TELEDYNE API
Everywhereyoulook™

User Manual

Models T700 and T700U Dynamic Dilution Calibrators

with NumaView™ Software

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NOTICE OF COPYRIGHT

TRADEMARKS

IMPORTANT SAFETY INFORMATION

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:

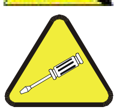
WARNING: Electrical Shock Hazard

HAZARD: Strong oxidizer

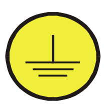
GENERAL WARNING/CAUTION: Read the accompanying message for specific information.

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 product should only be installed, commissioned, and used strictly for the purpose and in the manner described in this manual. If you improperly install, commission, or use this instrument in any manner other than as instructed in this manual or by our Technical Support team, unpredictable behavior could ensue with possible hazardous consequences.

Such risks, whether during installation and commission or caused by improper installation/commissioning/use, and their possible hazardous outcomes include but are not limited to:

RISK	HAZARD
Liquid or dust/debris ingress	Electrical shock hazard
Improper or worn power cable	Electrical shock or fire hazard
Excessive pressure from improper gas bottle connections	Explosion and projectile hazard
Sampling combustible gas(es)	Explosion and fire hazard
Improper lift & carry techniques	Personal injury

Note that the safety of a system that may incorporate this product is the end user's responsibility.

Note

For Technical Assistance regarding the use and maintenance of this instrument or any other Teledyne API product, please contact Teledyne API's Technical Support Department:

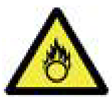
Telephone: +1 **800-324-5190**

Email: api-techsupport@teledyne.com

CONSIGNES DE SÉCURITÉ

Des consignes de sécurité importantes sont fournies tout au long du présent manuel dans le but d'éviter des blessures corporelles ou d'endommager les instruments. Veuillez lire attentivement ces consignes. Chaque consigne de sécurité est représentée par un pictogramme d'alerte de sécurité; ces pictogrammes se retrouvent dans ce manuel et à l'intérieur des instruments. Les symboles correspondent aux consignes suivantes :

AVERTISSEMENT : Risque de choc électrique



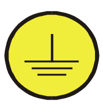
DANGER : Oxydant puissant

AVERTISSEMENT GÉNÉRAL / MISE EN GARDE : Lire la consigne complémentaire pour des renseignements spécifiques

MISE EN GARDE : Surface chaude

Ne pas toucher : Toucher à certaines parties de l'instrument sans protection ou sans les outils appropriés pourrait entraîner des dommages aux pièces ou à l'instrument.

Pictogramme « technicien » : Toutes les opérations portant ce symbole doivent être effectuées uniquement par du personnel de maintenance qualifié.



Mise à la terre : Ce symbole à l'intérieur de l'instrument détermine le point central de la mise à la terre sécuritaire de l'instrument.

MISE EN GARDE

Ce produit ne doit être installé, mis en service et utilisé qu'aux fins et de la manière décrites dans le présent manuel. Si vous installez, mettez en service ou utilisez cet instrument de manière incorrecte autre que celle indiquée dans ce manuel ou sous la direction de notre équipe de soutien technique, un comportement imprévisible pourrait entraîner des conséquences potentiellement dangereuses.

Ce qui suit est une liste, non exhaustive, des risques et résultats dangereux possibles associés avec une mauvaise utilisation, une mise en service incorrecte, ou causés mauvaise commission.

RISQUE	DANGER
Pénétration de liquide ou de poussière/débris	Risque de choc électrique
Câble d'alimentation incorrect, endommagés ou usé	Choc électrique ou risque d'incendie
Pression excessive due à des connexions de bouteilles de gaz incorrectes	Risque d'explosion et d'émission de projectile
Échantillonnage de gaz combustibles	Risque d'explosion et d'incendie
Techniques de manutention, soulevage et de transport inappropriées	Blessure corporelle

Notez que la sécurité d'un système qui peut incorporer ce produit est la responsabilité de l'utilisateur final.

WARRANTY STATEMENT

WARRANTY POLICY (02024J)

Teledyne Advanced Pollution Instrumentation (Teledyne API), a business unit of Teledyne Instruments, Inc., provides that:

Prior to shipment, Teledyne API equipment is thoroughly inspected and tested. Should equipment failure occur, Teledyne API assures its customers that prompt service and support will be available. (For the instrument-specific warranty period, please refer to the "Limited Warranty" Section in the Terms and Conditions of Sale on our website at the following link. http://www.teledyne-api.com/terms_and_conditions.asp).

COVERAGE

After the warranty period and throughout the equipment lifetime, Teledyne 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 are to be performed by the customer.

NON-TELEDYNE API MANUFACTURED EQUIPMENT

Equipment provided but not manufactured by Teledyne API is warranted and will be repaired to the extent and according to the current terms and conditions of the respective equipment manufacturer's warranty.

PRODUCT RETURN

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.

The complete Terms and Conditions of Sale can be reviewed at http://www.teledyne-api.com/terms_and_conditions.asp

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 the manual, Fundamentals of ESD, PN 04786, in its "Packing Components for Return to Teledyne API's Customer Service" section. The manual can be downloaded from our website at http://www.teledyne-api.com. RMA procedures can also be found on our website.

CONVENTIONS USED IN THIS MANUAL

In addition to the safety symbols as presented in the *Important Safety Information* page, this manual provides *special notices* related to the safety and effective use of the analyzer and other pertinent information.

Special Notices appear as follows:

ATTENTION	**COULD DAMAGE INSTRUMENT AND VOID WARRANTY** **This special notice provides information to avoid damage to your instrument and possibly invalidate the warranty.**
Important	**IMPACT ON READINGS OR DATA** **Provides information about that which could either affect accuracy of instrument readings or cause loss of data.**
Note	**Provides information pertinent to the proper care, operation or maintenance of the instrument or its parts.**

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1. INTRODUCTION, SPECIFICATIONS AND APPROVALS

This Section provides an overview of the Dynamic Dilution Calibrator, its features, and its options.

1.1. CALIBRATOR OVERVIEW

Teledyne API's Model T700 and Model T700U are microprocessor-controlled, dynamic dilution precision calibrators. The T700U is a modified version of the T700 calibrator, with the ability to calibrate both standard and trace-level gas analyzers. Both use highly accurate mass flow controllers, and while an ozone generator, photometer, and gas phase titration (GPT) chamber are optional in the T700, they are standard in the T700U. Both models essentially operate the same way and are referred to as "calibrator" or "this instrument" in this manual, except where they differ, in which case the trace calibrator will be specified by its model name, T700U.

Using a combination of highly accurate mass flow controllers and compressed sources of standard gases, the calibrator provides calibration standards for multipoint span and zero checks. Up to four gas sources may be used.

The calibrator can be equipped with an optional built-in, programmable ozone generator for accurate, dependable ozone calibrations. The calibrator also produces NO_2 when blended with NO gas in the internal GPT chamber. A multi-point linearization curve is used to control the generator to assure repeatable ozone concentrations. An optional photometer allows precise control of the ozone generator, both during calibrations and during GPTs. To ensure accurate NO_2 output, the calibrator with photometer option measures the ozone concentration prior to running a GPT.

Many independent calibration sequences may be programmed into the calibrator, covering time periods of up to one year. The setup of sequences is simple and intuitive. These sequences may be actuated manually, automatically, or by a remote signal. The sequences may be uploaded remotely, including remote editing. All programs are maintained in non-volatile memory.

The calibrator design emphasizes fast response, repeatability, overall accuracy and ease of operation. It may be combined with the Model 701 Zero Air Generator to provide the ultimate in easy-to-use, precise calibration for your gas calibrators.

1.2. FEATURES

Some of the exceptional features of your calibrator are:

- Advanced T-Series electronics
- LCD color graphics display with touch screen interface
- Microprocessor control for versatility
- Bi-directional USB (optional), RS-232, optional RS-485, and 10/100Base-T Ethernet for remote operation

- Precise calibration gas generation for O_3, NO, NO_2, CO, HC, H_2S, SO_2
- 12 independent timers for sequences
- Nested sequences (up to 5 levels)
- Software linearization of Mass Flow Controllers (MFC)
- 4 calibration gas ports configurable for single or multi-blend gases
- Optional 3rd MFC for wide dynamic range
- Optional gas phase titration (GPT) chamber
- Optional ozone generator and photometer to allow use as primary or transfer standard
- Inlets for external ozone reference sources

1.3. OPTIONS

The options available for your analyzer are presented in Table 1-1 with name, option number, a description and/or comments, and if applicable, cross-references to technical details in this manual, such as setup and calibration. To order these options or to learn more about them, please contact the Sales Department of Teledyne API at:

TOLL-FREE:	+1 800-324-5190
PHONE:	+1 858-657-9800
FAX:	+1 858-657-9816
EMAIL:	api-sales@teledyne.com
WEBSITE:	http://www.teledyne-api.com/

Table 1-1. Calibrator Options

OPTION	OPTION NUMBER	DESCRIPTION/NOTES	REFERENCE
Flow Options		For mass flow control (MFC)	
	7A	Source MFC 0-50 CC/MIN (Replaces 0-100 CC/MIN)	Section 2.3.2.9
	7B	Source MFC 0-200 CC/MIN (Replaces 0-100 CC/MIN)	
	8A	Diluent MFC 0-5 SLPM (Replaces 0-10 SLPM)	
	8B	Diluent MFC 0-20 SLPM (Replaces 0-10 SLPM)	
	9	Third MFC (Can only be on source)	
Calibration Options		Gas generators	
	1A	Internal Ozone (O_3) Generator with Optical Feedback and GPT Mixing Chamber	Section 2.3.2.9
	2A	UV Photometer Module (to increase accuracy of O_3 Generator, Option 1A)	Section 2.3.2.9
	5	Permeation Tube Oven	Section 2.3.2.12
	73	Dual Gas Output (NOy – special)	Figure 2-29

OPTION	OPTION NUMBER	DESCRIPTION/NOTES		REFERENCE
Rack Mounting		For mounting the analyzer in standard 19" racks		
	20A	Rack mount brackets with 26 in. (660 mm) chassis slides		N/A
	20B	Rack mount brackets with 24 in. (610 mm) chassis slides		N/A
	21	Rack mount brackets only		N/A
		CAUTION – GENERAL SAFETY HAZARD **THE CALIBRATOR WEIGHS CLOSE TO 18 KG (40 POUNDS) WITH ALL OPTIONS. TO AVOID PERSONAL INJURY WE RECOMMEND THAT TWO PERSONS LIFT AND CARRY IT AFTER DISCONNECTING ALL CABLES AND TUBING FROM THE CALIBRATOR BEFORE MOVING IT.**		
Parts Kits		Spare parts and expendables for 1-year operation		
	46A	Kit, Spares for One Unit		(Technical Support)
	46B	Photometer Kit, Spares for One Unit		(Technical Support)
	46C	Photometer W/ IZS Spares Kit For 1 Unit		(Technical Support)
Communications		For remote serial, network and Internet communication with the analyzer.		
		Type	Description	
Cables	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 DB-25 serial connectors.	Section 2.3.1.7
	60B	RS-232	Shielded, straight-through DB-9F to DB-9F cable of about 1.8 m length.	Section 2.3.1.7
	60C	Ethernet	Patch cable, 2 meters long, used for Internet and LAN communications.	Section 2.3.1.7,
	60D	USB	Cable for direct connection between instrument (rear panel USB port) and personal computer.	Section 2.3.1.7
USB Port	64A	For rear panel connection to personal computer.		Section 2.6.11
RS-232 Multidrop	62	Multidrop/LVDS card seated on the analyzer's CPU card. Each instrument in the multidrop network requires this card and a communications cable (Option 60B).		Section 2.3.1.7
External Valve Driver Capability - For driving up to eight, 8-watt valves				
	48C	12V External Valve Driver - without Power Supply Module		Section 2.3.1.6
	48E	12V External Valve Driver - with Power Supply Module		
NIST Traceable, Primary Standard Certification for use as a Primary Ozone Standard if purchased with the O_3 generator and photometer options, 1A and 2A, respectively.				
	95A	Factory Calibration		Section 2.3.2.2
	95B	Calibration as a Primary Standard		
	95C	Calibration to NIST-SRP		
For this application the Dynamic Dilution Calibrator's performance is calibrated to Standard Reference Photometer (SRP). Calibrators ordered with this option are verified and validated in accordance with procedures prescribed by the U.S. Environmental Protection Agency (EPA) under Title 40 of the Code of Federal Regulations, Part 50, Appendix D.				

OPTION	OPTION NUMBER	DESCRIPTION/NOTES	REFERENCE
Special Features		Built in features, software activated	
	N/A	Maintenance Mode Switch, located inside the instrument, places the analyzer in maintenance mode where it can continue sampling, yet ignore calibration, diagnostic, and reset instrument commands. This feature is of particular use for instruments connected to Multidrop or Hessen protocol networks. Call Technical Support for activation.	N/A
	N/A	Second Language Switch activates an alternate set of display messages in a language other than the instrument's default language. Call Technical Support for a specially programmed Disk on Module containing the second language.	N/A

1.4. T700 SPECIFICATIONS

All specifications are based on constant conditions.

Table 1-2. T700 Dilution System Specifications

PARAMETER	SPECIFICATION
Flow Measurement Accuracy	± 1.0% of Full Scale
Repeatability of Flow Control	± 0.2% of Full Scale
Linearity of Flow Measurement	± 0.5% of Full Scale
Flow Range of Diluent Air	0 to 10 SLPM – Optional Ranges: 0 to 5 SLPM; 0 to 20 SLPM
Flow Range of Cylinder Gases *	0 to 100 cc/min – Optional Ranges: 0 to 50 cc/min; 0 to 200 cc/min (others available)
Zero Air Requirements	10 SLPM @ 30 PSIG – Optional: 20 SLPM @ 30 PSIG
CAL Gas Input Ports	4 (configurable for single or multi-blend gases)
Diluent Gas Input Port	1

* Can select two Cylinder Gas ranges with 3rd MFC Option for wider dynamic range

Table 1-3. T700 Electrical and Physical Specifications

PARAMETER	SPECIFICATION	
AC Power	Rating	Typical Power Consumption
	85V – 264V, 47Hz – 63Hz	115 V: 65 W 230 V: 60 W
Analog Outputs	1 user configurable output	
Analog Output Ranges (Test Channel)	10V, 5V, 1V, 0.1V (selectable) Range with 5% under/over-range	
Analog Output Resolution	1 part in 4096 of selected full-scale voltage (12 bit)	
Standard I/O	1 Ethernet: 10/100Base-T 2 RS-232 (300 – 115,200 baud) 2 USB device ports 12 opto-isolated digital control outputs 12 opto-isolated digital control inputs 8 opto-isolated digital status outputs	
Optional I/O	1 USB com port 1 RS485 Multidrop RS232	
Operating Temperature Range	5-40ºC	
Humidity Range	0 - 95% RH, non-condensing	
Environmental Conditions	Installation Category (Over Voltage Category) II Pollution Degree 2 Intended for Indoor Use Only at Altitudes ≤ 2000m	
Materials	Cal Gas Output Wetted Surfaces: PTFE. Cal Gas Output Manifold: Glass-coated Steel	
Dimensions (H x W x D)	7" x 17" x 24" (178 mm x 432 mm x 609 mm)	
Weight	31 lbs (14.06 kg); 39.2 lbs (17.78 kg) with photometer, GPT, and O_3 generator options	

Table 1-4. T700 Optional Ozone (O_3) Generator Specifications**

PARAMETER	SPECIFICATION
Maximum Output	6 ppm LPM
Minimum Output	100 ppb LPM
Response Time	180 seconds to 98%
Optical Feedback	Standard
Stability (7 days)	1% with photometer option 3% without photometer option
Linearity	1% with photometer option 3% without photometer option
** GPT mixing chamber is included with the O_3 Generator option	

Table 1-5. T700 Optional UV Photometer Specifications

PARAMETER	SPECIFICATION
Full Scale Range	0 - 100 ppb to 0 to 10 ppm User Selectable
Precision	1.0 ppb
Linearity	1.0% of reading
Rise/Fall Time	< 20 sec (photometer response)
Response Time (95%)	180 sec (system response)
Zero Drift	<1.0 ppb / 24 hours
Span Drift	<1% / 24 hours
Minimum Gas Flow Required	800 cc/min

1.5. T700U SPECIFICATIONS

Table 1-6. T700U Dilution System Specifications

PARAMETER	SPECIFICATION
Flow Measurement Accuracy	± 1.0% full Scale
Repeatability of Flow Control	± 0.2% full Scale
Linearity of Flow Measurement	± 0.5% full Scale
Flow Range of Diluent Air	0 to 10 SLPM – Optional Ranges: 0 to 5 SLPM; 0 to 20 SLPM (others available)
Flow Range of Cylinder Gases*	0 to 200 cc/min – Optional Ranges: 0 to 50 cc/min; 0 to 100 cc/min (others available)
Zero Air Required	10 SLPM @ 30 psi Optional: 20 SLPM @ 30 psi
CAL Gas Input Ports	4 (configurable)
Diluent Gas Input Ports	1
* Can select 3rd MFC Option for wider dynamic range	

Table 1-7. T700U NO_2 Generation (GPT modes) Specifications

PARAMETER	SPECIFICATION
Minimum Output	20 ppb LPM
Minimum Concentration:	3 ppb
Precision	± 2.0% (with GPTPS)

Table 1-8. T700U Ozone Generator Module Specifications

PARAMETER	SPECIFICATION
Maximum Output	6 ppm LPM
Minimum Output	20 ppb LPM
Minimum Ozone Concentration	3 ppb
Response Time	180 seconds to 98%
Optical Feedback	Standard

Table 1-9. T700U UV Photometer Option Specifications

PARAMETER	SPECIFICATION
Range	100 ppb to 10 ppm (selectable)
Precision	1.0 ppb
Linearity	1.0% of reading
Rise/Fall Time	<20 seconds (photometer response)
Response Time	180 seconds to 95% (system response)
Zero Drift	<1.0 ppb / 24 hours

Table 1-10. T700U Electrical and Physical Specifications

PARAMETER	SPECIFICATION	
AC Power	Rating	Typical Power Consumption
	100-240 V~ 50/60 Hz, 1.5 A	115 V: 76 W 230 V: 80 W
Analog Outputs	1 user configurable output	
Analog Output Ranges	10V, 5V, 1V, 0.1V (selectable)	
Analog Output Resolution	1 part in 4096 of selected full-scale voltage (12 bit)	
Standard I/O	1 Ethernet: 10/100Base-T 2 RS-232 (300 – 115,200 baud) 2 USB device ports 12 digital control outputs 12 digital control inputs 8 digital status outputs	
Optional I/O	1 USB com port 1 RS485 Multidrop RS232	
Operating Temperature Range	5 - 40ºC	
Humidity Range	0 - 95% RH, non-condensing	
Environmental	Installation Category (Over Voltage Category) II Pollution Degree 2 Intended for Indoor Use Only at Altitudes ≤ 2000m	
Dimensions (H x W x D)	7” x 17” x 24” (178 mm x 432 mm x 609 mm)	
Weight	39.2 lbs (17.78 kg)	

1.6. COMPLIANCE AND CERTIFICATIONS

This product is CE compliant and adheres to the Low Voltage and ElectroMagnetic Compatibility directives.

For any other certifications, please refer to this product’s specifications sheet on our website.

2. GETTING STARTED

This Section addresses the procedures for unpacking the instrument and inspecting for damage, presents clearance specifications for proper ventilation, introduces the instrument layout, then presents the procedures for getting started: making electrical and pneumatic connections, and conducting an initial calibration check.

2.1. UNPACKING

CAUTION – RISK OF PERSONAL INJURY

The calibrator weighs about 18 kg (40 pounds) without options installed. To avoid personal injury, always use two persons and proper lift and carry techniques to move/relocate the calibrator.

ATTENTION

COULD DAMAGE INSTRUMENT AND VOID WARRANTY

Printed Circuit Assemblies (PCAs) are sensitive to electro-static discharges too small to be felt by the human nervous system. Failure to use ESD protection when working with electronic assemblies will void the instrument warranty. Refer to the manual, Fundamentals of ESD, PN 04786, which can be downloaded from our website at http://www.teledyne-api.com.

CAUTION – AVOID DAMAGE TO THE INSTRUMENT

BEFORE operating instrument, remove dust plugs from pneumatic ports.

Note

Teledyne API recommends that you store shipping containers and materials for future use if/when the instrument should be returned to the factory for repair and/or calibration service. See Warranty statement in this manual and Return Merchandise Authorization (RMA) on our Website at http://www.teledyne-api.com.

WARNING!

Never disconnect or reconnect electronic circuit boards, wiring harnesses or electronic subassemblies while the unit is under power.

1. Inspect the received packages for external shipping damage. If damaged, please advise the shipper first, then Teledyne API.
2. Included with your calibrator is a printed record of the final performance characterization performed on your instrument at the factory. This record, titled *Final Calibrated Test and Validation Data Sheet*, is an important quality assurance and calibration record and should be placed in the quality records file for this instrument.
3. Carefully remove the top cover of the calibrator and check for internal shipping damage.
    a. Remove the four screws located on the sides: two at front, two at rear.
    b. Lift the cover straight up.
    c. Inspect the interior of the instrument to ensure all circuit boards and other components are intact and securely seated.
    d. Check the connectors of the various internal wiring harnesses and pneumatic hoses to ensure they are firmly and securely seated.
    e. Verify that all of the optional hardware ordered with the unit has been installed. (These are checked on the paperwork accompanying the instrument).

2.1.1. Ventilation Clearance

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

Table 2-1. Instrument Ventilation Clearance Requirements

AREA	MINIMUM REQUIRED CLEARANCE
Behind the instrument	10 cm / 4 inches
Sides of the instrument	2.5 cm / 1 inch
Above and below the instrument	2.5 cm / 1 inch

Various rack mount kits are available for this instrument. See Table 1-1 of this manual for more information.

2.2. INSTRUMENT LAYOUT

The front panel (Figure 2-1) has two USB ports for peripheral device connections: mouse and keyboard as alternatives to the touchscreen interface, or flash drive for uploads/downloads (devices not included).

2.2.1. FRONT PANEL

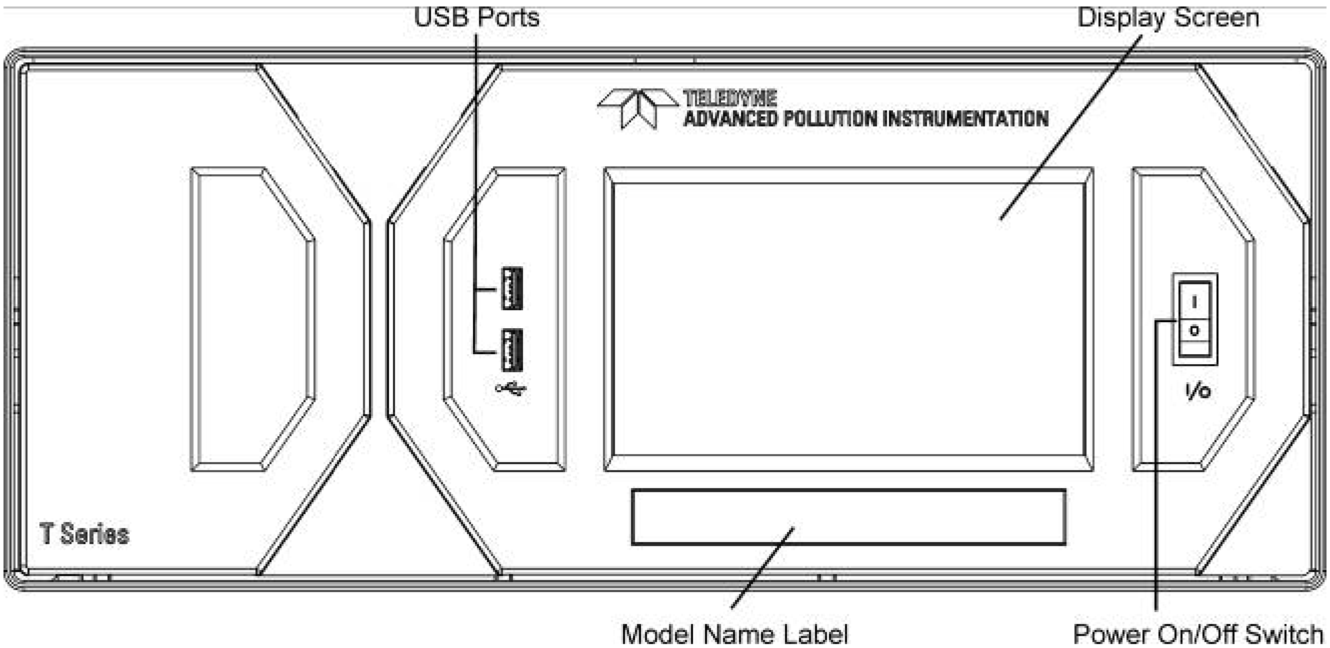


Figure 2-1. Calibrator Front Panel Layout

CAUTION – AVOID DAMAGING TOUCHSCREEN

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

2.2.2. REAR PANEL

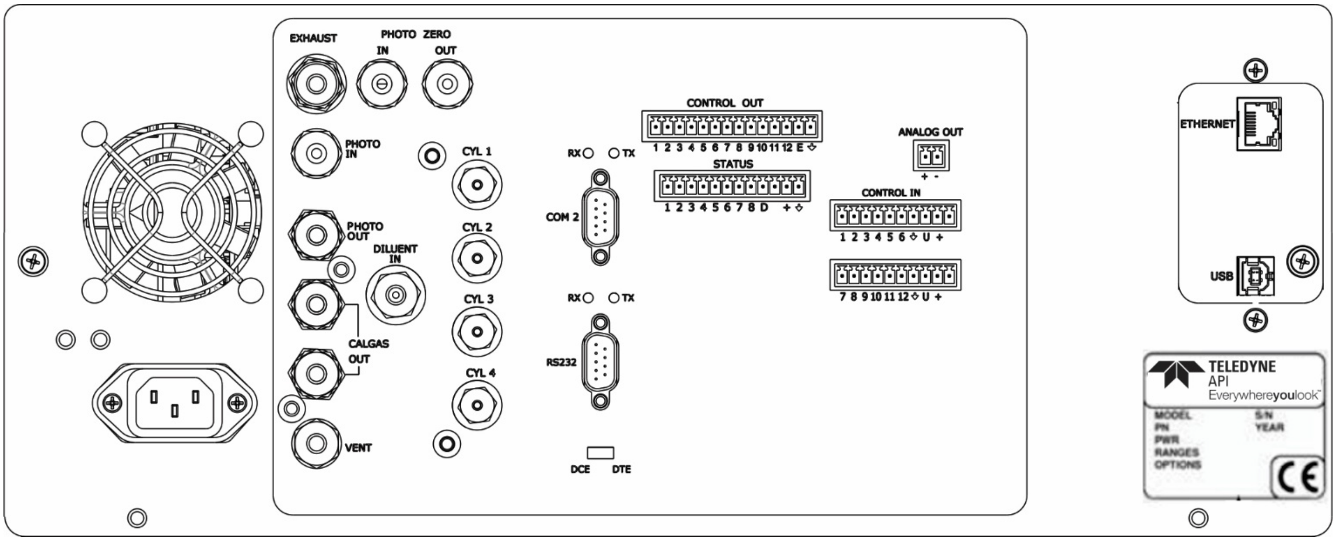


Figure 2-2. Calibrator Rear Panel Layout

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

Table 2-2. Rear Panel Description

COMPONENT	FUNCTION
Cooling fan	Pulls ambient air into chassis through side vents and exhausting 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 calibrator's rear panel Model number label.
* EXHAUST (option)	Exhaust gas from ozone generator and photometer CAUTION! Exhaust gas must be vented outside.
* PHOTOMETER INLET (Photometer option)	Measurement gas input for O_3 photometer
* PHOTOMETER OUTLET (Photometer option)	Calibration gas outlet to O_3 photometer
* PHOTO ZERO IN (Photometer option)	Inlet for photometer Zero Gas
* PHOTO ZERO OUT (Photometer option)	Outlet for photometer Zero Gas
DILUENT IN	Diluent or zero air gas inlet.
CALGAS OUT	Outlets for calibration gas
VENT	Vent port for output manifold
CYL 1 thru CYL 4	Inlets for up to 4 calibration gases.
COM 2	Serial communications port for RS-232 or RS-485.
RX TX	LEDs indicate receive (RX) and transmit (TX) activity on the when blinking.
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. (Section 4.1)
CONTROL OUT	For outputs to devices such as Programmable Logic Controllers (PLCs).
STATUS	For outputs 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.
ETHERNET	Connector for network or Internet remote communication, using Ethernet cable.
(optional) USB	Connector for direct connection to a personal computer, using USB cable.
Model/specs label	Identifies the analyzer model number and lists voltage and frequency specifications.
* Option in T700; standard in T700U	

2.2.3. INTERNAL LAYOUT

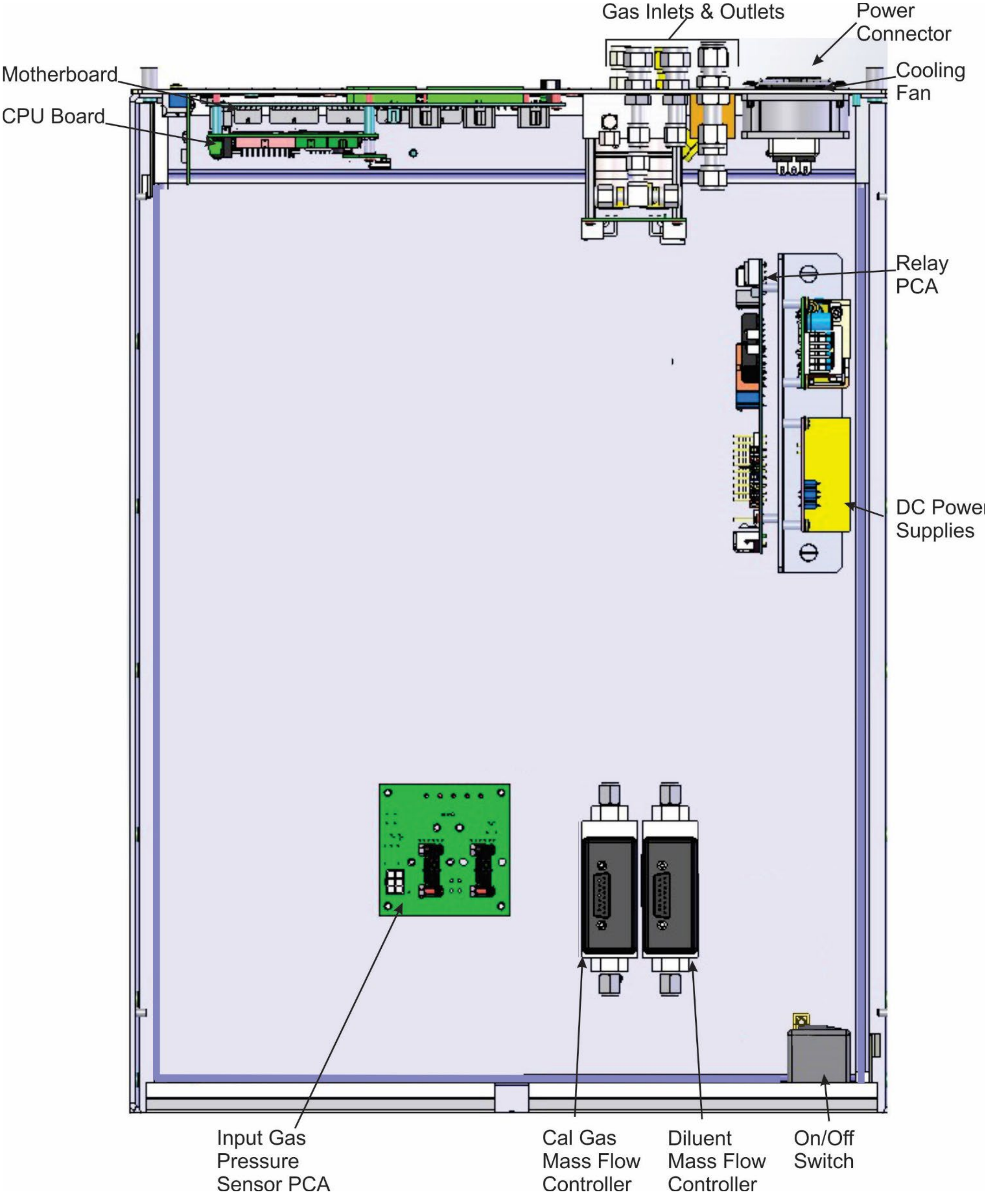


Figure 2-3. Internal Layout, T700 Base Unit

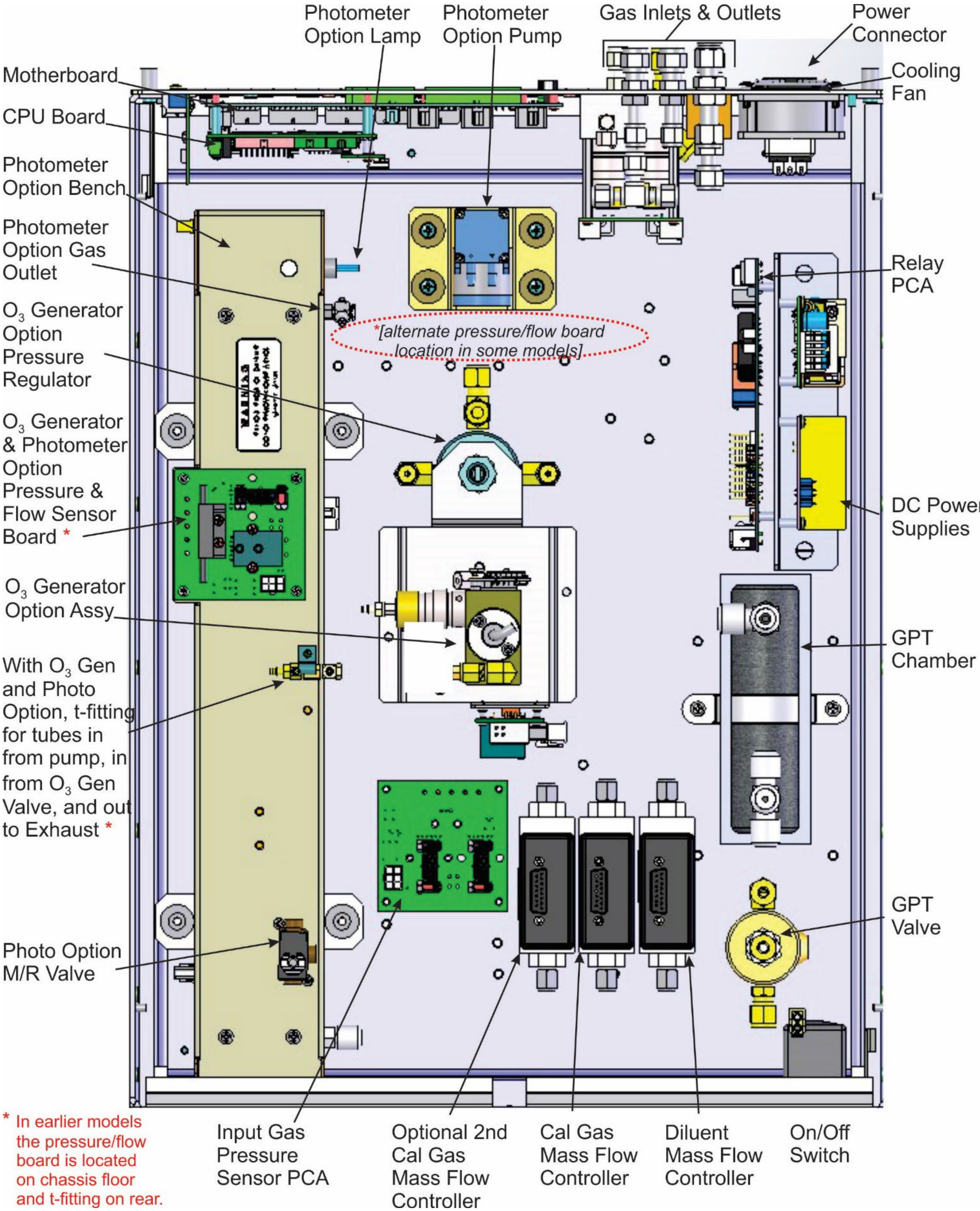


Figure 2-4. Internal Layout with O_3 Generator and Photometer (options in T700, standard in T700U)

2.3. CONNECTIONS

This Section presents the electrical (Section 2.3.1) and pneumatic (Section 2.3.2) connections for setting up and preparing the instrument for operation.

2.3.1. 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.**

WARNING – ELECTRICAL SHOCK HAZARD

- **High Voltages are present inside the instrument's case.**
- **Power connection must have functioning ground connection.**
- **Do not defeat the ground wire on power plug.**
- **Turn off instrument power before disconnecting or connecting electrical subassemblies.**
- **Do not operate with cover off.**

CAUTION – AVOID DAMAGE TO THE INSTRUMENT

Ensure that the AC power voltage matches the voltage indicated on the instrument's model/specs label before plugging it into line power.

2.3.1.1. CONNECTING POWER

Attach the power cord between the instrument's AC power connector and a power outlet capable of carrying at least the rated current at your AC voltage range. It is important to adhere to all safety and cautionary messages, and ensure that the outlet is equipped with a functioning earth ground.

CAUTION – AVOID PERSONAL INJURY

DO NOT look at the photometer UV lamp; UV light can cause eye damage.

Always wear glasses made from Safety UV filtering glass (plastic glasses are inadequate).

2.3.1.2. CONNECTING ANALOG OUTPUTS

The calibrator is equipped with an analog output channel for one of several diagnostic functions, and is accessible through the ANALOG OUT connector (Figure 2-5) on the rear panel. Its standard available output is 0-5 VDC.

Attach a strip chart recorder or data-logger to the analog output connector. Configuration information is presented in the Setup Section (Setup>Analog Outputs>, Section 2.6.9).

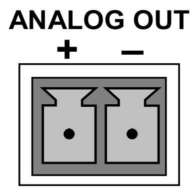


Figure 2-5. Calibrator Analog Output Connector

2.3.1.3. CONNECTING THE STATUS OUTPUTS (DIGITAL OUTPUTS)

The 12-pin STATUS connector allows the digital status outputs to report up to eight , user-selected calibrator conditions (configured through the Setup>Digital Outputs menu, Section 2.6.6) via optically isolated NPN transistors, which sink up to 50 mA of DC current. These outputs can be used to 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 emitters of these transistors are tied together and available at pin D (Figure 2-6).

ATTENTION

COULD DAMAGE INSTRUMENT AND VOID WARRANTY

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.

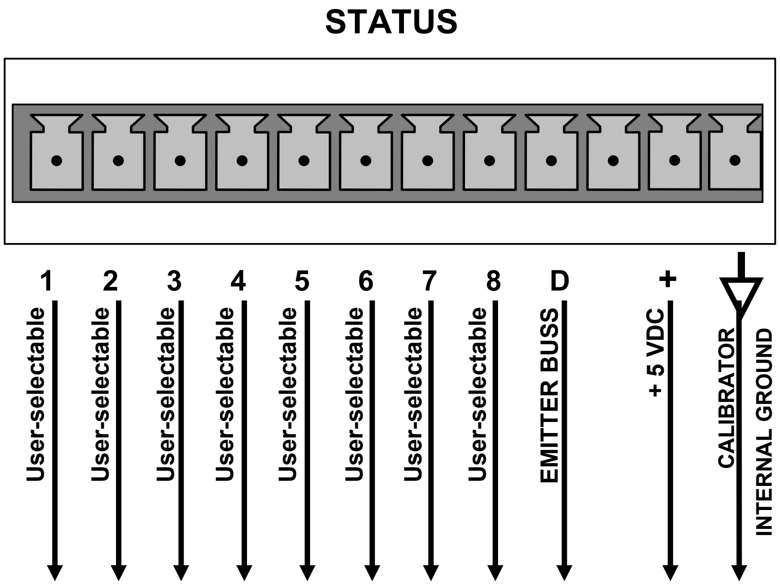


Figure 2-6. Status Output Connector

The pin assignments for the Status Outputs are:

Table 2-3. Status Output Pin Assignments

OUTPUT #	STATUS DEFINITION	CONDITION
1-8	User-Selectable	On or off
D	Emitter BUS	The emitters of the transistors on pins 1 to 8 are bussed together.
(blank)	(blank)	Not Used
+	DC POWER	+ 5 VDC
⏚	Digital Ground	The ground level from the calibrator's internal DC power supplies.

2.3.1.4. CONNECTING THE CONTROL INPUTS (DIGITAL INPUTS)

The calibrator is equipped with 12 digital control inputs (two separate 10-pin connectors on rear panel, labeled CONTROL IN), which can be used to initiate various user-programmable calibration sequences (see Section 2.6.7.1 for instructions on assigning the control inputs to specific calibration sequences).

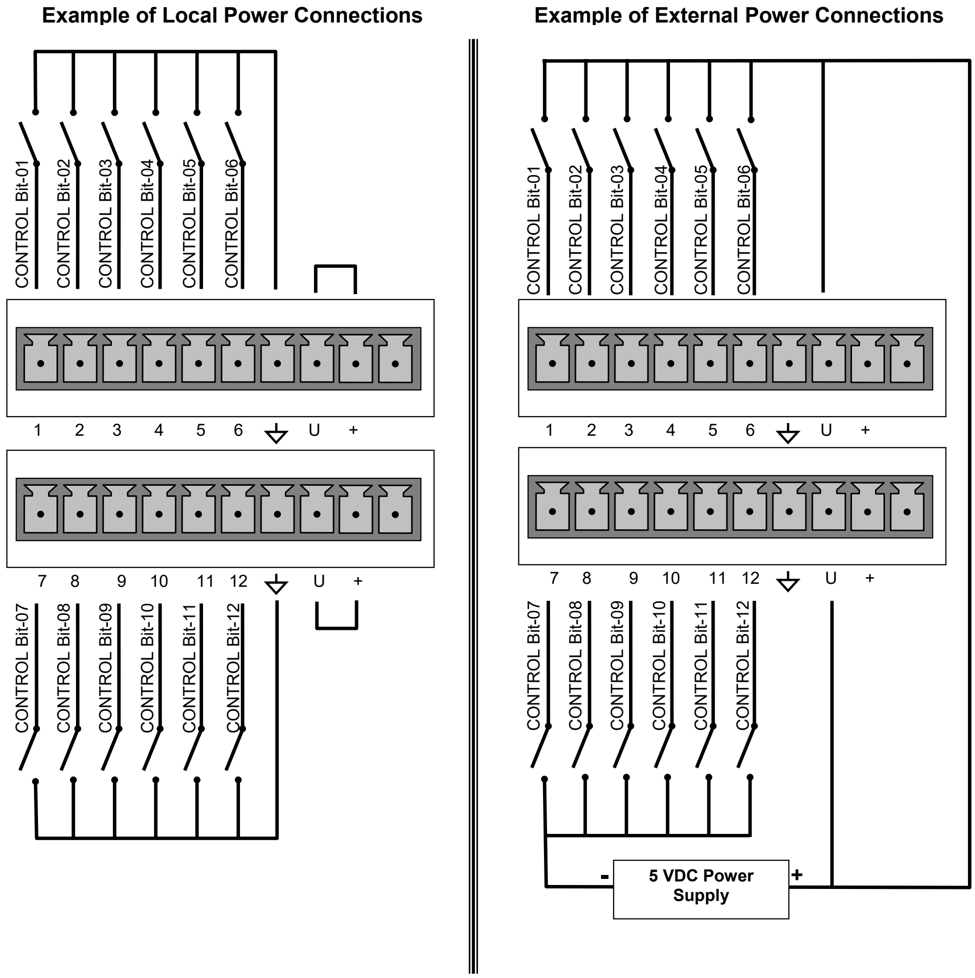


Figure 2-7. Calibrator Digital Control Input Connectors

There are two methods for energizing the control inputs. The internal +5V available from the pin labeled "+" is the most convenient method. However, if full isolation is required, an external 5 VDC power supply should be used.

Table 2-4. Calibrator Control Input Pin Assignments

CONNECTOR	INPUT	DESCRIPTION
Top	1 to 6	Can be used as either 6 separate on/off switches, or as bits 1 through 6 of a 12-bit wide binary activation code.
Bottom	7 to 12	Can be used as either 6 separate on/off switches, or as bits 7 through 12 of a 12-bit wide binary activation code.
BOTH	⏚	Chassis ground.
Top	U	Input pin for +5 VDC required to activate pins 1 – 6. This can be from an external source or from the "+" pin of the connector.
Bottom	U	Input pin for +5 VDC required to activate pins 7 – 12. This can be from an external source or from the "+" pin of the connector.
BOTH	+	Internal source of +5V used to actuate control inputs when connected to the U pin.

2.3.1.5. CONNECTING THE DIGITAL CONTROL OUTPUTS

The calibrator is equipped with 12 opto-isolated, digital control outputs on a 14-pin connector (Figure 2-8); see Figure 2-2 for rear panel location. These outputs may be used to interface with devices that accept logic-level digital inputs, such as Programmable Logic Controllers (plcs), data loggers, or digital relays/valve drivers, and are activated by the calibrator's user-programmable calibration sequences. Create the sequences in Setup>Sequences menu; then map the digital control outputs to the sequences through the Setup>Digital Outputs menu (see Section 2.6.7 for instructions on assigning the control outputs to specific calibration sequences).

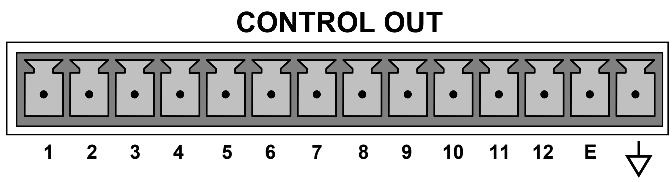


Figure 2-8. Calibrator Digital Control Output Connector

ATTENTION

COULD DAMAGE INSTRUMENT AND VOID WARRANTY

Most PLCs have internal provisions for limiting the current the input will draw. When connecting to a unit that does not have this feature, external resistors must be used to limit the current through the individual transistor outputs to ≤50mA (120 Ω for 5V supply).

The pin assignments for the control outputs are:

Table 2-5. Calibrator Control Output Pin Assignments

PIN #	STATUS DEFINITION	CONDITION
1 - 12	Outputs 1 through 12 respectively	Closed if the sequence or sequence step activating output is operating.
E	Emitter BUS	The emitters of the transistors on pins 1 to 12 are bussed together.
⏚	Digital Ground	The ground level from the calibrator's internal DC power supplies.

2.3.1.6. CONNECTING THE EXTERNAL VALVE DRIVER OPTION

Two 12V external valve driver assemblies (options listed in Table 2-6), are available that can drive up to eight, 8-watt valves based on the condition of the status block bits described below. The option consists of a custom Printed Circuit Assembly (PCA) that mounts to the back of the calibrator with or without a universal AC-to-DC power supply module (PSM).

The Valve Driver Outputs are mapped one-for-one to the Control Outputs 1 through 8 and can be manually actuated for troubleshooting using the Signal I/O diagnostic function in the calibrator software (see Section 7.3.11.5). However, the drive outputs are mapped in reverse to the status control bits such that Bit-0 (LSB) is valve drive 8 and Bit-7 is valve drive 1.

Figure 2-9. Calibrator Rear Panel Valve Driver Installed (with PSM connected to JP1)

Figure 2-10. Calibrator Rear Panel Valve Driver Installed (without PSM)

Table 2-6. External Valve Driver Options

OPTION	DESCRIPTION	PART NUMBER
48C	12V External Valve Driver - without PSM	072210100
48E	12V External Valve Driver - with PSM	072210300

Depending upon the capacity of the external supply either four (standard) or eight valves can be simultaneously energized.

The PCA is constructed such that it plugs through the rear panel into the Control Output connector, J1008, on the calibrator's motherboard.

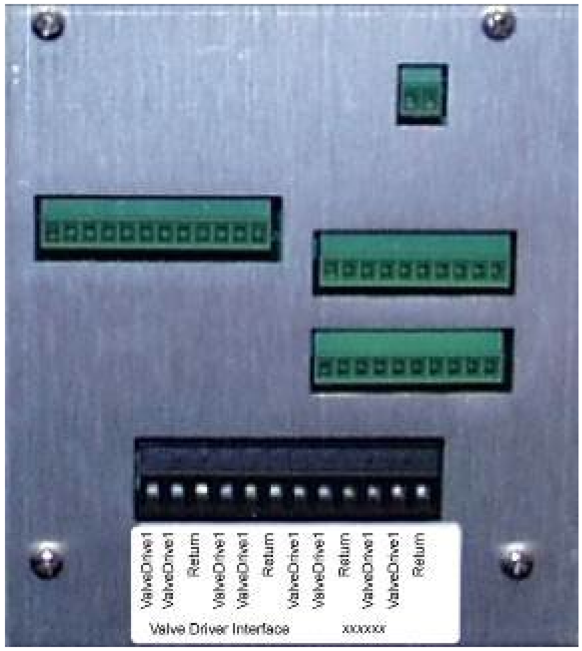


Figure 2-11. Valve-Driver Interface

OPTION 48C CONNECTIONS

CAUTION – AVOID DAMAGE TO VALVE DRIVER BOARD

Do NOT connect power supply to JP1 for Options 48C or 48D.

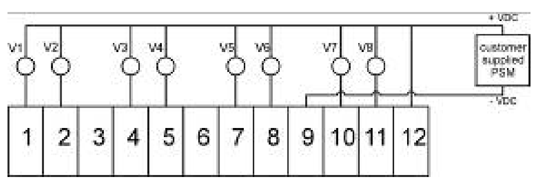


Figure 2-12. Option 48C Connections, Customer-supplied PSM to Pin 12 (+) & Pin 9 (-)

OPTION 48E CONNECTIONS

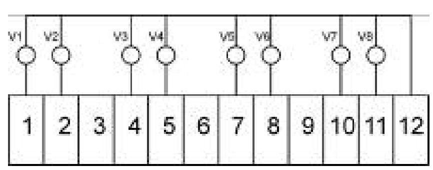


Figure 2-13. Option 48E Connections

2.3.1.7. CONNECTING THE COMMUNICATIONS INTERFACES

The T-Series analyzers are equipped with connectors for remote communications interfaces: **Ethernet**, **USB (Option)**, **RS-232**, **RS-232 Multidrop** and **RS-485** (each described below). (Configuration details for Setup>Comm are presented in Section 2.6.11).

ETHERNET CONNECTION

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. Although the analyzer is shipped with DHCP enabled by default, it should be manually assigned a static IP address (Setup>Comm>Network Settings, Section 2.6.11.4).

USB (OPTION) CONNECTION

The rear panel 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 (ensure baud rates match). A USB driver is required for complete configuration.

Note	**If this option is installed, the rear panel RS232 (COM2) port cannot be used for anything other than Multidrop communication.**

RS-232 CONNECTION

For **RS-232** communications with data terminal equipment (**DTE**) or with data communication equipment (**DCE**) connect either a DB9-female-to-DB9-female cable (Teledyne API part number WR000077) or a DB9-female-to-DB25-male cable (Option 60A), as applicable, from the analyzer's rear panel RS-232 port to the device. Adjust the DCE-DTE switch (Figure 2-2) to select DTE or DCE as appropriate (Section 4.1).

Important	**IMPACT ON READINGS OR DATA** **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 (Figure 2-14) before using.**

RS-232 COM PORT CONNECTOR PIN-OUTS

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.

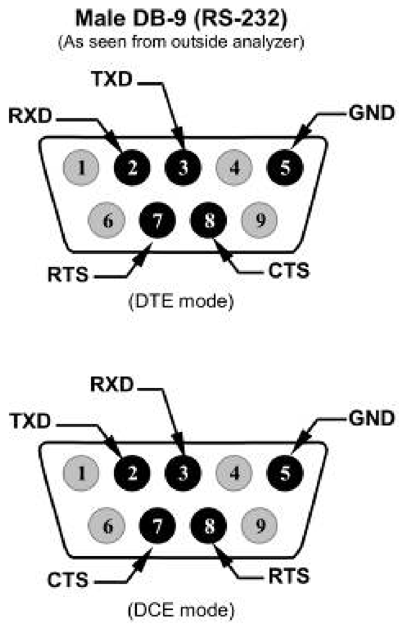


Figure 2-14. Rear Panel Connector Pin-Outs for RS-232 Mode

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 2-15).

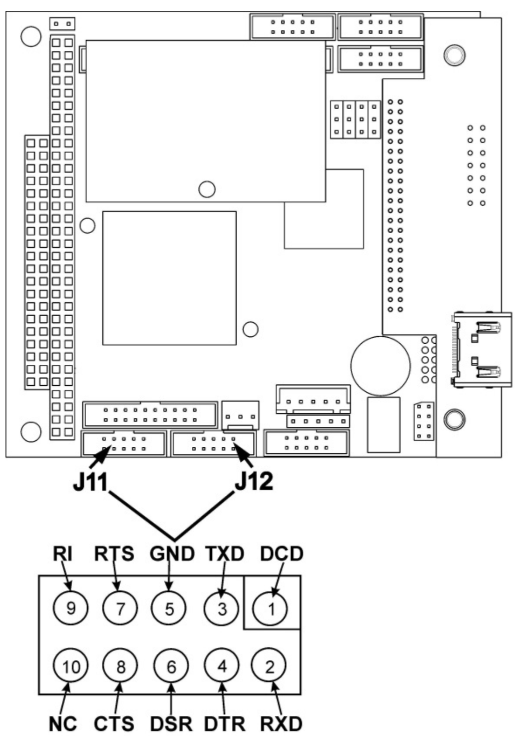


Figure 2-15. Default Pin Assignments for CPU COMM Port Connector (RS-232).

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.

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.

RS-232 COM PORT DEFAULT SETTINGS

Received from the factory, the analyzer is set up to emulate a DCE or modem, with Pin 3 of the DB-9 connector designated for receiving data and Pin 2 designated for sending data.

- **RS-232** (COM1): RS-232 (fixed) DB-9 male connector

Baud rate: 115200 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

RS-232 MULTI-DROP (OPTION 62) CONNECTION

When the RS-232 Multidrop option is installed, connection adjustments and configuration through the menu system are required. This Section provides instructions for the internal connection adjustments, then for external connections, and ends with instructions for menu-driven configuration.

Note	**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.**

ATTENTION	**COULD DAMAGE INSTRUMENT AND VOID WARRANTY** **Printed Circuit Assemblies (PCAs) are sensitive to electro-static discharges too small to be felt by the human nervous system. Failure to use ESD protection when working with electronic assemblies will void the instrument warranty. For more information on preventing ESD damage, see *A Primer on Electro-Static Discharge; t*he manual can be downloaded from our website at http://www.teledyne-api.com under Help Center > Product Manuals in the Special Manuals section.**

In each instrument with the Multidrop option there is a shunt jumpering two pins on the serial Multidrop and LVDS printed circuit assembly (PCA), as shown in Figure 2-16. This shunt must be removed from all instruments except that designated as last in the multidrop chain, which must remain terminated. This requires powering off and opening each instrument and making the following adjustments:

1. With NO power to the instrument, remove its top cover and lay the rear panel open for access to the Multidrop/LVDS PCA, which is seated on the CPU.
2. On the Multidrop/LVDS PCA's JP2 connector, remove the shunt that jumpers Pins 21 ↔ 22 as indicated in Figure 2-16. (Do this for all but the last instrument in the chain where the shunt should remain at Pins 21 ↔ 22).
3. Check that the following cable connections are made in all instruments (again refer to Figure 2-16):
   - J3 on the Multidrop/LVDS PCA to the CPU's COM1 connector
     (Be aware that the CPU's COM2 connector is not used in Multidrop)
   - J4 on the Multidrop/LVDS PCA to J12 on the motherboard
   - J1 on the Multidrop/LVDS PCS to the front panel LCD

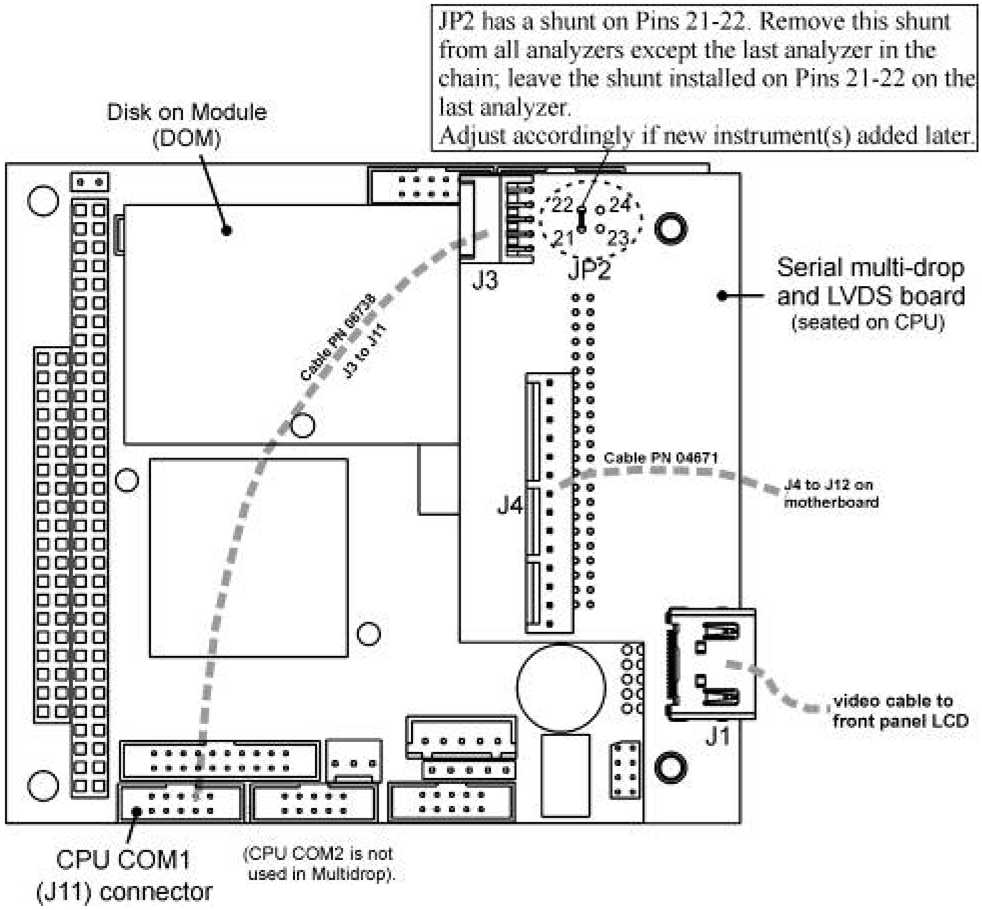


Figure 2-16. Jumper and Cables for Multidrop Mode

Note	If you are adding an instrument to the end of a previously configured chain, remove the shunt between Pins 21 ↔ 22 of JP2 on the Multidrop/LVDS PCA in the instrument that was previously the last instrument in the chain.

4. Close the instrument.

5. Referring to Figure 2-17, use straight-through DB9 male > DB9 female cables to interconnect the host RS232 port to the first analyzer's RS232 port. Do the same from the first analyzer's COM2 port to the second analyzer's RS232 port, and from the second analyzer's COM2 port to the third analyzer's RS232 port, etc. Connect in this fashion up to eight analyzers, subject to the distance limitations of the RS-232 standard.

6. On the rear panel of each analyzer, adjust the DCE DTE switch (see Figure 2-2 and Section 4.1) so that the green and the red LEDs (RX and TX) of the COM1 connector (labeled RS232) are both lit. (Ensure you are using the correct RS-232 cables internally wired specifically for RS-232 communication; see Table 1-1, "Communication Cables" and Section 2.3.1.7, Connecting the Communications Interfaces, "RS-232 Connection").

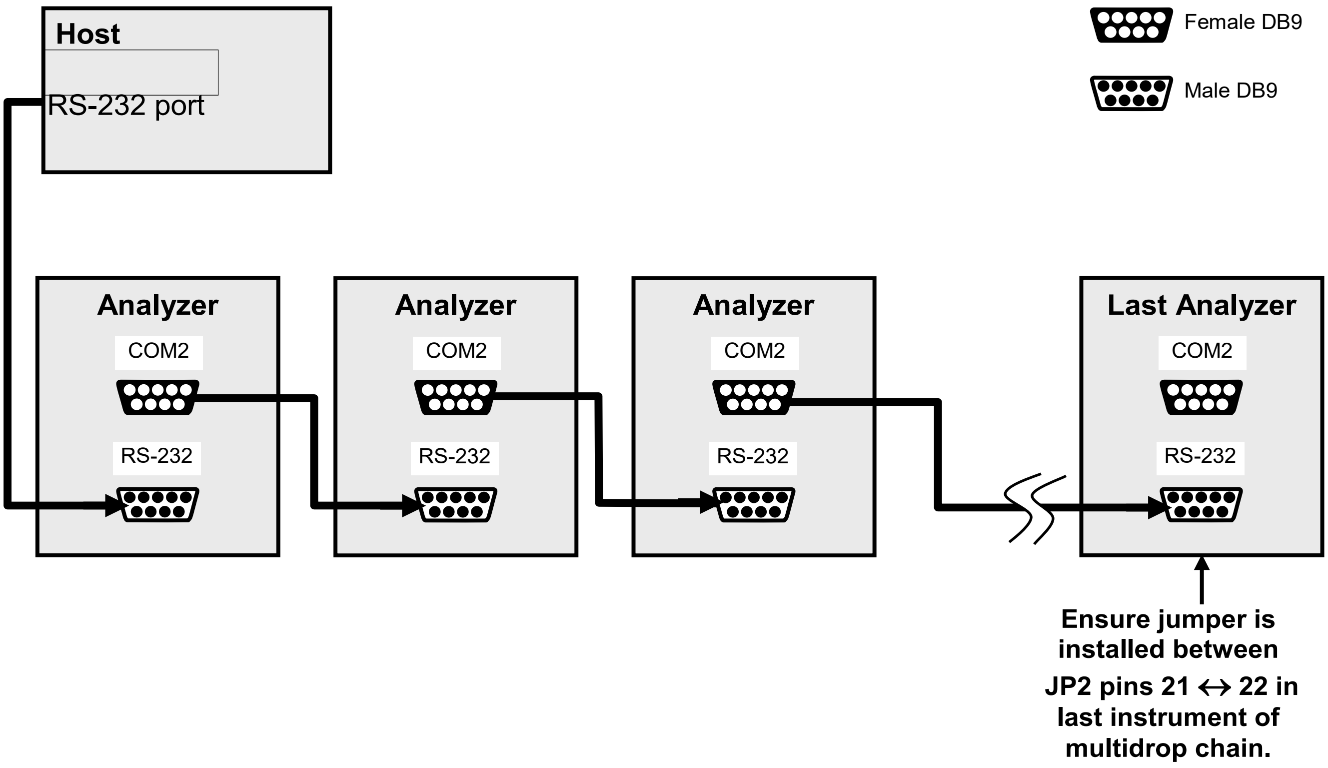


Figure 2-17. RS-232-Multidrop PCA Host/Analyzer Interconnect Diagram

7. BEFORE communicating from the host, power on the instruments and check that the Machine ID code is unique for each:

   a. In the Setup>Vars menu, check Instrument ID in the list of variables.

   b. To change, select the variable and press the Edit button.

   c. Once changed, press the Enter button to accept the new ID for that instrument.

8. Next, in the Setup>Comm>>COM1 menu (do not use the COM2 menu for multidrop), use the Edit button to set COM1 Quiet Mode and COM1 Multidrop to ENABLED; then press the Accept button.

9. Also check the COM1 Baud Rate to ensure it reads the same for all instruments (edit as needed and press the Accept button).

Note	**The (communication) Host instrument can address only one instrument at a time, each by its unique ID.**

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

RS-485 CONNECTION

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

2.3.2. PNEUMATIC CONNECTIONS

Important

IMPACT ON READINGS OR DATA

Each time the pneumatic configuration is changed for any purpose (whether locally to the instrument or to the sampling system), a back pressure compensation calibration must be performed (Section 5.2.6).

2.3.2.1. IMPORTANT INFORMATION ABOUT DILUENT GAS (ZERO AIR)

Zero Air is similar in chemical composition to the Earth's atmosphere but scrubbed of all components that might affect the calibrator's readings.

- Diluent Air should be dry (approximately -20ºC of Dew Point).
- Diluent Air should be supplied at a gas pressure of between 25 PSI and 35 PSI with a flow greater than the flow rate for the calibrator. For the standard unit this means greater than 10 SLPM.
- For calibrators with the 20 LPM diluent flow option (OPT) the diluent air should be supplied at a gas pressure of between 30 PSI and 35 PSI.
- Calibrators with optional O_3 generators installed require that the zero air source supply gas be flowing at a continuous rate of at least 100 cm3/min.
- If the calibrator is also equipped with an internal photometer, the zero air source supply gas must be capable of a continuous rate of flow of at least 1.1 LPM.

Zero Air can be purchased in pressurized canisters or created using Teledyne API's Model 701 Zero Air Generator.

2.3.2.2. IMPORTANT INFORMATION ABOUT CALIBRATION 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 measurement range. Usually it is a single gas type mixed with N_2 although bottles containing multiple mixtures of compatible gases are also available (e.g. H_2S, O_2 and CO mixed with N_2).

- Calibration gas should be supplied at a pressure of between 25 PSI and 35 PSI with a flow greater than the flow rate for the calibrator.

NIST TRACEABLE CALIBRATION GAS STANDARDS

All calibration gases should be verified against standards of the National Institute for Standards and Technology (NIST). To ensure NIST traceability, we recommend acquiring cylinders of working gases that are certified to be traceable to NIST Standard Reference Materials (SRM). These are available from a variety of commercial sources.

MINIMUM CALIBRATION GAS SOURCE CONCENTRATION

Determining minimum Cal Gas Concentration to determine the minimum concentration of a calibration gas required by your system:

1. Determine the Total Flow required by your system by adding the gas flow requirement of each of the analyzers in the system.
2. Multiply this by 1.5.
3. Decide on a Calibration Gas flow rate.
4. Determine the Calibration Gas ratio by divide the Total Flow by the Calibration Gas Flow Rate.
5. Multiply the desired target calibration gas concentration by the result from step 4.

EXAMPLE. Your system has two analyzers each requiring 2SLPM of cal gas flow.

2SLPM + 2SLPM = 4SLPM

4SLPM x 1.5 = 6SLPM = Total Gas Flow Rate

- If the Calibrator's cal gas flow rate is 2SLPM (therefore the Diluent Flow Rate would need to be set at 4 SLPM) the Calibration Gas ratio would be:
- 6SLPMm ÷ 2SLPM = 3:1
- Therefore if your Target Calibration Gas Concentration is intended to be 200 ppm, the minimum required source gas concentration for this system operating at these flow rates would be:

3 x 200ppm = 600 ppm

2.3.2.3. CONNECTING DILUENT SOURCE GAS TO THE CALIBRATOR

Use the fittings provided with the calibrator to connect the zero air source line to the port labeled DILUENT IN.

- Ensure to initially finger tighten.
- Then use a properly sized wrench to make an additional 1 and 1/4 turn.

2.3.2.4. CONNECTING CALIBRATION SOURCE GAS TO THE CALIBRATOR

Connect the source gas line(s) to the ports labeled CYL1 through CYL4 on the calibrator's rear panel (see Figure 2-2).

- Source gas delivery pressure should be regulated between 25 PSI to 30 PSI.
- Use stainless steel tubing with a 1/8 inch outer diameter.

2.3.2.5. SETUP FOR DIRECT CONNECTIONS TO OTHER INSTRUMENTS

Use this setup for connecting the calibrator directly to other instruments without the use of any shared manifolds.

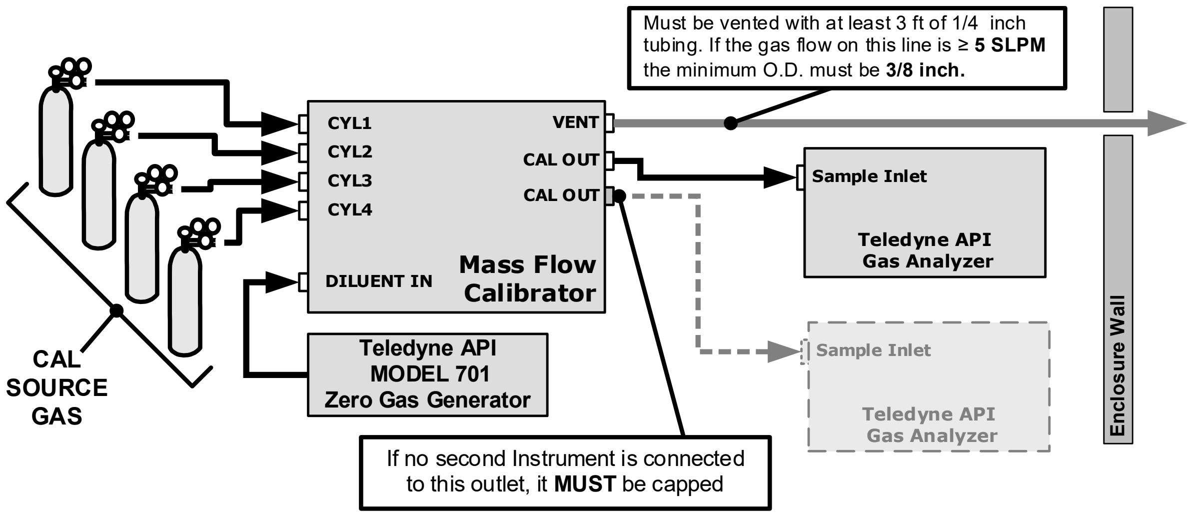


Figure 2-18. Setup – Connecting the Basic Calibrator to a Sample Manifold

To determine if the gas flow on the vent line is ≥ 5 SLPM, subtract the gas flow for each instrument connected to the outlets of the calibrator from the TOTAL FLOW setting for the calibrator (see Section 2.4.5).

If the calibrator has the optional O_3 photometer installed remember that this option requires 800 cc/min (0.8 LPM) of additional flow (see Section 2.4.5 or Figure 2-24).

EXAMPLE. Your system has two analyzers each requiring 2 SLPM of cal gas flow, and the calibrator includes the O_3 photometer. If the TOTAL FLOW rate for the calibrator is set at 10 SLPM:

10LPM - 2LPM - 2LPM - 0.8 LPM = 5.2LPM

Therefore, the vent would require a gas line with an O.D. 3/8 inch.

2.3.2.6. CONNECTING THE CALIBRATOR TO A SAMPLE GAS MANIFOLD

Use this setup when connecting the calibrator to an analyzer network using a sample manifold. In this case, the sampling cane and the manifold itself act as the T700's vent.

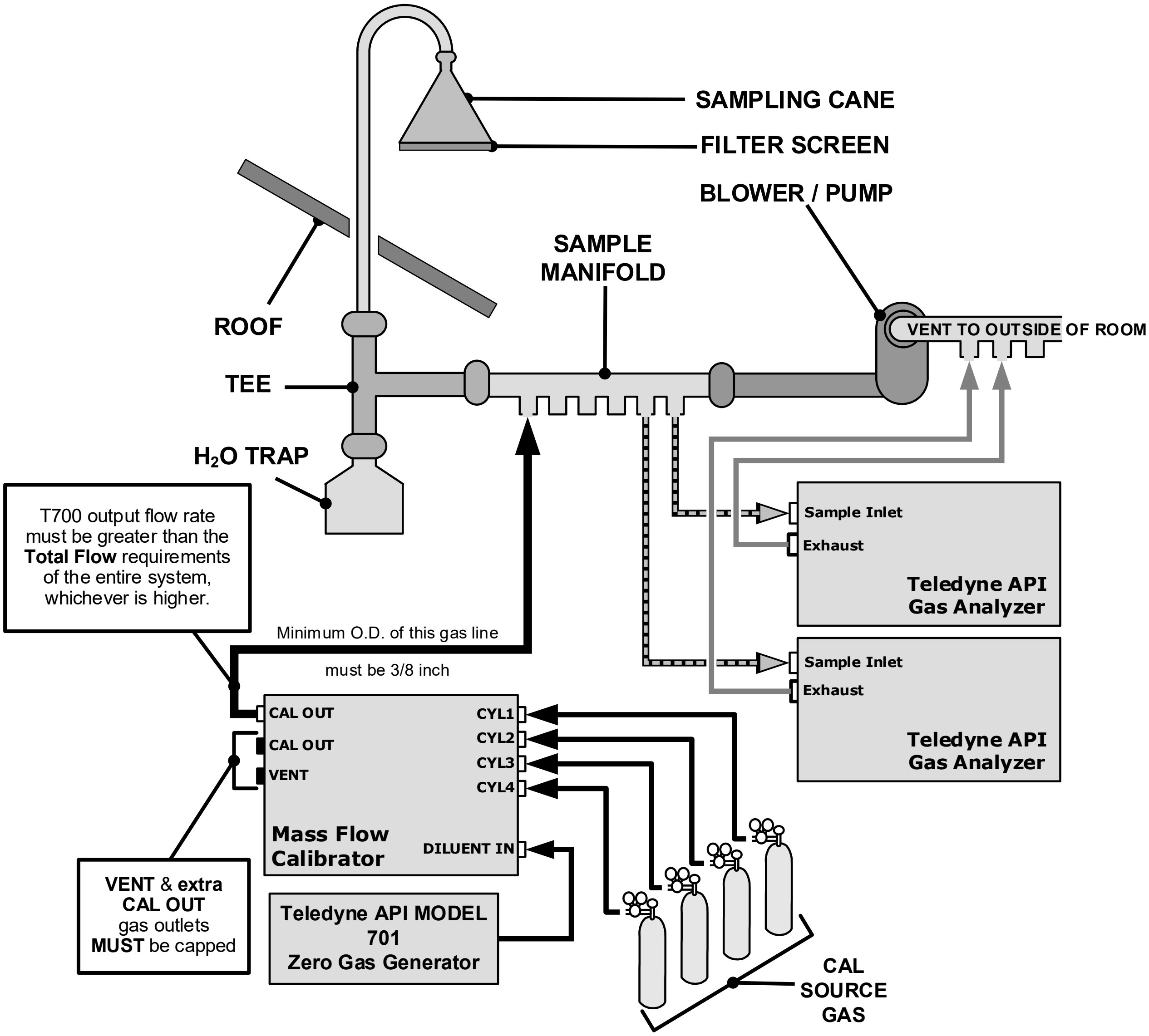


Figure 2-19. Setup – Connecting the Calibrator to a Sample Manifold

Note	
	This is the recommended method for connecting the calibrator to a system with analyzers that DO NOT have internal zero/span valves.
	The manifolds as shown in the above drawing are oriented to simplify the drawing. Their actual orientation in your set-up is with the ports facing upward. All unused ports must be capped.
	When initiating calibration, wait a minimum of 15 minutes for the calibrator to flood the entire sampling system with calibration gas.

2.3.2.7. CONNECTING THE CALIBRATOR TO A CALIBRATION MANIFOLD

Using a calibration manifold provides a pneumatic interface between the calibration system and other devices (or systems) which use the calibrator's gas output. Calibration manifolds usually have one or more ports for connections to other external devices (such as an analyzer).

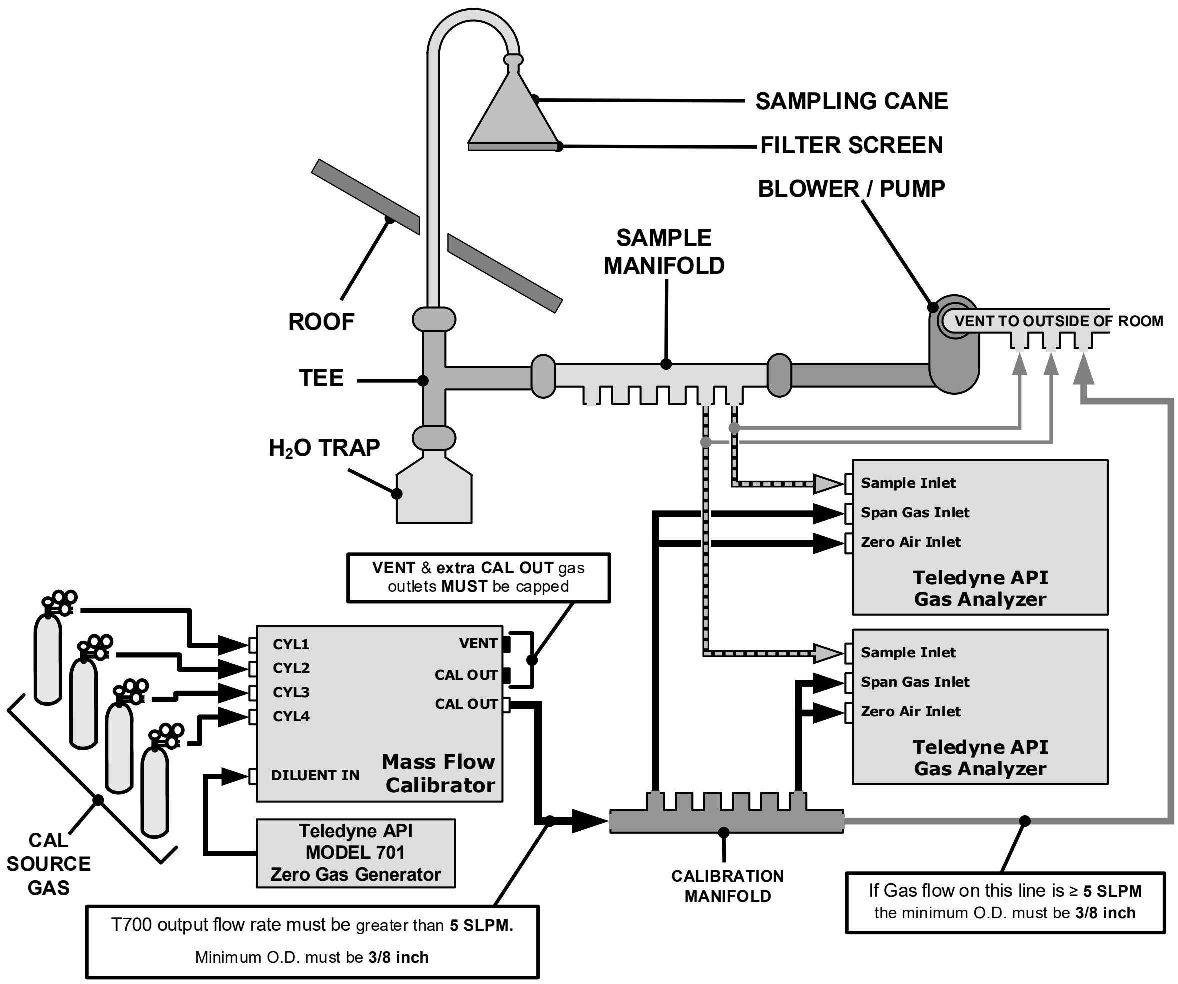


Figure 2-20. Setup – Connecting the Calibrator to a Calibration Manifold

Note	This method requires that analyzers connected to the calibration system have internal zero/span valves.

This method requires that analyzers connected to the calibration system have internal zero/span valves.

Keep the manifold as clean as possible to avoid loss of sample gas flow from blockages or constrictions.

The manifolds as shown in the above drawing are oriented to simplify the drawing. Their actual orientation in your set-up is with the ports facing upward. All unused ports must be capped.

When initiating calibration, wait a minimum of 15 minutes for the calibrator to flood the entire calibration manifold with calibration gas.

CALIBRATION MANIFOLD EXHAUST/VENT LINE

The calibration manifold's excess gas should be vented outside of the room. This vent should have an internal diameter large enough to avoid any appreciable pressure drop, and it must be located sufficiently downstream of the output ports to assure that no ambient air enters the manifold due to eddy currents or back diffusion.

2.3.2.8. CONNECTING THE CALIBRATOR TO A DUAL SPAN GAS / ZERO AIR CALIBRATION MANIFOLD

Another type of calibration setup utilizes separate span gas and the zero air manifolds (see Figure 2-21).

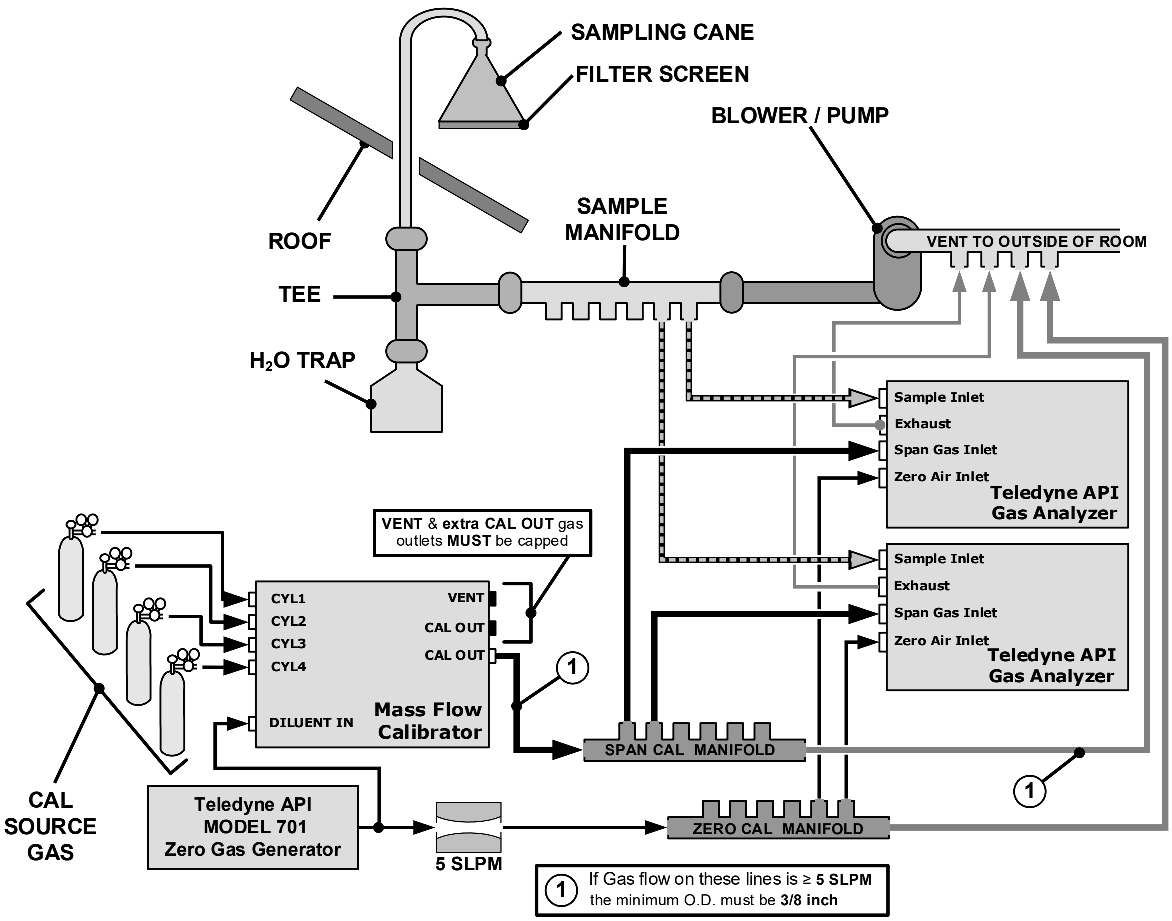


Figure 2-21. Setup – Connecting the Calibrator to a Dual Span Gas / Zero Air Manifold

Note

This set up is subject to the same notes and conditions as the single calibration manifold described previously with the following two exceptions:

- **The calibrator's total gas flow rate (Cal Gas Flow Rate + Diluent Flow Rate) out should be greater than the Total Flow requirements of the entire system.**
- **The manifolds as shown in the above drawing are oriented to simplify the drawing. Their actual orientation in your set-up is with the ports facing upward. All unused ports must be capped.**

SPAN GAS/ZERO AIR CALIBRATION MANIFOLD EXHAUST/VENT LINES

The span and zero air manifolds' excess gas should be vented to a suitable vent outside of the room. This vent should have an internal diameter large enough to avoid any appreciable pressure drop, and it must be located sufficiently downstream of the output ports to assure that no ambient air enters the manifold due to eddy currents or back diffusion.

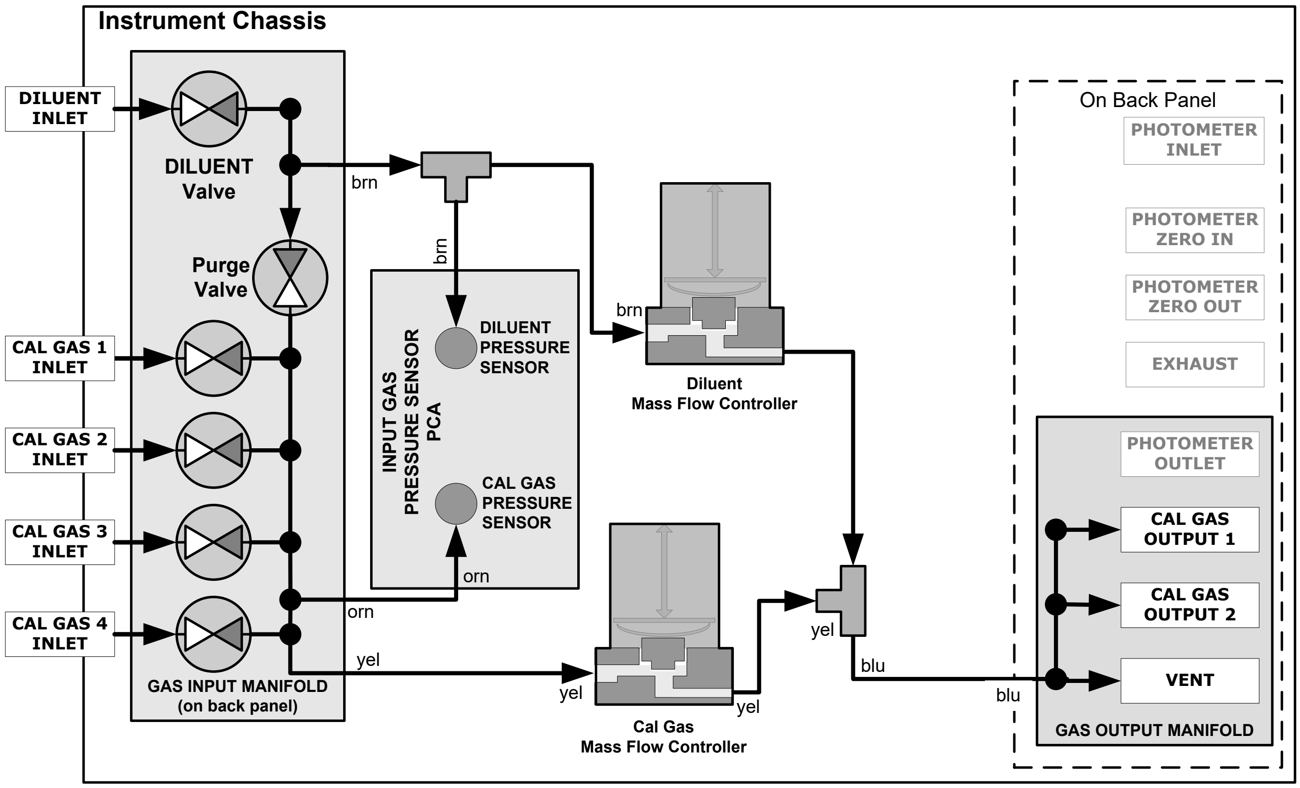


Figure 2-22. T700 Calibrator Pneumatic Diagram – Base Unit

The standard calibrator is equipped with one calibration gas mass flow controller (flow rate 0 – 100 cm^3/min) and one diluent gas mass flow controller (flow rate 0-10 LPM). See Table 1-1 for the various flow rate options.

2.3.2.9. T700 PNEUMATIC FLOW FOR O_3 GENERATOR OPTION

Because ozone (O_3) quickly breaks down into molecular oxygen (O_2), this calibration gas cannot be supplied in precisely calibrated bottles like other gases such as SO_2, CO, CO_2 NO, H_2S, etc. The internal O_3 generator extends the capabilities of the calibrator to dynamically generate calibration gas mixtures containing O_3.

Also, Gas Phase Titration (GPT) mixing chamber is included with the O_3 generator. This chamber, in combination with the O_3 generator, allows the calibrator to use the GPT technique to more precisely create NO_2 calibration mixtures

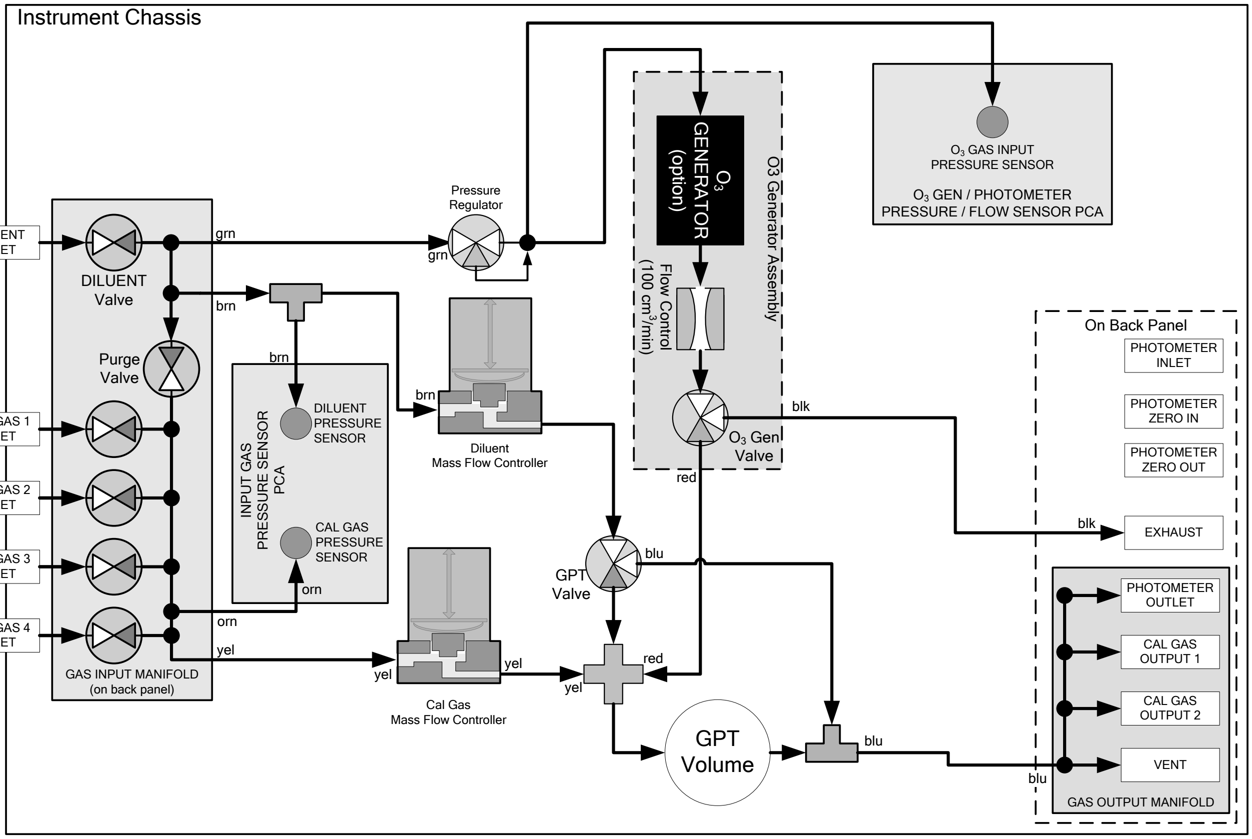


Figure 2-23. T700 Pneumatics for Calibrator with Optional O_3 Generator and GPT Chamber

Table 2-7. Operating Mode Valve States for Calibrator with O_3 Generator

MODE	VALVES (X = CLOSED; O = OPEN)								MFCS		
	CYL 1	CYL2	CYL 3	CYL 4	PURGE	DILUENT	GPT	O_3 GEN	CAL1	CAL2[1]	DILUENT
Generate Source Gas	O[2]	O[2]	O[2]	O[2]	X	O	X	X	ON[3]	ON[3]	ON
Generate O_3	X	X	X	X	X	O	X	O	OFF	OFF	OFF
Leak Check 0-17%	X	X	X	X	O	O	X	X	ON	ON	ON
Leak Check 17%-100%	X	X	X	X	O	X	X	X	ON	ON	ON
GPT	O[2]	O[2]	O[2]	O[2]	X	O	O	O	ON[3]	ON[3]	ON
GPTPS	X	X	X	X	X	O	O	O	OFF	OFF	ON
PURGE	X	X	X	X	O	O	O	O	ON[3]	ON[3]	ON
STANDBY	X	X	X	X	X	O	X	X	OFF	OFF	OFF

[1] Only present if multiple cal gas MFC option is installed.
[2] The valve associated with the cylinder containing the chosen source gas is open.
[3] In instruments with multiple MFCs the CPU chooses which MFC to use depending on the target gas flow requested.

The output of the O_3 generator can be controlled in one of two modes, depending on the calibrator's configuration at the factory: it will have either a choice between Constant and Bench modes or a choice between Constant and Reference modes.

- CONSTANT mode: In this mode, the user selects a specific, constant drive voltage (corresponding to a specific O_3 concentration) for the generator, or;
- BENCH mode: In this mode, the O_3 concentration control loop uses the photometer's O_3 measurement as input, and the bench feedback control will take over and adjust the O_3 generator drive voltage to match the requested concentration.
- REFERENCE mode: In this mode, the user selects a desired O_3 concentration whereby the calibrator's CPU sets the intensity of the O_3 generator's UV lamp, corresponding to that concentration. The voltage output of a reference detector, also internal to the generator, is digitized and sent to the T700's CPU where it is used as input for a control loop that maintains the intensity of the UV lamp at a level appropriate for the chosen set point.

See Section 8.5 for more details on the operation of the O_3 generator.

In addition to the diluent gas, calibration source gas, and gas output connections discussed in the preceding sections, this option requires an O_3 exhaust line be connected to the EXHAUST outlet on the calibrator's rear panel (see Figure 2-2).

Note

The EXHAUST line must be vented to atmospheric pressure using a maximum of 10 meters of ¼" PTFE tubing.

Venting must be outside the shelter or immediate area surrounding the instrument.

2.3.2.10. T700 PNEUMATIC FLOW FOR O_3 GENERATOR WITH PHOTOMETER OPTION

The photometer option, which includes the Ozone Generator, increases the accuracy of the calibrator's optional O_3 generator (OPT 1A) by directly measuring O_3 content of the gas output by the generator. It uses a more precise and stabile feature called the BENCH feedback mode, which controls the output of the O_3 generator. In BENCH mode the intensity of the O_3 generator's UV lamp is controlled (and therefore the concentration of the O_3 created) by the calibrator's CPU based on the actual O_3 concentration measurements made by the photometer.

See Section 8.6 for more details on the operation of the O_3 photometer.

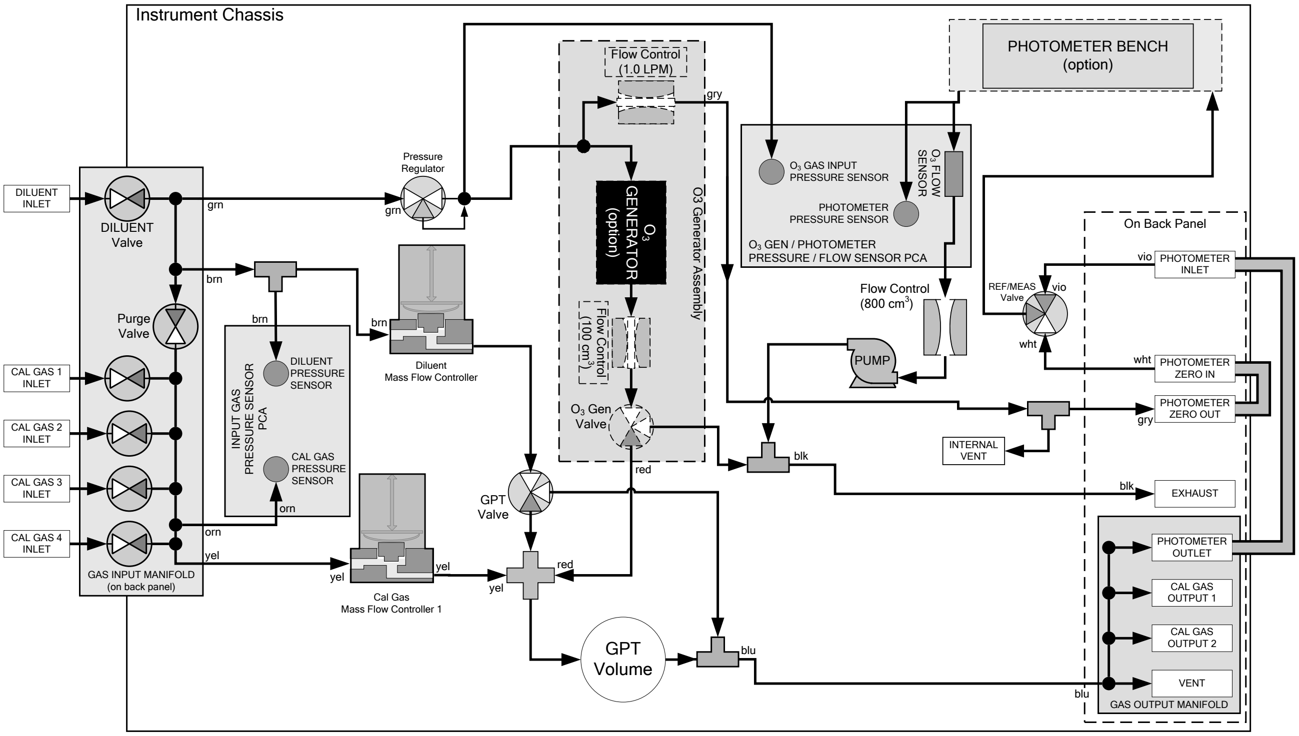


Figure 2-24. Pneumatics for T700U or for T700 with O_3 Generator and Photometer Options

Table 2-8. Operating Mode Valve States for Standard T700U or for T700 with O_3 Generator and Photometer Options

GAS TYPE	VALVES (X = CLOSED; O = OPEN)									MFCS			PHOT PUMP
	CYL 1	CYL 2	CYL 3	CYL 4	PURGE	DILUENT	GPT	O_3 GEN	PHOT M/R	CAL1	CAL2[1]	DILUENT	
Generate Source Gas	O[2]	O[2]	O[2]	O[2]	X	O	X	X	Reference Phase	ON[3]	ON[3]	ON	OFF
Generate O_3	X	X	X	X	X	O	X	O	Switching	OFF	OFF	OFF	ON[4]
Leak Check 0-17%	X	X	X	X	O	O	X	X		ON	ON	ON	
Leak Check 17%-100%	X	X	X	X	O	X	X	X		ON	ON	ON	
GPT	O[2]	O[2]	O[2]	O[2]	X	O	O	O	Reference Phase	ON[3]	ON[3]	ON	OFF
GPTPS	X	X	X	X	X	O	O	O	Switching	OFF	OFF	ON	ON[4]
PURGE	X	X	X	X	O	O	O	O	Reference Phase	ON[3]	ON[3]	ON	OFF
STANDBY	X	X	X	X	X	O	X	X	Reference Phase	OFF	OFF	OFF	OFF

[1] Only present if multiple cal gas MFC option is installed.
[2] The valve associated with the cylinder containing the chosen source gas is open.
[3] In an instrument with multiple MFCs the CPU chooses which MFC to use depending on the target gas flow requested.
[4] When generating O_3 or in GPT Pre-Set mode, the photometer pump is the primary creator of gas flow through the calibrator. Flow rates are controlled by critical flow orifice(s) located in the gas stream

In addition to the connections discussed in the previous sections, this configuration has the following requirements:

- Loop back lines must be connected between:
  - PHOTOMETER OUTLET fixture and the PHOTOMETER INLET fixture
  - PHOTOMETER ZERO OUT fixture and the PHOTOMETER ZERO IN fixture
- An O_3 exhaust line must be connected to the **EXHAUST** outlet.

See Figure 2-2 for the location of these fixtures.

Note	**The EXHAUST line must be vented to atmospheric pressure using a maximum of 10 meters of ¼" PTFE tubing. This venting must be outside the shelter or immediate area surrounding the instrument.**

2.3.2.11. T700 PNEUMATIC FLOW FOR MULTIPLE CALIBRATION SOURCE GAS MFCS

When the optional third mass flow controller is installed, the calibrator has both calibration gas MFCs on the same gas stream, installed in parallel (see Figure 2-25 and Figure 2-26). The calibrator turns on the MFC with the lowest flow rate that can accommodate the requested flow and can therefore supply the most accurate flow control. When a flow rate is requested that is higher than the highest rated MFC (but lower than their combined maximum flow rating), both controllers are activated.

EXAMPLE:

- Calibrator with one calibration gas MFC configured for 0-5 LPM:

Maximum gas flow = 5 LPM
Minimum gas flow = 500 cm^3/min

- Calibrator with two calibration gas MFCs configured for 0-1 LPM and 0-5 LPM:

Calibration gas flow rates:
5.001 to 6.000 LPM; both MFCs active
1.001 LPM – 5.000 LPM; High MFC active;
0.100 LPM – 1.000 LPM; Low MFC active

While the values for the MFC actual and target flows (i.e., **Cal Flow Actual**; **Cal Flow Targ**) show the sum of all the active MFCs flows, the value for the MFC pressure applies to only one MFC, not the sum as it is assumed that gas pressure is the same for all MFCs. (Use the Setup>Dashboard menu to display the flows and pressure).

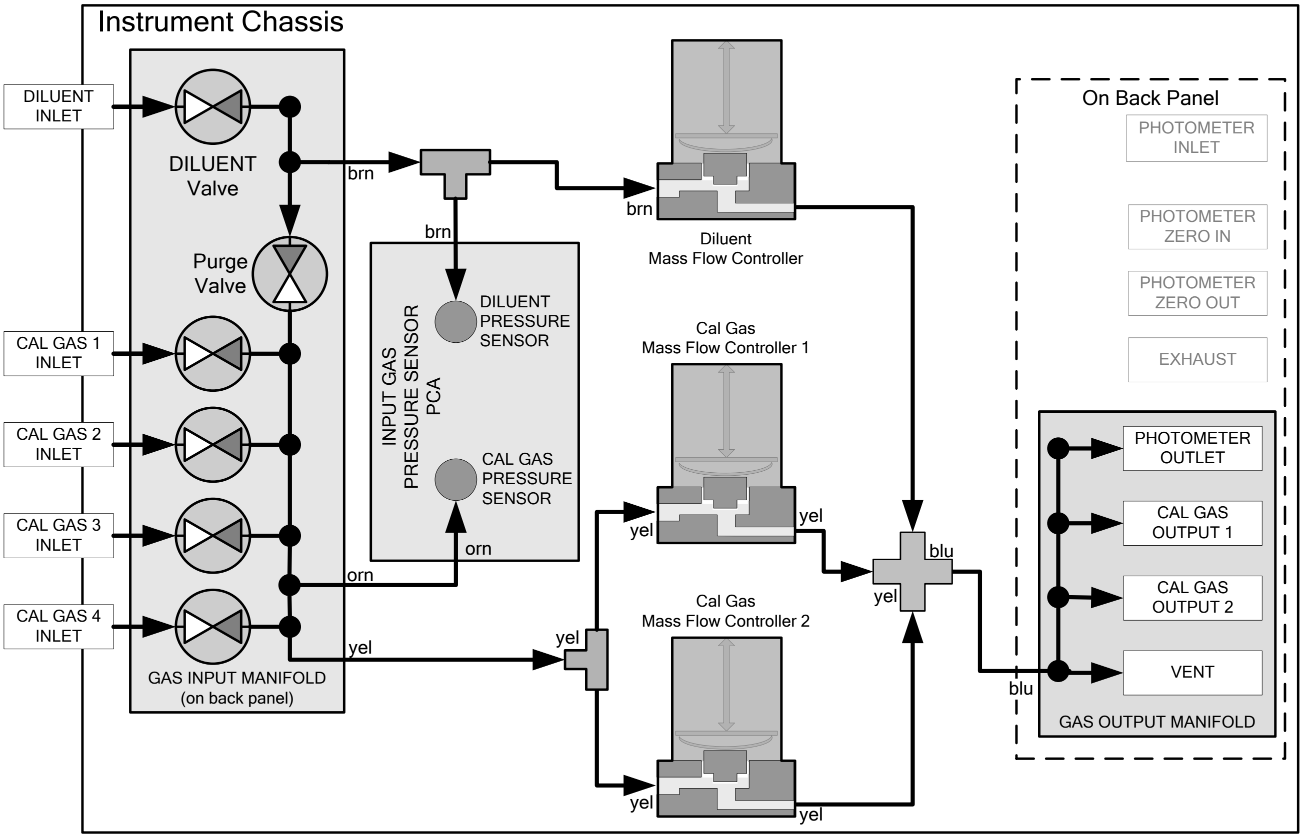


Figure 2-25. T700 Basic Calibrator with Multiple Calibration Gas MFCs

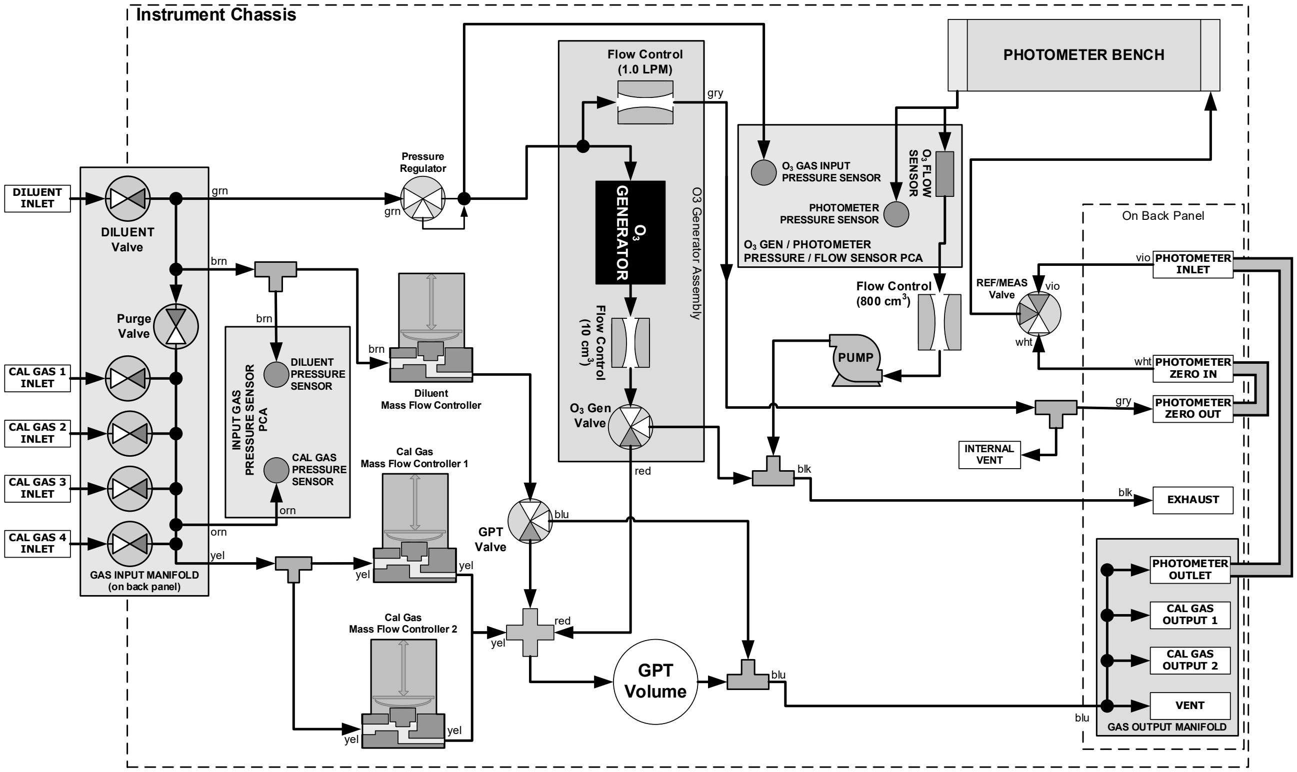


Figure 2-26. Pneumatics with All Options Installed (T700U, 3rd MFC; T700, O_3 Generator, Photometer, and GPT Chamber)

2.3.2.12. PNEUMATIC FLOW AND SETUP FOR PERMEATION TUBE GAS GENERATOR

The permeation tube gas generator (see Figure 2-27) is an alternative method for producing known concentrations of stable gas such as SO_2, NO_2, etc. The generator consists of a temperature regulated permeation tube oven, a flow restrictor, an optional output desorber, and a user-supplied permeation tube. The optional desorber can improve the response time of the calibrator especially when operating with NO_2 tubes (when operating with sulfur based gases it MUST be removed).

The permeation tube consists of a small container of a liquefied gas, with a small window of PTFE through which the gas slowly permeates at a rate in the nanogram/min range. If the tube is kept at constant temperature, usually about 50°C, the device will provide a stable source of gas for a year or more. A pneumatic diagram of the calibrator with this option is shown in Figure 2-28, including the generator.

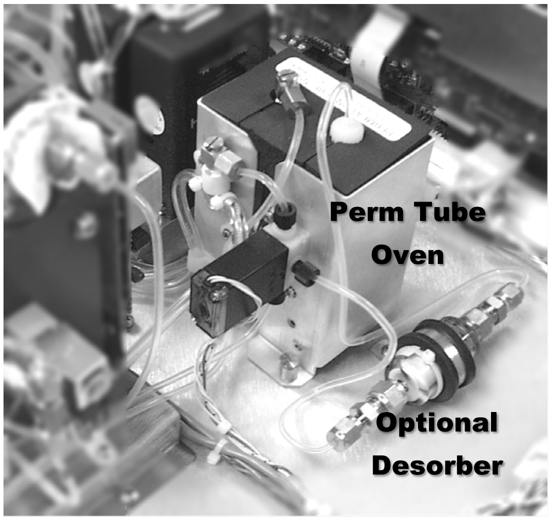


Figure 2-27. Permeation Tube Gas Generator Option

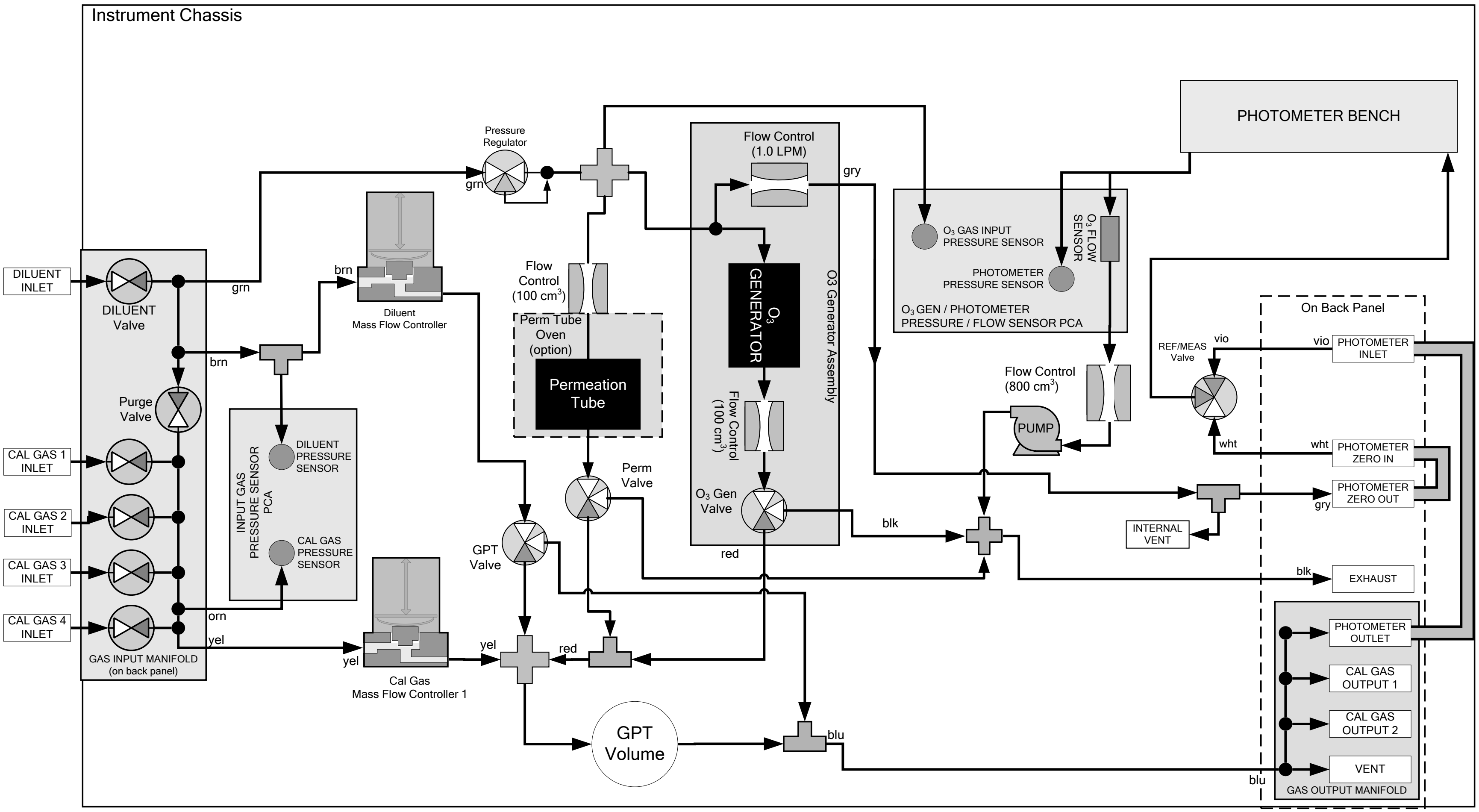


Figure 2-28. Pneumatic Flow with Permeation Generator

Once installed and stabilized, generating a calibration gas from the calibrator with a permeation generator is the same as if the gas were being produced using a gas cylinder as the source, with the following exceptions and note:

- If you need a particular flow and don't require a specific concentration, then use MANUAL mode. When generating in MANUAL mode, the output concentration is set by adjusting the DILUENT flow. The target and actual concentrations are displayed as test values.
- If you need a particular concentration but don't require a specific flow, then use AUTO mode. When generating in AUTO mode, the output concentration is set by entering the desired concentration. The TOTAL flow entry has no effect; the calibrator's output flow depends on the target concentration.
- Please note that the name for the permeation tube gas MUST be different from any gas supplied to the calibrator from a bottle. For example, there could be an H_2S permeation tube installed and a bottle of H_2S gas connected to the calibrator.

Important

IMPACT ON READINGS OR DATA

The generator is shipped WITHOUT a permeation tube installed. The tube MUST be removed during shipping or anytime that there is no diluent gas connected to the calibrator since there must be a continuous purge flow across the tube.

Permeation tubes require 48 hours at 50°C to reach a stable output. We recommend waiting this long before any calibration checks, adjustments, or conclusions are reached about the permeation tube.

Once the calibrator has stabilized, the response to the permeation tube is not expected to change more than ± 5% if the zero air is provided for Teledyne API's M701 or other dry zero air source.

Teledyne API recommends that replacement permeation tubes be purchased from:

VICI METRONICS
2991 Corvin Drive
Santa Clara, CA 95051 USA
Phone 408-737-0550 Fax 408-737-0346

PERMEATION TUBE SETUP FOR THE CALIBRATOR

1. Navigate to the Setup>Vars menu.
2. Set the Perm 1 Flow (this should be done with the flow standard connected at the outlet of the perm tube oven).
3. Select a gas for the Perm1 Gas (the name of the gas produced by the permeation tube generator MUST be different from the name of any bottled gas connected to the calibrator).
4. Set the Perm 1 Rate for specific output (or elution rate).

PERMEATION TUBE CONCENTRATION CALCULATION

The permeation tube concentration is determined by the permeation tube's specific output or elution rate (which is normally stated in ng/min), the permeation tube temperature (°C) and the air flow across it (slpm). The elution rate of the tube is normally stated at an operating temperature of 50°C and is usually printed on the tube's shipping container. By design, there is nominally 100 cm^3/min of airflow across the tube and the tube is maintained at 50°C. The output of the calibrator is the product of the elution rate with the total of the 100 cm^3/min through the generator and the flow of diluent gas.

The temperature is set at 50.0°C. Check Setup>Vars and scroll to the IZS-TEMP variable to verify that the temperature is properly set. It should be set to 50°C with over-and-under temperature warnings set at 49°C and 51°C. There is a 105 cm^3/min flow across the permeation tube at all times to prevent build-up of the gas in the tubing.

This permeation tube source gas is diluted with zero air to generate desired concentration of the specific gas. The calibrator's output concentration (gas concentration) can be calculated using the following equation:

$$C = \frac{P \times Km}{F}$$

Where:

P = permeation rate, ng/min @ 50°C.

Km = $\frac{24.46}{MW}$, where 24.46 is the molar volume in liters @ 25°C

and MW is the molecular weight.
760mmHg . Km for SO_2 = 0.382, NO_2 = 0.532, H_2S = 0.719, and NH_3 = 1.436.

F = total flow rate (sum of 100 cm^3/min and diluent flow), LPM.

C = concentration, ppm.

Thus, $$C = \frac{P}{F} \times \frac{24.46}{MW}$$

Where, Temperature at 50°C = 323

Temperature at 25°C = 298

DUAL GAS OUTPUT (NO_Y – SPECIAL) SETUP AND PNEUMATIC FLOW

The standard output manifold has been removed and replaced with 2 output fittings, labeled “Output A” and “Output B” (Figure 2-29). Output A is the primary calibration gas output, all calibration functions can be performed on this output. Output B is a secondary output, commonly used for NOy probe calibrations.

Note	**This output cannot be used for ozone generation using the photometer feedback. It can be used for standard dilution calibrations as well as GPT using ozone.**

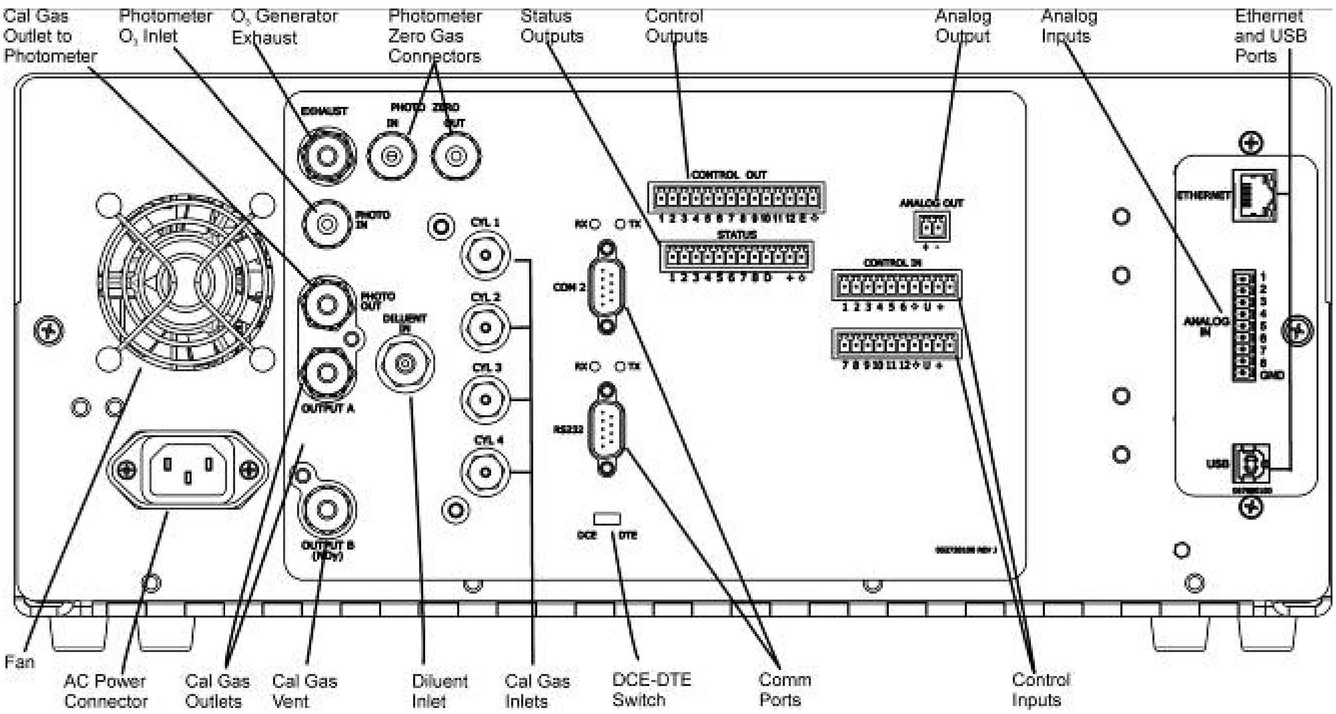


Figure 2-29. Rear Panel with Dual Output Option

When the dual gas output option is enabled, the output must be selected when generating gas. In the Generate menu, select A or B in the Output field to select the output for calibration.

Figure 2-30 depicts the pneumatic flow for the Calibrator with the optional dual gas output at the output valve.

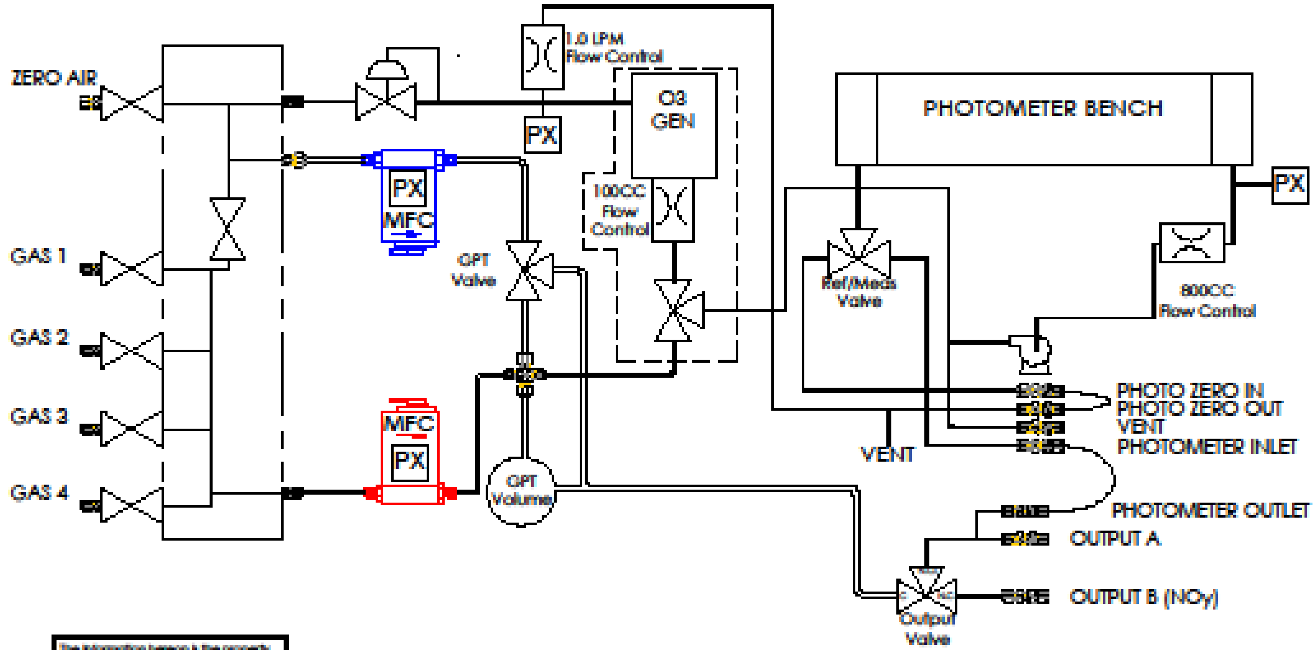


Figure 2-30. T700 Internal Pneumatics with Optional Dual Gas Output (NO_y – Special)

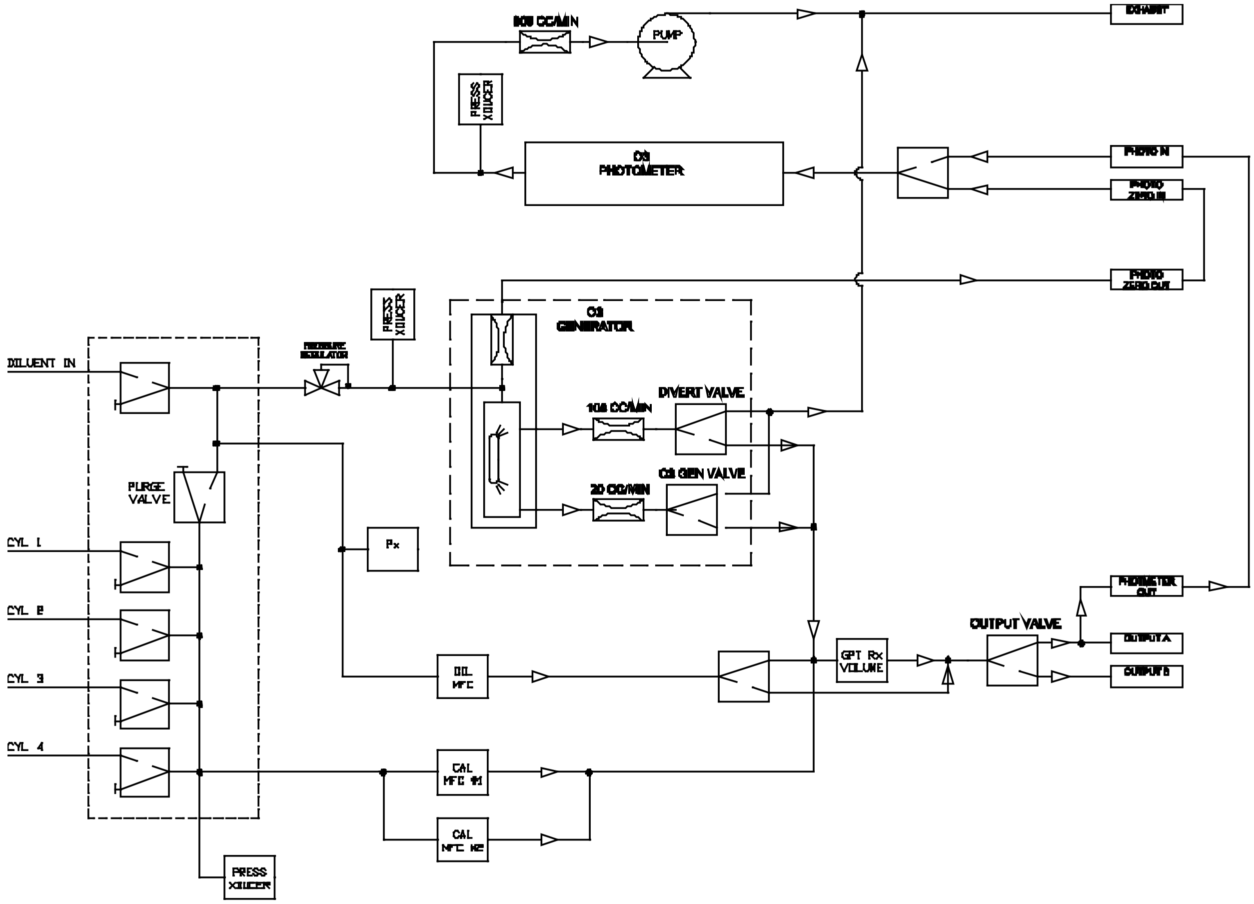


Figure 2-31. T700U Pneumatic Diagram, with Dual Output and Three MFC Options

2.4. STARTUP AND FUNCTIONAL CHECKS

If you are unfamiliar with the calibrator principles of operation, we recommend that you read Section 8.

2.4.1. Initial Startup

After making the electrical and pneumatic connections, turn on the instrument. The exhaust fan (and pump if photometer option installed) should start immediately. A sequence of status screens (Figure 2-32) appear prior to the Home page. The calibrator will be in STANDBY mode and requires a minimum of 30 minutes for all of its internal components to reach a stable operating temperature.

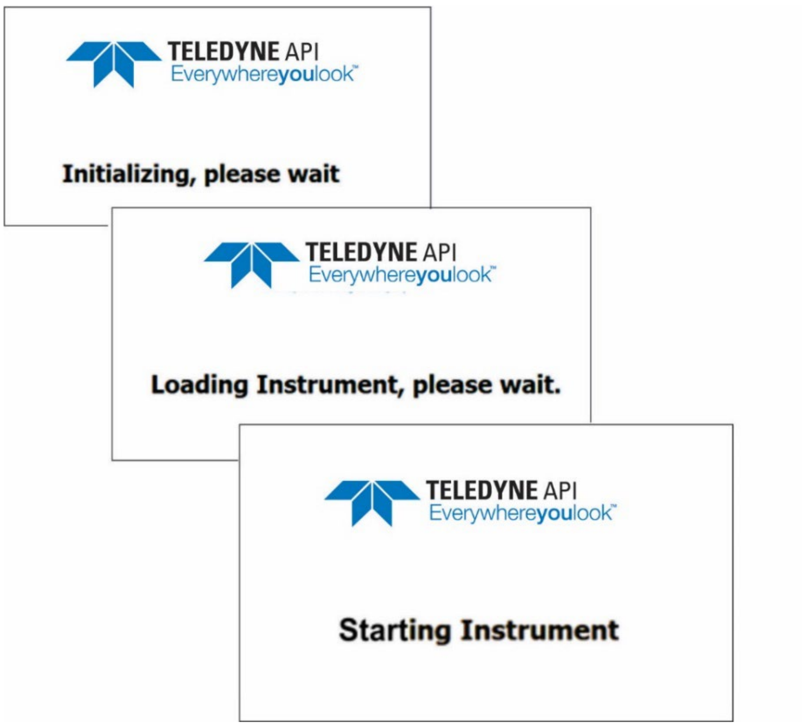


Figure 2-32. Status Screens at Startup

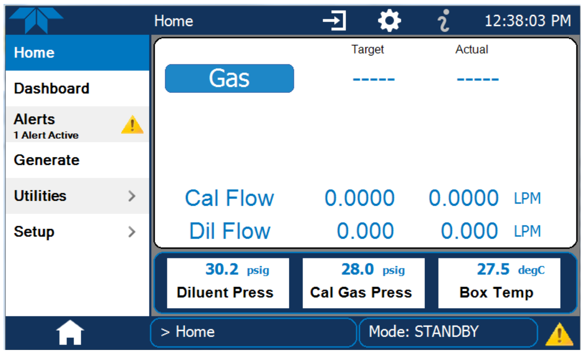


Figure 2-33. Typical Home Page Prior to Configuration

2.4.2. Alerts: Warnings and Other Messages

Because internal temperatures and other conditions may be outside the specified limits during the warm-up period, the software will suppress most Alerts for 30 minutes after power up. The Alerts page (Figure 2-34) shows the status of any active warning conditions or user-configured Events. (For more detailed information about Alerts, see Section 2.5.3 provides, and for Events, see Section 2.6.2).

Alerts can be viewed and cleared via either the Alerts menu or the Alerts shortcut (Caution symbol, bottom right corner of the screen). Although these alerts can be cleared from the Active Alerts page, a history of all alerts remains in the Utilities>Alerts Log.

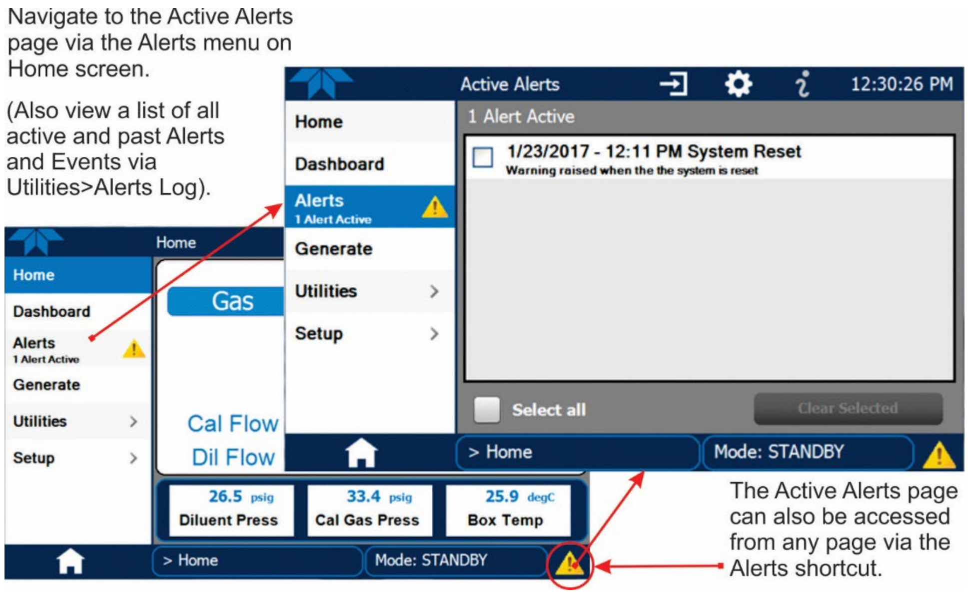


Figure 2-34. Viewing Active Alerts Page

2.4.3. Functional Checks and Verification

During warm-up, verify that the software properly supports any hardware options that are installed by navigating to the Setup>Instrument>Product Info page.

After warm-up, verify that the instrument is functioning within allowable operating parameters:

- Check values for the operating parameters in the Dashboard page against the instrument's Final Calibrated Test and Validation Data sheet, which lists these values as they appeared before the instrument left the factory. (If any functional parameters are not displayed, configure the Dashboard through the Setup>Dashboard menu to add them, Section 2.6.3).
- Verify MFC capacities through the Utilities>Diagnostics menu; select each MFC and note the value in the Flow Range field.
- Generate calibration gases by using the Generate>Auto menu (Section 3.2.1) and verify their values in the Dashboard.

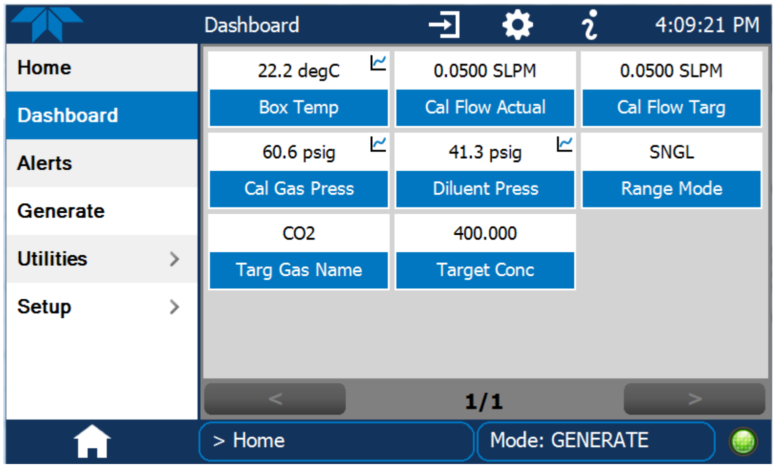


Figure 2-35. Sample Dashboard Page

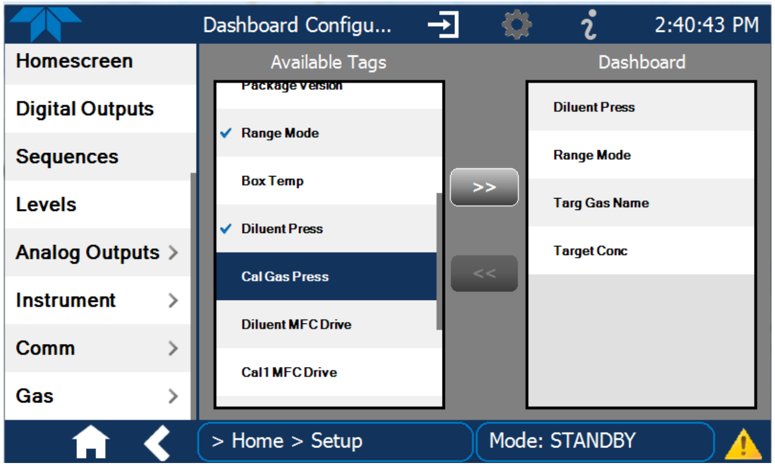


Figure 2-36. Dashboard Configurator

2.4.4. Calibration Gas Inlet Ports Setup

The calibrator generates calibration gases of various concentrations by precisely mixing component gases of known concentrations with diluent (zero air). Instruments with the O_3 generator and photometer can also use the gas phase titration method for generating very precise concentrations of NO_2.

As presented in Table 2-9, the calibrator is programmed with the most commonly used gases and allows for four additional user-defined gases, USR1 thru USR4, which can be used for either less common component gases or a different concentration of a gas already selected.

Ensure the calibrator is in Standby Mode (set via the Home page Generate menu), and navigate to the Setup>Gas>Cylinder menu to configure one to four cylinder ports for the component gases being used. Refer to Figure 2-37 for the following instructions:

1. Select the Port to be configured.

2. If a single-gas cylinder is connected to the port being configured, press the first configurable field under the Gas column and make a selection from the gas list (a common gas or user-defined). If a multi-gas cylinder is connected to the port being configured, repeat these steps for each gas.
3. Press the DONE button so that the gas name and the default fields for Concentration and Units appear.
4. Press the Concentration field and use the pop-up numeric keypad to input the concentration of the gas being programmed; then press the DONE button.
5. If the units of measure (Table 2-10) need to be changed, press the Units field and make a selection from the pop-up list.
6. For a single-gas cylinder, leave the remaining Gas fields at "NONE" and press the Apply button. For a multi-gas cylinder, program the next gas in the cylinder with its concentration and units of measure.

For two different concentrations of the same gas, select USR1[2,3,4] for the gas name of the second concentration.

If a port has no cylinder connected to it, leave all three of its settings at NONE.

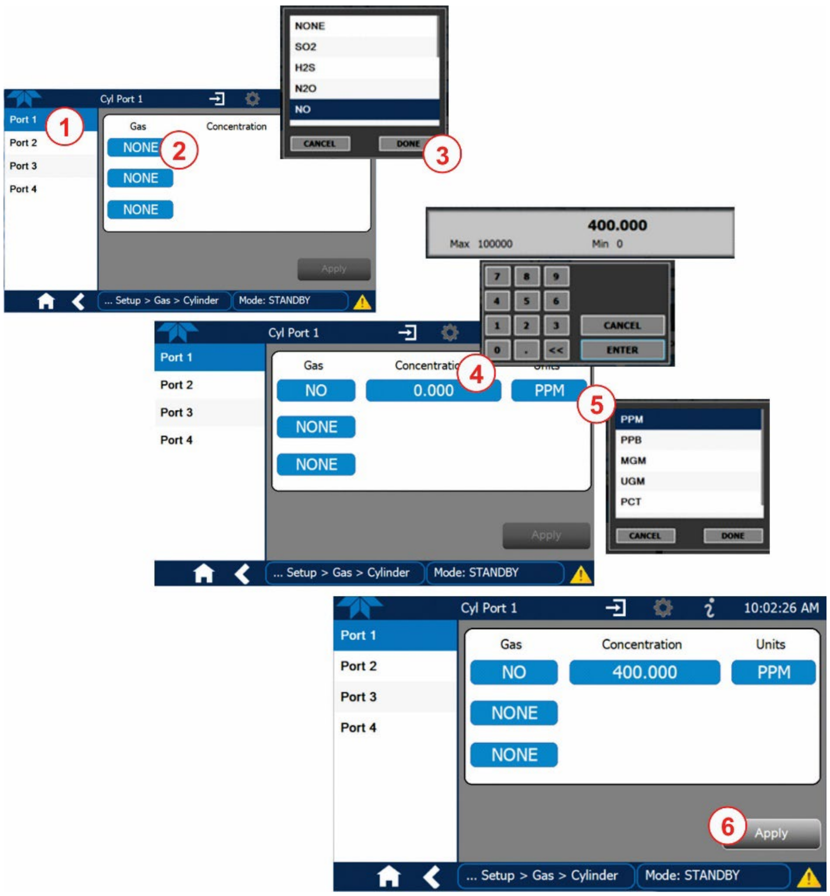


Figure 2-37. Calibration Gas Inlet Ports Setup

Repeat the above steps for each of the Calibrator's four gas inlet ports. If no gas is present on a particular port, leave it set at the default setting of **NONE.**

Table 2-9. Calibrator Gas Types

NAME	GAS TYPE
NONE	Used for gas inlet ports where no gas bottle is attached
SO_2	sulfur dioxide
H_2S	hydrogen sulfide
N_2O	nitrous oxide
NO	nitric oxide
NO_2	nitrogen dioxide
NH_3 [1]	Ammonia [1]
CO	carbon monoxide, and;
CO_2	carbon dioxide
HC	General abbreviation for hydrocarbon
USR1	User-assigned [2]
USR2	User-assigned [2]
USR3	User-assigned [2]
USR4	User-assigned [2]

[1] It is not recommended that ammonia be used in the calibrator.

[2] For bottles of less common component gases not listed above, or for a different concentration of another gas already selected

Table 2-10. Calibrator Units of Measure List

SYMBOL	UNITS	RESOLUTION
PPM	parts per million	000.0
PPB	parts per billion	000.0
MGM	milligrams per cubic meter	000.0
UGM	micrograms per cubic meter	000.0
PCT	percent	0.000
PPT	parts per thousand	00.00

2.4.5. SETTING THE CALIBRATOR'S TOTAL GAS FLOW RATE

The calibrator's default total gas flow rate is 5 LPM. It uses this flow rate, along with the concentrations programmed into the calibrator for the component gas cylinders during set up, to compute individual flow rates for both diluent gas and calibration source gases in order to produce calibration mixtures that match the desired output concentrations.

This Total Flow rate may be changed to fit the users' application. Once the flow is changed, then the new flow value becomes the total flow for all the gas concentration generated and computes again the individual flow rates of the component gases and diluent accordingly.

Note

The minimum total flow should equal 150% of the flow requirements of all of the instruments to which the calibrator will be supplying calibration gas.

Example: If the calibrator is expected to supply calibration gas mixtures simultaneously to a system composed of three analyzers, each requiring 2 LPM, the proper Total Flow output should be set at:

(2 + 2 + 2) x 1.5 = 9.000 LPM

Set the Total Flow by first ensuring that the calibrator is in Standby Mode (set in the Home page Generate menu); then in the **Setup>Vars** menu edit the Total Flow Var.

Note	**Set the TOTAL FLOW rate between 10% and 100% (avoid <10% or >100%) of the diluent MFC's full scale rating.**

The **TOTAL FLOW** is also affected by the following:

- The **GENERATE > AUTO** menu (see Section 3.2.1) or;
- As part of a **GENERATE** step when programming a sequence (see Section 2.6.7).

The operator can individually set both the diluent flow rate and flow rates for the component gas cylinders as part of the following:

- The **GENERATE > MANUAL** menu (see Section 3.2.2), or
- As part of a **MANUAL** step when programming a sequence (see Section 2.6.7).

Note	**When calculating total required flow for calibrators with O_3 photometers installed, ensure to account for the 800 cc/min flow it requires.**

2.4.6. SELECTING A MODE FOR THE O_3 GENERATOR OPTION

The O_3 generator can be set to operate in either of two different modes: Constant or Reference (Sections 2.4.6.1 and 2.4.6.2). However, when the photometer option is also installed, the O_3 generator can be set to operate in either Constant mode or Bench mode (Sections 2.4.6.1 and 2.4.6.3).

Set the O_3 Generator control mode by first ensuring that the calibrator is in Standby Mode (set via the Home page Generate menu); then in the Setup>Vars menu edit O3 Gen Mode, described in the next three subsections.

2.4.6.1. CNST (CONSTANT) MODE

In this mode, the O_3 output of the generator is based on a single, constant, drive voltage, and there is no Feedback loop control by the calibrator's CPU.

2.4.6.2. REF (REFERENCE) MODE

The O_3 control loop will use the generator reference detector's UV lamp measurement for input. The CPU sets the UV lamp intensity to a level that corresponds to the O_3 concentration set by the user.

2.4.6.3. BNCH (BENCH) MODE

The O_3 concentration control loop will use the photometer's O_3 measurement as input. To select a default O_3 generator mode, press.

2.5. MENU OVERVIEW

Table 2-11 describes the main menus and provides cross-references to the respective sections with configuration details.

Table 2-11. Menu Overview

MENU		DESCRIPTION	REFERENCE
Home		View and plot concentration readings and other user-selected parameters set up through the configuration shortcut or the Setup>Homescreen menu.	Sections 2.5.1 and 2.6.5
Dashboard		View user-selected parameters (Setup>Dashboard) and their values, some of which can be displayed in a live-plot graph (Figure 2-38).	Sections 2.5.2 and 2.6.3
Alerts		View and clear active Alerts that were triggered by either factory-defined or user-configured Events (see Setup>Events). Active and past Alerts are recorded in the Utilities>Alerts Log).	Section 2.5.3
Generate		Generate calibration gas mixtures based on the source gas(es) and concentration(s) configured in the Setup>Gas>Cylinder menu. Perform gas phase titration (GPT) calibrations. Execute sequences configured in the Setup>Sequences menu. Execute Levels configured in the Setup>Levels menu. Place the calibrator in Standby mode.	Section 3.2 Section 2.4.4 Section 3.2.4 Section 2.6.7 Section 2.6.8 Section 3.1
Utilities		View logs, download data and firmware updates, copy configurations between instruments, and run diagnostics.	Section 2.5.5
	Datalog View	Displays the data logs that were configured via the Setup>Data Logging menu. From this list a log can be selected and filters applied to view the desired data, which is downloadable through the Utilities>USB Utilities page.	Section 2.5.5.1
	Alerts Log	Displays a history of Alert messages triggered by factory-defined and user-defined Events, such as warnings and alarms (See Section 2.6.2 for Events configuration).	Section 2.5.5.2
	USB Utilities	Serves multiple purposes using a flash drive connected to the instrument's front panel USB port: • download data from instrument's Data Acquisition System (DAS), the Data Logger, to a flash drive (Section 2.5.5.3) • update firmware (Section 6.2) • transfer instrument configuration from/to other instruments of the same model (Section 2.5.5.3) • download a basic operation functionality report (Section	Section 2.5.5.3

MENU	DESCRIPTION	REFERENCE
Diagnostics	Provides access to various pages that facilitate troubleshooting.	(various)
Analog Inputs	This page shows voltage signals of several analog input parameters, including those from other instrumentation when the External Analog Inputs Option is installed.	Section 7.1.3
Analog Outputs	Shows voltage signals for one parameter (configured through Setup>Analog Outputs, Section 2.6.9).	Section 7.1.4
Digital Inputs	Shows whether specific available Signal In features are active (ON) or inactive (OFF).	Section 7.1.3
Digital Outputs	Activate (ON)/deactivate (OFF) user-specified Signal Out features (configured in the Setup>Digital Outputs menu, Section 2.6.6.	Section 7.1.3
(with Photometer option) Photo Flow Cal	Calibrate the photometer flow.	Section 5.2.5
Diluent MFC Cfg	Configure flow range, slope, offset, and sensor offset for the diluent MFC, and finely adjust the drive and flow for each of 21 points.	Section 5.1
Cal1 MFC Cfg	Configure flow range, slope, offset, and sensor offset for the Cal1 MFC, and finely adjust the drive and flow for each of 21 points.	Section 5.1
Auto Leak Check	Run an automatic check for a measurable drop in pneumatic pressure.	Section 6.5.1
(with Photometer option) Back Pressure Compensation	Required any time there is a change made in the pneumatic configuration (whether locally to the instrument or to the sampling system) or after a gas pressure calibration.	Section 5.2.6
(with Photometer option) Bench Cal	Calibrate the ozone photometer (bench)	Section 5.2.3
Pressure Cal	Calibrate pressure sensors	Section 5.4
Setup	Configure a variety of features and functions through these submenus for customized operation.	Section 2.6
Datalogging	Track and record concentration and calibration data and selectable diagnostic parameters, the reports for which can be viewed in the Utilities>Datalog View menu and downloaded to a flash drive via the Utilities>USB Utilities menu (Section 2.6.1.3).	Section 2.6
Events	Select parameters and define the conditions by which they are to be flagged and recorded in the Alerts log (Utilities>Alerts Log) when they are triggered.	Section 2.6.2
Dashboard	Select parameters monitoring instrument functionality (Figure 2-35, Figure 2-36).	Section 2.6.3
Vars	Manually adjust several software variables that define specific operational parameters.	Section 2.6.4
Homescreen	Configure the three meters located along the bottom of the display to show desired functions (Figure 2-57, Figure 2-38).	Section 2.6.5
Digital Outputs	Map the rear-panel digital status outputs to a variety of signals present in the instrument to monitor operating conditions or custom Events (Setup>Events).	Section 2.6.6
Sequences	Create automated sequential calibration steps.	Section 2.6.7
Levels	Create individual flow and concentration outputs for LEADS	Section 2.6.8

MENU	DESCRIPTION		REFERENCE
	Analog Outputs	Send user-selected parameter readings in the form of user-defined voltage or current loop signals as outputs to a strip chart recorder and/or the data logger.	Section 2.6.9
	Instrument	View product and system information, including list of options, if any; view network settings; calibrate touchscreen; view/adjust Date and Time settings; and check for firmware updates when connected to a network that is connected to the Internet.	Section 2.6.10
	COMM	View and configure network and serial communications.	Section 2.6.11
	Gas	Configure the cylinder ports for the component gases being used.	Section 2.4.4, Figure 2-37

2.5.1. Home

Figure 2-38 shows the features of the main interface from the Home page. The meters at the bottom of the display are user-selectable (see Section 2.6.5).

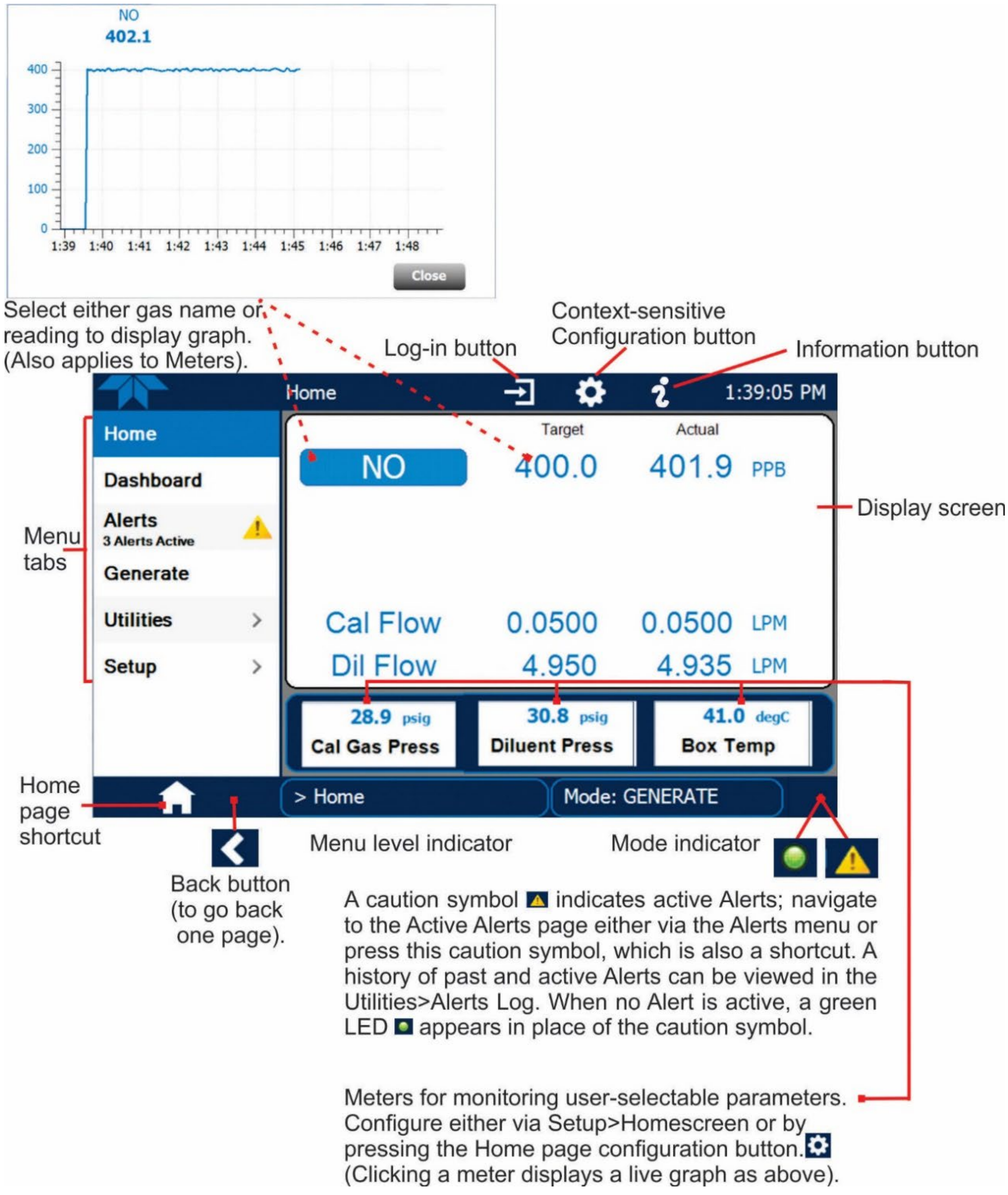


Figure 2-38. User Interface Orientation

Note	**The last page on display prior to drilling into a menu remains on display until a choice in the menu is selected.**

2.5.2. Dashboard

The dashboard displays an array of user-selected parameters and their values (Figure 2-39). If there is a graphing icon in the upper right corner of a parameter, pressing that parameter displays a live plot of its readings, as in Figure 2-40. Depending on the number of available parameters selected, the Dashboard can have more than one page. See Section 2.6.3 for configuration details.

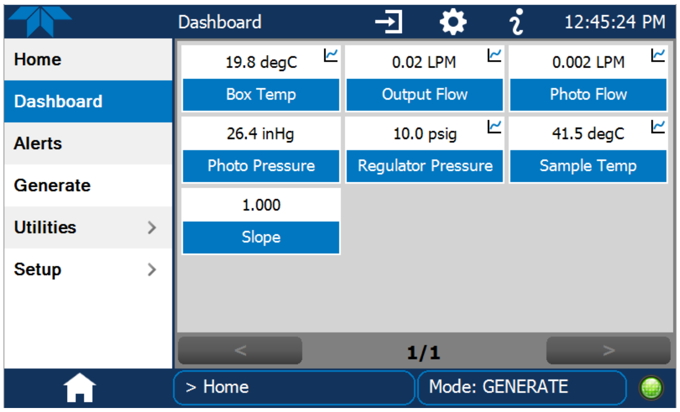


Figure 2-39. Dashboard Page

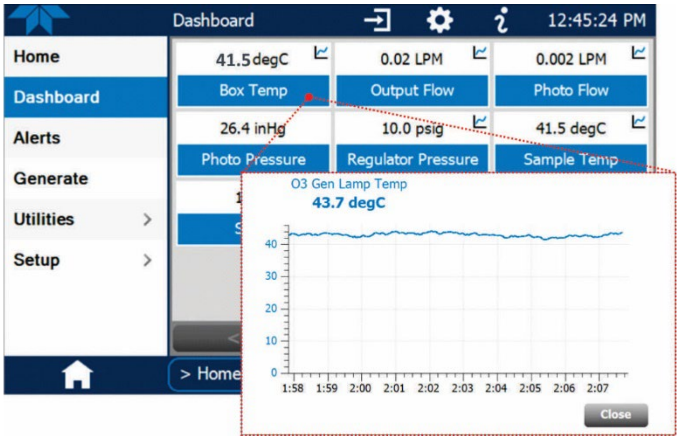


Figure 2-40. Viewing a Live Plot from Dashboard Page

Three of the dashboard parameters can be set up for continuous display as meters located below the concentration display of the Home page through the Setup>Homescreen menu (Section 2.6.5).

2.5.3. ALERTS

Alerts are notifications triggered by specific criteria having been met by either factory-defined conditions (standard and not editable) or user-defined Events (Section 2.6.2). The Active Alerts page shows the status of any active warning conditions or Events that have been triggered.

When Alerts are triggered, a caution symbol appears in both the Alerts menu tab and in the bottom right corner of the software interface, which serves as a shortcut to the Alerts page from any other page. View a list of currently active Alerts by pressing either the Alerts menu on the Home screen or by pressing the Alerts shortcut (Figure 2-41).

While Alerts can be cleared from the Active Alerts page, they remain recorded in the Utilities>Alerts Log.

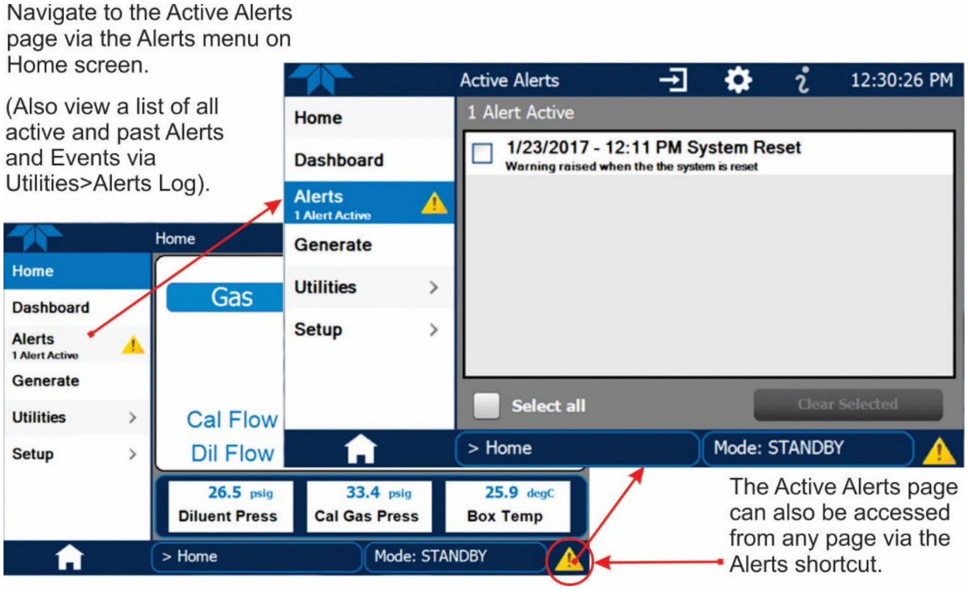


Figure 2-41. Navigating to the Active Alerts Page

Alerts appear as either latching or non-latching:

- Latching: displayed in Active Alerts screen when an Event is triggered and must be cleared by the user.
- Non-latching: Active Alerts screen continuously updates based on the Event criteria, clearing on its own.

To clear Alerts from the Active Alerts page, either check individual boxes to choose specific Alerts, or check the Select All box to choose all Alerts, then press the Clear Selected button.

When all Alerts are cleared, the Alerts menu tab no longer shows the caution symbol, and a green LED replaces the caution symbol in the bottom right corner of the interface (Figure 2-42). However, Alerts can reappear if the conditions causing them are not resolved. For troubleshooting guidance, refer to the instrument's user manual.

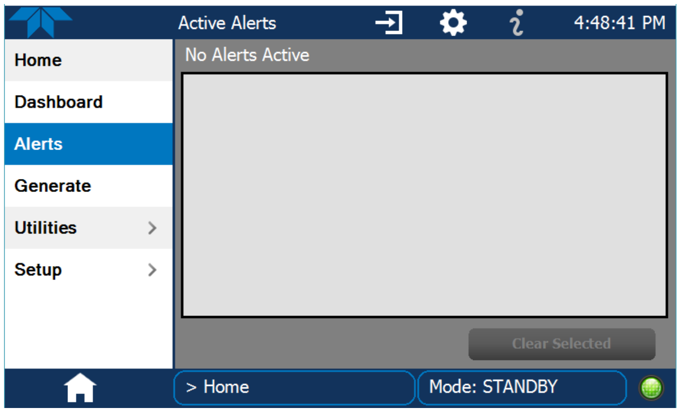


Figure 2-42. Active Alerts Cleared

2.5.4. GENERATE

The Generate menu provides the ability to:

- Generate either ozone or zero air
- Execute a Sequence (configured in the Setup menu)
- Execute a Level (configured in the Setup menu)
- Place the instrument into Standby mode (suspend generating gas)

The Generate menu is presented in Section 3.2. To configure Sequences, see Section 2.6.7or to configure Levels, see Section 2.6.8

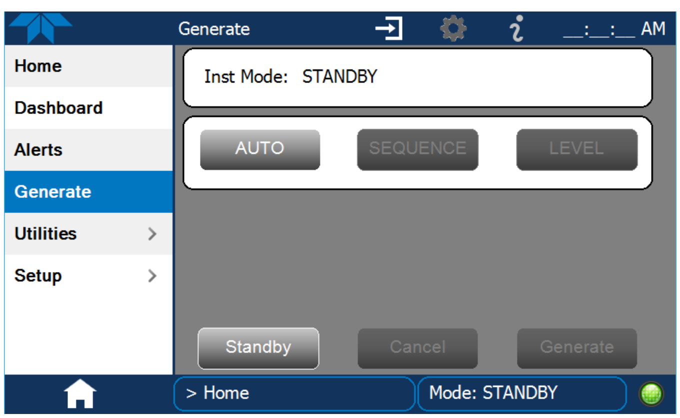


Figure 2-43. Generate Page

2.5.5. UTILITIES

The Utilities menu opens to the Datalog View, the Alerts Log, the USB Utilities, and the Diagnostics submenus.

2.5.5.1. DATALOG VIEW

The Datalog View tab displays a list of data logs that were configured in the Setup>Data Logging menu (Section 2.6.1). From this list a log can be selected and filters applied to view the desired data.

2.5.5.2. ALERTS LOG

The Alerts Log holds a history of alerts that were triggered by factory-defined and user-defined Events, such as warnings and alarms.

2.5.5.3. USB UTILITIES (DOWNLOADS AND UPDATES)

The USB Utility page serves multiple purposes using a flash drive connected to the instrument's front panel USB port:

- downloading Data Acquisition System (DAS) data from the instrument to a flash drive (presented below).
- updating firmware (presented below and in Section 6.3).
- copying a configuration from one instrument to other same-model instruments (presented below).
- downloading a basic operation functionality report (presented below and in Section 6.2)

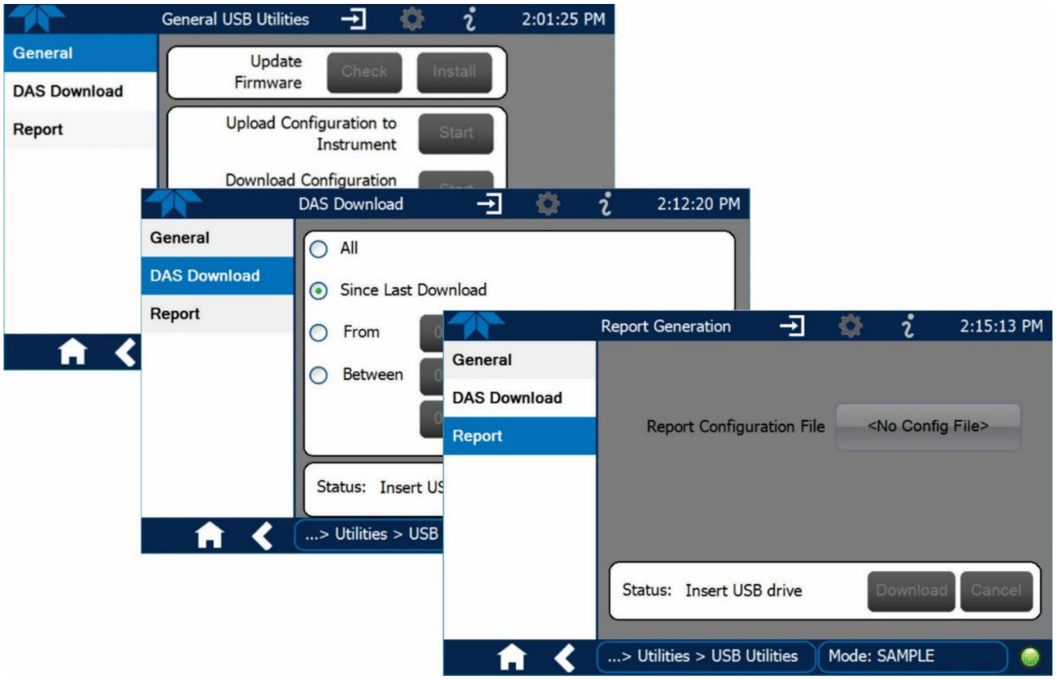


Figure 2-44. USB Utilities Pages

The Status field shows when an inserted flash drive has been detected, at which time firmware updates, configuration copying and DAS downloading can be carried out.

DOWNLOADING DAS (DATA ACQUISITION SYSTEM) DATA

DAS data (collected by the Datalogger, Section 2.6.1) can be downloaded from the instrument to a flash drive through the Utilities>USB Utilities>DAS Download menu, as follows:

1. Insert a flash drive into a front panel USB port and wait for the Status field to indicate that the drive has been detected; available buttons will be enabled.

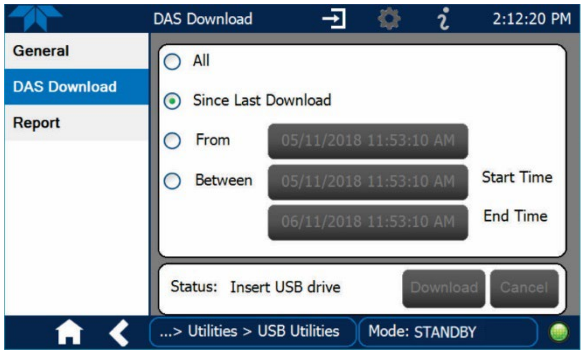


Figure 2-45. DAS Download Page

2. To copy the data to the flash drive, press the Start button next to “Download DAS Data from Instrument.” (The Cancel button will be enabled).
3. When complete, as indicated in the Status field, the Cancel button becomes the Done button: press Done and then remove the flash drive.

UPDATING FIRMWARE

It is possible to check for firmware updates, reload current firmware, and to update firmware remotely. Because this is a maintenance item and there is more than one way to implement an update, instructions are provided in Section 6.3.

Transferring Configuration to Other Instruments

Once an instrument is configured, the same configuration can be copied to other instruments of the same Model. This encompasses essentially anything the user can configure and does not apply to instrument-specific settings such as those that are configured at the factory for calibration.

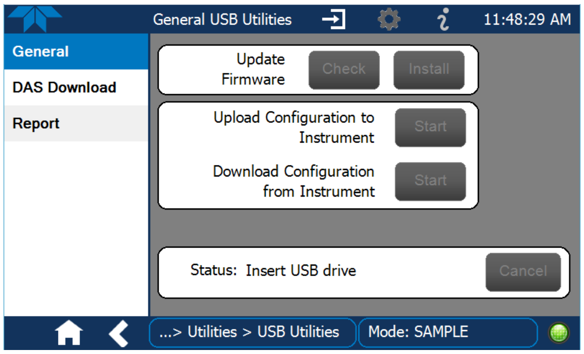


Figure 2-46. Configuration Transfer

1. In the source instrument, navigate to the Home>Utilities>USB Utilities>General page.
2. Insert a flash drive into either of the two front panel USB ports.
3. When the Status field indicates that the USB drive has been detected, press the “Download Configuration from Instrument” Start button.
4. When the Status field indicates that the download is complete, remove the flash drive.
5. In the target instrument, navigate to the Home>Utilities>USB Utilities>General page.
6. Insert a flash drive into either of the two front panel USB ports.
7. When the Status field indicates that the USB drive has been detected, press the “Upload Configuration to Instrument” Start button.

When the Status field indicates that the upload is complete, remove the flash drive.

Generating a Report

The Report page is used typically for monitoring the functionality of the instrument. A new report is generated every 24 hours and can be downloaded, and it can be uploaded to a Cloud service for TAPI Technical Support. Because it is used in maintenance and troubleshooting, the Report feature is presented in Section 6.2.

2.5.5.4. DIAGNOSTICS

The Diagnostics menu provides access to several diagnostics features, which can be helpful in troubleshooting (Section 7). When an item in the menu is selected, the display shows its description. Table 2-11 on page 76 also provides descriptions.

Note	**Some Diagnostics items do not appear in the menu unless the instrument has been placed in Standby mode (Home>Generate menu).**

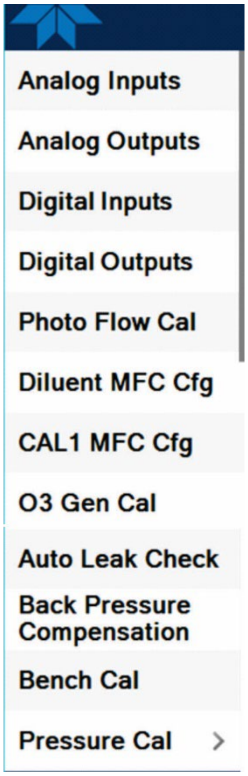


Figure 2-47. Sample Diagnostics Menu (differs by calibrator configuration)

2.5.6. SETUP

The Setup menu is used to configure the instrument's software features, gather information on the instrument's performance, and configure and access data from the Datalogger, the instrument's internal data acquisition system (DAS). Section 2.6 provides details for the menus under Setup.

2.6. SETUP MENU: FEATURES/FUNCTIONS CONFIGURATION

Use the Setup menu to configure the instrument's software features, to gather information on the instrument's performance, and to configure and access data from the Datalogger, the instrument's internal data acquisition system (DAS). Once the setups are complete, the saved configurations can be downloaded to a USB drive through the Utilities>USB Utilities menu and uploaded to other instruments of the same model (Section 2.7).

2.6.1. SETUP>DATA LOGGING (DATA ACQUISITION SYSTEM, DAS)

The Data Logger captures and stores user-defined data. In the Setup>Data Logging menu press the ADD button to create a new log, or select an existing log from the Data Logging list and press the EDIT or DELETE button to make the desired changes. Follow instruction shown in Figure 2-48.

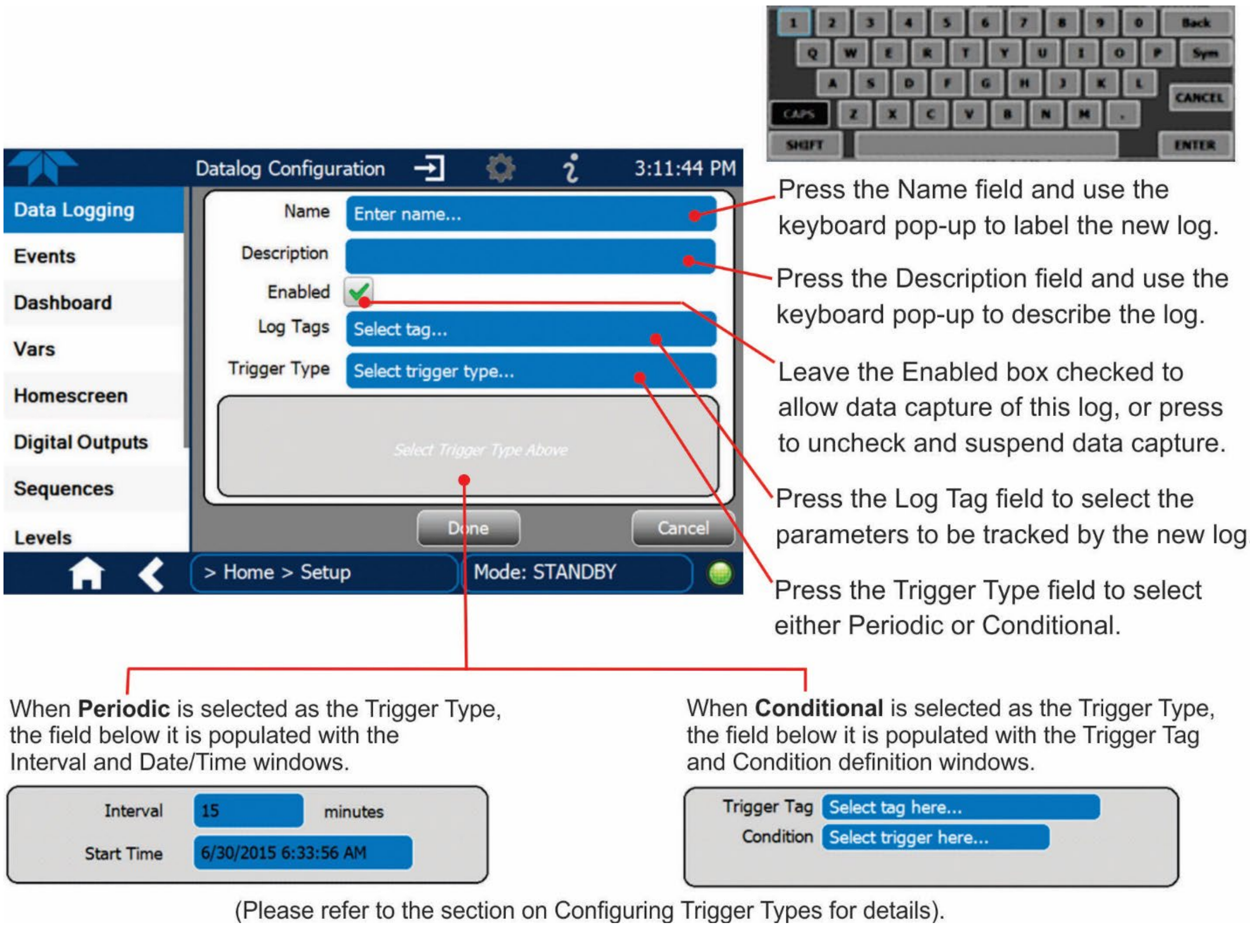


Figure 2-48. Data Log Configuration

2.6.1.1. CONFIGURING TRIGGER TYPES: PERIODIC

The Periodic trigger is a timer-based trigger that is used to log data at a specific time interval. Periodic Trigger requires an interval that is set to number of minutes and a start time that is set to date and clock time.

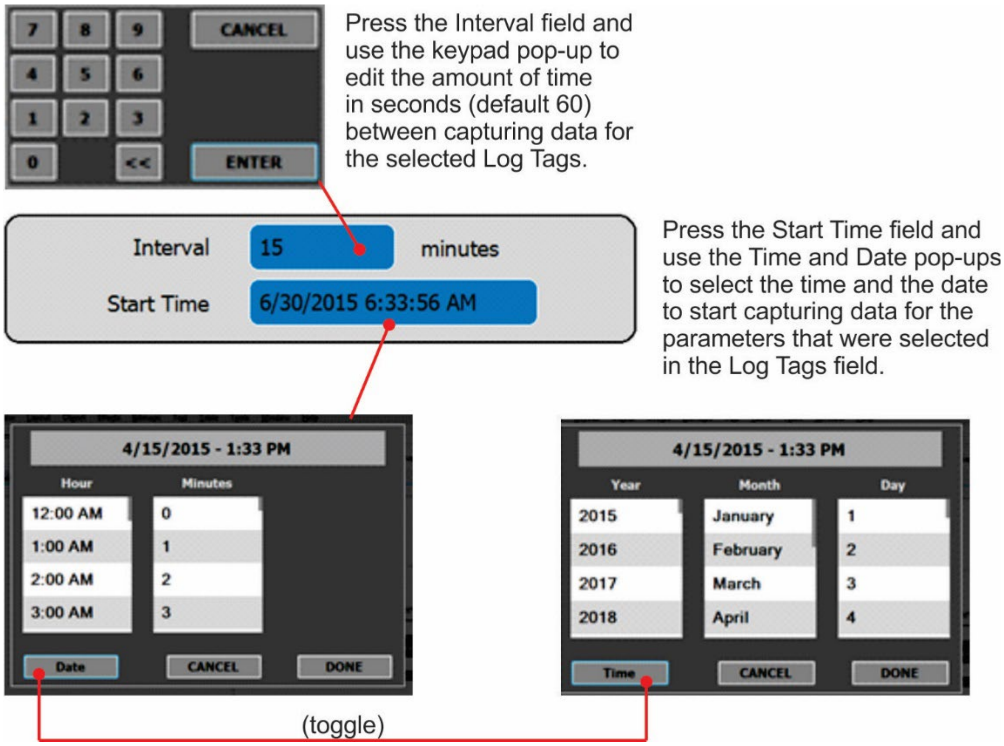


Figure 2-49. Datalog Periodic Trigger Configuration

2.6.1.2. CONFIGURING TRIGGER TYPES: CONDITIONAL

Conditional Trigger tracks/records data for user-selected parameters that meet specified conditions.

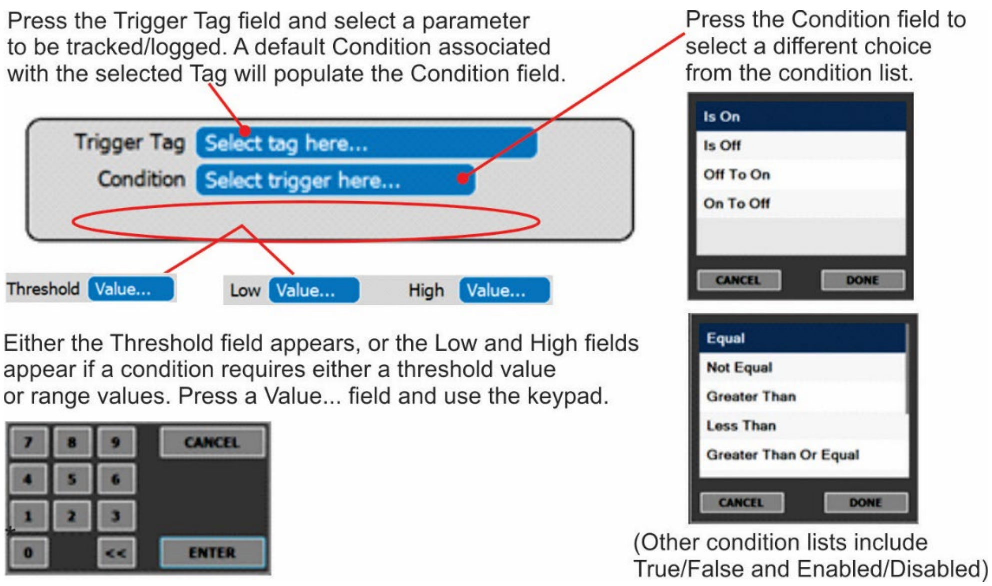


Figure 2-50. Datalog - Conditional Trigger Configuration

2.6.1.3. DOWNLOADING DAS (DATA ACQUISITION SYSTEM) DATA

In the Utilities>USB Utilities menu, instrument data can be downloaded to a flash drive, as presented here.

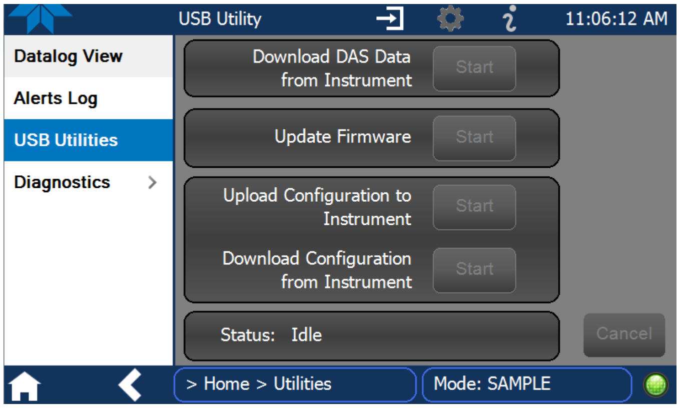


Figure 2-51. USB Utility Page

8. Press USB Utilities menu to open the utility page (Figure 2-51).
9. Insert a flash drive into a front panel USB port and wait for the Status field to indicate that the drive has been detected and available buttons are enabled (Figure 2-52).

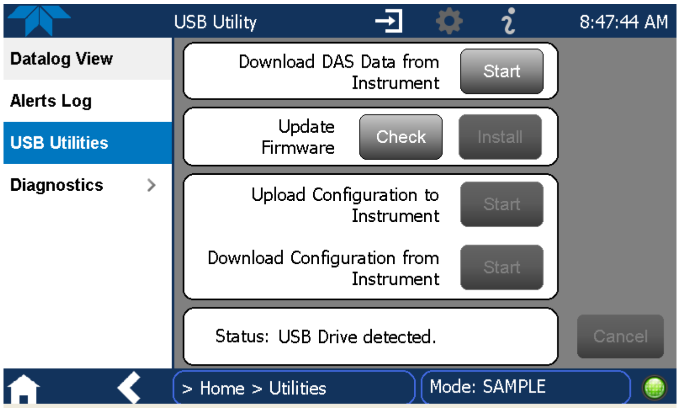


Figure 2-52. DAS Data Download

10. To copy the data to the flash drive, press the Start button next to “Download DAS Data from Instrument.” (The Cancel button will be enabled).
11. Wait for the Status field to indicate that the transfer is complete and the Cancel button becomes the Done button.
12. Press the Done button; then remove the flash drive.

(The Update Firmware field is for checking for and installing firmware updates when the instrument is connected to the Internet, and is presented in Section **6.2**. The Upload/Download Configuration field is for transferring instrument configuration from/to other instruments, and is presented in Section 2.7).

2.6.2. SETUP>EVENTS

Events are occurrences that relate to any operating function, and will trigger Alerts (Section 2.5.3). Events can provide diagnostic information about the instrument, typically referred to as “Warnings”, or they can provide additional instrument functionality, such as concentration alarms. The instrument comes from the factory with a number of pre-defined warning Events, while the Setup>Events Configuration page provides the capability to create additional, user-defined Events. Events are listed in the Events page (Figure 2-53) under the Setup menu.

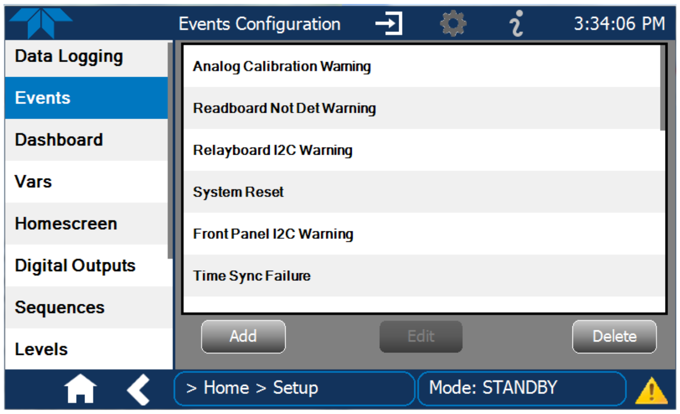


Figure 2-53. Events List

Access the Events Configuration page either from the Active Alerts page (Alerts Menu) by pressing the configuration button, or through the Home>Setup>Events menu (Figure 2-53). Press ADD to create a new Event (refer to Figure 2-54 for details), or select an existing Event to either Edit or Delete it.

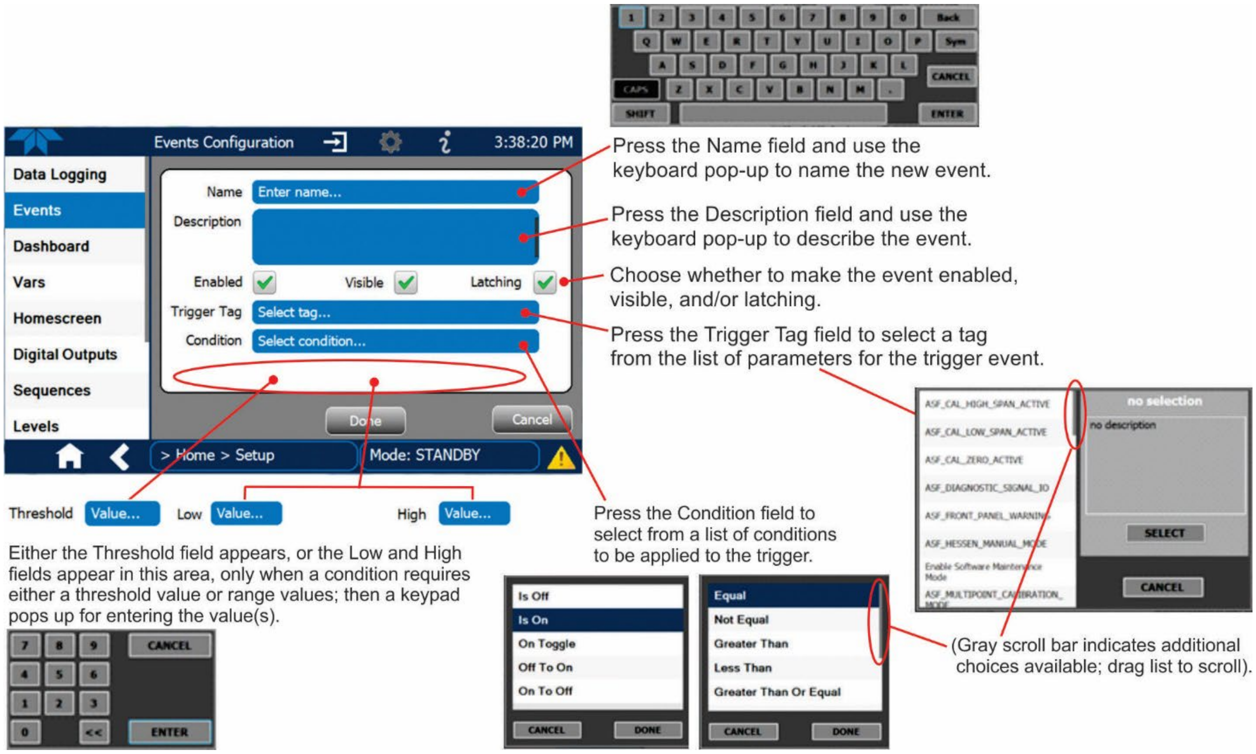


Figure 2-54. Event Configuration

- Enabled ✓ allows the choice of whether to track and record the Event (uncheck this box to "turn off" or deactivate the Event without deleting it). An Event must be enabled in order to use the Visible and the Latching options.
- Visible ✓ allows the choice of whether or not to display the Event in the Alerts page when it is triggered (it will still be recorded and can be viewed in the Utilities>Alerts Log).To use this option, the Event must be enabled.
- Latching ✓ allows the choice of whether or not to keep an Event visible even if the conditions that triggered it were to correct themselves. (Latching requires that the user interact with the Active Alerts screen to manually clear the Alert and internal Event state. Non-latching allows the entry in the Active Alerts screen and the internal Event state to continuously update based on the Event criteria, requiring no user interaction to clear the Alert or Event state).

2.6.3. SETUP>DASHBOARD

Configure the Dashboard to show the functions and conditions desired for viewing. Select an available tag in the left column and press the right arrow to populate the Dashboard.

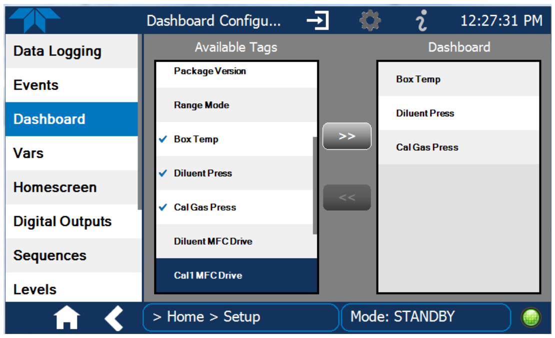


Figure 2-55. Dashboard Configuration

2.6.4. SETUP>VARS: INTERNAL VARIABLES

The calibrator 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 Setup>Vars menu. Select a Var to see its description to the right in the VARS Configurator. Press the Edit button to change the attributes of the selected Var.

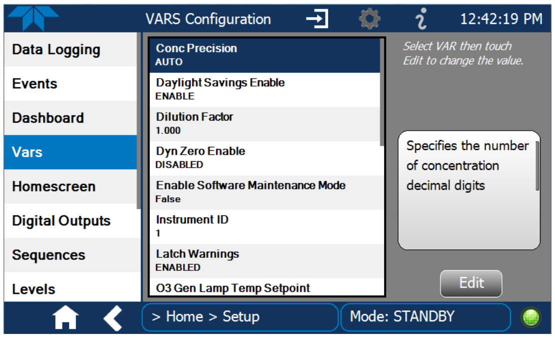


Figure 2-56. Vars Configuration

2.6.5. SETUP>HOMESCREEN

Configure the Homescreen to display three of the available tags and their values in the meters located along the bottom of Home page. Refer to Figure 2-38 for an orientation to Home page and Figure 2-57 for Homescreen configuration page.

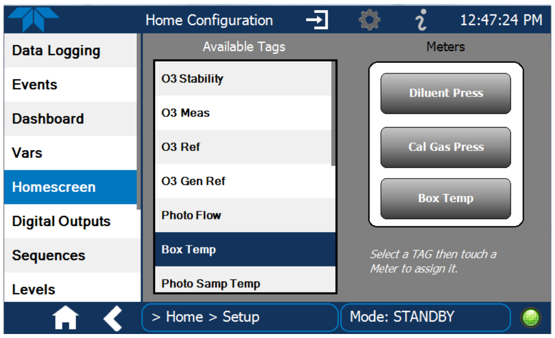


Figure 2-57. Homescreen Configuration

2.6.6. SETUP>DIGITAL (STATUS) OUTPUTS

Specify the function of each digital output (connected through the rear panel STATUS connector) by mapping the output to a selection of "Signals" present in the instrument. Create custom "Signals" in the Setup>Events menu (Section 2.6.2). (If the Motherboard Relay Option was installed, the four additional relays can also be mapped).

To map Digital Outputs to Signals:

1. In the Outputs list select a pin to be configured.
2. In the Signals list select a parameter to assign to the selected pin.
3. Press the Map button.
4. If/as needed, toggle the polarity by pressing the Polarity button.
5. To save, press the Apply button, or to discard, press the Home or the back icon (a pop-up provides a warning that the changes will be lost, and will prompt for confirmation to apply changes or not). Another option is to reassign the pin to the "Not Mapped" parameter.

These status outputs are visible in the Utilities>Diagnostics>Digital Outputs menu, and are labeled "Digital Output [#]" followed by the signal name. They can be selected and their state changed between ON and OFF. (Note that the Digital Outputs list in the Utilities>Diagnostics menu also includes the Control Outputs and other functions).

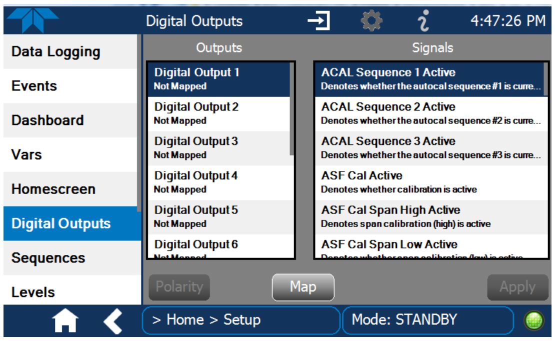


Figure 2-58. Digital Outputs Setup

2.6.7. SETUP>SEQUENCES: AUTOMATIC CALIBRATION OPERATIONS

(This menu appears only when the Mode is set to STANDBY (from the Generate menu)). The calibrator can be set up to perform automatic calibration sequences of multiple steps. These sequences can perform all of the calibration mixture operations available for manual operation and can be initiated by one of the following methods:

- front panel touch screen buttons
- internal timer
- external digital control inputs
- RS-232 interface
- Ethernet interface
- sub-processes in another sequence

Multiple sequences can be programmed and enabled or disabled. Configurable sequence attributes are listed and described in Table 2-12. Figure 2-59 illustrates sequence setup.

Note **Last in = first out: the last step input into the program during configuration under "Edit Steps" is the first step executed, which means that multiple steps must be input in their reverse order; advanced planning is recommended.**

Table 2-12. Calibration Sequences Configuration Attributes

ATTRIBUTE NAME	DESCRIPTION
Name	Allows the user to input a unique label identifying the sequence.
Timer	Controls the date and time to start the sequence (Timer Start) and the amount of time to wait before repeating the sequence (Timer Delta) if the Repeat Count attribute is set.
Repeat Count	Number of times to execute the same sequence.
Input CC	Specifies which of the calibrator's Digital Control Inputs will initiate the sequence.
Output CC	Specifies which of the calibrator's Digital Control Outputs will be set when the sequence is active.
☑ Enable	Checked Enable box enables the attribute to initiate the sequence as configured. Unchecked Enable box disables the attribute's initiation of the sequence.

ATTRIBUTE NAME	DESCRIPTION	
Step Types	Selections for programming the activities and instructions that make up the calibration sequence.	
	MANUAL	Puts the instrument into generate mode, similar in operation and effect to the Generate>Generate>MANUAL function used at the front panel.
	GENERATE	Puts the instrument into GENERATE mode. Similar in operation and effect to the Generate>Generate>AUTO function used at the front panel.
	GPT	Initiates a Gas Phase Titration operation (recommended to be preceded first by a GPTZ and then a GPTPS).
	GPTZ	Initiates a Gas Phase Titration Zero operation
	GPTPS	Initiates a Gas Phase Titration Preset procedure.
	PURGE	Puts the calibrator into PURGE mode.
	STANDBY	Puts the calibrator in Standby mode for the duration
	EXECSEQ	Calls another sequence to be executed at this time. The calling sequence will resume running when the called sequence is completed. Up to 5 levels of nested sequences can be programmed.
	SET CC OUTPUT	Causes the sequence to activate the calibrator's digital control outputs. Similar to the CC OUTPUT attribute, but can be set and reset by individual steps. It is very useful in situations where the control outputs are being used to trigger other devices that need to be turned off and on in sync with the operation of the calibrator as it progresses through the sequence.
	LEVEL	Allows the sequence to execute a LEADS function created in the Setup>Levels menu.
	SET STATUS BLOCK	Allows activation of Status Block 1 for rear panel physical Control Outputs and/or Status Block 2 for communicating status.

Note **It is generally a good idea to end each calibration sequence with a PURGE instruction followed by an instruction to return the instrument to STANDBY mode. Even if a PURGE is not included, the last instruction in a sequence should always be to place the calibrator in STANDBY mode.**

Figure 2-59 shows the main screens in Sequence configuration.

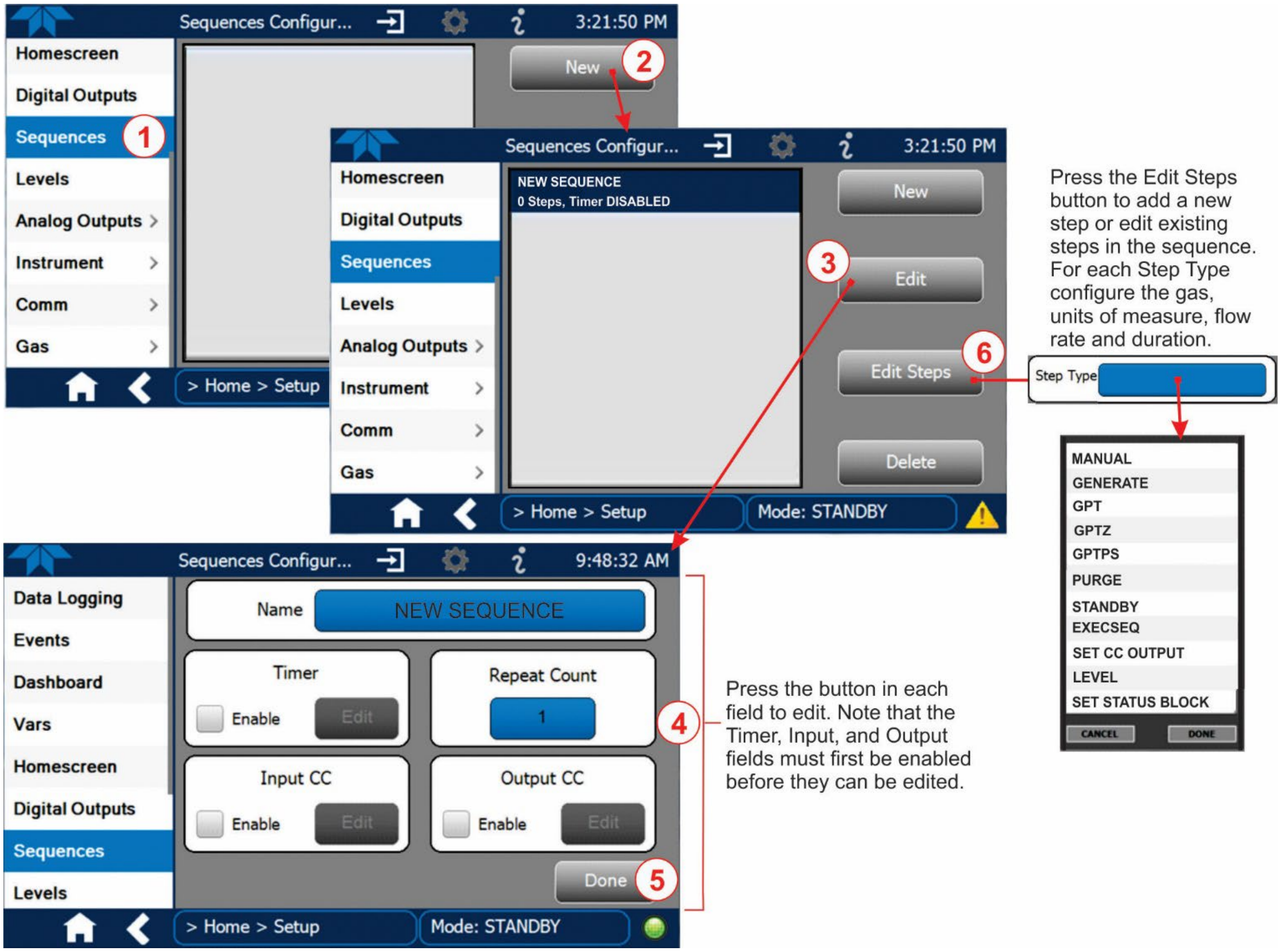


Figure 2-59. Sequence Configuration

Note **When the start time is set for a date/time that has passed, the sequence will properly calculate the next run time based on that past date/time.**

2.6.7.1. SETTING UP CONTROL INPUTS FOR A SEQUENCE

The calibrator's control inputs allow the entire sequence to be triggered from an external source. This feature allows the calibrator to operate in a slave mode so that external control sources, such as a data logger can initiate the calibration sequences.

The calibrator's control inputs connector is located on the rear panel (Figure 2-2).

- 12 separate ON/OFF switches assigned to separate calibration sequences or;
- A 12-bit wide bus allowing the user to define activation codes for up to 4095 separate calibration sequences.

To assign a **CC INPUT** pattern/code to a particular sequence in the Setup>Sequences menu:

1. Select the desired Sequence (or create a new Sequence).
2. In the Input CC field check the Enable box.
3. Press the Edit button.
4. Check the desired control input pin(s).
5. Press Done.

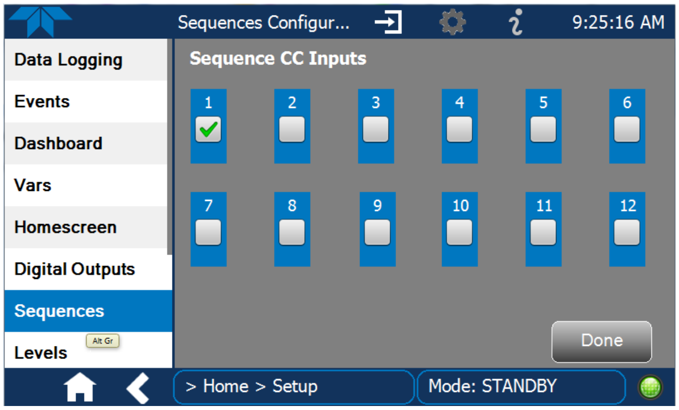


Figure 2-60. Sequence CC Inputs Setup Page

2.6.7.2. SETTING UP CONTROL OUTPUTS FOR A SEQUENCE

The calibrator's control outputs allow the calibrator to control devices that accept logic-level digital inputs, such as programmable logic controllers (PLCs), data loggers, or digital relays/valve drivers.

They can be used as:

- 12 separate ON/OFF switches assigned to separate calibration sequences, or
- a 12-bit wide bus allowing the user to define activation codes for up to 4095 separate calibration sequences.

They can be set so that they are:

- active whenever a particular calibration sequence is operating, or
- activated or deactivated as individual steps within a calibration sequence (see Section 2.6.7.4).

To assign a **CC OUTPUT** pattern/code to a particular sequence in the Setup>Sequences menu:

1. Select the desired Sequence (or create a new Sequence).
2. In the Output CC field check the Enable box.
3. Press the Edit button to open the Sequence CC Outputs page.
4. Check the desired control output pin(s).
5. Press Done.

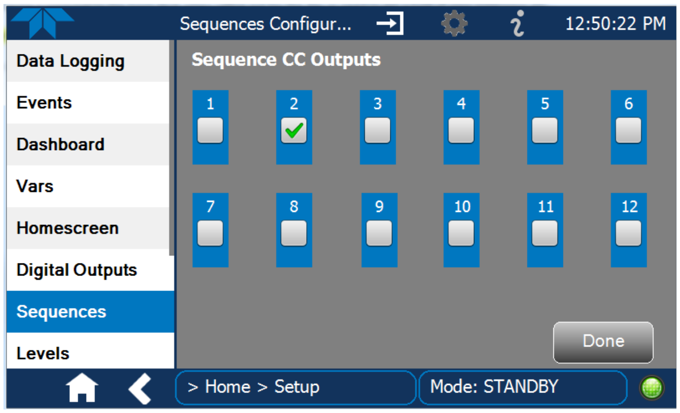


Figure 2-61. Sequence CC Outputs Setup Page

2.6.7.3. PARAMETERS FOR THE STEP TYPES

Several parameters are configurable within a Step Type (Table 2-12 contains step type descriptions), such as gas, concentration, units of measure, and/or flow. Each Step Type has its own parameters, and all allow setting a Duration in minutes, except EXECSEQ, which is for nesting previously configured sequences. Duration causes the calibrator to continue performing the Step Type for the number of minutes input.

2.6.7.4. DELETING OR EDITING SEQUENCES OR INDIVIDUAL STEPS IN A SEQUENCE

In the Setup>Sequences menu, select the Sequence to be changed, and press the button for the intended action:

Edit: Edit the Sequence name, timer, repeat count, input and output CCs.

Edit Steps: Add a new step within the sequence (New).

Select a specific step within the sequence to change (Edit or Delete).

Delete: Delete the entire sequence with all of its steps.

2.6.8. SETUP > LEVELS: SETTING UP AND USING LEADS (DASIBI) OPERATING LEVELS

(This menu appears only when the Mode is set to STANDBY (from the Generate menu)).

2.6.8.1. GENERAL INFORMATION ABOUT LEADS LEVELS

The calibrator can be equipped with a version of firmware that includes support for LEADS, a data collection and analysis system LEADS specifically designed for handling meteorological and environmental data particularly when there is a need to integrate data and control instrumentation from several different manufacturers. When a calibrator is equipped with the optional LEADS software used in conjunction with data loggers located in the central data analysis facility, it is possible to collect and buffer data between the various calibrators, analyzers and metrological equipment remotely located at an air monitoring station.

Because LEADS was originally developed for use with TNRCC using Dasibi 5008 calibrators, the LEADS version of the calibrator includes support for Dasibi “Dot” serial data commands and operational “Levels”.

It also includes a method for driving external devices via contact closure control outputs in conjunction with an optional bolt-on valve driver assembly (see Section 2.3.1.6).

Note	**For more information on the LEADS system, please visit http://www.meteostar.com/.**

2.6.8.2. DOT COMMANDS

The Dasibi “Dot” commands form a text-based (ASCII) data protocol that is transmitted between a control computer (XENO data logger in this case) and a calibrator or ambient gas analyzer over an RS-232 connection. The details of the protocol are beyond the scope of this document, but in its simplest form the protocol is based on a two or three digit integer preceded by a control-A and a period (.) and then followed by a “!” and a two digit checksum.

EXAMPLE: **^A.xxx!nn**

For further information on Dot commands, please contact Teledyne API’S Technical Support team.

A calibrator equipped with LEADS software can be simultaneously operated over the same COMM port using standard Teledyne API’s serial data commands and is compatible with APICOM versions 5 and later which include an added feature that allows a user to edit, upload and download Level tables.

2.6.8.3. PROGRAMMING, EDITING, AND ACTIVATING LEVELS

Up to twenty Levels can be programmed and used with the calibrator, using a range of ID numbers from 0-98. Level 99 is reserved for standby. The Levels are not time based and do not include characteristics such as start time or duration; therefore, a single LEVEL cannot switch between different concentration levels and flow rates. Separate flow and concentration outputs must be programmed into separate LEVELs which are then individually started and stopped either by an operator at the calibrator's front panel or through a serial data operation over the RS-232 or Ethernet ports.

2.6.8.4. PROGRAMMING LEVELS

To program a new Level, refer to Figure 2-62 for the following steps:

1. Navigate to the Setup>Levels menu.
2. Use the New button to start a new Level (Default first new Level ID is 0; default Action is Generate)
3. Use the Edit button to start programming the new Level.
4. Use the Level field to assign a different ID (numeric keypad pops up)
5. Use the Action field to assign the type of step to execute
6. As applicable, assign a target concentration, gas type, and/or flow rate(s). If the applicable is installed, assign a Mode for O3 Gen depending on the option: For the O_3 Generator option, choose OFF, Constant, or Reference For the Photometer option or the O3 Generator and Photometer options together, choose OFF, Constant, or Bench
7. Configure one or both of two Status output blocks:
    - Status Block1: This block corresponds to the physical CONTROL OUTPUT connections located on the back panel of the calibrator (see Figure 2-2 and Section 2.3.1.5).
    - Status Block2: The second status block does not correspond to any physical output but is used to communicate status over the serial data port.
8. Press the Done button to complete the programming for the individual Level.

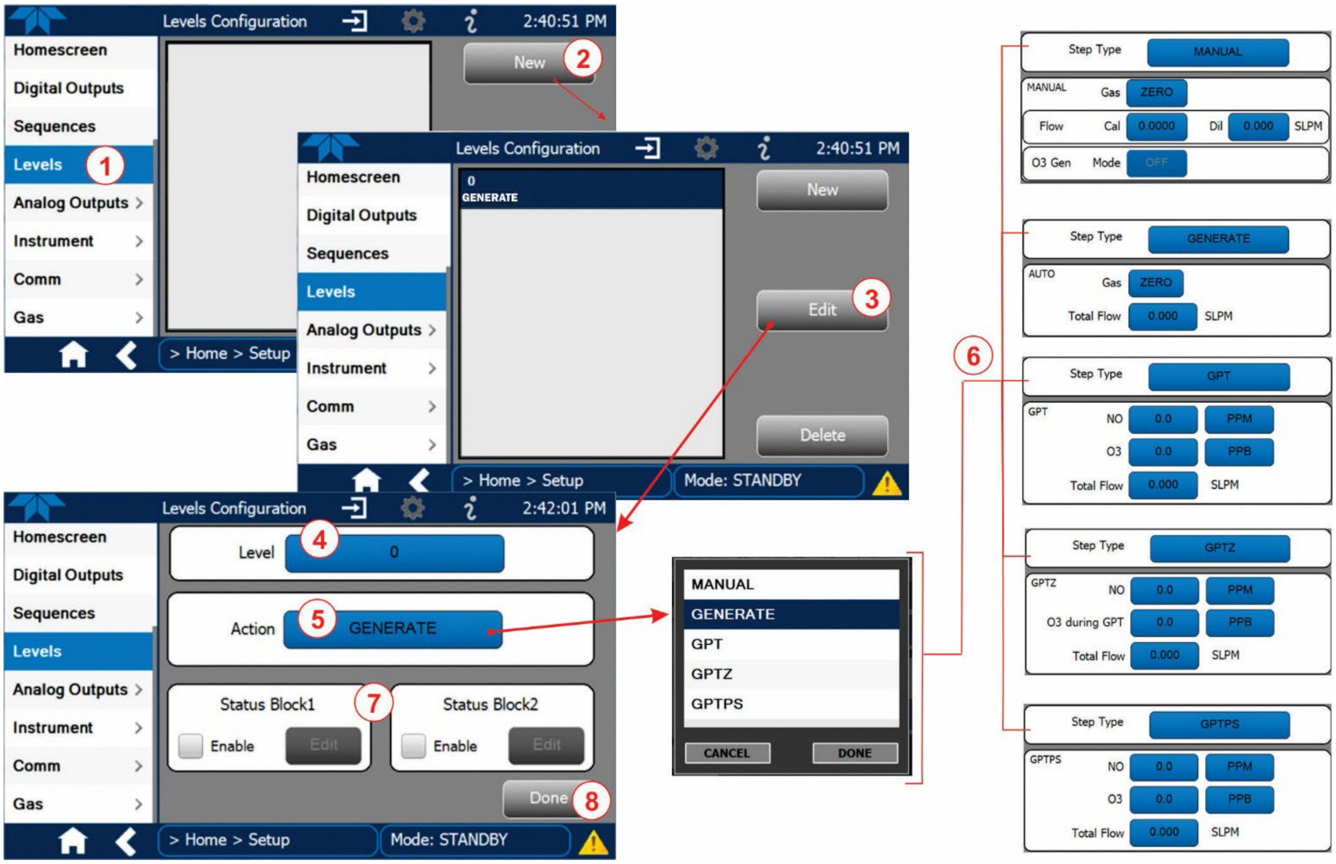


Figure 2-62. Levels Programming and Editing

2.6.8.5. EDITING/DELETING LEVELS

To edit an existing Level, navigate to the Setup>Levels menu, select a Level and start with Step 3 above.

To delete an existing Level, navigate to the Setup>Levels menu, select a Level and use the Delete button.

2.6.8.6. ACTIVATING LEVELS

To activate an existing Level, from Home page navigate to the Generate menu, press the LEVEL button, then select the Level by its ID, and press the Generate button.

2.6.9. SETUP > ANALOG OUTPUT

The calibrator comes equipped with one configurable analog output. It can be set by the user to carry the current signal level of any one of several functions in the calibrator. The Analog Out connector will output an analog VDC signal that rises and falls in relationship with the value of the selected function.

1. In the Setup>Analog Outputs>Analog Output Cfg menu press the button in the Signal Out field and select a function from the pop-up list. (Selecting "Not Mapped" disables all other fields in the Analog Output Configurator).

2. In the Min Max fields input the minimum and maximum values for the slected function's range.
3. In the Calibration Type field, select either AUTO or MANUAL.
   - AUTO sets the software to automatically calibrate not only the user-selected Signal Out function, but also the available MFCs.
   - MANUAL allows fine and coarse adjustments when calibrating the user-selected Signal Out function.
4. In the Range field* select the desired full-scale value of the signal output (see Section 2.6.9.1).
5. In the Recorder Offset field* input a bipolar voltage offset if needed to compensate for noise (see Section 2.6.9.2). This field is not available when Range is set to Current loop.
6. For the Allow Overrange box, either check to allow ± 5% overrange, or leave blank if your recording device is sensitive to excess voltage or current.
7. Press the Apply button.
8. Go to the Analog Output Cal menu to calibrate the new settings (see Section 2.6.9.3).

* Changes to Range or Recorder Offset require that this output be recalibrated.

Figure 2-63. Analog Output Configuration

2.6.9.1. ANALOG OUTPUT VOLTAGE RANGE CONFIGURATION

In its standard configuration, the analog outputs is set to output a 0 – 5 VDC signals. Several other output ranges are available (see Table 2-13). Each range is usable from -5% to + 5% of the rated span.

Table 2-13. Analog Output Voltage Range Min/Max

RANGE SPAN	MINIMUM OUTPUT	MAXIMUM OUTPUT
0-100 mVDC	-5 mVDC	105 mVDC
0-1 VDC	-0.05 VDC	1.05 VDC
0-5 VDC	-0.25 VDC	5.25 VDC
0-10 VDC	-0.5 VDC	10.5 VDC
The default offset for all ranges is 0 VDC.		

2.6.9.2. ADDING A RECORDER OFFSET

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 calibrator by defining a zero offset, a small voltage (e.g., 10% of span).

2.6.9.3. ANALOG OUTPUT CHANNEL CALIBRATION

Analog Output calibration needs to be carried out on first startup of the calibrator (performed in the factory as part of the configuration process) or whenever recalibration is required. The analog outputs can be calibrated automatically 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.

Note	**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.**

MANUAL CALIBRATION OF THE ANALOG OUTPUTS CONFIGURED FOR VOLTAGE RANGES

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

Calibration is performed with a voltmeter connected across the output terminals and by changing the actual output signal level in 100, 10 or 1-count increments in the Analog Output Cal page with the Calibration Type set to Manual.

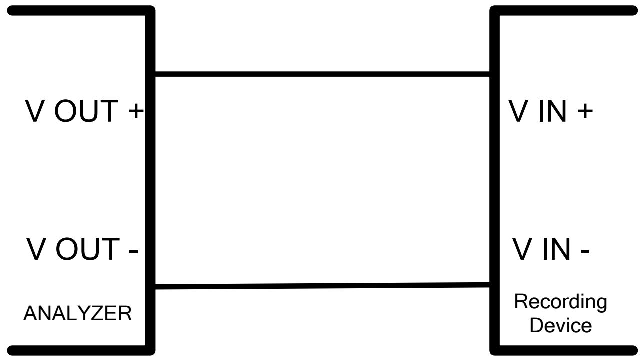


Figure 2-64. Setup for Calibrating the Analog Output Signals

Table 2-14. Voltage Tolerances for the Analog Output 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

Adjust the signal levels of the analog output in the Setup>Analog Outputs>Analog Output Cal menu.

2.6.10. Setup > Instrument

This submenu displays product, system, and software information for the instrument (useful for identifying the software and hardware when contacting Technical Support), and allows time zone and language selection. It is also an alternate place to check for and install software updates.

Special instrument or software features or installed options may also be listed here.

2.6.11. SETUP > COMM: COMMUNICATIONS PORTS

This menu is for specifying the various communications configurations.

2.6.11.1. COM1/COM2

Configure the instrument's COM1 or COM2 ports to operate in modes listed in Table 2-15.

Table 2-15. COM1/COM2 Configuration

MODE	DESCRIPTION
Baud Rate	Set the baud rate for the COM1 or COM2 port being configured.
Command Prompt Display	Enable/disable a command prompt to be displayed when in terminal mode.
Data Bits	Set the data bits to 7 or 8 (typically set in conjunction with Parity and Stop bits).
Echo and Line Editing	Enable/disable character echoing and line editing.
Handshaking Mode	Choose SOFTWARE handshaking for data flow control (do NOT use SOFTWARE handshaking mode when using MODBUS RTU for Protocol mode; select only HARDWARE or OFF for MODBUS RTU), or HARDWARE for CTS/RTS style hardwired transmission handshaking. (This style of data transmission handshaking is commonly used with modems or terminal emulation protocols). Or choose to turn OFF handshaking.
Hardware Error Checking	Enable/disable hardware error checking.
Hardware FIFO	Enable/disable the hardware First In – First Out (FIFO) for improving data transfer rate for that COM port.
Modem Connection	Select either a modem connection or a direct cable connection.
Modem Init String	Input an initialization string to enable the modem to communicate.
Multidrop	Enable/disable multidrop mode for multi-instrument configuration on a single communications channel. Multidrop requires a unique ID for each instrument in the chain (Setup>Vars>Instrument ID).
Parity	Select odd, or even, or no parity (typically set in conjunction with Data Bits and Stop Bits).
Protocol	Select among the communications protocols: TAPI, MODBUS RTU, or MODBUS ASCII (MODBUS: Section 4.4)
Quiet Mode	Enable/disable Quiet mode, which 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.
RS-485	Enable/disable the rear panel **COM2** Port for RS-485 communication. RS-485 mode has precedence over Multidrop mode if both are enabled. Also, RS-485 configuration disables the rear panel USB port.
Security	Enable/disable the requirement for a password for this serial port to respond. The only command that is active is the request-for-help command (? CR).
Stop bits	Select either 0 or 1 stop bit (typically set in conjunction with Parity and Data bits).

2.6.11.2. TCP PORT1

TCP Port1 allows choosing whether or not to display the command prompt, editing the Port 1 number for defining the terminal control port by which terminal emulation software addresses the instrument, such as Internet or NumaView™ Remote software, and enabling or disabling security on this port.

2.6.11.3. TCP PORT2

TCP Port2 is configured with the port number for MODBUS.

2.6.11.4. NETWORK SETTINGS

The Setup>Comm>Network Settings menu is for Ethernet configuration. The address settings default to automatic configuration by Dynamic Host Configuration Protocol (DHCP). Most users will want to configure the instrument with a static IP address: click the Static radio button to manually assign a static IP address (consult your network administrator, and see Table 2-16 for information).

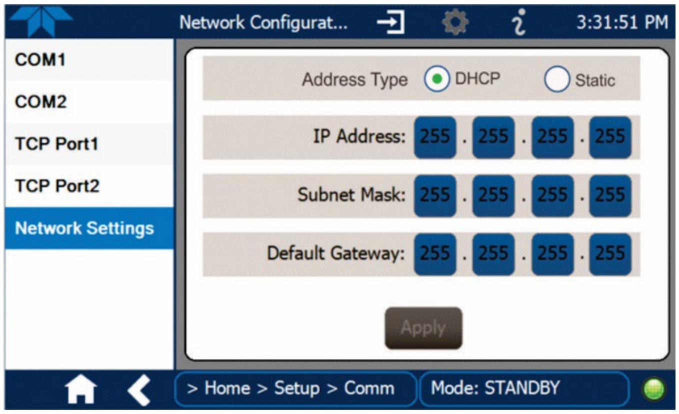


Figure 2-65. Communications Configuration, Network Settings

Table 2-16. LAN/Ethernet Configuration Properties

IP address	A string of four packets of 1 to 3 numbers each (e.g. 192.168.76.55.) is the internet protocol address of the instrument itself.
Subnet Mask	A string of four packets of 1 to 3 numbers each (e.g. 255.255.252.0) number that masks an IP address, and divides the IP address into network address and host address and 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.
Default Gateway	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 and serves as a router to access the Internet or another network.

2.6.12. SETUP>GAS

Gas configuration was detailed during the Startup procedures in Section 2.4.4.

2.7. TRANSFERRING CONFIGURATION TO OTHER INSTRUMENTS

Once an instrument is configured, the same configuration can be copied to other instruments of the same Model.

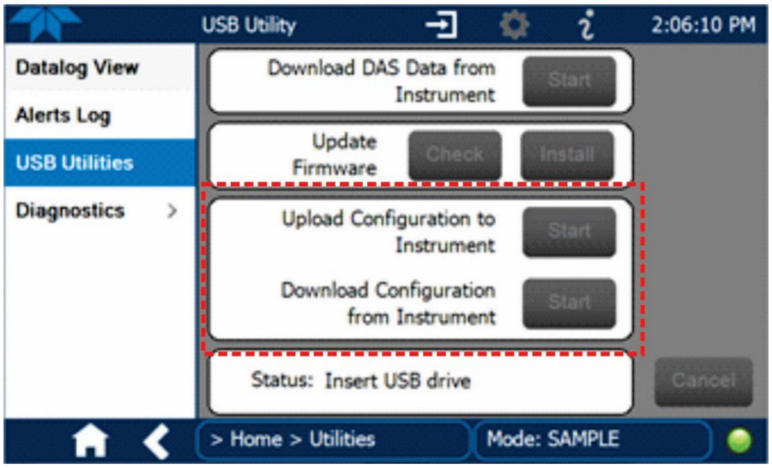


Figure 2-66. Configuration Transfer

1. In the source instrument, go to the Home>Utilities>USB Utilities page.
2. Insert a flash drive into either of the two front panel USB ports.
3. When the Status field indicates that the USB drive has been detected, press the “Download Configuration from Instrument” Start button.
4. When the Status field indicates that the download is complete, remove the flash drive.
5. In the target instrument, go to the Home>Utilities>USB Utilities page.
6. Insert a flash drive into either of the two front panel USB ports.
7. When the Status field indicates that the USB drive has been detected, press the “Upload Configuration to Instrument” Start button.
8. When the Status field indicates that the upload is complete, remove the flash drive.

3. OPERATING MODES, BASIC OPERATION, AND CONFIGURATIONS

This Section starts with a description of the basic modes of operation in order to begin operation right away, and then provides configuration instructions for other functions.

Standby is the most common of the calibrator's software operating modes (Section 3.1); use this mode to configure the calibrator and perform other procedures. Generate is another common mode (Section 3.2); use this mode produce calculated calibration gas mixtures.

Note that the ozone generator in the T700U can operate in a high range or a low range. High range is similar to the standard T700 with an ozone generator option. Low range is more like a fractional mode in that it is used for producing low levels of ozone during a GPT calibration. The T700U low range operation is automatically invoked based on the O_3 concentration and total flow specified, i.e., when O_3 output is < 500 PPB*LPM.

Table 3-1 presents descriptions of the modes. Sections 3.1 through 3.2.9 provide details.

Table 3-1. Calibrator Operating Modes

MODE	DESCRIPTION	
STANDBY	The calibrator and all of its subsystems are inactive. Always ensure that the calibrator is in this mode when performing configurations (Section 3.1). The Standby button is in the Generate page.	
GENERATE	In this mode, the instrument is engaged in producing calibration gas mixtures (Section 3.2).	
	AUTO	The calibrator performs basic generation of calibration mixtures (Section 3.2.1). Supports low range in T700U when generating ozone.
	MANUAL	The calibrator produces calibration gas mixtures (Section 3.2.2).
	PURGE	The calibrator uses diluent (zero air) to purge its internal pneumatics of all source gas and previously created calibration mixtures (Section 3.2.3).
	GPT[1]	Gas Phase Titration method where the calibrator uses the O_3 generator and source gas inputs to mix and generate calibration gas (Section 3.2.4). Supports low range in T700U.
	GPTZ[1]	Gas Phase Titration Zero where the calibrator obtains the baseline NO and NOx readings for calculating the NOx converter efficiency (CE) (Section 3.2.5). Supports low range in T700U.
	GPTPS[2]	Gas Phase Titration Preset where the calibrator determines the precise performance characteristics of the O_3 generator at the target values for an upcoming GPT calibration (Section 3.2.6). Supports low range in T700U.
	SEQUENCE	The calibrator executes Sequences (Section 3.2.7) that were configured in the Setup>Sequences menu (Section 2.6.7).
	LEVEL	The calibrator executes Levels (Section 3.2.9), which are operational functions for LEADS (Section 2.6.8.1) that were configured in the Setup>Levels menu (Section 2.6.8.3).

[1] This mode is not available in units without an O_3 generator option installed.

[2] This mode is not available in units without a photometer option installed.

3.1. STANDBY MODE

When the calibrator is in Standby mode (Generate>Standby), it and all of its subsystems (including the O_3 generator and photometer options, if installed) are inactive, although Dashboard functions and Alerts continuously update as displayed in the front panel. All internal valves are closed except the diluent inlet valve. The mass flow controllers are also turned off.

- Some functions are not available unless the instrument is in Standby mode, e.g., Setup>Gas or Utilities>Diagnostics>Pressure Cal.
- Some functions that conflict with the accurate creation of calibration gas mixtures automatically place the calibrator into Standby mode when activated.
- The MFC pressures are not monitored in Standby mode since the MFCs are turned OFF in this mode. This prevents erroneous Alerts from appearing.

Note **The calibrator should always be placed in STANDBY mode (Home>Generate>Standby button) when not needed to produce calibration gas. The last step of any calibration sequences should always be the STANDBY instruction.**

Table 3-2 shows the status of the calibrator's various pneumatic components when the calibrator is in Standby mode.

Table 3-2. Status of Internal Pneumatics during STANDBY Mode

MODE	VALVES (X = CLOSED; O = OPEN; D = DEENERGIZED; E = ENERGIZED)								MFCS			PHOT PUMP
	CYL 1	CYL 2	CYL 3	CYL 4	PURGE	DILUENT	GPT	O_3 GEN	PHOT M/R[1]	CAL1	CAL2[1]	DILUENT	
Standby	X	X	X	X	X	O	D	D	Reference Phase	OFF	OFF	OFF	OFF

[1] Only present if multiple cal gas MFC option is installed.

In instruments with optional O_3 generators installed, airflow is maintained during Standby mode so that the generator can continue to operate at its most efficient temperature.

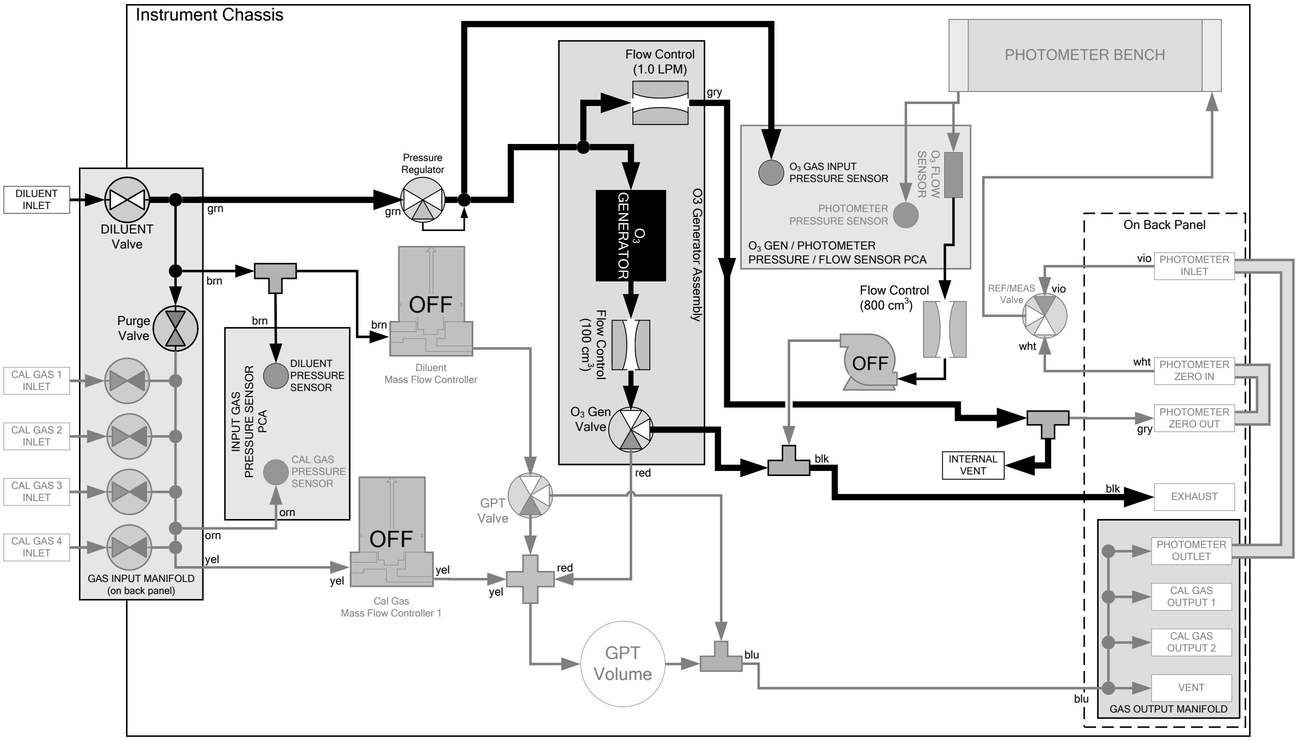


Figure 3-1. Gas Flow with O_3 Generator and Photometer Options during Standby Mode

3.2. GENERATE MODE

In Generate Mode the calibrator generates the user's desired calibration gas mixtures based on the source gas(es) and concentration(s) entered during initial cylinder port configuration through the Setup>Gas>Cylinder menu (see Section 2.4.4). If the unit has an optional O_3 generator installed, various concentrations of O_3 can be set up and generated as well.

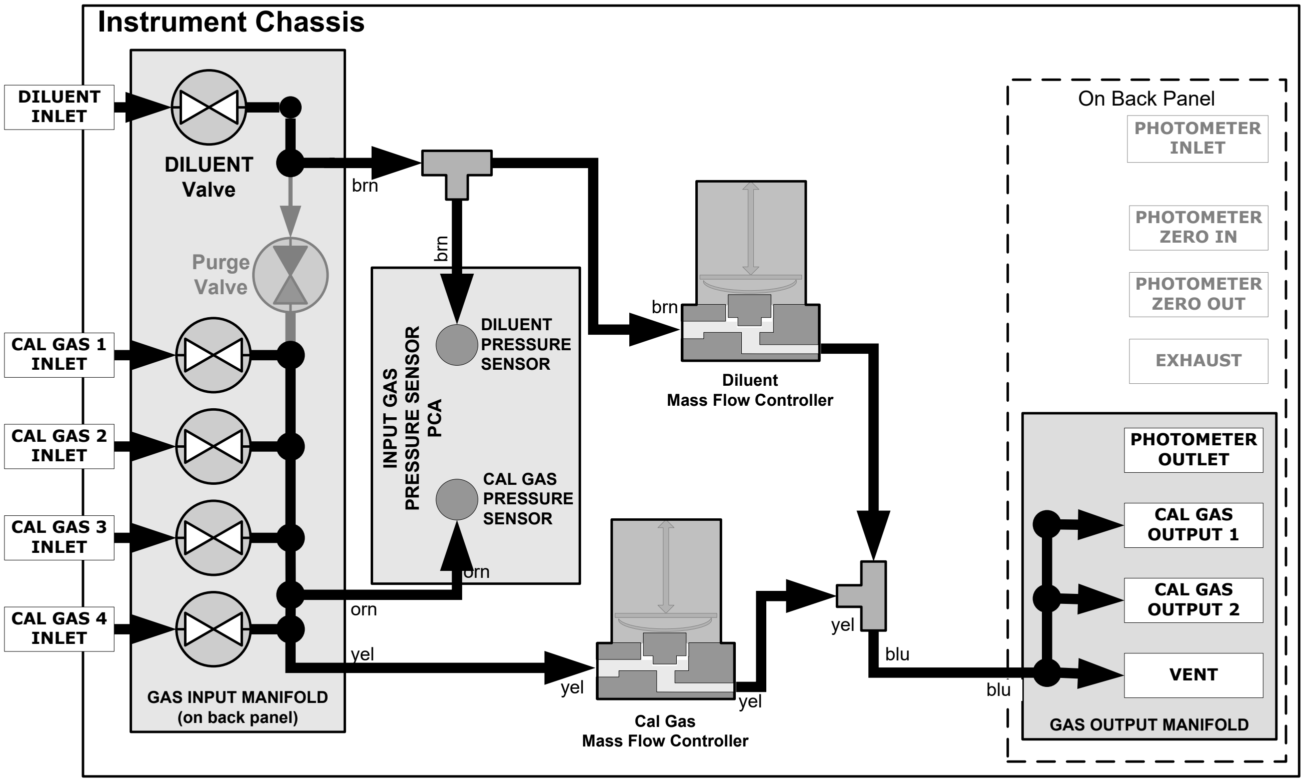


Figure 3-2. Gas Flow through Basic Calibrator in Generate Mode

Table 3-3 shows the status of the calibrator's various pneumatic components when the calibrator is in Generate mode:

Table 3-3. Status of Internal Pneumatics During Generate Mode

GAS TYPE	VALVES (X = CLOSED; O = OPEN; D = DEENERGIZED; E = ENERGIZED)									MFCs			PHOT PUMP
	CYL 1	CYL2	CYL 3	CYL 4	PURGE	DILUENT	GPT	O_3 GEN	PHOT M/R	CAL1	CAL2[1]	DILUENT	
Generate Source Gas	O[2]	O[2]	O[2]	O[2]	X	O	D	D	Reference Phase	ON[3]	ON[3]	ON	OFF
Generate O_3	X	X	X	X	X	O	D	E	Switching	OFF	OFF	OFF	ON

[1] Only present if multiple cal gas MFC option is installed.
[2] The valve associated with the cylinder containing the chosen source gas is open.
[3] In instrument with multiple MFCs the CPU chooses which MFC to use depending on the target gas flow requested.

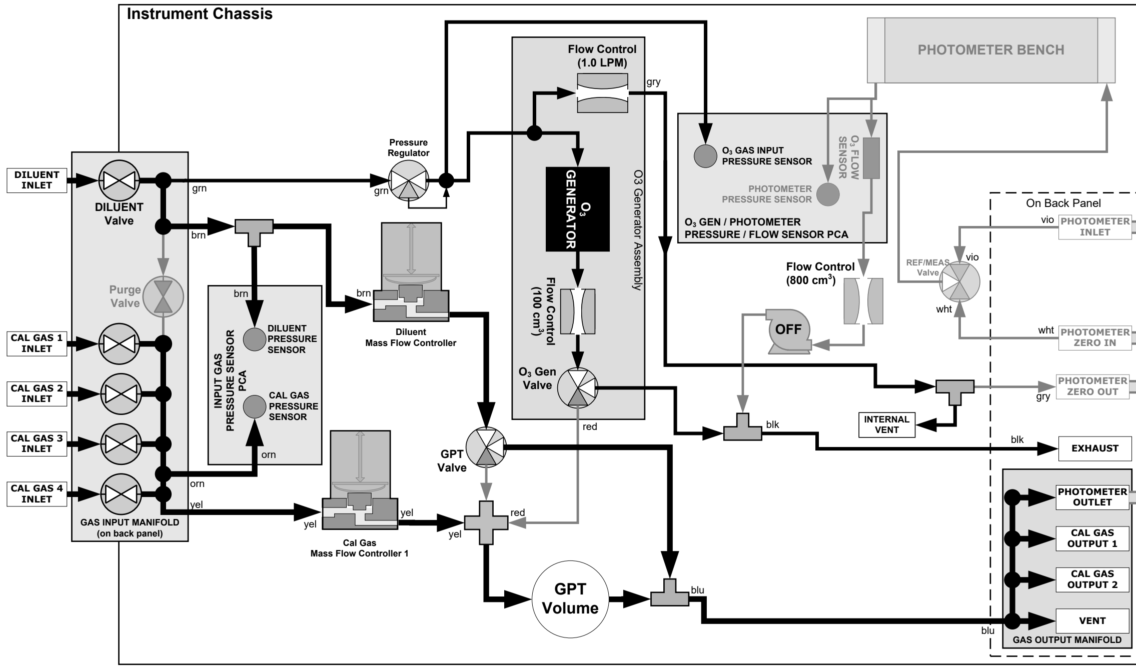


Figure 3-3. T700U Gas Flow and T700 with O_3 Options when Generating Non-O_3 Source Gas

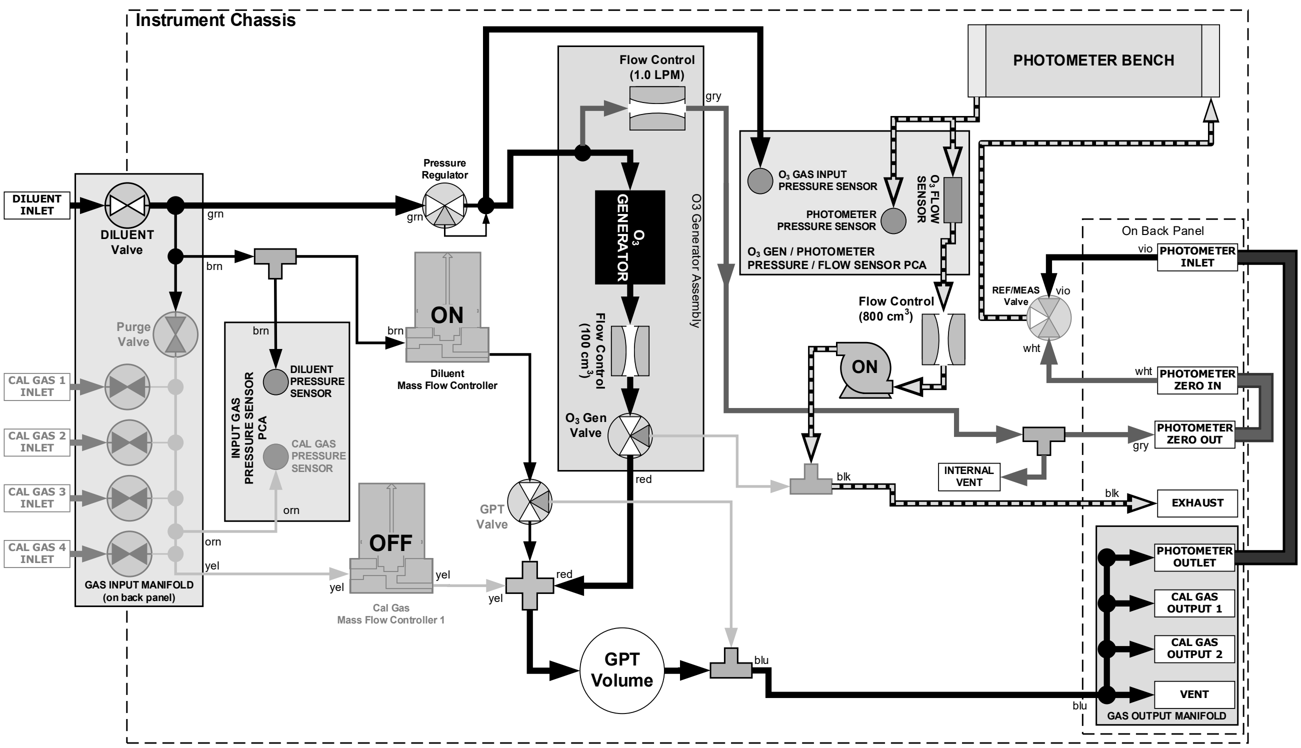


Figure 3-4. T700U Gas Flow and T700 with O_3 Options when Generating O_3

Modes in the Generate menu are illustrated in Figure 3-5, briefly described in Table 3-1, and detailed in Sections 3.2.1 through 3.2.9.

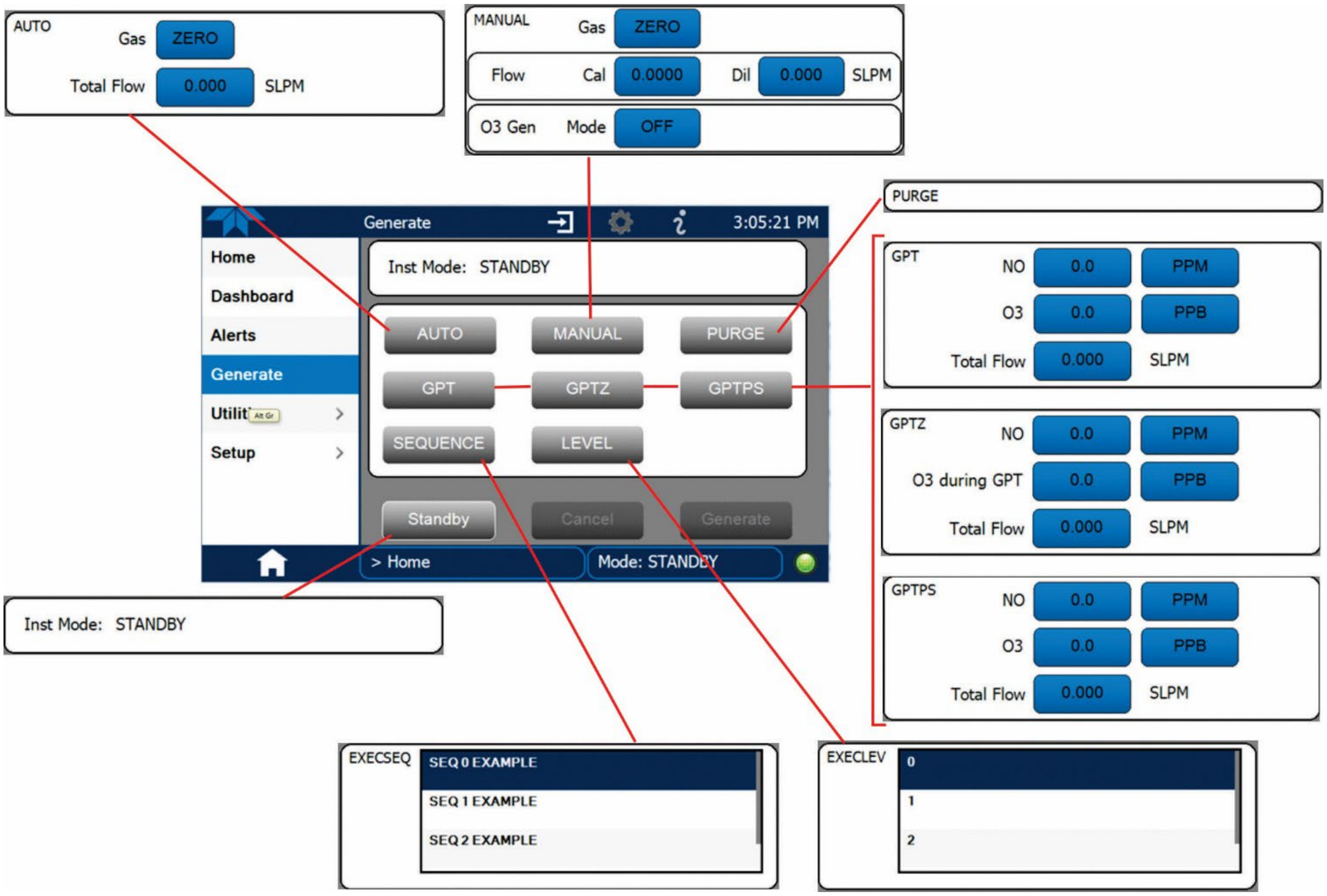


Figure 3-5. Modes in the Generate Menu

3.2.1. GENERATE > AUTO: BASIC GENERATION OF CALIBRATION MIXTURES

The AUTO mode can be used to generate ozone as a calibration gas for performing calibrations and calibration checks on ambient ozone analyzers. This is the simplest procedure for generating calibration gas mixtures. In this mode, the user makes four choices (Figure 3-6):

- type of component gas to be used from the list of gases selected during configuration in the Setup>Gas menu (Section 2.4.4);
- target concentration
- units of measure
- flow rate to be output by the calibrator

Note

In the **T700U**, when generating very low levels of ozone, care must be taken to ensure that the concentration-flow product is kept above the 20 ppb*LPM minimum value. This value is the target concentration (in ppb) multiplied by the total flow value.

Example: To determine the minimum flow rate required to generate 3 ppb:

3 ppb * X LPM > 20 ppb*LPM

or

X LPM > (20 ppb * LPM) / (3 ppb) = 6.7 LPM

Therefore, the flow rate should be a minimum of 6.7 LPM to generate 3 ppb.

These equations can be used to determine the minimum flow rate for any desired concentration.

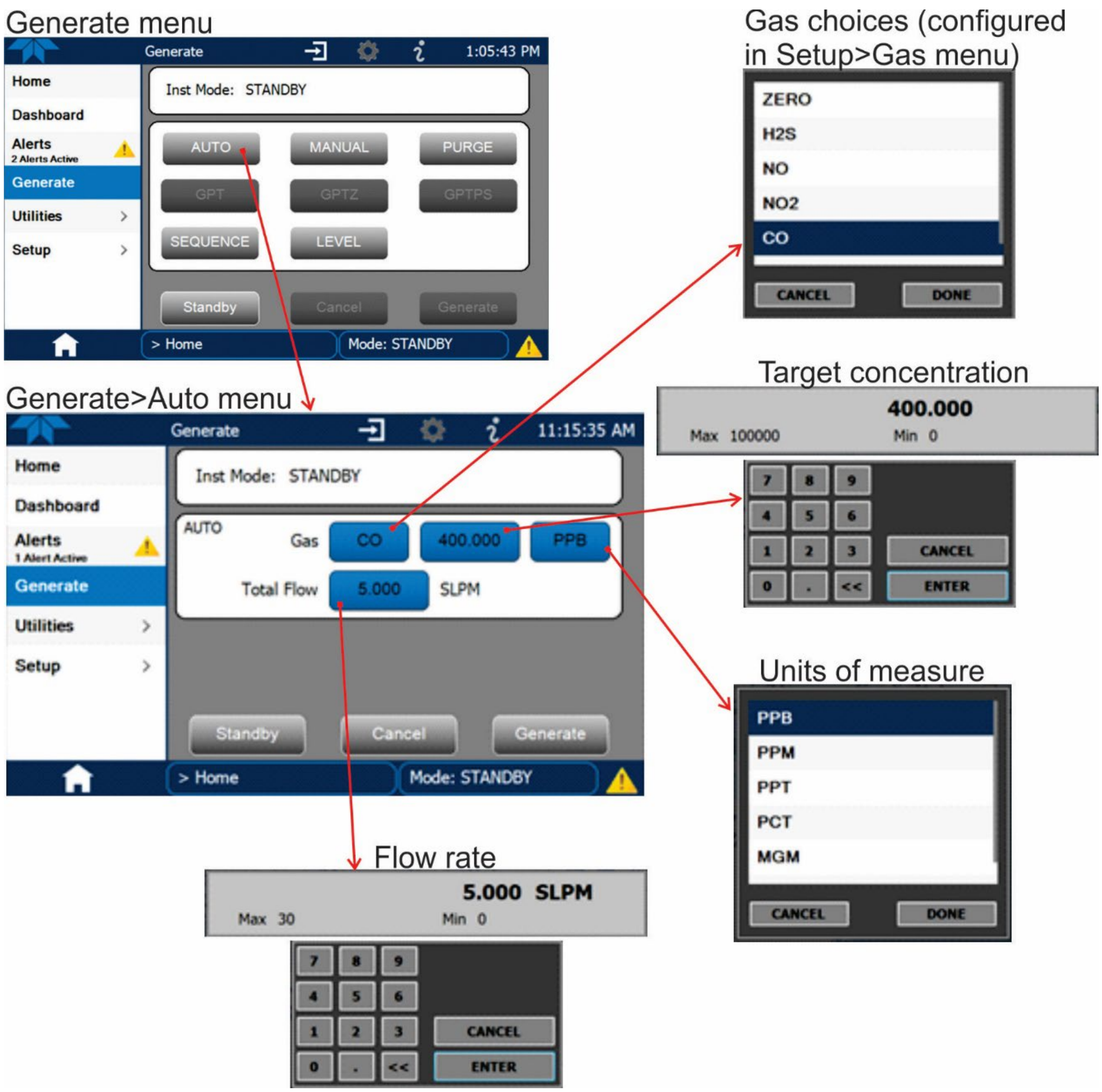


Figure 3-6. Auto Generate Calibration Mixtures

Using this information, the Calibrator automatically calculates and sets the individual flow rates for the Diluent and chosen component gases to create the desired calibration mixture.

3.2.2. GENERATE > MANUAL: GENERATING CALIBRATION MIXTURES MANUALLY

This mode provides the user with more control of the gas mixture process. Unlike the **AUTO** mode, **MANUAL** mode requires the user set the both the component gas flow rate and diluent air flow rate (see Figure 3-7). This allows the user control over the mixing ratio and total calibration gas flow rate.

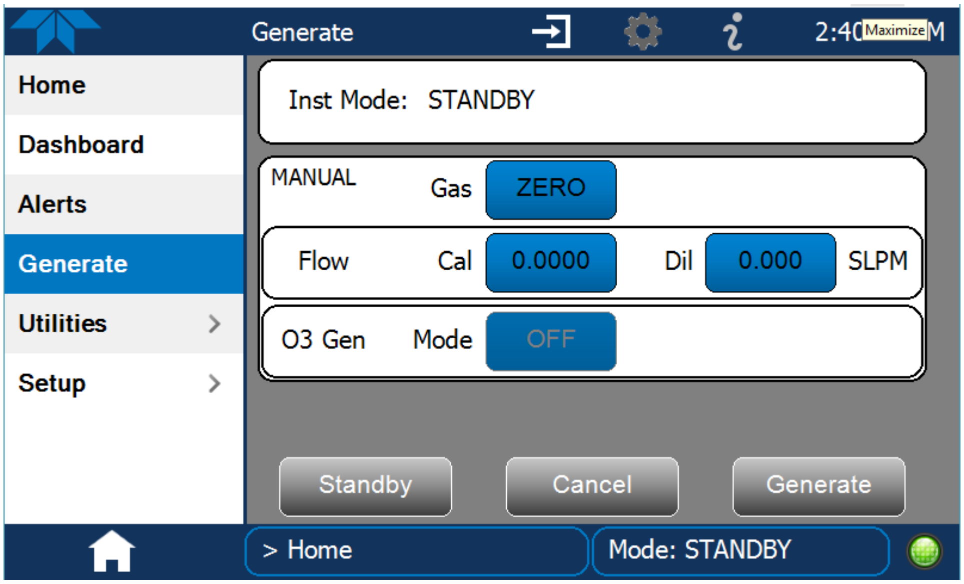


Figure 3-7. Generate>Manual Menu

In addition, if the Calibrator is equipped with the optional O_3 Generator (with or without optional Photometer), and O_3 is to be included in the calibration mixture (e.g. using the GPT or GPTPS features), the user also needs to set the ozone generator mode and set point see Figure 3-8.

However, start with computations for the desired settings, as presented in this section.

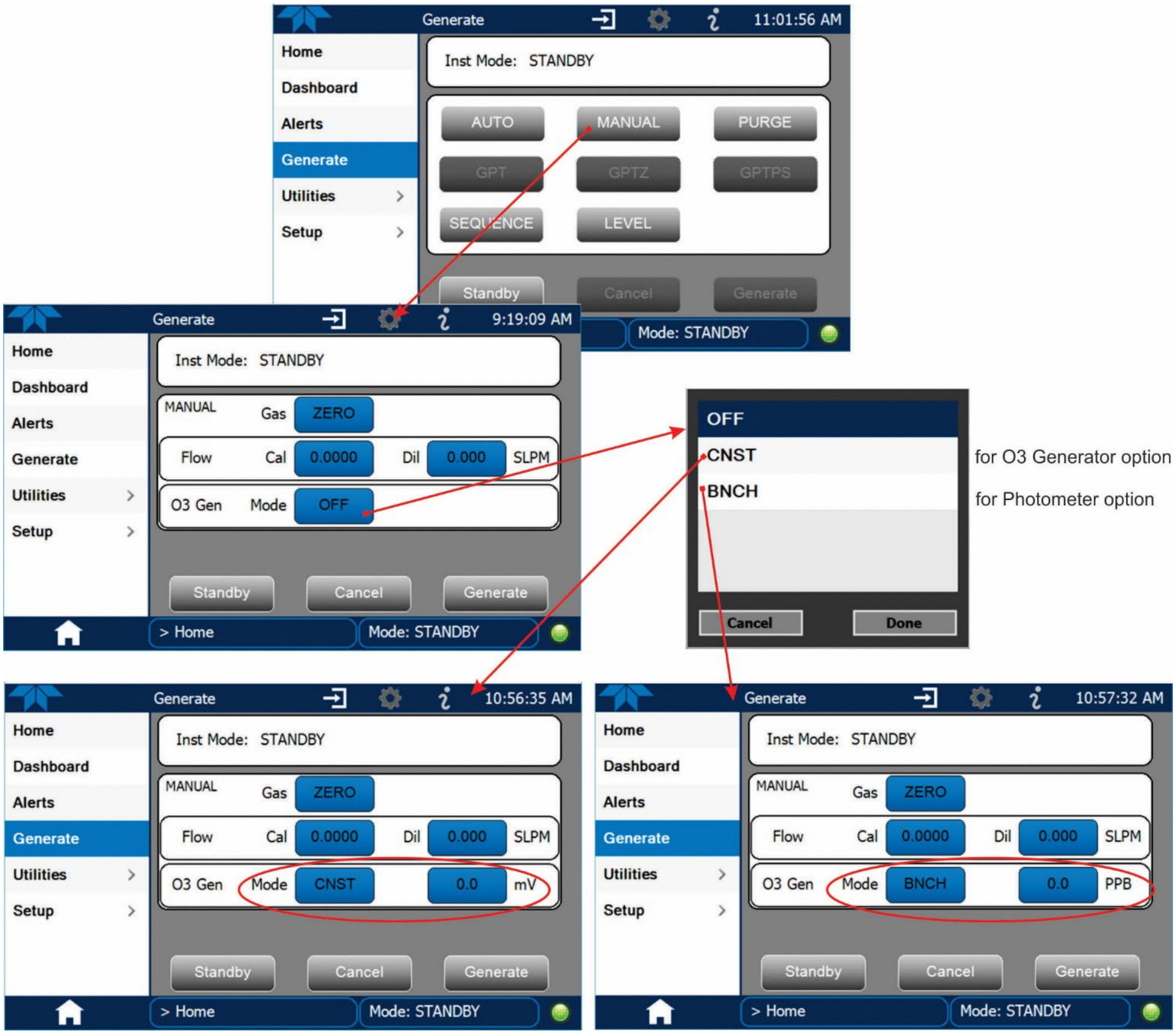


Figure 3-8. Generate>Manual with Ozone Generator

The **TOTAL FLOW** is defined by the user depending on system requirements.

Note	**The minimum total flow should equal 150% of the flow requirements of all of the instruments to which the calibrator will be supplying calibration gas.** **Example: If the calibrator is to supply calibration gas mixtures simultaneously to a system composed of three analyzers, each requiring 2 LPM, the proper Total Flow output should be set at: (2 + 2 + 2) x 1.5 = 9.000 LPM.**

3.2.2.1. DETERMINING THE SOURCE GAS FLOW RATE

To determine the required flow rate of the component source gas, use the following formula:

Equation 3-1

$$GAS_{flow} = \frac{C_f \times Totalflow}{C_i}$$

WHERE:

C_f = target concentration of diluted gas

C_i = concentration of the source gas

GAS_{flow} = source gas flow rate

EXAMPLE:

- A target concentration of 200 ppm of SO_2 is needed.
- The Concentration of the SO_2 Source is 600 ppm
- The requirement of the system are 9.000 LPM
- The required source gas flow rate would be:

GAS_{flow} = (200 ppm x 9.000 LPM) ÷ 600 ppm

GAS_{flow} = 1800.000 ppm/LPM) ÷ 600 ppm

GAS_{flow} = 3.000 LPM

3.2.2.2. DETERMINING DILUENT FLOW RATE

To determine the required flow rate of the diluent gas use the following formula:

Equation 3-2

$$DIL_{flow} = Totalflow - GAS_{flow}$$

WHERE:

GAS_{flow} = source gas flow rate (from Equation 6-1)

Totalflow = total gas flow requirements of the system

DIL_{flow} = required diluent gas flow

EXAMPLE:

- If the requirement of the system is 9.000 LPM,
- The source gas flow rate is set at 3.00 LPM.
- The required source gas flow rate would be:

DIL_{flow} = 9.0 LPM – 3.0 LPM

DIL_{flow} = 6.0 LPM

3.2.2.3. DETERMINING DILUENT FLOW RATE WITH O_3 GENERATOR OPTION INSTALLED

If the optional O_3 generator is installed and in use, Equation 6.2 will be slightly different, since the O_{3flow} is a constant value and can be configured for display in a Home page meter or in the Dashboard. A typical value for O_{3flow} is 105 cm^3/min.

Equation 3-3

$$DIL_{flow} = Totalflow - O_{3\,flow}$$

WHERE:

GAS_{flow} = source gas flow rate (from Equation 6-1)

Totalflow = total gas flow requirements of the system.

$O_{3\ flow}$ = the flow rate set for the O_3 generator; a constant value (typically about 0.105 LPM)

DIL_{flow} = required diluent gas flow

EXAMPLE:

- If the requirement of the system are 9.000 LPM,
- The source gas flow rate is set at 3.00 LPM.
- The required source gas flow rate would be:

DIL_{flow}-= 9.0 LPM – 0.105 LPM

DIL_{flow} = 8.895 LPM

Note

It is not recommended that any flow rate be set to <10% or >100% of the full scale rating of that associated mass flow controller.

For calibrators with multiple MFCs installed, their combined flow potential is available within limits: <10% of the lowest rated MFC or >100% of the combined full-scale ratings for both mass flow controllers. The calibrator automatically selects the MFC with the lowest flow rate that can accommodate the requested flow, thereby affording the most precise flow control. If no single MFC can accommodate the requested flow rate, then multiple mass flow controllers are used.

3.2.2.4. SETTING SOURCE GAS AND DILUENT FLOW RATES USING THE GENERATE > MANUAL MENU

After determining the flow values with the equations provided above, press the MANUAL button and edit the flow values as needed for the Cal and Dil fields, respectively (Figure 3-7).

3.2.3. GENERATE > PURGE: ACTIVATING THE CALIBRATOR'S PURGE FEATURE

The calibrator's PURGE feature clears the instrument's internal pneumatics of residual source gases and calibration mixtures previously generated, as well as any external pneumatic lines downstream from the calibrator.

When activated, the **PURGE** feature:

- Opens the Diluent (zero air) inlet valve allowing zero air to flow into the calibrator form its external, pressurized source;
- Adjusts the diluent air mass flow controller (MFC1) to maximum flow;
- Adjusts all of the component gas mass flow controllers installed in the calibrator to maximum flows, 10 SLPM and 100 SCCPM accordingly, to flush out the pneumatic system of the calibrator.

To activate the **PURGE** feature, press the PURGE button in the Generate page.

The **PURGE** air is vented through the VENT port of the rear panel of the instrument (see Figure 2-2).

Table 3-4. Internal Pneumatics during Purge Mode

MODE	VALVES (X = CLOSED; O = OPEN; D = DEENERGIZED; E = ENERGIZED)									MFCS			PHOT PUMP
	CYL1	CYL 2	CYL 3	CYL 4	PURGE	DILUENT	GPT	O_3 GEN	PHOT M/R	CAL1	CAL2[1]	DILUENT	
Purge	X	X	X	X	O	O	E	E	Switching	ON[3]	ON[3]	ON	ON

[1] Only present if multiple cal gas MFC option is installed.
[2] The valve associated with the cylinder containing the chosen source gas is open.
[3] In instrument with multiple MFCs the CPU chooses which MFC to use depending on the target gas flow requested.

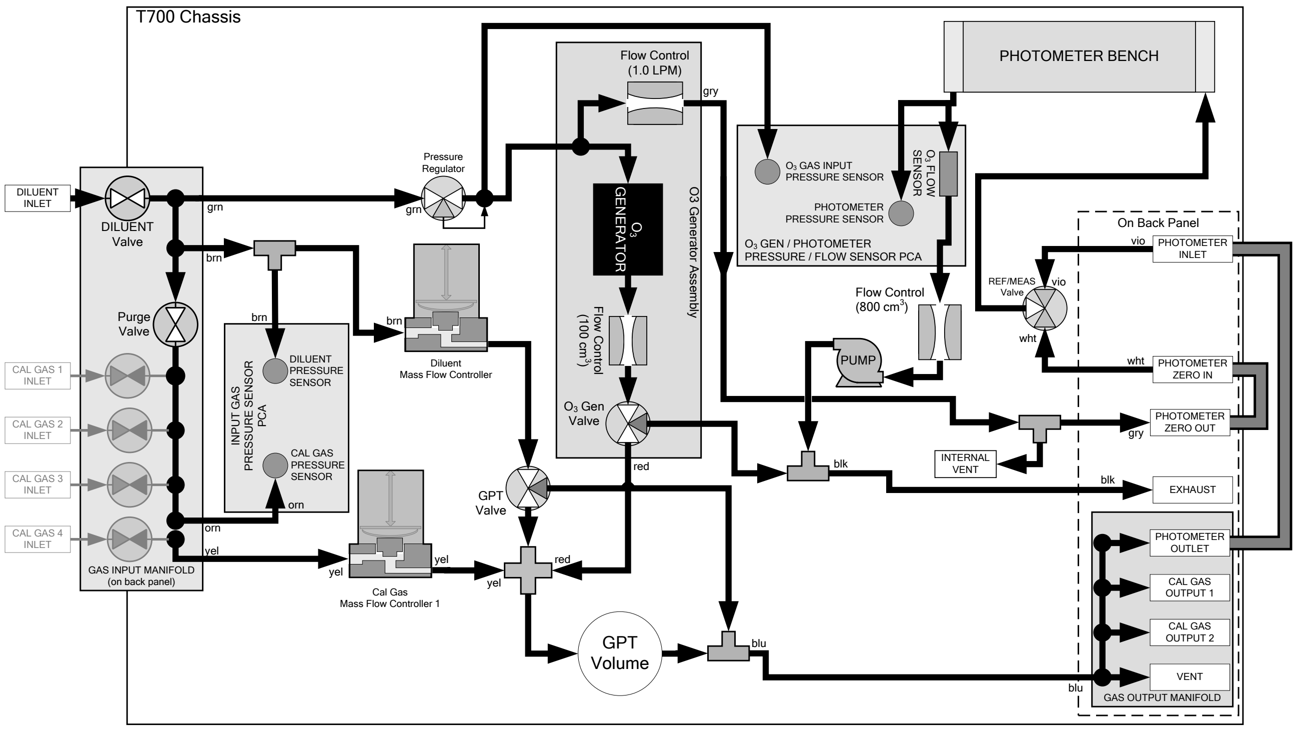


Figure 3-9. Gas Flow with O_3 Options during Purge mode

Important	IMPACT ON READINGS OR DATA
	This Purge feature does not stop automatically. Manually press the Standby button to stop the purging process.

3.2.4. GENERATE: GAS PHASE TITRATION (GPT) CALIBRATION

In Gas Phase Titration, it is important to know the following information:

- the principles of gas phase titration
- how to choose an input concentration for the NO gas
- the target concentration for the O_3
- how to determine the total flow for the GPT calibration mixtures
- the order of operation to ensure greatest accuracy: GPTZ, GPTPS, GPT

3.2.4.1. MEETING THE USEPA GUIDELINES FOR GPT CALIBRATION

The USEPA has published guidelines for the pneumatic parameters involving GPT calibrations. These guidelines are meant to ensure that the O3/NO reaction is complete, and that the risk of producing other un-wanted reactions is minimized. These guidelines are published in the U.S. 40 CFR pt. 50, appendix F. In this appendix are requirements for the Residence Time in the reaction volume as well as a Dynamic Parameter specification.

For the purposes of calculating these parameters, the volume of the GPT reaction chamber is 130 cc.

3.2.4.2. GPT THEORY

The principle of GPT is based on the rapid gas phase reaction between NO and O_3, which produces quantities of NO_2 as shown by the following equation:

Equation 4-4

$$NO + O_3 \longrightarrow NO_2 + O_2 + h\nu_{(light)}$$

It has been empirically determined that under controlled circumstances the NO-O_3 reaction is very efficient (<1% residual O_3), therefore the concentration of NO_2 resulting from the mixing of NO and O_3 can be precisely predicted and controlled as long as the following conditions are met:

- The amount of O_3 used in the mixture is known.
- The amount of NO used in the mixture is AT LEAST 10% greater than the amount of O_3 (per EPA requirements) in the mixture.
- The volume of the mixing chamber is known (130 cc, as previously stated).
- The NO and O_3 flow rates (from which the time the two gases are in the mixing chamber) are low enough to give a residence time of the reactants in the mixing chamber of >2.75 ppm min.

Given the above conditions, the amount of NO_2 being output by the calibrator will be equal (at a 1:1 ratio) to the amount of O_3 added.

Once the user has determined the appropriate flow and NO gas bottle required, performing the GPT is as simple as entering the following parameters in the GPT menu:

- desired Ozone concentration
- desired NO concentration
- desired Total Flow Rate (see recommendation in Section 3.2.4.3 below)

Since the O_3 flow rate of the calibrator's O_3 generator is a set fixed value (typically about 0.105 LPM), the calibrator will calculate the additional flow required from the zero air MFC from the user's Total Gas Flow entry in the Generate menu. The NO MFC flow rate will be determined based on the NO concentration and the total flow rate.

For multi-point (M-P) NO_2 checks, TAPI recommends keeping the NO concentration and Total Flow Rate constant and only adjusting the Ozone concentration for each of the NO_2 concentrations needed, keeping in mind the guidelines mentioned above.

3.2.4.3. DETERMINING THE TOTAL FLOW FOR GPT CALIBRATION MIXTURES

The total flow rate is defined by the user depending on system requirements.

The minimum total flow should equal 150% of the flow requirements of all of the instruments to which the calibrator will be supplying calibration gas.

EXAMPLE:

- If the calibrator is will be expected to supply calibration gas mixtures simultaneously to a system in composed of three analyzers each requiring 2 LPM, the proper Total Flow output should be set at:
- (2 + 2 + 2) x 1.5 = 9.000 LPM

Note

It is not recommended to set any flow rate to <10% or >100% of the full scale rating of that associated mass flow controller.

For calibrators with multiple MFCs installed, their combined flow potential is available within limits: <10% of the lowest rated MFC or >100% of the combined full-scale ratings for both mass flow controllers. The calibrator automatically selects the MFC with the lowest flow rate that can accommodate the requested flow, thereby affording the most precise flow control. If no single MFC can accommodate the requested flow rate, then multiple mass flow controllers are used.

Given this information, the calibrator determines the NO gas flow by the formula:

Equation 4-5

$$NO\ GAS_{flow} = \frac{C_{NO2} \times Totalflow}{C_{NO}}$$

WHERE:

C_{NO2} = target concentration for the NO_2 output

C_{NO} = concentration of the NO gas input

NO GAS_{flow} = NO source gas flow rate

And the diluent (zero air) gas flow by the formula:

Equation 4-6

$$DIL_{flow} = Totalflow - NO\ GAS_{flow} - O_{3\,flow}$$

WHERE:

GAS_{flow} = source gas flow rate (from Equation 6-1)

Totalflow = total gas flow requirements of the system.

$O_{3\ flow}$ = the flow rate set for the O_3 generator; a constant value (typically about 0.105 LPM)

DIL_{flow} = required diluent gas flow

3.2.5. GENERATE > GPTZ: PERFORMING A GAS PHASE TITRATION ZERO

The GPTZ feature is used for obtaining the baseline NO and NO_X readings for calculating the NO_X converter efficiency (CE); it simulates the flow condition of GPT without generating ozone, which provides accuracy of GPT. (These readings are referred to as $[NO]_{orig}$ and $[NO_X]_{orig}$, respectively in the EPA calibration guidelines).

During GPTZ, NO gas is generated in the same manner as a GPT calibration, except the the O_3 generator lamp is not energized, thus producing no O_3. This allows accurate measurement of the baseline NO and NO_X readings from the instrument under test.

3.2.5.1. GPTZ VS AUTO GENERATE MODES

It may appear that the GPTZ and AUTO Generation modes are performing the same function: generating NO cal gas at a specified concentration and flow rate. However, there is an important difference in the flow configuration of these two modes.

In GPTZ mode, the total flow includes flow from the (un-energized) O_3 generator. This flow is not directly measured by the calibrator. The O_3 generator flow is measured at the factory and programmed into the calibrator and assumed to be constant thereafter. Since pressure and temperature changes between the factory cal and the customer's ambient conditions cannot be accounted for, there may be small discrepancies between the actual O_3 generator flow and the assumed flow that is used in the dilution calculations that the calibrator performs. Since these small flow discrepancies are present in both the GPTZ and GPT modes, they do not affect the accuracy of the converter efficiency calculations.

For the best overall dilution accuracy, for span calibrations for instance, the AUTO mode should still be used.

3.2.5.2. CALIBRATOR GPTZ OPERATION

The following table and figure show the status of the calibrator's internal pneumatic components and internal gas flow when the instrument is in **GPTZ** generating mode.

Table 3-5. Status of Internal Pneumatics during GENERATE > GPTZ Mode

MODE	VALVES[2] (X = CLOSED; O = OPEN; D = DEENERGIZED; E = ENERGIZED)									MFCs[3]			PHOT PUMP
	CYL 1	CYL 2	CYL 3	CYL 4	PURGE	DILUENT	GPT	O_3 GEN	PHOT M/R	CAL1	CAL2[1]	DILUENT	
GPTZ	X	X	X	X	X	O	**E**	**D**	Ref Phase	ON	ON	ON	OFF

[1] Only present if multiple cal gas MFC option is installed.
[2] The valve associated with the cylinder containing NO source gas is open.
[3] In instruments with multiple MFCs the CPU chooses which MFC to use depending on the target gas flow requested.

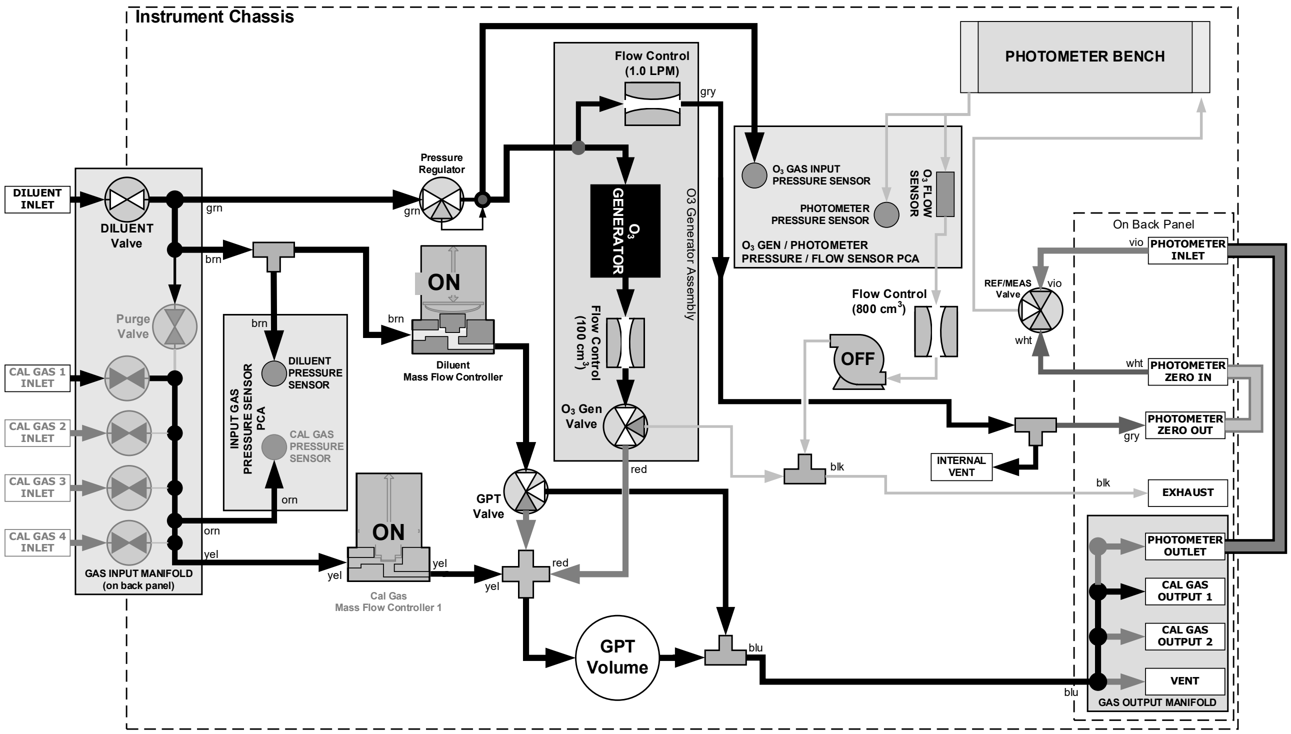


Figure 3-10. Gas Flow during GPTZ Mode

3.2.5.3. INITIATING A GPTZ

To activate the **GPTZ** feature you will need to know:

- Total Gas Flow for the mixture output
- Target O_3 concentration (equal to the target NO_2 concentration being simulated)
- The NO source gas concentration

In the Generate menu, press the GPTZ button and edit the applicable fields, then press the Generate button.

3.2.6. GENERATE > GPTPS: PERFORMING A GAS PHASE TITRATION PRE-SET

The GPT Pres-Set (GPTPS) feature is used to fine-tune the ozone generator calibration to improve the accuracy of the O_3 concentration prior to running GPT. (In the T700 this function is only available if the optional O_3 photometer is installed). GPTPS simulates a **GPT** mixing operation in order to determine the exact output of the calibrator's O_3 generator. As described in Section 3.2.4.1, all other things being equal, the concentration of the NO_2 being generated using the GPT feature will be equal to the amount of O_3 used. Therefore, the more accurately the O_3 generator performs, the more accurate the NO_2 output will be.

When operating in **GPTPS** mode, diluent gas (zero air) is substituted for the NO gas that would be mixed with the O_3 in normal GPT mode. The resulting unaffected O_3 output of the O_3 generator is shunted through the calibrator's internal photometer, which measures the ACTUAL O_3 concentration in the gas.

Once the exact O_3 concentration being output by the generator is determined, the calibrator's software adjusts the O_3 drive voltage up or down ("O3 Gen Drive" parameter can be viewed in the Dashboard and/or a Home Page Meter), so that the output of the generator matches as closely as possible the target concentration requested. This adjusted generator setting will be used during any subsequent real GPT operation that uses the same target NO_2 value.

Note

The calibrator has a learning algorithm during the O_3 generation (see Section 3.2) or Gas Phase Titration Pre-Set Mode (GPTPS) (Sections 3.2.7.2 and 3.2.5). It may take up to one hour for each new concentration/flow (point) that is entered into the instrument. Once the instrument has several points memorized in its cache, any new point that is entered will automatically be estimated within ±1% error (with photometer) and ±10% error (with O_3 generator and GPTPS).

This adjustment is only valid for the O_3 concentration used during the Pre-Set operation. GPT Presets must be re-run for each different target NO_2 value.

In order to keep the resulting concentration of O_3 consistent with the GPT mixture being simulated, the instrument's software adjusts the flow rate of the diluent gas to substitute an amount of diluent gas equal to the amount of NO gas that would normally be used.

3.2.6.1. CALIBRATOR GPTPS OPERATION

The following table and figures show the status of the calibrator's internal pneumatic components and internal gas flow when the instrument is in **GPTPS** generating modes.

Table 3-6. Status of Internal Pneumatics during GENERATE > GPTPS Mode

MODE	VALVES[2] (X = CLOSED; O = OPEN; D = DEENERGIZED; E = ENERGIZED)									MFCs[3]			PHOT PUMP
	CYL 1	CYL 2	CYL 3	CYL 4	PURGE	DILUENT	GPT	O_3 GEN	PHOT M/R	CAL1	CAL2[1]	DILUENT	
GPTPS	X	X	X	X	X	O	**E**	**E**	Switching	OFF	OFF	ON	ON

[1] Only present if multiple cal gas MFC option is installed.

[2] The valve associated with the cylinder containing NO source gas is open.

[3] In instrument with multiple MFCs the CPU chooses which MFC to use depending on the target gas flow requested.

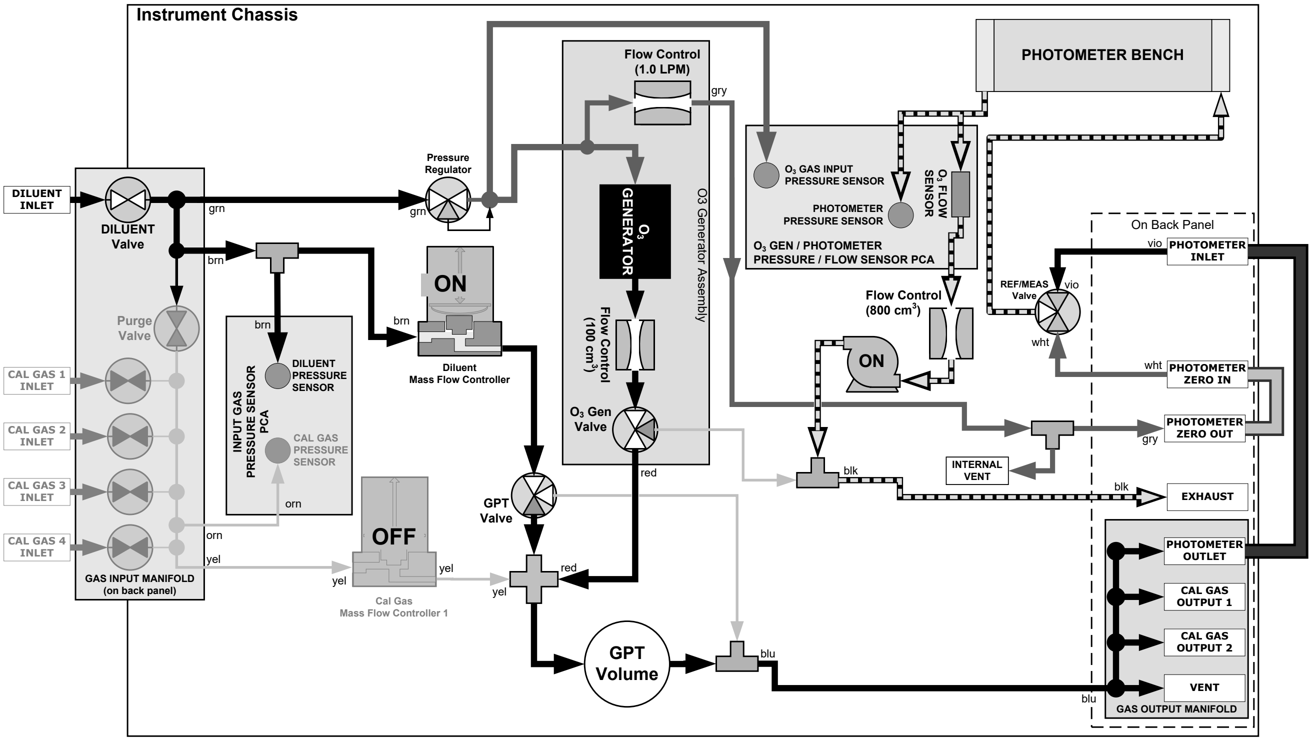


Figure 3-11. Gas Flow during GPTPS Mode

3.2.6.2. INITIATING A GPTPS

To activate the **GPTPS** feature you will need to know the values for the following parameters that will be entered for the subsequent GPT (if a multi-point GPT will be run, then a separate GPTPS should be run for each O_3 concentration point:

- The Total Gas Flow for the mixture output
- The Target O_3 concentration (equal to the target NO_2 concentration being simulated)
- The NO source gas concentration

In the Generate menu, press the GPTPS button and edit the applicable fields, then press the Generate button.

3.2.7. GENERATE > GPT: PERFORMING A GAS PHASE TITRATION

The GPT mode is used for performing the actual NO + O_3 titration used to produce the NO_2 test gas.

3.2.7.1. CALIBRATOR GPT OPERATION

The following table and figures show the status of the calibrator's internal pneumatic components and internal gas flow when the instrument is in **GPT** generating modes.

Table 3-7. Status of Internal Pneumatics during GENERATE > GPT Mode

MODE	VALVES (X = Closed; O = Open; D = Deenergized; E = Energized)									MFCs			PHOT PUMP
	CYL 1	CYL 2	CYL 3	CYL 4	PURGE	DILUENT	GPT	O_3 GEN	PHOT M/R	CAL1	CAL2[1]	DILUENT	
GPT	O[2]	O[2]	O[2]	O[2]	X	O	E	E	Reference Phase	ON[3]	ON[3]	ON	OFF

[1] Only present if multiple cal gas MFC option is installed.
[2] The valve associated with the cylinder containing NO source gas is open.
[3] In instrument with multiple MFCs the CPU chooses which MFC to use depending on the target gas flow requested.

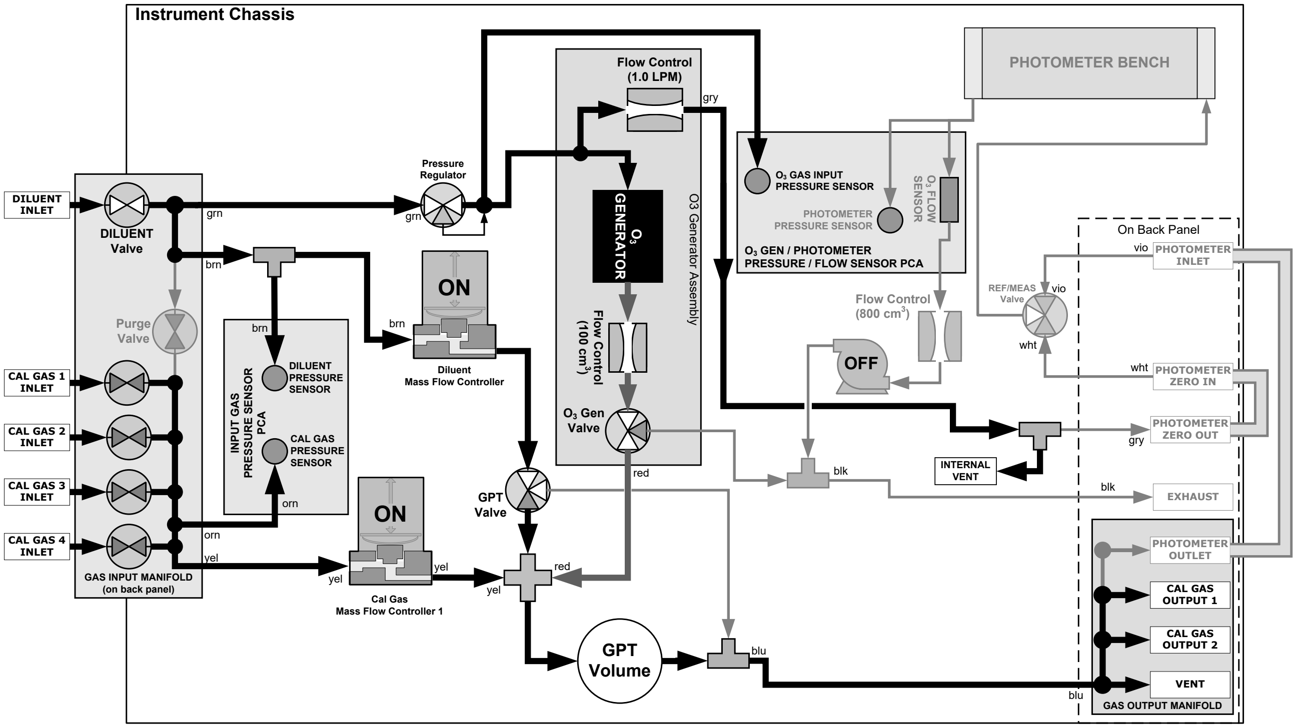


Figure 3-12. Gas Flow during GPT Mode

3.2.7.2. INITIATING A GPT CALIBRATION GAS GENERATION

Note **It is highly recommended that a GPTZ (Section 3.2.5) be performed and followed by a GPTPS (Section 3.2.6) prior to initiating any GPT gas generation.**

To initiate GPT gas generation you will need to know:

- Total Flow for the mixture output
- Target O_3 concentration (equal to the target NO_2 concentration to be generated)
- NO source gas concentration

The following requirements should be used for determining total flow:

- Instrument's Flow Demand

The number and flow rate requirements of the instruments sampling from the output of the calibrator. The flow demand of all instruments connected to the test manifold, even those not directly involved in the testing, must be taken into account. The minimum output flow rate should be calculated as the sum of all instrument demand flows plus 10% minimum excess.

- Target O_3 Concentration

The output flow must be chosen to keep the O_3 generator output above the minimum specification of 20 PPB * LPM. The minimum flow rate (FT) can then be calculated using the following equation:

$$F_T \geq \frac{20\,ppb \bullet LPM}{O_3 Conc}$$

- NO Flow Requirements

To achieve a reasonable response time during the GPT and to satisfy the EPA requirement(1) (2) that the residence time in the GPT reaction chamber be less than two minutes, the NO flow rate should be **greater than 45 cc/min**. Therefore, larger dilution flows may be required to achieve low concentrations of NO. An appropriate NO gas bottle concentration must be used in order to achieve this flow rate.

In the Generate menu, press the GPT button and edit the applicable fields, then press the Generate button.

3.2.8. GENERATE > SEQUENCE

Sequences, a set of calibration steps for serial execution, are configured in the Setup>Sequences menu (Section 2.6.7). To execute a Sequence, navigate to the Generate menu (Figure 3-5), press the SEQUENCE button, and select the desired Sequence, then press the Generate button.

3.2.9. GENERATE > LEVEL

Levels, operational functions for LEADS (Section 2.6.8.1), are configured in the Setup>Levels menu (Section 2.6.8). To execute a Level, navigate to the Generate menu (Figure 3-5), press the LEVEL button, and select the desired Level, then press the Generate button.

4. COMMUNICATIONS AND REMOTE OPERATION

The instrument rear panel connections include an Ethernet port, a USB port (option) and two serial communications ports (labeled RS232, which is the COM1 port, and COM2) located on the rear panel (refer to Figure 2-2). These ports allow the ability to communicate with, issue commands to, and receive data from the analyzer through an external computer system or terminal.

This Section provides pertinent information regarding communication equipment, the communications ports, and communications protocol. Data acquisition is set up through the Datalogger (Section 2.6).

4.1. DATA TERMINAL/COMMUNICATION EQUIPMENT (DTE DCE)

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

To allow the analyzer to be used with terminals (DTE), modems (DCE) and computers (which can be either), a switch mounted below the serial ports on the rear panel, labeled **DCE DTE**, allows the user to set the RS-232 configuration for one of these two data devices. This switch exchanges the Receive and Transmit lines on RS-232 emulating a cross-over or null-modem cable. The switch has no effect on COM2.

4.2. MODES, BAUD RATE AND SERIAL COMMUNICATION

Referring to Table 2-15, use the SETUP>COMM menu to configure COM1 (labeled **RS232** on instrument rear panel) and/or COM2 (labeled **COM2** on instrument rear panel) for communication modes, baud rate and serial communications. If using a USB option communication connection, setup requires the instrument's baud rate to match your personal computer baud rate.

4.2.1. SERIAL COMMUNICATION: RS-232

The RS232 and COM2 communications (COMM) ports operate on the RS-232 protocol (default configuration). Configurations for these two COM ports (Section 2.6.11.1) are:

- **RS232** port can also be configured to operate in single or RS-232 Multidrop mode (Option 62); refer to Section .
- **COM2** port can be left in its default configuration for standard RS-232 operation including multidrop, or it can be reconfigured for half-duplex RS-485 operation (please contact the factory for this configuration).

Note **When the rear panel COM2 port is in use, except for multidrop communication, the rear panel USB port cannot be used. (Alternatively, when the USB port is enabled, COM2 port cannot be used except for multidrop).**

A code-activated switch (CAS), can also be used on either port to connect typically between 2 and 16 send/receive instruments (host computer(s) printers, data loggers, analyzers, monitors, calibrators, etc.) into one communications hub. Contact Teledyne API Sales (front cover, this manual) for more information on CAS systems.

4.2.2. SERIAL COMMUNICATION: RS-485 (OPTION)

The COM2 port of the instrument's rear panel is set up for RS-232 communication but can be reconfigured for RS-485 communication. Contact Technical Support for reconfiguration unless this option was elected at the time of purchase, then the rear panel was preconfigured at the factory.

4.3. 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 NumaView™ Remote, terminal emulators or other programs.

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

Table 4-1. Ethernet Status Indicators

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

4.4. MODBUS COMMUNICATIONS PROTOCOL

The following set of instructions assumes that the user is familiar with MODBUS communications, and provides minimal information to get started. For additional instruction, please refer to the Teledyne API MODBUS manual, PN 06276. Also refer to www.modbus.org for MODBUS communication protocols.

Minimum Requirements:

- instrument firmware with MODBUS capabilities installed
- MODBUS-compatible software (TAPI uses MODBUS Poll for testing; see www.modbustools.com)
- personal computer
- Communications cable (Ethernet or USB or RS232).
- Possibly a null modem adapter or cable.

4.4.1.1. MODBUS COM PORT CONFIGURATION

MODBUS communications can be configured for transmission over Ethernet or serial COM port through the Setup>Comm menu. Make the appropriate cable connections (Ethernet or COM port) between the instrument and a PC.

Ethernet: MODBUS is available on TCP port 502. By default, port 502 is assigned to the instrument's TCP Port 2. In the Setup>Comm> TCP Port menu, check to see that it is set to "502" (Figure 4-1).

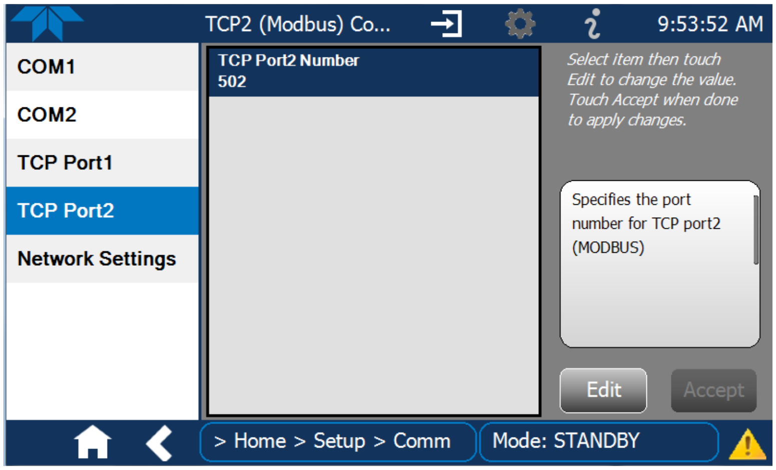


Figure 4-1. MODBUS via Ethernet

Serial COM: Both COM1 (labeled "RS232" on the instrument's rear panel) and COM2 are configurable for RS-232 or RS-485 communication with either MODBUS RTU or MODBUS ASCII transmission modes. In the Setup>Comm COM1[COM2] menu, edit the Protocol parameter to select a MODBUS transmission mode; edit Baud Rate, Parity, Data Bits, etc., if necessary (see descriptions in Table 2-15).

Important	When using MODBUS RTU, ensure that the COM1[COM2] Handshaking Mode is set to either Hardware or OFF. Do NOT set it to Software.

Press the Accept button to apply the settings. (Figure 4-2 shows an example for MODBUS RTU).

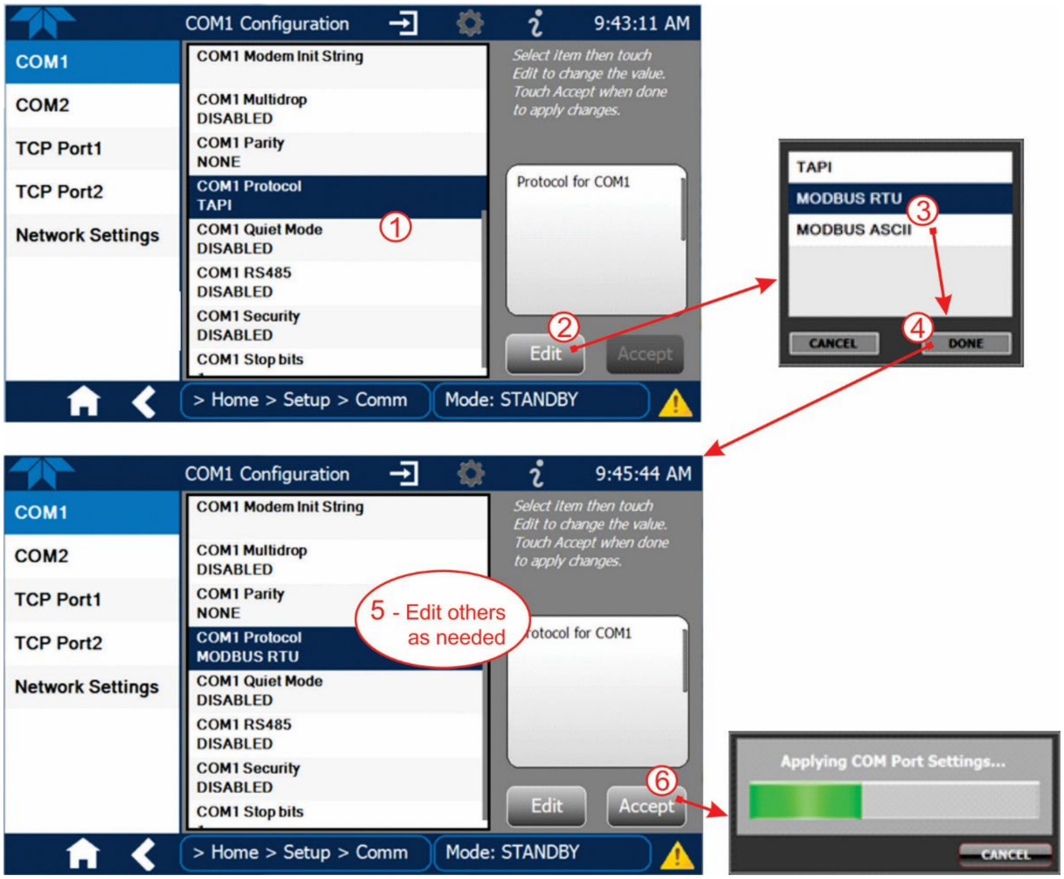


Figure 4-2. MODBUS via Serial Communication (example)

Important	When more than one analyzer is connected to the network, create a unique identification number for each in the Setup>Vars>Instrument ID menu.

Next, for the settings to take effect, power off the analyzer, wait 5 seconds, and power it on again.

5. CALIBRATION AND VERIFICATION

Basic electronic calibration of the Dynamic Dilution Calibrator is performed at the factory. Normally there is no need to perform this factory calibration in the field; however, the performance of several of the instrument's key subsystems should be verified periodically and adjusted if necessary. These subsystems are:

- Mass Flow Controllers: The accuracy of the mass flow controller outputs is intrinsic to achieving the correct calibration mixture concentrations; therefore, the accuracy of their output should be checked and if necessary adjusted every 6 months (see Section 5.1).
- O_3 Photometer: If your calibrator is equipped with the optional O_3 photometer, its performance should be periodically verified against and external transfer standard (see Section 5.2).
- O_3 Generator: If your calibrator is equipped with the optional O_3 generator, it should be periodically calibrated (see Section 5.3).

5.1. VERIFYING AND CALIBRATING THE MFCS

View the parameters for each MFC under the Utilities>Diagnostics menu.

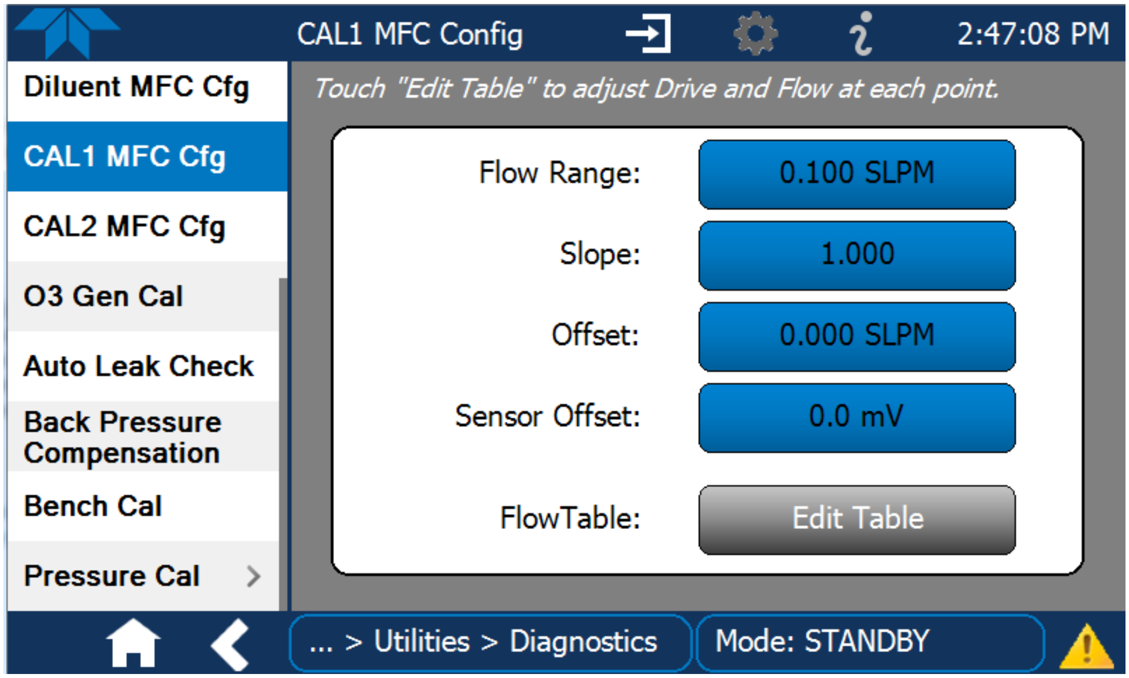


Figure 5-1. MFC Performance Statistics

The Flow Table for each MFC sets its output at each of 20 equally spaced control points along its entire performance range. In the Utilities>Diagnostics menu view the FlowTable field for each MFC by clicking the Edit Table button. For each calibration point, the following is displayed:

- The drive voltage in 20 equal, incremental steps from 0 mVDC to 5000 mVDC;
- The expected flow rate corresponding to each drive voltage point (each equal to1/20th of the full scale for the selected mass flow controller).

This table can also be used to calibrate the output of the MFCs by adjusting either the control voltage of a point or its associated flow output value (see Section 5.1.2).

Table 5-1. Examples of MFC Calibration Points

CAL POINT	DRIVE VOLTAGE	MFC FULL SCALE			
		1.0 LPM	3.0 LPM	5.0 LPM	10.0 LPM
		MFC TARGET OUTPUT			
0	000 mV	0.000	0.000	0.000	0.000
1	250 mV	0.050	0.150	0.250	0.500
2	500 mV	0.100	0.300	0.500	1.000
3	750 mV	0.150	0.450	0.750	1.500
4	1000 mV	0.200	0.600	1.000	2.000
5	1250 mV	0.250	0.750	1.250	2.500
6	1500 mV	0.300	0.900	1.500	3.000
7	1750 mV	0.350	1.050	1.750	3.500
8	2000 mV	0.400	1.200	2.000	4.000
9	2250 mV	0.450	1.350	2.250	4.500
10	2500 mV	0.500	1.500	2.500	5.000
11	2750 mV	0.550	1.650	2.750	5.500
12	3000 mV	0.600	1.800	3.000	6.000
13	3250 mV	0.650	1.950	3.250	6.500
14	3500 mV	0.700	2.100	3.500	7.000
15	3750 mV	0.750	2.250	3.750	7.500
16	4000 mV	0.800	2.400	4.000	8.000
17	4250 mV	0.850	2.550	4.250	8.500
18	4500 mV	0.900	2.700	4.500	9.000
19	4750 mV	0.950	2.850	4.750	9.500
20	5000 mV	1.000	3.000	5.000	10.000

5.1.1. SETUP FOR VERIFYING AND CALIBRATING THE MFCS

Note	**A separate flow meter is required for the procedure.**

1. Turn off the calibrator.
2. Open the calibrator's front panel for easiest access to the MFC output ports.
3. Attach the flow meter directly to the output port of the MFC to be checked/tested.

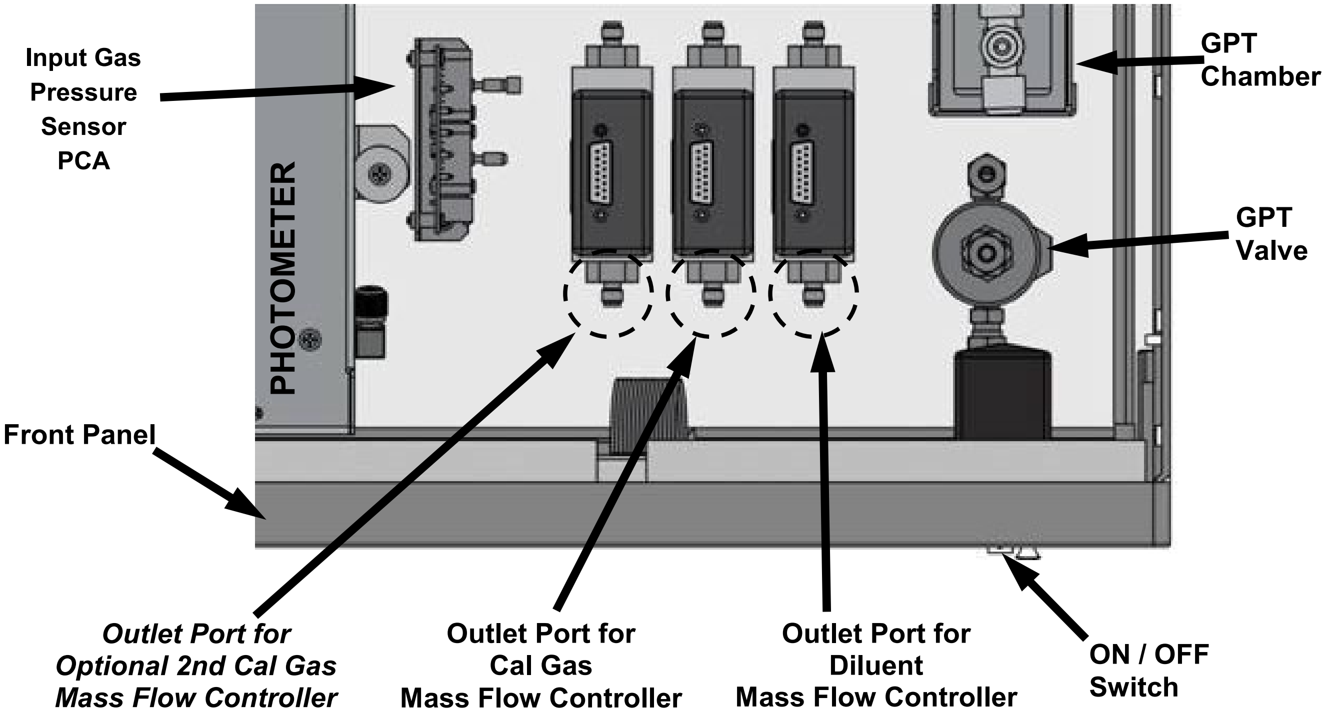


Figure 5-2. Location of MFC Outlet Ports

4. Turn ON power to the calibrator.
5. Ensure the calibrator is in Standby mode (change in Generate page if needed).

5.1.2. VERIFYING AND CALIBRATING THE MFCS

Once the external flow meter is connected to the output of the MFC being verified/calibrated, perform the following steps (refer to Figure 5-3):

1. In the Diagnostics menu select the MFC to be tested and press the Edit Table button in the Flow Table field.
2. Check the Enable Drive box to start the flow.
3. Scroll to each calibration point in the table and check that the external flow meter is reading within 1% of the value in the flow table (± flow meter accuracy):
   a. If it is, scroll to the next calibration point in the flow table and repeat.
   b. If not, press the Edit Flow button and adjust the flow value to match that of the external flow meter
4. If any flow values were adjusted in Step 3, press the Apply button. (If changes were made without pressing the Apply button, a prompt will appear when the Done button is pressed, asking whether to save the changes).
5. Press the Done button when adjustments are completed; this will stop the flow and return to the Diagnostics menu.

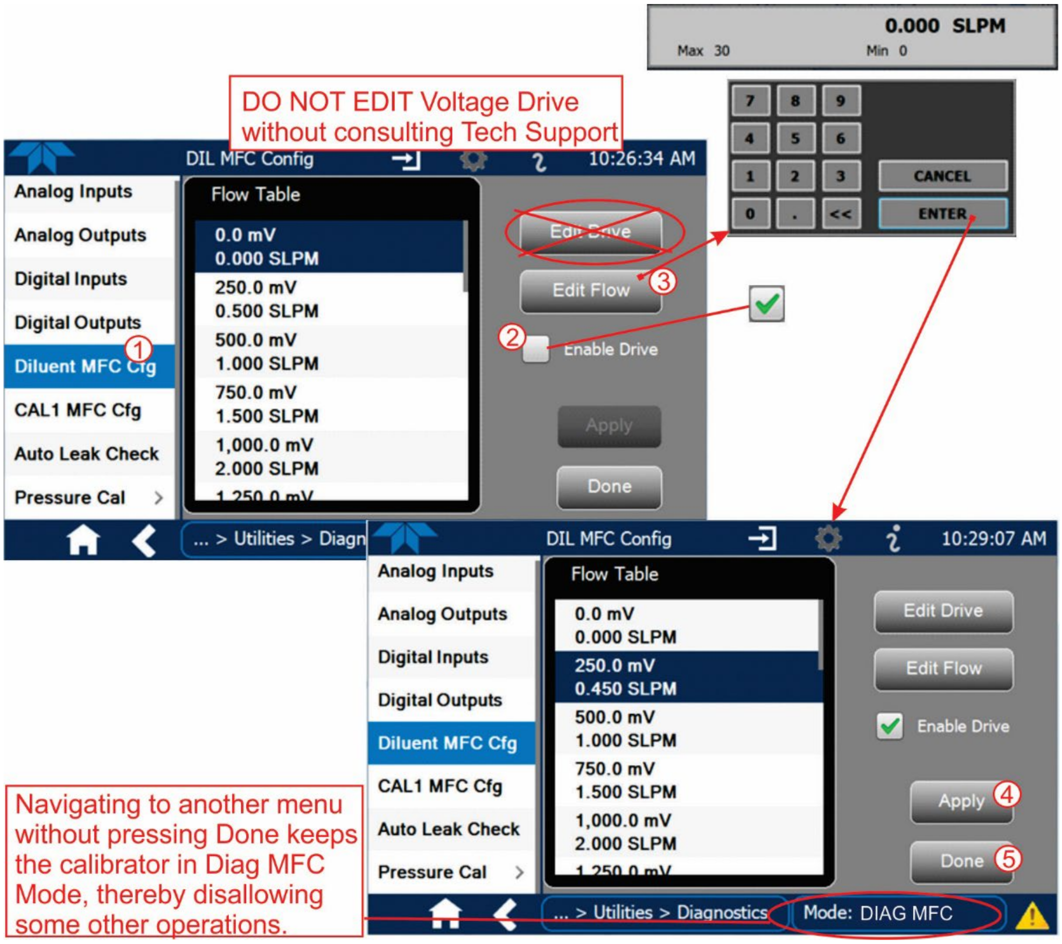


Figure 5-3. MFC Calibration

5.2. VERIFYING AND CALIBRATING THE O_3 PHOTOMETER (BENCH) OPTION

For calibrators equipped with the O_3 photometer option (also called sensor or bench), the accuracy of calibration mixtures involving O_3 produced by the calibrator depends entirely on the accuracy of the photometer; therefore, it is very important to verify its accuracy and calibrate if necessary. Figure 5-4 illustrates the setup for performance verification, and Section 5.2.2 describes the steps to run the verification. If calibration is required, Sections 5.2.3 and 5.2.4 provide instructions.

5.2.1. SETUP FOR VERIFYING O_3 PHOTOMETER (OPTION) PERFORMANCE

Note **This operation requires an external reference photometer.**

Set up the calibrator and reference photometer as illustrated in Figure 5-4.

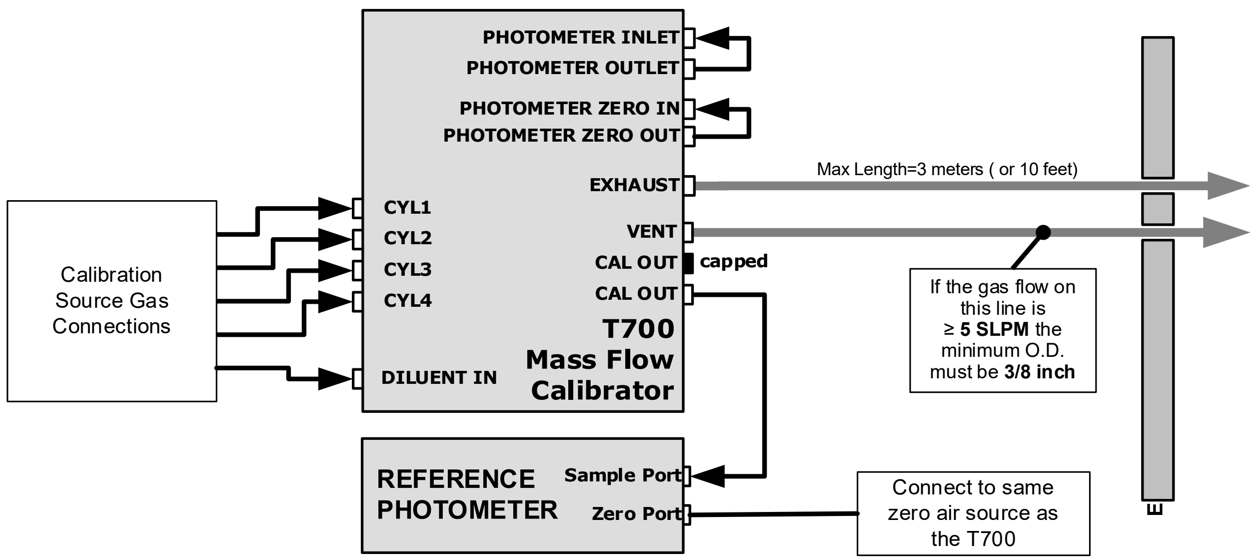


Figure 5-4. Set up for Verifying Optional O_3 Photometer Performance

5.2.2. VERIFYING O_3 PHOTOMETER (OPTION) PERFORMANCE

To verify the performance of the optional internal photometer, place the calibrator in Standby mode (in Generate menu), and perform the following steps (refer to Figure 5-5):

1. In the Generate menu press the AUTO button.
2. In the pop-up window press the button in the Gas field.
3. Change the Gas to O3, and set the target concentration, units of measure, and total flow as desired.
4. Press the Generate button, and see the target settings in the upper portion of the display.
5. Go to Home page and wait about 10 minutes or more until the reading under “Actual” stabilizes before comparing that value to the reading of the reference photometer to ensure they are within 1% of each other (If not, calibrate per Sections 5.2.3 and 5.2.4).

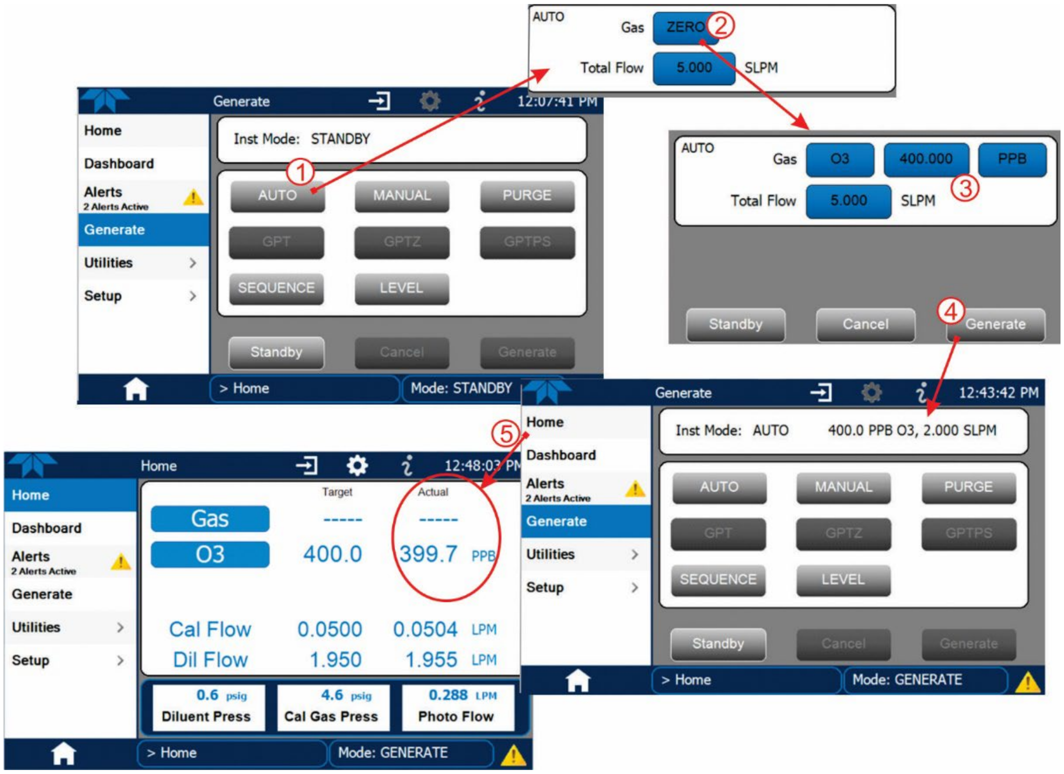


Figure 5-5. O_3 Photometer Performance Verification

5.2.3. Setup for Calibrating the O_3 Photometer (Bench) Option

Note	This procedure requires external sources for zero air and O_3 as an external reference photometer.

Calibrating the optional internal photometer requires a different set up than that used during the normal operation of the calibrator. There are two ways to make the connections between these instruments and the calibrator: either with direct connections (Section 5.2.3.1) or with calibration manifolds (Section 5.2.3.2).

5.2.3.1. SETUP USING DIRECT CONNECTIONS

Create the setup as illustrated in Figure 5-6, which shows the external Zero air and O_3 sources as well as the reference photometer connected directly to the fixtures on the calibrator's rear panel.

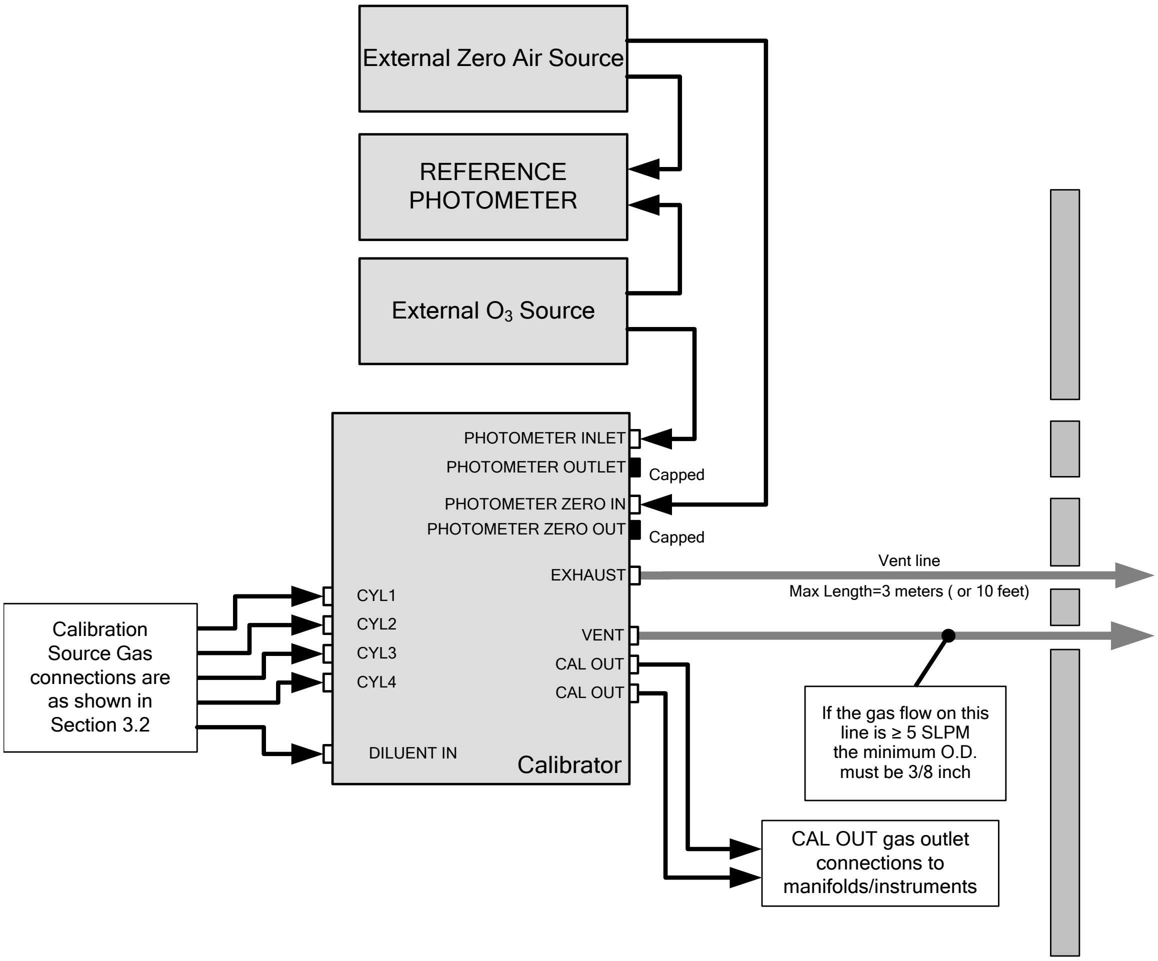


Figure 5-6. External Photometer Validation Setup – Direct Connections

Note	A minimum of 1.1 LPM is required for the external zero air source.

5.2.3.2. SETUP USING A CALIBRATION MANIFOLD

Create the setup as illustrated in Figure 5-7, which shows the external zero air and O_3 sources as well as the reference photometer connected to the calibrator via calibration manifolds for both Zero air and O_3.

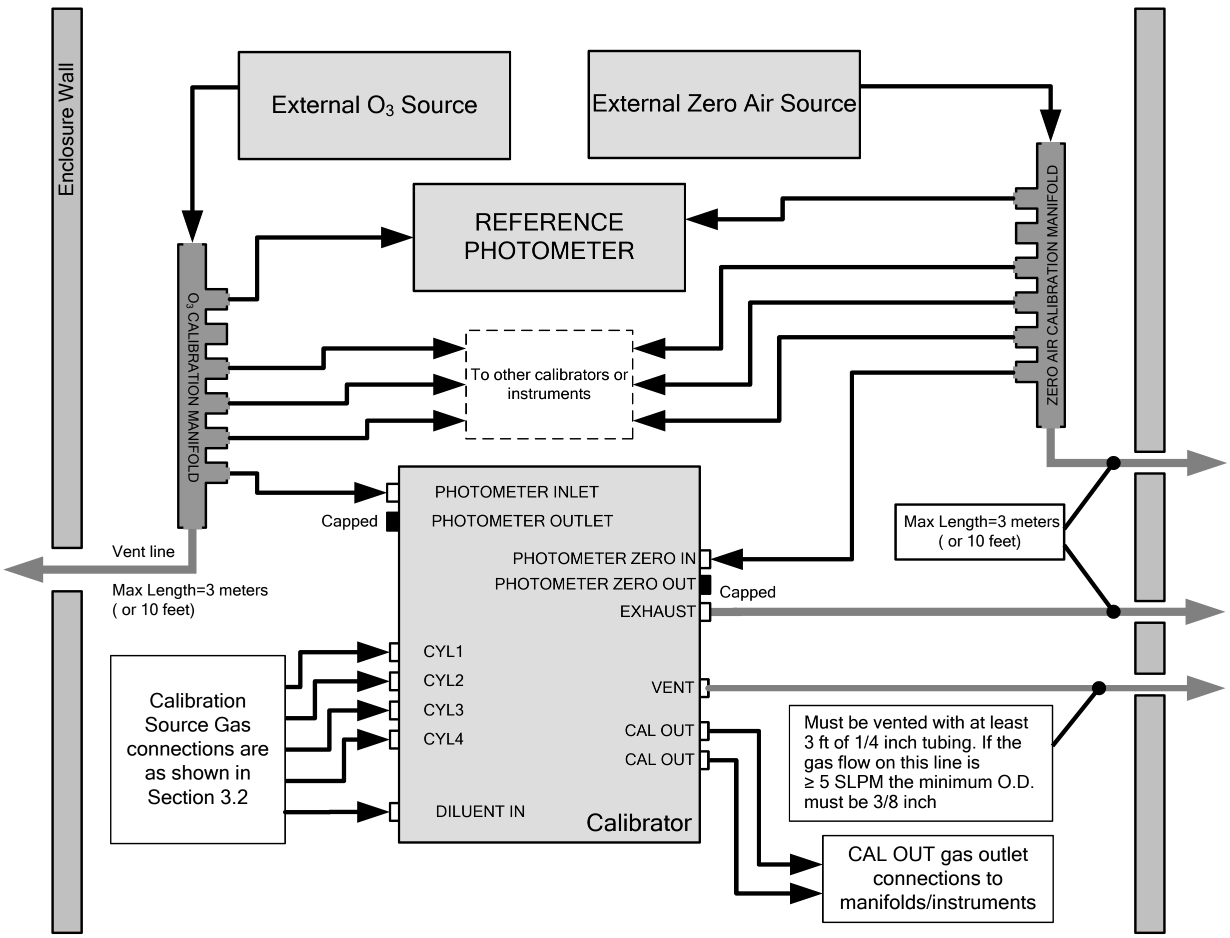


Figure 5-7. External Photometer Validation Setup with Calibration Manifolds

Note **The manifolds as shown in the above illustration are oriented to simplify the drawing. The actual orientation in your setup is with the ports facing upward. All unused ports should be capped. A minimum of 1.1 LPM is required for the external zero air source.**

5.2.3.3. CALIBRATION MANIFOLD EXHAUST/VENT LINE REQUIREMENTS

The manifold's excess gas should be vented to a suitable vent outside of the room. The internal diameter of this vent should be large enough to avoid any appreciable pressure drop, and it must be located sufficiently downstream of the output ports to ensure that no ambient air enters the manifold due to eddy currents or back diffusion.

5.2.4. PERFORMING O_3 PHOTOMETER (OPTION) CALIBRATIONS

To calibrate the photometer, first set the Vars>O3 Gen Mode to BNCH (bench):

1. Navigate to the Utilities>Diagnostics menu.
2. Select the Bench Cal function.

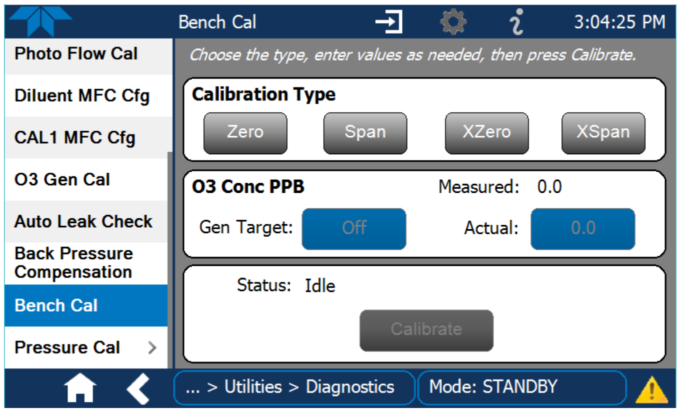


Figure 5-8. Bench Cal Page

3. To calibrate the offset for Zero:
   - for an internal O_3 Generator press the Zero button.
   - for an external O_3 Generator press the XZero button.
4. Allow Zero air to enter the PHOTO ZERO IN port of the calibrator's rear panel.
5. Press the Calibrate button. (Pressing "Yes" in the Confirm Calibration window changes the Offset and Flow values for the O_3 measurement, where "No" aborts the calibration).
6. To calibrate the slope for Span:
   - for an internal O_3 Generator press the Span button and input the Gen Target (desired) value and the Actual value from the "Measured" value that appears (after ~2 minutes) in that field.
   - for an external O_3 Generator press the XSpan button and input the Actual value from the external reference photometer's reading.
7. Allow calibration gas to enter the PHOTO IN port of the calibrator's rear panel.
8. Press the Calibrate button. (Pressing "Yes" in the Confirm Calibration window changes the slope value for the O_3 measurement, where "No" aborts the calibration).

5.2.5. O_3 PHOTOMETER GAS FLOW CALIBRATION

Note **A separate flow meter is required for the procedure.**

To calibrate the flow of gas through the calibrator's optional photometer bench.

1. Turn OFF power to the calibrator.
2. Attach the flow meter directly to the EXHAUST port of the calibrator.
3. Turn ON power to the calibrator.
4. In the Utilities>Diagnostics menu press the button in the Actual Flow field to input the external flow meter's reading.
5. Press the Calibrate button.

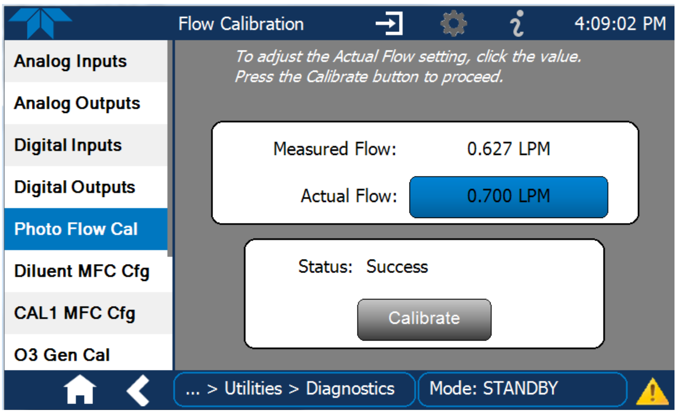


Figure 5-9. Photometer Flow Calibration Screen

5.2.6. O_3 PHOTOMETER BACK PRESSURE COMPENSATION CALIBRATION

Any time there is a pneumatic configuration change (whether locally to the instrument or to the sampling system) or a gas pressure calibration, there is risk of impacting the internal measure/reference pressure. To compensate for this, a back pressure compensation calibration should be performed. To do this, first place the calibrator in Standby Mode (see Generate menu), then navigate to the Utilities>Diagnostics>Back Pressure Compensation menu and press the Calibrate button; the operation will take a few minutes.

Another occasion to run a Back Pressure Compensation is if there is a fluctuating difference of more than .2 in Hg in the Photo Pressure parameter while ozone is being generated. This would be where the Meas/Ref valve is cycling (about six seconds per full cycle), and the Photo Pressure reading changes by more than .2 as the valve switches approximately every three seconds.

5.3. VERIFYING AND CALIBRATING THE O_3 GENERATOR OPTION

5.3.1. SETUP FOR VERIFICATION AND CALIBRATION THE O_3 GENERATOR

Note **An external reference photometer is required for the procedure.**

Figure 5-10 shows the reference photometer connected directly to the fixtures on the rear panel.

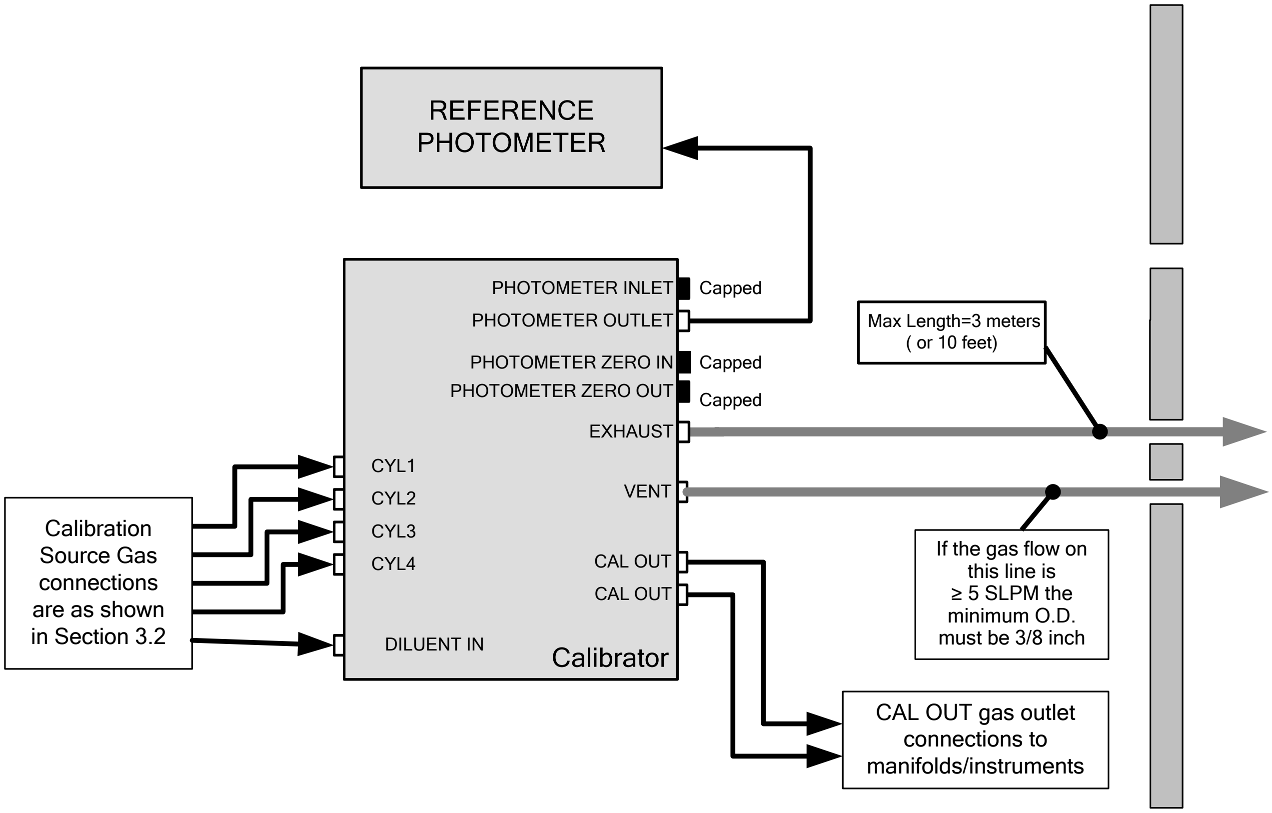


Figure 5-10. O_3 Generator Calibration Setup – Direct Connections

5.3.2. VERIFYING O_3 GENERATOR PERFORMANCE WITH EXTERNAL PHOTOMETER

After setting up as shown in Figure 8-4 (including the external reference photometer), navigate to the Generate page.

1. Ensure that the calibrator is in Standby mode (press the Standby button in the Generate menu).
2. Press the Auto button.
3. Press the Gas button and select O_3.

4. Press the concentration button and/or the units buttons to adjust their values as needed.
5. Press the Total Flow button to adjust the value for the target flow.
6. Press the Generate button, and then the AUTO button.

Note **The readings recorded from the AUTO generate function and the reference photometer should be within 1% of each other.**

5.3.3. O_3 Generator Option with Photometer Calibration Procedure

The calibrator's software includes a routine for automatically calibrating the O_3 generator.

Note **This procedure requires that the calibrator have an optional photometer installed.**

To run the automatic O_3 generator calibration program, navigate to Utilities>Diagnostics and press O3 Gen Cal.

5.4. VERIFYING AND CALIBRATING THE GAS PRESSURE SENSORS

Note **The procedures described in this Section require a separate pressure meter/monitor.**

The Dynamic Dilution Calibrator has several sensors that monitor the pressure of the gases flowing through the instrument. The data collected by these sensors is used to compensate the final concentration calculations for changes in atmospheric pressure and is stored in the CPU's memory as various test functions:

Table 5-2. Calibrator Pressure Sensor Calibration Setup

SENSOR	ASSOCIATED DASHBOARD TAG	UNITS	PRESSURE MONITOR MEASUREMENT POINT
Diluent Pressure Sensor	Diluent Press	PSIG	Insert monitor just before the inlet port of the diluent MFC
Cal Gas Pressure Sensor	Cal Gas Press	PSIG	Insert monitor just before the inlet port of the cal gas MFC
O_3 Regulator Pressure Sensor (Optional O_3 Generator)	Reg pressure	PSIG	Insert monitor in line between the regulator and the O_3 gas pressure sensor located on the O_3 generator / photometer pressure / flow sensor PCA
Sample Gas Pressure Sensor (Optional O_3 Photometer)	Photo Press	IN-HG-A	Use monitor to measure ambient atmospheric pressure at the calibrator's location.

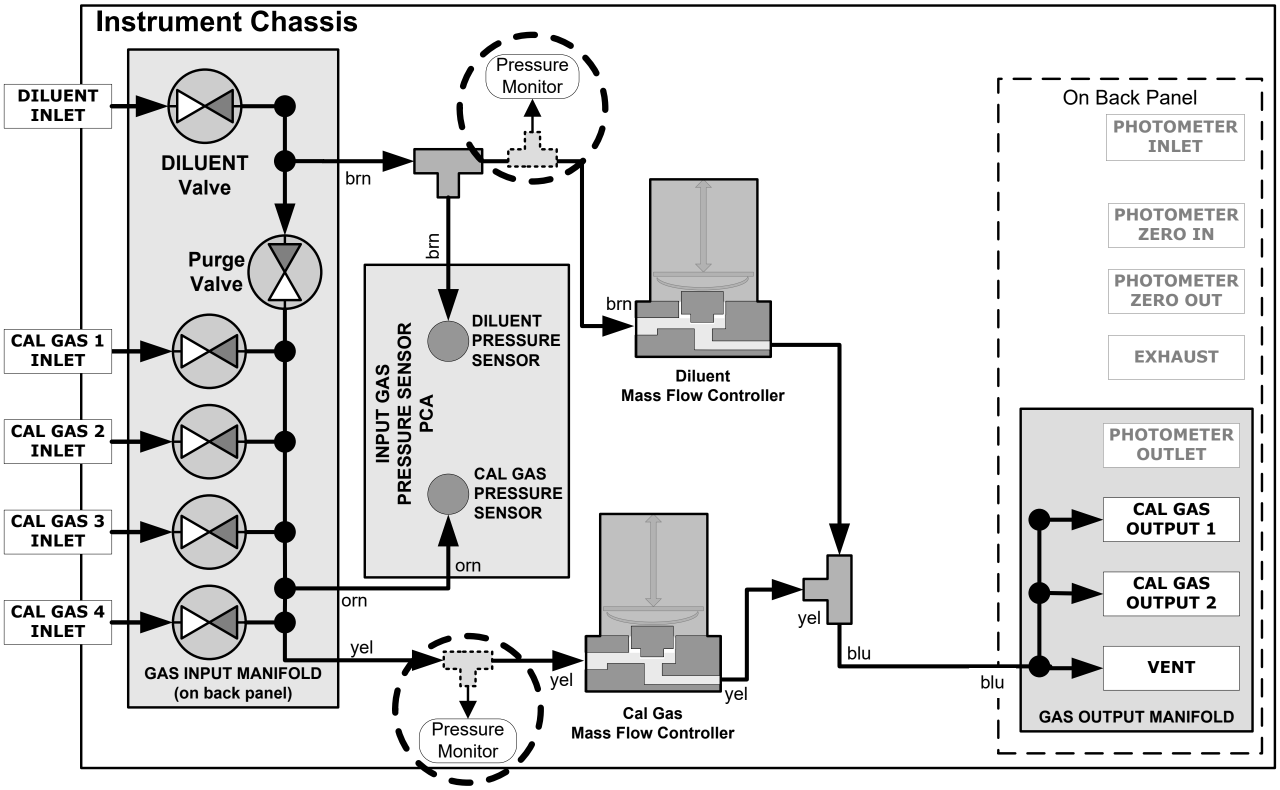


Figure 5-11. Pressure Monitor Points in Basic Unit

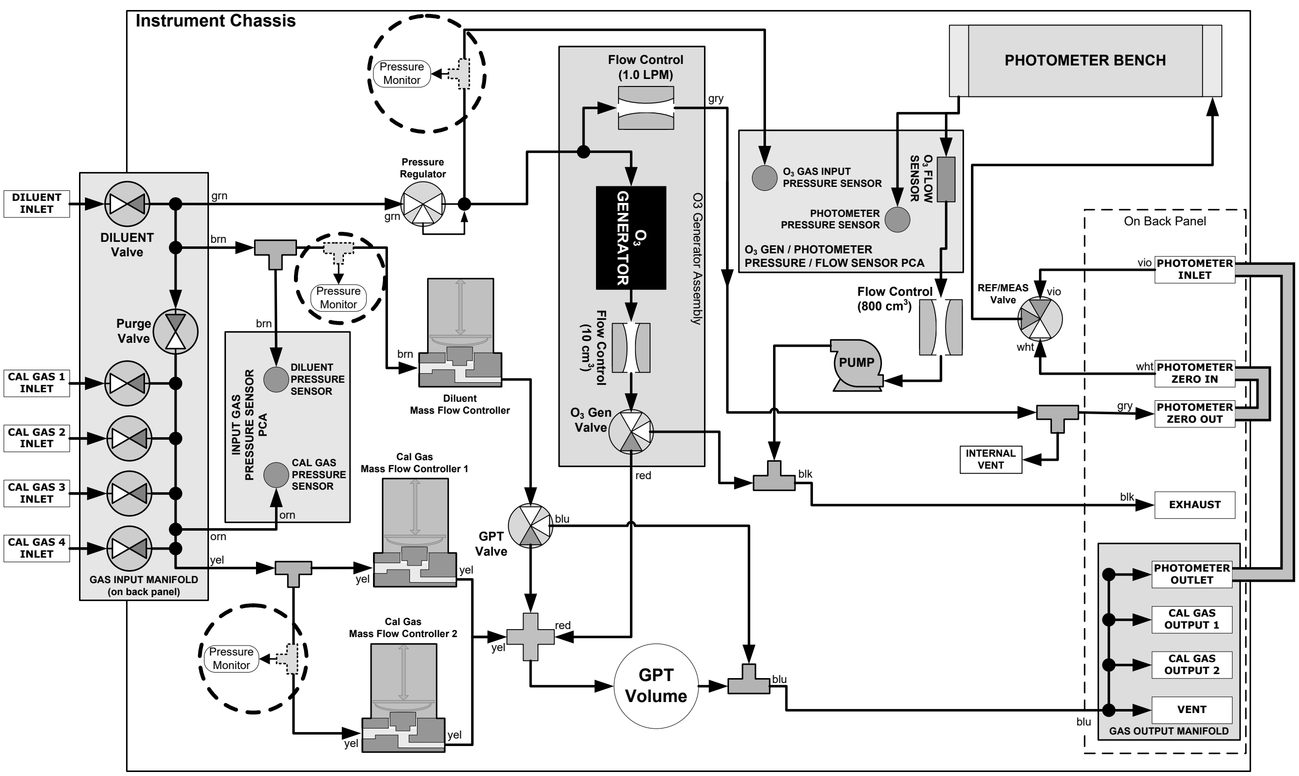


Figure 5-12. Pressure Monitor Points with O_3 Options and Multiple Cal MFCs Installed

5.4.1.1. CALIBRATING DILUENT, CAL GAS, OR OPT O_3 GENERATOR PRESSURE SENSORS

1. Turn off the calibrator and open the top cover.
2. For the sensor being calibrated, insert a “T” pneumatic connector and pressure monitor at the location described in Table 5-2 and shown in Figure 5-11 and Figure 5-12.
3. Turn on the calibrator, and in the Diagnostics>Pressure Cal menu (Figure 5-13) highlight the pressure sensor to be calibrated.
4. In the Actual Pressure field (press to bring up keypad) input the value obtained from pressure meter.
5. (Enable the valve if interface shows an Enable button).
6. Press the Calibrate button, and then confirm that the calibration is to be carried out.

   The Status field should read “Success”.

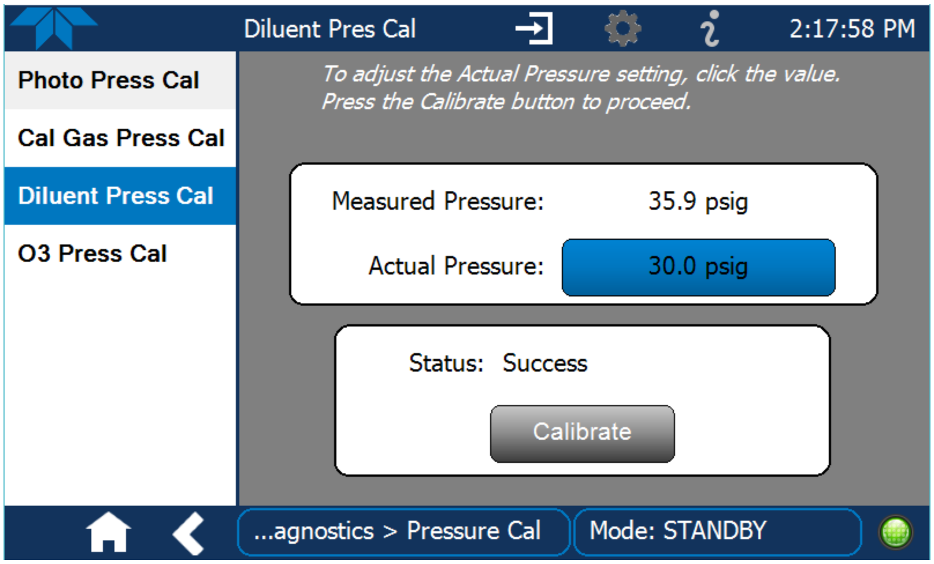


Figure 5-13. Pressure Sensor Calibration Page (Diluent Example)

7. Turn OFF power to the calibrator.
8. Remove the pressure monitor.
9. Restore the pneumatic lines to their proper connections.
10. Close the calibrator’s cover.

5.4.1.2. CALIBRATING THE PHOTOMETER (OPTION) SAMPLE GAS PRESSURE SENSOR

Note **This calibration must be performed when the pressure of the photometer sample gas is equal to ambient atmospheric pressure.**

1. Turn off the calibrator and open the top cover.
2. Disconnect power to the photometer's internal pump.
3. Independently measure the local ambient atmospheric pressure of the calibrator's location in In-Hg-A.
4. Turn on the calibrator, and in the Diagnostics>Pressure Cal menu (Figure 5-14) highlight Photo Press Cal.
5. In the Actual Pressure field (press to bring up keypad) input the value obtained from the ambient atmospheric pressure measurement.

   The Status field should read "Success".

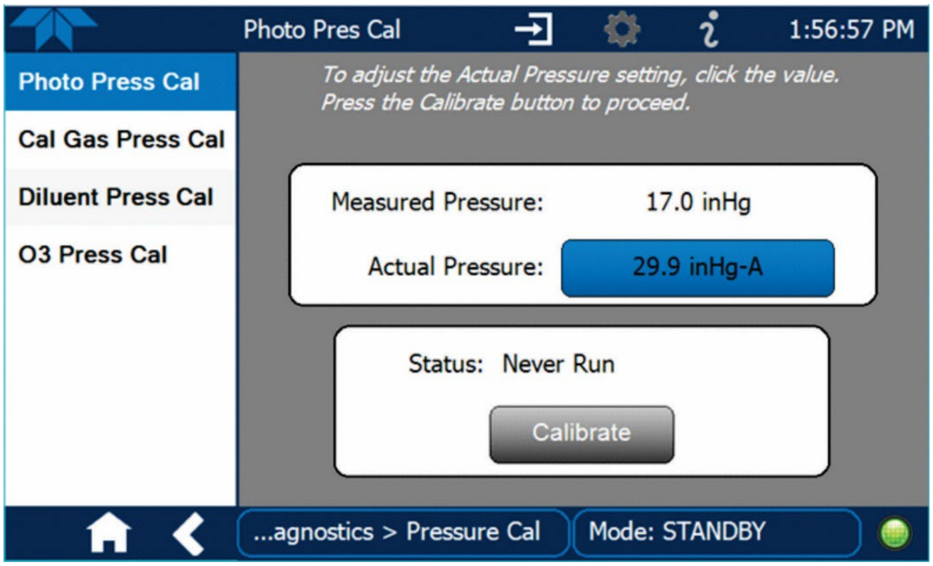


Figure 5-14. O3 Photometer Pressure Sensor Calibration Page

6. Turn OFF the calibrator.
7. Reconnect the internal pump.
8. Close the calibrator's cover.

6. MAINTENANCE

Predictive diagnostic functions including failure warnings and alarms built into the calibrator's firmware allow the user to determine when repairs are necessary without performing painstaking preventative maintenance procedures.

Follow the maintenance schedule provided in this section.

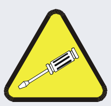
6.1. MAINTENANCE SCHEDULE

Table 6-1 shows a typical maintenance schedule for the calibrator. The actual frequency of performing these procedures can vary depending on the operating environment. Additionally, in some cases, there are local regulations or standards that also need to be considered. 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 **If the instrument has the optional O_3 photometer installed, a Span and Zero Calibration Check must be performed on the photometer following some of the maintenance procedure listed below. See Section 5.2 for instructions on performing checks.**

CAUTION

Risk of electrical shock. Disconnect power before performing any of the following operations that require entry into the interior of the calibrator.



CAUTION

The operations outlined in this Section are to be performed by qualified maintenance personnel only.

Table 6-1. Maintenance Schedule

<table>
<tr><th rowspan="2">ITEM</th><th rowspan="2">ACTION</th><th rowspan="2">FREQ</th><th rowspan="2">CAL CHECK REQ'D.[1]</th><th rowspan="2">MANUAL SECTION</th><th colspan="10">DATE PERFORMED</th></tr>
<tr><th></th><th></th><th></th><th></th><th></th><th></th><th></th><th></th><th></th><th></th></tr>
<tr><td>Verify Test Functions</td><td>Record and analyze</td><td>Weekly or after any Maintenance or Repair</td><td>No</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>Pump Diaphragm[1]</td><td colspan="14">No Replacement Required. Under Normal Circumstances this Pump Will Last the Lifetime of the Instrument.</td></tr>
<tr><td>Absorption Tube[1]</td><td>Inspect
- - -
Clean</td><td>As Needed</td><td>Yes after cleaning</td><td>6.5.2</td><td colspan="10">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 calibrator</td></tr>
<tr><td>Perform Flow Check</td><td>Verify Flow of MFCs</td><td>Annually or any time the calibrator's internal DAC is recalibrated</td><td>No</td><td>5.1</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>Perform Leak Check</td><td>Verify Leak Tight</td><td>Annually or after any Maintenance or Repair</td><td>Yes</td><td>6.5.1</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>Pneumatic lines</td><td>Examine and clean</td><td>As needed</td><td>Yes if cleaned</td><td>- - -</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
</table>

[1] Only applies to calibrator's with O_3 photometer options installed.

6.2. OPERATIONAL HEALTH CHECKS

Navigate to the Utilities>USB Utilities>Report menu (Figure 6-1) to download a report on the basic operations of the instrument. To download the report for your own viewing on a computer or to send to others, insert a flash drive into a front panel USB port and press the Download button, which is enabled when the instrument detects the flash drive.

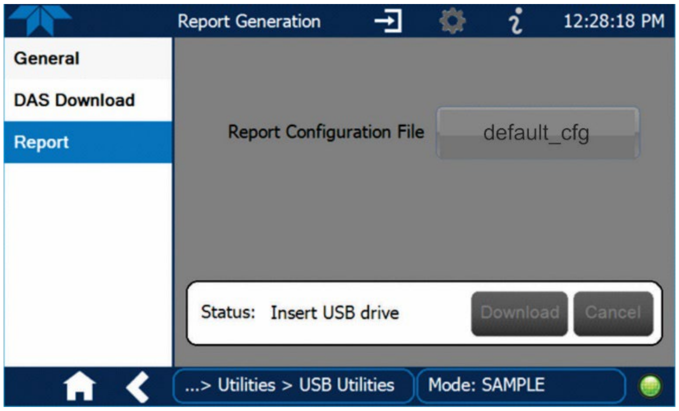


Figure 6-1. Report Generation Page

The report can also be set to generate periodically and sent to a Web services "cloud" where it is available for viewing by Teledyne API technical support personnel. Set this function with two Vars:

Setup>Vars>Upload Report to Cloud: set to True.

Setup>Vars>Report Upload>Interval: edit the number of hours between report uploads.

6.3. SOFTWARE/FIRMWARE UPDATES

There are two ways to check for and acquire updates: either remotely or manually.

6.3.1. REMOTE UPDATES

The instrument must be connected to a network that is connected to the Internet. In the Setup>Instrument menu, select the Remote Update menu and the Check for Updates button. If an update is available, it can be downloaded through this page.

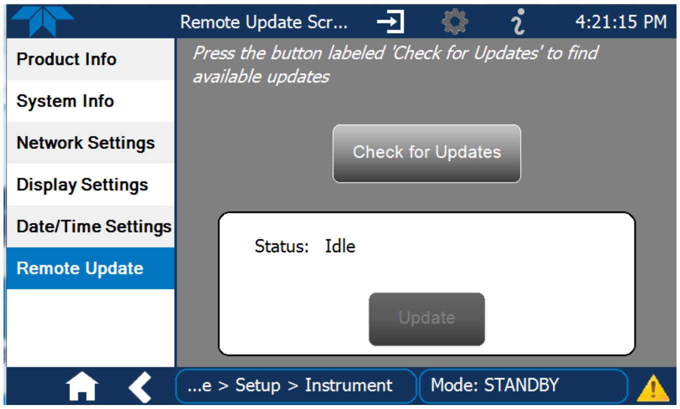


Figure 6-2. Remote Update Page

6.3.2. MANUAL RELOAD/UPDATE PROCEDURES

To reload or update firmware, first contact Technical Support to obtain the applicable file(s): api-techsupport@teledyne.com / 800-324-5190.

1. Follow Technical Support's instructions for copying the firmware files to a flash drive.
2. Go to the Utilities>USB Utilities>General menu.

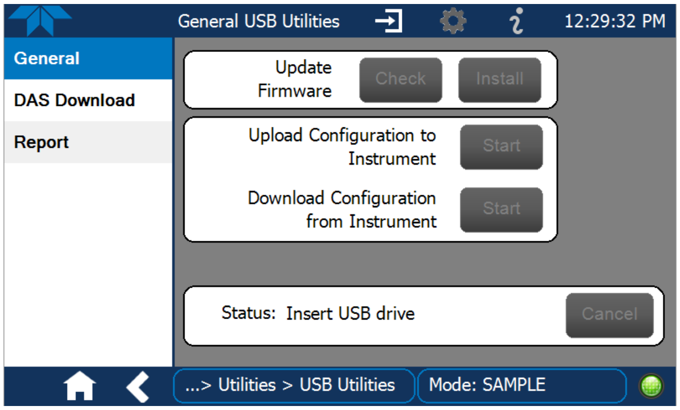


Figure 6-3. General Utilities Page

3. Insert a flash drive into a front panel USB port and wait for the Status field to indicate that the drive has been detected.
4. In the Update Firmware field, press the Check button for the instrument to determine whether the firmware on the flash drive is more recent than what is

currently installed. Once it's been determined that the firmware is new, the Install button will be enabled; if the firmware version on the flash drive is the same as or older than the current firmware of the instrument, the Install button will not be enabled.

5. Press the Install button, and note the messages in the Status field at the bottom of the page. Use the Cancel button if necessary.
6. When complete, as indicated in the Status field, press the Done button, which replaces the Cancel button, and remove the flash drive.
7. Power off and restart the instrument to complete the new firmware installation.

6.3.3. Instrument Display Calibration (for earlier instruments

This Section applies to instruments shipped before January 2017. Although unlikely, if ever the touchscreen appears unresponsive or responds incorrectly, the screen can be calibrated via the Setup>Instrument>Display Settings menu.

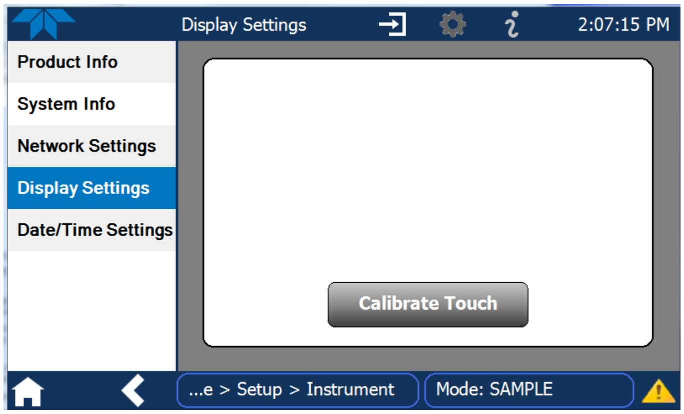


Figure 6-4. Touchscreen Calibration Page

1. Connect a mouse to either of the front panel USB ports.
2. Navigate with the pointer to Setup>Instrument>Display Settings.
3. Click on "Calibrate Touch" and a crosshair appears in the center of the display screen.
4. Note that a timer function is enabled, allowing only 15 seconds to start the calibration process. If the timer expires, the instrument will exit the calibration screen and return to normal operation.
5. Click the very center of the crosshair.
6. When a new crosshair appears in the upper left corner of the screen, carefully and accurately click and hold the very center of that crosshair until it finishes shrinking, then release.
7. Repeat Step 6 for each of the corners.
8. Once the process is completed, a CANCEL and an ACCEPT button appear in the lower left corner: Test the accuracy of the calibration by touching parts of the screen and see that the mouse pointer follows your touches.
9. If you press the CANCEL button, the calibration won't be altered. Otherwise, press the ACCEPT button.

6.4. TIME ZONE CHANGES

There is an option to change between 12-hour and 24-hour format in the Setup>Vars menu (System Time Format), effectively changing the Time Zone requires a specific procedure as follows:

1. In Setup>Instrument>Date/Time Settings select the applicable Time Zone.
2. Allow adequate time for the selected Time Zone to be properly accepted.
3. Verify: return to Home page then back to the Date/Time Settings page, and check that the selected Time Zone is now highlighted.
4. Without making any other changes, power OFF the instrument and power ON again.
5. Once restarted, return to the Date/Time Settings page where the newly selected Time Zone should be highlighted. (If not, it means that not enough time had passed for the instrument to accept the change before the power was cycled OFF).
6. After the Time Zone is implemented first (Steps 1 through 5), then other changes to the date and/or time can be made, and recycling the power is not necessary.

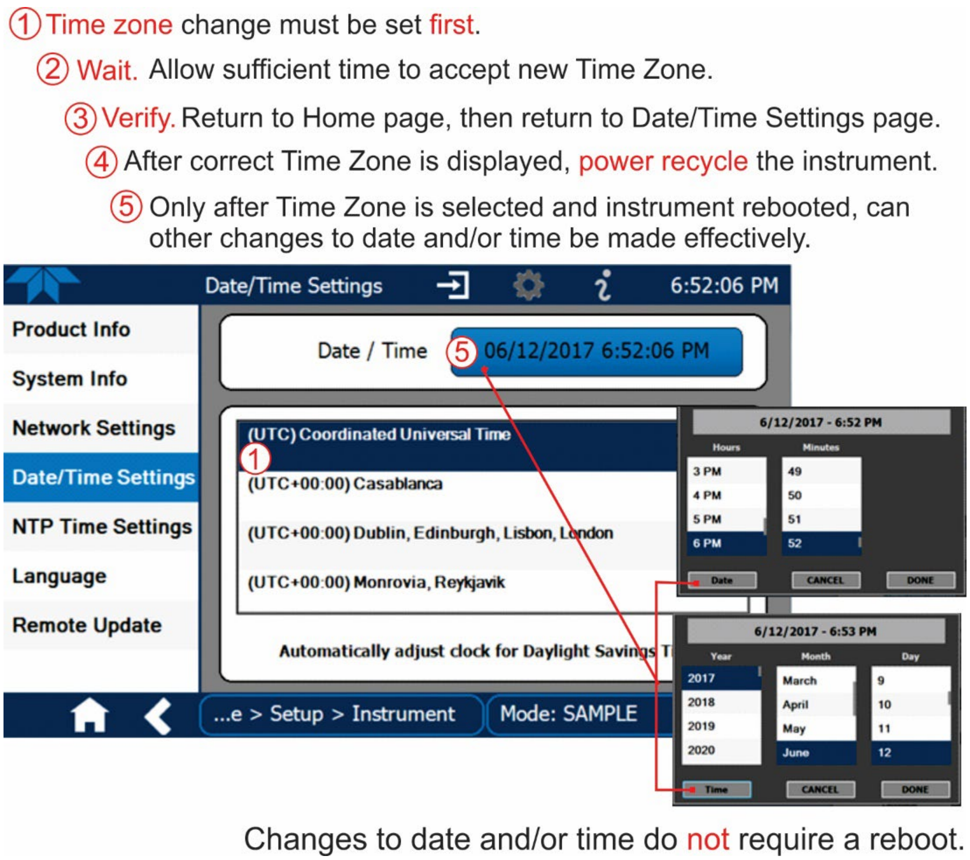


Figure 6-5. Time Zone Change Requirements

6.5. MAINTENANCE PROCEDURES

The following procedures are to be performed periodically as part of the standard maintenance of the calibrator.

6.5.1. AUTO LEAK CHECK

6.5.1.1. EQUIPMENT REQUIRED

- Four (4) 1/4" Pneumatic caps
- One (1) 1/8" Pneumatic Cap
- One (1) # 6 hexagonal Driver/Wrench
- One (1) Pneumatic "T" fitting

6.5.1.2. SETUP FOR AUTO LEAK CHECK

Refer to Figure 6-6 and Figure 6-7 for this procedure. To perform a leak-check on the calibrator, start by removing the cover from the calibrator. For instruments with basic configuration, skip to Step 3. For instruments with the optional O_3 photometer installed, bypass the pressure/flow board, the pump, and the O_3 generator as follows:

1. Using a #6 nut driver, remove hex nut at the photometer's gas outlet.

2. Using a #6 nut driver, remove hex nut from the end of the T-fitting mounted on top of the photometer (or, in older models, on back of O_3 Gen/Photometer Pressure/Flow Sensor board mounted to floor of chassis), and reconnect it to the photometer's gas outlet. (The other end of this tube is connected to the O_3 generator valve). Now continue to Step 3.

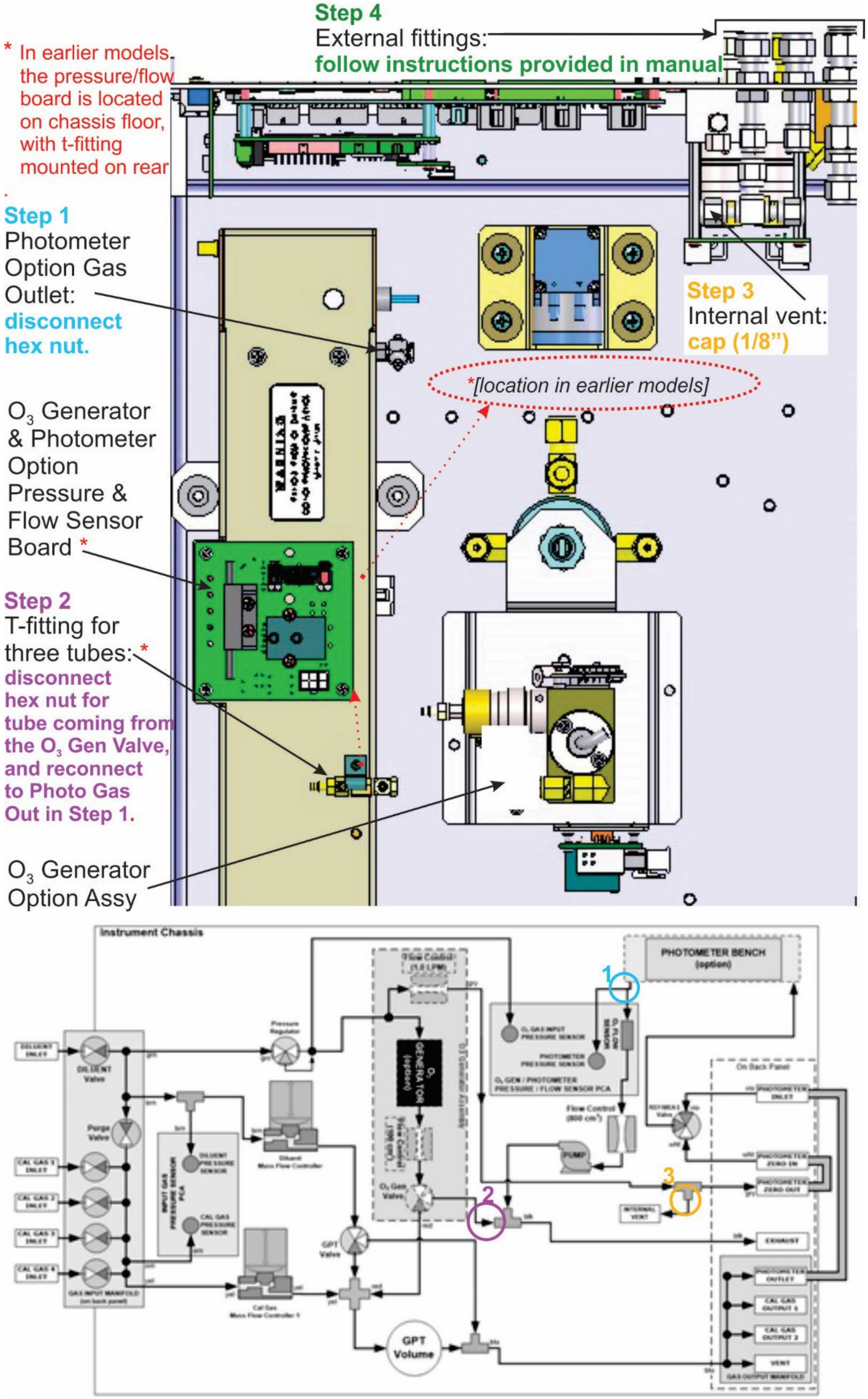


Figure 6-6. Bypassing the Photometer Sensor PCA and Pump

3. Using the 1/8” cap, securely cover the outlet of the internal vent (see Figure 6-6) located just behind the valve relay PCA.

4. Use the 1/4" caps to cover the following gas outlet ports on the calibrator’s rear panel (see Figure 6-7).
   - EXHAUST port (Only required for calibrators with O_3 generators installed).
   - both CAL GAS OUT ports
   - the VENT port

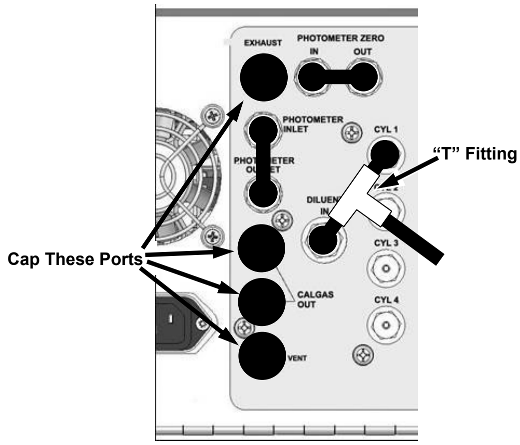


Figure 6-7. Gas Port Setup for Auto-Leak Check Procedure

5. If a bottle of source gas is connected to the CYL 1 port, close the bottle’s gas outlet and disconnect it from the port.

6. Using a “T” type pneumatic fitting, connect a gas line from the zero air gas source to the Diluent In and to the CYL 1 port u (see Figure 6-7).

7. In the Utilities>Diagnostics>Auto Leak Check menu, press the Check button.

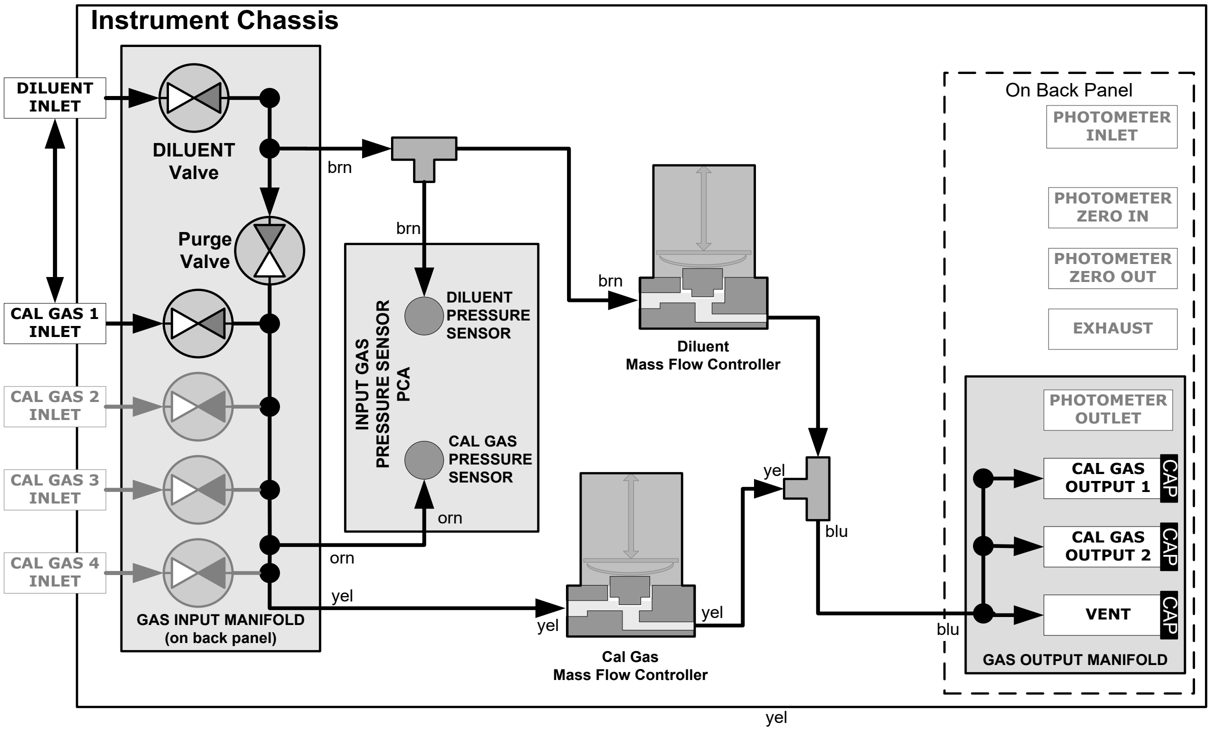


Figure 6-8. Gas Flow for Auto-Leak Check of Base Model Calibrators

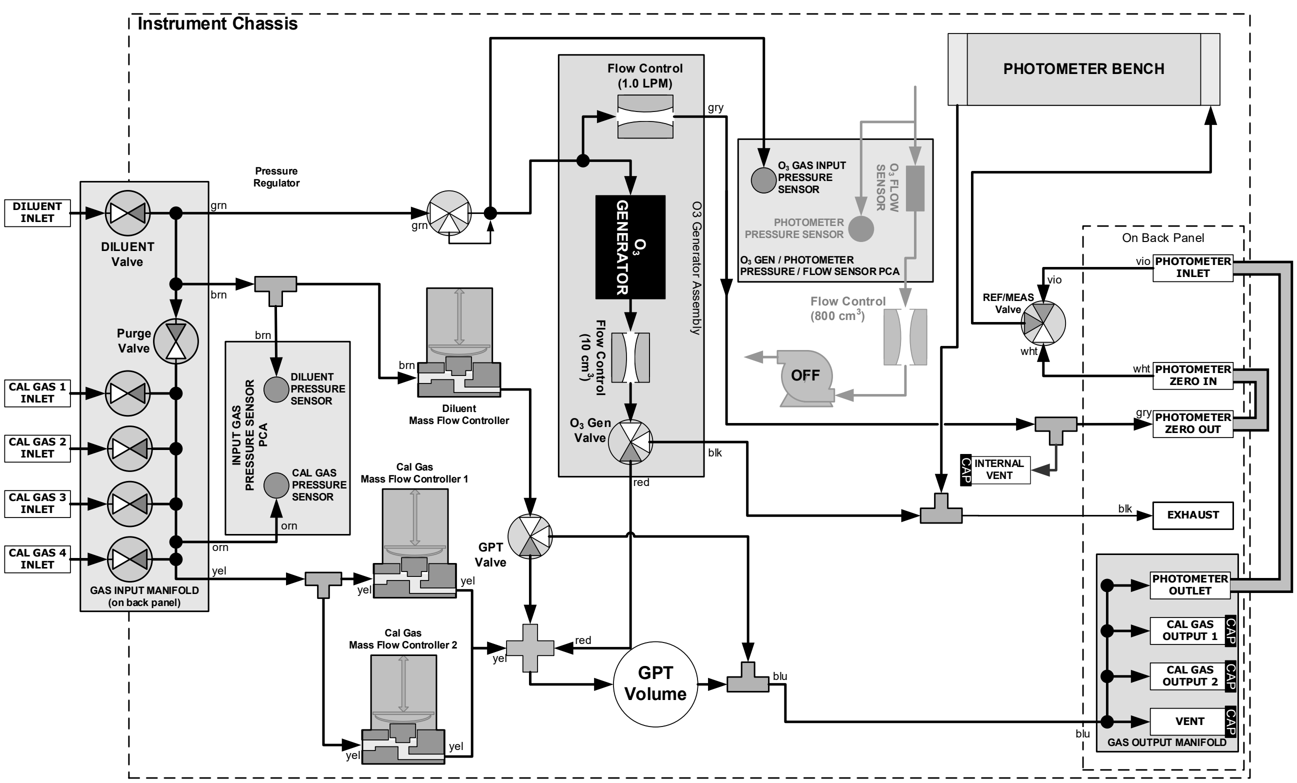


Figure 6-9. Gas Flow for Auto-Leak Check of Calibrators with O_3 Generator and Photometer Option

6.5.1.3. RETURNING THE CALIBRATOR TO SERVICE AFTER PERFORMING AN AUTO LEAK CHECK

1. Remove all of the caps from the EXHAUST, CAL GAS OUTPUTS (2) and the VENT port and from the internal vent.
2. On instruments with an optional O_3 photometer, reconnect the internal gas lines so that the Sensor PCA and pump are functional.
3. Remove the tee from the DILUENT IN and CYL 1.
4. Reconnect the ZERO AIR SOURCE to the DILUENT IN.
5. Reconnect Cal Gas bottle to CYL 1 and open the bottle's outlet port.
6. Replace the calibrator's top cover.
7. The calibrator is now ready to be used.

6.5.2. CLEANING OR REPLACING THE ABSORPTION TUBE

Note **Although this procedure should never be needed as long as the user is careful to supply the photometer with clean, dry and particulate free zero air only, it is included here for those rare occasions when cleaning or replacing the absorption tube may be required.**

1. Remove the center cover from the optical bench.
2. Unclip the sample thermistor from the tube.
3. Loosen the two screws on the round tube retainers at either end of the tube.
4. Using both hands, carefully rotate the tube to free it.
5. Slide the tube towards the lamp housing.
   - The front of the tube can now be slid past the detector block and out of the instrument.

CAUTION

Do not cause the tube to bind against the metal housings. The tube may break and cause serious injury.

6. Clean the tube by rinsing with de-ionized water.
7. Air dry the tube.
8. Check the cleaning job by looking down the bore of the tube.
   - It should be free from dirt and lint.
9. Inspect the o-rings that seal the ends of the optical tube (these o-rings may stay seated in the manifolds when the tube is removed).

10. If there is any noticeable damage to these o-rings, they should be replaced.
11. Re-assemble the tube into the lamp housing and perform an Auto Leak Check on the instrument.

Note	**It is important for proper optical alignment that the tube be pushed all the way towards the front of the optical bench when it is reassembled prior to gently retightening the tube retainer screws. This will ensure that the tube is assembled with the forward end against the stop inside the detector manifold.**

6.5.3. UV Source Lamp Adjustment

This procedure provides in detail the steps for adjustment of the UV source lamp in the optical bench assembly. This procedure should be done whenever the Photo Reference function (in the Vars menu) value drops below 3000 mV.

1. Ensure that the calibrator is warmed-up and has been running for at least 30 minutes before proceeding.
2. Remove the cover from the calibrator.
3. Locate the Photometer option (see Figure 2-4).
4. Locate the UV detector gain adjust pot on the photometer assembly (see Figure 6-10).
5. Navigate to the Utilities>Diagnostics>Analog Inputs menu and scroll to the Photo Detector input.
6. Using an insulated pot adjustment tool, Turn the UV Detector Gain Adjustment Pot until the value of Photo Detector is as close as possible to **4600.0 MV.**
    - Additional adjustment can be made by physically rotating the lamp in its housing. To do this:
        a. Slightly loosen the UV lamp setscrew.
        b. Next, slowly rotate the lamp up to ¼ turn in either direction while watching the Photo Detector signal until the optimum lamp position is determined, then re-tighten the lamp setscrew.
7. If a minimum reading of **3500.0 mV** cannot be reached, the lamp must be replaced.
8. Replace the cover on the calibrator.

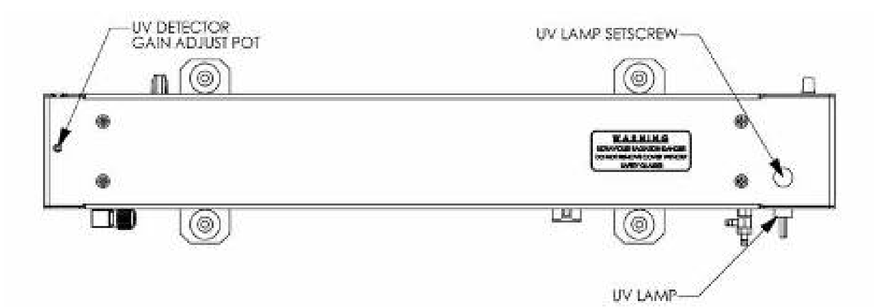


Figure 6-10. Photometer Assembly – Lamp Adjustment / Installation

6.5.4. UV Source Lamp Replacement

This procedure details the steps for replacement of the UV source lamp in the optical bench assembly. This procedure should be done whenever the lamp can no longer be adjusted as described in Section 6.5.3.

1. Turn the calibrator off.
2. Remove the cover from the calibrator.
3. Locate the Optical Bench Assembly (see Figure 2-4).
4. Locate the UV lamp at the front of the optical bench assembly (see Figure 6-10).
5. Unplug the lamp cable from the power supply connector on the side of the optical bench.
6. Slightly loosen (do not remove) the UV lamp setscrew and pull the lamp from its housing.
7. Install the new lamp in the housing, pushing it all the way in. Leave the UV lamp setscrew loose for now.
8. Turn the calibrator back on and allow it to warm up for at least 30 minutes.
9. Turn the UV detector gain adjustment pot (See Figure 6-10) clockwise to its minimum value. The pot may click softly when the limit is reached.
10. Perform the UV Lamp Adjustment procedure described in Section 6.5.3, with the following exceptions:
    Slowly rotate the lamp in its housing (up to ¼ turn in either direction) until a **MINIMUM** value is observed.
    - Ensure the lamp is pushed all the way into the housing while performing this rotation.
    - If the Photo Detector value (Utilities>Diagnostics>Analog Inputs>Photo Detector) will not drop below 5000 mV while performing this rotation, contact Teledyne API'S Technical Support for assistance.

    Once a lamp position is found that corresponds to a minimum observed value for Photo Detector, tighten the lamp setscrew at the approximate minimum value observed.

    Adjust Photo Detector within the range of 4400 – 4600 mV.
11. Replace the cover on the calibrator.

CAUTION

The UV lamp contains mercury (Hg), which is considered hazardous waste. The lamp should be disposed of in accordance with local regulations regarding waste containing mercury.

6.5.5. OZONE GENERATOR UV LAMP ADJUSTMENT OR REPLACEMENT

This procedure details the steps for replacement and initial adjustment of the ozone generator lamp. If you are adjusting an existing lamp, skip to Step 8.

1. Turn off the calibrator.
2. Remove the cover from the calibrator.
3. Locate the O_3 generator (see Figure 2-4).

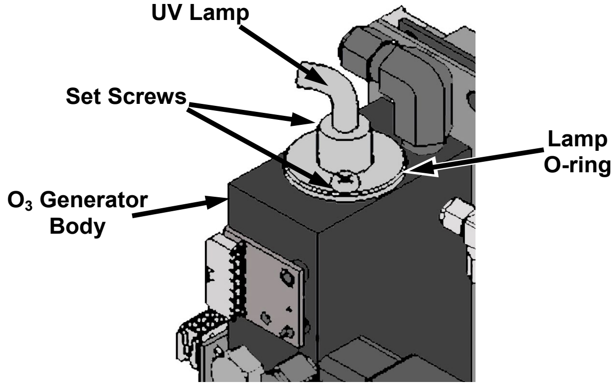


Figure 6-11. O_3 Generator UV Lamp Location

4. Remove the two setscrews on the top of the O_3 generator and gently pull out the old lamp.
5. Inspect the o-ring beneath the nut and replace if damaged.
6. Install the new lamp in O_3 generator housing, ensuring that it is fully seated.
7. Tighten the two setscrew
8. Turn on calibrator and allow it to stabilize for at least 30 minutes.
9. Replace the calibrator's cover.
10. Perform an auto-leak check (See Section 6.5.1).
11. Perform an Ozone Generator calibration (see Section 5.3).

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7. TROUBLESHOOTING AND SERVICE

This Section contains a variety of methods for identifying and solving performance problems with the calibrator.

ATTENTION

The operations outlined in this Section must be performed by qualified maintenance personnel only.

WARNING

- 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 calibrator.
- Do not drop tools into the calibrator or leave those after your procedures.
- Do not shorten or touch electric connections with metallic tools while operating inside the calibrator.
- Use common sense when operating inside a running calibrator.

7.1. GENERAL TROUBLESHOOTING

The Dynamic Dilution Calibrator 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 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. View and compare Dashboard functions' values 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 calibrator's DC power wiring is color-coded and these colors match the color of the corresponding test points on the relay PCA.
   - Follow the procedures defined in Section 2.4.2 to confirm that the calibrator's vital functions are working (power supplies, CPU, relay PCA, etc.).

7.1.1. FAULT DIAGNOSIS WITH ALERTS

The most common and/or serious instrument failures will result in a warning message being displayed as an Alert. Table 7-1 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 indication of the specific failures referenced by the warnings. In this case, it is recommended that proper operation of power supplies (See Section 7.3.3), the relay PCA (See Section 7.3.7), and the motherboard (See Section7.3.11) be confirmed before addressing the specific warning messages.

Table 7-1. Warning Messages in Alerts Page

ALERT	FAULT CONDITION	POSSIBLE CAUSES
CONFIG INITIALIZED	Configuration and Calibration data reset to original Factory state.	- Failed Disk-on-Module - User has erased configuration data
DATA INITIALIZED	Data Storage in DAS was erased.	- Failed Disk-on-Module. - User cleared data.
LAMP DRIVER WARN[1, 2]	The CPU is unable to communicate with either the O_3 generator or photometer lamp I^2C driver chip.	- I^2C has failed
MFC COMMUNICATION WARNING	Firmware is unable to communicate with any MFC.	- I^2C has failed - One of the MFCs has failed - Cabling loose or broken between MFC and motherboard
MFC PRESSURE WARNING	One of the calibrator's mass flow controllers internal gas pressure is <15 PSIG or > 36 PSIG	- Zero or source air supply is incorrectly set up or improperly vented. - Leak or blockage exists in the calibrator's internal pneumatics - Failed CAL GAS or DUILUENT pressure sensor
O3 GEN LAMP TEMP WARNING[1]	IZS Ozone Generator Temp is outside of control range of 48°C ± 3°C.	- No IZS option installed, instrument improperly configured - O_3 generator heater - O_3 generator temperature sensor - Relay controlling the O_3 generator heater - Entire Relay PCA - I^2C Bus
O3 PUMP WARNING[1]	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[2]	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

ALERT	FAULT CONDITION	POSSIBLE CAUSES
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[2]	Occurs when Ref is <2500 mVDC or >4950 mVDC.	Possible failure of: - UV Lamp - UV Photo-Detector Preamp
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
REGULATOR PRESSURE WARNING	Regulator pressure is < 15 PSIG or > 25 PSIG.	- Zero or source air supply is incorrectly set up or improperly vented. - Incorrectly adjusted O_3 zero air pressure regulator - Leak or blockage exists in the calibrator's internal pneumatics - Failed O_3 Generator Input pressure sensor
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
VALVE BOARD WARN	The CPU is unable to communicate with the valve board.	- I^2C Bus failure - Failed valve driver PCA - Loose connectors/wiring

[1] Only applicable for calibrators with the optional the O_3 generator installed.

[2] Only applicable for calibrators with the optional photometer installed.

[3] On instrument with multiple Cal Gas MFCs installed, the MFC FLOW WARNING occurs when the flow rate requested is <10% of the range of the lowest rated MFC (i.e. all of the cal gas MFC are turned off).

7.1.2. FAULT DIAGNOSIS WITH DASHBOARD FUNCTIONS

Besides being useful as predictive diagnostic tools, the Dashboard functions viewable from the calibrator's front panel can be used to isolate and identify many operational problems when combined with a thorough understanding of the calibrator's Theory of Operation (see Section 8).

The acceptable ranges for these functions are listed in the "Nominal Range" column of the calibrator Final Calibrated Test and Validation Data Sheet shipped with the instrument. Values outside these acceptable ranges indicate a failure of one or more of the calibrator'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.

Table 7-2 contains some of the more common causes for these values to be out of range.

Table 7-2. Dashboard Functions – Indicated Failures

FUNCTION	DIAGNOSTIC RELEVANCE AND CAUSES OF FAULT CONDITIONS.
O3 Flow[1]	Gas flow problems directly affect the concentration accuracy of the calibrator's calibration gas mixtures. - Check for Gas Flow problems.
O3 Gen Drive[1]	Check the O_3 generator heater and temperature sensors. Possible causes of faults are the same as O3 GEN LAMP TEMP WARNING from Table 7-1.
O3 LampTemp[1]	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 7-1.
Cal Gas Press	Affects proper flow rate of Cal gas MFCs. Possible causes of faults are the same as MFC PRESSURE WARNING from Table 7-1.
Diluent Press	Affects proper flow rate of Diluent gas MFCs. Possible causes of faults are the same as MFC PRESSURE WARNING from Table 7-1.
REG PRES	Same as REGULATOR PRESSURE WARNING from Table 7-1.
Box Temp	Box Temperature typically runs ~7°C warmer than ambient temperature. If the Box Temperature is out of range, ensure that the: - the exhaust fan is running. - there is sufficient space on the exterior sides and rear of the instrument to allow adequate ventilation.
O3 Meas[2] & O3 Ref[2]	If the value displayed is too high (>4950 mV) 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: - < 200mV – Bad UV lamp or UV lamp power supply. - < 2500mV – 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 O3 Ref value changes by more than 10mV between zero and span gas: - Defective/leaking M/R switching valve.
Photo Flow[2]	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.
Photo Lamp Temp[2]	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 7-1.
Photo Press[2]	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 7-1.

FUNCTION	DIAGNOSTIC RELEVANCE AND CAUSES OF FAULT CONDITIONS.
Photo Samp Temp[2]	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[2]	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[2]	Values outside range indicate: Contamination of the Zero Air supply.

[1] Only appears when the optional O_3 generator is installed.
[2] Only appears when the optional O_3 photometer is installed

7.1.3. USING THE SIGNALS FOR DIAGNOSTICS

The Signal I/O parameters found in the Dashboard and in the Utilities>Diagnostics submenus, combined with a thorough understanding of the instrument's Theory of Operation (found in Section 8), are useful for troubleshooting in three ways:

- The technician can view the raw, unprocessed signal level of the calibrator'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 calibrator.

7.1.4. USING THE ANALOG OUTPUTS MENU

The signals available for output over the calibrator's analog output channel can also be used as diagnostic tools. Table 7-3 lists the functions that can be viewed from the Utilities>Diagnostics>Analog Outputs menu. Analog Outputs 1 through 3 are wired for the MFCs, while the 4th is user-configurable through the Setup>Analog Outputs>Analog Output Cfg menu (Section 2.6.9).

Table 7-3. DIAG – Analog Output Functions

SUB MENU	FUNCTION
Analog Output 1: Diluent MFC Drive	These channels are used by the calibrator internally as drive voltages for instruments with analog MFCs. The settings are preconfigured at the factory and not user-editable.
Analog Output 2: Cal1 MFC Drive	
Analog Output 3: Cal2 MFC Drive (Option)	
Analog Output 4: [*user-selected function*]	This is the analog output, user-configured in the Setup>Analog Outputs>Analog Output Cfg[1] menu, with the following parameters: • Signal Out: function selected for output. • Min Max: allowable value range for the Signal Out function. • Calibration Type. Sets the channel for automatic or manual calibration • Range[1]: signal type (voltage or current loop) and full-scale value of the output. • Recorder Offset[1]: bipolar voltage offset (not available when Range is set to Current loop). • Allow Overrange: ± 5% over-range feature enabled or disabled for this output channel.

[1]After making changes to this output, recalibrate from the Setup>Analog Outputs>Analog Output Cal menu.

Compare the Utilities>Diagnostics>Analog Outputs>Analog Output 4's voltage value to the reading for the same parameter in Home>Dashboard. The scaled voltage signal should be relative to the Dashboard reading. For example, if Analog Output 4 were mapped to Box Temp (in the Setup>Analog Outputs>Analog Output Cfg menu), and its Min Max values were set to 0 and 100, respectively, then a Dashboard Box Temp reading of ~30ºC (6-7° above room temperature) should correspond to a voltage signal around ~1450 mV. (See Section 7.3.15.1 for this example).

Table 7-4. Analog In Readings as Diagnostic Tools

PARAMETER	DESCRIPTION	ZERO	FULL SCALE	CAUSES OF EXTREMELY HIGH / LOW READINGS
Photo Pressure Raw	The pressure of gas in the photometer absorption tube	0 "Hg	40 "Hg-In-A	Check for Gas Flow problems.
Photo Flow	The gas flow rate through the photometer	0 cm^3/min	1000 cm^3/m	Check for Gas Flow problems.
Photo Samp Temp	The temperature of gas in the photometer absorption tube	0 C°	70 C°	Possible causes of faults are the same as Photo Samp Temp from Table 7-2.
Photo Lamp Temp Raw	The temperature of the photometer UV lamp	0 C°	70 C°	Possible failure of: - Bench lamp heater - Bench lamp temperature sensor - Relay controlling the bench heater - Entire Relay PCA - I^2C Bus - Hot Lamp
O3 Gen Lamp Temp Raw	The temperature of the O_3 generator's UV lamp	0 C°	70 C°	Same as O3 GEN LAMP TEMP WARNING from Table 7-1.

PARAMETER	DESCRIPTION	ZERO	FULL SCALE	CAUSES OF EXTREMELY HIGH / LOW READINGS
Photo Detector	The current concentration of O_3 being measured by the photometer.	- - -		- I^2C Bus malfunction - Gas flow problem through the photometer. - Electronic failure of the photometer subsystems. - Failure or pressure / temperature sensors associated with the photometer. - Bad/incorrect Span Gas concentration. - Contamination of the Zero Air supply. - Malfunction of the O_3 generator. - Internal A/D converter problem.

7.2. USING THE INTERNAL ELECTRONIC STATUS LEDS

Several LEDs are located inside the instrument to assist in determining if the calibrators CPU, I^2C bus and Relay PCA are functioning properly.

7.2.1. 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 DS5 does not flash then the program files may have become corrupted; contact Technical Support because it may be possible to recover operation of the calibrator. If after 30 – 60 seconds, DS5 is flashing, then the CPU is bad and must be replaced.

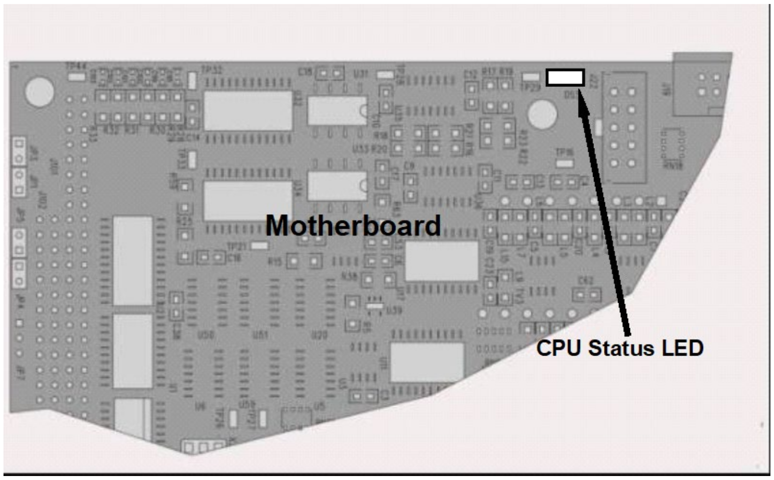


Figure 7-1. CPU Status Indicator

7.2.2. RELAY PCA STATUS LEDS

There are seven LEDs located on the Relay PCA. Some are not used on this model.

7.2.2.1. I²C BUS WATCHDOG STATUS LEDS

The most important LED is D1, which indicates the health of the I²C bus).

Table 7-5. Relay PCA Watchdog LED Failure Indications

LED	FUNCTION	FAULT STATUS	INDICATED FAILURE(S)
D1 (Red)	I²C bus Health (Watchdog Circuit)	Continuously ON or Continuously OFF	Failed/Halted CPU Faulty motherboard, valve driver board or relay PCA Faulty connectors/wiring between motherboard, valve driver board 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.

7.2.2.2. O_3 OPTION STATUS LEDS

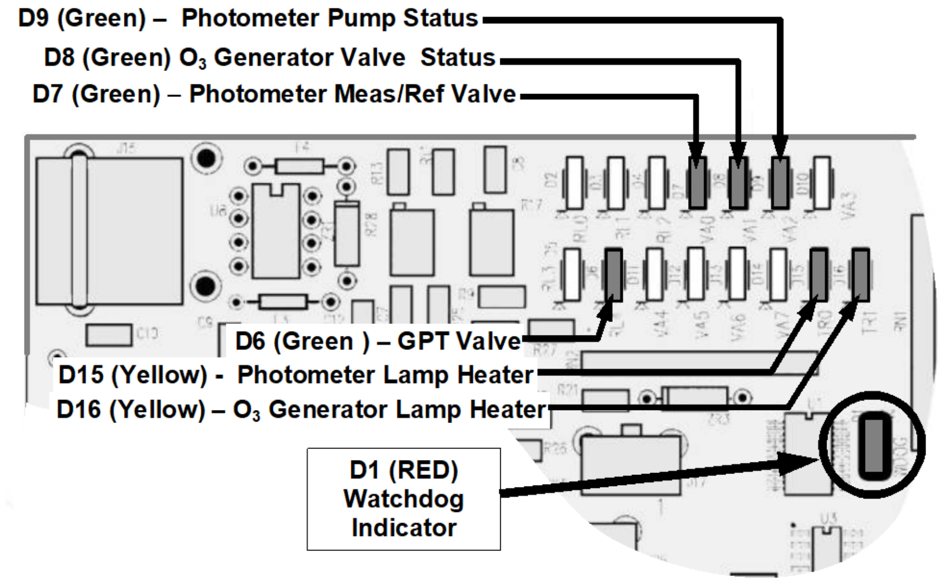


Figure 7-2. Relay PCA Status LEDS Used for Troubleshooting

Table 7-6. Relay PCA Status LED Failure Indications

LED	FUNCTION	SIGNAL I/O PARAMETER		DIAGNOSTIC TECHNIQUE
		ACTIVATED BY	VIEW RESULT	
D7[1] Green	Photometer Meas/Ref Valve	PHOTO_REF_VALVE	N/A	Valve should audibly change states. If not: • Failed Valve • Failed Relay Drive IC on Relay PCA • Failed Relay PCA • Faulty +12 VDC Supply (PS2) • Faulty Connectors/Wiring
D8[2] Green	O_3 Generator Valve Status	O3_GEN_VALVE	N/A	
D9[1] Green	Photometer Pump Status	O3-PUMP-ON	N/A	
D6[1,2] Yellow	GPT Valve Status	GPT_VALVE	N/A	
D15[1] Yellow	Photometer Heater Status	PHOTO_LAMP_HEATER	PHOTO_LAMP_TEMP	Voltage displayed should change. If not: • Failed Heater • Faulty Temperature Sensor • Failed AC Relay • Faulty Connectors/Wiring
D16[2] Green	O_3 Generator Heater Status	O3_GEN_HEATER	O3_GEN_TEMP	

[1] Only applies on calibrators with photometer options installed.
[2] Only applies on calibrators with O_3 generator options installed.

7.2.3. VALVE DRIVER PCA STATUS LEDS

The Signal I/O submenu also includes VARS that can be used to turn the various input gas valves on and off as part of a diagnostic investigation.

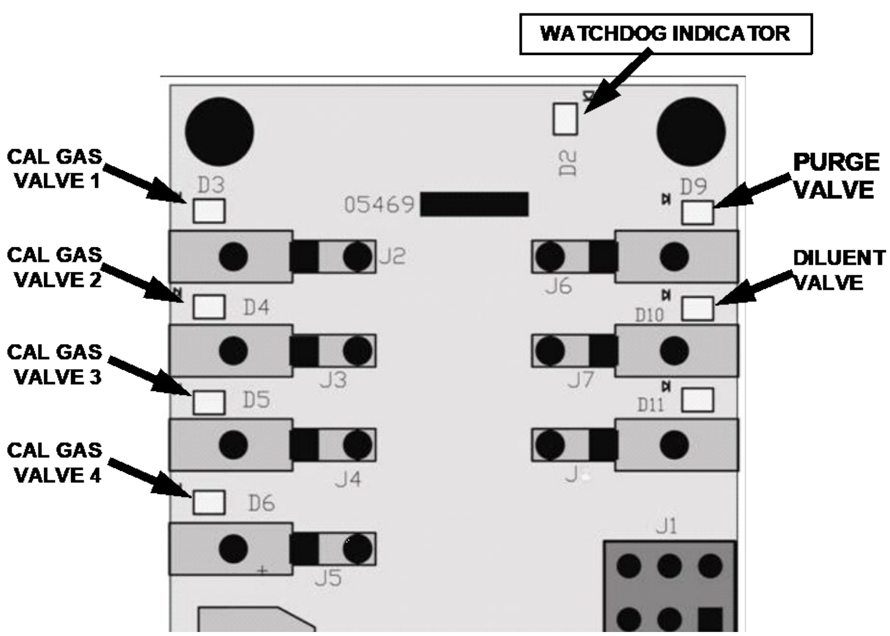


Figure 7-3. Valve Driver PCA Status LEDS Used for Troubleshooting

Table 7-7. Valve Driver Board 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, valve driver board or relay PCA • Faulty connectors/wiring between motherboard, valve driver board or relay PCA • Failed/faulty +5 VDC power supply (PS1)

Table 7-8. Relay PCA Status LED Failure Indications

LED	FUNCTION	ACTIVATED BY SIGNAL I/O PARAMETER	DIAGNOSTIC TECHNIQUE
D3	Cal Gas CYL1	CYL_VALVE_1	Valve should audibly change states and LED should glow. If not: • Failed valve • Failed valve driver IC on relay PCA • Failed valve driver board • Faulty +12 VDC power supply (PS2) • Faulty connectors/wiring
D4	Cal Gas CYL2	CYL_VALVE_2	
D5	Cal Gas CYL3	CYL_VALVE_3	
D6	Cal Gas CYL4	CYL_VALVE_4	
D9	Purge Valve Status	PURGE_VALVE	
D10	Diluent Valve Status	INPUT_VALVE	

7.3. SUBSYSTEM CHECKOUT

The preceding sections of this manual discussed a variety of methods for identifying possible sources of failures or performance problems within the calibrator. In most cases, this included a list of possible components or subsystems that might be the source of the problem. This Section describes how to check individual components or subsystems to determine if which is actually the cause of the problem being investigated.

7.3.1. VERIFY SUBSYSTEM CALIBRATION

A good first step when troubleshooting the operation of the calibrator is to verify that its major subsystems are properly calibrated. These are:

- The mass flow controllers (see Section 5.1).
- Test Channel D > A conversion (see Sections 7.3.11.1, and 8.3.4.1).
- Gas pressure calibration (see Section 5.4).

When optional O_3 components are installed, you should also check:

- Photometer calibration (see Section 5.2).
- O_3 generator calibration (see Section 5.3).

7.3.2. AC MAIN POWER

The calibrator'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.

WARNING

Should the AC power circuit breaker trip, investigate and correct the condition causing this situation before turning the calibrator back on.

7.3.3. DC Power Supply

If you have determined that the calibrator'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 Figure 7-4 and Table 7-9.

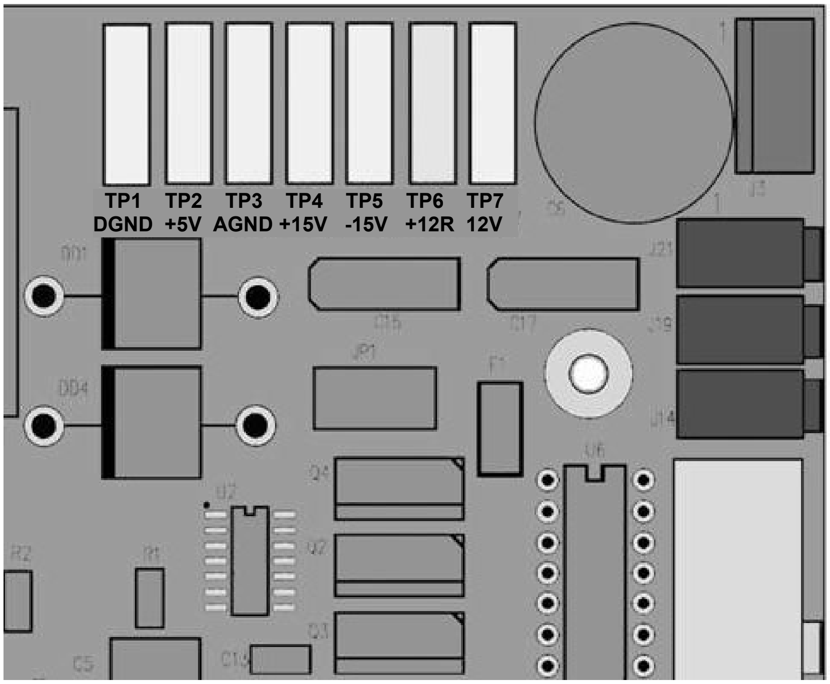


Figure 7-4. Location of DC Power Test Points on Relay PCA

Table 7-9. DC Power Test Point and Wiring Color Codes

NAME	TEST POINT#	TP AND WIRE COLOR
Dgnd	1	Black
+5V	2	Red
Agnd	3	Green
+15V	4	Blue
-15V	5	Yellow
+12R	6	Purple
+12V	7	Orange

A voltmeter should be used to verify that the DC voltages are correct per the values in Table 7-10, 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 7-10. DC Power Supply Acceptable Levels

POWER SUPPLY ASSY	VOLTAGE	CHECK RELAY PCA TEST POINTS				MIN V	MAX V
		FROM TEST POINT		TO TEST POINT			
		NAME	#	NAME	#		
PS1	+5	Dgnd	1	+5	2	4.8	5.25
PS1	+15	Agnd	3	+15	4	13.5	16V
PS1	-15	Agnd	3	-15V	5	-14V	-16V
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	11.75	12.5
PS2	Dgnd	+12V Ret	6	Dgnd	1	-0.05	0.05

7.3.4. I^{2}C Bus

Operation of the I^{2}C 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^{2}C 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^{2}C bus if both D1 on the relay PCA and D2 of the Valve Driver PCA are ON/OFF constantly.

7.3.5. Touchscreen 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.

7.3.6. 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 process.

7.3.7. RELAY PCA

The Relay PCA can be most easily checked by observing the condition of the status LEDs on the Relay PCA (see Section 7.2.2), and using the Utilities>Diagnostics>Digital Outputs menu 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. Table 7-11 lists the control device associated with a particular function.

Table 7-11. Relay PCA Control Devices

FUNCTION	CONTROL DEVICE	IN SOCKET
UV Lamp Heater	Q2	No
O_3 Gen Heater	Q3	No
All Valves	U5	Yes

7.3.8. VALVE DRIVER PCA

Like the Relay PCA the valve driver PCA is checked by observing the condition of the its status LEDs on the Relay Board (see Section 7.2.2), and using the **SIGNAL I/O** submenu under the **DIAG** menu (see Section 7.1.3) to toggle each LED **ON** or **OFF.**

If D2 on the valve driver board is flashing and the status indicator for the output in question (Gas Cyl 1, Purge Valve, etc.) toggles properly using the Signal I/O function, then the control IC is bad.

7.3.9. INPUT GAS PRESSURE / FLOW SENSOR ASSEMBLY

The input gas pressure/flow sensor PCA, located at the front of the instrument to the left of the MFCs (see Figure 2-4) can be checked with a voltmeter. The following procedure assumes that the wiring is intact and that the motherboard as well as the power supplies is operating properly:

7.3.9.1. BASIC PCA OPERATION

- Measure the voltage across C1: it should be 5 VDC ± 0.25 VDC. If not, then the board is bad

7.3.9.2. CAL GAS PRESSURE SENSOR

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:

$$\text{Expected mVDC} = \left(\frac{\text{Pressure}}{34.18_{\text{psig}}} \times 4250_{\text{mvDC}}\right) + 750_{\text{mvDC}} \quad \pm 10\%_{\text{rdg}}$$

EXAMPLE. If the measured pressure is 25 PSIG, the expected voltage level between TP4 and TP1 would be between 3470 mVDC and 4245 mVDC.

EXAMPLE. If the measured pressure is 30 PSIG, the expected voltage level between TP4 and TP1 would be between 4030 mVDC and 4930 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.

7.3.9.3. DILUENT PRESSURE SENSOR

1. Measure the pressure on the inlet side of S2 with an external pressure meter.
2. Measure the voltage across TP5 and TP1.
3. Evaluate the reading in the same manner as for the cal gas pressure sensor.

7.3.10. PHOTOMETER O_3 GENERATOR PRESSURE/FLOW SENSOR ASSEMBLY

This assembly is only present in calibrators with O_3 generator and/or photometer options installed. The pressure/flow sensor PCA, located at the rear of the instrument between the O_3 generator and the photometer pump (see Figure 2-4) can be checked with a voltmeter. The following procedure assumes that the wiring is intact and that the motherboard as well as the power supplies are operating properly:

7.3.10.1. BASIC PCA OPERATION

- Measure the voltage across C1 it should be 5 VDC ± 0.25 VDC. If not, then the board is bad.
- Measure the voltage between TP2 and TP1 C1. It should be 1o VDC ± 0.25 VDC. If not then the board is bad.

7.3.10.2. PHOTOMETER PRESSURE SENSOR

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:

$$\text{Expected mVDC} = \left(\frac{\text{Pressure}}{30.0_{\text{In-Hg-A}}} \times 4660_{\text{mvDC}} \right) + 250_{\text{mvDC}} \quad \pm 10\%_{\text{rdg}}$$

EXAMPLE. If the measured pressure is 20 In-Hg-A, the expected voltage level between TP4 and TP1 would be between 2870 mVDC and 3510 mVDC.

EXAMPLE. If the measured pressure is 25 In-Hg-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.

7.3.10.3. O_3 GENERATOR PRESSURE SENSOR

1. Measure the pressure on the inlet side of S2 with an external pressure meter.
2. Measure the voltage across TP5 and TP1.
   - Evaluate the reading in the same manner as for the cal gas pressure sensor (see Section 7.3.9).

7.3.10.4. PHOTOMETER FLOW SENSOR

1. Measure the voltage across TP3 and TP1.
   - With proper flow (800 cm3/min through the photometer), this should be approximately 4.5V (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 or there is a leak upstream of the sensor.

7.3.11. MOTHERBOARD

7.3.11.1. A/D FUNCTIONS

The simplest method to check the operation of the A-to-D converter on the motherboard is to view the two Signal I/O functions to check the two A/D reference voltages and input signals that can be easily measured with a voltmeter.

1. View the value of Ref 4096mV and of Ref Ground. If both are within 3 mV of nominal (4096 and 0), and are stable ±0.5 mV, then the basic A/D is functioning properly. If not, then the motherboard is bad.
2. Alternatively, choose a parameter in the Utilities>Diagnostics>Analog Inputs menu such as Diluent Press Sensor.
   - Compare the voltage measured at its origin (see the interconnect drawing in Appendix B) with the voltage displayed on the front panel.
   - If the wiring is intact but there is a large difference between the measured and displayed voltage (±10 mV) then the motherboard is bad.

7.3.11.2. ANALOG OUTPUTS VOLTAGE TEST

To verify that Analog Output 4, if configured, is working properly, connect a voltmeter to the rear panel ANALOG OUT connector and perform an output step test as follows:

1. Navigate to the Utilities>Diagnostics>Analog Outputs page.

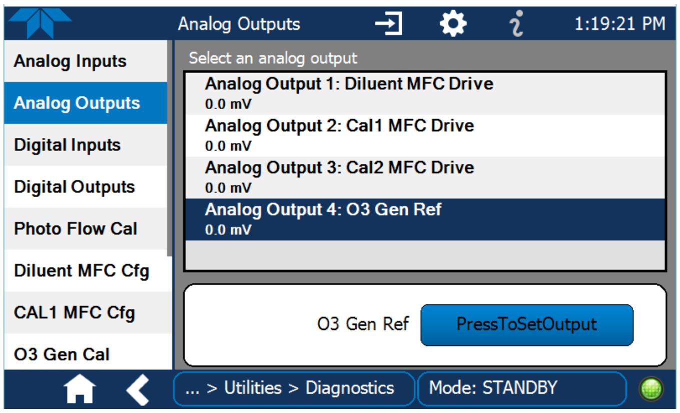


Figure 7-5. Analog Outputs Page Example

2. Press the “PresstoSetOutput” button.
3. Set the desired percent of the signal output in the numeric keypad that pops up, and press Enter.
4. Compare the value displayed in the Analog Output field to the voltmeter.

For each percentage set, the output should be within 1% of the nominal value. Use the table below as an example. Ensure to take into account any offset that may have been programmed into the analog output channel.

Table 7-12. Analog Output Test Function - Nominal Values Voltage Outputs

	FULL SCALE OUTPUT OF VOLTAGE RANGE			
	100MV	1V	5V	10V
SIGNAL %	NOMINAL OUTPUT VOLTAGE			
0	0	0	0	0
20	20 mV	0.2	1	2
40	40 mV	0.4	2	4
60	60 mV	0.6	3	6
80	80 mV	0.8	4	8
100	100 mV	1.0	5	10

If one or more of the readings fails to be within range, it is likely that there has been a failure of the either or both of the DACs and their associated circuitry on the motherboard.

7.3.11.3. DIGITAL (STATUS) OUTPUTS

To test the status output electronics:

1. Connect a jumper between the "D" pin and the "▽" pin on the rear panel STATUS output connector.
2. Connect a 1000 ohm resistor between the "+" pin and the pin corresponding to the status output that is being tested.
3. Connect a voltmeter between the "▽" pin and the pin of the output being tested (as mapped in the Setup>Digital Outputs menu).
4. Under the Utilities>Diagnostics menu, scroll through the inputs and outputs until you get to the output in question and observe whether it toggles ON or OFF.
5. Alternatively, highlight the Output in the Utilities>Diagnostics menu and toggle it ON or OFF while observing the voltage on the voltmeter. It should vary between 0 volts for ON and 5 volts for OFF.

7.3.11.4. DIGITAL CONTROL INPUTS

The rear panel CONTROL IN connectors correspond to the Digital Inputs panel in the Utilities>Diagnostics menu.

Table 7-13. Calibrator Control Input Pin Assignments and Digital Inputs Panel

CONNECTOR	INPUT	CORRESPONDING
Top	1	Control Input 01
Top	2	Control Input 02
Top	3	Control Input 03
Top	4	Control Input 04
Top	5	Control Input 05
Top	6	Control Input 06
Bottom	7	Control Input 07
Bottom	8	Control Input 08
Bottom	9	Control Input 09
Bottom	10	Control Input 10
Bottom	11	Control Input 11
Bottom	12	Control Input 12

The control input bits can be tested by applying a trigger voltage to an input and watching status changes of the associated function in the Utilities>Diagnostics>Digital Inputs:

EXAMPLE: to test the rear panel CONTROL IN pin "1":

1. In the Utilities>Diagnostics>Digital Inputs menu view the output named Control Input 01.
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 "1" pin.
4. The status of Control Input 01 should change to read "ON".

7.3.11.5. CONTROL OUTPUTS

To test the Control Output electronics:

1. Connect a jumper between the "E" 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 (see Table 7-14).
4. Scroll the Utilities>Diagnostics>Digital Outputs menu 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 7-14. Control Outputs Pin Assignments and Functions Check

PIN (LEFT TO RIGHT)	CORRESPONDING DIGITAL OUTPUTS
1	Control Output 01
2	Control Output 02
3	Control Output 03
4	Control Output 04
5	Control Output 05
6	Control Output 06
7	Control Output 07
8	Control Output 08
9	Control Output 09
10	Control Output 10
11	Control Output 11
12	Control Output 12

7.3.12. 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.

7.3.13. The Calibrator Doesn't Appear on the LAN or Internet

Most problems related to Internet communications via the Ethernet card will be due to problems external to the calibrator (e.g. bad network wiring or connections, failed routers, malfunctioning servers, etc.) However, there are several symptoms that indicate the problem may be with the Ethernet card itself.

If neither of the Ethernet cable's two status LED's (located on the back of the cable connector) is lit while the instrument is connected to a network:

Verify that the instrument is being connected to an active network jack.

Check the internal cable connection between the Ethernet card and the CPU board.

7.3.14. RS-232 Communications

7.3.14.1. GENERAL RS-232 TROUBLESHOOTING

Teledyne API calibrators 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 2.3.1.7 for connector and pin-out information.
- The BAUD rate and protocol are incorrectly configured. See Section 2.6.11.1.
- If a modem is being used, additional configuration and wiring rules must be observed. See Section 2.6.11.1.
- Incorrect setting of the DTE-DCE Switch is set correctly. See Section 4.1.
- Verify that the cable (P/N 03596) that connects the serial COMM ports of the CPU to J12 of the motherboard is properly seated.

7.3.15. Temperature Problems

Individual control loops are used to maintain the set point of the Photometer UV Lamp (optional), and the Ozone Generator Lamp (optional). If any of these temperatures are out of range or are poorly controlled, the calibrator will perform poorly.

7.3.15.1. BOX / CHASSIS TEMPERATURE

The box temperature sensor can't be directly accessed with a voltmeter to check its resistance. Instead, the **Box Temp** voltage signal must be configured in the Setup>Analog Outputs>Analog Output Cfg menu first: Map the Signal Out field to Box Temp and scale it 0.0 degC (Min) to 100.0 degC (Max); set the Calibration type to AUTO. Start calibration in the Analog Output Cal menu. Compare the Home>Dashboard>Box Temp value to the Utilities>Diagnostics>Analog Outputs>Analog Output 4: Box Temp voltage. That voltage signal on a scale of 0 to 5,000 mV should be relative to the scaled temperature value. For example, at ~30°C (6-7° above room temperature) the signal should be ~1450 mV.

7.3.15.2. PHOTOMETER OPTION SAMPLE CHAMBER TEMPERATURE

In the Dashboard, the temperature of the gas in the photometer sample chamber (Photo Samp Temp) should read approximately 5.0°C higher than the Box Temp reading.

7.3.15.3. UV LAMP TEMPERATURE

There are three possible causes for the UV Lamp temperature to have failed.

  - The UV Lamp heater has failed. Check the resistance between pins 5 and 6 on the six-pin connector adjacent to the UV Lamp on the Optical Bench.
- It should be approximately 30 Ohms.
  - Assuming that the I^2C bus is working and that there is no other failure with the Relay board, the FET Driver on the Relay Board may have failed.
- Using the PHOTO_LAMP HEATER parameter under the Signal I/O function of the Diag menu, as described above, turn on and off the UV Lamp Heater (D15 on the relay board should illuminate as the heater is turned on).
- Check the DC voltage present between pin 1 and 2 on J13 of the Relay Board.
- If the FET Driver has failed, there will be no change in the voltage across pins 1 and 2.
  - If the FET Driver Q2 checks out OK, the thermistor temperature sensor in the lamp assembly may have failed.
- Unplug the connector to the UV Lamp Heater/Thermistor PCB, and measure the resistance of the thermistor between pins 5 and 6 of the 6-pin connector.
- The resistance near the 58 ºC set point is ~8.1k ohms.

7.3.15.4. OZONE GENERATOR TEMPERATURE

There are three possible causes for the Ozone Generator temperature to have failed.

  - The O3 Gen heater has failed. Check the resistance between pins 5 and 6 on the six-pin connector adjacent to the UV Lamp on the O3 Generator. It should be approximately 5 Ohms.
  - Assuming that the I^2C bus is working and that there is no other failure with the Relay board, the FET Driver on the Relay Board may have failed. Using the O3 Gen Lamp Heater Control parameter in the

Utilities>Diagnostics>Digital Outputs menu as described above, turn the UV Lamp Heater on and off. Check the DC voltage present between pin 1 and 2 on J14 of the Relay Board.

If the FET Driver has failed, there should be no change in the voltage across pins 1 and 2.

- If the FET Driver checks out OK, the thermistor temperature sensor in the lamp assembly may have failed. Unplug the connector to the Ozone Generator Heater/Thermistor PCB, and measure the resistance of the thermistor between pins 5 and 6 of the 6-pin connector.

7.4. TROUBLESHOOTING THE OPTIONAL O_3 PHOTOMETER

7.4.1. DYNAMIC PROBLEMS WITH THE OPTIONAL O_3 PHOTOMETER

Dynamic problems are problems that only manifest themselves when the photometer is measuring O_3 concentration gas mixtures. These can be the most difficult and time consuming to isolate and resolve.

Since many photometer behaviors that appear to be a dynamic in nature are often a symptom of a seemingly unrelated static problems, it is recommended that dynamic problems not be addressed until all static problems, warning conditions and subsystems have been checked and any problems found are resolved.

Once this has been accomplished, the following most common dynamic problems should be checked.

7.4.1.1. NOISY OR UNSTABLE O_3 READINGS AT ZERO

- Check for leaks in the pneumatic system as described in Section 6.5.1.
- Confirm that the Zero gas is free of Ozone.
- Confirm that the Source Lamp is fully inserted and that the lamp hold-down thumb-screw is tight.
- Check for a dirty Absorption Cell and/or pneumatic lines. Clean as necessary as described in Section 6.5.2.
- Disconnect the exhaust line from the optical bench (the pneumatic line at the lamp end of the bench) and plug the port in the bench. If readings remain noisy, the problem is in one of the electronic sections of the instrument. If readings become quiet, the problem is in the instrument's pneumatics.

7.4.1.2. NOISY, UNSTABLE, OR NON-LINEAR SPAN O_3 READINGS

- Check for leaks in the pneumatic systems as described in Section 6.5.1.
- Check for dirty absorption cell and clean or replace as necessary as described in Section 6.5.2.

- Check for operation of the A/D circuitry on the motherboard. See Section 7.3.11.1.
- Confirm the Sample Temperature, Sample Pressure and Sample Flow readings are correct. Check and adjust as required.

7.4.1.3. SLOW RESPONSE TO CHANGES IN CONCENTRATION

- Check for dirty absorption cell and clean or replace as necessary as described in Section 6.5.2.
- Check for pneumatic leaks as described in Section 6.5.1.
- The photometer needs 800 cm3/min of gas flow. Ensure that this is accounted for when calculating total required output flow for the calibrator (see Section 2.4.5).

7.4.1.4. THE ANALOG OUTPUT SIGNAL LEVEL DOES NOT AGREE WITH FRONT PANEL READINGS

- Confirm that the recorder offset (see Section 2.6.9.2) is set to zero.
- Perform an Analog Output calibration (see Section 2.6.9.3).

7.4.1.5. CANNOT ZERO

- Check for leaks in the pneumatic system as described in Section 6.5.1.
- Confirm that the Zero gas is free of Ozone.
- The photometer needs 800 cm^3/min of gas flow. Ensure that this is accounted for when calculating total required output flow for the calibrator (see Section 2.4.5).

7.4.1.6. CANNOT SPAN

- Check for leaks in the pneumatic systems as described in Section 6.5.1.
- Check for dirty absorption cell and clean or replace as necessary as described in Section 6.5.2.
- Check for operation of the A/D circuitry on the motherboard. See Section 7.3.11.1.
- Confirm the Sample Temperature, Sample Pressure and Sample Flow readings are correct. Check and adjust as required.
- The photometer needs 800 cm3/min of gas flow. Ensure that this is accounted for when calculating total required output flow for the calibrator (see Section 2.4.5).

7.4.2. Checking The UV Lamp Power Supply

Note **A schematic and physical diagram of the Lamp Power Supply can be found in Appendix B.**

WARNING
HAZARDOUS VOLTAGE PRESENT - USE CAUTION.

It is not always possible to determine with certainty whether a problem is the result of the UV Lamp or the Lamp Power Supply. However, the following steps will provide a reasonable confidence test of the Lamp Power Supply.

1. Unplug the cable connector at P1 on the Lamp Power Supply and confirm that +15VDC is present between Pins 1 and 2 on the cable connector.
2. If this voltage is incorrect, check the DC test points on the relay PCA as described in Section 7.3.3.
3. Remove the cover of the photometer and check for the presence of the following voltages on the UV lamp power supply PCA (see Figure 8-20):
   - +4500 mVDC ±10 mVDC between TP1 and TP4 (grnd)
   - If this voltage is incorrect, either the UV lamp power supply PCA is faulty or the I2C bus is not communicating with the UV lamp power supply PCA.
   - +5VDC between TP3 and TP4 (grnd)
   - If this voltages is less than 4.8 or greater than 5.25 either the 5 VDC power supply or the UV lamp power supply PCA are faulty.
   - If the above voltages check out, it is more likely that a problem is due to the UV Lamp than due to the Lamp Power Supply.
   - Replace the Lamp and if the problem persists, replace the Lamp Power Supply.

7.5. TROUBLESHOOTING THE OPTIONAL O_3 GENERATOR

The only significant components of the O_3 generator that might reasonable malfunction is the power supply assembly for the UV source lamp and the lamp itself.

7.5.1. CHECKING THE UV SOURCE LAMP POWER SUPPLY

Note **Appendix B includes a schematic of the Lamp Power Supply.**

WARNING
Hazardous voltage present - use caution.

It is not always possible to determine with certainty whether a problem is the result of the UV Lamp or the Lamp Power Supply, however, the following steps will provide a reasonable confidence test of the Lamp Power Supply.

1. Ensure that the calibrator is in STANDBY mode.
2. Unplug the cable connector at P1 on the Lamp Power Supply and confirm that +15VDC is present between Pins 1 and 2 on the cable connector.
3. If this voltage is incorrect, check the DC test points on the relay PCA as described in Section 7.3.3.
4. Remove the cover of the photometer and check for the presence of the following voltages on the UV lamp power supply PCA (see Figure 8-20):
   - +800 mVDC ±10 mVDC between TP1 and TP4 (grnd)
   - If this voltage is incorrect, either the UV lamp power supply PCA is faulty or the I2C bus is not communicating with the UV lamp power supply PCA.
   - +5VDC between TP3 and TP4 (grnd)
   - If this voltages is less than 4.8 or greater than 5.25 either the 5 VDC power supply or the UV lamp power supply PCA are faulty.
   - If the above voltages check out, it is more likely that a problem is due to the UV Lamp than due to the Lamp Power Supply.
   - Replace the Lamp and if the problem persists, replace the Lamp Power Supply.

7.6. REPLACING THE DISK-ON-MODULE

Replacing the Disk-on-Module (DOM) will cause loss of all DAS data; it may also cause some of the instrument configuration parameters to be lost 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 DOM all the way in and reinsert the offset clip.
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.

7.7. TECHNICAL ASSISTANCE

If this manual and its Service Section do not solve your problems, technical assistance may be obtained from Teledyne API, Technical Support:

Toll-free Phone:	+1 800-324-5190
Phone:	+1 858-657-9800
Fax:	+1 858-657-9816
Email:	api-techsupport@teledyne.com
Website:	**http://www.teledyne-api.com/**

7.8. FREQUENTLY ASKED QUESTIONS (FAQS)

The following list of FAQs is from the Teledyne API's Technical Support Department's most commonly asked questions relating to the Dynamic Dilution Calibrator.

QUESTION	ANSWER
My ozone reading is not what I should expect - why?	Look at the Photo Ref/Meas. These are most likely too low and need to be adjusted up to 4500mV. Another possible cause would be no gas flow to the photometer causing the O_3 reading to be out of range - low
When I generate ozone, it takes a long time to settle out, or it fluctuates around the value until finally stabilizing.	Perform an O_3 Gen Adjust (Section 6.5.5), and then an O_3 Gen Calibration (Section 5.3). Re-run points.
Why do some buttons appear grayed out or disappear?	They are deactivated until applicable.
Why does my RS-232 serial connection not work?	There are several possible reasons: The wrong cable: please use the provided or a generic "straight-through" cable (do not use a "null-modem" type cable) and ensure the pin assignments are correct (Section 2.3.1.7 under RS-232 COM Port Connector Pin-outs). The DCE/DTE switch on the back of the analyzer is not set properly; ensure that both green and red lights are on (Section 4.1). The baud rate of the analyzer's COM port does not match that of the serial port of your computer/data logger.
When should I change the sintered filter(s) in the calibrator's critical flow orifice(s) and how do I change them?	The sintered filters do not require regular replacement. Should one require replacement as part of a troubleshooting or repair exercise, contact Technical Support.
How often should I rebuild the photometer pump on my calibrator?	It does not require rebuilding; the entire pump should be replaced every two years.
How long do the UV lamps of the optional O_3 generator and photometer last?	The typical lifetime is about 2-3 years.

8. PRINCIPLES OF OPERATION

8.1. BASIC PRINCIPLES OF DYNAMIC DILUTION CALIBRATION

The Dynamic Dilution Calibrator generates calibration gas mixtures by mixing bottled source gases of known concentrations with a diluent gas (zero air). Using several Mass Flow Controllers (MFCs) the calibrator creates exact ratios of diluent and source gas by controlling the relative rates of flow of the various gases, under conditions where the temperature and pressure of the gases being mixed are known (and therefore the density of the gases are known).

The central processing unit (CPU) calculates both the required source gas and diluent gas flow rates and controls the corresponding MFCs by the following equation.

Equation 8-1

$$C_f = C_i \times \frac{GAS_{flow}}{Totalflow}$$

WHERE:

Cf = final concentration of diluted gas

Ci = source gas concentration

GAS_{flow} = source gas flow rate

Totalflow = the total gas flow through the calibrator

Total flow is determined as:

Equation 8-2

$$TOTALFLOW = GAS_{flow} + Diluent_{flow}$$

WHERE:

GAS_{flow} = source gas flow rate

$Diluent_{flow}$ = zero air flow rate

For instruments with multiple source gas MFC total Flow is:

Equation 8-3

$$Totalflow = GAS_{flow\ MFC1} + GAS_{flow\ MFC2} \ldots + GAS_{flow\ MFCn} + Diluent_{flow\ rate}$$

This dilution process is dynamic. The CPU not only keeps track of the temperature and pressure of the various gases, but also receives data on actual flow rates of the various MFCs in real time so the flow rate control can be constantly adjusted to maintain a stable output concentration.

The calibrator's level of control is so precise that bottles of mixed gases can be used as source gas. Once the exact concentrations of all of the gases in the bottle are programmed into the calibrator, it will create an exact output concentration of any of the gases in the bottle.

8.1.1. GAS PHASE TITRATION MIXTURES FOR O_3 AND NO_2

Because ozone is a very reactive and therefore under normal ambient conditions a short-lived gas, it cannot be reliably bottled, however, an optional O_3 generator can be included in the calibrator that allows the instrument to be use to create calibration mixtures that include O_3.

This ability to generate O_3 internally also allows the Dynamic Dilution Calibrator to be used to create calibration mixture containing NO_2 using a gas phase titration process (GPT) by precisely mixing bottled NO of a known concentration with O_3 of a known n concentration and diluent gas (zero air).

The principle of GPT is based on the rapid gas phase reaction between NO and O_3 that produces quantities of NO_2 as according to the following equation:

Equation 8-4

$$NO + O_3 \longrightarrow NO_2 + O_2 + h\nu_{(light)}$$

Under controlled circumstances, the NO-O_3 reaction is very efficient (<1% residual O_3), therefore the concentration of NO_2 resulting from the mixing of NO and O_3 can be accurately predicted and controlled as long as the following conditions are met:

- The amount of O_3 used in the mixture is known.
- The amount of NO used in the mixture is **AT LEAST** 10% greater than the amount O_3 in the mixture.
- The volume of the mixing chamber is known.
- The NO and O_3 flow rates (from which the time the two gases are in the mixing chamber) are low enough to give a residence time of the reactants in the mixing chamber of >2.75 ppm min.

Given the above conditions, the amount of NO_2 being output by the calibrator will be equal to (at a 1:1 ratio) the amount of O_3 added.

Since:

- The O_3 flow rate of the O_3 generator is a fixed value (typically about 0.105 LPM);
- The GPT chamber's volume is known,
- The source concentration of NO is a fixed value,

Once the **TOTAL FLOW** is determined and entered into the calibrator's memory and target concentration for the O_3 generator are entered into the calibrator's software, the calibrator adjusts the NO flow rate and diluent (zero air) flow rate to precisely create the appropriate NO_2 concentration at the output.

In this case, Totalflow is calculated as:

Equation 10-4

$$DIL_{flow} = Totalflow - NO\ GAS_{flow} - O_{3\,flow}$$

WHERE:

$NOGAS_{flow}$ = NO source gas flow rate (For calibrators with multiple source gas MFC, $NOGAS_{flow}$ is the sum of the flow rate for all of the active cal gas MFCs)

Totalflow = total gas flow requirements of the system.

$O_{3\,flow}$ = the flow rate set for the O_3 generator.

DIL_{flow} = required diluent gas flow

Again, this is a dynamic process. An optional photometer can be added to the calibrator that allows the CPU to track the chemiluminescent reaction created when the NO and O_3 interact to measure the decrease in NO concentration as NO_2 is produced. This information, along with the other data (gas temperature and pressure, actual flow rates, etc.) is used by the CPU to establish a very accurate NO_2 calibration mixture.

8.2. PNEUMATIC OPERATION

The calibrator pneumatic system consists of the precision dilution system and valve manifold consisting of four gas port valves and one diluent air valve. When bottles of source gas containing different, gases are connected to the four source-gas inlet-ports, these valves are used to select the gas type to be used by opening and closing off gas flow from the various bottles upstream of the MFCs.

IMPORTANT

IMPACT ON READINGS OR DATA

Exceeding 35 PSI may cause leakage that could cause unwanted gases to be included in the calibration mixture. Each valve is rated for up to 40 PSI zero air pressure and the source gas pressure should be between 25 to 30 PSI and never more than 35 PSI.

By closing all of the four source gas input valves so that only zero air is allowed into the calibrator, the entire pneumatic system can be purged with zero air without having to manipulate the MFCs.

For an instrument in which the O_3 generator and GPT pneumatics are installed, a glass volume carefully selected per the U.S. E.P.A. guidelines is used to optimize NO_2 creation.

See Figure 2-22 and Section 2.3.2 for descriptions of the internal pneumatics for the calibrator.

8.2.1. GAS FLOW CONTROL

The precision of gas flow through the Dynamic Dilution Calibrator is centrally critical to its ability to mix calibration gases accurately. This control is established in several ways.

8.2.1.1. DILUENT AND SOURCE GAS FLOW CONTROL

Diluent and source gas flow in the calibrator are directly and dynamically controlled by using a highly accurate Mass Flow Controller (MFC). These MFCs include internal sensors, which determine the actual flow of gas though each, and feedback control circuitry that uses this data to adjust the flow as required. The MFCs consist of a shunt, a sensor, a solenoid valve and the electronic circuitry required to operate them.

The shunt divides the gas flow such that the flow through the sensor is a precise percentage of the flow through the valve.

The MFC's internal sensor operates on a unique thermal-electric principle. A metallic capillary tube is heated uniformly by a resistance winding attached to the midpoint of the capillary. Thermocouples are welded at equal distances from the midpoint of the tube. At zero air flow the temperature of both thermocouples will be the same. When flow occurs through the tubing, heat is transferred from the tube to the gas on the inlet side and from the gas back to the tube on the outlet side creating an asymmetrical temperature distribution. The thermocouples sense the changes of temperature in the capillary tube and produce a mVDC output signal proportional to that change, which is proportional to the rate of flow through the MFC's valve.

The electronic circuitry reads the signal output by the thermal flow sensor measured through a capillary tube. This signal is amplified so that it is varies between 0.00 VDC and 5.00 VDC. A separate 0 to 5 VDC command voltage is also generated that is proportional to the target flow rate requested by the CPU. The 0-5VDC command signal is electronically subtracted from the 0-5VDC flow signal. The amount and direction of the movement is dependent upon the value and the sign of the differential signal.

The MFC's valve is an automatic metering solenoid type; its height off the seat is controlled by the voltage in its coil. The controller's circuitry amplifies and the differential signal obtained by comparing the control voltage to the flow sensor output and uses it to drive the solenoid valve.

As the solenoid valve opens and closes to vary the flow of gas through the shunt, the valve, and the sensor, in an attempt to minimize the differential between the control voltage for the target flow rate and the flow sensor output voltage that's generated by the actual flow rate of gas through the controller.

This process is heavily dependent on the capacity of the gas to heat and cool. Since the heat capacity of many gases is relatively constant over wide ranges of temperature and pressure, the flow meter is calibrated directly in molar mass units for known gases. Changes in gas composition usually only require application of a simple multiplier to the air calibration to account for the difference in heat capacity and thus the flow meter is capable of measuring a wide variety of gases.

8.2.1.2. FLOW CONTROL ASSEMBLIES FOR OPTIONAL O_3 COMPONENTS

Whereas the gas flow rates for the final mixing of gases is controlled directly by the calibrator's MFCs, under direction of the CPU, other gas flow rates in the calibrator are set by various flow control assemblies located in the gas stream(s). These assemblies are not adjusted but maintain precise volumetric control as long as the a critical pressure ratio is maintained between the upstream and the downstream orifice.

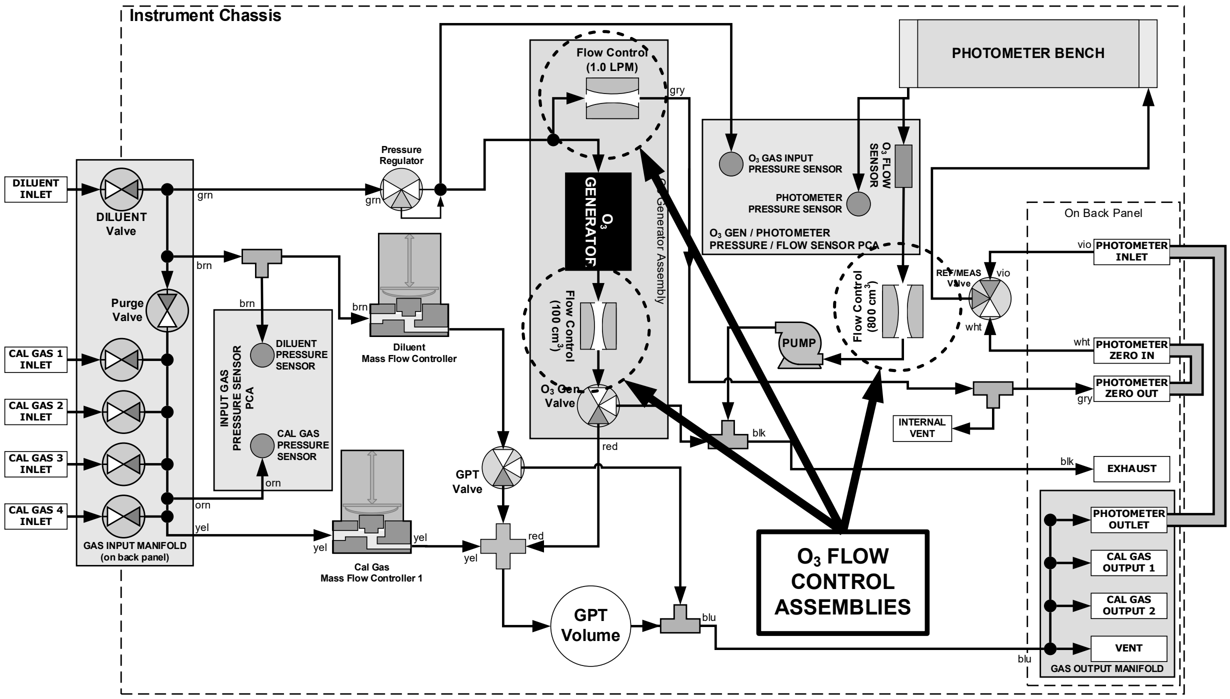


Figure 8-1. Location of Gas Flow Control Assemblies with O_3 Generator Installed

The flow control 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 spring: Applies mechanical force needed to form the seal between the o-rings, the critical flow orifice and the assembly housing.

8.2.1.3. CRITICAL FLOW ORIFICES

The most important component of the flow control assemblies is the critical flow orifice.

Critical flow orifices are a remarkably simple way 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 though the orifice, a pressure differential is created. This pressure differential combined with the action of the calibrator's 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.

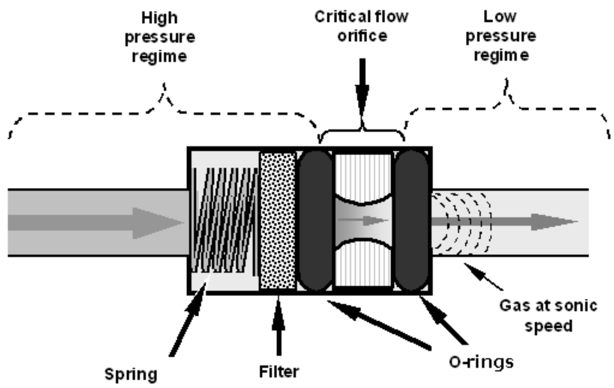


Figure 8-2. Flow Control Assembly & Critical Flow Orifice

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.

With a nominal pressure of 10 in-Hg-A in the sample/reaction cell, the necessary ratio of reaction cell pressure to pump vacuum pressure of 2:1 is exceeded and accommodating a wide range of variability in atmospheric pressure and accounting for pump degradation. This extends the useful life of the pump. Once the pump degrades to the point where the sample and vacuum pressures is less than 2:1, a critical flow rate can no longer be maintained.

8.2.2. INTERNAL GAS PRESSURE SENSORS

The calibrator includes a single pressure regulator. Depending upon how many and which options are installed, there are between two and four pressure sensors installed as well.

In the basic unit a printed circuit, assembly located near the front of the calibrator near the MFCs includes sensors that measure the pressure of the diluent gas and the source gas currently selected to flow into the calibrator. The calibrator monitors these sensors.

- Should the pressure of one of them fall below 15 PSIG or rise above 36 PSIG a warning is issued.

In units with the optional O_3 generator installed a second PCA located at the rear of the calibrator just behind the generator assembly includes a sensor that measures the gas pressure of the zero air flowing into the generator. A regulator is also located on the gas input to the O_3 generator that maintains the pressure differential needed for the critical flow orifice to operate correctly.

- Should the pressure of one of this sensor fall below 15 PSIG or rise above 25 PSIG a warning is issued.

In calibrators with O_3 photometers installed, a second pressure located on the rear PCA measures the pressure of gas in the photometer’s absorption tube. This data is used by the CPU when calculating the O_3 concentration inside the absorption tube.

8.3. ELECTRONIC OPERATION

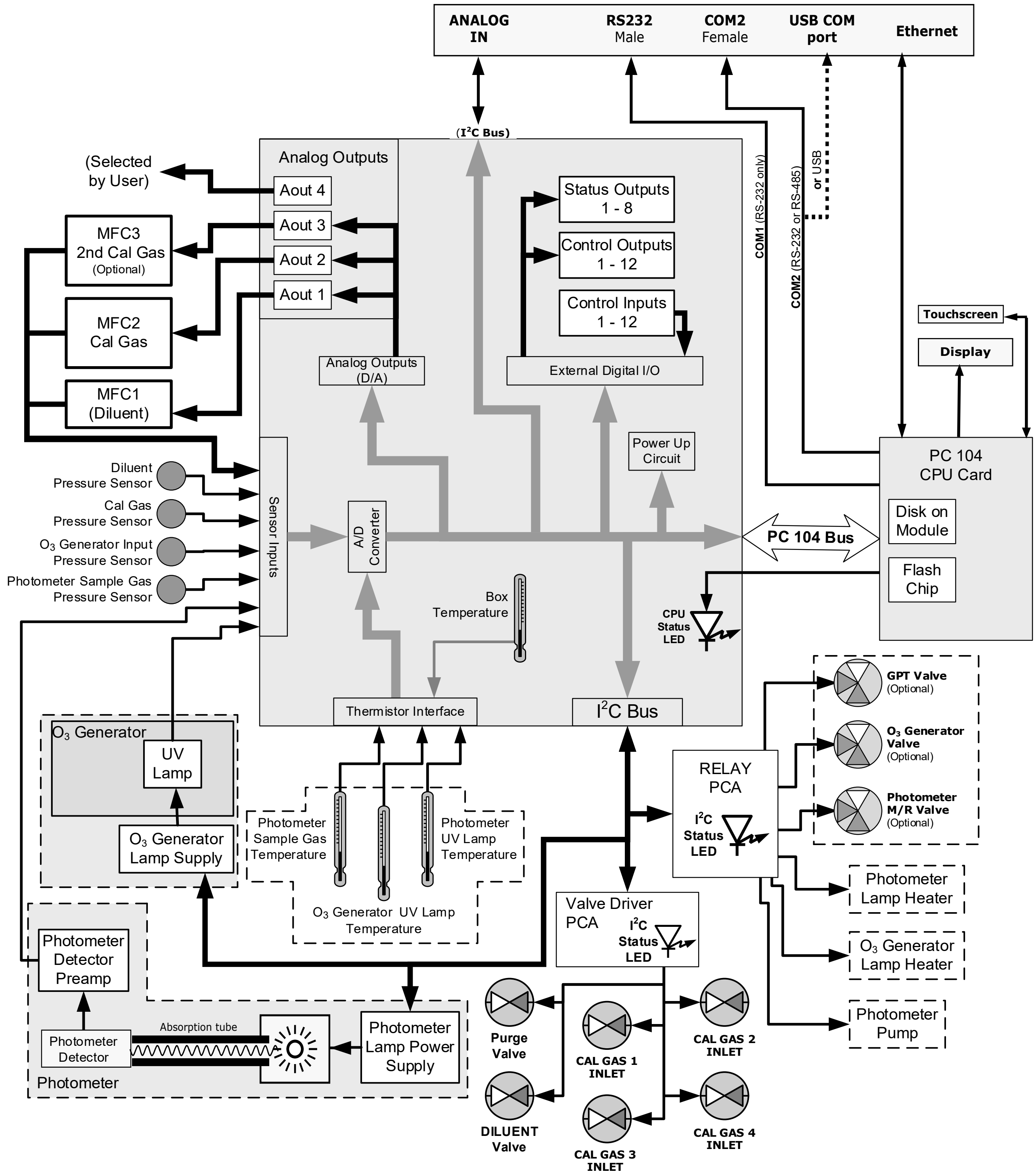


Figure 8-3. Electronic Block Diagram

The core of the calibrator is a microcomputer (referred to as the 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 called 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 calibrator's other major components.

Data are generated by the various subcomponents, such as flow data from the MFCs, O_3 concentration from the optional photometer. Analog signals are 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 calibrator's major components, again through the signal processing capabilities of the motherboard. These status reports are used as data for the concentration calculations and as trigger events for certain control commands issued by the CPU. They are stored in memory by the CPU and in most cases can be viewed but the user via the front panel display.

The CPU communicates with the user and the outside world in a variety of manners:

- Through the calibrator's front panel LCD touchscreen interface;
- RS232 and RS485 serial I/O channels;
- Via Ethernet;
- Various digital and analog outputs, and
- A set of digital control input channels.

Finally, the CPU issues commands via a series of relays and switches (also over the I^2C bus) located on a separate printed circuit assembly to control the function of key electromechanical devices such as heaters, motors and valves.

8.3.1. CPU

The unit's CPU card (Figure 8-4) is installed on the motherboard located inside the rear panel. It 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 and features the following:

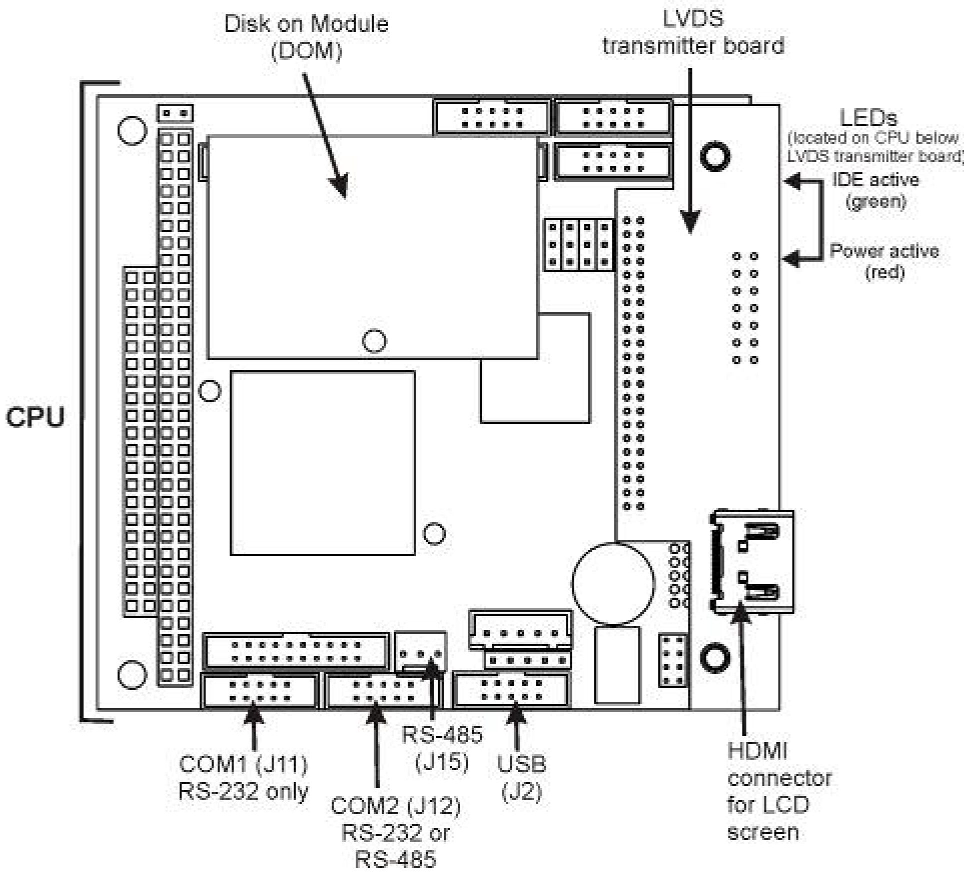


Figure 8-4. Calibrator CPU Board Annotated

The CPU includes two types of non-volatile data storage: an embedded 2MB flash chip and a Disk on Module (DOM).

8.3.2. RELAY PCA

The relay PCA is one of the central switching and power distribution units of the calibrator; it communicates with the motherboard over the I^2C bus and can be used for detailed trouble-shooting of power problems and valve or heater functionality.

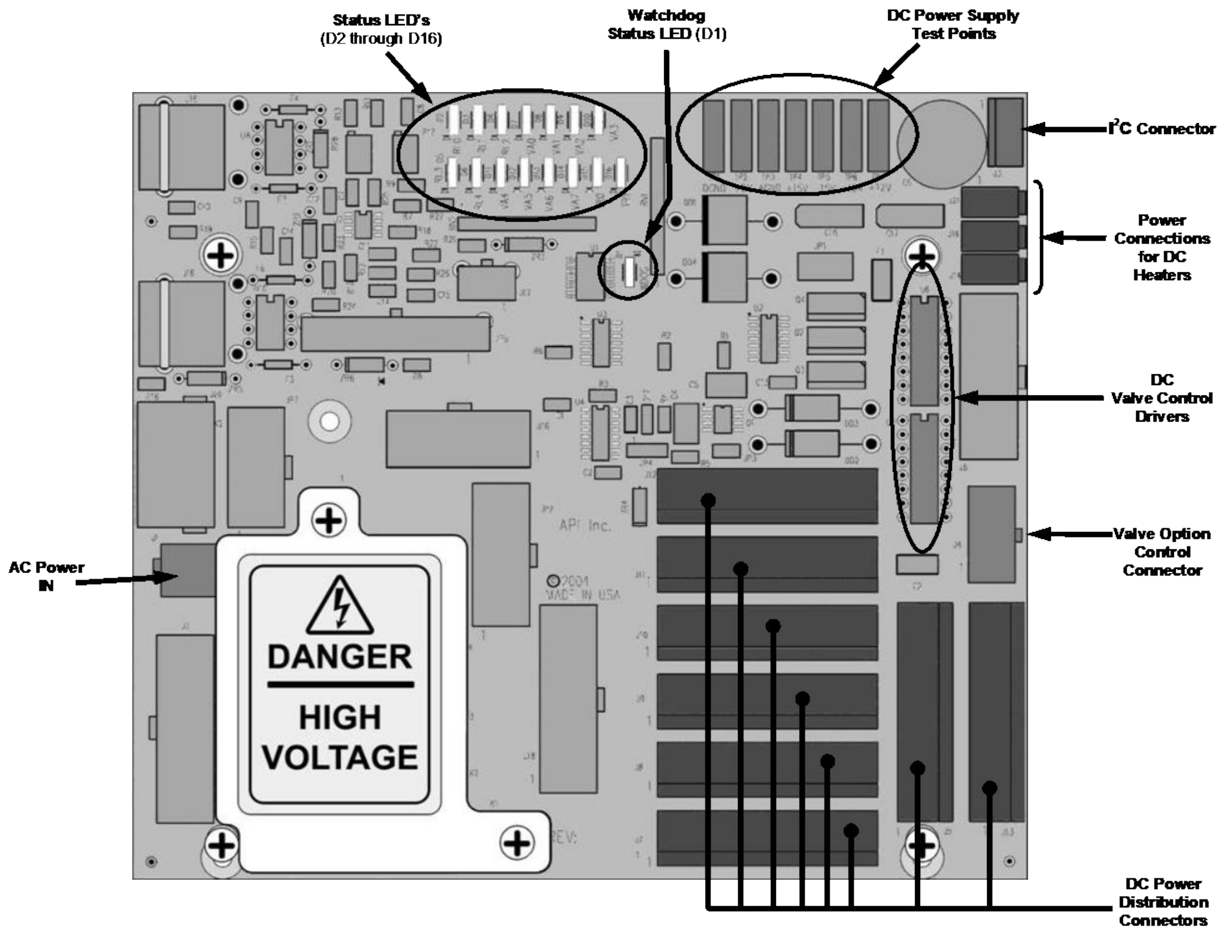


Figure 8-5. Relay PCA

This is the base version of the Relay PCA. It does not include the AC relays and is used in instruments where there are no AC powered components requiring control. A plastic insulating safety shield covers the empty AC Relay sockets.

WARNING

Never remove this safety shield 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

8.3.2.1. VALVE CONTROL

The relay PCA also hosts valve driver chips that control the valves associated with the O_3 generator and photometer. Other valves related to source gas and diluent gas flow are controlled by a separate valve driver PCA (see Section 8.3.3).

8.3.2.2. HEATER CONTROL

The relay PCA controls the various DC heaters related to the O_3 generator and photometer.

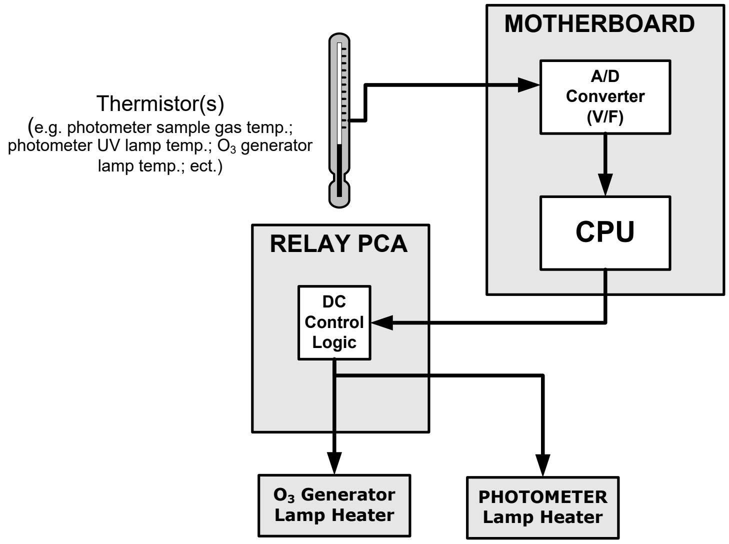


Figure 8-6. Heater Control Loop Block Diagram.

8.3.2.3. RELAY PCA STATUS LEDS & WATCH DOG CIRCUITRY

Several LEDs located on the calibrator's relay PCA indicate the status of the calibrator's heating zones and some of its valves, as well as a general operating watchdog indicator. Table 8-1 shows the status and functions of these LEDs.

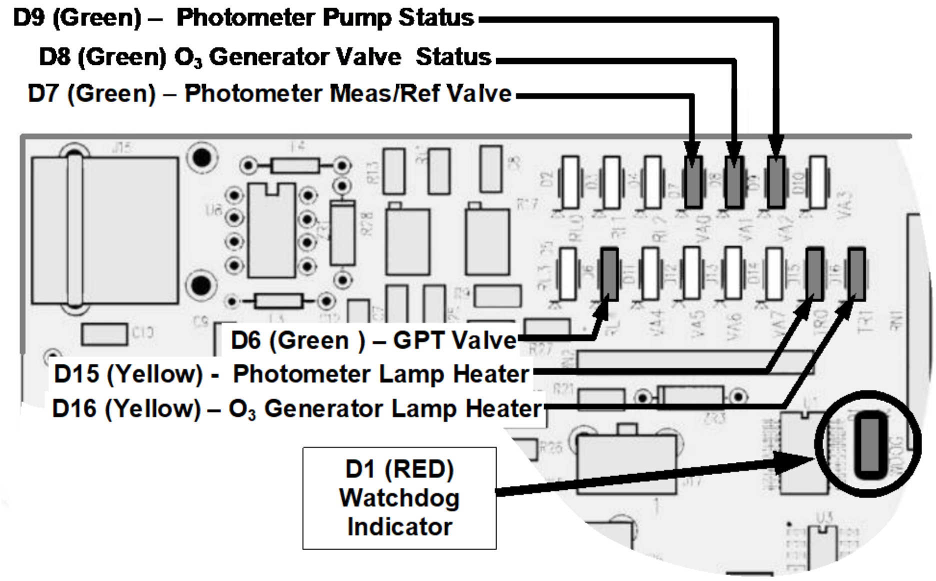


Figure 8-7. Status LED Locations – Relay PCA

Table 8-1. Relay PCA Status LEDs

LED	COLOR	DESCRIPTION	FUNCTION
D1	Red	Watchdog Circuit; I^2C bus operation.	Blinks when I^2C bus is operating properly
D2-6	SPARE		
D7[1]	Green	Photometer Meas/Ref Valve	When lit the valve opens the REFERENCE gas path
D8[2]	Green	O_3 generator Valve status	When lit the valve open to O_3 generator gas path
D9	Green	Photometer Pump status	When lit the pump is turned on.
D6[1,2]	Yellow	GPT Valve status	When lit the valve opens the GT Chamber
D10 - 14	SPARE		
D15[1]	Yellow	Photometer Heater Status	When lit the photometer UV lamp heater is on
D16[2]	Yellow	O_3 Generator Heater Status	When lit the O_3 generator UV lamp heater is on

[1] Only applies on calibrators with photometer options installed.
[2] Only applies on calibrators with O_3 generator options installed.

8.3.2.4. RELAY PCA WATCHDOG INDICATOR (D1)

The most important of the status LEDs on the relay PCA is the red I^2C Bus watchdog LED, D1. It is controlled directly by the calibrator's CPU over the I^2C bus. Special circuitry on the relay PCA monitors D1 for solid on or off of 30-second duration (indicating that the CPU or I^2C bus has stopped functioning) and automatically closes all valves and turns off all heaters and lamps.

8.3.3. VALVE DRIVER PCA

A valve driver PCA controls the valves that operate the main source gas and diluent gas inputs. Like the relay board, this PCA communicates with the CPU through the motherboard over the I^2C bus.

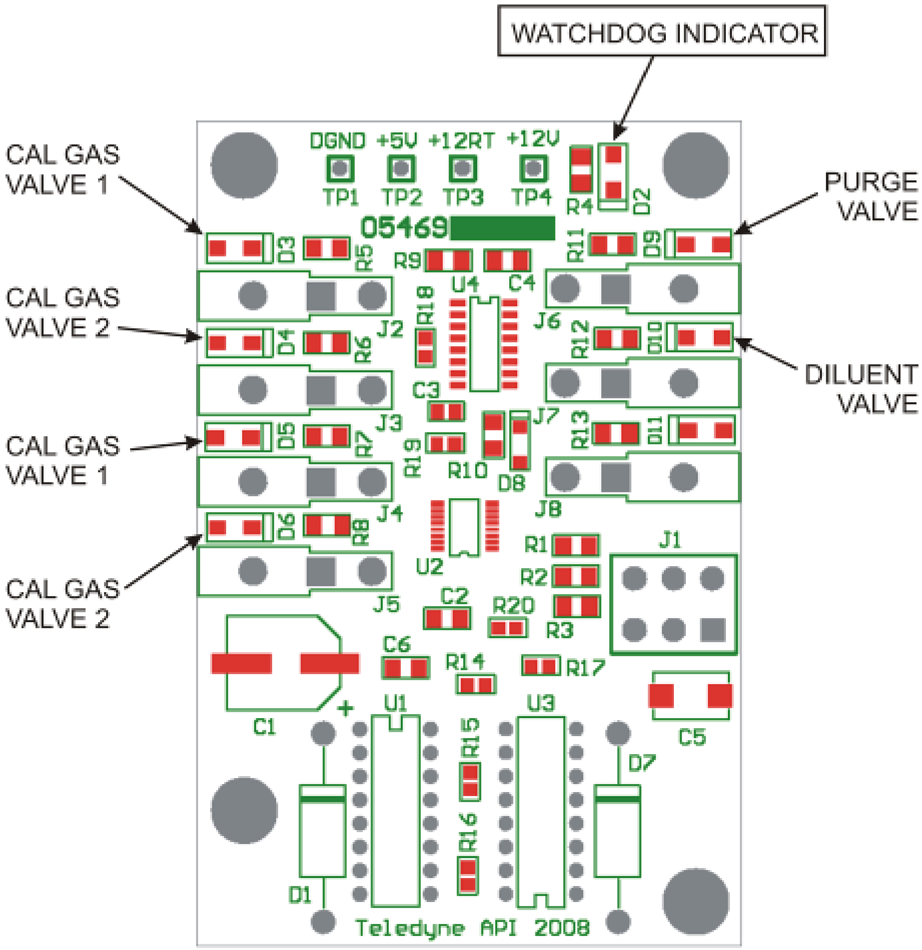


Figure 8-8. Status LED Locations – Valve Driver PCA

8.3.3.1. VALVE DRIVER PCA WATCHDOG INDICATOR (D2)

The most important of the status LEDs on the relay PCA is the red I^2C Bus watchdog LED, D2. It is controlled directly by the calibrator's CPU over the I^2C bus. Like the relay PCA watchdog, this board's circuitry monitors this LED and automatically closes all valves and turns off all heaters and lamps if D2 indicates that the I^2C bus has stopped functioning.

8.3.4. MOTHERBOARD

This is the largest electronic assembly in the calibrator and is the base for the CPU board and all I/O connectors. 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.

8.3.4.1. ANALOG-TO-DIGITAL (A/D) CONVERSION

The A/D converter converts analog signals, such as the voltages received from the calibrator's various sensors, to digital signals that the CPU can understand.

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 period, 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 uni-polar 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, the A/D converter receives two reference voltages: reference ground and +4.096 VDC. During calibration, the device measures these two voltages and outputs their digital equivalent to the CPU, which uses these values to compute offset and slope for subsequent calculations.

8.3.4.2. SENSOR INPUTS

The key analog sensor signals are coupled to the A/D converter through the master multiplexer from two connectors on the motherboard. Terminating resistors (100 kΩ) on each of the inputs prevent crosstalk between the sensor signals.

8.3.4.3. THERMISTOR INTERFACE

This circuit provides excitation, termination and signal selection for several negative-coefficient, thermistor temperature sensors located inside the calibrator.

8.3.4.4. ANALOG OUTPUTS

The calibrator has one analog output that the user can set to output a VDC signal level representing the value of any one of several selectable parameters.

8.3.4.5. EXTERNAL DIGITAL I/O

The external digital I/O performs two functions.

The **STATUS** outputs carry logic-level (5V) signals through an optically isolated 8-pin connector on the rear panel. These outputs convey on/off information about certain conditions, such as **SYSTEM OK,** and can be used to interface with certain types of programmable devices.

The **CONTROL** outputs can be used to initiate actions by external peripheral devices in conjunction with individual steps of a calibration sequence.

The **CONTROL** inputs can be initiated by applying 5V DC power from an external source such as a PLC or data logger (Section 2.6.7.1). Zero and span calibrations can be initiated by contact closures on the rear panel.

8.3.4.6. I^{2}C DATA BUS

I^{2}C is a two-way, clocked, bi-directional, digital serial I/O bus. A transceiver on the motherboard converts data and control signals from the PC-104 bus to I^{2}C. The data is then fed to the relay board, optional analog input board and valve driver board circuitry.

8.3.4.7. 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^{2}C circuitry to specific values until the CPU boots and the instrument software can establish control.

8.3.5. INPUT GAS PRESSURE SENSOR PCA

This PCA, physically located to the just to the left of the MFCs, houses two pressure sensors that measure the pressure of the incoming diluent gas (zero air) and calibration gases relative to ambient pressure. Pneumatically, both sensors measure their respective gases just upstream of the associated MFC.

This data is used in calculating the concentration of calibration mixtures.

8.3.6. POWER SUPPLY AND CIRCUIT BREAKER

The calibrator operates in two main AC power ranges: 100-120 VAC and 220-240 VAC (both ± 10%) between 47 and 63 Hz. A 5-ampere 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 calibrator.

ATTENTION **COULD DAMAGE INSTRUMENT AND VOID WARRANTY**

This instrument is equipped with a universal power supply that allows it to accept any AC power configuration within the limits specified in its rear panel label. If the power circuit breaker trips, correct the cause before powering on the instrument.

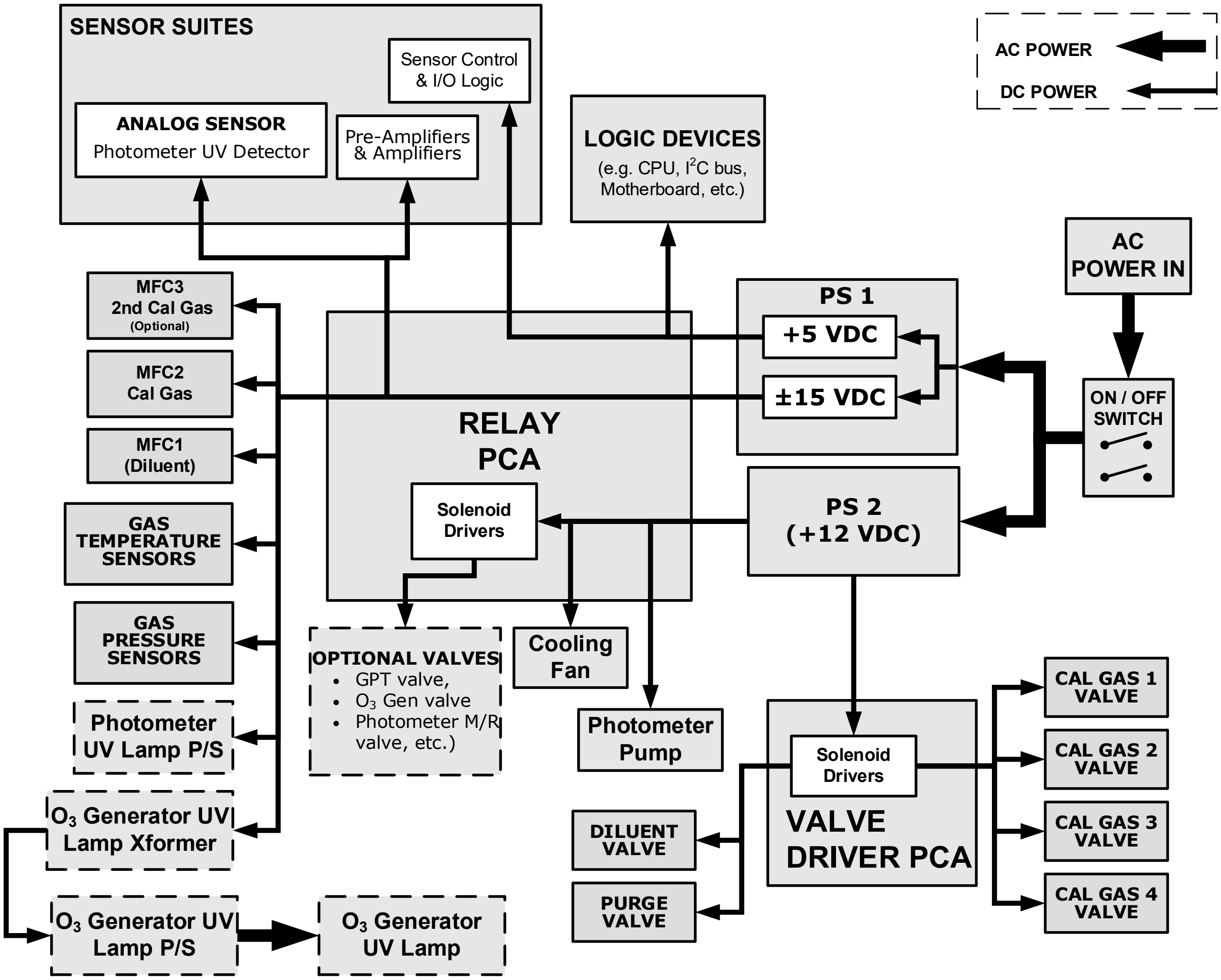


Figure 8-9. Power Distribution Block Diagram

8.3.7. Front Panel Touchscreen/Display Interface

The most commonly used method for communicating with the calibrator is via the instrument's front panel LCD touchscreen display from where users can input data and receive information directly.

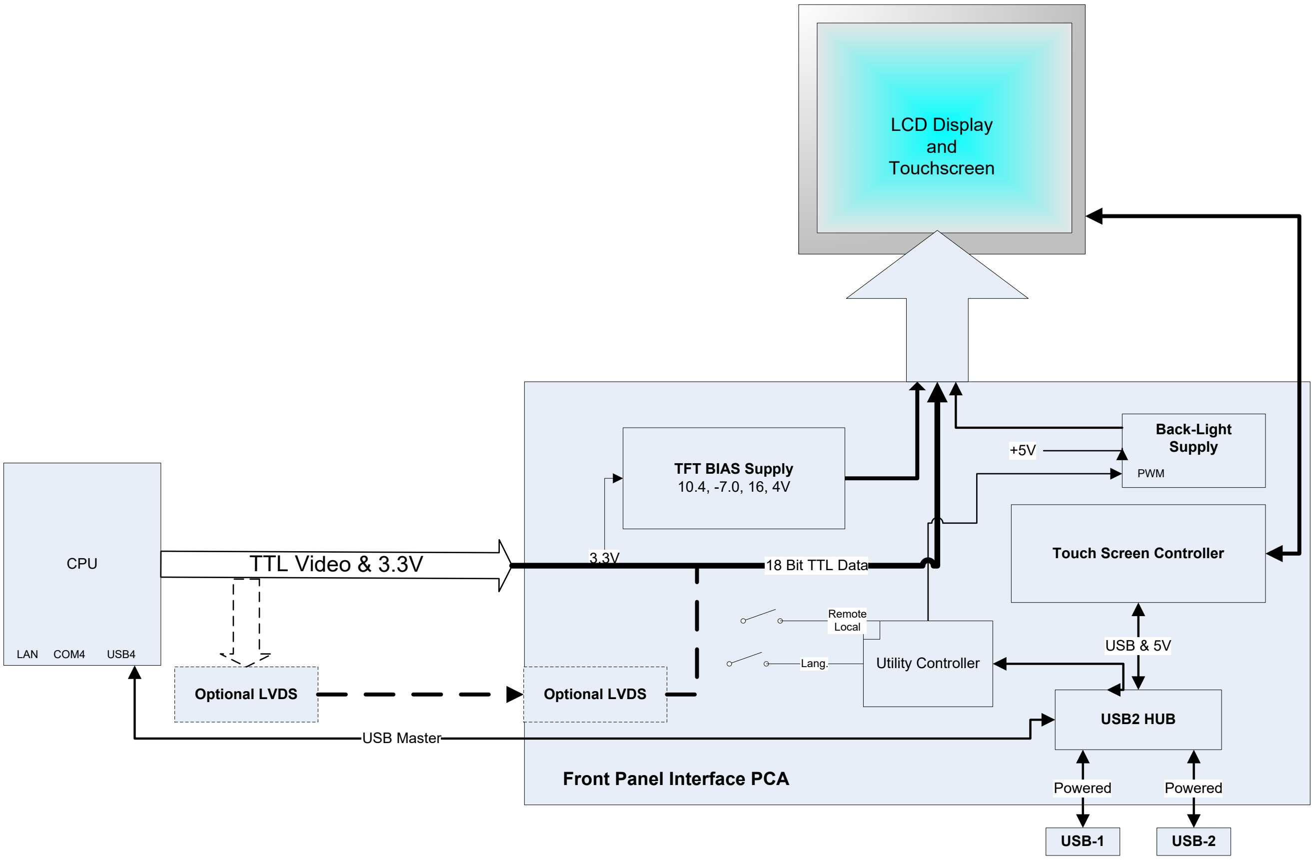


Figure 8-10. Front Panel Display Interface Block Diagram

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.

8.3.7.1. 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

8.4. SOFTWARE OPERATION

The calibrator's core module is a high performance, X86-based microcomputer running Windows CE. On top of the Windows CE shell, special software developed by Teledyne API interprets user commands from various interfaces, performs procedures and tasks and stores data in the CPU's memory devices. Figure 8-11 shows a block diagram of this software functionality.

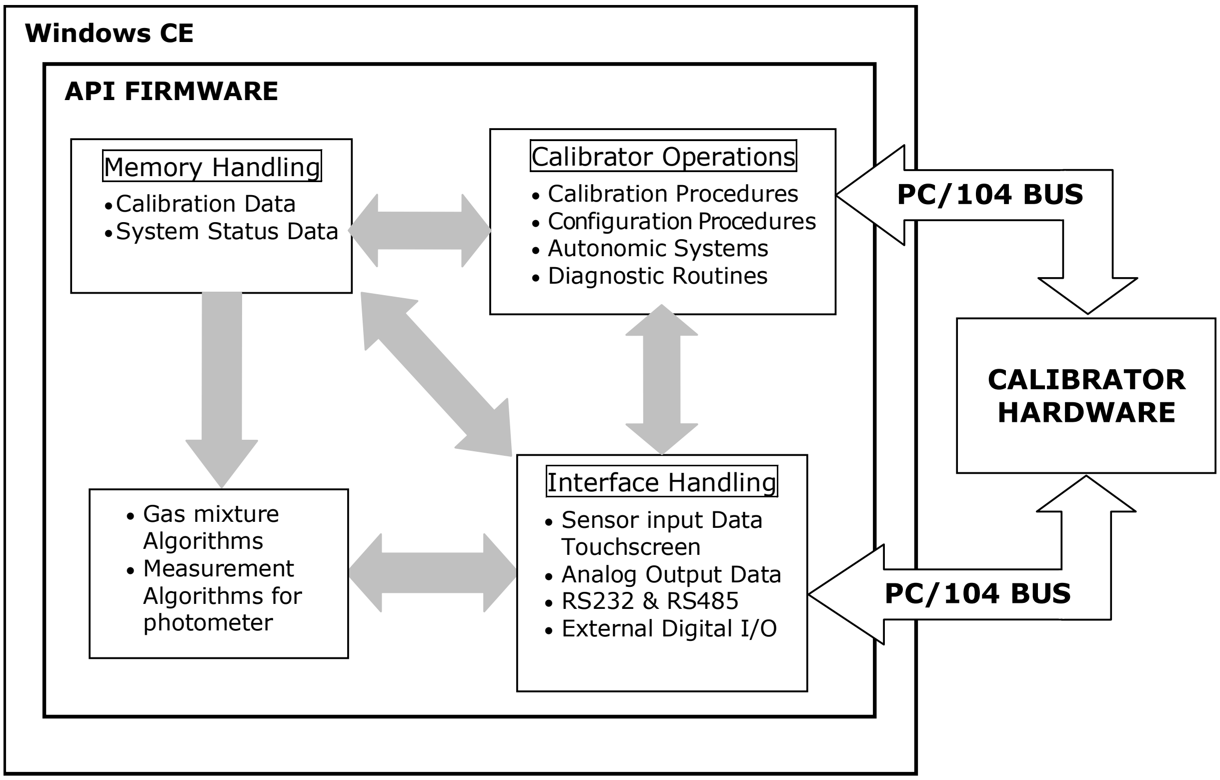


Figure 8-11. Schematic of Basic Software Operation

8.5. O_3 GENERATOR OPERATION

8.5.1. 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 therefore 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 applications 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 (185 nm). Ambient air is passed over an ultraviolet lamp, which splits some of the molecular oxygen (O_2) in the gas into individual oxygen atoms that attach to other existing oxygen molecules (O_2), forming ozone (O_3).

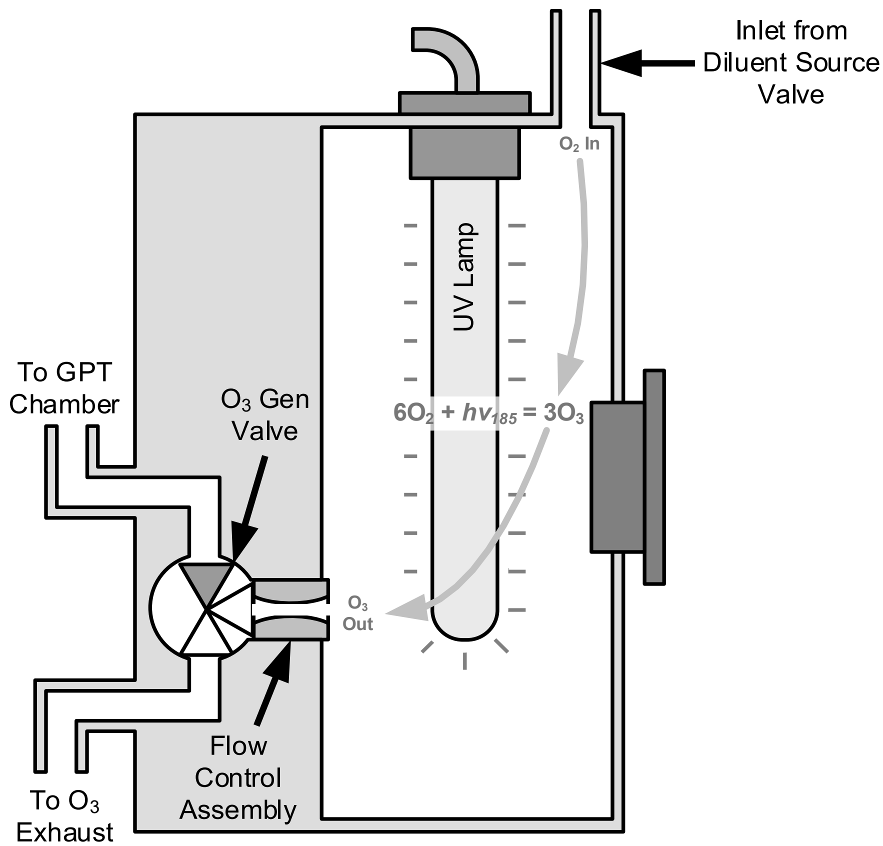


Figure 8-12. O_3 Generator Internal Pneumatics

8.5.2. O_3 GENERATOR – PNEUMATIC OPERATION

Pneumatic flow through the O_3 generator is created by supplying zero air (diluent) to it under pressure. The zero air source must be capable of maintaining a continuous flow rate of at least 100 cm^3/min unless the optional photometer is also installed, in which case the minimum continuous flow rate must be at least 1.1 LPM.

Input and output gas flow is directed by two valves, both of which must be open:

- The diluent inlet valve: This valve is located on the back panel and allows diluent / zero air into the calibrator.
- The O_3 generation valve. This valve is located on the body of the O_3 generator is downstream from the generator chamber itself and directs the output of the generator to either the GPT mixing chamber or the exhaust vent at the back of the calibrator.

The rate of flow through the O_3 generator is controlled by a 100 cm^3/min flow control assembly positioned between the O_3 generation chamber and the O_3 generation valve. A self-adjusting pressure regulator on the zero air (diluent) supply gas line maintains the pressure across the critical flow orifice of the flow control assembly (see Section 8.2.1.3).

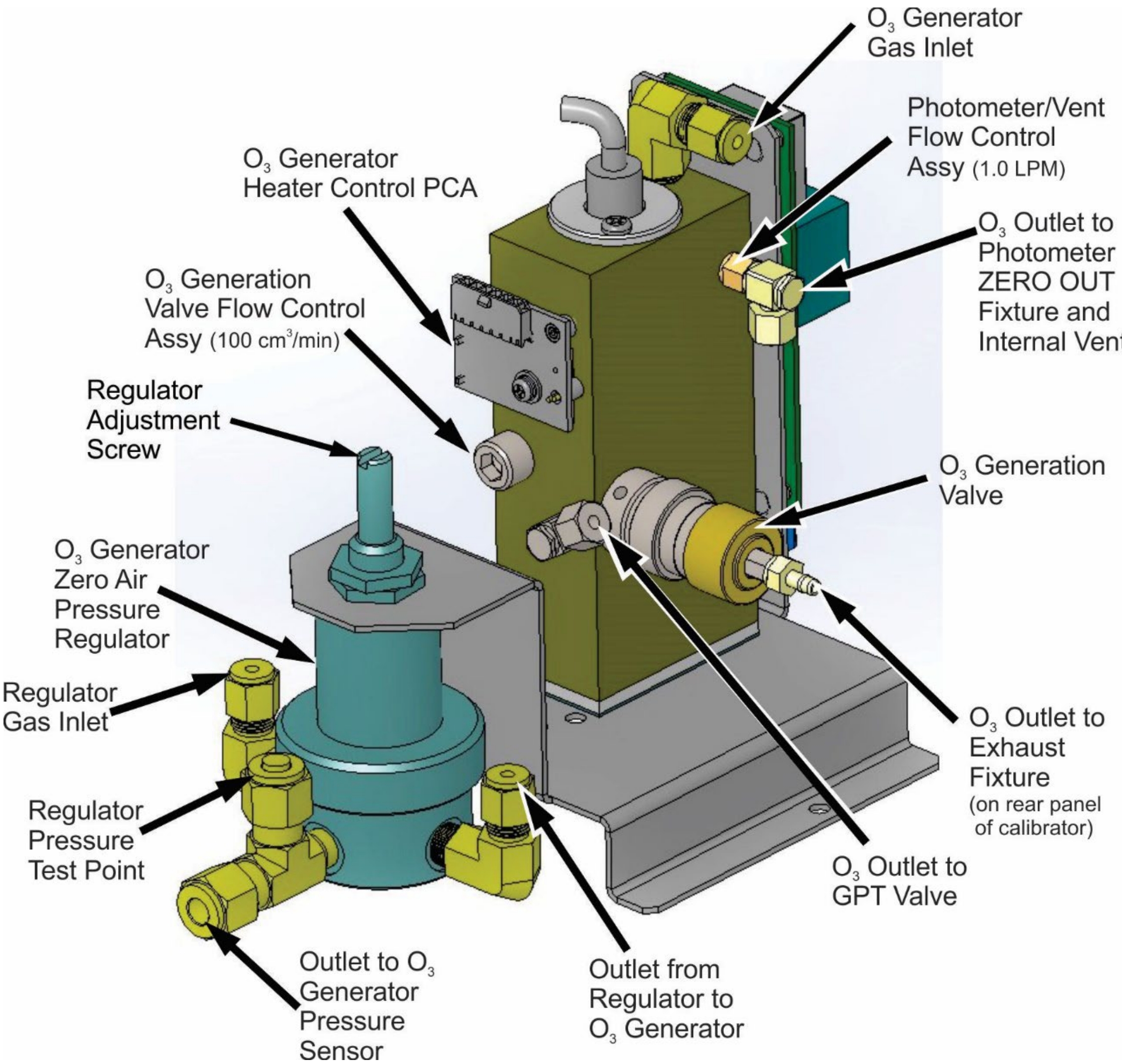


Figure 8-13. O_3 Generator Valve and Gas Fixture Locations

8.5.3. O_3 GENERATOR – ELECTRONIC OPERATION

Electronically the O_3 generator and its subcomponents act as peripheral devices operated by the CPU via the motherboard. Sensors, such as the UV lamp thermistor send analog data to the motherboard, where it is 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-Module. Commands from the CPU are sent to the motherboard and forwarded to the various devices via the calibrators I^2C bus.

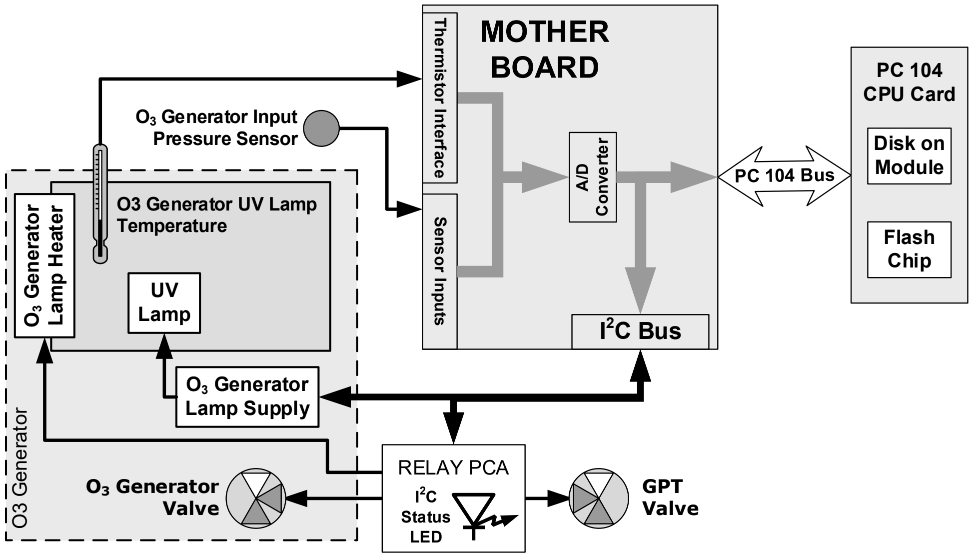


Figure 8-14. O_3 Generator – Electronic Block Diagram

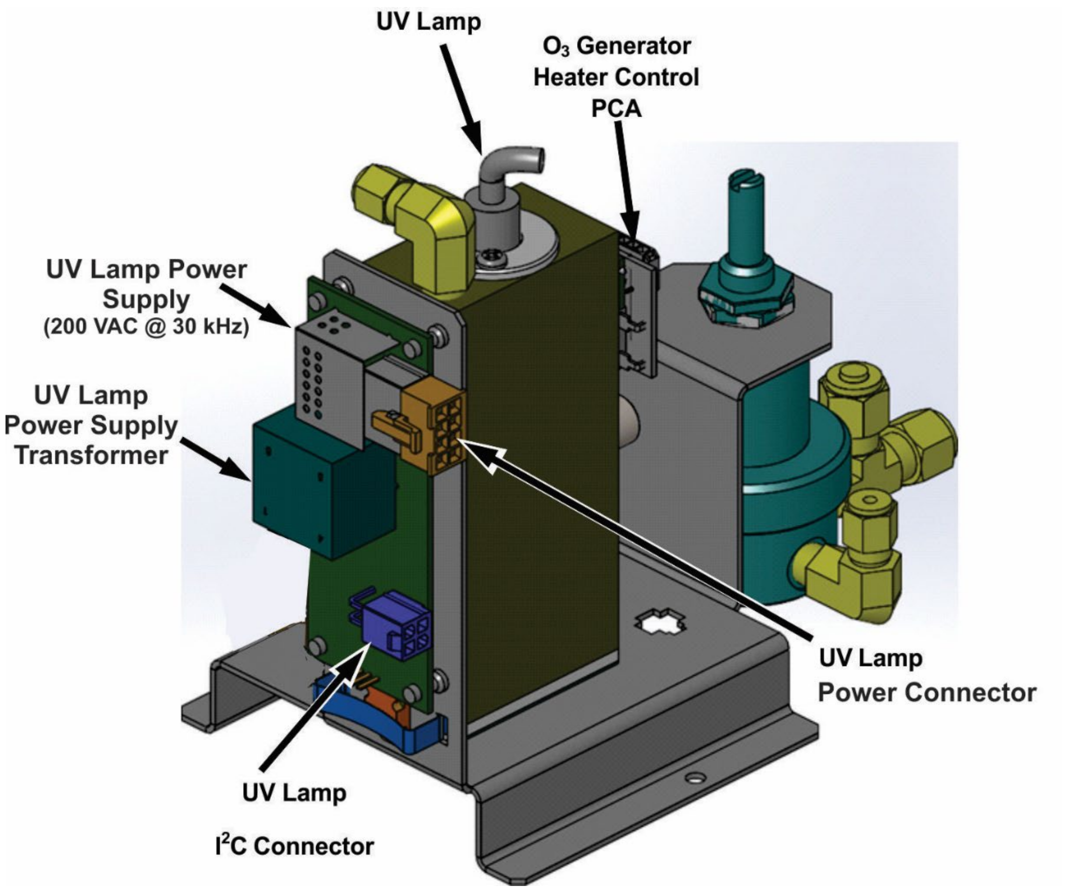


Figure 8-15. O_3 Generator Electronic Components Location

8.5.3.1. O_3 GENERATOR TEMPERATURE CONTROL

In order to operate at peak efficiency the UV lamp of the calibrator'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 as described in the Section on the Relay PCA (Section 8.3.2). The location of the thermistor and heater associated with the O_3 generator is shown in Figure 8-16:

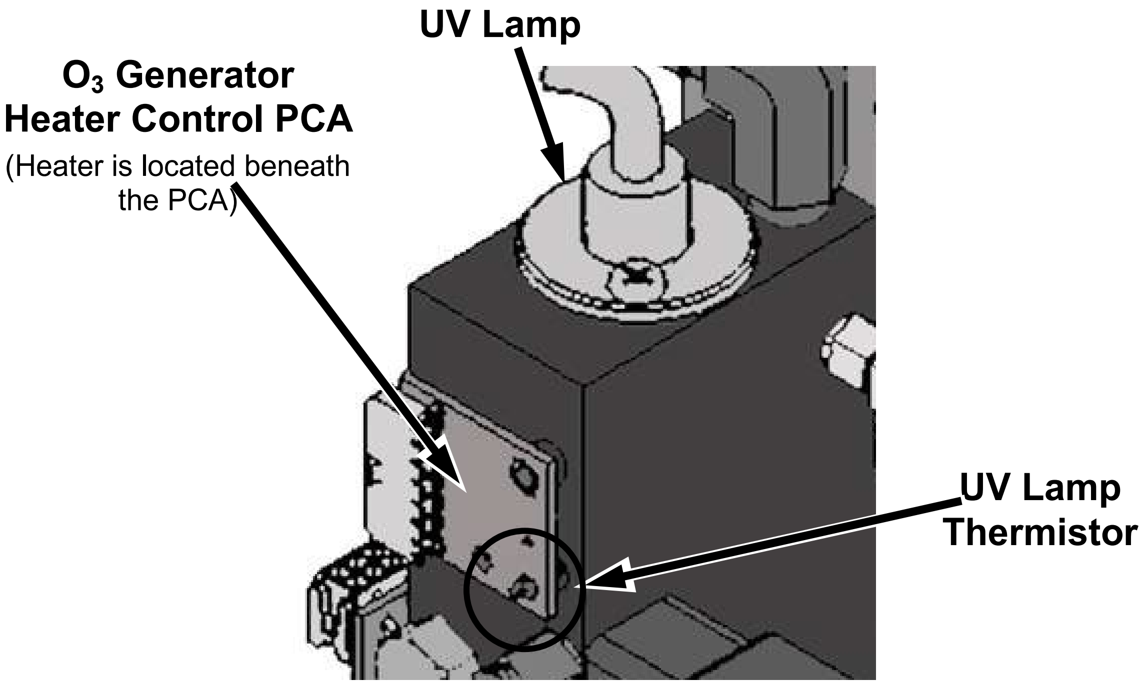


Figure 8-16. O_3 Generator Temperature Thermistor and DC Heater Locations

8.5.3.2. PNEUMATIC SENSOR FOR THE O_3 GENERATOR

A pressure sensor, located on the O3 generator and photometer, pressure/flow sensor PCA (see Figure 2-4), monitors the output gas pressure of the regulator on the O_3 generator's zero air supply. The regulator is adjusted at the factory to maintain a pressure of 20 PSIG on this line. If the pressure drops below 15 PSIG or rises above 25 PSIG a warning is issued.

8.6. PHOTOMETER OPERATION

The photometer's operation is based on the principle that ozone molecules absorb UV light of a certain wavelength (in this case 254 nm). A mercury lamp internal to the photometer emits UV light at that wavelength. This light shines down a hollow glass tube (absorption tube) that is alternately filled with sample gas during the measure phase and zero (calibration) gas during the reference phase. (Supplying the sample and calibration gases at ambient atmospheric pressure establishes a stable gas flow through the absorption tube). A detector, located at the other end of the glass tube measures the brightness of the UV light after it passes through the gas in the tube with and without O_3 present. The ratio of the UV light intensity between the measure phase (O_3 present) and the reference phase (no O_3 present) is a key component, along with other data such as the current temperature and pressure of the gas, to the CPU's calculating the O_3 content.

8.6.1. Measurement Method

This Section presents further details on the method of measurement.

8.6.1.1. 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 how the 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 gases at Standard Temperature and Pressure (STP) is:

Equation 8-5

$$I = I_0 e^{-\alpha LC} \quad \text{at STP}$$

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 calibrator, 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 algebra is required to rearrange the equation as follows:

Equation 8-6

$$C = \ln \frac{I_o}{I} \times \frac{1}{\alpha L} \quad \text{at STP}$$

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 8-7

$$C = \ln \frac{I_o}{I} \times \frac{1}{\alpha\, L} \times \frac{T}{273^o K} \times \frac{29.92 inHg}{P}$$

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 8-8

$$C = \ln \frac{I_o}{I} \times \frac{10^9}{\alpha\, L} \times \frac{T}{273^o K} \times \frac{29.92 inHg}{P}$$

The calibrator photometer:

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

8.6.1.2. 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 (see Figure 2-4 and Figure 8-13) 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 8-2. Calibrator 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 gases.
2 – 3 Seconds	Calibrator 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	Calibrator measures the average UV light intensity of Non-O_3 bearing Sample Gas (I_0) during this period.
CYCLE REPEAT EVERY 6 SECONDS	

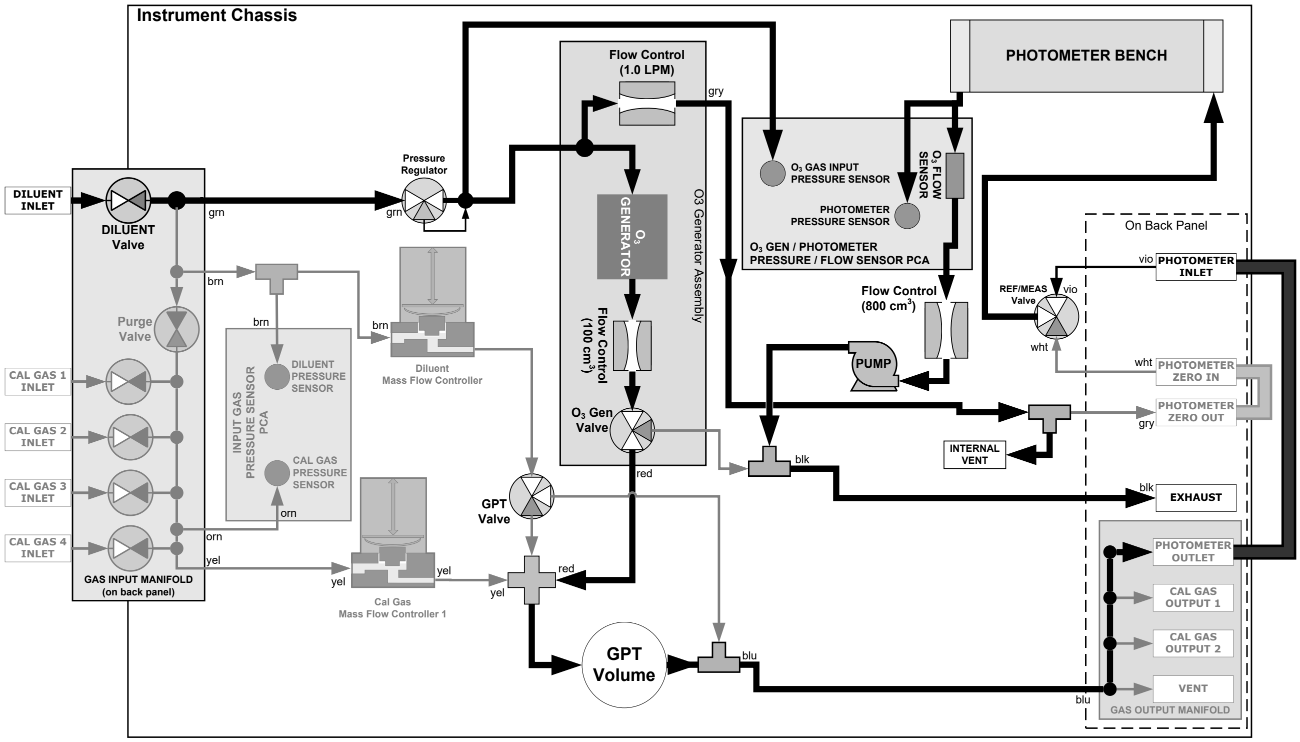


Figure 8-17. O_3 Photometer Gas Flow – Measure Cycle

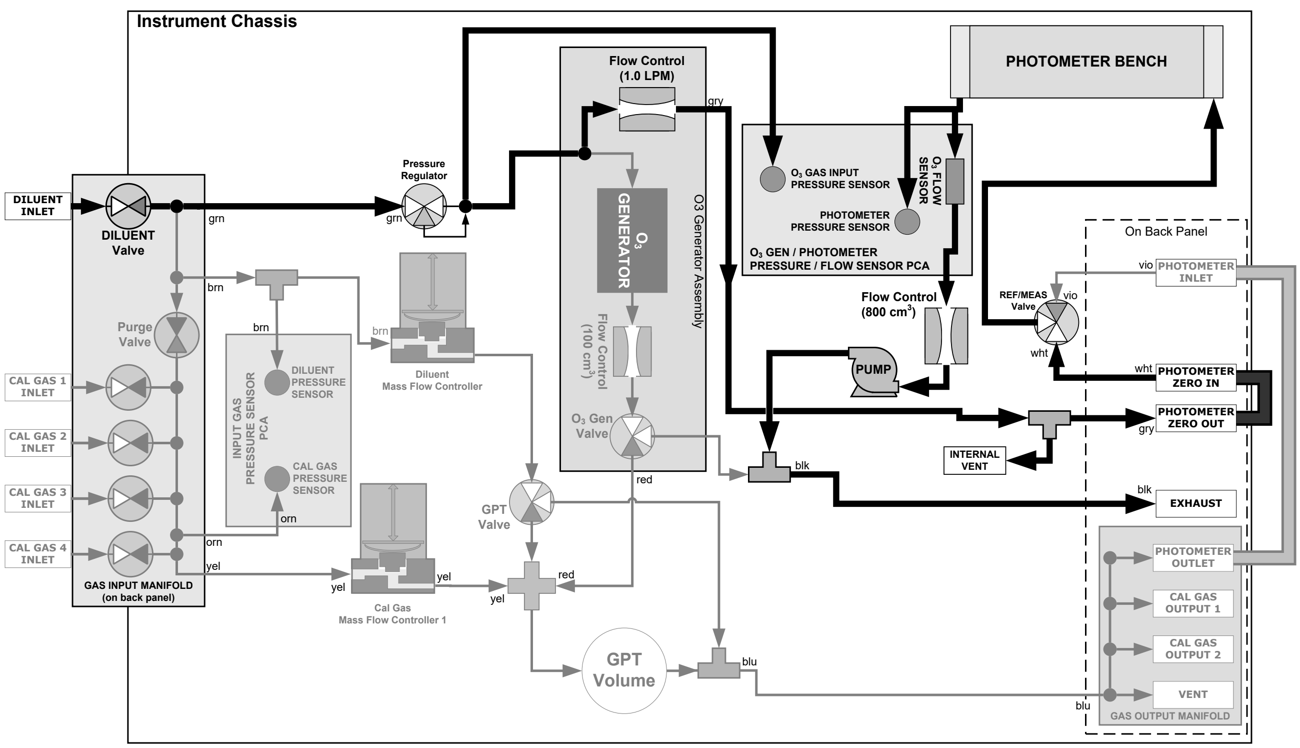


Figure 8-18. O_3 Photometer Gas Flow – Reference Cycle

8.6.1.3. THE ABSORPTION PATH

In the most basic terms, the calibrator 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 254nm 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 42 cm) 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 254nm. 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 VDC voltage analog signal voltage sent to the instrument's motherboard where it is digitized. The CPU to be uses this digital data in computing the concentration of O_3 in the absorption tube.

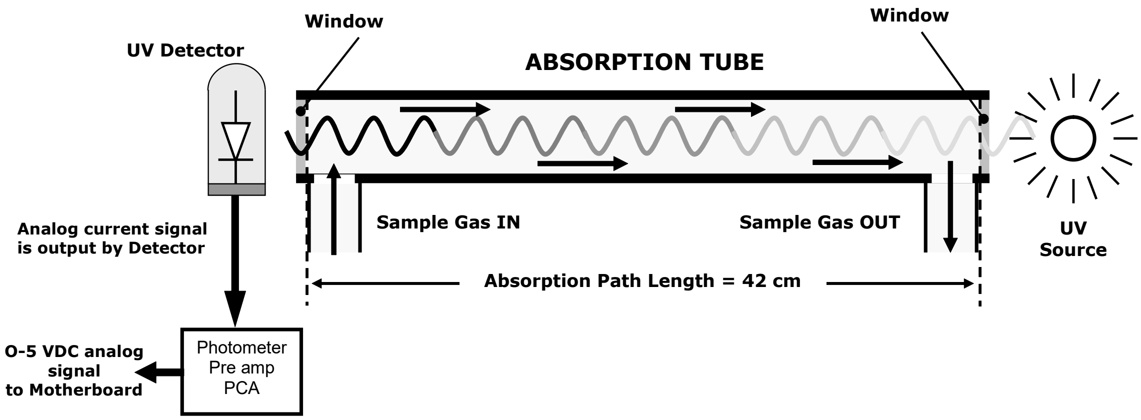


Figure 8-19. O_3 Photometer Absorption Path

8.6.1.4. INTERFERENT REJECTION

It should be noted that the UV absorption method for detecting ozone is subject to interference from a number of sources. The calibrator's photometer has been successfully tested for its ability to reject interference from sulfur dioxide, nitrogen dioxide, nitric oxide, water, and meta-xylene.

While the photometer rejects interference from the aromatic hydrocarbon meta-xylene, it should be noted that there are a very large number of volatile aromatic hydrocarbons that could potentially interfere with ozone detection. If the calibrator is installed in an environment where high aromatic hydrocarbon concentrations are suspected, specific tests should be conducted to reveal the amount of interference these compounds may be causing.

8.6.2. 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 185nm radiation. Only light at 254nm is emitted.
- An AC power supply to supply 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.
- 42 cm long quartz absorption tube.
- A thermistor attached to the quartz tube for measuring sample gas temperature.
- Gas inlet and outlet mounting blocks that route 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.
-

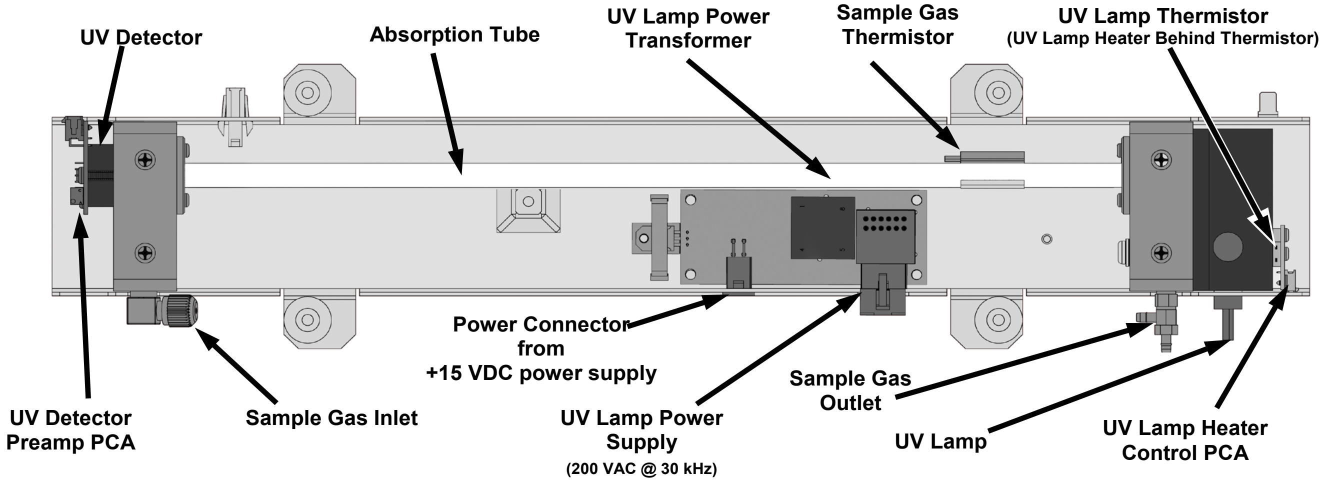


Figure 8-20. O_3 Photometer Layout – Top Cover Removed

8.6.3. 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 downstream from the absorption tube avoids problems caused by the pumping process heating and compressing the sample.

In order to 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 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 photometers absorption tube.

See Figure 8-17 and Figure 8-18 for depictions of the airflow related to the photometer.

8.6.4. Photometer Electronic Operation

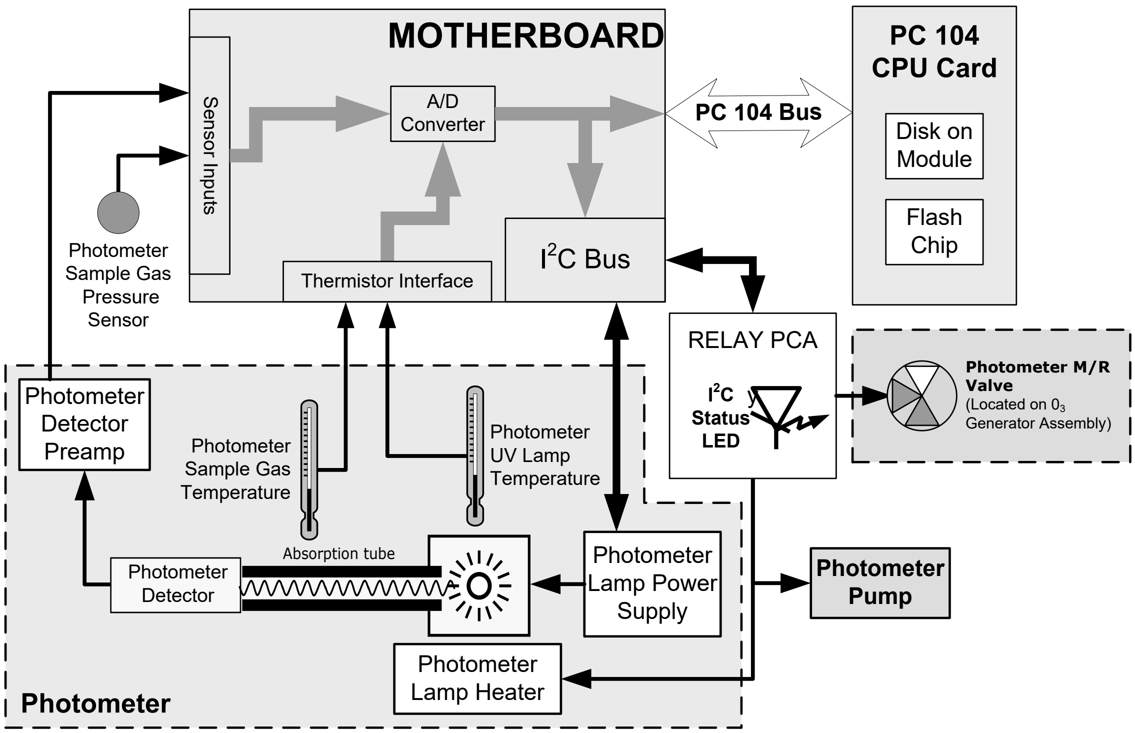


Figure 8-21. O_3 Photometer Electronic Block Diagram

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, or 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.

Incoming data from the UV light detector is amplified locally then converted to digital information by the motherboard. Output from the photometer's temperature sensors is 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 calibrator's pressure sensors.

8.6.4.1. O_3 PHOTOMETER TEMPERATURE CONTROL

In order to operate at peak efficiency, the UV lamp of the calibrator's O_3 photometer is maintained at a constant 58ºC. This is intentionally set at a temperature higher than the ambient temperature of the calibrator's operating environment to ensure 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.

This temperature is controlled as described in the Section on the relay pca (Section 8.3.2.2).

The following 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 Samp Temp** - The temperature of the Sample gas in the absorption tube reported in ºC.

8.6.4.2. PNEUMATIC SENSORS FOR THE O_3 PHOTOMETER

The 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 (See Equation 10-7). 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:

- **PHOTOFLOW** - flow rate of gas through the photometer measured in LPM.
- **PHOTOSPRESS** – 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**

.

GLOSSARY

Note: Some terms in this glossary may not occur elsewhere in this manual.

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 light energy that is actually converted into electricity
CEM	*Continuous Emission Monitoring*
Chemical formulas that may be included in this document:	
C_{O2}	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
NOx	nitrogen oxides, here defined as the sum of NO and NO_2
NOy	nitrogen oxides, often called odd nitrogen: the sum of NOx 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 256MB 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
LED	*Light Emitting Diode*
LPM	Liters Per Minute
MFC	*Mass Flow Controller*
M/R	Measure/Reference

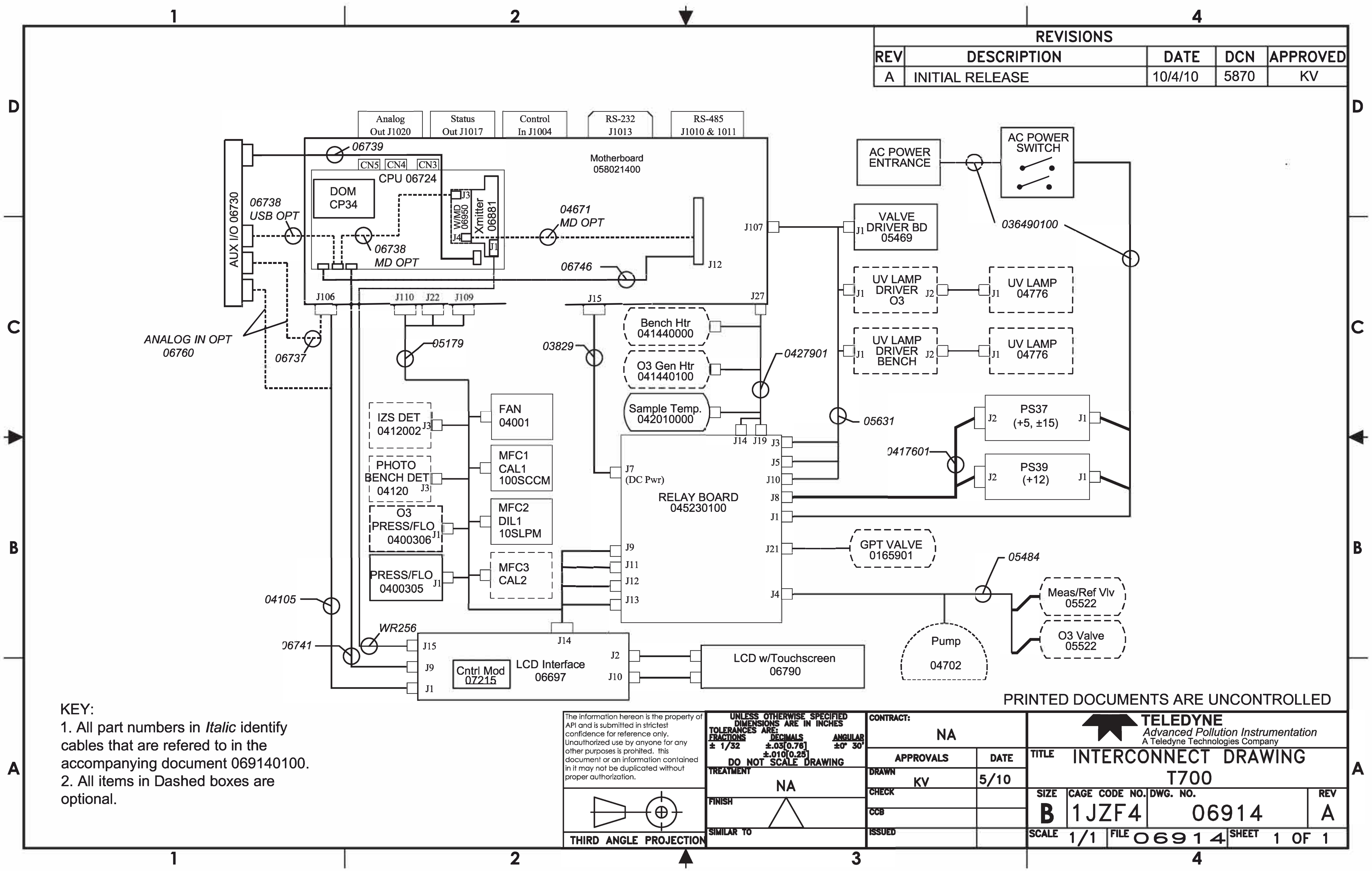
TERM	DESCRIPTION/DEFINITION
MOLAR MASS	the mass, expressed in grams, of 1 mole of a specific substance. Conversely, one mole is the amount of the substance needed for the molar mass to be the same number in grams as the atomic mass of that substance. EXAMPLE. The atomic weight of Carbon is 12 therefore 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
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*

TERM	DESCRIPTION/DEFINITION
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*

MODBUS Register Address (dec., 0-based)	Description	Units
MODBUS Floating Point Input Registers (32-bit IEEE 754 format; read in high-word, low-word order; read-only)		
0	Actual cal. gas flow rate	LPM
2	Actual diluent flow rate	LPM
4	Photometer measured ozone concentration	PPB
6	N/A	—
8	Ozone generator flow rate	LPM
10	Ozone generator lamp drive	mV
12	Ozone generator lamp temperature	°C
14	Cal. gas pressure	PSIG
16	Diluent pressure	PSIG
18	Regulator pressure	PSIG
20	Internal box temperature	°C
22	Permeation tube #1 temperature [3]	°C
24	Permeation tube flow rate [3]	LPM
26	Photometer detector measure reading	mV
28	Photometer detector reference reading	mV
30	Photometer sample flow rate	LPM
32	Photometer lamp temperature	°C
34	Photometer sample pressure	Inches Hg
36	Photometer sample temperature	°C
38	Photometer slope computed during zero/span bench calibration	—
40	Photometer offset computed during zero/span bench calibration	PPB
42	Ground reference	mV
44	Precision 4.096 mV reference	mV
46	Permeation tube #2 temperature [1]	°C
48	Ozone Gen Fraction [2]	—

MODBUS Register Address (dec., 0-based)	Description	Units
MODBUS Discrete Input Registers (single-bit; read-only)		
0	System reset warning	
1	Box temperature warning	
2	Photometer lamp temperature warning	
3	O_3 generator lamp temperature warning	
4	Permeation tube #1 temperature warning [3]	
5	Photometer reference warning	
6	Photometer lamp stability warning	
7	N/A	
8	Regulator pressure warning	
9	Any MFC pressure outside of warning limits	
10	Any MFC drive less than 10% of full scale or greater than full scale	
11	Any MFC sensor offset greater than allowable limit	
12	Rear board communication warning	
13	Relay board communication warning	
14	Valve board communication warning	
15	O_3 generator or photometer lamp I^2C driver chip communication warning	
16	Front panel communication warning	
17	Firmware is unable to communicate with any MFC	
18	Analog calibration warning	
19	System is OK (same meaning as *SYSTEM_OK* I/O signal)	
20	O_3 generator not yet stabilized	
21	Permeation tube #2 temperature warning [1]	
MODBUS Coil Registers (single-bit; read/write)		
00-99	Trigger execution of sequence whose name begins with “00” - “99”. Turning a coil on executes a sequence. Turning a coil off does nothing. When reading coils, the value indicates which sequence is executing. If a coil is on, the sequence is executing; if off the sequence is not executing. Supports nested sequences, so multiple sequence coils may be on simultaneously.	
100	Turning coil on turns on purge. Turning coil off does nothing. When reading coil, the value indicates whether purge is active. If on, purge is active; if off, purge is not active. Purge may be invoked within a sequence, so purge coil may be on at the same time as a sequence coil.	
101	Turning coil on puts instrument in standby. Turning coil off does nothing. When reading coil, the value indicates whether instrument is in standby mode. If on, instrument is in standby; if off, instrument is not in standby.	
200-211	Connected to the control outputs (CONTROL_OUT_1– CONTROL_OUT_12). These coils may be turned both on and off. Reading the coils indicates the current state.	

[1] Dual permeation tube option.
[2] Low range option.
[3] Permeation tube option.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Analog Out J1020
Status Out J1017
Control In J1004
RS-232 J1013
RS-485 J1010 & 1011
06739
Motherboard 058021400
CN5 CN4 CN3
CPU 06724
DOM CP34
WMD 06950
Xmitter 06881
J3
J4
J1
06738 USB OPT
06738 MD OPT
04671 MD OPT
AUX I/O 06730
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J12
J107
J106
J110 J22 J109
J15
J27
ANALOG IN OPT 06760
06737
05179
03829
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O3 Gen Htr 041440100
Sample Temp. 042010000
0427901
AC POWER ENTRANCE
AC POWER SWITCH
036490100
VALVE DRIVER BD 05469
UV LAMP DRIVER O3
UV LAMP 04776
UV LAMP DRIVER BENCH
UV LAMP 04776
J1 J2
05631
PS37 (+5, ±15)
0417601
PS39 (+12)
IZS DET 0412002
PHOTO BENCH DET 04120
O3 PRESS/FLO 0400306
PRESS/FLO 0400305
FAN 04001
MFC1 CAL1 100SCCM
MFC2 DIL1 10SLPM
MFC3 CAL2
J14 J19
J3 J5 J10 J8 J1
J7 (DC Pwr)
RELAY BOARD 045230100
J9 J11 J12 J13
J21
J4
GPT VALVE 0165901
05484
Meas/Ref Vlv 05522
O3 Valve 05522
Pump 04702
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LCD Interface 06697
J2 J10
LCD w/Touchscreen 06790
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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 5/10
CHECK
CCB
ISSUED
TELEDYNE
Advanced Pollution Instrumentation
A Teledyne Technologies Company
TITLE INTERCONNECT DRAWING T700
SIZE B
CAGE CODE NO. 1JZF4
DWG. NO. 06914
REV A
SCALE 1/1
FILE 06914
SHEET 1 OF 1