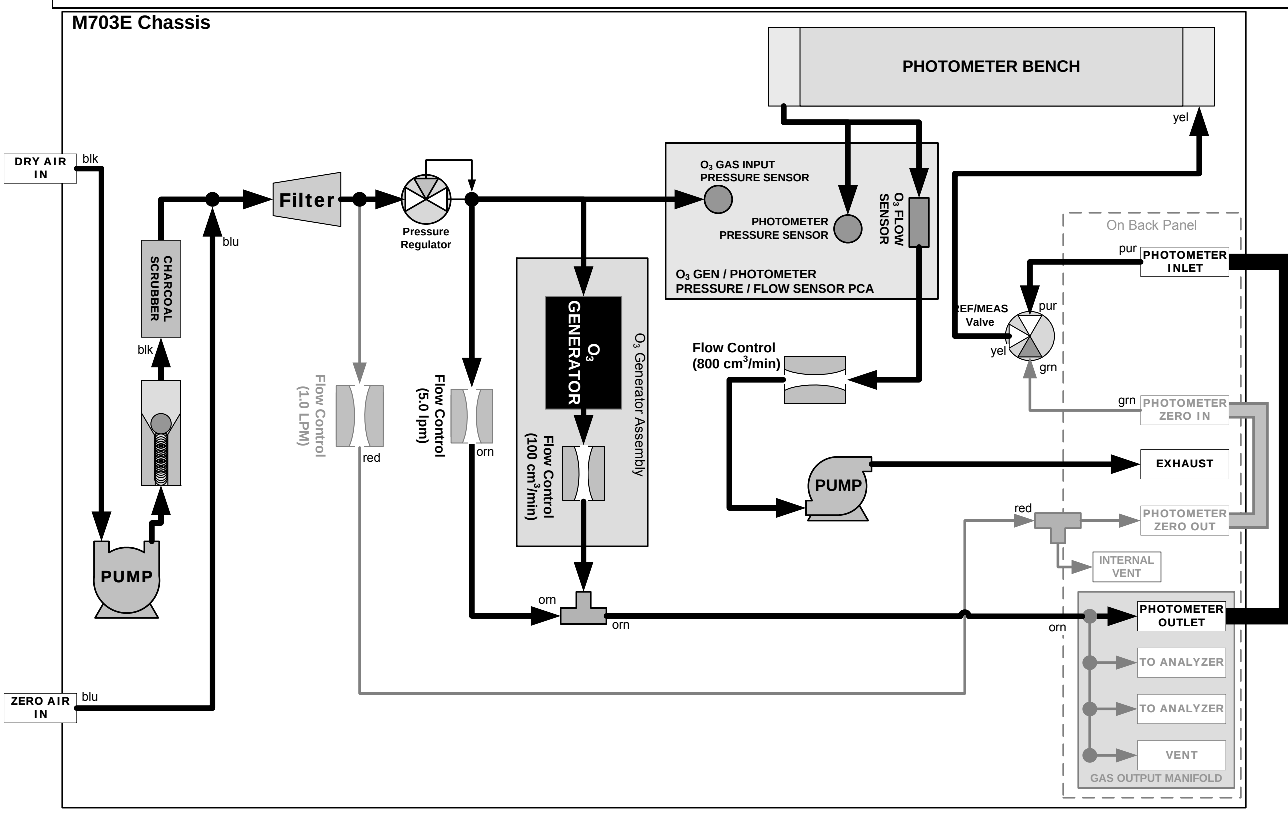


Figure 1-6: O_3 Photometer Gas Flow – Measure Cycle

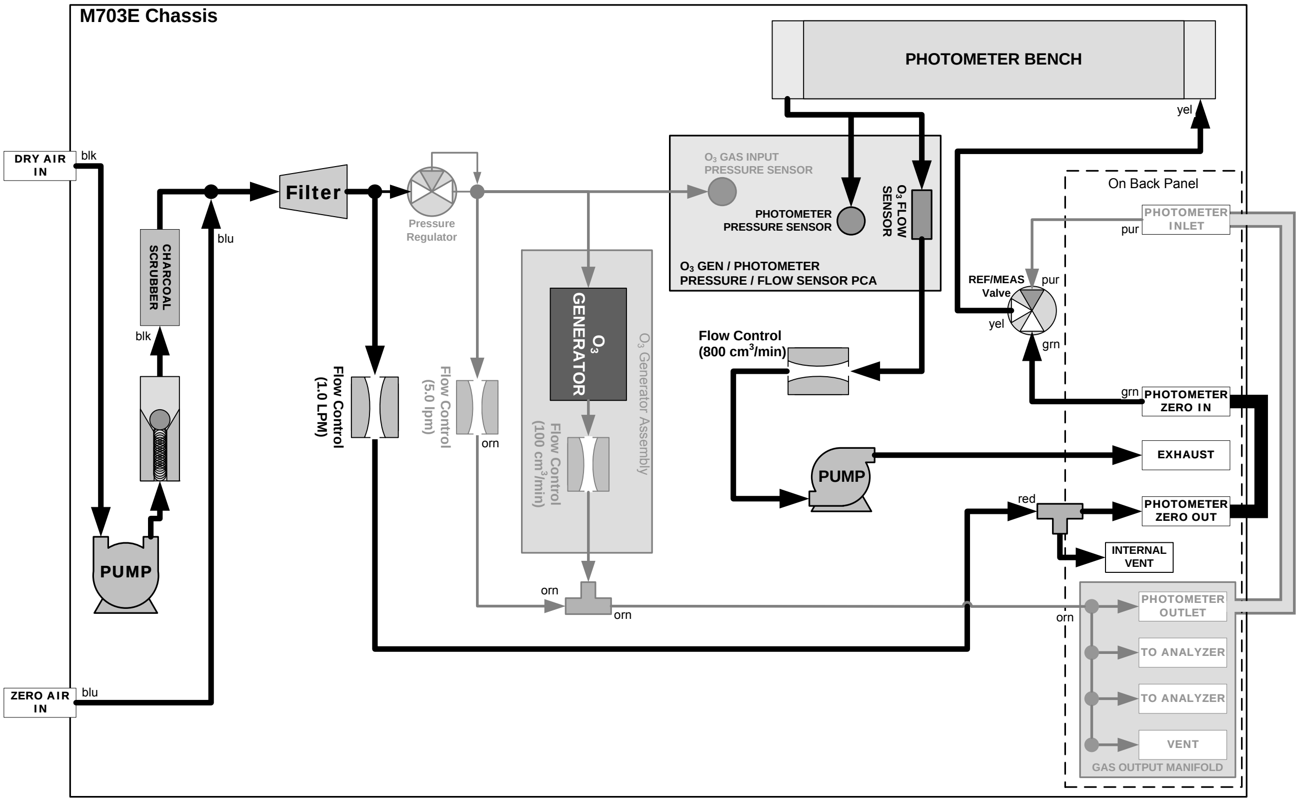


Figure 1-7: O_3 Photometer Gas Flow – Reference Cycle

1.2.1.3. THE ABSORPTION PATH

In the most basic terms, the M703E photometer uses a high energy, mercury vapor lamp to generate a beam of UV light. This beam passes through a window of material specifically chosen to be both non-reactive to O_3 and transparent to UV radiation at 254ηm and into an absorption tube filled with sample gas.

Because ozone is a very efficient absorber of UV radiation the absorption path length required to create a measurable decrease in UV intensity is short enough (approximately 42cm) that the light beam is only required to make one pass through the absorption tube. Therefore, no complex mirror system is needed to lengthen the effective path by bouncing the beam back and forth.

Finally, the UV passes through a similar window at the other end of the absorption tube and is detected by a specially designed vacuum diode that only detects radiation at or very near a wavelength of 254ηm. The specificity of the detector is high enough that no extra optical filtering of the UV light is needed.

The detector reacts to the UV light and outputs a current signal that varies in direct relationship with the intensity of the light shining on it. This current signal is amplified and converted to a 0 to 5 volt analog signal is sent to the instrument's motherboard where it is digitized. The CPU uses this data in computing the concentration of O_3 in the absorption tube.

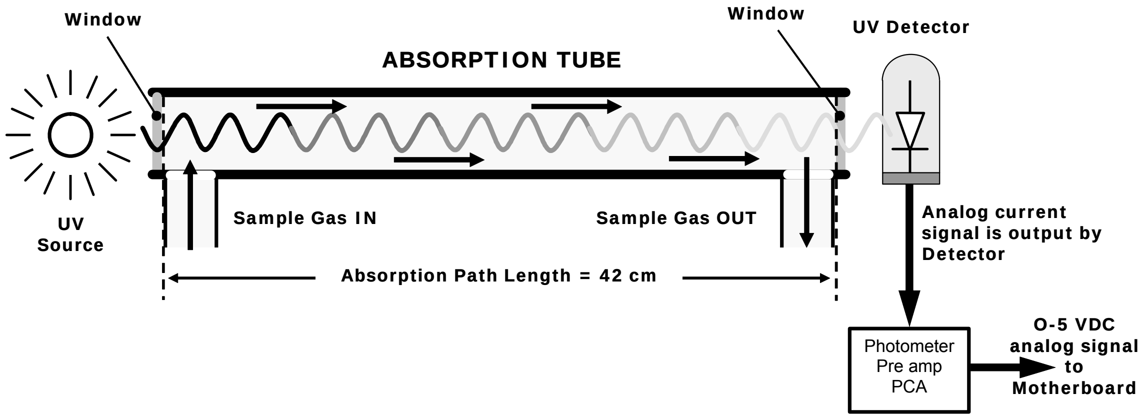


Figure 1-8: O_3 Photometer Absorption Path

1.2.2. PHOTOMETER LAYOUT

The photometer is where the absorption of UV light by ozone is measured and converted into a voltage. It consists of several sub-assemblies:

- A mercury-vapor UV lamp. This lamp is coated in a material that optically screens the UV radiation output to remove the O_3 producing 185ηm radiation. Only light at 254ηm is emitted.
- An AC power supply that supplies the current for starting and maintaining the plasma arc of the mercury vapor lamp.
- A thermistor and DC heater attached to the UV Lamp to maintain the lamp at an optimum operating temperature.
- 42cm long quartz absorption tube.
- A thermistor attached to the quartz tube for measuring sample gas temperature.
- Gas inlet and outlet mounting blocks that rout sample gas into and out of the photometer.
- The vacuum diode, UV detector that converts UV light to a DC current.
- A preamplifier assembly, which convert the detector's current output into a DC voltage then amplifies it to a level readable by the A to D converter circuitry of the instrument's motherboard
-

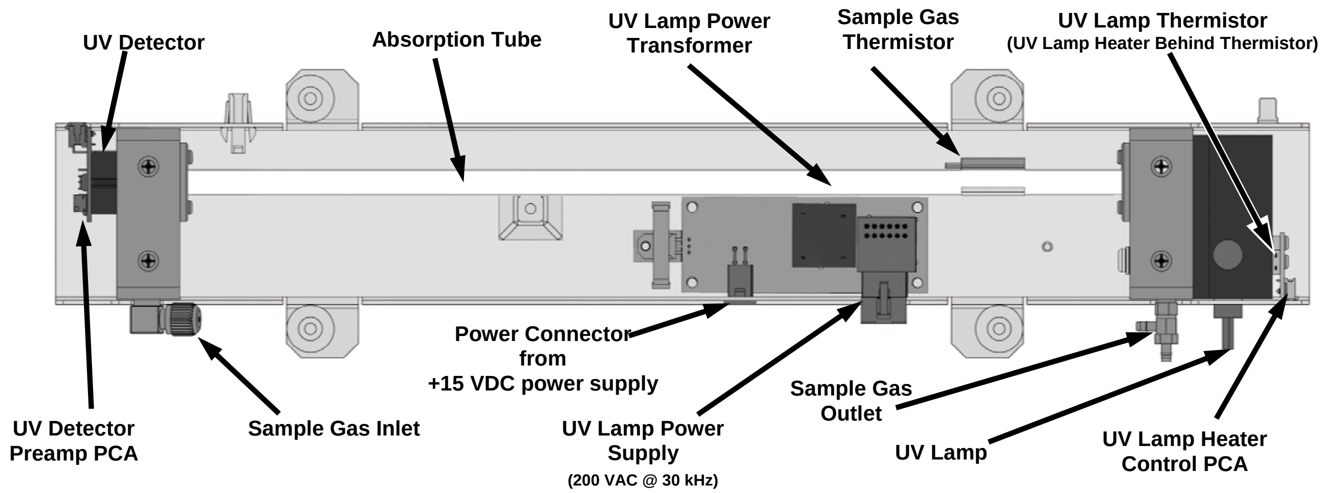


Figure 1-9: O_3 Photometer Layout – Top Cover Removed

1.2.3. PHOTOMETER PNEUMATIC OPERATION

The flow of gas through the photometer is created by a small internal pump that pulls air though the instrument. There are several advantages to this "pull through" configuration. Placing the pump down stream from the absorption tube avoids problems caused by the pumping process heating and compressing the sample.

In order to accurately measure the presence of low concentrations of O_3 in the sample air, it is necessary to establish and maintain a relatively constant and stable volumetric flow of sample gas through the

photometer. The simplest way to accomplish this is by placing a flow control assembly containing a critical flow orifice directly upstream of the pump but down stream from the absorption tube.
The critical flow orifice installed in the pump supply line is tuned to create a gas flow of 800 cm^3/min. A pressure sensor and a flow sensor, located on the O_3 generator / photometer pressure flow sensor PCA, monitor the pressure and flow rate of the gas passing through the photometer's absorption tube.

1.2.4. PHOTOMETER ELECTRONIC OPERATION

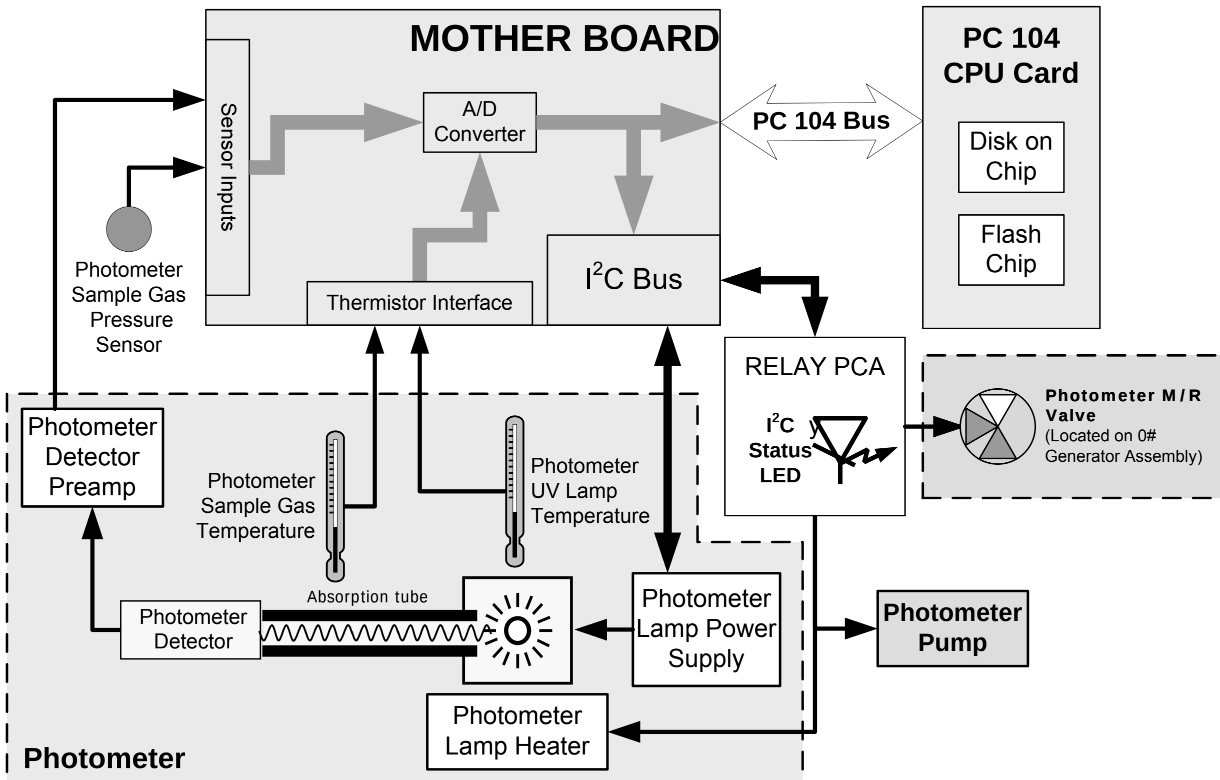


Figure 1-11: O_3 Photometer Electronic Block Diagram

Like the O_3 generator, the O_3 photometer and its subcomponents act as peripheral devices operated by the CPU via the motherboard. Communications to and from the CPU are handled by the motherboard.

Outgoing commands for the various devices such as the photometer pump, the UV lamp power supply, and the UV Lamp heater are issued via the I^2C bus to circuitry on the relay PCA which turns them ON/OFF. The CPU also issues commands over the I^2C bus that cause the relay PCA to cycle the measure/reference valve back and forth.

Data from the UV light detector is amplified locally then converted to digital information by the motherboard. Output from the photometer's temperature sensors are also amplified and converted to digital data by the motherboard. The O_3 concentration of the sample gas is computed by the CPU using this data (along with gas pressure and flow data received from the M703E's pressure sensors.

1.2.4.1. O_3 PHOTOMETER TEMPERATURE CONTROL

In order to operate at peak efficiency, the UV lamp of the M703E's O_3 photometer is maintained at a constant 58ºC. This is intentionally set at a temperature higher than the ambient temperature of the M703E's operating environment to make sure that local changes in temperature do not affect the UV Lamp. If the lamp temperature falls below 56ºC or rises above 61ºC a warning is issued by the calibrator's CPU.
The following TEST functions report these temperatures and are viewable from the instrument's front panel:

- **PHOTO LAMP TEMP** - The temperature of the UV Lamp reported in ºC.
- **PHOTO STEMP** - The temperature of the sample gas in the absorption tube reported in ºC.

1.2.4.2. PNEUMATIC SENSORS FOR THE O_3 PHOTOMETER

The several sensors located on the pneumatic sensor just to the left rear of the O_3 generator assembly measure the absolute pressure and the flow rate of gas inside the photometer's absorption tube. This information is used by the CPU to calculate the O_3 concentration of the sample gas. Both of these measurements are made downstream from the absorption tube but upstream of the pump. A critical flow orifice located between the flow sensor and the pump maintains the gas flow through the photometer at 800 cm^3/min.
The following TEST functions are viewable from the instrument's front panel:

- **PHOTO FLOW** - The flow rate of gas through the photometer measured in cc/min.
- **PHOTO SPRESS** – the pressure of the gas inside the absorption tube. This pressure is reported in inches of mercury-absolute (**in-Hg-A**), i.e. referenced to a vacuum (zero absolute pressure). This is not the same as **PSIG.**

USER NOTES:

USER NOTES:

2. PNEUMATIC DIAGRAM

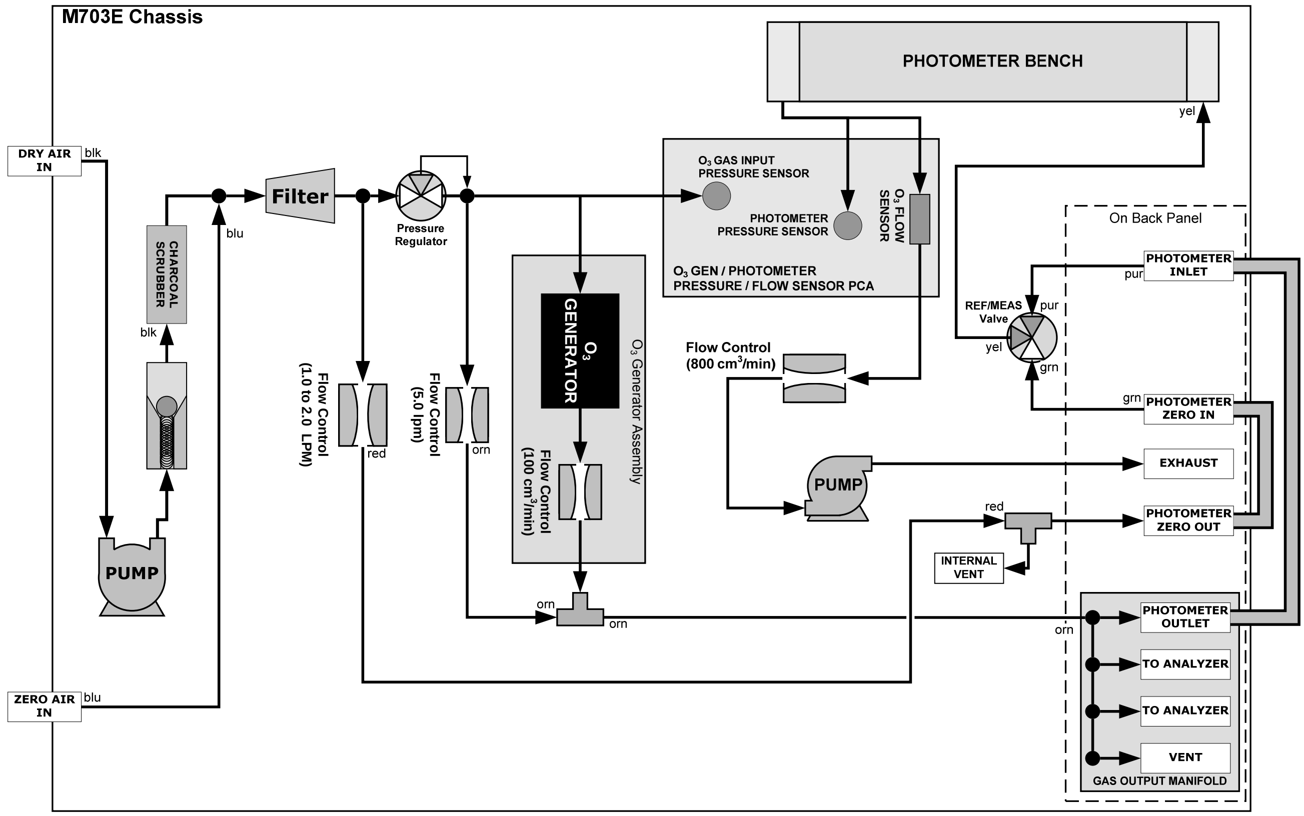


Figure 2-1: M703E Pneumatic Diagram

USER NOTES:

3. MENU STRUCTURE

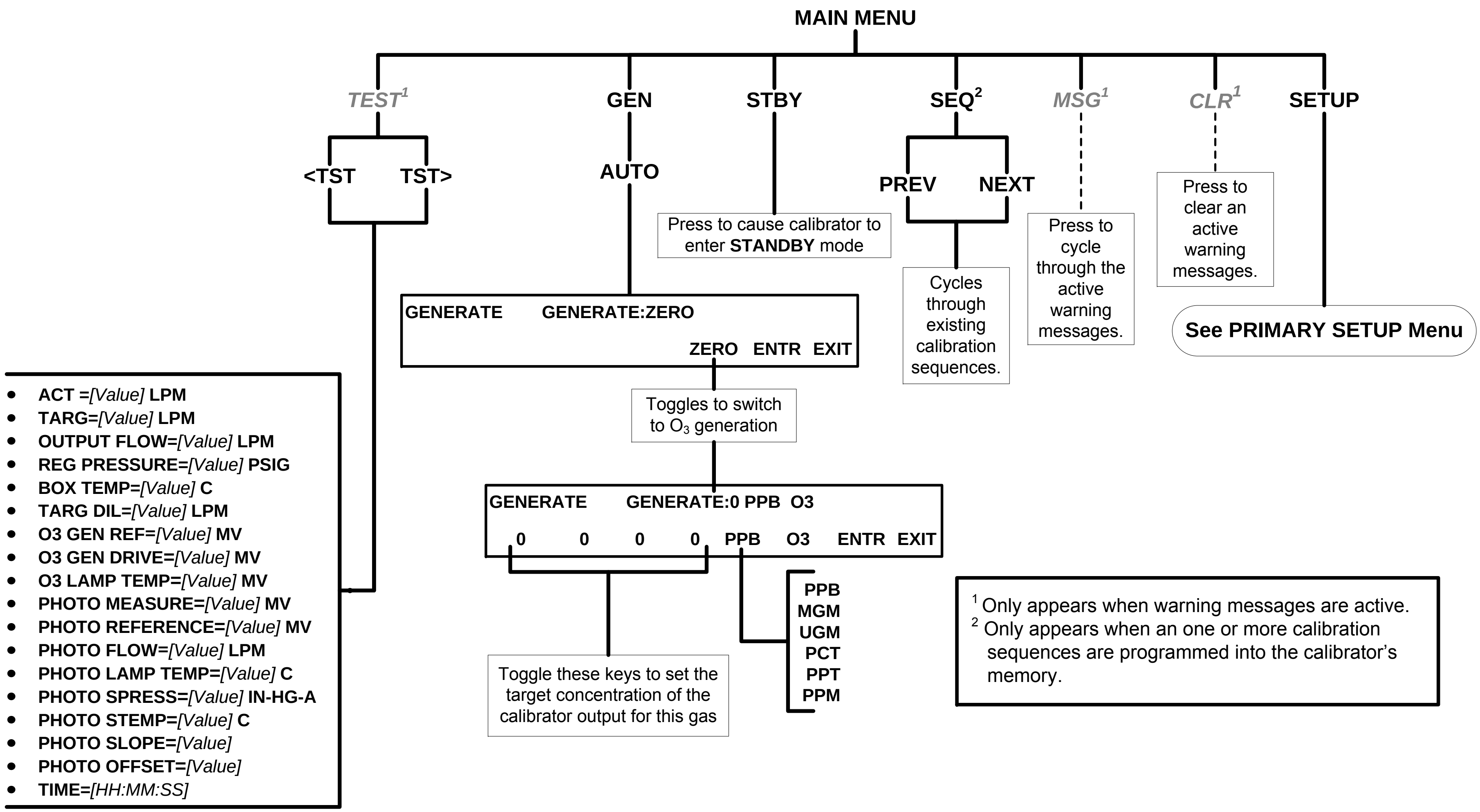


Figure 3-1: Main Menu

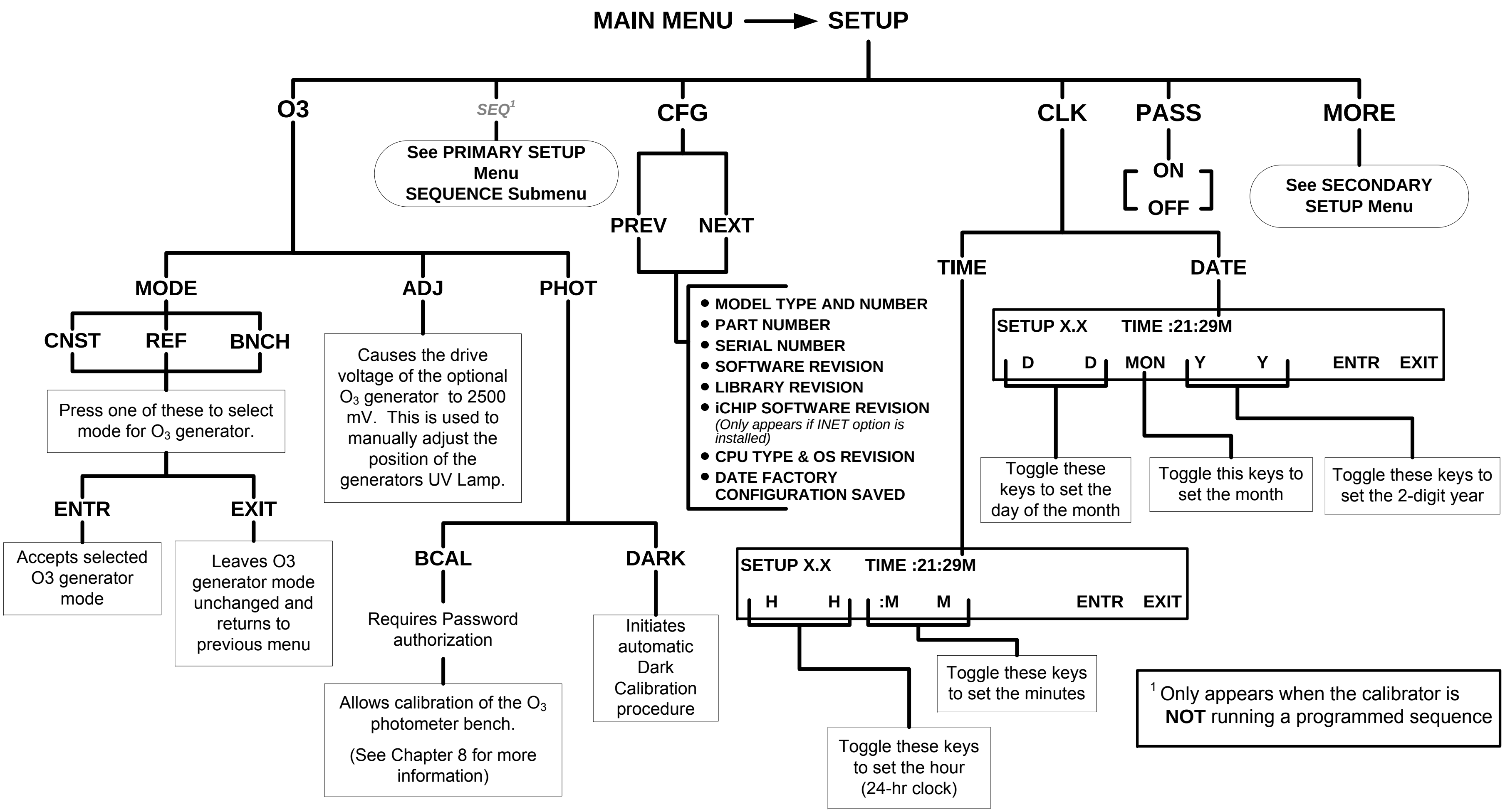


Figure 3-2: PRIMARY SETUP MENU - Basics

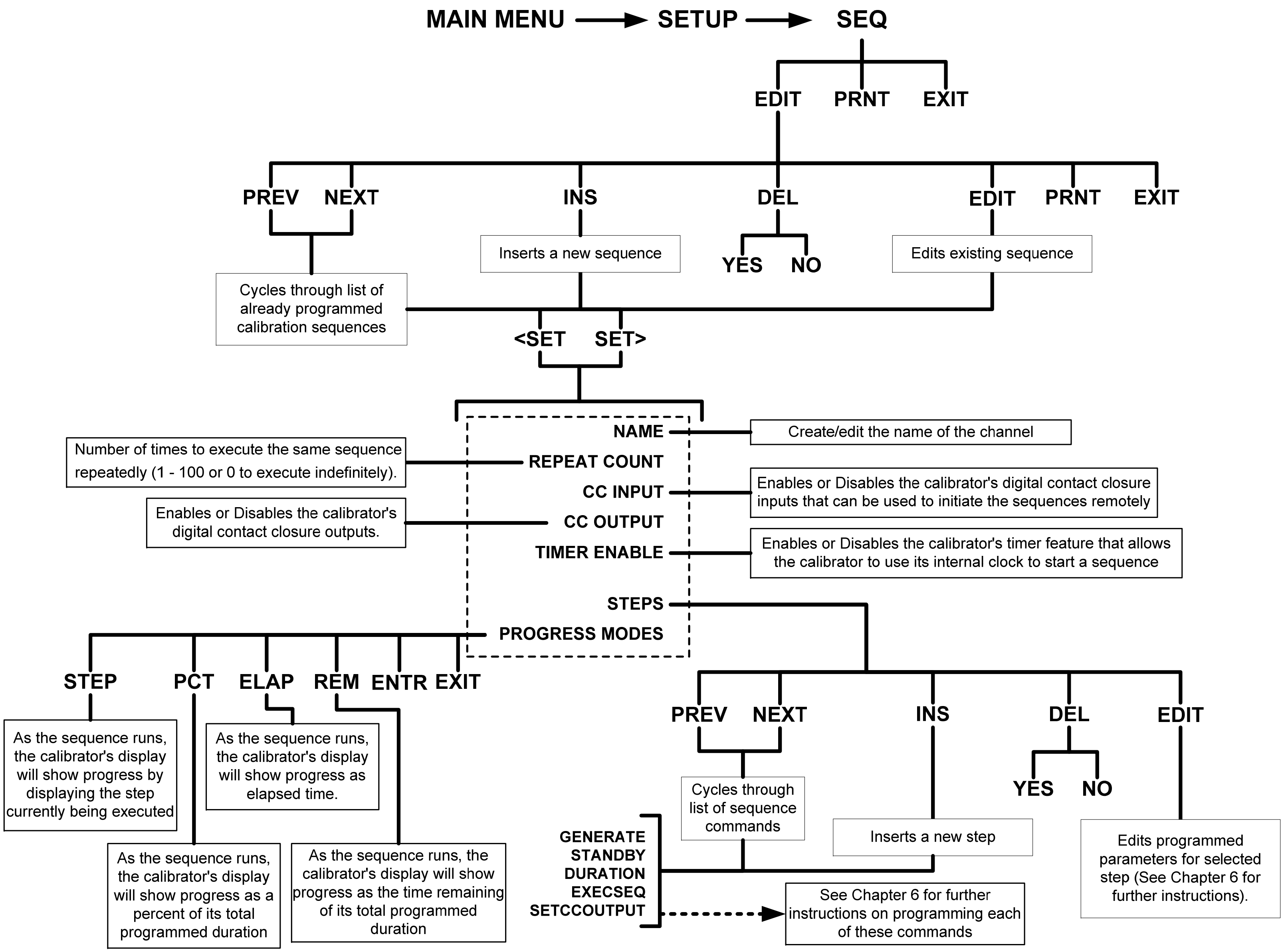


Figure 3-3: PRIMARY SETUP Menu - SEQUENCE CONFIGURATION Submenu

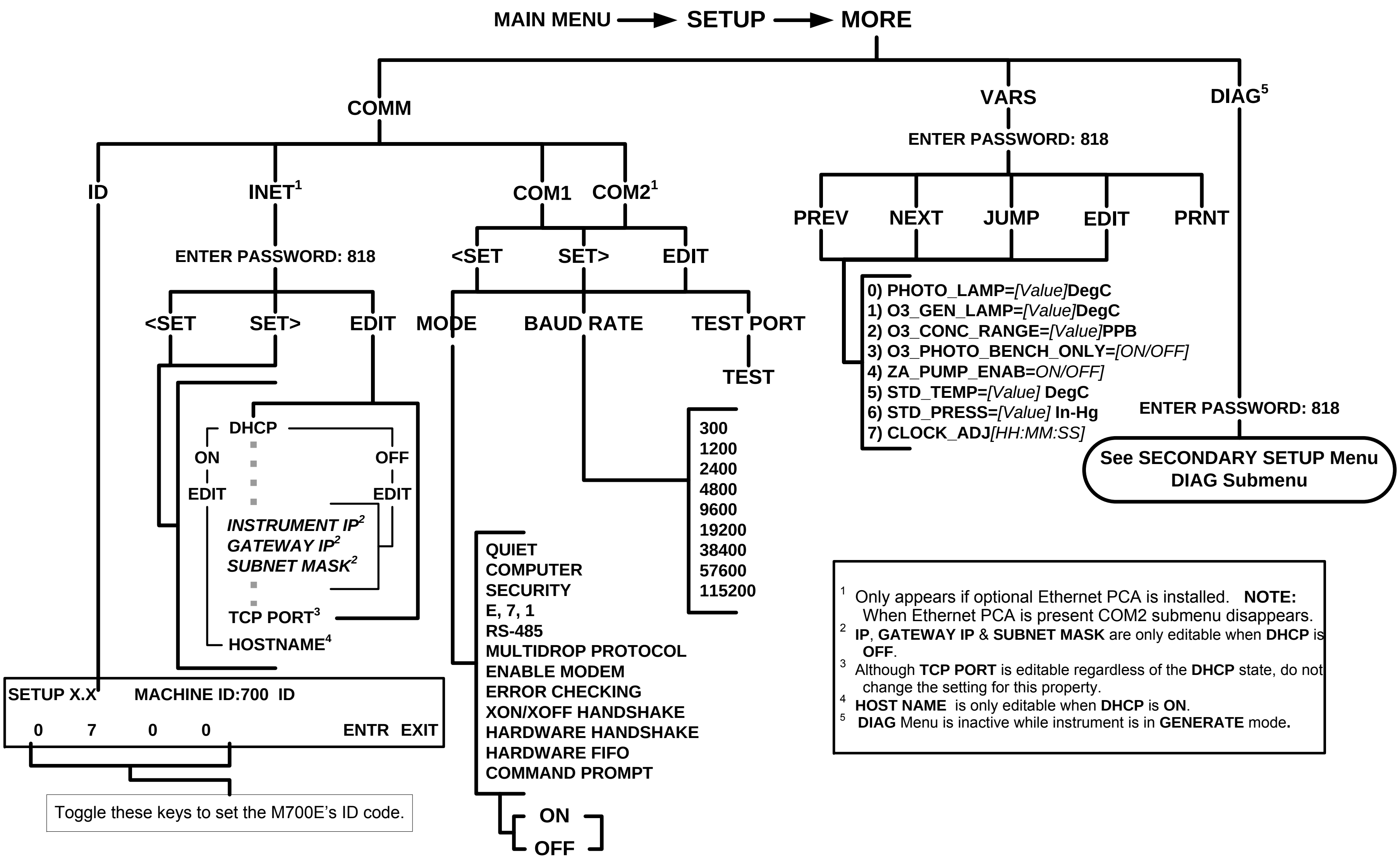
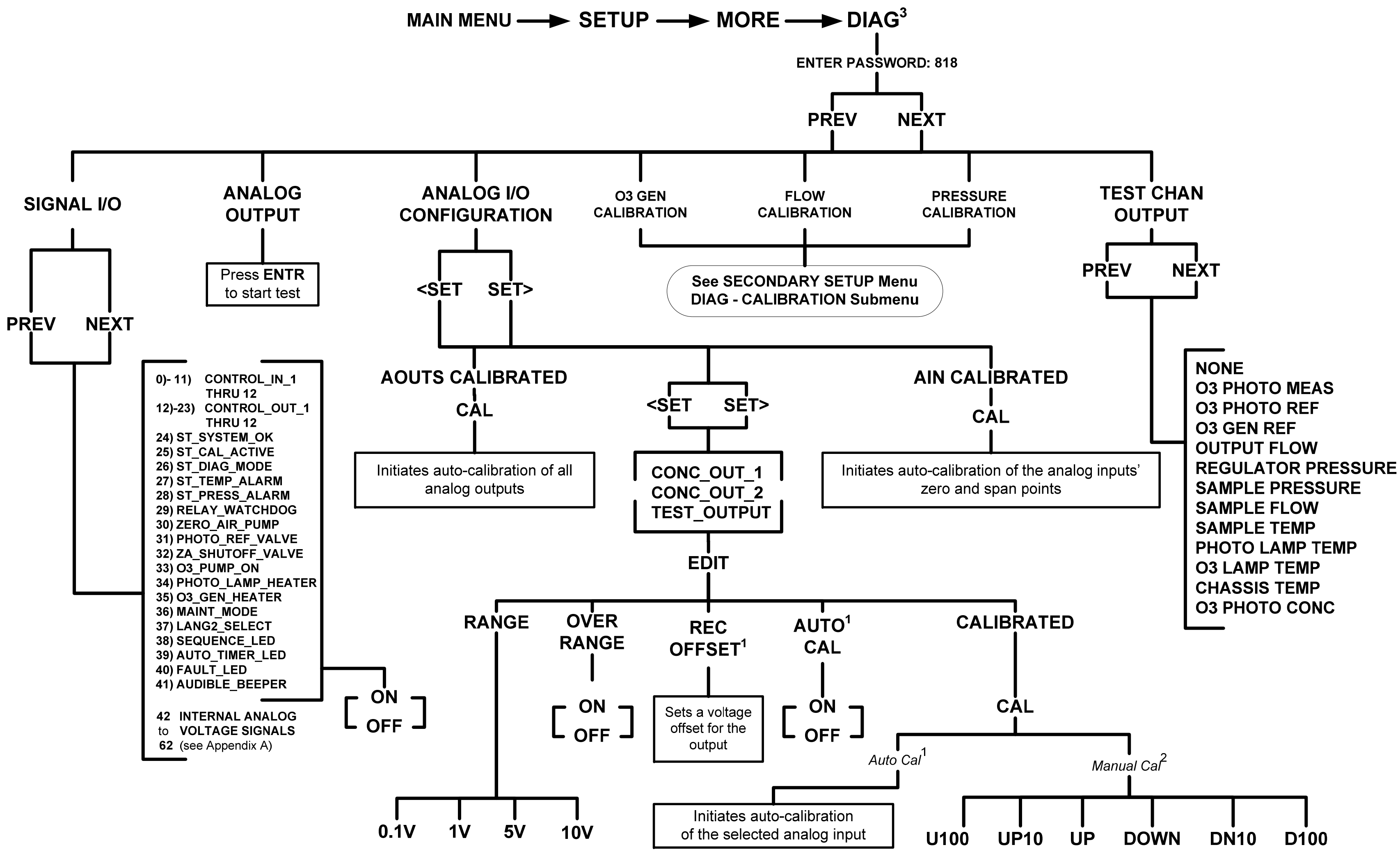


Figure 3-4: SECONDARY SETUP Menu - Basic



[1] Only occurs if one of the voltage ranges is selected.
[2] Manual adjustment menu only appears if either the **AUTO CAL** feature is **OFF**
[3] **DIAG** Menu is inactive while instrument is in **GENERATE** mode.

Figure 3-5: SECONDARY SETUP Menu; DIAG Submenu – Basics

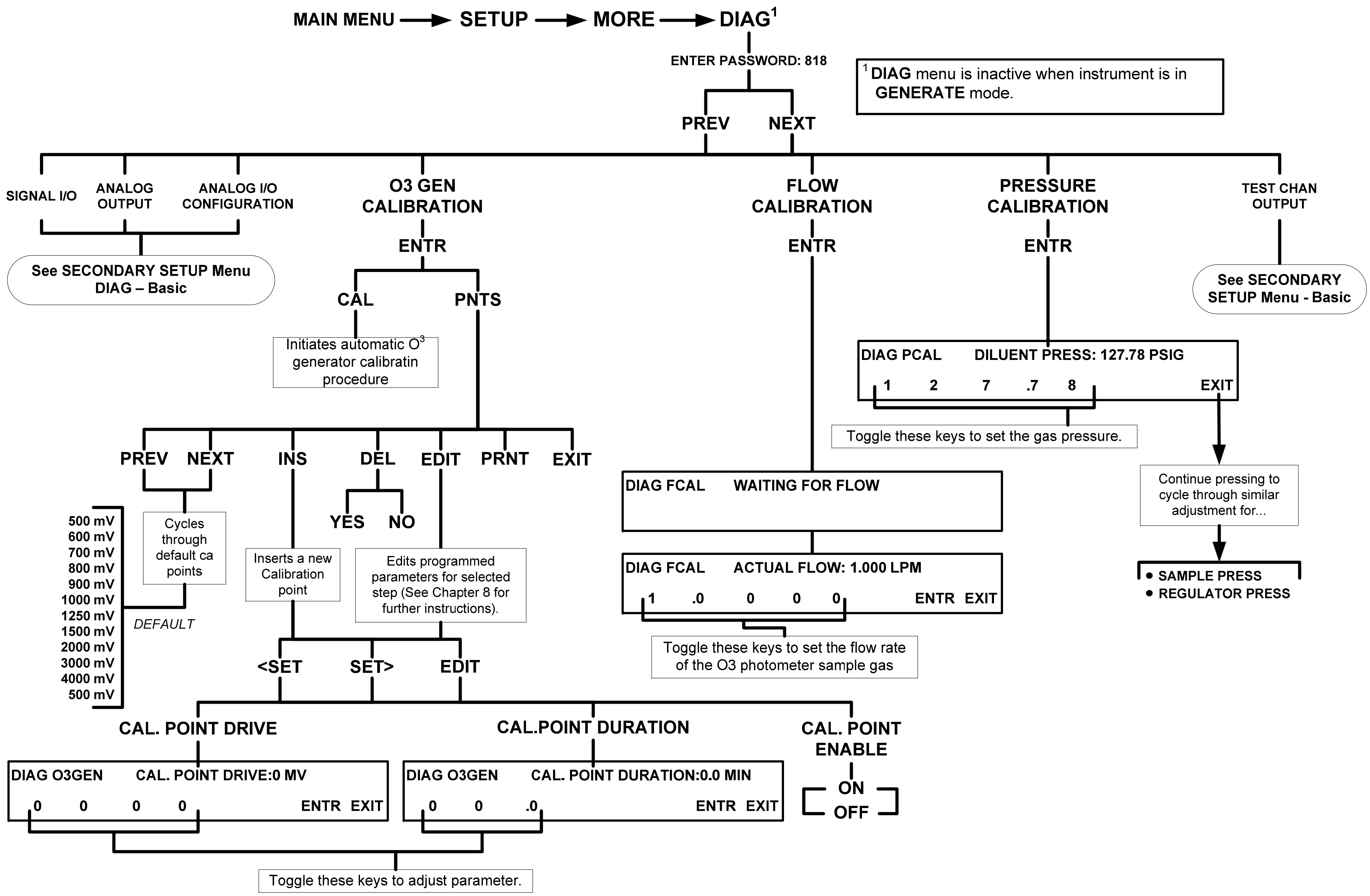


Figure 3-6: SECONDARY SETUP Menu; DIAG Submenu – GAS CONFIGURATION

USER NOTES:

4. QUICK CALIBRATION

4.1 ANALOG CALIBRATION

1. From the Main Menu press [SETUP] [MORE] [DIAG] [929] [ENTR] [NEXT] [ANALOG I/O CONFIGURATION] [ENTER] [CAL]. This will calibrate all of the analog outputs.
2. From the Main Menu press [SETUP] [MORE] [DIAG] [929] [ENTR] [NEXT] [ANALOG I/O CONFIGURATION] [ENTER] [SET>] [AIN CALIBRATED] [CAL]. This will calibrate the Analog Inputs.
3. This calibration should always be done AUTOMATICALLY never MANUALLY.

4.2 PRESSURE/FLOW CALIBRATIONS

4.2.3 REGULATOR PRESSURE CALIBRATION

1. Disconnect the 1/8" cap on the PRESSURE REGULATOR and attach a pressure gauge to this port.
2. Press [SETUP] [MORE] [DIAG] [929] [ENTER].
3. Press [NEXT] until the top line reads PRESSURE CALIBRATION press [ENTER].
4. Adjust the screw on the REGULATOR until the pressure gauge reads the Maximum PSI, record this pressure.
5. Leave every pressure except the O_3 pressure setting the same.
6. Set the O_3 REGULATOR pressure setting to the pressure recorded in step 4 and press [ENTER].
7. Disconnect the pressure gauge and reinstall the 1/8" cap.

4.2.4 PHOTO PRESSURE CALIBRATION

1. Find the current local ambient pressure in inches of mercury, from either a local weather station or a calibrated barometer.
2. Press [SETUP] [MORE] [DIAG] [929] [ENTER].
3. Press [NEXT] until the top line reads PRESSURE CALIBRATION press [ENTER].
4. Leave every pressure except the SAMPLE pressure setting the same.
5. Set the SAMPLE pressure setting to the current local ambient pressure and press [ENTER]

4.2.5 PHOTO FLOW CALIBRATION

1. Generate 0ppb of O_3.
2. Remove the sample fitting on the O_3 bench and measure the O_3 flow going into the Teflon Elbow.
3. This flow rate should be 800cc/min ±80cc's. Reconnect the sample fitting.
4. Now put the calibrator into STANDBY.
5. Press [SETUP] [MORE] [DIAG] [929] [ENTER]. Press [NEXT] until the top line reads FLOW CALIBATION press [ENTER]
6. Enter the measured flow in step 2 above. Press [ENTER].
7. EXIT out to the main menu and generate 0ppb of ozone.
8. Press the <TST TST> buttons until the top line reads PHOTO FLOW. This should read the measure value that was entered in step 2
9. The calibration is complete.
10. EXIT back out to the Main Menu and ensure that the flow is correct.

4.3 OZONE CALIBRATIONS

4.3.1 REFERENCE ADJUSTMENT

1. Put the calibrator into STANDBY.
2. Press [SETUP] [O3] [ADJ].
3. Press the <TST TST> buttons until O3 GEN DRIVE, this value should be 2500mv.
4. Press the <TST TST> buttons until O3 GEN REF, this value should be 2500mv ±200mv. If it is not you will need to peak the UV LAMP and adjust the reference detector potentiometer VR1 until the value is within specifications.
5. Exit back to the Main Menu.

4.3.2 BENCH CALIBRATION

1. The calibrator must be in STANDBY mode.
2. Press [SETUP] [O3] [PHOT] [BCAL] [717] [ENTER] [CAL] [ZERO] [ENTER], wait 30 minutes until you have a good stable zero reading on your photometer and then press [ZERO] [YES], the Zero has now been calibrated. Press [EXIT] one time.
3. Press [CAL] [SPAN] [ENTER]
4. Select your target concentration and press [ENTER] and wait 30 minutes for the photometer become stable.
5. Press [SPAN], enter the amount of ozone read by your photometer and then press [ENTER] [YES].
6. The internal photometer reading should now match your external photometer reading.
7. Exit back to the Main Menu.

4.4.3 IZS CALIBRATION

1. Press [SETUP] [MORE] [DIAG] [929] [NEXT] until the top line reads O3 GEN CALIBRATION.
2. Press [ENTER] [CAL]
3. This procedure will be performed automatically and take 1 hour to complete.
4. Once the calibration has been completed exit back out to the main menu.

4.5 USING THE M703E AS A PHOTOMETER

4.5.1 The M703E will normally generate its own ozone levels and read that, adjusting for the proper concentration requested. However; there is a new feature that allows you to use the M703E as a photometer, monitoring external ozone concentrations.

To do this simply remove the two U shaped tubing jumpers on the back of the calibrator. You will now plumb your ozone to the “PHOTOMETER INLET” (Measure) and your Zero Air to the “PHOTO ZERO INLET” (Reference). Make sure that both of these are at ambient pressure use a vent to ensure that these are at ambient.

Once this has been plumbed up simply hit [GEN] [AUTO] [0ppb O3]. The calibrator will now act as though it is generating ozone except it will be pulling gas from the outside of the calibrator. From the front panel press the <TST TST> buttons until the top line reads ACT=, this will be displaying the current ozone concentration

USER NOTES:

5. MAINTENANCE

Table 5-1: M703E Maintenance Schedule

Item	Action	Freq	Cal Check Req'd.	MISC NOTES	Date Performed									
Verify Test Functions	Record and analyze	Weekly or after any Maintenance or Repair	No											
Photometer Pump Diaphragm	**No Replacement Required. Under Normal Circumstances the Pumps Will Last the Lifetime of the Instrument.**													
Dry Air Pump Diaphragm	Replace	Annually	Yes											
Absorption Tube	Inspect - - - Clean	As Needed	Yes after cleaning		**Cleaning of the Photometer Absorption Tube Should Not Be Required as long as ONLY CLEAN, DRY, PARTICULATE FREE Zero Air (Diluent Gas) is used with the M703E Calibrator**									
Perform Leak Check	Verify Leak Tight	Annually or after any Maintenance or Repair	N0											
Pneumatic lines	Examine and clean	As needed	Yes if cleaned											

USER NOTES:

6. LEAK CHECKING

6.1 PERFORMING LEAK CHECKS

6.1.1 PRESSURE LEAK CHECK

Obtain a leak checker similar to the Teledyne Instruments' part number 01960, which contains a small pump, shut-off valve and pressure gauge. 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

Once the fittings have been wetted with soap solution, do not apply a vacuum as this will cause soap solution to be drawn into the instrument, contaminating it.

DO NOT EXCEED 15 PSI PRESSURE.

1. Turn OFF power to the calibrator.
2. Remove the instrument cover
3. Install a leak checker or tank of gas as described above on the "dry air in" port at the rear panel.
4. Install caps on the following fittings on the rear panel.
   - Exhaust
   - Vent
   - Internal Vent
   - Zero
   - Air Inlet
   - Both CALGAS OUT fittings

NOTE

The M703E calibrator cannot be leak checked with the pump in line due to internal leakage that normally occurs in the pump.

5. Locate the dry air pump.
6. Disconnect the two fittings on the dry air pump and install a union fitting in place of the pump.
7. Locate the photometer pump.
8. Disconnect the two fittings on the photometer pump and install a union fitting in place of the pump.

9. Pressurize the calibrator with the leak checker, allowing enough time to pressurize the instrument fully.
10. Check each fitting with soap bubble solution, looking for bubbles.
    - Once the fittings have been wetted with soap solution.
    - Do not re-apply vacuum as it will draw soap solution into the instrument and contaminate it.
    - Do not exceed 15 psi pressure.
11. Once the leak has been located and repaired, the leak-down rate should be < 1 in-Hg (0.4 psi) in 5 minutes after the pressure is shut off.

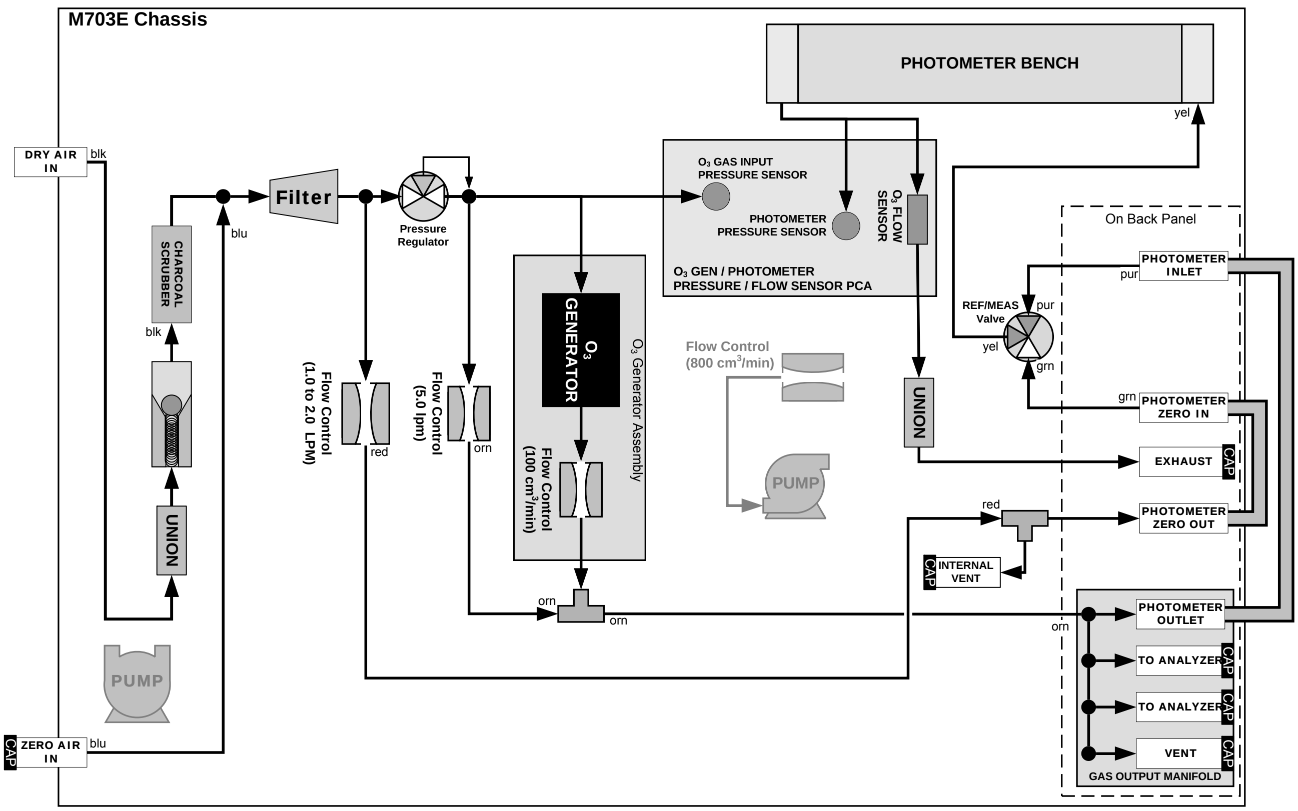


Figure 6-1: Pneumatic setup for performing Pressure Leak Checks

USER NOTES:

7. SPECIFICATIONS

Table 7-2: M703E Analytical Specifications

Linearity	+/- 1.0% of full scale
Precision	1.0 ppb
Stability	+/- 2.0 ppb (photometer feedback mode)
Response Time	180 seconds to 95%
Stability (7-days)	1% photometer feedback; 3% without photometer feedback (CNST or REF)

Table 7-3: M703E Electrical and Physical Specifications

Temperature Range	5-40ºC
Humidity Range	0 - 95% RH, non-condensing
Dimensions (HxWxD)	7” (178 mm) x 17” (432 mm) x 24” (609 mm)
Operating Altitude	10,000 ft Maximum
Weight	35.5 lbs (16.1 kg) including internal zero air pump
AC Power	115VAC, 60Hz 230VAC,50HZ
Analog Outputs	1 user configurable output
Analog Output Ranges	0.1 V, 1 V, 5 V or 10 V Range with 5% under/over-range
Analog Output Resolution	1 part in 4096 of selected full-scale voltage (12 bit)
Digital Control Outputs	12 opto-isolated outputs
Digital Control Inputs	12 opto-isolated outputs
Status Outputs	12 opto-isolated outputs, 5 defined, 7 spare
Serial I/O	2 ports: 1x RS-232; 1x RS-485 or RS-232 (configurable) Communication speed: 300 - 115200 baud (user selectable)
Certifications	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. IEC 61010-1:90 + A1:92 + A2:95,

Table 7-4: M703E Specifications for Ozone Generator

Maximum Output	6 ppm LPM
Minimum Output	100 ppb LPM
Response Time:	180 Sec. (98%)
Optical Feedback	Standard

Table 7-5: M703E Specifications for O_3 Photometer

Full Scale Range	100 ppb to 10 ppm ; User Selectable
Precision	1.0 ppb
Linearity	1.0% of Full Scale
Rise/Fall Time	<20 sec (photometer response)

Zero Drift	<1.0 ppb / 7 days
Span Drift	<1% / 24 hours; <2% / 7 days
Minimum Gas Flow Required	800 cc^3/min

USER NOTES:

8. WARNINGS AND TEST FUNCTIONS

Table 8-6: Front Panel Warning Messages

WARNING	FAULT CONDITION	POSSIBLE CAUSES
CONFIG INITIALIZED	Configuration and Calibration data reset to original Factory state.	- Failed Disk on Chip - User has erased configuration data
DATA INITIALIZED	Data Storage in iDAS was erased.	- Failed Disk-on-Chip. - User cleared data.
FRONT PANEL WARN	The CPU is unable to Communicate with the Front Panel Display Keyboard	- *WARNING* only appears on Serial I/O COM Port(s) - Front Panel Display will be frozen, blank or will not respond. - Failed Keyboard - I^2C Bus failure - Loose Connector/Wiring
LAMP DRIVER WARN	The CPU is unable to communicate with either the O_3 generator or photometer lamp I^2C driver chip.	- I^2C has failed
O3 GEN LAMP TEMP WARNING	IZS Ozone Generator Temp is outside of control range of 48°C ± 3°C.	- O_3 generator heater - O_3 generator temperature sensor - Relay controlling the O_3 generator heater - Entire Relay PCA - I^2C Bus
O3 GEN REFERENCE WARNING	The O_3 generator's reference detector output has dropped below 50 mV.	Possible failure of: - O_3 generator UV Lamp - O_3 generator reference detector - O_3 generator lamp power supply - I^2C bus
O3 PUMP WARNING	The photometer pump failed to turn on within the specified timeout period (default = 30 sec.).	- Failed Pump - Problem with Relay PCA - 12 VDC power supply problem
PHOTO LAMP TEMP WARNING	The photometer lamp temp is < 51°C or >61°C.	Possible failure of: - Bench lamp heater - Bench lamp temperature sensor - Relay controlling the bench heater - Entire Relay PCA - I^2C Bus - Hot Lamp
PHOTO LAMP STABILITY WARNING	Value output during the Photometer's reference cycle changes from measurements to measurement more than 25% of the time.	- Faulty UV source lamp - Noisy UV detector - Faulty UV lamp power supply - Faulty ± 15 VDC power supply
PHOTO REFERENCE WARNING	Occurs when Ref is <2500 mVDC or >4950 mVDC.	Possible failure of: - UV Lamp - UV Photo-Detector Preamp
REAR BOARD NOT DET	Mother Board not detected on power up.	- THIS WARNING only appears on Serial I/O COM Port(s) Front Panel Display will be frozen, blank or will not respond. - Failure of Mother Board

(table continued)

Table 8-1: Front Panel Warning Messages (cont.)

WARNING	FAULT CONDITION	POSSIBLE CAUSES
RELAY BOARD WARN	The CPU cannot communicate with the Relay PCA.	- I^2C Bus failure - Failed relay PCA - Loose connectors/wiring
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

Table 8-7: Test Functions - Indicated Failures

TEST FUNCTION	DIAGNOSTIC RELEVANCE AND CAUSES OF FAULT CONDITIONS.
O3 GEN REF[1]	Possible causes of faults are the same as **O3 GEN REFERENCE WARNING** from Table 8-6
OUTPUT FLOW	Gas flow problems directly affect the concentration accuracy of the M703E's O_3 calibration gases. This number is computed using data from the calibrator's - Check for Gas Flow problems. - Check the pressure regulator
O3 GEN DRIVE	Check the O_3 generator heater and temperature sensors Possible causes of faults are the same as **O3 GEN LAMP TEMP WARNING** from Table 8-6
O3 LAMP TEMP	Incorrect lamp temperature can affect the efficiency and durability of the O_3 generators UV lamp. Possible causes of faults are the same as **O3 GEN LAMP TEMP WARNING** from Table 8-6
REG PRESSURE	Same as **REGULATOR PRESSURE WARNING** from Table 8-6
BOX TEMP	If the Box Temperature is out of range, make sure that the: Box Temperature typically runs ~7°C warmer than ambient temperature. - The Exhaust-Fan is running - The there is sufficient open space to the side and rear of instrument to allow adequate ventilation.
PHOTO MEASURE & PHOTO REFERENCE	If the value displayed is too high the UV Source has become brighter. Adjust the variable gain potentiometer on the UV Preamp Board in the optical bench. If the value displayed is too low: - < 100mV – Bad UV lamp or UV lamp power supply. - < 2000mV – Lamp output has dropped, adjust UV Preamp Board or replace lamp. If the value displayed is constantly changing: - Bad UV lamp. - Defective UV lamp power supply. - Failed I^2C Bus. ▪ If the PHOTO REFERENCE value changes by more than 10mV between zero and span gas: - Defective/leaking switching valve.
PHOTO FLOW	Gas flow problems directly affect the accuracy of the photometer measurements and therefore the concentration accuracy of cal gas mixtures involving O_3 and GPT mixtures. - Check for Gas Flow problems.

TEST FUNCTION	DIAGNOSTIC RELEVANCE AND CAUSES OF FAULT CONDITIONS.
PHOTO LAMP TEMP	Poor photometer temp control can cause instrument noise, stability and drift. Temperatures outside of the specified range or oscillating temperatures are cause for concern. Possible causes of faults are the same as **PHOTO LAMP TEMP WARNING from** Table 8-6
PHOTO SPRESS	The pressure of the gas in the photometer's sample chamber is used to calculate the concentration of O_3 in the gas stream. Incorrect sample pressure can cause inaccurate readings. - Check for Gas Flow problems. See Section Table 8-6.
PHOTO STEMP	The temperature of the gas in the photometer's sample chamber is used to calculate the concentration of O_3 in the gas stream. Incorrect sample temperature can cause inaccurate readings. Possible causes of faults are: - Bad bench lamp heater - Failed sample temperature sensor - Failed relay controlling the bench heater - Failed Relay PCA - I^2C Bus malfunction - Hot Lamp
PHOTO SLOPE	Values outside range indicate: ▪ Contamination of the Zero Air or Span Gas supply. ▪ Instrument is miss-calibrated. ▪ Blocked Gas Flow. ▪ Faulty Sample Pressure Sensor or circuitry. ▪ Bad/incorrect Span Gas concentration.
PHOTO OFFSET	Values outside range indicate: ▪ Contamination of the Zero Air supply.
TIME	Time of Day clock is too fast or slow. ▪ Battery in clock chip on CPU board may be dead.

USER NOTES:

9. LAYOUT

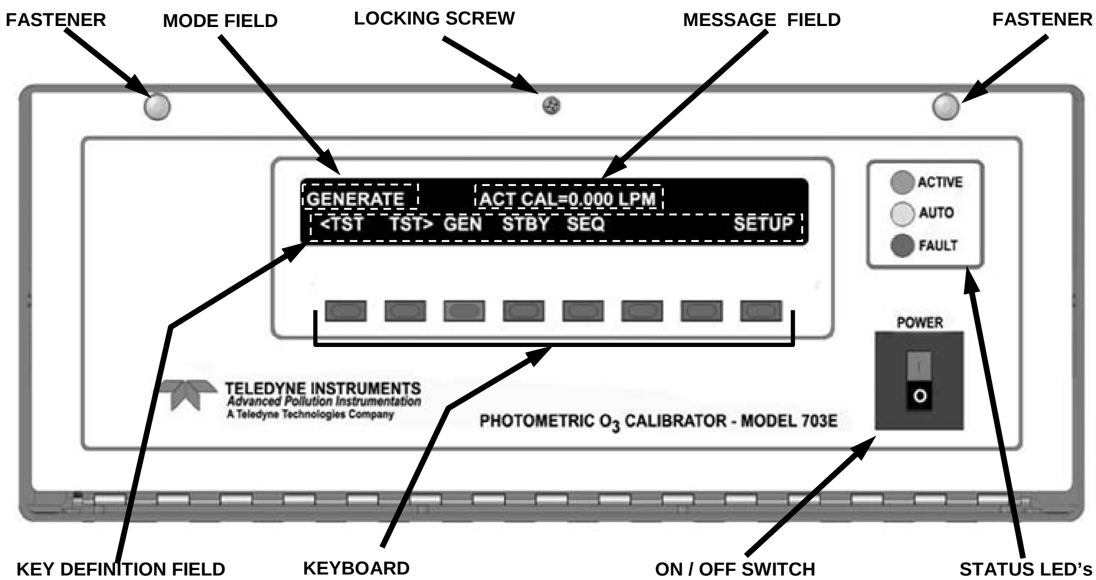


Figure 9-2: M703E Front Panel Layout

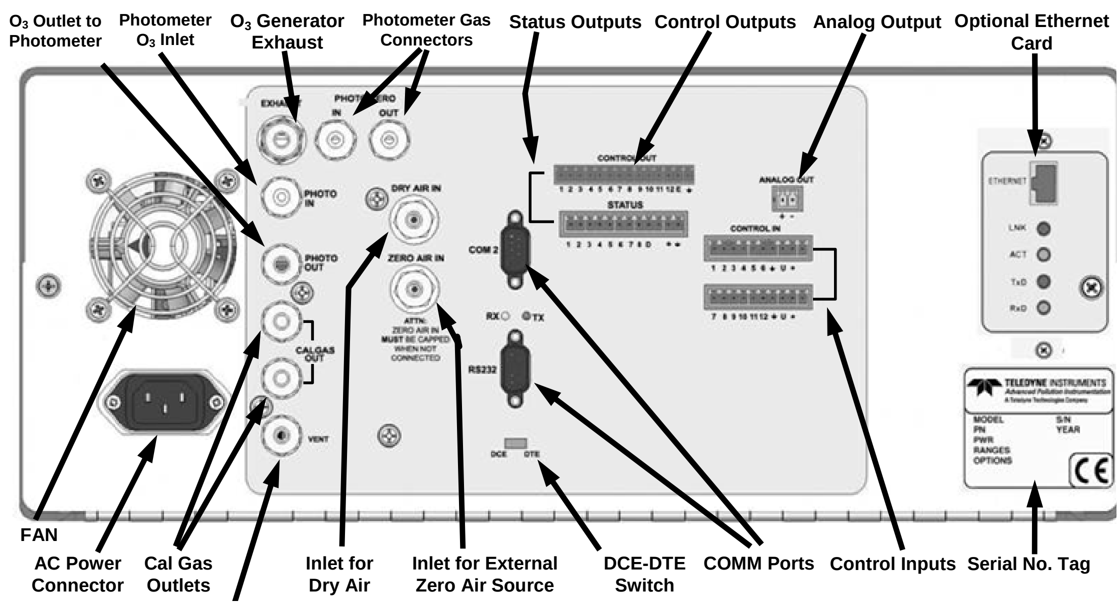


Figure 9-3: M703E Rear Panel Layout

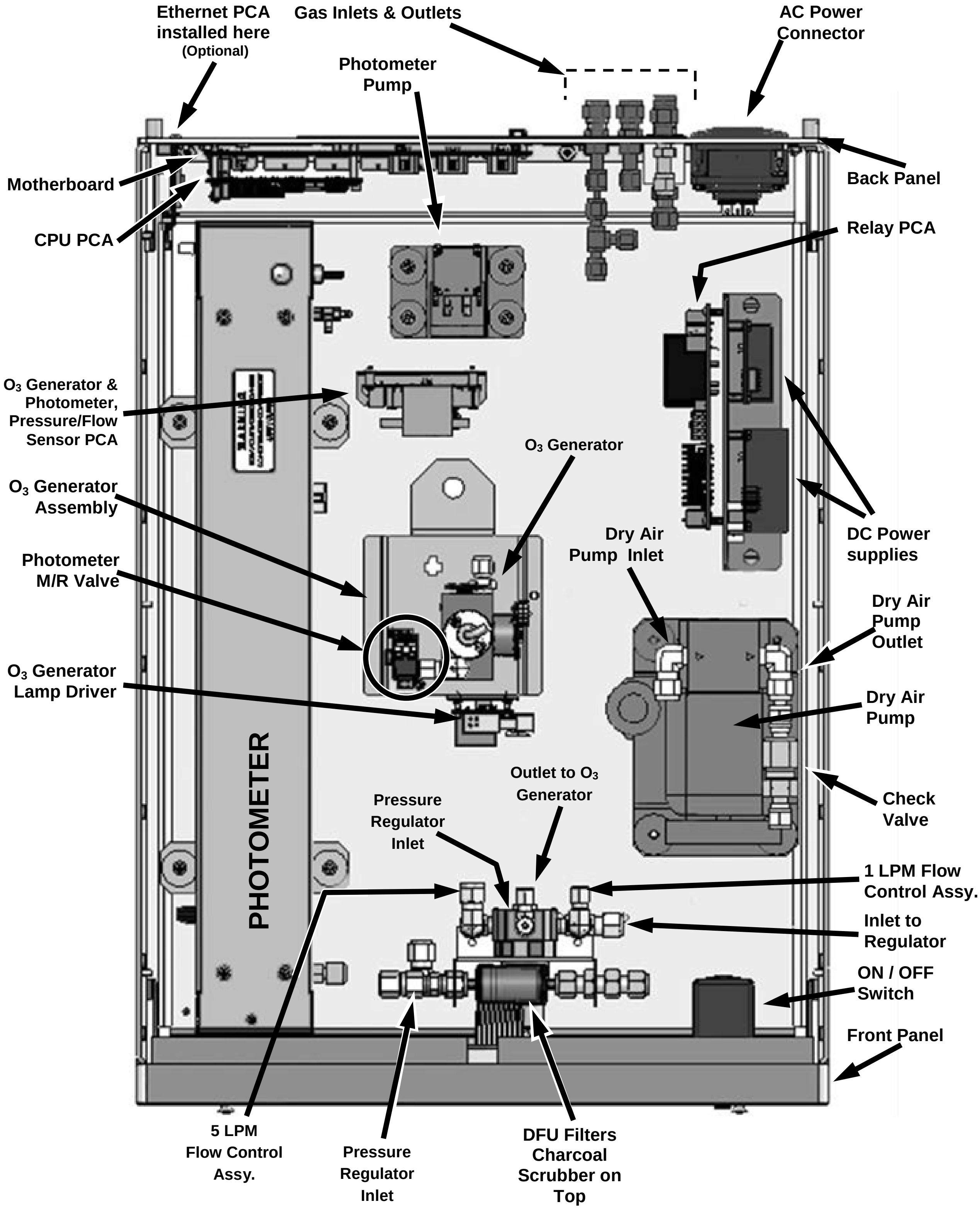


Figure 9-4: M703E Internal Layout – Top View

USER NOTES:

10. OTHER OPTIONS

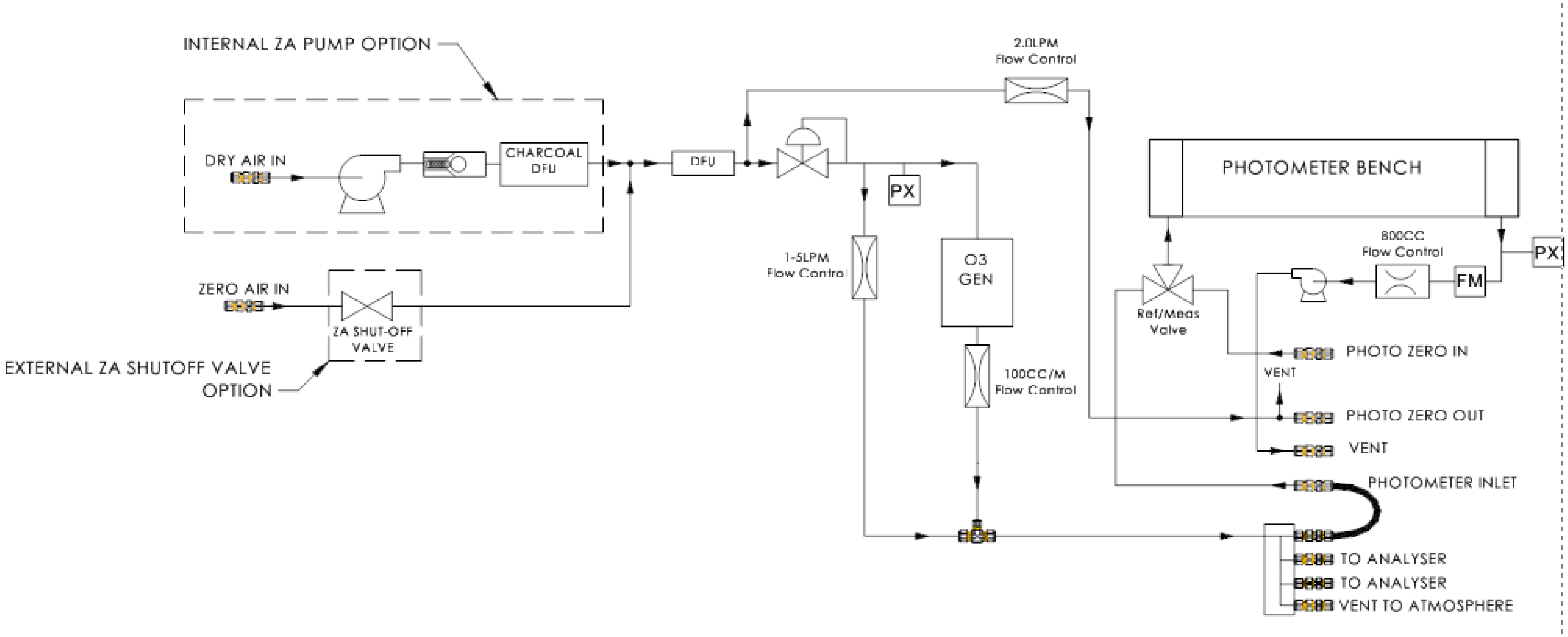


Figure 10.1 Different Possible Plumbing Styles (depending on options)

USER NOTES:

USER NOTES:

USER NOTES:

USER NOTES:

11. T SERIES ADDENDUM

Front panel, rear panel, and display

Getting Started

This section introduces you to the instrument components of the front and rear panel, which are unique to the T series analyzers.

Front Panel

Figure 11-1 shows the analyzer's front panel layout, followed by a close-up of the display screen in Figure 11-2, which is described in Table 11-1. 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 upload new versions of software (contact T-API Customer Service for information).
- plug-in keyboard (not included) to reach the touchscreen display calibration menu

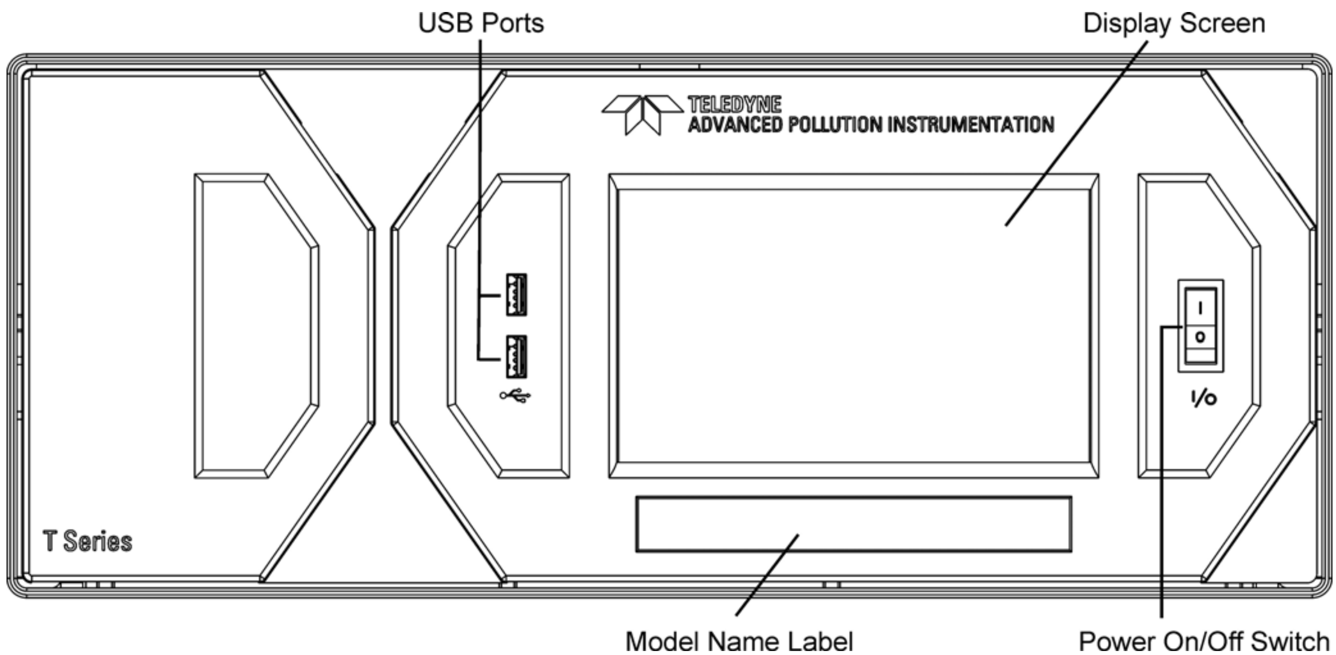


Figure 11-1: Front Panel Layout

Figure 11-2: Display Screen and Touch Control

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 9-2 above (may or may not display a Fault alarm). The lights 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 11-1 provides detailed information for each component of the screen.

ATTENTION

COULD DAMAGE INSTRUMENT

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

Table 11-1: Display Screen and Touch Control Description

Field	Description/Function			
Status	Lights 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 11-3 shows how the front panel display is mapped to the menu charts illustrated in 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.

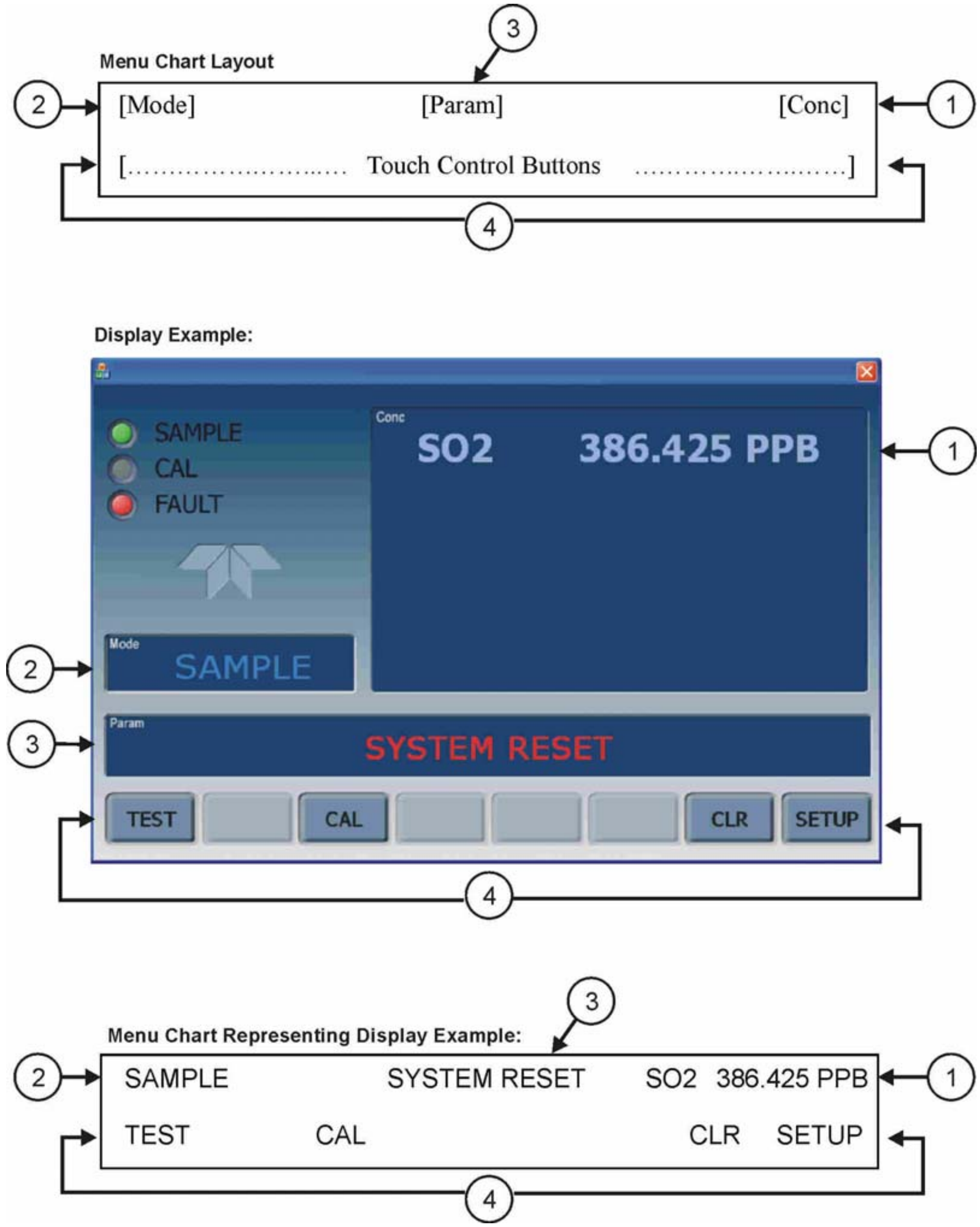


Figure 9-3: Display/Touch Control Screen Mapped to Menu Charts

Front Panel/Display Interface

Users can input data and receive information directly through the front panel touch-screen 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.

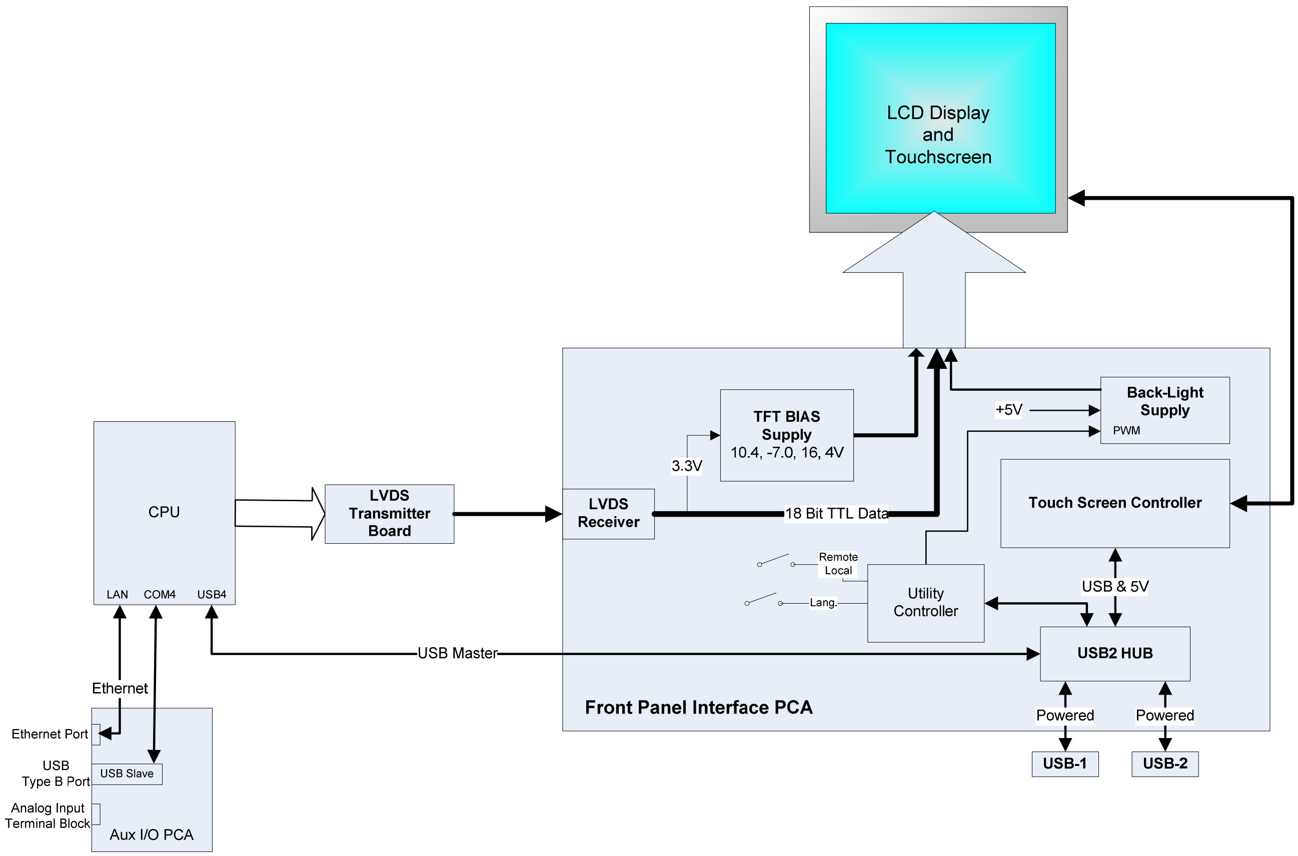


Figure 11-4: Front Panel and Display Interface Block Diagram

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.

Front Panel 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 (current driven)

Rear panel

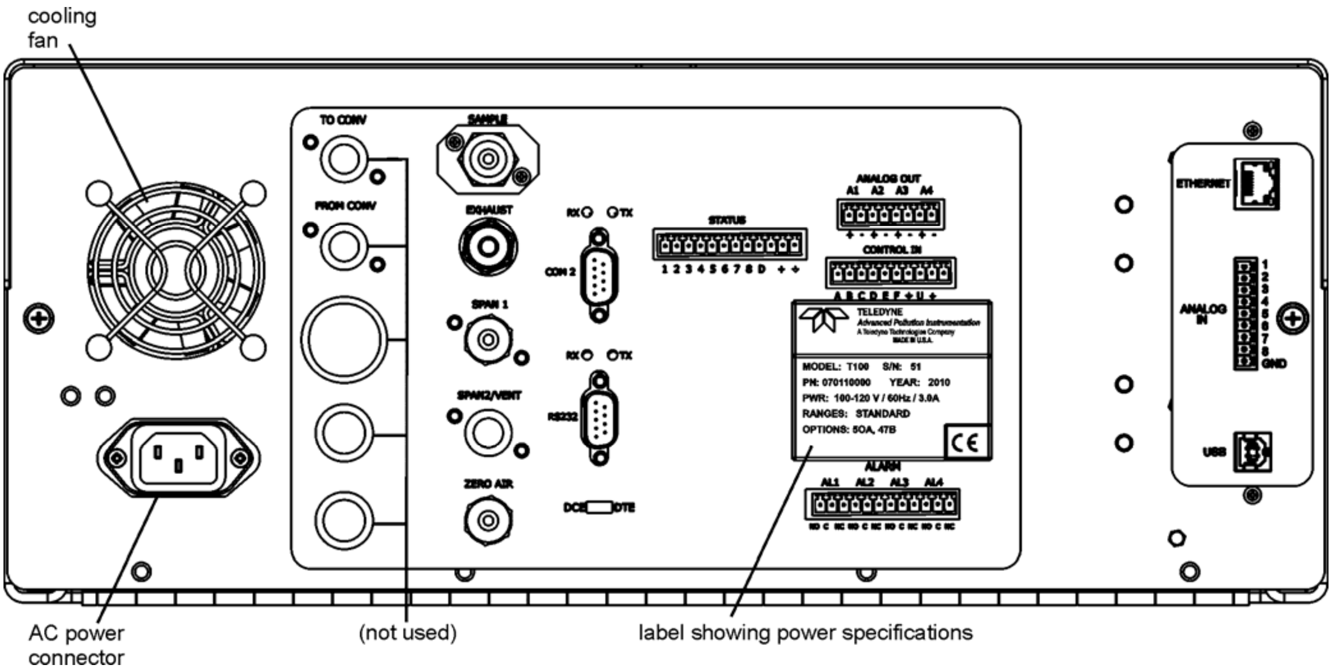


Figure 11-5: Rear Panel Layout

Table 11-2 provides a description of new components on the rear panel.

Table 11-2: Rear Panel Description

Component	Function
ANALOG IN	Option for external voltage signals from other instrumentation and for logging these signals
USB	Connector for direct connection to personal computer, using USB cable.

Connecting Analog Inputs (Option)

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.

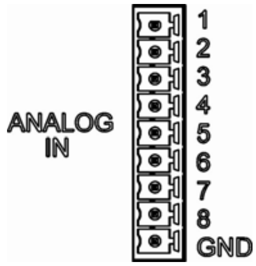


Figure 11-6: Analog In Connector

Pin assignments for the Analog In connector are presented in Table 11-3.

Table 11-3: 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

USB Connection (Option)

For direct communication between the analyzer and a PC, connect a USB cable between the analyzer and desktop or laptop USB ports. (If this option is installed, the **COM2** port can only be used for Multidrop communication).The baud rate of the PC and the analyzer must match.

Calibration & update procedures

Display Calibration

The touchscreen display for the T series analyzer can be calibrated for the user's individual touch. To calibrate the display, you will need a USB keyboard. With the keyboard plugged into either USB port on the front panel, power off the instrument and then re-power.

A Teledyne logo will appear and flash, wait until a logo appears again with the words **System Booting** and a loading bar appear below the logo, and hold down the left shift and left control key on the keyboard throughout the rest of the boot up. This may take several minutes to reach the destination screen.

Once the screen becomes solid blue and a mouse curser appears on the center of the display, release the left shift and left control keys. A red and white target will appear near the center of the screen. Press the target to start the calibration. The target will now appear in a different location. Press and hold each target following the instructions on the display until you are asked to hit either ACCEPT or CANCEL. Hit accept to accept the changes or cancel to decline the changes. After you hit accept, remove the keyboard and re-power the instrument.

Analog Input Calibration

Analog I/O Configuration for Analog In

Table 11-4: DIAG - Analog I/O Functions (Example functions for a T100, AOUTS may vary)

SUB MENU	FUNCTION
AOUTS CALIBRATED:	Shows the status of the analog output calibration (YES/NO) and initiates a calibration of all analog output channels.
CONC_OUT_1	Sets the basic electronic configuration of the A1 analog output (SO_2). There are three options: • **RANGE:** Selects the signal type (voltage or current loop) and full scale level of the output. • **REC_OFS:** Allows setting a voltage offset, not available when RANGE is set to Current Loop (**CURR**). • **AUTO_CAL:** Performs the same calibration as AOUT CALIBRATED, but on this one channel only. NOTE: Any change to RANGE or REC_OFS requires recalibration of this output.
CONC_OUT_2	Same as for CONC_OUT_1 but for analog channel 2 (SO_2)
TEST OUTPUT	Same as for CONC_OUT_1 but for analog channel 4 (TEST)
CONC_OUT_3	(Not available in the analyzer's standard configuration; applies when optional sensor installed).
AIN CALIBRATED	Shows the calibration status (YES/NO) and initiates a calibration of the analog input channels.
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.

AIN Calibration

This is the sub-menu to conduct the analog input calibration. This calibration should only be necessary after major repair such as a replacement of CPU, motherboard or power supplies. Navigate to the **ANALOG I/O CONFIGURATION MENU** from the DIAG Menu, then press:

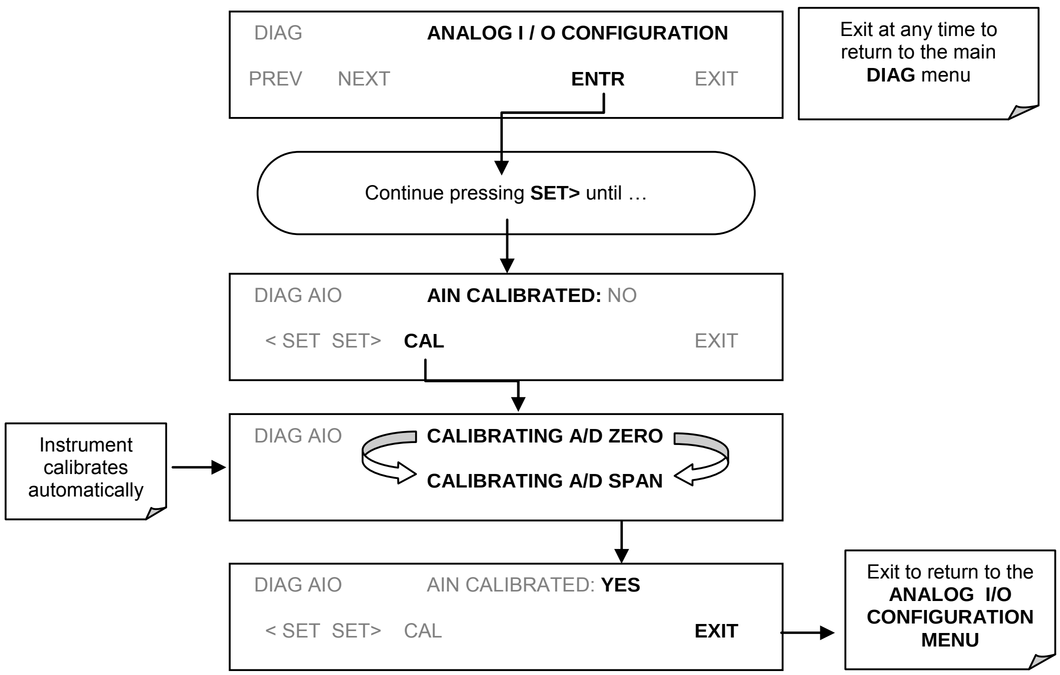


Figure 11-7: DIAG – Analog I/O Configuration – AIN Calibration

Analog Inputs (XIN1…XIN8) Option Configuration

To configure the analyzer's optional 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

To adjust settings for the Analog Input option parameters press:

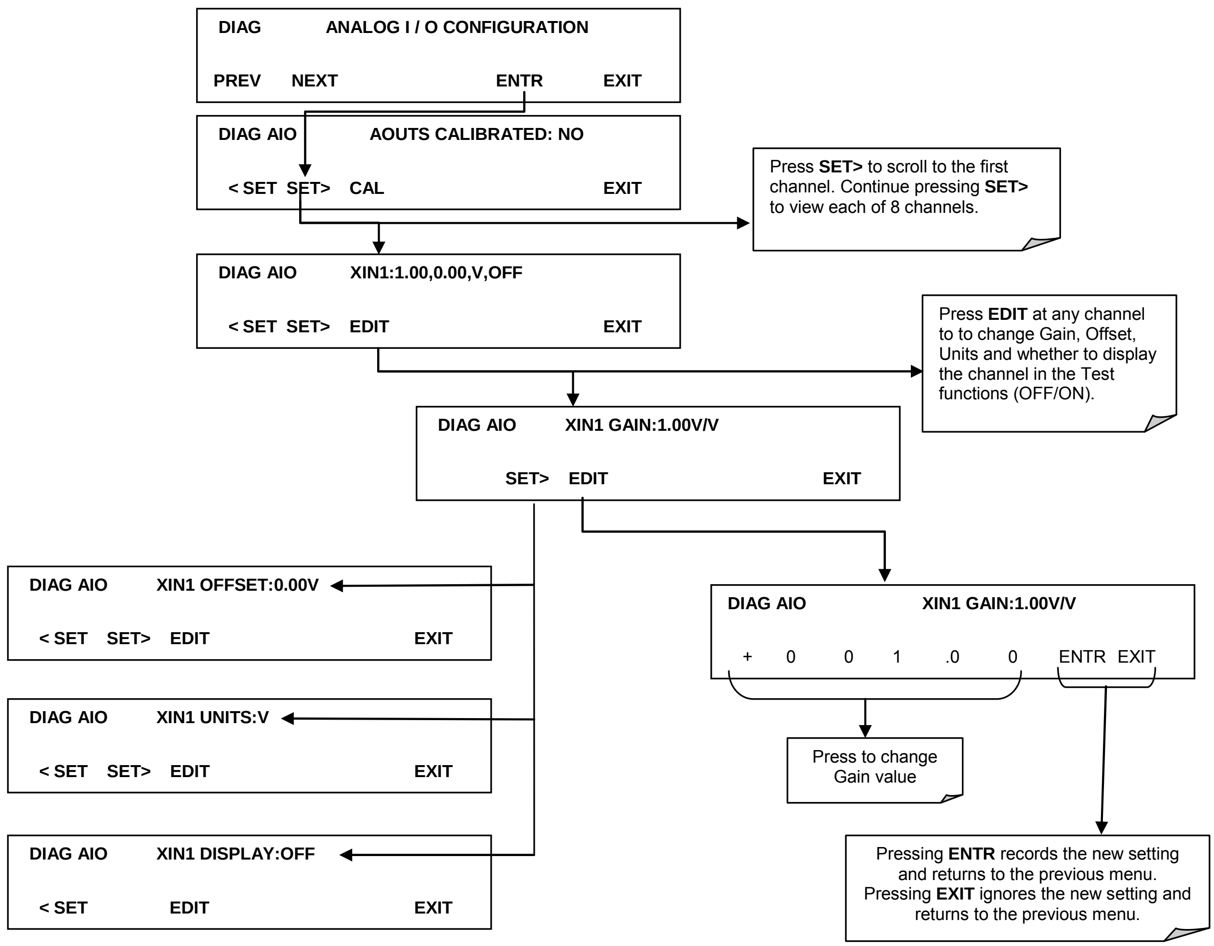


Figure 11-8 DIAG – Analog Inputs (Option) Configuration Menu

USB Configuration

After connecting a USB cable between your PC and the instrument, ensure their baud rates match (change the baud rate setting for either your PC's software or the instrument). COM2 is the default setup menu for USB configuration.

Also, while there are various communication modes available, the default settings are recommended for USB, except to change the baud rate if desired.

Your computer may need the correct drivers in order to communicate via the USB port. These drivers will be available on TAPI's website in the near future. You can contact API customer service if you need the drivers and instructions before then. Once the drivers are installed, the instrument's USB port should work as a standard COM2 port.

Firmware Updates via USB

The T series analyzers can receive firmware updates using a flash drive and the USB ports on the front panel. To update the firmware, locate the file you want to use for the update, and rename it to "update.exe" and copy to the flash drive. This file must not be in a folder on your flash drive in order to be recognized by the T series instrument. Plug in the flash drive and the instrument will give you a popup message with the model the firmware is intended for and the version of firmware, the analyzer will ask if you wish to continue, press yes to continue.

Warning, the instrument will load any recognizable firmware you tell it to regardless of if it is intended for that instrument or not. Double check the firmware model and version before selecting continue.

Troubleshooting faults

Touch-screen Interface

Verify the functioning of the touch screen by observing the display when pressing a touch-screen control button. Assuming that there are no wiring problems and that the DC power supplies are operating properly, but pressing a control button on the touch screen does not change the display, any of the following may be the problem:

- The touch-screen controller may be malfunctioning.
- The internal USB bus may be malfunctioning.

You can verify this failure by logging on to the instrument using APICOM or a terminal program. If the analyzer responds to remote commands and the display changes accordingly, the touch-screen interface may be faulty.

LCD Display Module

Verify the functioning of the front panel display by observing it when power is applied to the instrument. 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

Touch-screen not working correctly

If you experience problems where the display reacts to touch in a different location to where you are pressing, you may need to re-calibrate the touch-screen. Also, if you are in the touch-screen calibration mode and press cancel at the end of the calibration sequence, you will loose the previous calibration and the display will be mis-calibrated. To correct this, follow the calibration procedure in the Display Calibration section.

Diagrams and schematics

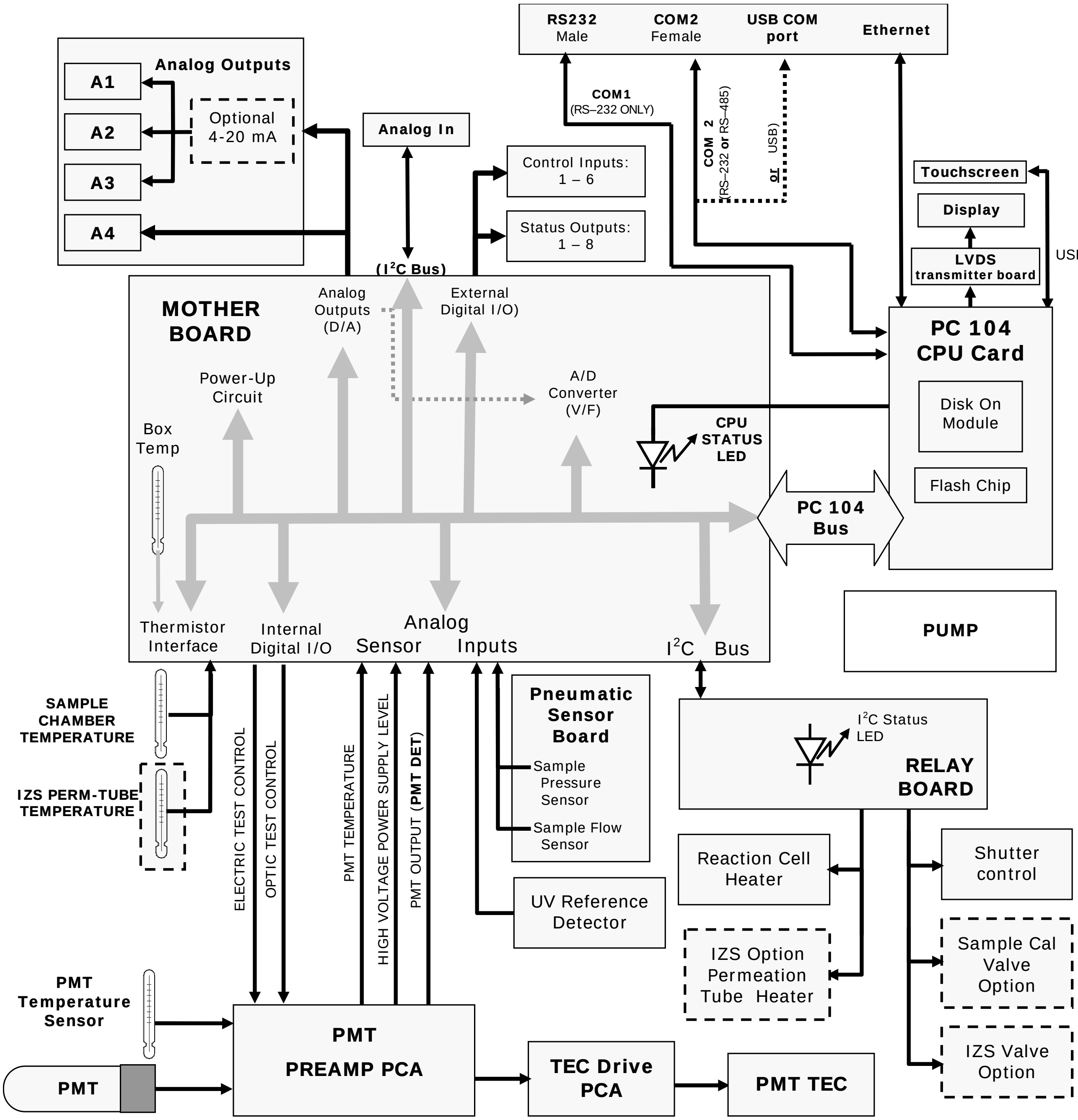


FIGURE 11-9, EXAMPLE OF AN ELECTRONIC BLOCK DIAGRAM (T100)

"E" series compatibility

Incompatible components

The following components are not compatible between E series and T series analyzers:

CPU
Multidrop
Display and Keyboard components
Ethernet
USB
Analog Inputs

Analog Inputs