



TELEDYNE

ADVANCED POLLUTION INSTRUMENTATION

A Teledyne Technologies Company

Operation Manual

Model T700 Dynamic Dilution Calibrator

Also supports operation of

Model T700U

(when used in conjunction with T700U addendum, PN 06876)

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ABOUT TELEDYNE ADVANCED POLLUTION INSTRUMENTATION (TAPI)

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

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

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

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

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

Note

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

Telephone: 800-324-5190 Email: api-customerservice@teledyne.com
or by accessing various service options on our website:

<http://www.teledyne-api.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



Cet instrument doit être utilisé aux fins décrites et de la manière décrite dans ce manuel. Si vous utilisez cet instrument d'une autre manière que celle pour laquelle il a été prévu, l'instrument pourrait se comporter de façon imprévisible et entraîner des conséquences dangereuses.

NE JAMAIS utiliser un analyseur de gaz pour échantillonner des gaz combustibles!

WARRANTY

WARRANTY POLICY (02024F)

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

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

COVERAGE

After the warranty period and throughout the equipment lifetime, TAPI 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-TAPI MANUFACTURED EQUIPMENT

Equipment provided but not manufactured by TAPI 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 "Packing Components for Return to Teledyne API's Customer Service" in the *Primer on Electro-Static Discharge* section of this manual, and for RMA procedures please refer to our Website at <http://www.teledyne-api.com> under Customer Support > Return Authorization.

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ABOUT THIS MANUAL

Presented here is information regarding the documents that are included with this manual (Structure) and how the content is organized (Organization).

STRUCTURE

This T700 manual, PN 06873, is comprised of multiple documents, assembled in PDF format, as listed below.

Part No.	Rev	Name/Description
06873	B	Operation Manual, T700 Dynamic Dilution Calibrator
05623	D	Appendix A, Menu Trees and related software documentation
06852	B	Spare Parts List (in Appendix B of this manual)
07565	A	Recommended Spares Stocking Levels (in Appendix B of this manual)
05625	B	Appendix C, Repair Form
069140100	A	Interconnect List (in Appendix D of this manual)

Appendix D, Schematics:

06914	A	Interconnect Diagram
04420	B	SCH, PCA 04120, UV DETECTOR
04422	A	SCH, PCA 04144, DC HEATER/TEMP SENSOR
04421	A	SCH, PCA 04166, UV LAMP POWER SUPPLY
04354	D	SCH, PCA 04003, Pressure/Flow Transducer Interface
04524	E	SCH, PCA 04523, RELAY CARD
05698	B	SCH, PCA 05697 ADPTR, EXT VALVE DRIVER
05803	B	SCH, PCA 05802, MOTHERBOARD, GEN-5
06698	D	SCH, PCA 06670, INTRFC, LCD TCH SCRN,
06882	B	SCH, LVDS TRANSMITTER BOARD
06731	B	SCH, AUX-I/O BOARD

Note

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

ORGANIZATION

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

Part I contains introductory information that includes an overview of the calibrator, descriptions of the available options, specifications, installation and connection instructions, and the initial calibration and functional checks..

Part II comprises the operating instructions, which include basic, advanced and remote operation, calibration, diagnostics, testing, validating and verifying.

Part III provides detailed technical information, such as principles of operation, maintenance, and troubleshooting and repair. It includes Frequently Asked Questions

and a Glossary, and also has a section that provides important information about electrostatic discharge and avoiding its consequences.

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

REVISION HISTORY

This section provides information regarding the initial release and subsequent changes to this manual.

T700 Manual, PN 06873 Rev B, DCN 6388			
Date	Rev	DCN	Change Summary
2012 May 08	B	6388	Administrative changes: restructure/reformat Technical changes: various
2010 October 06	A	5839	Initial Release

Document part numbers and revision letters included in the initial release are as follows:		
PN	Rev	Document
06873	B	Operation Manual, T700 Dynamic Dilution Calibrator
05623	D	Appendix A, Menu Trees w/ related software documentation
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PART I
—
GENERAL INFORMATION

1. INTRODUCTION

This section provides an overview of the Model T700 calibrator, its features, and its options.

1.1. T700 CALIBRATOR OVERVIEW

The Model T700 (typically referred to as T700) is a microprocessor-controlled calibrator for precision gas calibrators. Using a combination of highly accurate mass flow controllers and compressed sources of standard gases, calibration standards are provided for multipoint span and zero checks. Up to four gas sources may be used.

The T700 can be equipped with an optional built-in, programmable ozone generator for accurate, dependable ozone calibrations. The T700 also produces NO₂ 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 Gas Phase Titrations (GPT). To ensure accurate NO₂ output, the calibrator with photometer option measures the ozone concentration prior to doing a GPT.

As many as 50 independent calibration sequences may be programmed into the T700, 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 T700 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 T700 Dynamic Dilution 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 Ozone, NO, NO₂, CO, HC, H₂S, SO₂
- 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 chamber
- Optional zone 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 present in 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 Advanced Pollution Instruments at:

TOLL-FREE: 800-324-5190

PHONE: +1 858-657-9800

FAX: +1 858-657-9816

EMAIL: apisales@teledyne.com

WEBSITE: <http://www.teledyne-api.com/>

Table 1-1: Analyzer 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 3.3.2.6
	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 3.3.2.6
	2A	UV Photometer Module (to increase accuracy of O ₃ Generator, Option 1A)	Section 3.3.2.6
	5	Permeation Tube Oven	Section 3.3.3
	73	Dual Gas Output (NO _y – special)	Section 3.3.4 Figure 3-28
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

Option	Option Number	Description/Notes	Reference	
 CAUTION – GENERAL SAFETY HAZARD THE T700 CALIBRATOR WEIGHS CLOSE TO 18 KG (40 POUNDS) WITH ALL OPTIONS. TO AVOID PERSONAL INJURY WE RECOMMEND THAT TWO PERSONS LIFT AND CARRY IT BUT FIRST 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	(Customer Svc)	
	46B	Photometer Kit, Spares for One Unit	(Customer Svc)	
	46C	Photometer W/ IZS Spares Kit For 1 Unit	(Customer Svc)	
Communications		For remote serial, network and Internet communication with the analyzer.		
Cables		Type	Description	
	60A	RS-232	Shielded, straight-through DB-9F to DB-25M cable, about 1.8 m long. Used to interface with older computers or code activated switches with DB-25 serial connectors.	Section 3.3.1.7
	60B	RS-232	Shielded, straight-through DB-9F to DB-9F cable of about 1.8 m length.	Section 3.3.1.7
	60C	Ethernet	Patch cable, 2 meters long, used for Internet and LAN communications.	Section 3.3.1.7, 4.7.2, and 5.4
	60D	USB	Cable for direct connection between instrument (rear panel USB port) and personal computer.	Section 3.3.1.7
USB Port	64A	For rear panel connection to personal computer.		Sections 4.7 and 5.4.3
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).		Sections 3.3.1.7 and 4.7.3
External Valve Driver Capability - For driving up to eight, 8-watt valves				
	48A	12V External Valve Driver Capability		Section 3.3.1.6
	48B	24V External Valve Driver Capability		
NIST Traceable, Primary Standard Certification for use as a Primary Ozone Standard if purchased with the O₃ generator and photometer options, 1A and 2A, respectively.				
	95A	Factory Calibration		Section 3.3.2.2
	95B	Calibration as a Primary Standard		
	95C	Calibration to NIST-SRP		
For this application the T700 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.				
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 Customer Service 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 Customer Service for a specially programmed Disk on Module containing the second language.		N/A

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2. SPECIFICATIONS AND APPROVALS

2.1. SPECIFICATIONS

Table 2-1: 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
Zero Air Required	10 SLPM @ 30 PSIG Optional: 20 SLPM @ 30 PSIG
CAL Gas Input Ports	4 (configurable)
Diluent Gas Input Ports	1
Response Time	60 Seconds (98%)

Table 2-2: T700 Dilution Electrical and Physical Specifications

Parameter	Specification
AC Power	85V-264V, 47Hz-63Hz
Actual Power Draw	At 115V ~ Start up: 110 W, Steady State: 140 W At 230V ~ Start up: 159 W, Steady State: 148 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	5-40°C
Humidity Range	0 - 95% RH, non-condensing

Parameter	Specification
Operating Altitude	10,000 ft Maximum
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 optional photometer, GPT, and O ₃ generator

Table 2-3: T700 Specifications for Optional Ozone Generator

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

Table 2-4: T700 Specifications for Optional O₃ Photometer

Parameter	Specification
Full Scale Range	100 ppb 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

2.2. APPROVALS AND CERTIFICATIONS

The Teledyne API Model T700 calibrator was tested and certified for Safety and Electromagnet Compatibility (EMC). This section presents the compliance statements for those requirements and directives.

2.2.1. SAFETY

IEC 61010-1:2001

CE: 2006/95/EC, Low-Voltage Directive

North American:

cNEMKO (Canada): CAN/CSA-C22.2 No. 61010-1-04

NEMKO-CCL (US): UL No. 61010-1 (2nd Edition)

2.2.2. EMC

EN 61326-1 (IEC 61326-1), Class A Emissions/Industrial Immunity

EN 55011 (CISPR 11), Group 1, Class A Emissions

FCC 47 CFR Part 15B, Class A Emissions

CE: 2004/108/EC, Electromagnetic Compatibility Directive

2.2.3. OTHER TYPE CERTIFICATIONS

For additional certifications, please contact Customer Service.

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3. 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.

3.1. UNPACKING AND INITIAL SETUP



CAUTION – RISK of Personal Injury

THE T700 WEIGHS ABOUT 18 KG (40 POUNDS) WITHOUT OPTIONS INSTALLED.
TO AVOID PERSONAL INJURY, WE RECOMMEND USING TWO PERSONS TO
LIFT AND CARRY 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. See *A Primer on Electro-Static Discharge* in this manual for more information on preventing ESD damage.



CAUTION – Avoid Damage to the Instrument

BEFORE operating instrument, remove dust plugs from pneumatic ports.

Note

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

**WARNING!**

NEVER DISCONNECT 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 Test and Validation Data Sheet* (P/N 05731) is an important quality assurance and calibration record for this instrument. It should be placed in the quality records file for this instrument.
3. Carefully remove the top cover of the calibrator and check for internal shipping damage.
 - Remove the locking screw located in the top, center of the Front panel.
 - Remove the two screws fastening the top cover to the unit (one per side towards the rear).
 - Slide the cover backwards until it clears the calibrator's front bezel.
 - Lift the cover straight up.
4. Inspect the interior of the instrument to ensure all circuit boards and other components are in good shape and properly seated.
5. Check the connectors of the various internal wiring harnesses and pneumatic hoses to ensure they are firmly and properly seated.
6. Verify that all of the optional hardware ordered with the unit has been installed. These are checked on the paperwork accompanying the calibrator.

3.1.1. VENTILATION CLEARANCE

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

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 calibrator. See Table 1-1 of this manual for more information.

3.2. CALIBRATOR LAYOUT

Figure 3-1 shows the calibrator's front panel layout, followed by a close-up of the display/touchscreen in and description in Table 3 1. The two USB ports on the front panel are provided for the connection of peripheral devices:

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

3.2.1. FRONT PANEL

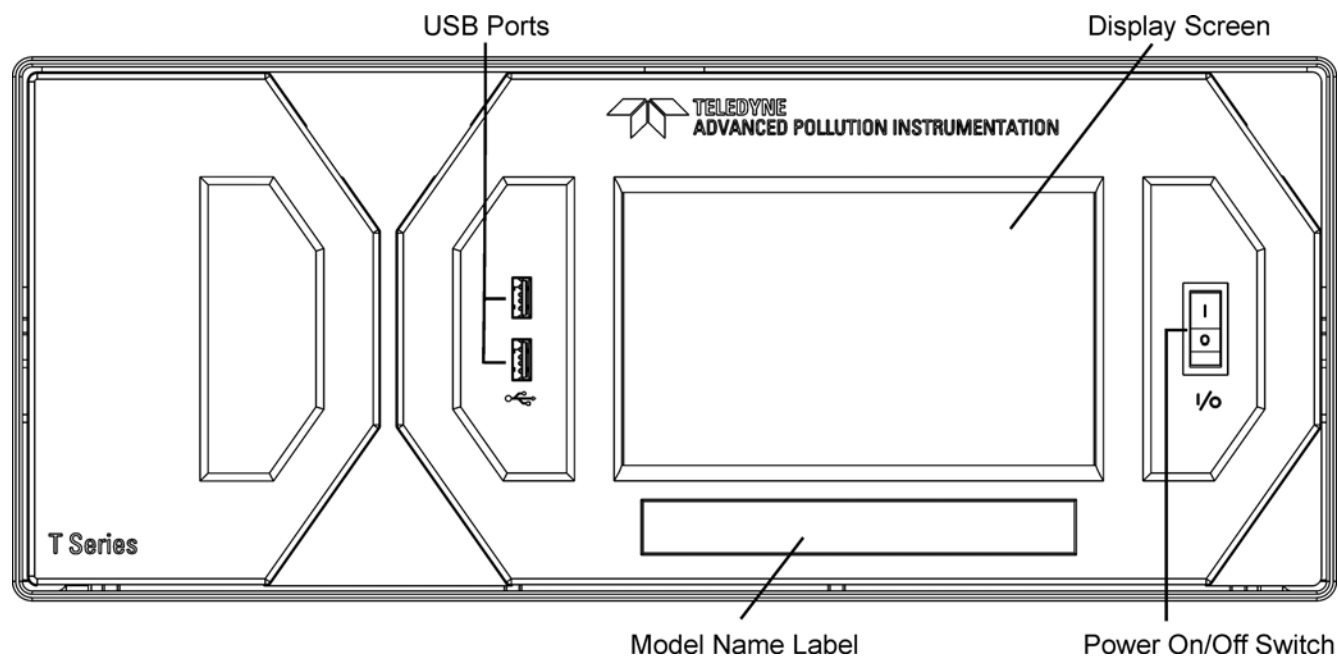


Figure 3-1: T700 Front Panel Layout



Figure 3-2: Display Screen and Touch Control

The front panel liquid crystal display (LCD) screen includes touch control. Upon calibrator start-up, the LCD shows a splash screen and other initialization indicators before the main display appears, similar to Figure 3-2 above.



CAUTION – Avoid Damaging Touchscreen
Do not use hard-surfaced instruments such as pens to operate the touch screen buttons.

Table 3-1: Display Screen and Touch Control Description

Field	Description/Function			
LEDs indicating the states of the calibrator:				
	Name	Color	State	Definition
	Active	Green	off	Unit is operating in STANDBY mode. This LED is lit when the instrument is actively producing calibration gas (GENERATE mode).
	Auto Timer	Yellow	off	This LED is lit only when the calibrator is performing an automatic calibration sequence.
	Fault	Red	blinking	The calibrator is warming up and therefore many of its subsystems are not yet operating within their optimum ranges. Various warning messages may appear in the Param field.
Target/ Actual	Gas concentrations, Cal gas MFC and Diluent MFC values with unit of measure			
Mode	Displays the name of the calibrator's current operating mode (default is STANDBY at initial startup).			
Param	Displays a variety of informational messages such as warning messages, operational data, test function values and response messages during interactive tasks.			
Touchscreen control: row of eight buttons with dynamic, context sensitive labels; buttons are blank when inactive/inapplicable.				

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

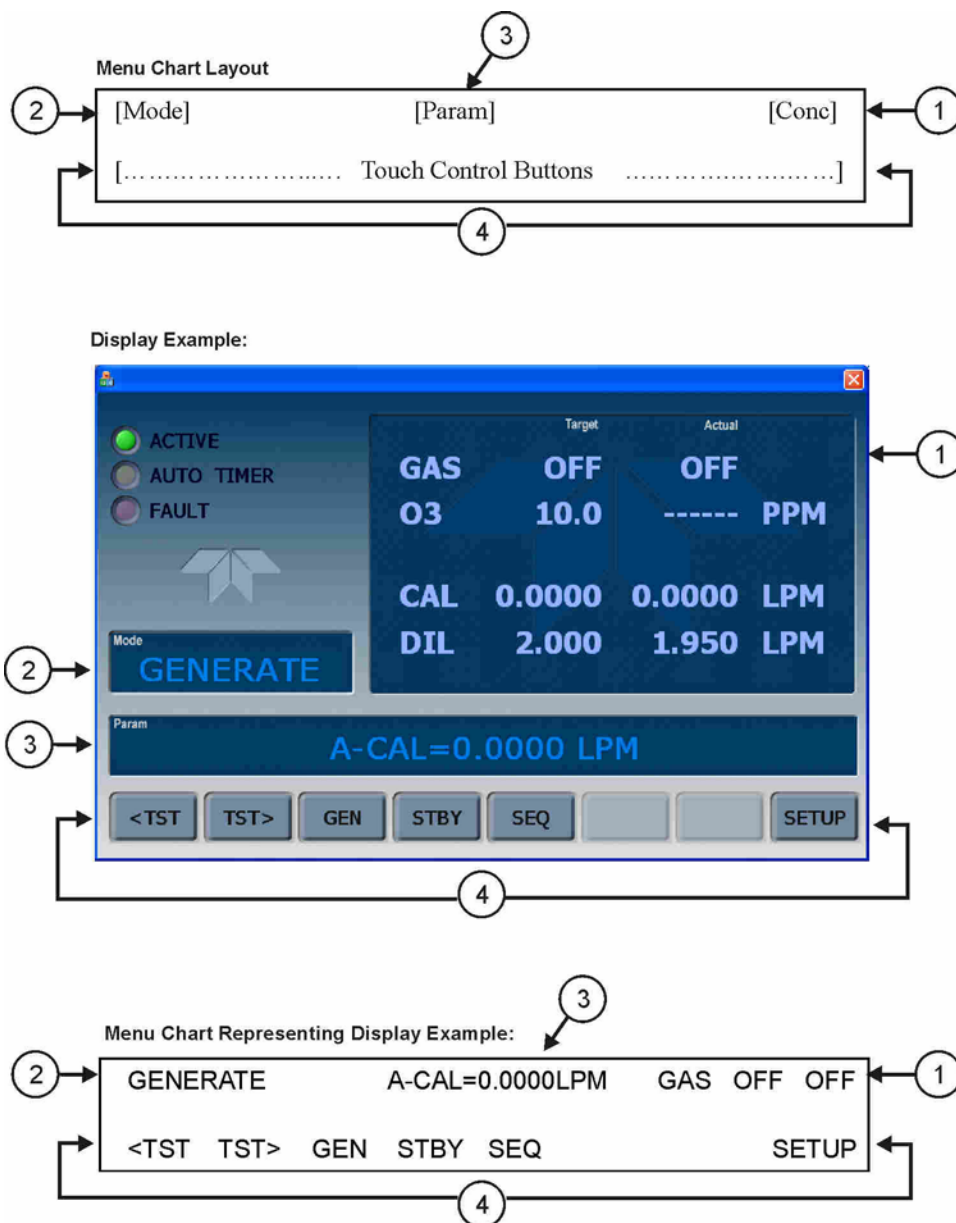


Figure 3-3: Display/Touch Control Screen Mapped to Menu Charts

3.2.2. REAR PANEL

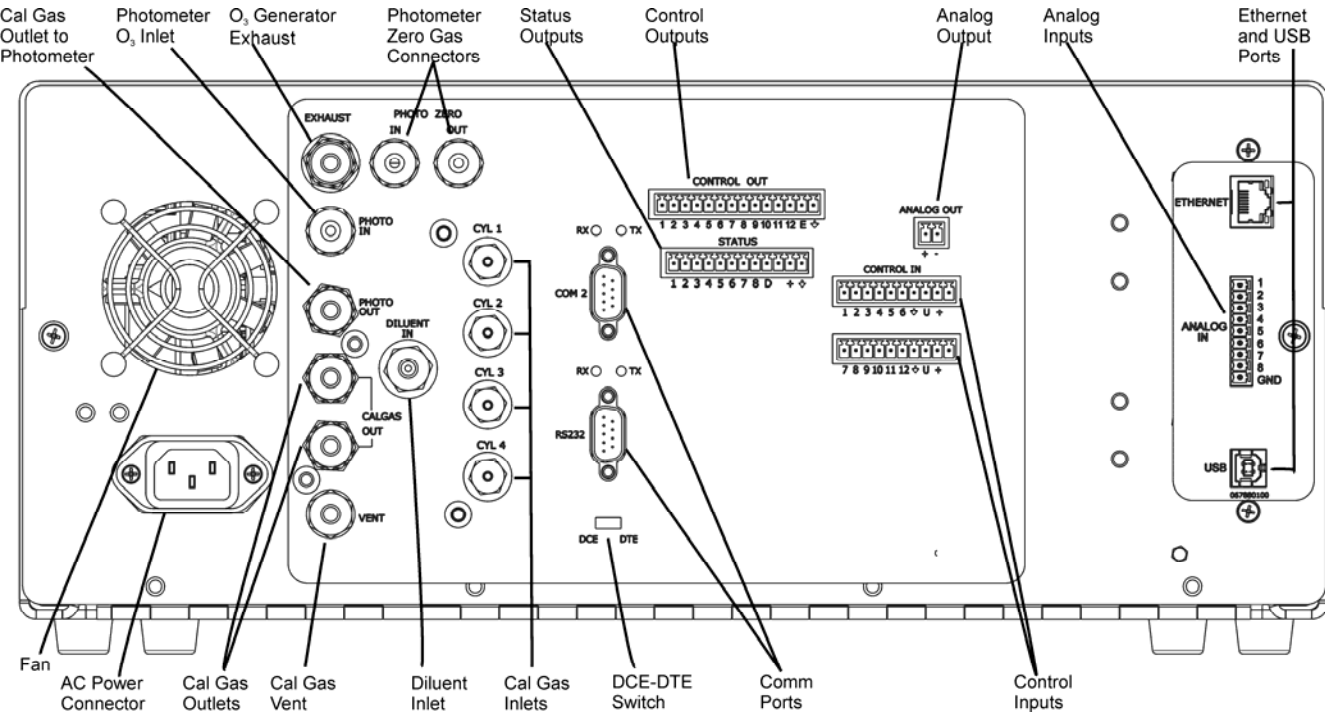


Figure 3-4: T700 Rear Panel Layout

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

Table 3-2: Rear Panel Description

Component	Function
Fan	Cools instrument by pulling 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 5.1)
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.
Label w/power specs	Identifies the analyzer model number and lists voltage and frequency specifications

3.2.3. INTERNAL LAYOUT

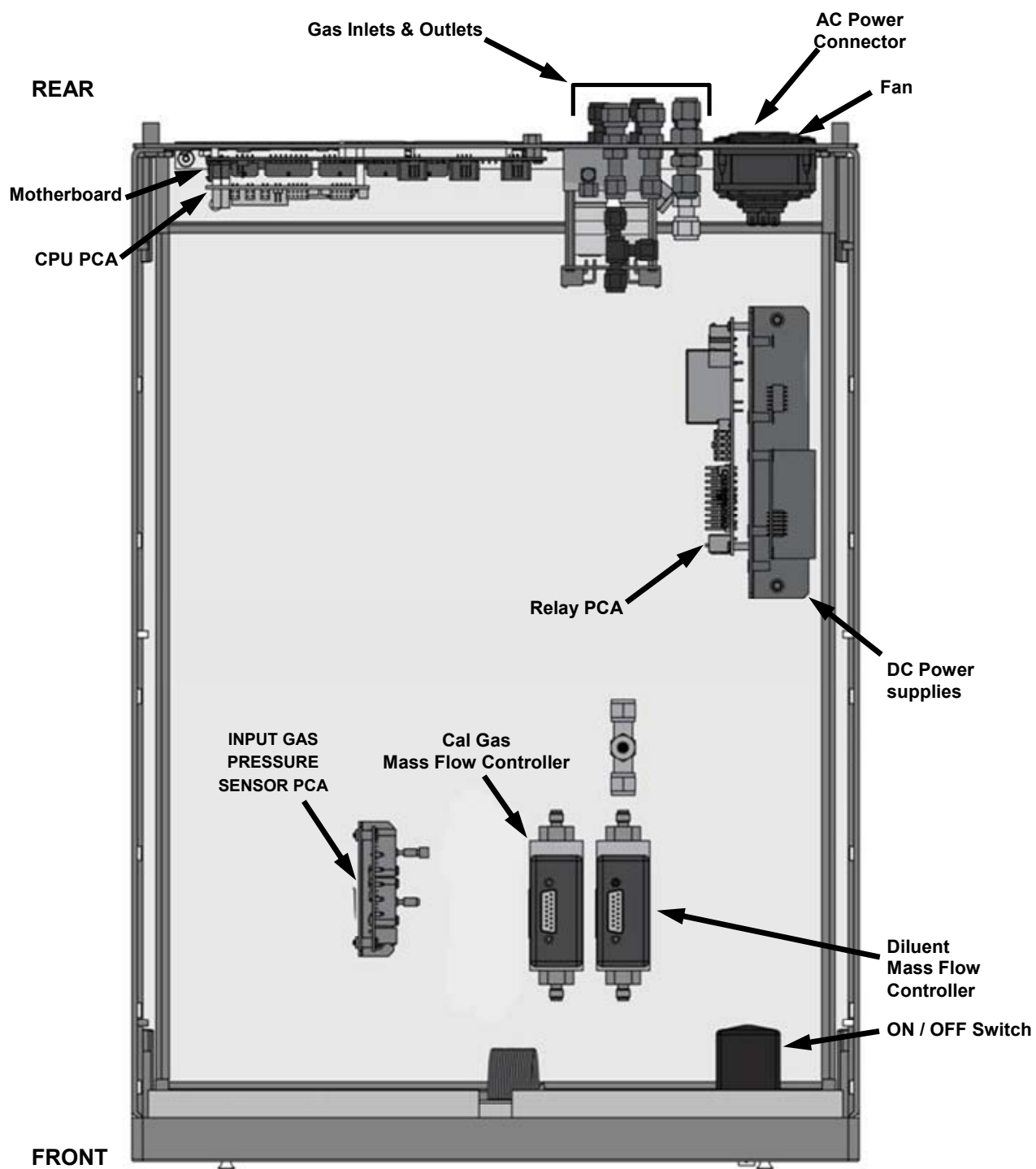


Figure 3-5: T700 Internal Layout – Top View – Base Unit

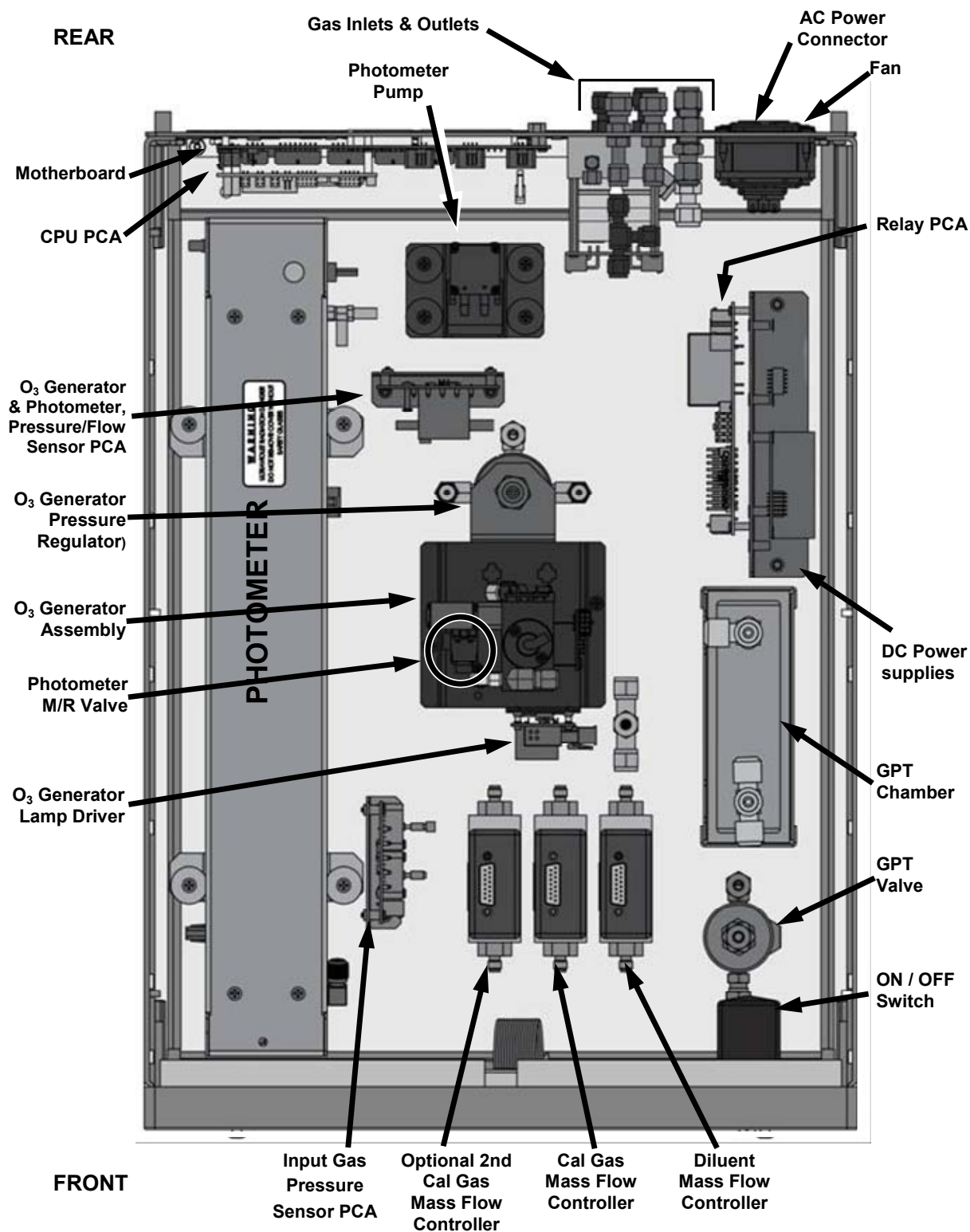


Figure 3-6: T700 Internal Layout – Top View – with Optional O₃ Generator and Photometer

3.3. CONNECTIONS AND SETUP

This section presents the electrical (Section 3.3.1) and pneumatic (Section 3.3.2) connections for setup and preparing for instrument operation.

3.3.1. 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, which include Analog In, Analog Out, Status Out, Control In, Ethernet/LAN, USB, RS-232, and RS-485.

3.3.1.1. Connecting Power

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



WARNING – ELECTRICAL SHOCK HAZARD

- HIGH VOLTAGES ARE PRESENT INSIDE THE CALIBRATORS CASE.
- POWER CONNECTION MUST HAVE FUNCTIONING GROUND CONNECTION.
- DO NOT DEFEAT THE GROUND WIRE ON POWER PLUG.
- TURN OFF CALIBRATOR POWER BEFORE DISCONNECTING OR CONNECTING ELECTRICAL SUBASSEMBLIES.
- DO NOT OPERATE WITH COVER OFF.



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).

Note

The T700 calibrator is equipped with a universal power supply that allows it to accept any AC power configuration, within the limits specified in Table 2-2.

3.3.1.2. Connecting Analog Outputs

The T700 is equipped with an analog output channel accessible through a connector on the back panel of the instrument. The standard configuration for this output is 0-5 VDC. It can be set by the user to output one of a variety of diagnostic test functions (see Section 4.10.1.2).

To access these signals attach a strip chart recorder and/or data-logger to the appropriate analog output connections on the rear panel of the calibrator.

Pin-outs for the analog output connector at the rear panel of the instrument are:

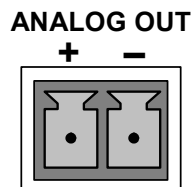


Figure 3-7: T700 Analog Output Connector

3.3.1.3. Connecting the Status Outputs

The status outputs report calibrator conditions 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 of the emitters of these transistors are tied together and available at D.

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.

The status outputs are accessed via a 12-pin connector on the calibrator's rear panel labeled STATUS. The function of each pin is defined in Table 3-3.

STATUS

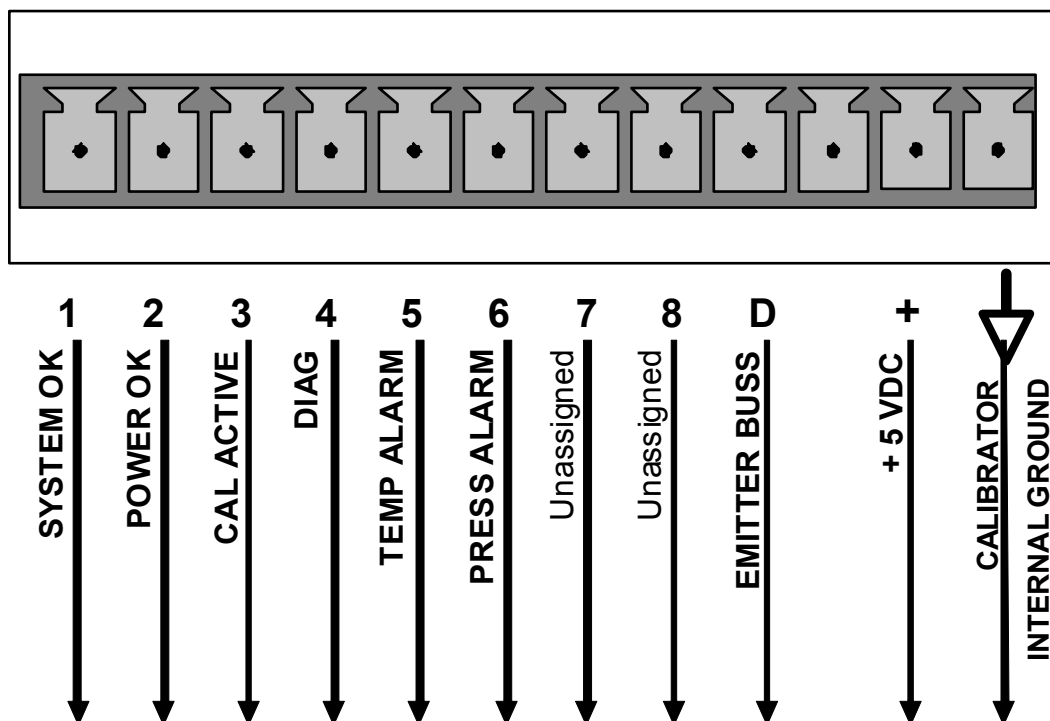


Figure 3-8: Status Output Connector

The pin assignments for the Status Outputs are:

Table 3-3: Status Output Pin Assignments

OUTPUT #	STATUS DEFINITION	CONDITION
1	SYSTEM OK	On if no faults are present.
2	POWER OK	On if no faults are present.
3	CAL ACTIVE	On if the calibrator is in GENERATE mode.
4	DIAG	On if the calibrator is in DIAGNOSTIC mode.
5	TEMP ALARM	On whenever a temperature alarm is active.
6	PRESS ALARM	On whenever gas pressure alarm is active.
7 & 8	Unassigned	
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.

3.3.1.4. Connecting the Control Inputs

The calibrator is equipped with 12 digital control inputs that can be used to initiate various user programmable calibration sequences (see Section 4.3.1.5 for instructions on assigning the control inputs to specific calibration sequences).

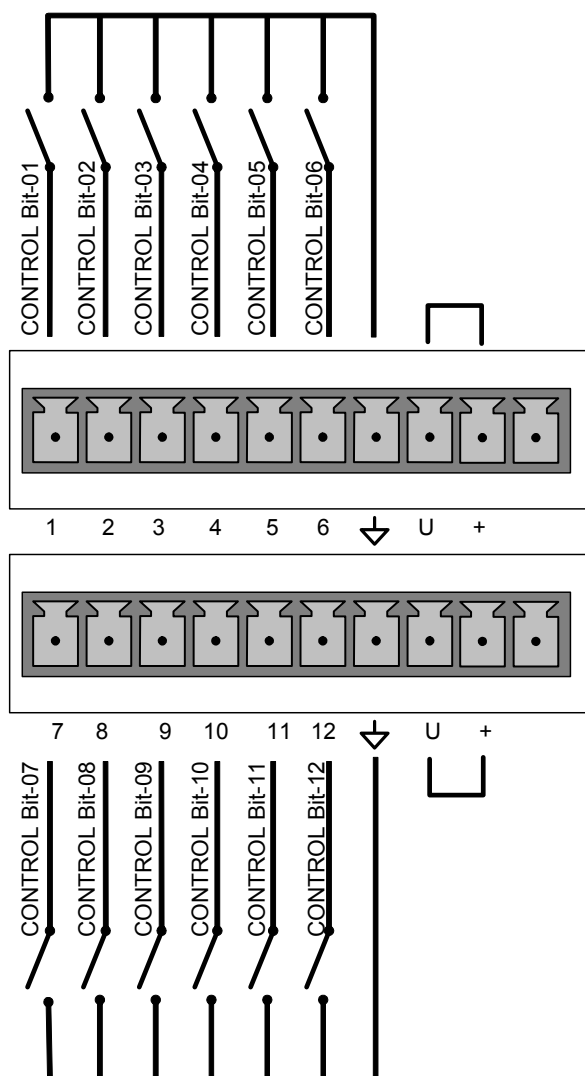
Access to these inputs is via two separate 10-pin connectors, labeled CONTROL IN, that are located on the calibrator's rear panel.

Table 3-4: T700 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.

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.

Example of Local Power Connections



Example of External Power Connections

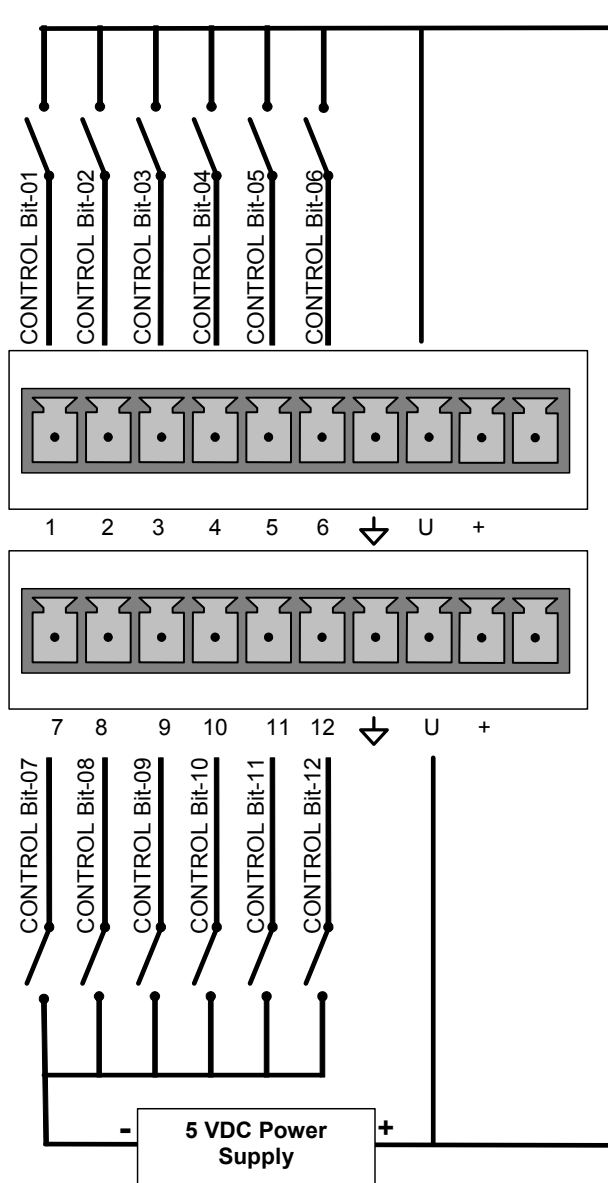


Figure 3-9: T700 Digital Control Input Connectors

3.3.1.5. Connecting the Control Outputs

The calibrator is equipped with 12 opto-isolated, digital control outputs. These outputs are activated by the T700's user-programmable calibration sequences (see Sections 4.3.1.6 and 4.3.2.8 for instructions on assigning the control inputs to specific calibration sequences).

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.

They are accessed via a 14-pin connector on the calibrator's rear panel (see Figure 3-4).

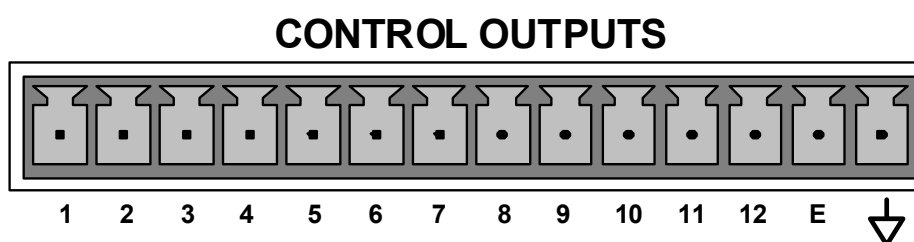


Figure 3-10: T700 Digital Control Output Connector

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 $\leq 50\text{mA}$ ($120\ \Omega$ for 5V supply).

The pin assignments for the control outputs are:

Table 3-5: T700 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.

3.3.1.6. Connecting the External Valve Driver Option

Either one of two external valve driver assemblies (12V or 24V) is 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 T700 and a universal AC-to-DC power supply.



Figure 3-11: T700 Rear Panel Valve Driver Installed

OPTION	DESCRIPTION
OPT 48A	External Valve Driver Capability – 12V
OPT 48B	External Valve Driver Capability – 24 V

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 T700's motherboard.

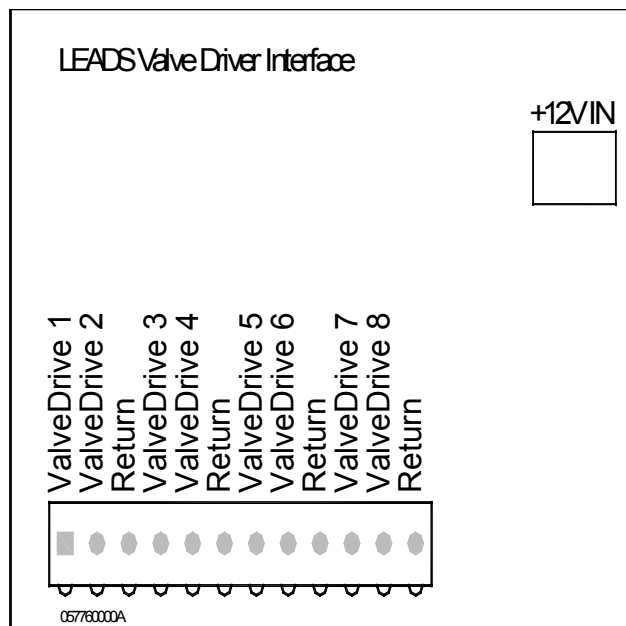


Figure 3-12: Valve Driver PCA Layout

When one of the Control Outputs is energized, the base of the associated PNP valve driver transistor (U1 through U8) is taken to ground and the emitter-collector junction becomes active.

Electronic connections should be made as follows:

- Valves should be connected between one of the Valve Drive outputs and one of the Return pins.
- The external power supply must be connected to the Valve Driver Interface using the +12V coaxial input connector on the top, right-hand side of the assembly.
- The external supply in turn must be connected to 85-264V, 47-63Hz mains.

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 T700 software (see Section 9.4.11.5). 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.

3.3.1.7. Connecting the Communications Interfaces

The T-Series analyzers are equipped with connectors for remote communications interfaces: **Ethernet**, **USB**, **RS-232**, **RS-232 Multidrop** and **RS-485** (each described here). In addition to using the appropriate cables, each type of communication method must be configured using the SETUP>COMM menu (see Sections 4.7 and 5).

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 (Section 5.4), it should be manually assigned a static IP address.

Configuration: (manual, i.e., static) Section 5.4.1.1

USB (OPTION) CONNECTION

The USB option can be used for direct communication between the analyzer and a PC; connect a USB cable between the analyzer and computer USB ports. A USB driver is required for complete configuration.

Note

If this option is installed, the COM2 port cannot be used for anything other than Multidrop communication.

Configuration: Section 5.4.3.

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 3-4) to select DTE or DCE as appropriate (Section 5.1).

Configuration: Section 4.7.3

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 3-13) 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.

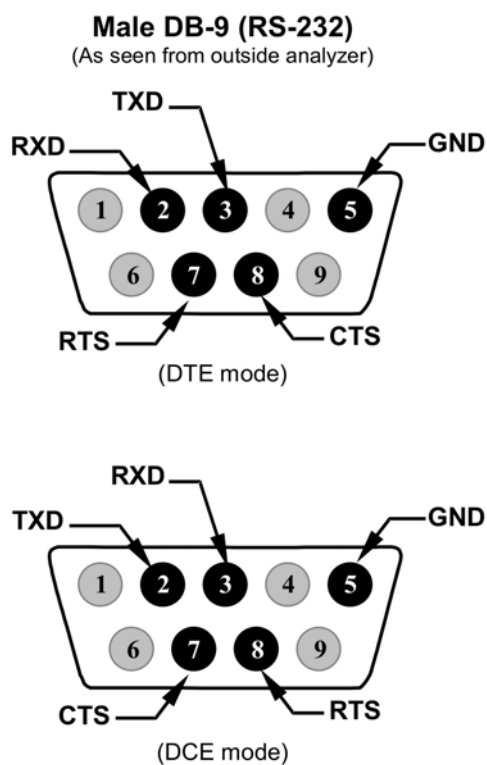


Figure 3-13: Rear Panel Connector Pin-Outs for RS-232 Mode

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 3-14).

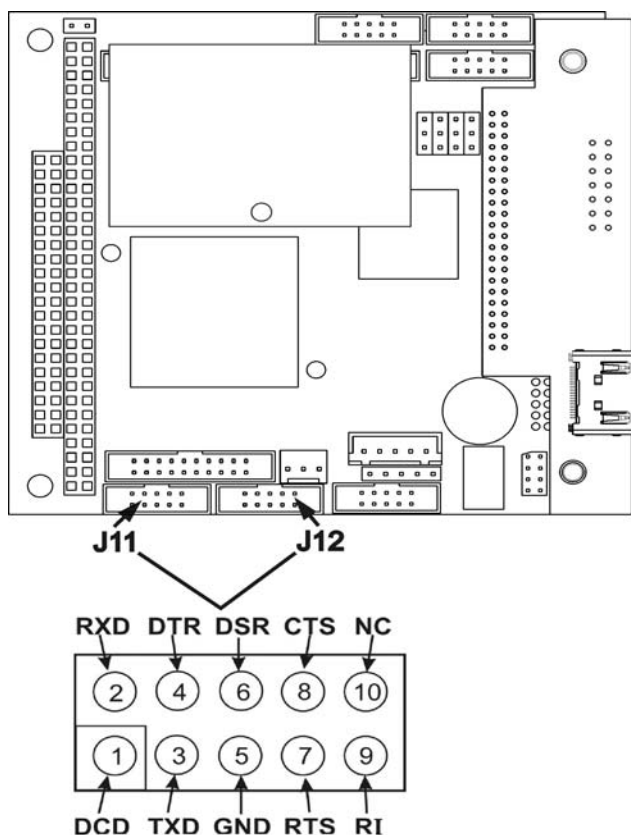


Figure 3-14: Default Pin Assignments for CPU COMM Port Connector (RS-232).

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:** 115200 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. Refer to Section 11 for more information on preventing ESD damage.

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 3-15. 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 jumperes Pins 21 ↔ 22 as indicated in. (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 3-15):
4. J3 on the Multidrop/LVDS PCA to the CPU's COM1 connector
5. (Note that the CPU's COM2 connector is not used in Multidrop)
6. J4 on the Multidrop/LVDS PCA to J12 on the motherboard
7. J1 on the Multidrop/LVDS PCS to the front panel LCD

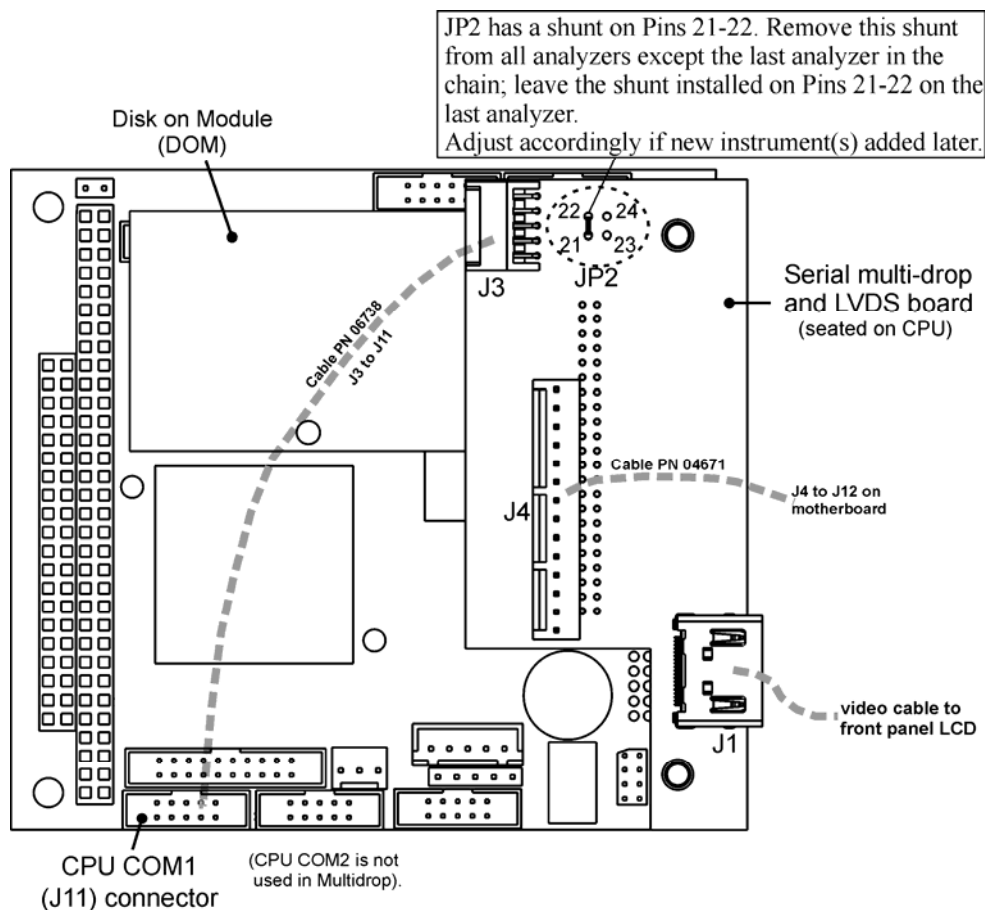


Figure 3-15: Jumper and Cables for Multidrop Mode

8. (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.)
9. Close the instrument.
10. Referring to Figure 3-16 use straight-through DB9 male → DB9 female cables to interconnect the host RS232 port to the first analyzer's RS232 port; then from the first analyzer's COM2 port to the second analyzer's RS232 port; from the second analyzer's COM2 port to the third analyzer's RS232 port, etc., connecting in this fashion up to eight analyzers, subject to the distance limitations of the RS-232 standard.

11. On the rear panel of each analyzer, adjust the DCE DTE switch (see Figure 3-4 and Section 5.1) 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 3.3.1.7: Connecting the Communications Interfaces, “RS-232 Connection”).

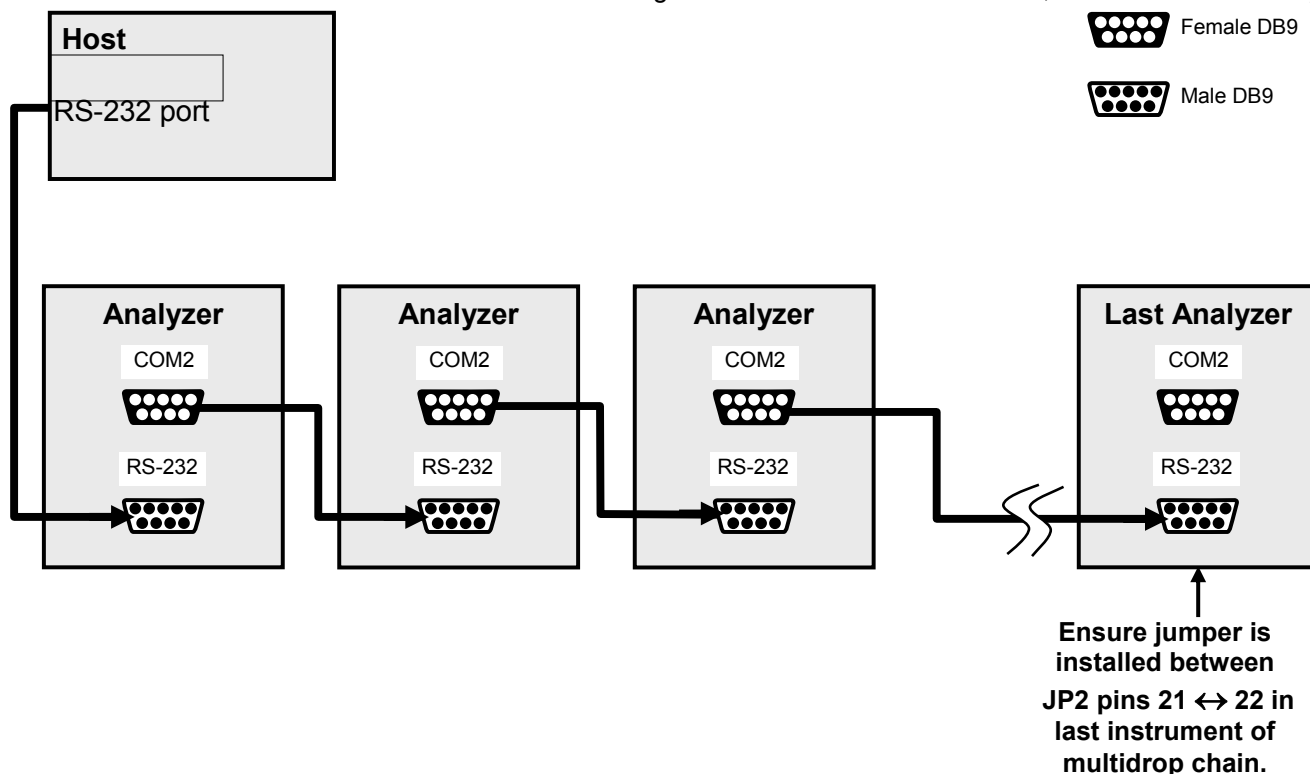


Figure 3-16: RS-232-Multidrop PCA Host/Analyzer Interconnect Diagram

12. BEFORE communicating from the host, power on the instruments and check that the Machine ID code is unique for each (Section 4.7.1).
 - a. In the SETUP Mode menu go to SETUP>MORE>COMM>ID. The default ID is typically the model number or “0”.
 - b. to change the identification number, press the button below the digit to be changed.
 - c. Press/select ENTER to accept the new ID for that instrument.
13. Next, in the SETUP>MORE>COMM>COM1 menu (do not use the COM2 menu for multidrop), edit the COM1 MODE parameter as follows: press/select EDIT and set only QUIET MODE, COMPUTER MODE, and MULTIDROP MODE to ON. Do not change any other settings.
14. Press/select ENTER to accept the changed settings, and ensure that COM1 MODE now shows 35.
15. Press/select SET> to go to the COM1 BAUD RATE menu and ensure it reads the same for all instruments (edit as needed so that all instruments are set at the same baud rate).

Note The (communication) Host instrument can address only one instrument at a time, each by its unique ID (see step 12 above).

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 communications. This port 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.

3.3.2. PNEUMATIC CONNECTIONS

Note that each time the pneumatic configuration is changed for any purpose, a backpressure compensation calibration must be performed (Section 7.3.7).

3.3.2.1. 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 -20°C 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 calibrator's 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.
- T700 calibrator's with optional O₃ generators installed require that the zero air source supply gas 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 a Teledyne API's Model 701 Zero Air Generator.

3.3.2.2. 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 N₂ although bottles containing multiple mixtures of compatible gases are also available (e.g. H₂S, O₂ and CO mixed with N₂).

- 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 gas that are certified to be traceable to NIST Standard Reference Materials (SRM). These are available from a variety of commercial sources.

The following tables lists some of the most common NIST Primary gas standards

Table 3-6: NIST Standards for CO₂

SRM	Description	Nominal Amount of Substance
1676	Carbon Dioxide in Air	365 ppm
1674b	Carbon Dioxide in Nitrogen	7 %
1675b	Carbon Dioxide in Nitrogen	14 %
2619a	Carbon Dioxide in Nitrogen	0.5 %
2620a	Carbon Dioxide in Nitrogen	1.0 %
2621a	Carbon Dioxide in Nitrogen	1.5 %
2622a	Carbon Dioxide in Nitrogen	2.0 %
2623a	Carbon Dioxide in Nitrogen	2.5 %
2624a	Carbon Dioxide in Nitrogen	3.0 %
2625a	Carbon Dioxide in Nitrogen	3.5 %
2626a	Carbon Dioxide in Nitrogen	4.0 %
2745	Carbon Dioxide in Nitrogen	16 %

Table 3-7: NIST Standards for CO

SRM	Description	Nominal Amount of Substance
2612a	Carbon Monoxide in Air	10 ppm
2613a	Carbon Monoxide in Air	20 ppm
2614a	Carbon Monoxide in Air	42 ppm
1677c	Carbon Monoxide in Nitrogen	10 ppm
1678c	Carbon Monoxide in Nitrogen	50 ppm
1679c	Carbon Monoxide in Nitrogen	100 ppm
1680b	Carbon Monoxide in Nitrogen	500 ppm
1681b	Carbon Monoxide in Nitrogen	1000 ppm
2635a	Carbon Monoxide in Nitrogen	25 ppm
2636a	Carbon Monoxide in Nitrogen	250 ppm
2637a	Carbon Monoxide in Nitrogen	2500 ppm
2638a	Carbon Monoxide in Nitrogen	5000 ppm
2639a	Carbon Monoxide in Nitrogen	1 %
2640a	Carbon Monoxide in Nitrogen	2 %
2641a	Carbon Monoxide in Nitrogen	4 %
2642a	Carbon Monoxide in Nitrogen	8 %
2740a	Carbon Monoxide in Nitrogen	10 %
2741a	Carbon Monoxide in Nitrogen	13 %

Table 3-8: NIST Standards for H₂S

SRM	Description	Nominal Amount of Substance
2730	Hydrogen Sulfide in Nitrogen	5 ppm
2731	Hydrogen Sulfide in Nitrogen	20 ppm

Table 3-9: NIST Standards for CH₄

SRM	Description	Nominal Amount of Substance
1658a	Methane in Air	1 ppm
1659a	Methane in Air	10 ppm
2750	Methane in Air	50 ppm
2751	Methane in Air	100 ppm
1660a	Methane-Propane in Air	4 : 1

Table 3-10: NIST Standards for O₂

SRM	Description	Nominal Amount of Substance
2657a	Oxygen in Nitrogen	2 %
2658a	Oxygen in Nitrogen	10 %
2659a	Oxygen in Nitrogen	21 %

Table 3-11: NIST Standards for SO₂

SRM	Description	Nominal Amount of substance
1661a	Sulfur Dioxide in Nitrogen	500
1662a	Sulfur Dioxide in Nitrogen	1000 ppm
1663a	Sulfur Dioxide in Nitrogen	1500 ppm
1664a	Sulfur Dioxide in Nitrogen	2500 ppm
1693a	Sulfur Dioxide in Nitrogen	50 ppm
1694a	Sulfur Dioxide in Nitrogen	100 ppm
1696a	Sulfur Dioxide in Nitrogen	3500 ppm

Table 3-12: NIST Standards for NO

SRM	Description	Nominal Amount of Substance
1683b	Nitric Oxide in Nitrogen	50 ppm
1684b	Nitric Oxide in Nitrogen	100 ppm
1685b	Nitric Oxide in Nitrogen	250 ppm
1686b	Nitric Oxide in Nitrogen	500 ppm
1687b	Nitric Oxide in Nitrogen	1000 ppm
2627a	Nitric Oxide in Nitrogen	5 ppm
2628a	Nitric Oxide in Nitrogen	10 ppm
2629a	Nitric Oxide in Nitrogen	20 ppm
2630	Nitric Oxide in Nitrogen	1500 ppm
2631a	Nitric Oxide in Nitrogen	3000 ppm
2735	Nitric Oxide in Nitrogen	800 ppm
2736a	Nitric Oxide in Nitrogen	2000 ppm
2737	Nitric Oxide in Nitrogen	500 ppm
2738	Nitric Oxide in Nitrogen	1000 ppm

Table 3-13: NIST Standards for Propane (C₃H₈)

SRM	Description	Nominal Amount of Substance
1665b	Propane in Air	3 ppm
1666b	Propane in Air	10 ppm
1667b	Propane in Air	50 ppm
1668b	Propane in Air	100 ppm
1669b	Propane in Air	500 ppm
2764	Propane in Air	0.25 ppm
2644a	Propane in Nitrogen	250 ppm
2646a	Propane in Nitrogen	1000 ppm
2647a	Propane in Nitrogen	2500 ppm
2648a	Propane in Nitrogen	5000 ppm

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.
6. $2\text{SLPM} + 2\text{SLPM} = 4\text{SLPM}$
7. $4\text{SLPM} \times 1.5 = 6\text{SLPM} = \text{Total Gas Flow Rate}$
8. If the T700 calibrator so that the 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:
9. $6\text{SLPM} \div 2\text{SLPM} = 3:1$
10. 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:
11. $3 \times 200\text{ppm} = 600 \text{ ppm}$

3.3.2.3. Connecting Diluent Gas to the Calibrator

12. Attach the zero air source line to the port labeled Diluent In.
13. Use the fittings provided with the calibrator to connect the zero air source line.
 - First, finger tighten.
 - Then using the properly sized wrench, make an additional 1 and ¼ turn.

3.3.2.4. Connecting Calibration Source Gas to the T700 Calibrator

14. Connect the source gas line(s) to the ports labeled CYL1 through CYL4 on the back of the calibrator (see Figure 3-4).
 - Source gas delivery pressure should be regulated between 25 PSI to 30 PSI.
 - Use stainless steel tubing with a 1/8 inch outer diameter.

3.3.2.5. Connecting Gas Outputs from the Calibrator

SET UP FOR DIRECT CONNECTIONS TO OTHER INSTRUMENTS

Use this setup if you are connecting the T700 calibrator directly to other instruments without the use of any shared manifolds.

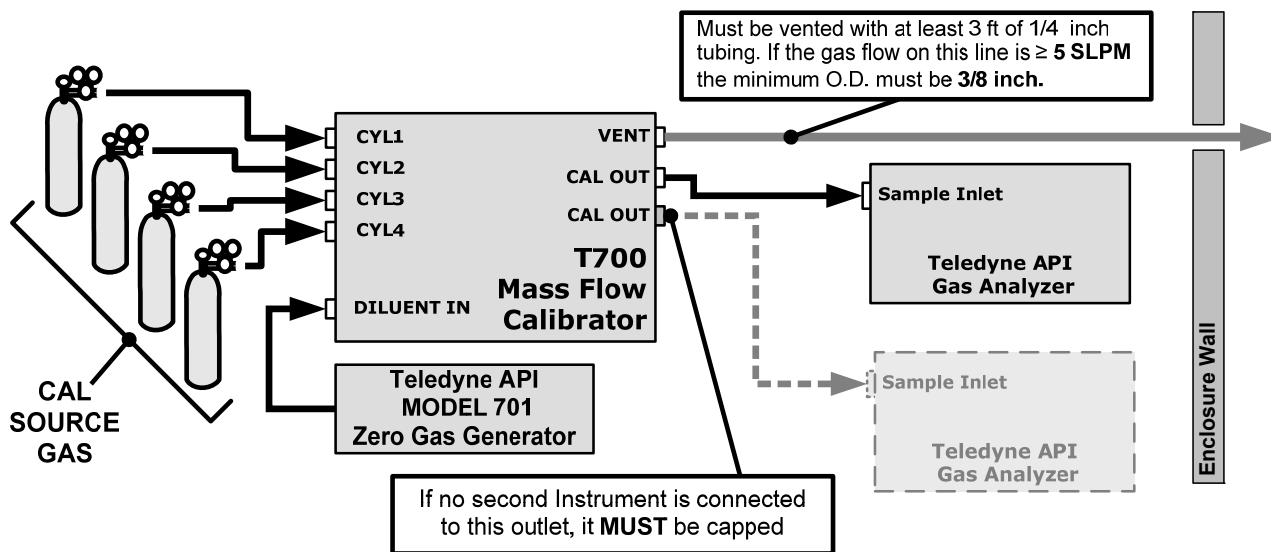


Figure 3-17: Set up for T700 – Connecting the Basic T700 to a Sample Manifold

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 T700 from the TOTAL FLOW setting for the calibrator (see Section 3.4.9).

If the T700 has the optional O₃ photometer installed remember that this option requires 800 cc³/min (0.8 LPM) of additional flow (see Section 3.4.9 or Figure 3-23).

EXAMPLE: Your system has two analyzers each requiring 2SLPM of cal gas flow and the T700 includes the O₃ photometer. If the TOTAL FLOW rate for the calibrator is set at 10 SLPM:

$$10\text{LPM} - 2\text{LPM} - 2\text{LPM} - 0.8\text{LPM} = 5.2\text{LPM}$$

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

CONNECTING THE CALIBRATOR TO A SAMPLE GAS MANIFOLD

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

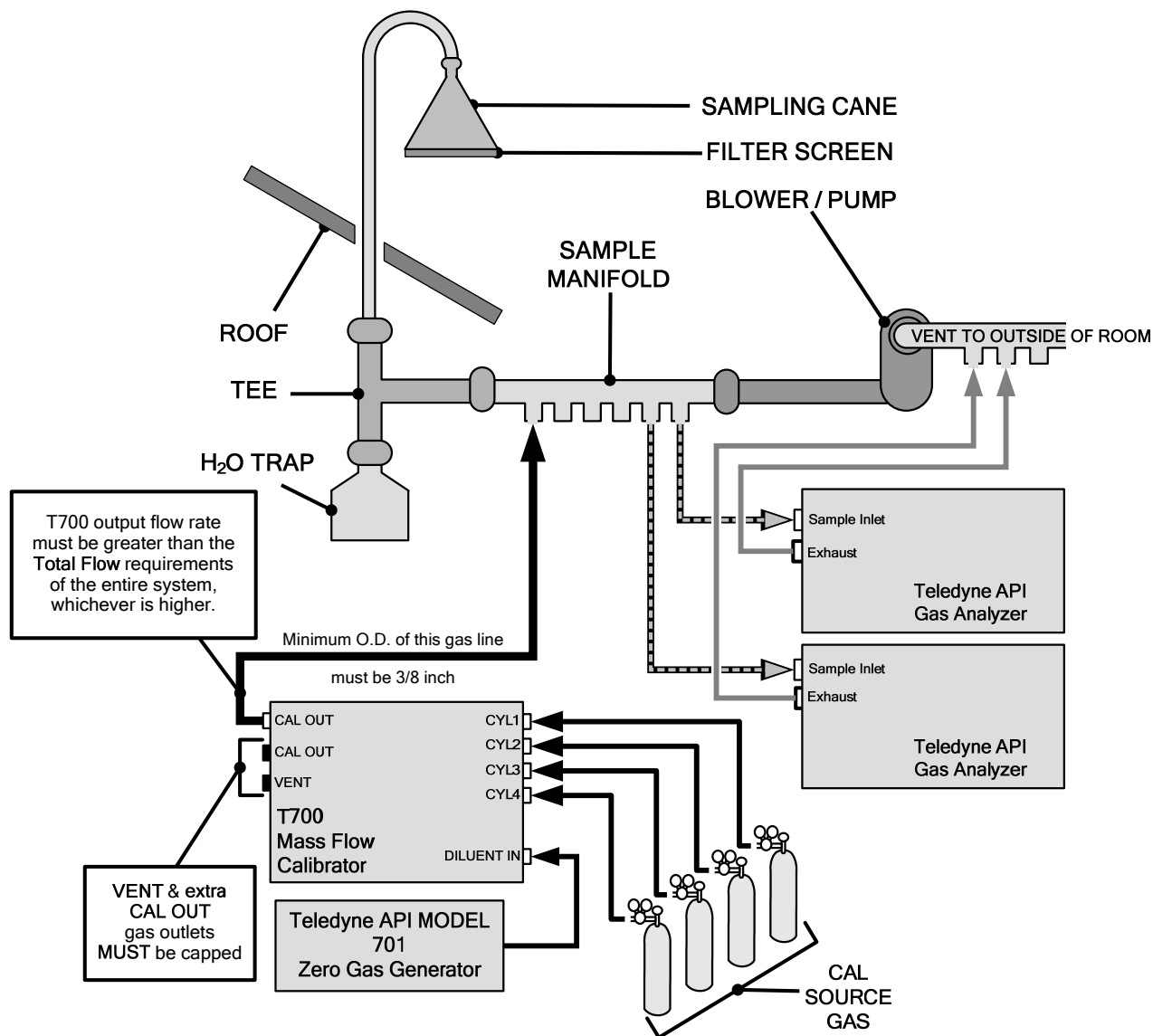


Figure 3-18: Set up for T700 – Connecting the T700 to a Sample Manifold

Note

- This is the recommended method for connecting the T700 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.

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).

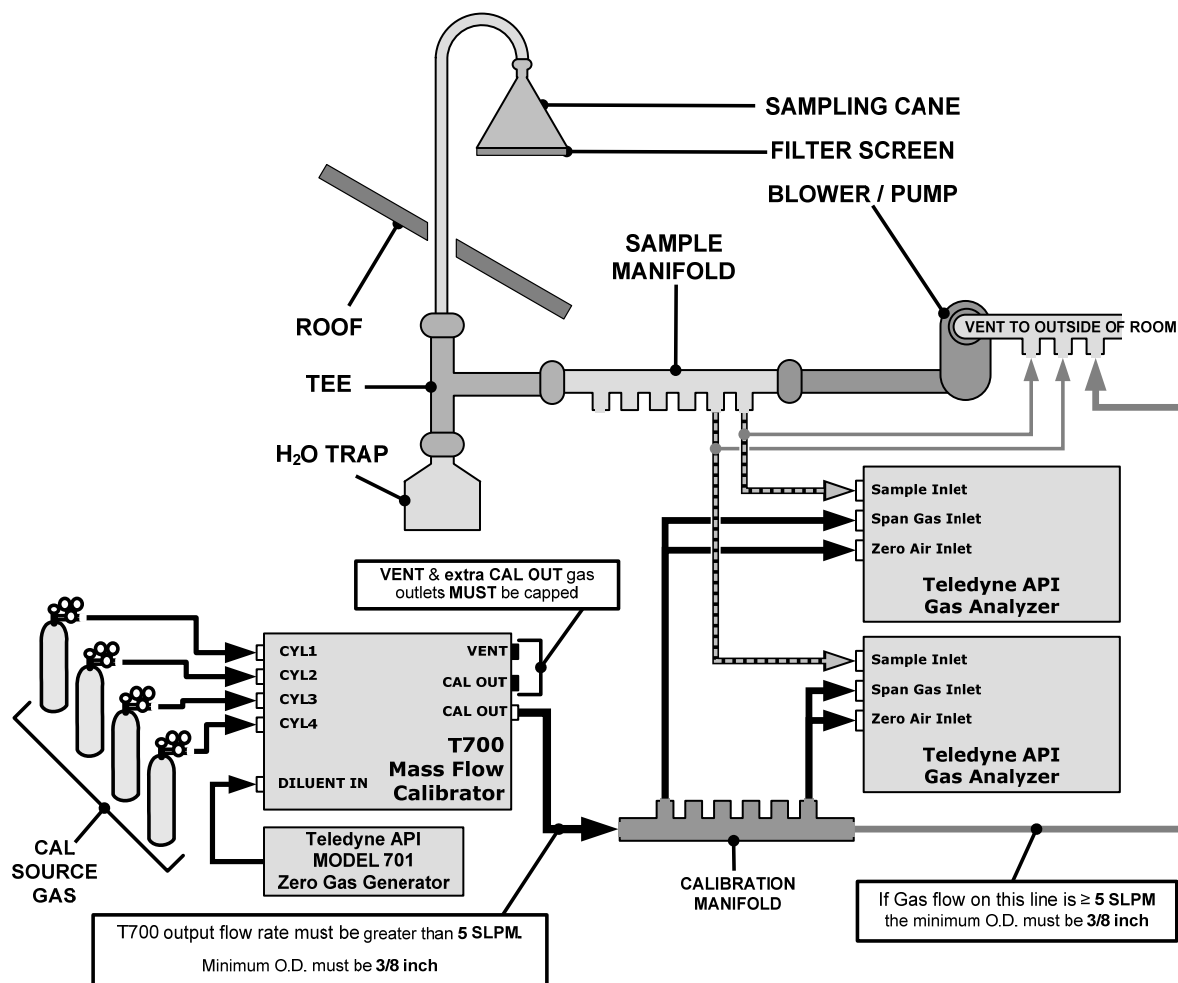


Figure 3-19: Set up for T700 – Connecting the T700 to a Calibration Manifold

Note

- This method requires the analyzers connected to the calibration system have internal zero/span valves.
- The manifold should be kept 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 manifold's excess gas should be vented outside of the room. This vent should be of large enough internal diameter 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.

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 3-20).

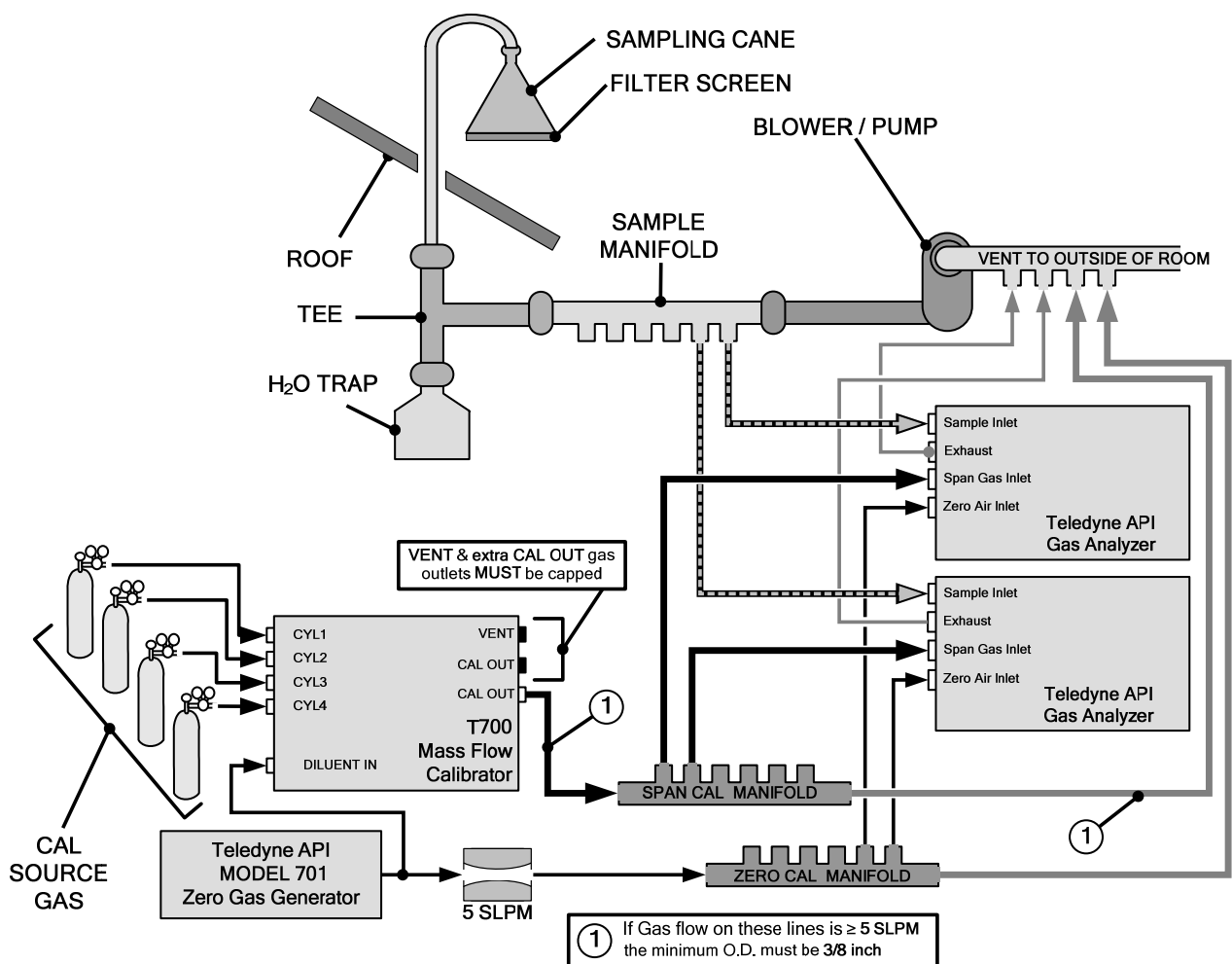


Figure 3-20: Set up for T700 – Connecting the T700 to a Dual Span Gas / Zero Air Manifold

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 T700 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 be of large enough internal diameter 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.

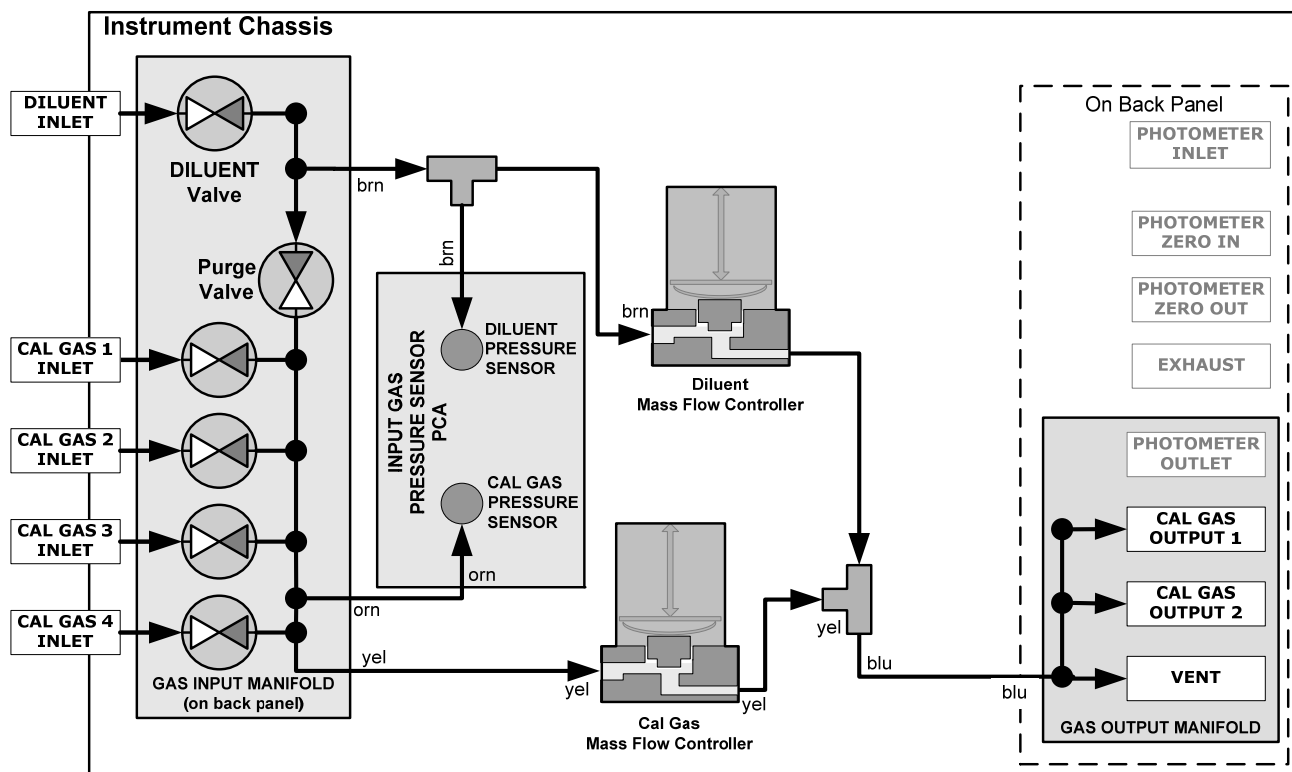


Figure 3-21: T700 Pneumatic Diagram – Base Unit

The standard T700 Dynamic Dilution Calibrator is equipped with one calibration gas mass flow controller (flow rate 0 – 100 cm³/min) and one diluent gas mass flow controller (flow rate 0-10 LPM). See Table 1-1 for the various flow rate options.

3.3.2.6. Other Pneumatic Connections

Some of the T700 Dynamic Dilution Calibrator's optional equipment requires additional pneumatic connections.

O₃ GENERATOR OPTION

Because ozone (O₃) quickly breaks down into molecular oxygen (O₂), this calibration gas cannot be supplied in precisely calibrated bottles like other gases such as SO₂, CO, CO₂, NO, H₂S, etc. The optional O₃ generator extends the capabilities of the T700 Dynamic Dilution Calibrator dynamically generate calibration gas mixtures containing O₃.

Additionally a glass mixture volume, designed to meet US EPA guidelines for Gas Phase Titration (GPT), is included with this option. This chamber, in combination with

the O₃ generator, allow the T700 to use the GPT technique to more precisely create NO₂ calibration mixtures

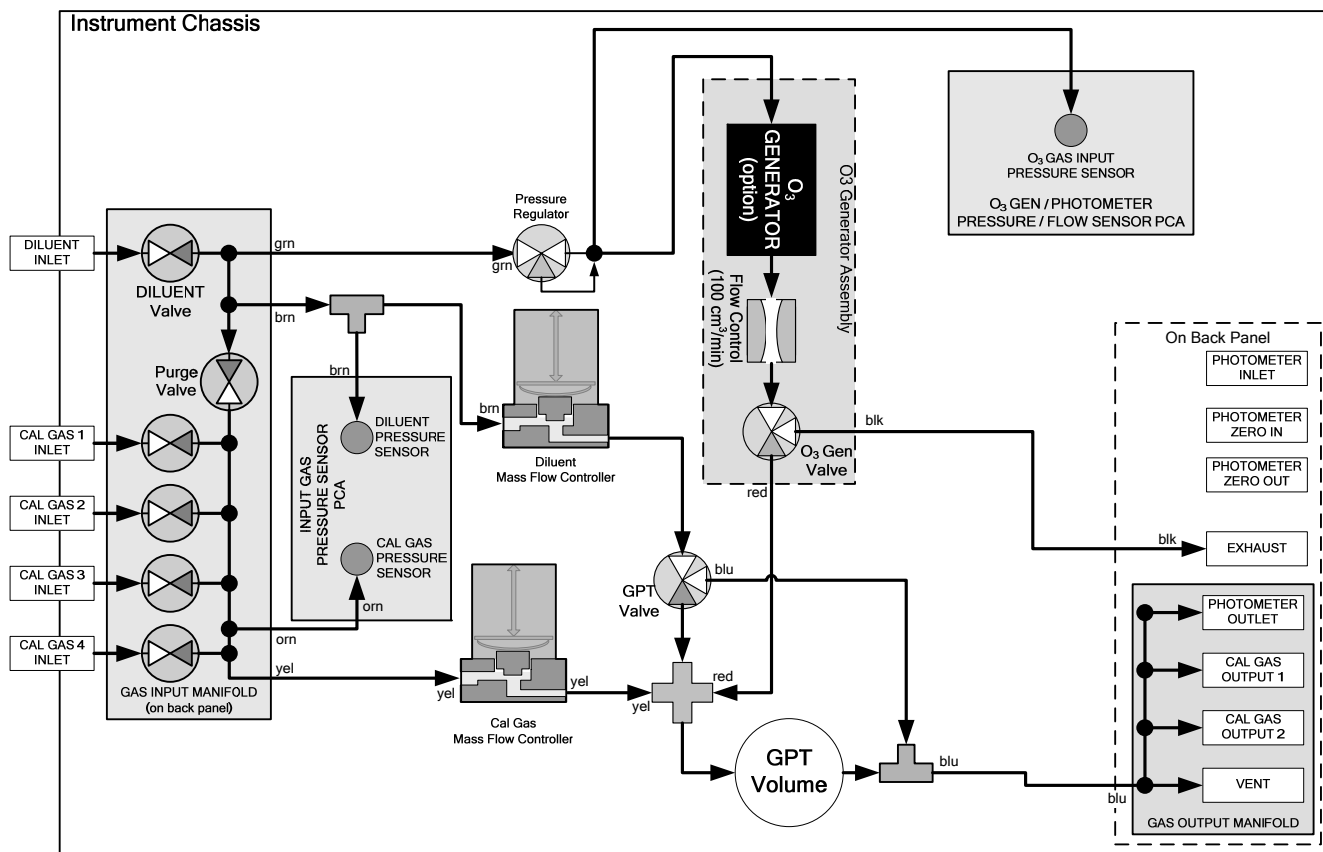


Figure 3-22: Internal Pneumatics for T700 Calibrator with Optional O₃ Generator and GPT Chamber.

Table 3-14: Operating Mode Valve States for T700 Calibrator with Optional O₃ Generator.

MODE	VALVES (X = Closed; O = Open)								MFCs		
	CYL 1	CYL 2	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 instrument with multiple MFCs the CPU chooses which MFC to use depending on the target gas flow requested.

The output of the O₃ generator can be controlled in one of two ways:

- **CONSTANT mode:** By selecting a specific, constant drive voltage (corresponding to a specific O₃ concentration) for the generator, or;
- **REFERENCE mode:** The user selects a desired O₃ concentration and the calibrator's CPU sets the intensity of the O₃ generator's UV lamp to an intensity 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 10.6 for more details on the operation of the O₃ generator.

In addition to the diluent gas, calibration source gas, and gas output connections discussed in the preceding sections, this option also requires an O₃ exhaust line be connected to the EXHAUST outlet on the back of the T700 (see Figure 3-4).

Note

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

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

O₃ GENERATOR WITH PHOTOMETER OPTION

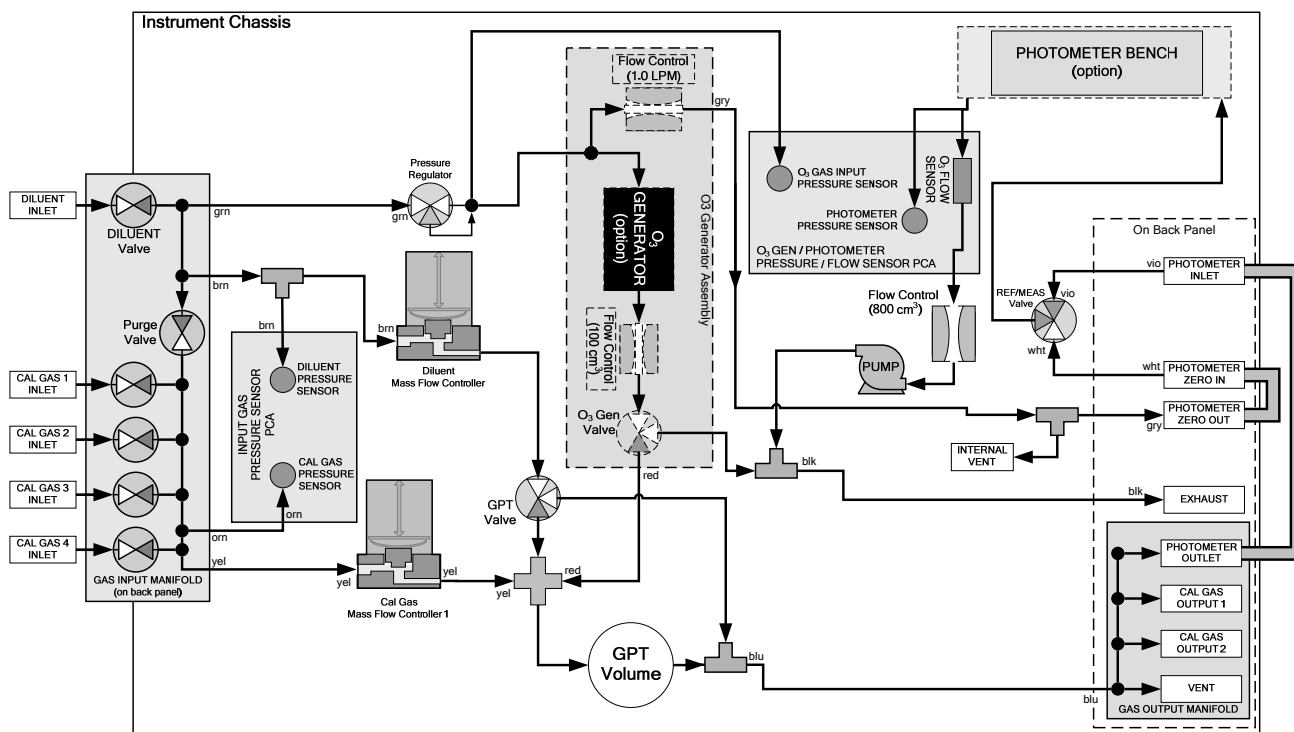
The photometer option increases the accuracy of the T700 calibrator's optional O₃ generator (OPT 1A) by directly measuring O₃ content of the gas output by the generator.

The photometer's operation is based on the principle that ozone molecules absorb UV light of a certain wavelength. A mercury lamp internal to the photometer emits UV light at that wavelength. This light shines down a hollow glass tube that is alternately filled with sample gas (the measure phase), and zero gas (the reference phase). A detector, located at the other end of the glass tube measure the brightness of the UV light after it passes through the gas in the tube. The O₃ content of the gas is calculated based on the ratio the UV light intensity during the measure phase (O₃ present) and the reference phase (no O₃ present).

When the photometer option is installed, a third more precise and stable option, called the BENCH feedback mode, exists for controlling the output of the O₃ generator. In BENCH mode the intensity of the O₃ generator's UV lamp is controlled (and therefore the concentration of the O₃ created) by the T700's CPU based on the actual O₃ concentration measurements made by the photometer.

See Section 10.7 for more details on the operation of the O₃ photometer.

This option requires that the O₃ generator (OPT 1A) be installed.

Figure 3-23: Internal Pneumatics for T700 Calibrator with Optional O₃ Generator and PhotometerTable 3-15: Operating Mode Valve States for T700 Calibrator with Optional O₃ Generator and Photometer

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 O₃ or in GPT Pre-Set mode, the photometer pump is the primary creator of gas flow through the T700. 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 option also requires the following:

- 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 O₃ exhaust line must be connected to the **EXHAUST** outlet.

See Figure 3-4 for the location of these fixtures.

Note

The EXHAUST line must be vented to atmospheric pressure using maximum of 10 meters of 1/4" PTEF tubing. This venting must be outside the shelter or immediate area surrounding the instrument.

MULTIPLE CALIBRATION SOURCE GAS MFC'S

An optional third mass flow controller can be added on the calibration gas stream. When this option is installed the T700 has both calibration gas MFCs on the same gas stream, installed in parallel (see Figure 3-24 and Figure 3-25). 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 cm³/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

When this option is installed the test measurements that show the MFC actual and target flows (e.g., **ACT CAL**; **TARG CAL**) show the sum of the flows of all the active MFCs. On the other hand, the pressure test measurements show the pressure for only one MFC, not the sum as it is assumed that gas pressure is the same for all MFCs.

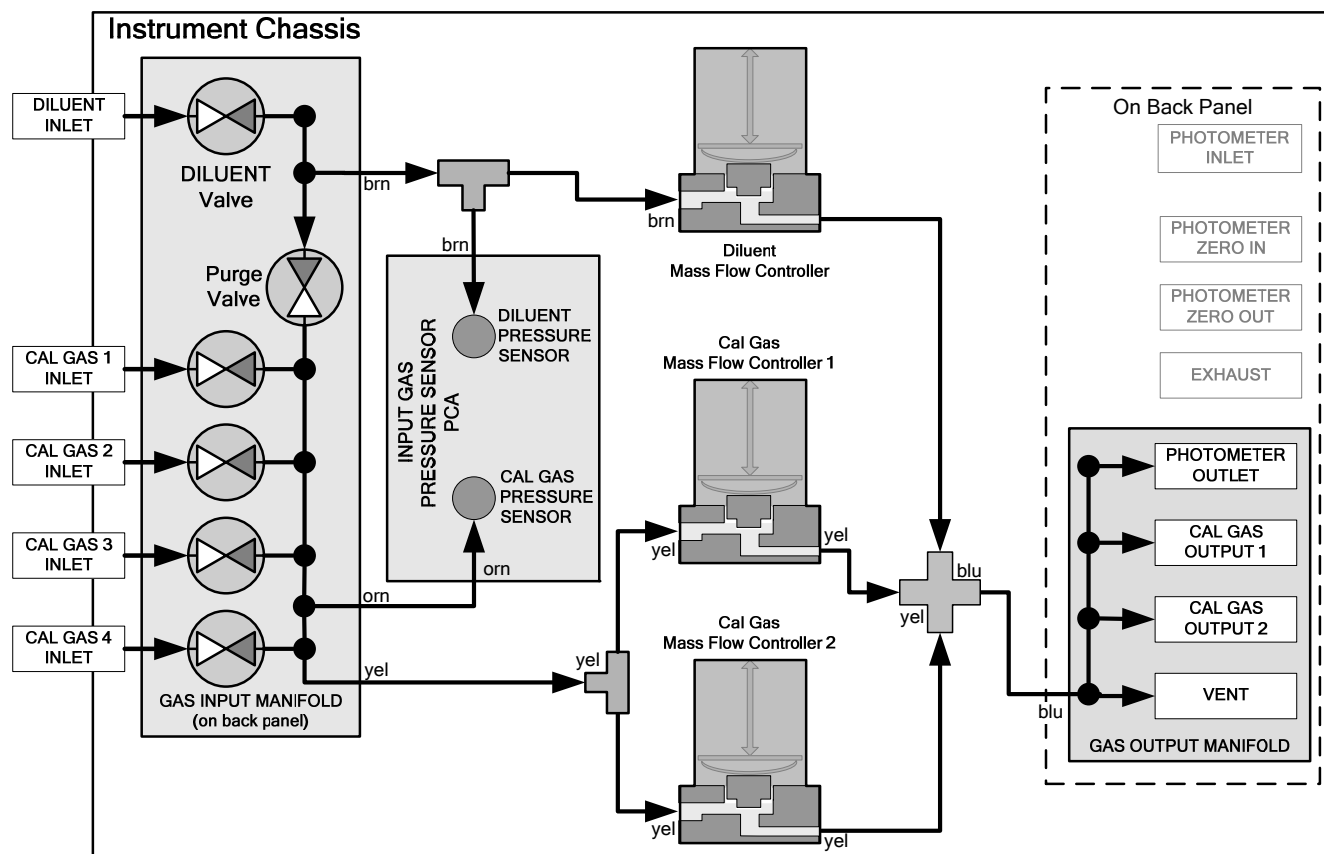


Figure 3-24: Basic T700 with Multiple Calibration Gas MFCs

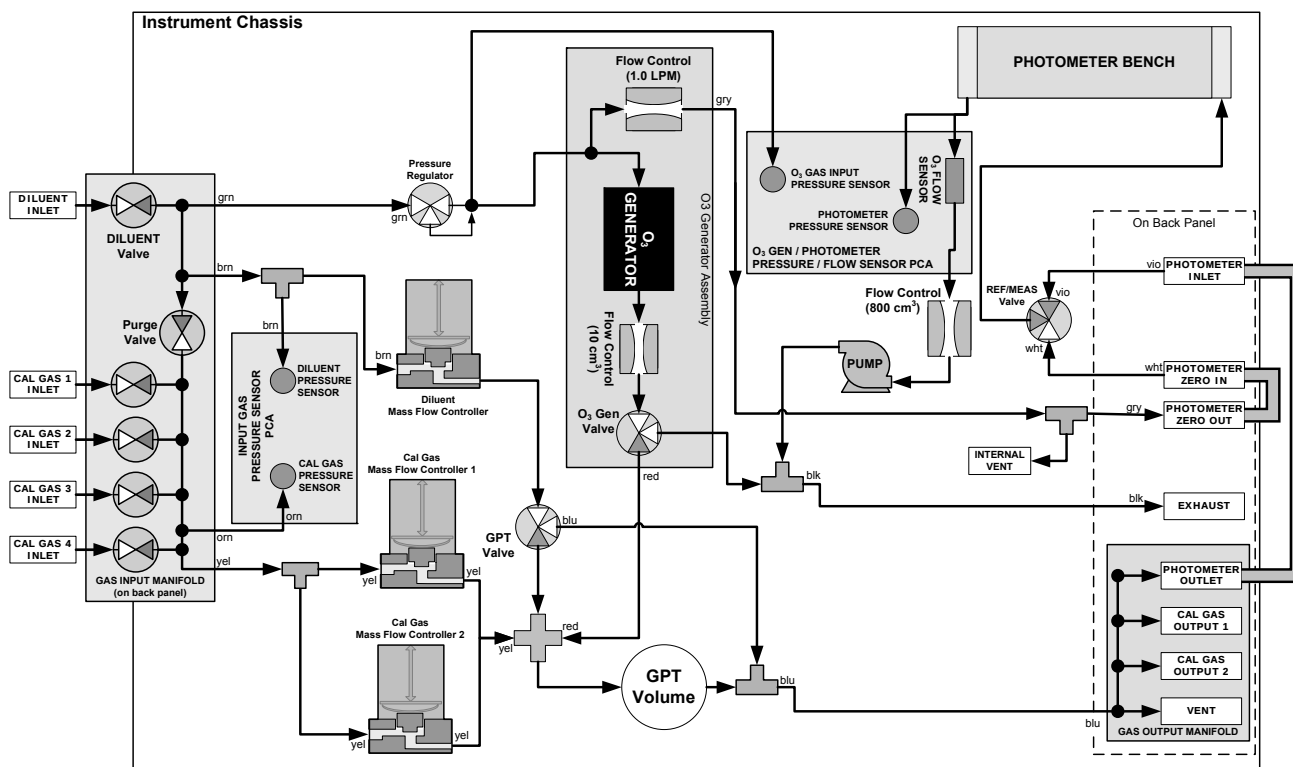


Figure 3-25: T700 with Multiple Calibration Gas MFCs and O₃ Options 1A and 2A Installed

PERMEATION TUBE GAS GENERATOR PNEUMATICS AND SETUP

The permeation tube gas generator (see Figure 3-26) is an alternative method for producing known concentrations of stable gas such as SO₂, NO₂, 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 NO₂ 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 T700 with this option is shown in Figure 3-27, including the generator.

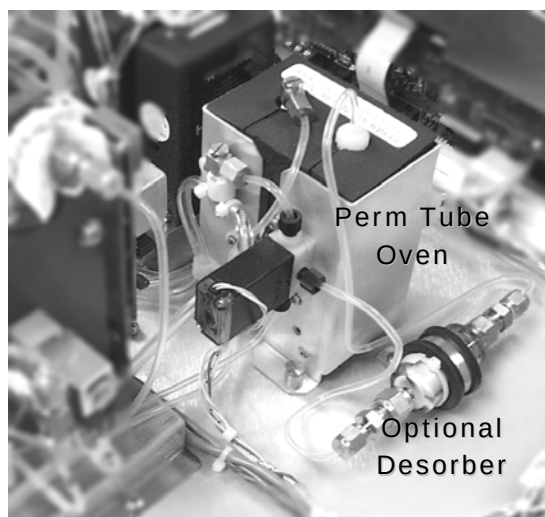


Figure 3-26: Permeation Tube Gas Generator Option

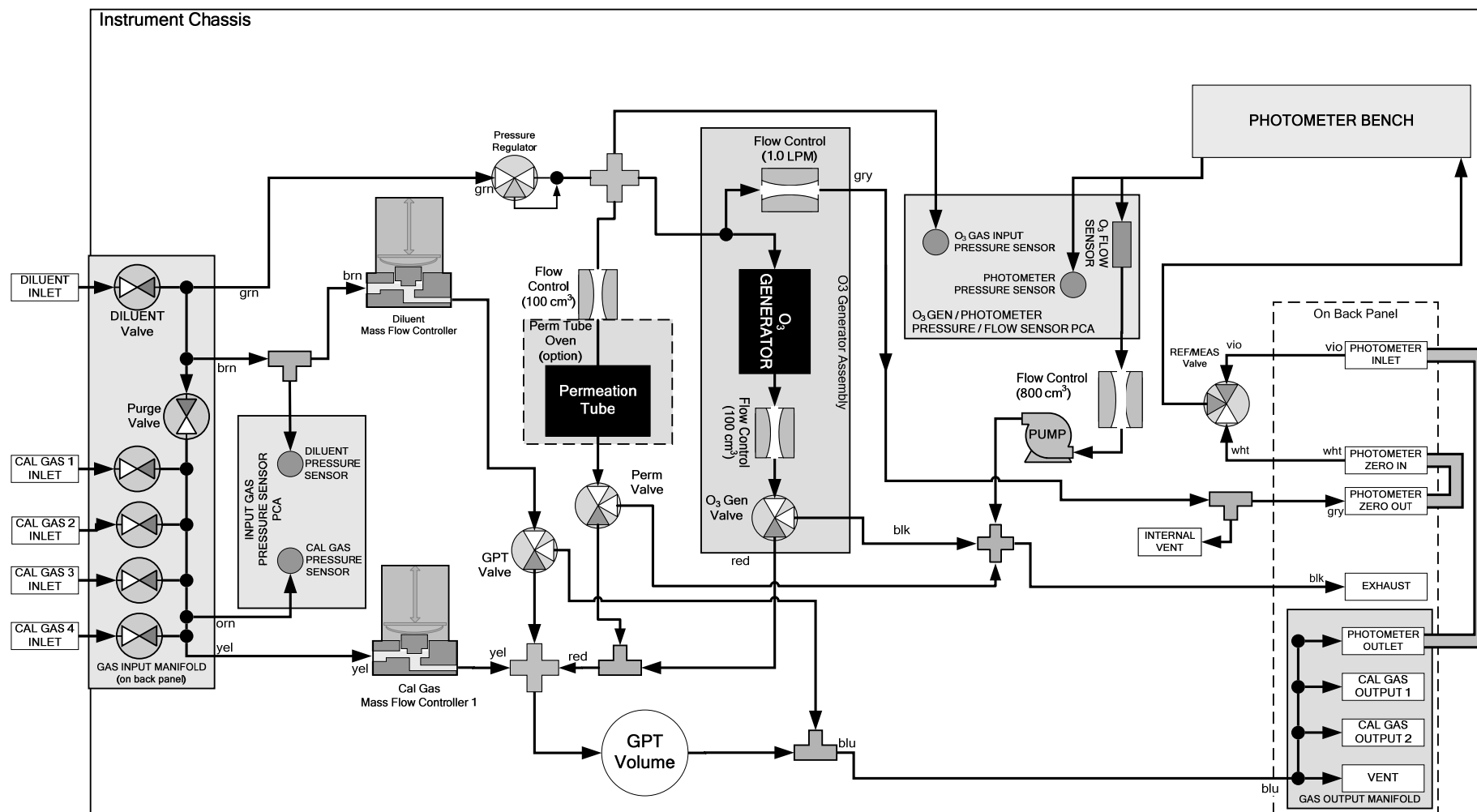


Figure 3-27: Pneumatic Diagram of T700 with Permeation Generator

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Once installed and stabilized, generating a calibration gas from the T700 with a permeation generator is the same as if the gas was 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. Again the target and actual concentrations as well as the target and actual flows will be indicated as test parameters.
- Please note that the name for the permeation tube gas MUST be different than any gas supplied to the calibrator from a bottle. For example if there is a H₂S permeation tube installed and a bottle of H₂S gas connected to the calibrator, one should be named H₂S, while the second should be named something like H₂S₂.

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 T700 has stabilized, the response to the permeation tube is not expected to change more than $\pm 5\%$ if the zero air is provided for Teledyne API's M701 or other dry zero air source.

Teledyne API recommends that you purchase replacement permeation tubes from:

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

3.3.3. PERMEATION TUBE SETUP FOR THE T700

1. Press SETUP and GAS

SETUP X.X	PRIMARY SETUP MENU						
GAS	SEQ	CFG	CLK	PASS	MORE	EXIT	

2. Press PERM

SETUP X.X	SOURCE GAS CONFIG						
CYL	PERM	USER					EXIT

3. Enter the elution rate for the permeation tube and select the type of gas by pressing the gas button to scroll through the gas list until the desired gas is shown.

Note

The name of the gas produced by the permeation tube generator **MUST** be different from the name of any bottle connected to the calibrator.

SETUP X.X	PERM TUBE 1:10.0 NGM NO2						
0	1	0	.0	NGM	NO2	ENTR	EXIT

4. Then enter the gas flow through the permeation tube. This should be done with the flow standard connected at the outlet of the perm tube oven.

SETUP X.X	PERM TUBE 1:0.105 LPM							
0	.1	0	5				ENTR	EXIT

3.3.4. PERMEATION TUBE 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 cm³/min of air flow 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 cm³/min through the generator and the flow of dilutant gas.

The temperature is set at 50.0°C. Check SETUP-MORE-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 cm³/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.

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

and MW is the molecular weight.

760mmHg . Km for SO₂ = 0.382, NO₂ = 0.532, H₂S = 0.719, and NH₃ = 1.436.

F = total flow rate (sum of 100 cm³/min and diluent flow), LPM.

C = concentration, ppm.

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

Where, Temperature at 50°C = 323

Temperature at 25°C = 298

DUAL GAS OUTPUT (NO_y – SPECIAL) (OPT 73)

The standard output manifold has been removed and replaced with 2 output fittings, labeled “Output A” and “Output B” (Figure 3-28). 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 NO_y probe calibrations. 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.

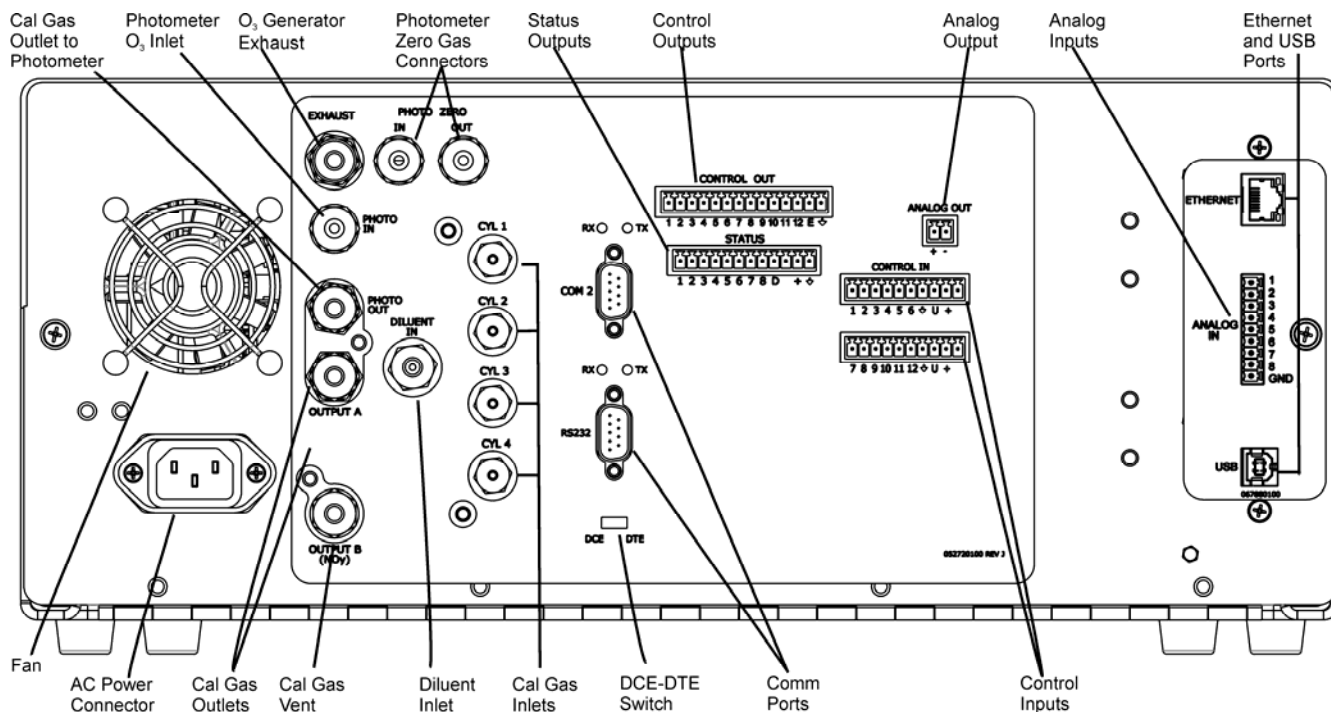


Figure 3-28: Rear Panel with Dual Output Option

When the dual gas output option is enabled, the output must be selected when generating gas. Use the following menu sequence: GEN>AUTO>[Select A or B]>ENTR. Your chosen output is now selected for calibration.

The following illustration depicts the pneumatic flow for the T700 Calibrator with the optional dual gas output at the output valve.

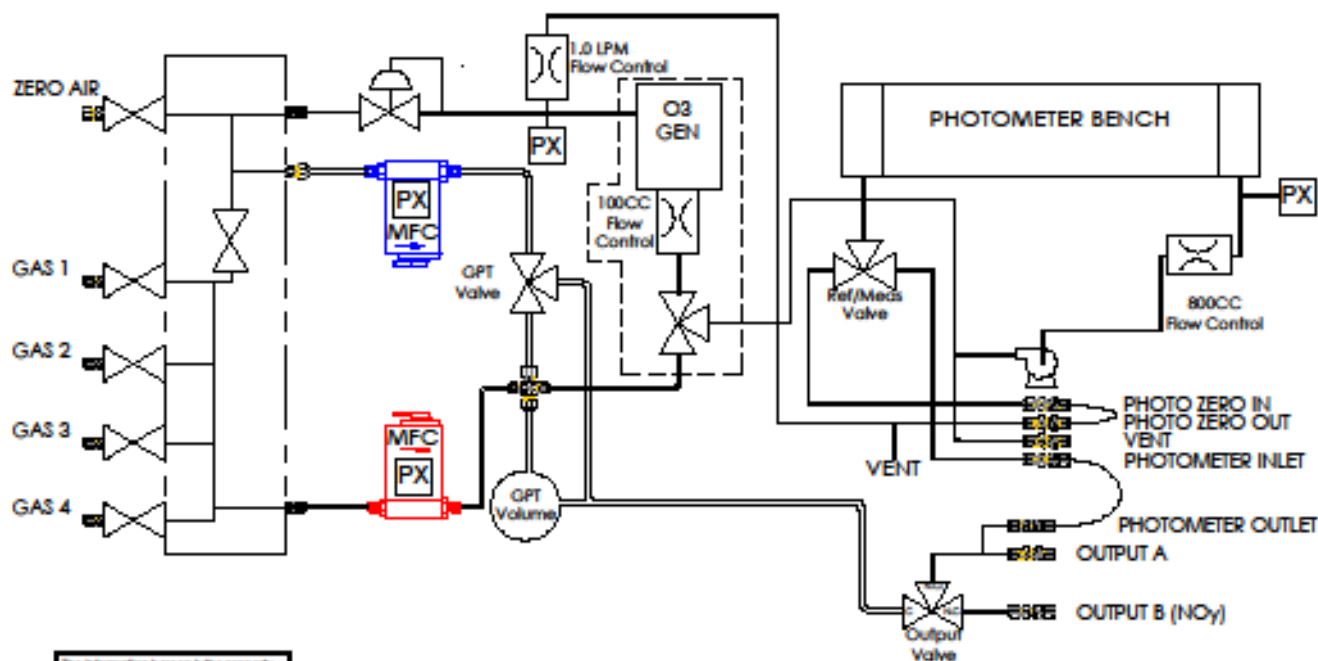


Figure 3-29: Internal Pneumatics for T700 Calibrator with Optional Dual Gas Output (NO_y – Special)

3.4. STARTUP, FUNCTIONAL CHECKS, AND INITIAL CALIBRATION

If you are unfamiliar with the T700 principles of operation, we recommend that you read Section 10.

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

3.4.1. START UP

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

The calibrator should automatically switch to STANDBY mode after completing the brief boot-up sequence. However, the T700 dynamic dilution calibrator requires a minimum of 30 minutes for all of its internal components to reach a stable operating temperature. During the warm-up period, the front panel display may show messages in the Parameters field.

3.4.2. WARNING MESSAGES

Because internal temperatures and other conditions may be outside specified limits during the calibrator's warm-up period, the software will suppress most warning

conditions for 30 minutes after power up. If warning messages persist after the 30 minutes warm up period is over, investigate their cause using the troubleshooting guidelines in Section 9 of this manual.

To view and clear warning messages, press:

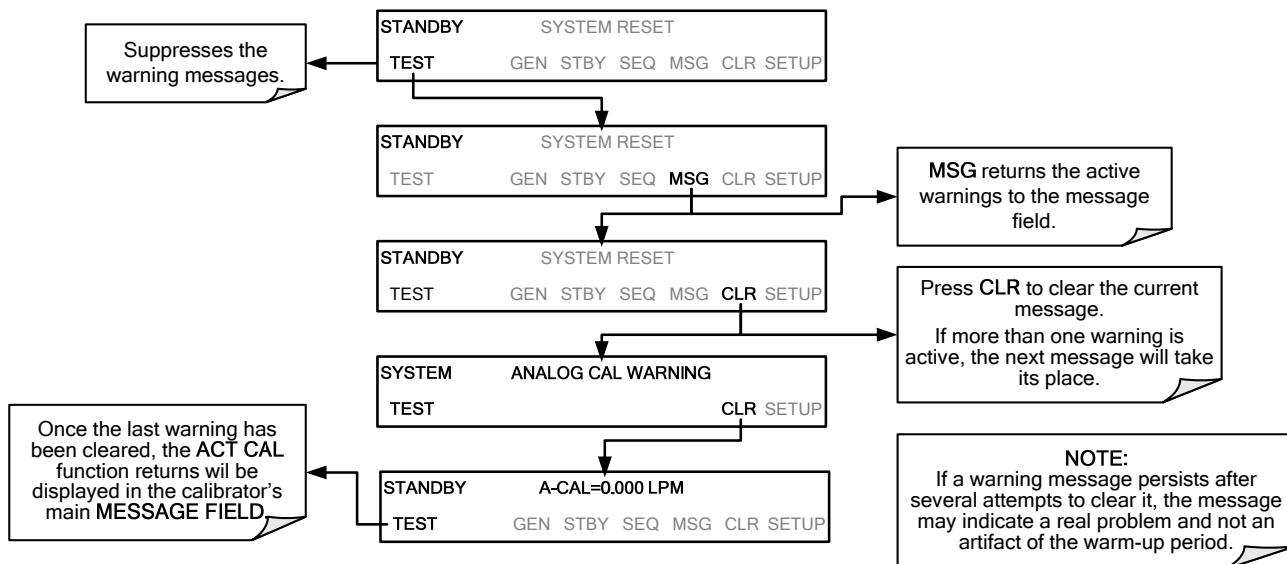


Table 3-16 lists brief descriptions of the warning messages that may occur during start up.

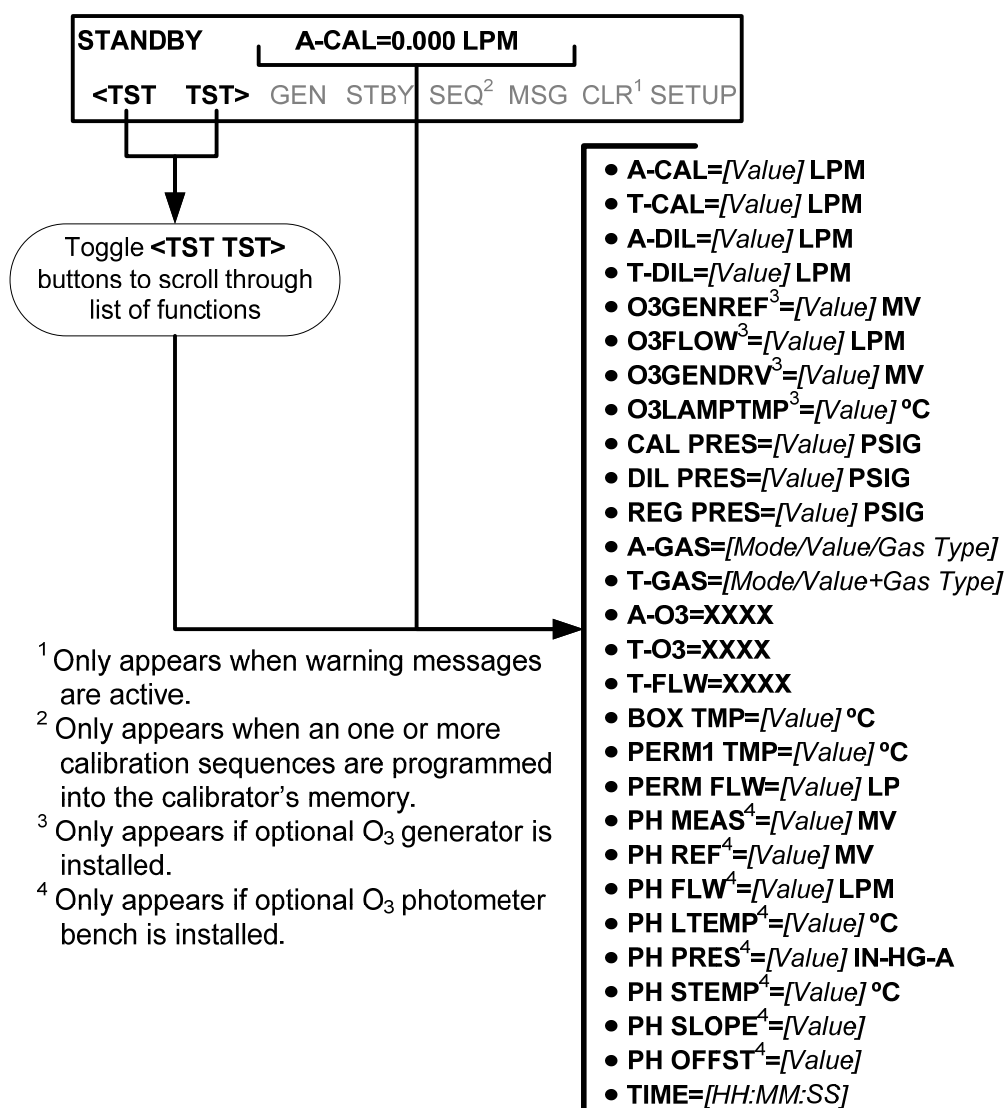
Table 3-16: Possible Warning Messages at Start-Up

MESSAGE	MEANING
ANALOG CAL WARNING	The calibrator's A/D converter or at least one analog input channel has not been calibrated.
CONFIG INITIALIZED	Stored Configuration information has been reset to the factory settings or has been erased.
DATA INITIALIZED	The calibrator's data storage was erased.
LAMP DRIVER WARN^{1, 2}	The firmware is unable to communicate with either the O ₃ generator or photometer lamp I ² C driver chips. ^{1, 2}
MFC CALIBRATION WARNING	The flow setting for one of the calibrator's mass flow controllers is less than 10% or greater than 100% of the flow rating for that controller.
MFC COMMUNICATION WARNING	Firmware is unable to communicate with any MFC.
MFC FLOW WARNING³	One of the calibrator's mass flow controllers is being driven at less than 10% of full scale or greater than full scale.
MFC PRESSURE WARNING	One of the calibrator's mass flow controllers internal gas pressure is outside of allowable limits.
O₃ GEN LAMP TEMP WARNING¹	The O ₃ generator lamp temperature is outside of allowable limits. ¹
O₃ GEN REFERENCE WARNING¹	The O ₃ generator's reference detector has dropped below the minimum allowable limit. ¹
O₃ PUMP WARNING¹	The pump associated with the O ₃ photometer has failed to turn on. ¹
PHOTO LAMP TEMP WARNING²	The photometer lamp temperature is outside of allowable limits. ²
PHOTO LAMP STABILITY WARNING	Photometer lamp reference step changes occur more than 25% of the time.

MESSAGE	MEANING
PHOTO REFERENCE WARNING²	The photometer reference reading is outside of allowable limits. ²
REAR BOARD NOT DET	The calibrator's motherboard was not detected during power up. - THIS WARNING only appears on Serial I/O COMM Port(s). - The Front Panel Display will be frozen, blank or will not respond.
REGULATOR PRESSURE WARNING	The gas pressure regulator associated with the internal O ₃ generator option is reporting a pressure outside of allowable limits.
RELAY BOARD WARN	The firmware is unable to communicate with the calibrator's relay PCA.
SYSTEM RESET	The calibrator has been turned off and on or the CPU was reset.
VALVE BOARD WARN	The firmware is unable to communicate with the valve controller board.
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).	

3.4.3. FUNCTIONAL CHECKS

5. After the calibrator's components have warmed up for at least 30 minutes, verify that the software properly supports any hardware options that are installed.
6. Check to ensure that the calibrator is functioning within allowable operating parameters. Appendix C includes a list of test functions viewable from the calibrator's front panel as well as their expected values. These functions are also useful tools for diagnosing problems with your calibrator (Section 9.1.2). The enclosed Final Test and Validation Data sheet (P/N 05731) lists these values before the instrument left the factory. To view the current values of these parameters press the following button sequence on the calibrator's front panel. Remember that until the unit has completed its warm-up, these parameters may not have stabilized.



7. If your calibrator is operating via Ethernet and your network is running a dynamic host configuration protocol (DHCP) software package, the Ethernet will automatically configure its interface with your LAN. However, it is a good idea to check these settings

to ensure that the DHCP has successfully downloaded the appropriate network settings from your network server (See Section 5.4.1).

8. If your network is not running DHCP or if you wish to establish a more permanent Ethernet connection, you will have to configure the calibrator's Ethernet interface manually (See Section 5.4.1.1).

3.4.4. SETTING UP THE CALIBRATION GAS INLET PORTS

The T700 Dynamic Dilution Calibrator generates calibration gases of various concentrations by precisely mixing component gases of known concentrations with diluent (zero air). When the instrument is equipped with the optional O₃ generator and photometer, it can also use the gas phase titration method for generating very precise concentrations of NO₂.

In either case, it is necessary to program the concentrations of the component gases being used into the T700's memory.

3.4.5. DEFAULT GAS TYPES

The T700 calibrator is programmed with the following default gas types corresponding to the most commonly used component gases:

Table 3-17: T700 Default Gas Types

NAME	GAS TYPE
NONE	Used for gas inlet ports where no gas bottle is attached
SO ₂	sulfur dioxide
H ₂ S	hydrogen sulfide
N ₂ O	nitrous oxide
NO	nitric oxide
NO ₂	nitrogen dioxide
NH ₃	Ammonia ¹
CO	carbon monoxide, and;
CO ₂	carbon dioxide
HC	General abbreviation for hydrocarbon
¹ It is not recommended that ammonia be used in the T700.	

3.4.6. USER DEFINED GAS TYPES

3.4.6.1. User Defined Gas Types – General

The T700 calibrator can accept up to four different user defined gases. This allows the use of:

- Less common component gases not included in the T700's default list;
- More than one bottle of the same gas but at different concentrations. In this case, different user-defined names are created for the different bottles of gas.

EXAMPLE: Two bottles of CO₂ are being used, allow the calibrator to create two different CO₂ calibration gases at the same flow rate.

Since identical names must not be assigned to two different bottles, one bottle can be programmed using the default name "CO2" and the other bottle programmed by assigning a user defined name such as "CO2A".

Alternatively, both bottles can be assigned user defined names; e.g. CO2A and CO2B

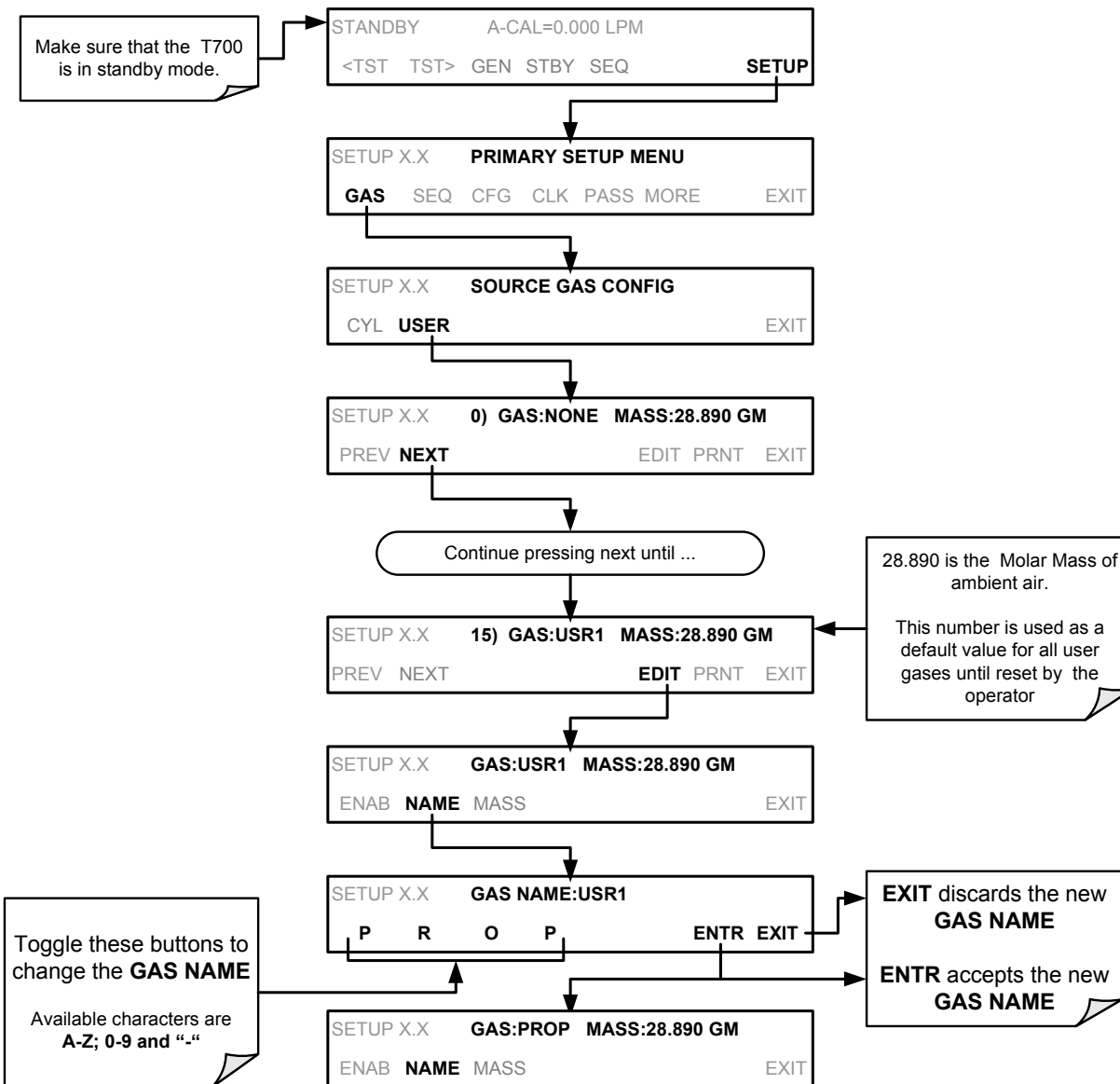
User defined gas names are added to the T700's gas library and will appear as choices during the various calibrator operations along with the default gas names listed in Section 3.4.5.

In its default state, the T700's four user defined gases are named usr1, usr2, usr3 and usr4, each with a default MOLAR mass of 28.890 (the MOLAR mass of ambient air). All four are enabled.

To define a user gas you must first define the GAS NAME and then set the MOLAR MASS.

3.4.6.2. User Defined Gas Types – Defining the Gas Name

In this example, we will be using PROPANE (C_2H_8). Press:



Alternatively, one could use the chemical formula for this gas, c_2h_8 or any other 4-letter name (e.g., PRPN, MY-1, etc.)

Note

If you have the same type of gas, but two different concentrations (for example, two concentrations of CO_2), assign the second concentration to one of the user defined gases (e.g. CO_2 {default name} and CO_2B {user defined}).

3.4.6.3. User Defined Gas Types – Setting the MOLAR MASS

The molar mass of a substance is the mass, expressed in grams, of 1 mole of that 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 12.011 therefore the molar mass of Carbon is 12.011 grams, conversely, one mole of carbon equals the amount of carbon atoms that weighs 12.011 grams.

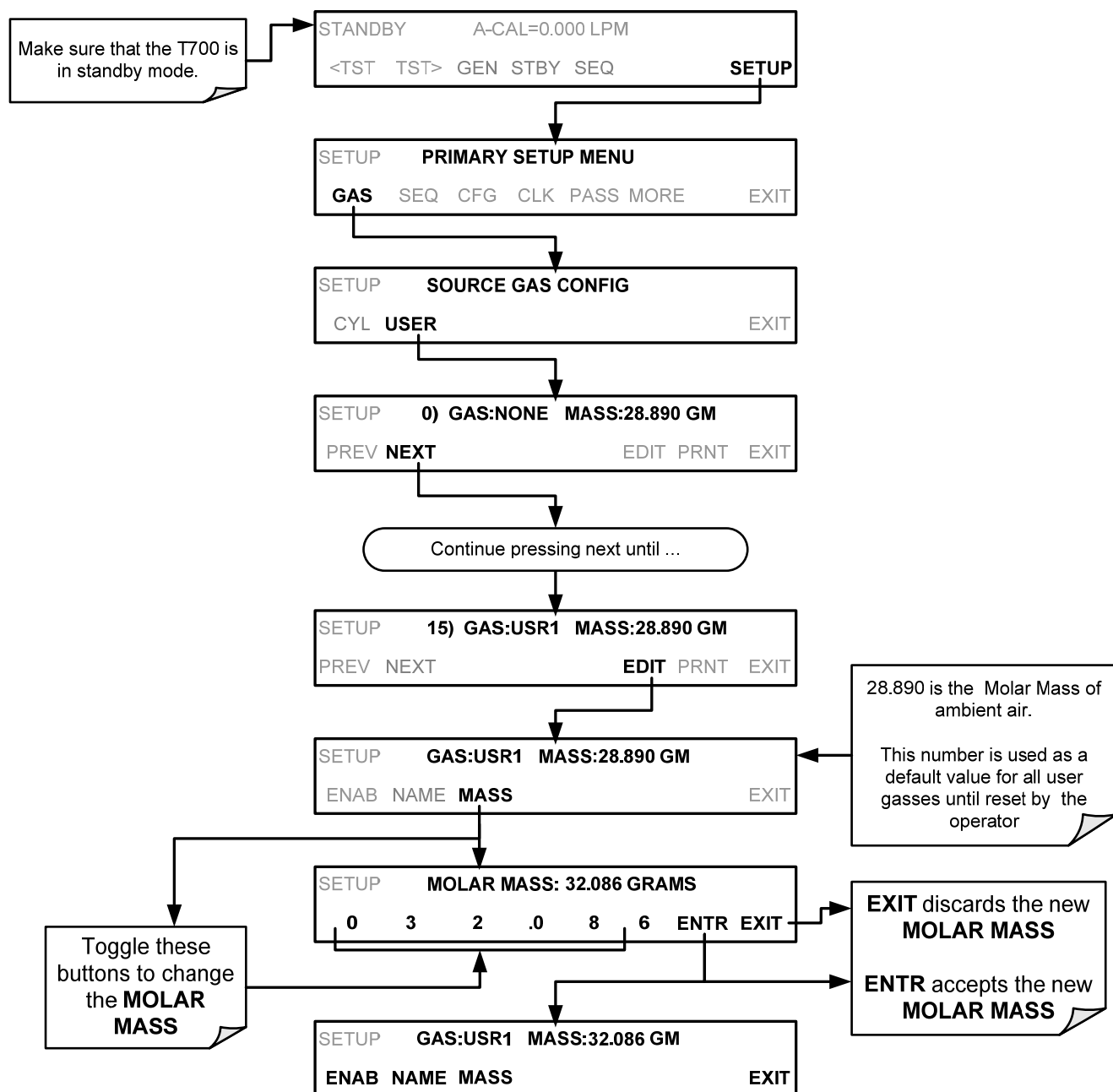
Atomic weights can be found on any Periodic Table of Elements.

To determine the Molar mass of a gas, add together the atomic weights of the elements that make up the gas.

EXAMPLE: The chemical formula for Propane is **C₂H₈**. Therefore the molecular mass of propane is:

$$(12.011 \times 2) + (1.008 \times 8) = 24.022 + 8.064 = \mathbf{32.086}$$

To set the molar mass of a user defined gas, press:



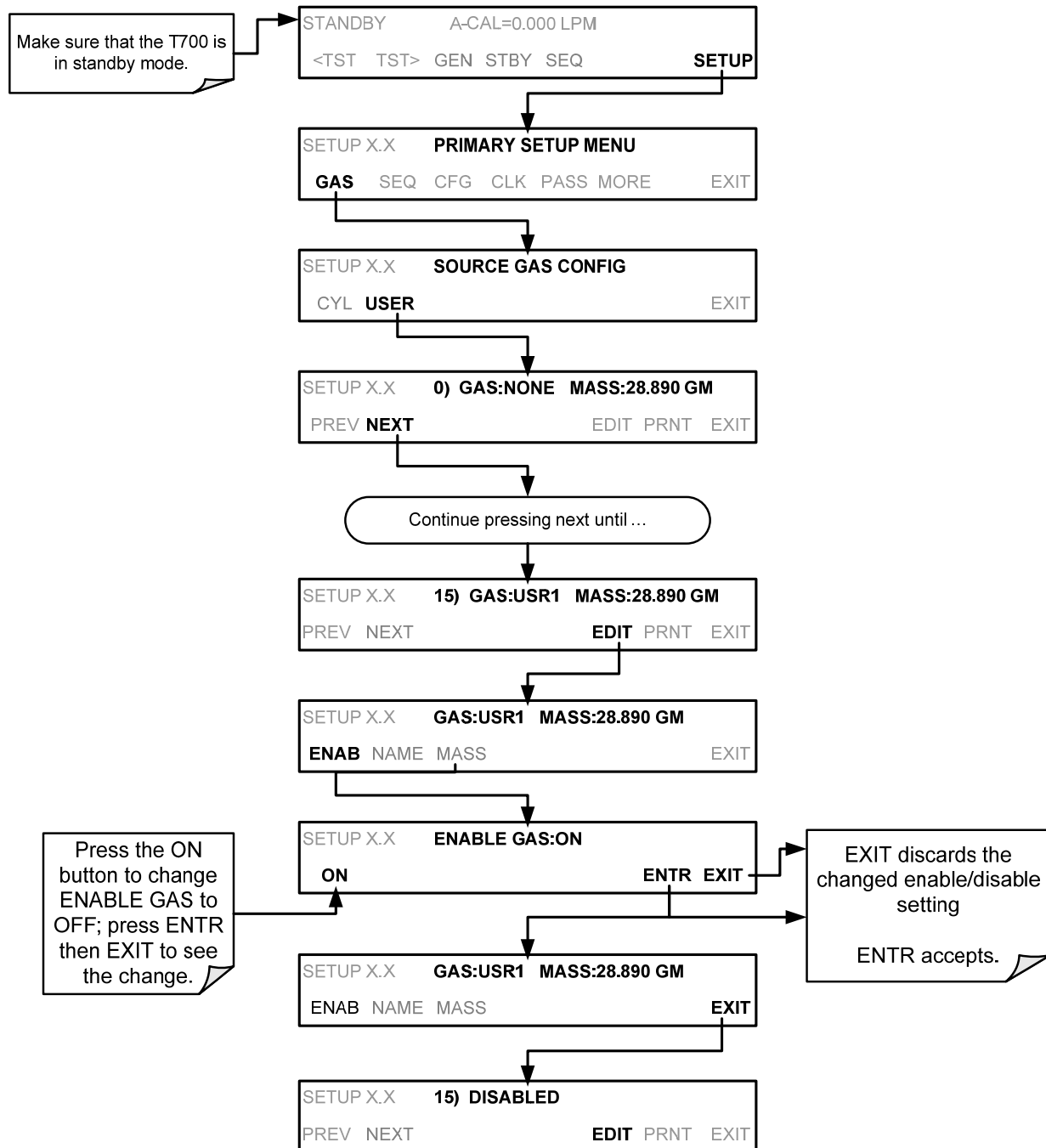
Note

If the contents of the bottle are predominantly N_2 , use the molar mass of N_2 (28.01).

3.4.6.4. Enabling and Disabling Gas Types

By default, all of the gases listed in Section 3.4.5 and the four undefined **USER** gases are **ENABLED**. Any of these can be disabled. Disabling a gas type means that it does not appear in certain prompts during portions of the T700's operation (e.g. setting up sequences) and is not figured into the calibrators calculating when determining calibration mixtures.

To disable a gas type, press:



3.4.7. DEFINING CALIBRATION SOURCE GAS CYLINDERS

3.4.7.1. Setting Up the Ports with Single Gas Cylinders

To program the T700 calibrator's source gas input ports for a single gas cylinder, press:

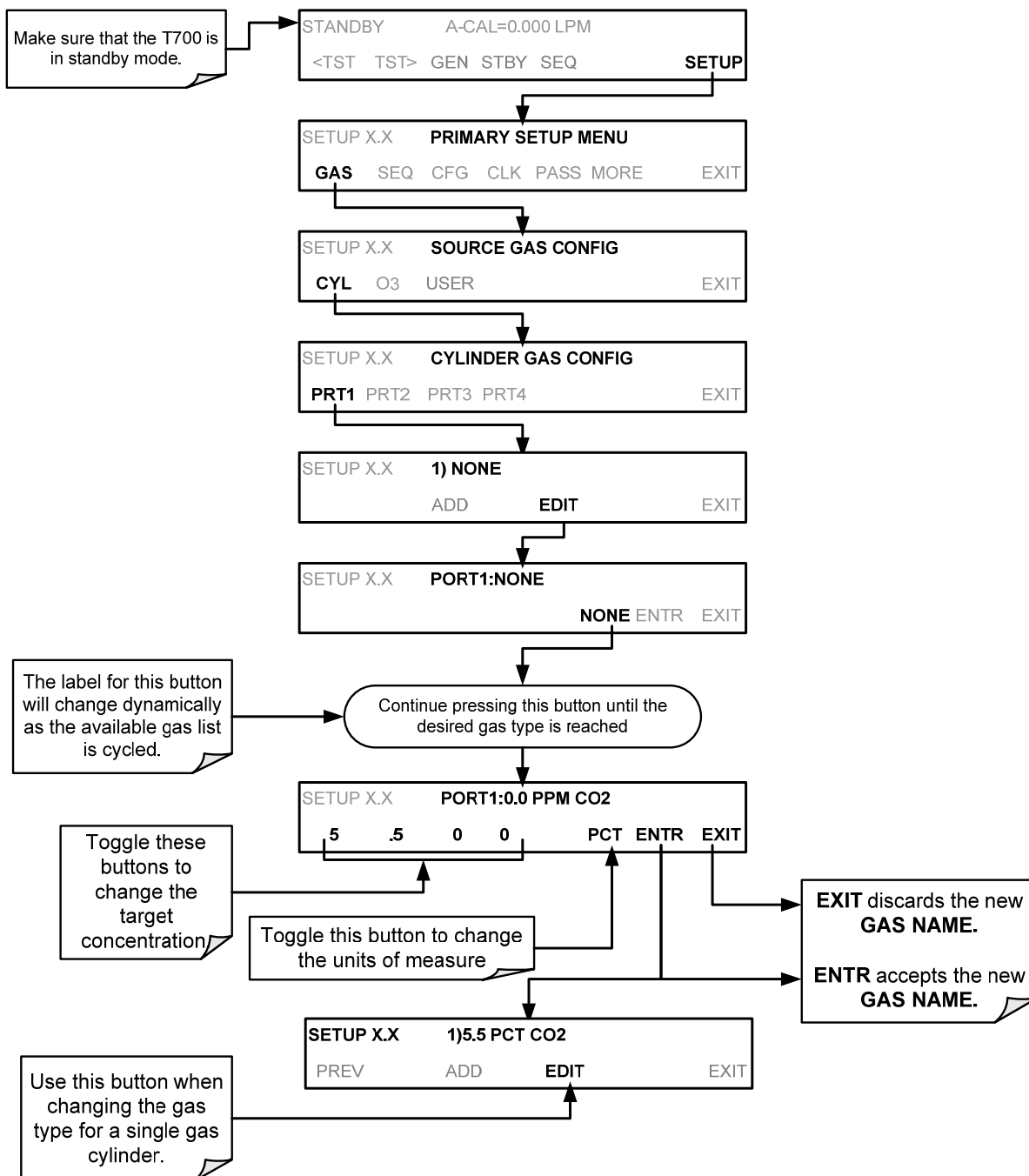


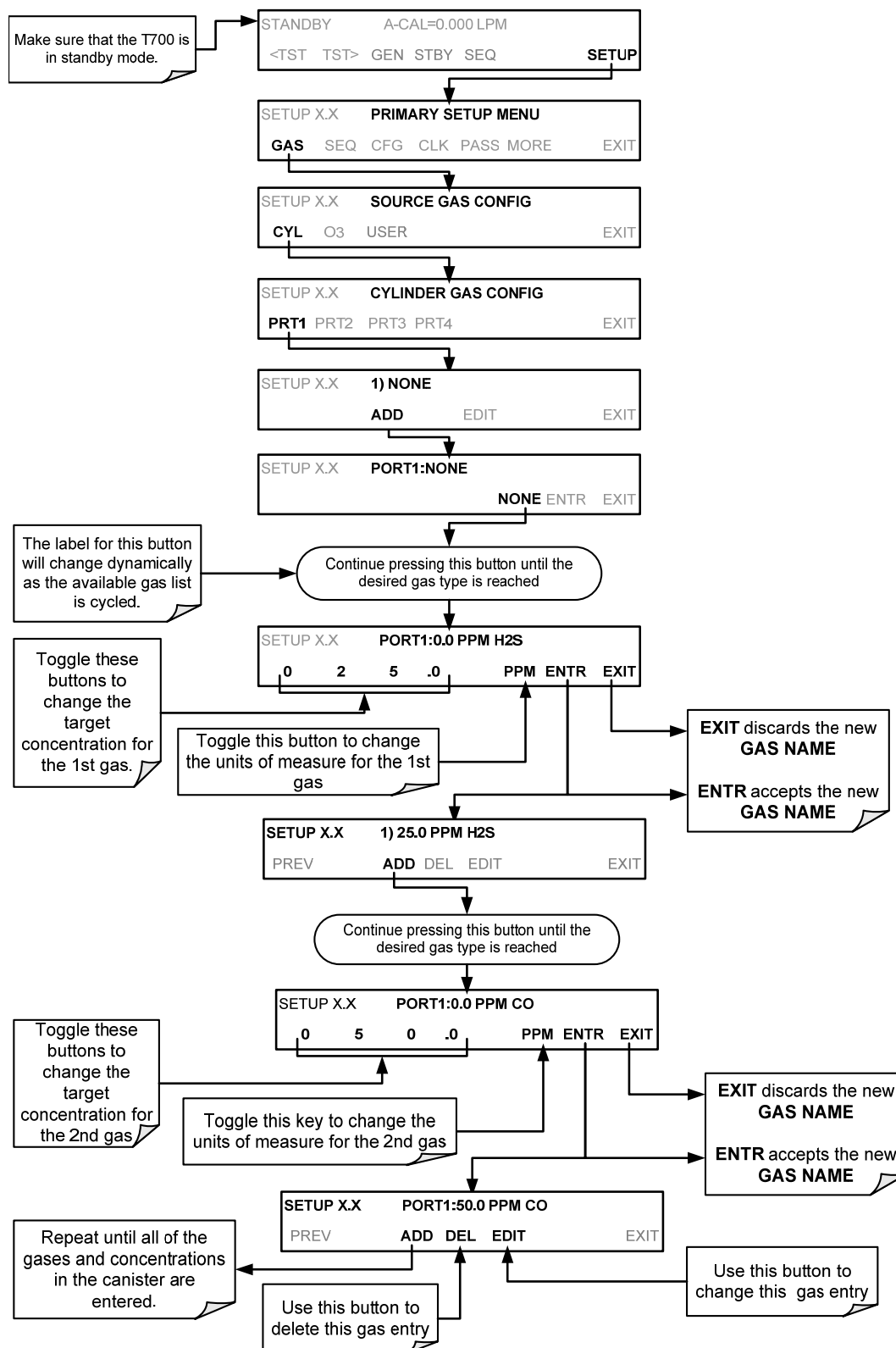
Table 3-18: T700 Units of Measure List

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

Repeat the above steps for each of the T700 calibrator's four gas inlet ports. If no gas is present on a particular port, leave it set at the default setting of **NONE**.

3.4.7.2. Setting Up the Ports with Multiple Gas Cylinders

When an application utilizes multiple gas cylinders, program as follows (note that the GENERATE>AUTO menu (Section 4.2.6) differs from that for a single gas (Section 4.2.1):



3.4.8. SELECTING AN OPERATING MODE FOR THE O₃ GENERATOR

The O₃ generator can be set to operate in three different modes: Constant, Reference, and Bench.

3.4.8.1. CNST (CONSTANT)

In this mode, the O₃ output of the generator is based on a single, constant, drive voltage. There is no Feedback loop control by the T700's CPU in this mode.

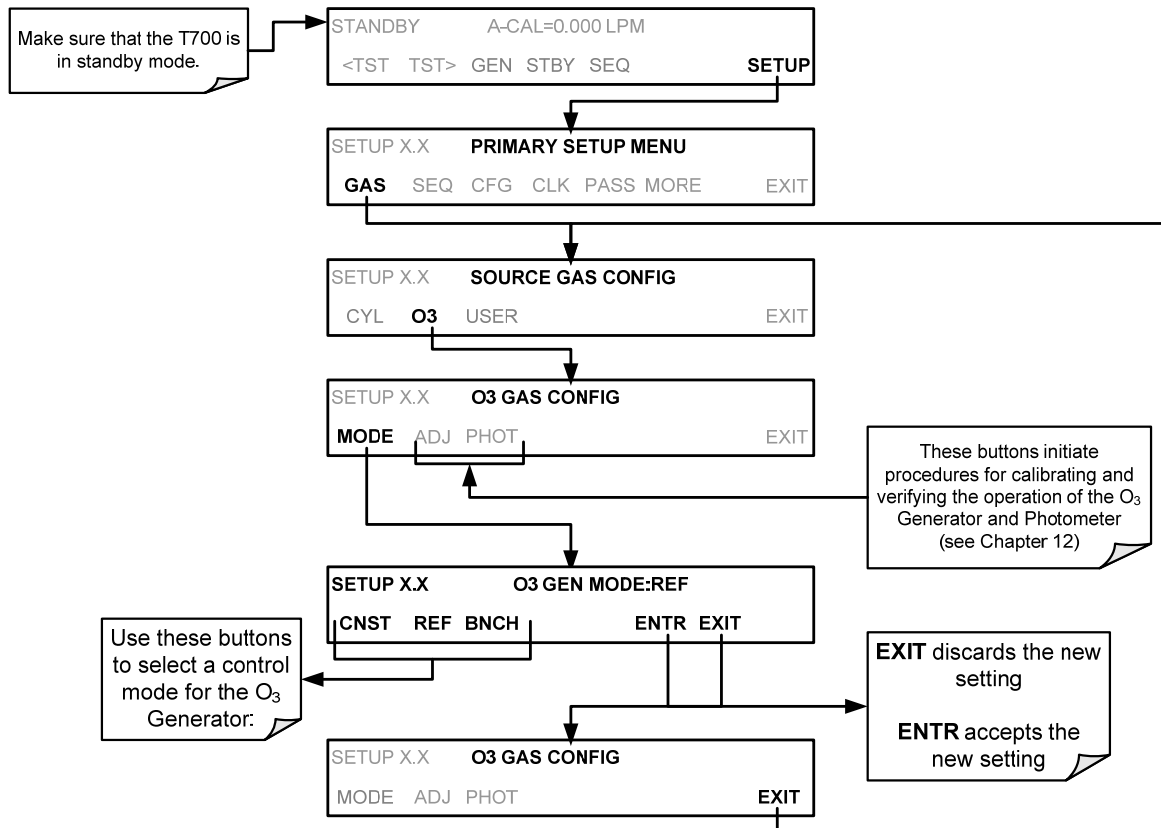
3.4.8.2. REF (REFERENCE)

The O₃ control loop will use the generator reference detector's UV lamp measurement as input. This mode does not use the photometer to control the ozone generator.

This setting will be the default mode (if not equipped with the photometer option) of the T700 calibrator and will be used whenever the calibrator is using the **GENERATE → AUTO** command or the **GENERATE** sequence step to create a calibration mixture. When the **GENERATE → MAN** command or the **MANUAL** sequence steps are active, the local O₃ generator mode (chosen during when the command/step is programmed) will take precedence.

3.4.8.3. BNCH (BENCH)

The O₃ concentration control loop will use the photometer's O₃ measurement as input. To select a default O₃ generator mode, press:



3.4.9. SETTING THE T700'S TOTAL GAS FLOW RATE

The default total gas flow rate for the T700 Dynamic Dilution Calibrator is 2 LPM. The calibrator 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.

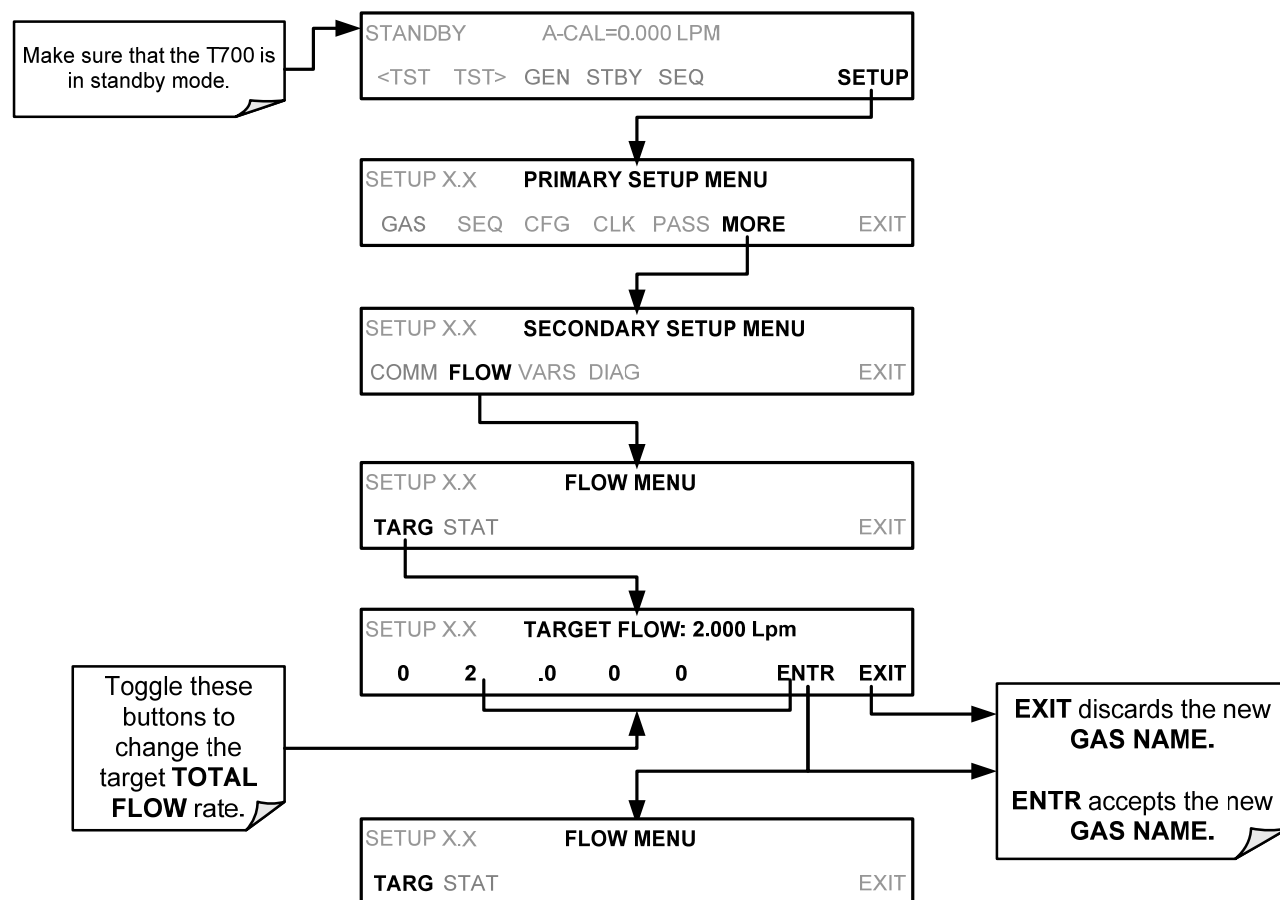
This Total Flow rate may be changed to fit the users' application. Once the flow is changed, then the new flow value becomes the total flow for all the gas concentration generated and computes again the individual flow rates of the component gases and diluent accordingly.

Note

- The minimum total flow should equal 150% of the flow requirements of all of the instruments to which the T700 will be supplying calibration gas.
- Example: If the T700 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:

$$(2 + 2 + 2) \times 1.5 = 9.000 \text{ LPM}$$

To set the **TOTAL FLOW** of the of the T700 Dynamic Dilution Calibrator, press:



Note

It is not recommended that you set the **TOTAL FLOW** rate to be <10% or >100% of the full scale rating of the diluent MFC

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

- The **GENERATE → AUTO** menu (see Section 4.2.1) or;
- As part of a **GENERATE** step when programming a sequence (see Section 4.3.2.1).

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 4.2.2) or;
- As part of a **MANUAL** step when programming a sequence (see Section 4.3.2.9).

Note

When calculating total required flow for T700's with O₃ photometers installed ensure to account for the 800 cc/min flow it requires.

PART II
—
OPERATING INSTRUCTIONS

4. OVERVIEW OF OPERATING MODES AND BASIC OPERATION

The T700 calibrator is a micro-computer-controlled calibrator with a dynamic menu interface for easy and yet powerful and flexible operation. All major operations are controlled from the front panel touch screen control.

To assist in navigating the system's software, a series of menu trees can be found in Appendix A of this manual.

Note

The flowcharts in this section depict the manner in which the front panel touch screen is used to operate the T700 Dynamic Dilution Calibrator. They depict typical representations of the display during the various operations being described. They are not intended to be exact and may differ slightly from the actual display of your system.

Note

The ENTR button may disappear if you select a setting that is invalid or out of the allowable range for that parameter, such as trying to set the 24-hour clock to 25:00:00. Once you adjust the setting to an allowable value, the ENTR button will reappear.

The T700 calibrator software has a variety of operating modes, which are controlled from the front panel touch screen. (Remote operation is described in Section 6). The most common mode that the calibrator will be operating in is the **STANDBY** mode. In this mode, the calibrator and all of its subsystems are inactive (no LED lit on front panel display), although **TEST** functions and **WARNING** messages are still updated and can be examined via the front panel display.

The second most important operating mode is **SETUP** mode. This mode is used for performing certain configuration operations, such as programming the concentration of source gases, setting up automatic calibration sequences and configuring the analog/digital inputs and outputs. The **SETUP** mode is also used for accessing various diagnostic tests and functions during troubleshooting.



Figure 4-1: Front Panel Display

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

Besides **STANDBY** and **SETUP**, other modes the calibrator can be operated in are listed in Table 4-1:

Table 4-1: Calibrator Operating Modes

MODE	DESCRIPTION	
STANDBY	The calibrator and all of its subsystems are inactive.	
GENERATE	In this mode, the instrument is engaged in producing calibration gas mixtures.	
	MANUAL	In this mode, the instrument is engaged in producing calibration gas mixtures.
	PURGE	The calibrator is using diluent (zero air) to purge its internal pneumatics of all source gas and previously created calibration mixtures.
	GPT¹	The calibrator is using the O ₃ generator and source gas inputs to mix and generate calibration gas using the gas phase titration method.
	GPTPS²	Stands for Gas Phase Titration Preset. In this mode the T700 determines the precise performance characteristics of the O ₃ generator at the target values for an upcoming GPT calibration.
SETUP³	SETUP mode is being used to configure the calibrator.	
	DIAG	One of the calibrator's diagnostic modes is being utilized. When the diagnostic functions that have the greatest potential to conflict with generating concentrations are active, the instrument is automatically placed into standby mode.
¹ This mode is not available in units without O ₃ generators installed. ² This mode is not available in units without internal photometers installed. ³ The revision of the Teledyne API software installed in this calibrator will be displayed following the word SETUP . E.g. " SETUP G.4 "		

4.1. STANDBY MODE

When the T700 Dynamic Dilution Calibrator is in standby mode, it is at rest. All internal valves are closed except the diluent inlet valve. The mass flow controllers are turned off. On units with O₃ generator and photometer options installed, these subsystems are inactive.

- The **SETUP → GAS** submenu is only available when the instrument is in **STANDBY** mode.
- Some functions under the **SETUP → MORE → DIAG** submenu, those which conflict with accurate creation of calibration gas mixtures (e.g. **ANALOG OUTPUT STEP TEST**) automatically place the calibrator into **STANDBY** mode when activated.
- The MFC pressures are not monitored in standby mode since the MFCs are turned OFF. This prevents erroneous **MASS FLOW WARNING** messages from appearing.

Note

The T700 calibrator should always be placed in **STANDBY** mode when not needed to produce calibration gas. The last step of any calibration sequences should always be the **STANDY** instruction.

Table 4-2 shows the status of the T700's various pneumatic components when the calibrator is in **STANDBY** mode.

Table 4-2: Status of Internal Pneumatics During STANDBY Mode

VALVES (X = Closed; O = Open)									MFCs			PHOT PUMP
CYL1	CYL2	CYL3	CYL4	PURGE	DILUENT	GPT	O ₃ GEN	PHOT M/R ¹	CAL1	CAL2 ¹	DILUENT	
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.

In instruments with optional O₃ generators installed, airflow is maintained during **STANDBY** mode so that the generator can continue to operate at its most efficient temperature.

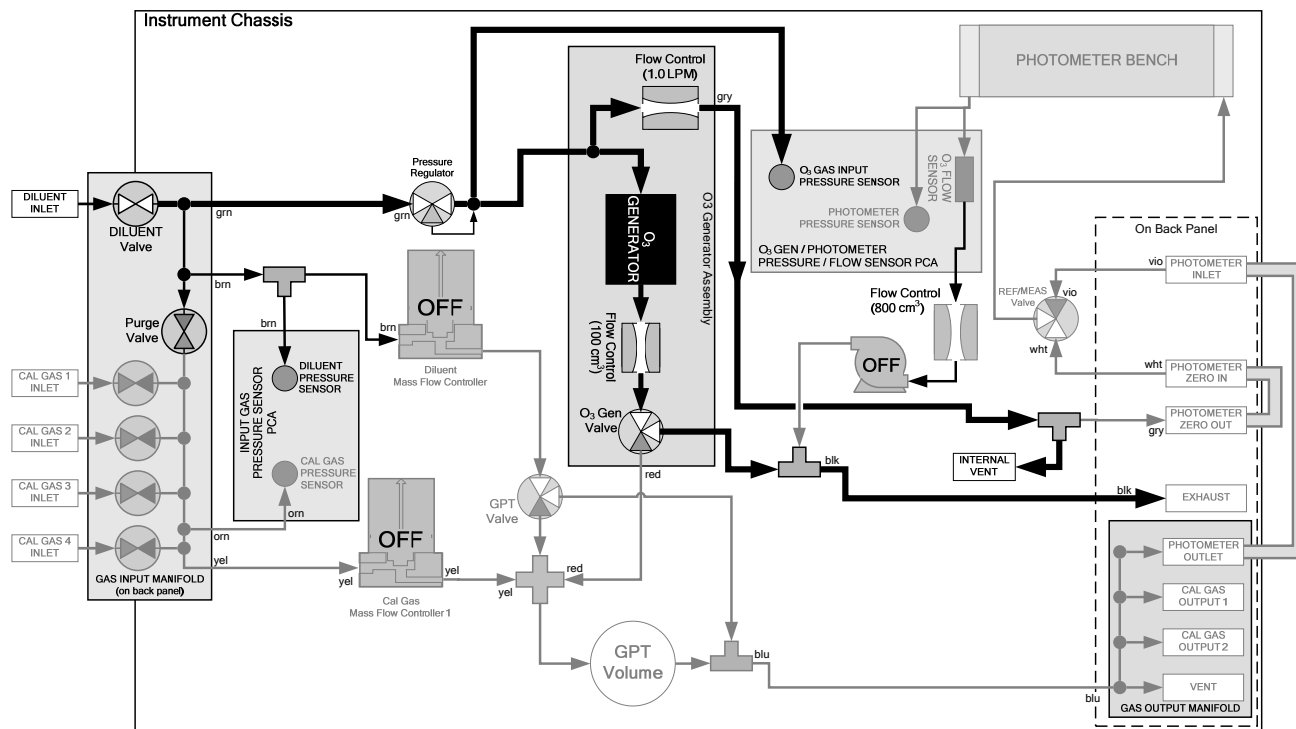


Figure 4-2: Gas Flow through T700 with O₃ Generator and Photometer Options during STANDBY

4.1.1. TEST FUNCTIONS

A variety of **TEST** functions are available for viewing at the front panel whenever the calibrator is in STANDBY Mode. These functions provide information about the present operating status of the calibrator and are useful during troubleshooting (see Section 9). Table 4-3 lists the available **TEST** functions.

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

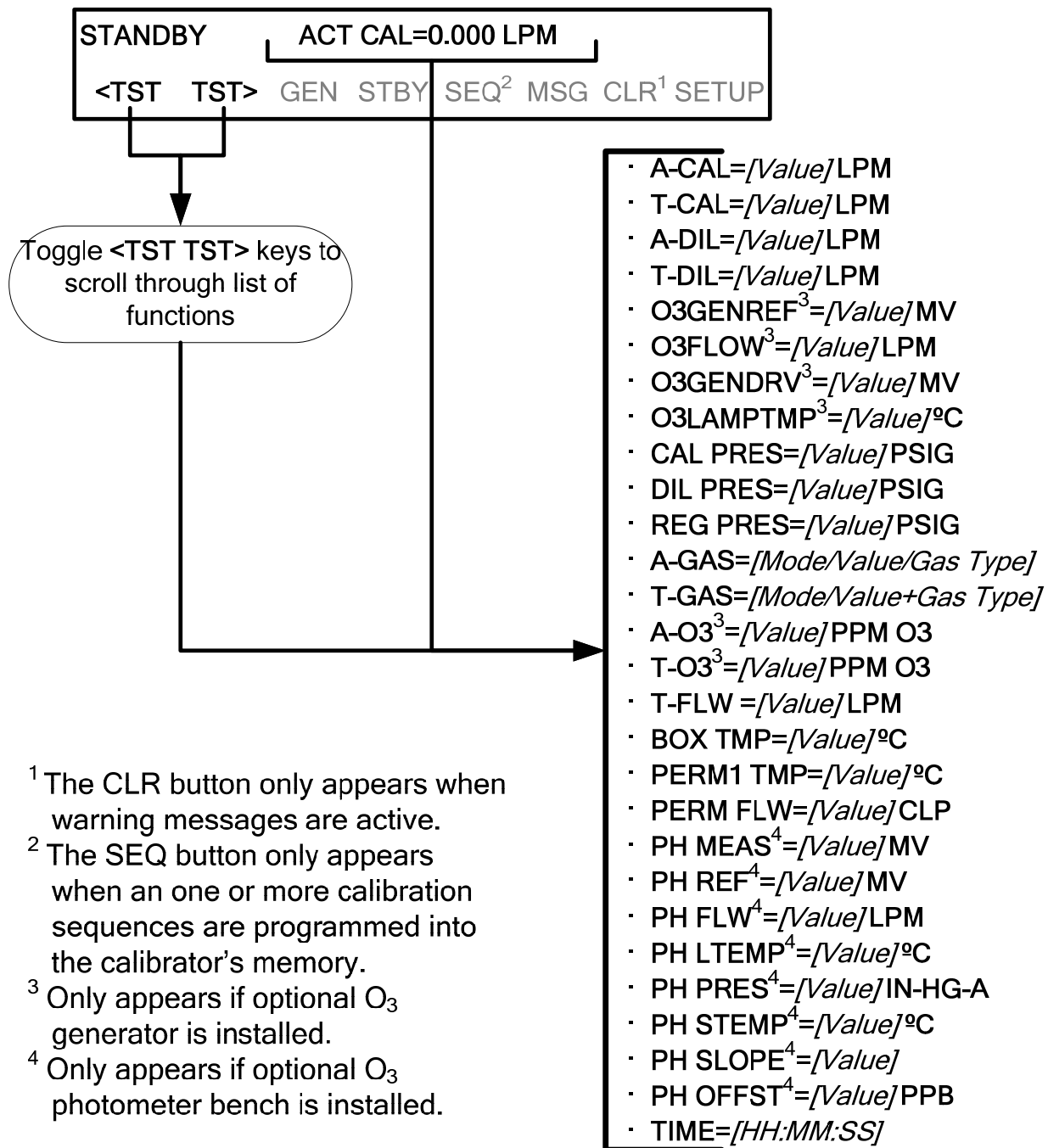


Figure 4-3: Viewing T700 Test Functions

Table 4-3: Test Functions Defined

DISPLAY	UNITS	DESCRIPTION
A-CAL	LPM	The actual gas flow rate of source gas being output by the calibrator.
T-CAL	LPM	Target source gas flow rate for which the calibrator output is set.
A-DIL	LPM	The actual gas flow rate of diluent (zero) gas being output by the calibrator.
T-DIL	LPM	Target diluent (zero) gas flow rate for which the calibrator output is set.
O3GENREF ¹	mV	The voltage being output by the O ₃ generator reference detector.
O3FLOW ¹	LPM	The gas flow rate for which the O ₃ generator is set.
O3GENDRV ¹	mV	The drive voltage of the O ₃ generator UV lamp.
O3LAMPTMP ¹	°C	O ₃ generator UV lamp temperature.
CAL PRES	PSIG	The gas pressure of the source gas being supplied to the calibrator.
DIL PRES	PSIG	The gas pressure of the Diluent gas being supplied to the calibrator Diluent pressure.
REG PRES ²	PSIG	The gas pressure at the pressure regulator on the O ₃ generator supply line.
A-GAS		Actual concentration, and in some modes the actual flow rate, of the source gas in the calibration mixture being generated is displayed.
T-GAS		The Target concentration, and in some modes the target flow rate, of the source gas in the calibration mixture being generated is displayed.
BOX TMP	°C	Internal chassis temperature.
PH MEAS ²	mV	The average UV Detector output during the SAMPLE PORTION of the optional photometer's measurement cycle.
PH REF ²	mV	The average UV Detector output during the REFERENCE portion of the optional photometer's measurement cycle.
PH FLW ²	LPM	The gas flow rate as measured by the flow sensor located between the optical bench and the internal pump.
PH LTEMP ²	°C	The temperature of the UV lamp in the photometer bench.
PH PRES ²	In-hg-A	The pressure of the gas inside the photometer's sample chamber as measured by a solid-state pressure sensor located downstream of the photometer.
PH STEMP ²	°C	The temperature of the gas inside the sample chamber of the photometer.
PH SLOPE ²	1.000	Photometer slope computed when the photometer was calibrated at the factory.
PH OFFST ²	ppb	Photometer offset computed when the photometer was calibrated at the factory.
TEST ³	mV	Displays the analog signal level of the TEST analog output channel.
TIME	HH:MM:SS	Current time as determined by the calibrator's internal clock.
¹ Only appears when the optional O ₃ generator is installed.		
² Only appears when the optional O ₃ photometer is installed.		
³ Only appears when the TEST channel has been activated.		

4.2. GENERATE MODE

The Generate Mode allows the user to generate the desired calibration gas mixtures. The types of gas include NO, NO₂, SO₂, CO, HC or ZERO gas based on the source gas concentration entered during initial setup (see Section 3.4.7). If the unit has an optional O₃ generator installed, various concentrations of O₃ can be generated as well.

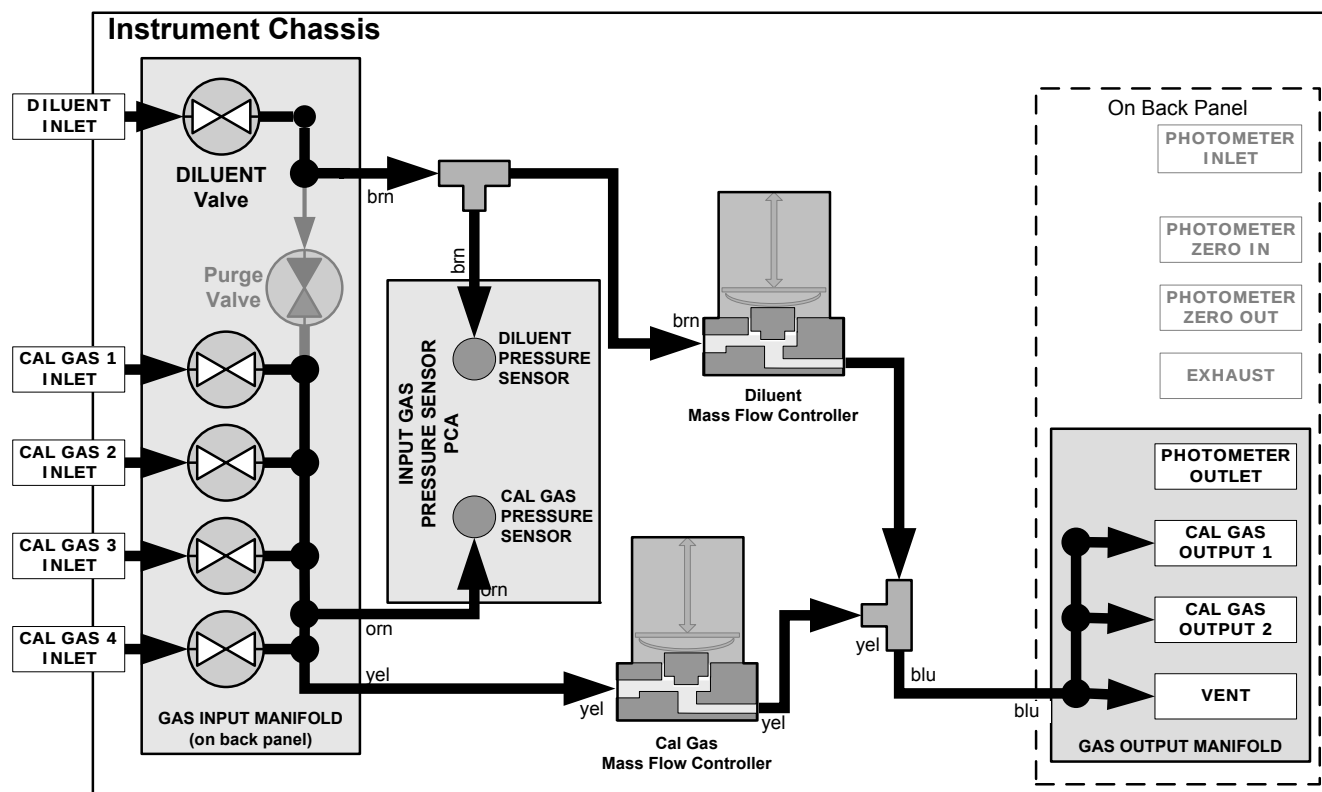


Figure 4-4: Gas Flow through Basic T700 in GENERATE Mode

Table 4-4 shows the status of the T700's various pneumatic components when the calibrator is in **GENERATE** mode:

Table 4-4: Status of Internal Pneumatics During GENERATE Mode

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

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.

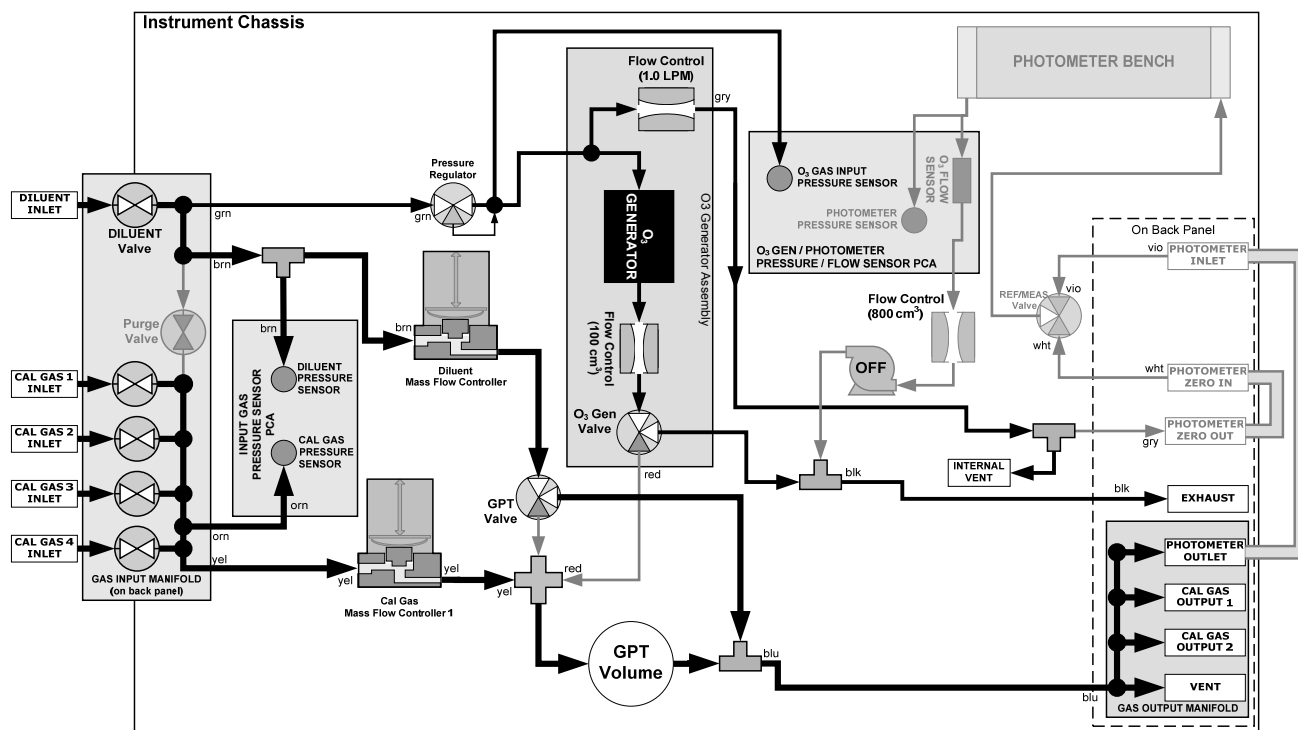


Figure 4-5: Gas Flow through T700 with O₃ Options when Generating Non-O₃ Source Gas

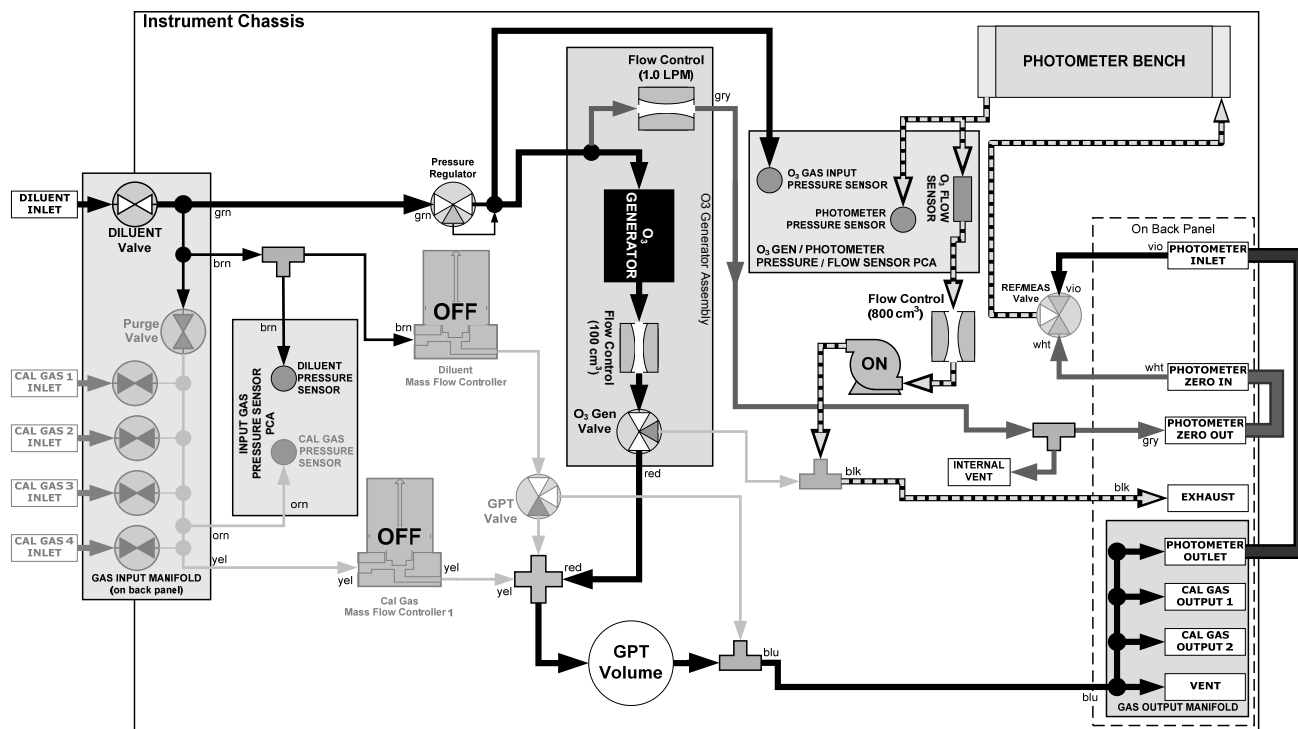


Figure 4-6: Gas Flow through T700 with O₃ Options when Generating O₃

4.2.1. GENERATE → AUTO: BASIC GENERATION OF CALIBRATION MIXTURES

This is the simplest procedure for generating calibration gas mixtures. In this mode, the user makes three choices:

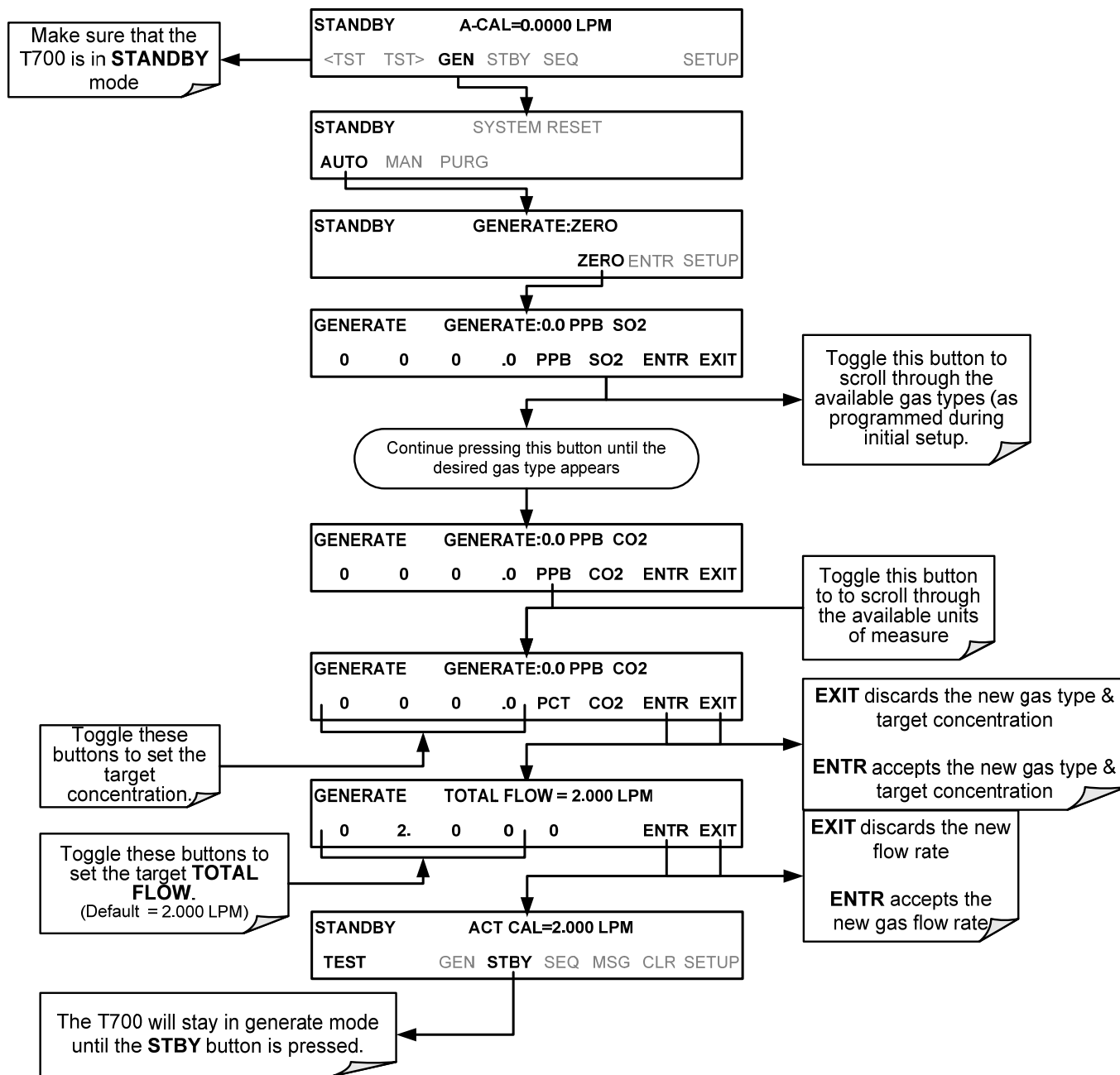
- The type of component gas to be used from the list of gases input during initial set up (see Section 3.4.7);
- The target concentration, and;
- The **TOTAL FLOW** to be output by the T700.

Using this information, the T700 calibrator automatically calculates and sets the individual flow rates for the Diluent and chosen component gases to create the desired calibration mixture.

Note

This menu, which shows the SEQ (sequence) button, differs from the GENERATE>AUTO menu for cylinders of multiple gases (Section 4.2.6).

To use the **GENERATE → AUTO** feature, press:



4.2.2. GENERATE → MAN: GENERATING CALIBRATION MIXTURES MANUALLY

This mode provides complete the user with more complete control of the gas mixture process. Unlike the **AUTO** mode, **MAN** mode requires the user set the both the component gas flow rate and diluent airflow rate. This allows the user control over the mixing ratio and total calibration gas flow rate.

In addition, if the T700 calibrator is equipped with the optional O₃ generator and O₃ 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.

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 T700 will be supplying calibration gas.
- Example: If the T700 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:

$$(2 + 2 + 2) \times 1.5 = 9.000 \text{ LPM}$$

4.2.2.1. Determining the Source Gas Flow Rate

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

Equation 4-1

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

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 SO₂ is needed.
- The Concentration of the SO₂ Source is 600 ppm
- The requirement of the system are 9.000 LPM
- The required source gas flow rate would be:

$$GAS_{flow} = (200 \text{ ppm} \times 9.000 \text{ LPM}) \div 600 \text{ ppm}$$

$$GAS_{flow} = 1800.000 \text{ ppm/LPM} \div 600 \text{ ppm}$$

$$GAS_{flow} = 3.000 \text{ LPM}$$

4.2.2.2. Determining the Diluent Gas Flow Rate

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

Equation 4-2

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

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:

$$DIL_{flow} = 9.0 \text{ LPM} - 3.0 \text{ LPM}$$

$$DIL_{flow} = 6.0 \text{ LPM}$$

4.2.2.3. Determining the Diluent Gas Flow Rate with the Optional O₃ Generator Installed

If the optional O₃ generator is installed and in use, Equation 6.2 will be slightly different, since the O_{3flow} is a constant value and is displayed as a **TEST** function on the T700's front panel. A typical value for O_{3flow} is 105 cm³/min.

Equation 4-3

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

WHERE:

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

Totalflow = total gas flow requirements of the system.

O_{3flow} = the flow rate set for the O₃ 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:

$$DIL_{flow} = 9.0 \text{ LPM} - 0.105 \text{ LPM}$$

$$DIL_{flow} = 8.895 \text{ LPM}$$

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.

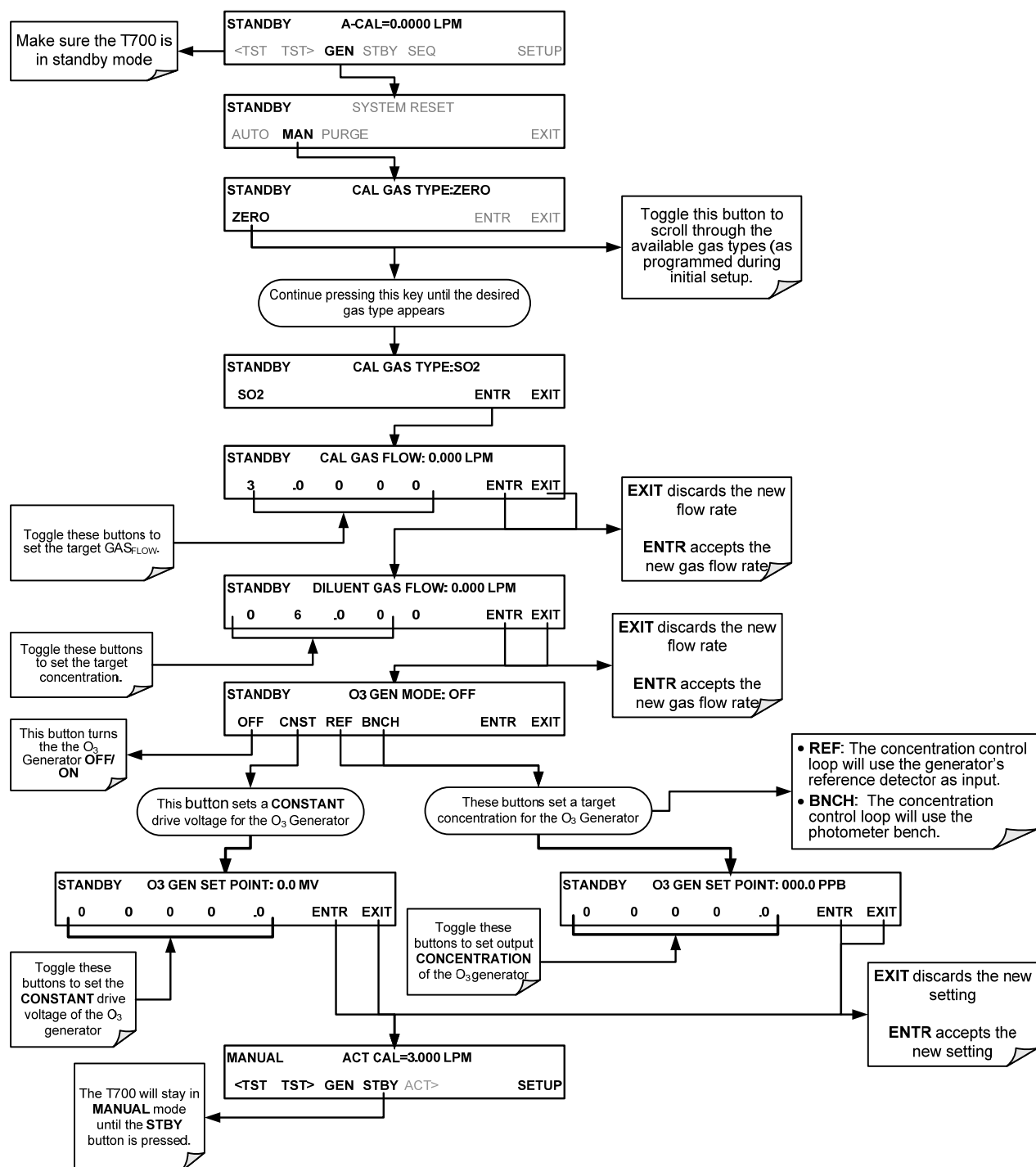
WITH MULTIPLE CALIBRATIONS MASS FLOW CONTROLLERS INSTALLED:

- The combined flow potential of both mass flow controllers is available with the following limits: The limits are <10% of the lowest rated MFC or >100% of the combined full-scale ratings for both mass flow controllers.
- The T700 will automatically select 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, multiple mass flow controllers are used.

4.2.2.4. Setting the Source Gas and Diluent Flow Rates Using the GENERATE → MAN Menu

In the following demonstration we will be using the values from the examples given with Equations 6-1 and 6-2 above and assume a T700 calibrator with at least one source gas mass flow controller capable of 3.0 LPM output.

Using the example from Equations 6-1 and 6-2 above, press:



4.2.3. GENERATE → GPT: PERFORMING A GAS PHASE TITRATION CALIBRATION

4.2.3.1. GPT Theory

The principle of GPT is based on the rapid gas phase reaction between NO and O₃, which produces quantities of NO₂ as shown by the following equation:

Equation 4-4



It has been empirically determined that under controlled circumstances the NO-O₃ reaction is very efficient (<1% residual O₃), therefore the concentration of NO₂ resulting from the mixing of NO and O₃ can be precisely predicted and controlled as long as the following conditions are met:

- The amount of O₃ used in the mixture is known.
- The amount of NO used in the mixture is **AT LEAST** 10% greater than the amount O₃ in the mixture.
- The volume of the mixing chamber is known.
- The NO and O₃ 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 NO₂ being output by the T700 will be equal to (at a 1:1 ratio) to the amount of O₃ added.

Since the O₃ flow rate of the T700's O₃ generator is a set fixed value (typically about 0.105 LPM) and the GPT chamber's volume is known, once the **TOTAL GAS FLOW** requirements, the source concentration of NO, and the target concentration for the O₃ generator are entered into the calibrator's software. The T700 adjusts the NO flow rate and diluent (zero air) flow rate to create the appropriate NO₂ concentration at the output.

4.2.3.2. Choosing an Input Concentration for the NO

It is important to ensure that there is enough NO in the GPT chamber to use up all of the O₃. Excess O₃ will react with the resulting NO₂ to produce NO₃. Since NO₃ is undetectable by most NO_x analyzers, this will result in false low readings.

The EPA requires that the NO content of a GPT mixture be at least 10% higher than the O₃ content. Since there is no negative effect to having too much NO in the GPT chamber, Teledyne API recommends that the NO concentration be chosen to be some value higher (as much as twice as high) as the highest intended target NO₂ value and kept constant.

As long as the flow rate is also kept constant three of the four conditions listed in Section 4.2.3.1 above are therefore constant and the NO₂ output can be easily and reliably varied by simply changing the O₃ concentration.

EXAMPLE:

- Calibration values of NO₂ from 200 ppb to 450 ppb will be needed.
- The NO gas input concentration should be no lower than 495 ppb and can be as high as 900 ppb.

4.2.3.3. 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 T700 will be supplying calibration gas.

EXAMPLE:

- If the T700 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:
- $(2 + 2 + 2) \times 1.5 = 9.000 \text{ LPM}$

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.

WITH MULTIPLE CALIBRATIONS MASS FLOW CONTROLLERS INSTALLED:

- The full combined flow potential of both mass flow controllers is available to use with the following limits: The limits are <10% of the lowest rated MFC or >100% of the combined full-scale ratings for both mass flow controllers.
- The T700 will automatically select 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, multiple mass flow controllers are used.

Given this information, the T700 calibrator determines the NO gas flow by the formula:

Equation 4-5

$$NO \text{ GAS}_{flow} = \frac{C_{NO_2} \times Totalflow}{C_{NO}}$$

WHERE:

C_{NO_2} = target concentration for the NO₂ output

C_{NO} = concentration of the NO gas input

$NO \text{ GAS}_{flow}$ = NO source gas flow rate

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

Equation 4-6

$$DIL_{flow} = Totalflow - NOGAS_{flow} - O_{3flow}$$

WHERE:

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

Totalflow = total gas flow requirements of the system.

O_{3flow} = the flow rate set for the O₃ generator; a constant value (typically about 0.105 LPM)

DIL_{flow} = required diluent gas flow

4.2.3.4. T700 Calibrator GPT Operation

The following table and figures show the status of the T700's internal pneumatic components and internal gas flow when the instrument is in **GPT** generating modes.

Table 4-5: Status of Internal Pneumatics During GENERATE → GPT Mode

MODE	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	
GPT	O ²	O ²	O ²	O ²	X	O	O	O	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.

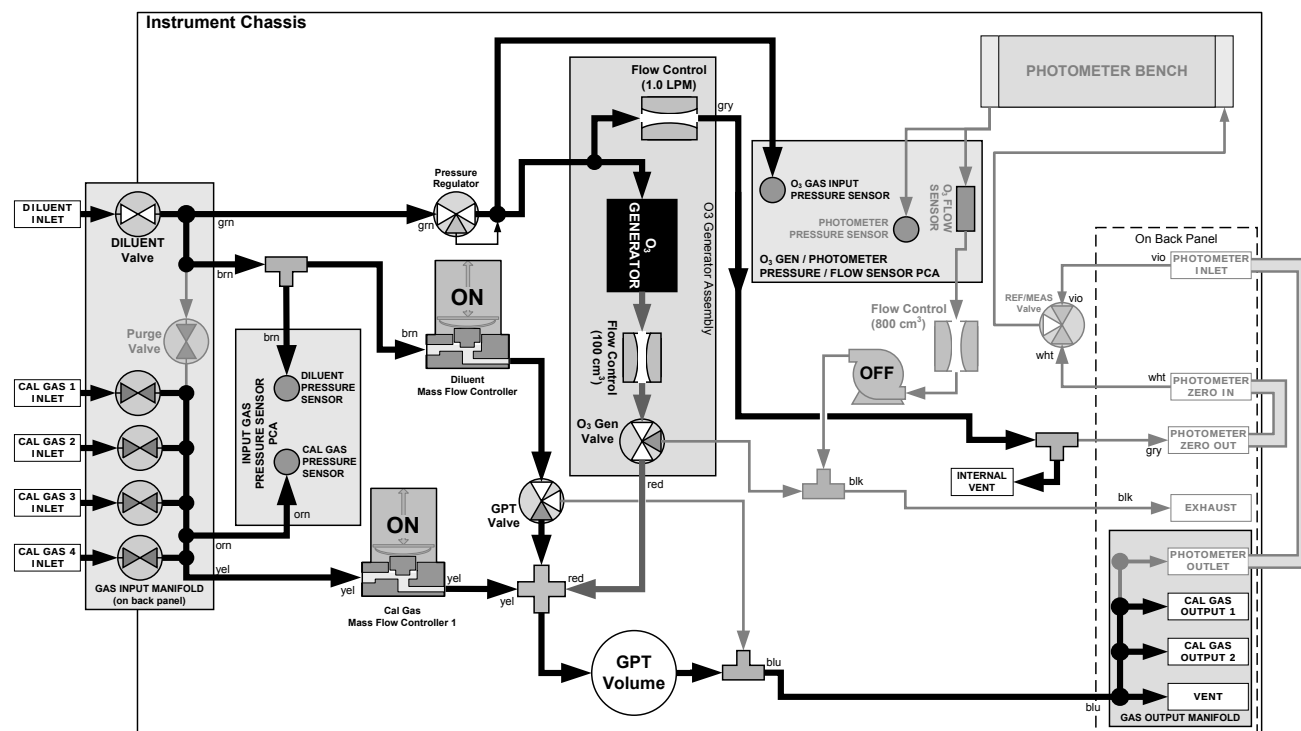


Figure 4-7: Gas Flow through T700 with O₃ Options when in GPT Mode

4.2.3.5. Initiating a GPT Calibration Gas Generation

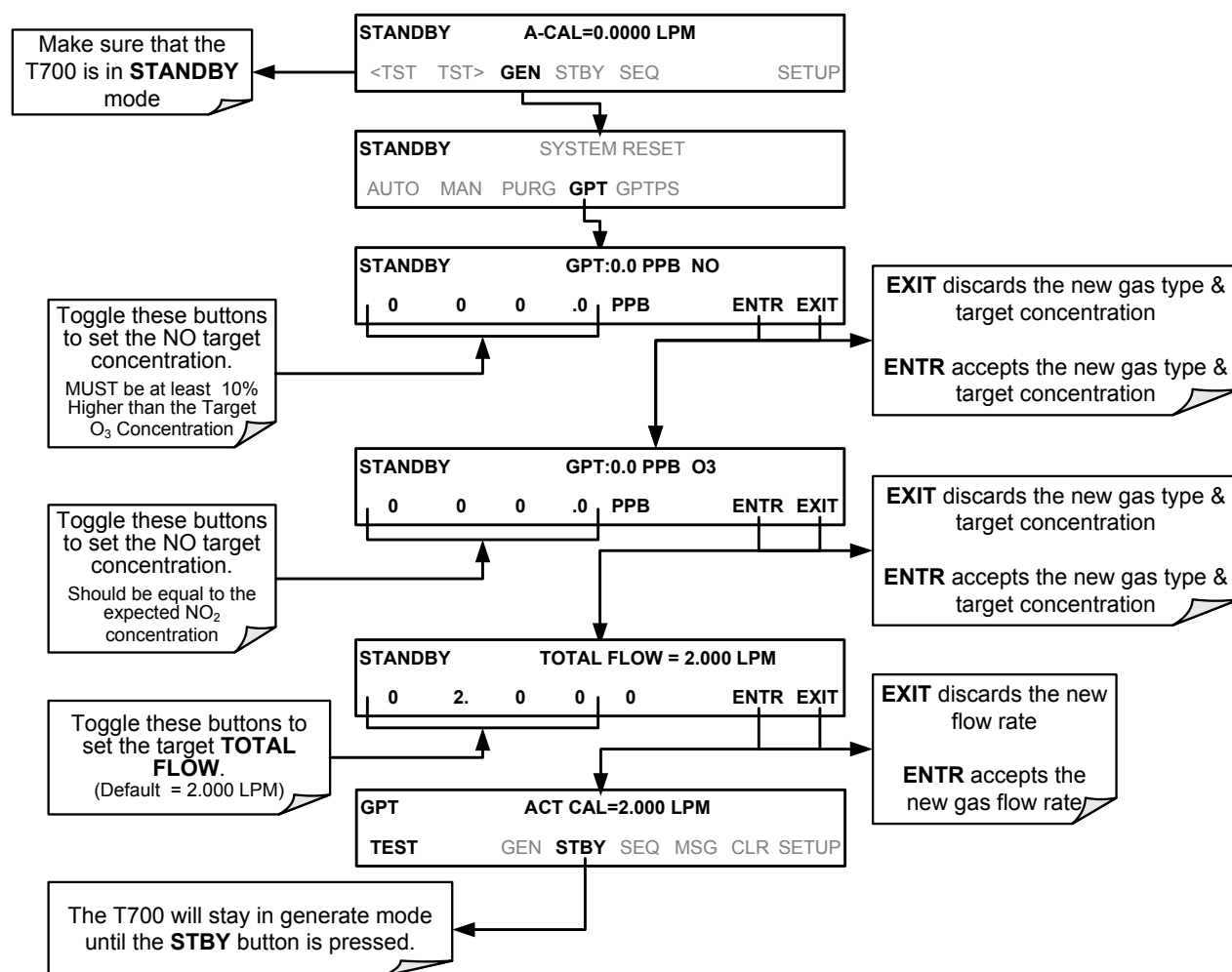
Note

It is highly recommended to perform a GPT Pre-Set before initiating any GPT gas generation (Section 4.2.4).

To initiate GPT gas generation you will need to know:

- The **TOTAL GAS FLOW** for the mixture output;
- The Target O₃ concentration (equal to the target NO₂ concentration to be generated), and;
- The NO source gas concentration.

Then, press:



4.2.4. GENERATE → GPTPS: PERFORMING A GAS PHASE TITRATION PRE-SET

The GPT Pre-Set feature simulates a **GPT** mixing operation in order to determine the exact output of the calibrators O₃ generator. As described in Section 4.2.3.1, all other things being equal, the concentration of the NO₂ being generated using the GPT feature will be equal to the amount of O₃ used. Therefore, the more accurately the O₃ generator performs the more accurate the NO₂ output will be.

When operating in **GPTPS** mode diluent gas (zero air) is substituted for the NO gas that would be mixed with the O₃ in normal GPT mode. The resulting unaffected O₃ output of the O₃ generator is shunted through the T700's internal photometer, which measures the ACTUAL O₃ concentration in the gas.

Once the exact O₃ concentration being output by the generator is determined, the calibrator's software adjusts the O₃ drive voltage up or down 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.

Note

The T700 has a learning algorithm during the O₃ generation (see Section 4.2) or Gas Phase Titration Pre-Set Mode (GPTPS) (Sections 4.2.3.5 and 4.2.4). 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 O₃ generator and GPTPS).

Note

This adjustment is only valid for the O₃ concentration used during the Pre-Set operation. GPT Presets must be re-run for each different target NO₂ value.

In order to keep the resulting concentration of O₃ consistent with the GPT mixture being simulated, the instrument's software adjust the flow rate of the diluent gas to substitutes an amount of diluent gas equal to the amount of NO gas that would normally be used.

4.2.4.1. T700 Calibrator GPTPS Operation

The following table and figures show the status of the T700's internal pneumatic components and internal gas flow when the instrument is in **GPTPS** generating modes.

Table 4-6: Status of Internal Pneumatics During GENERATE → GPTPS Mode

MODE	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	
GPTPS	X	X	X	X	X	O	O	O	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.

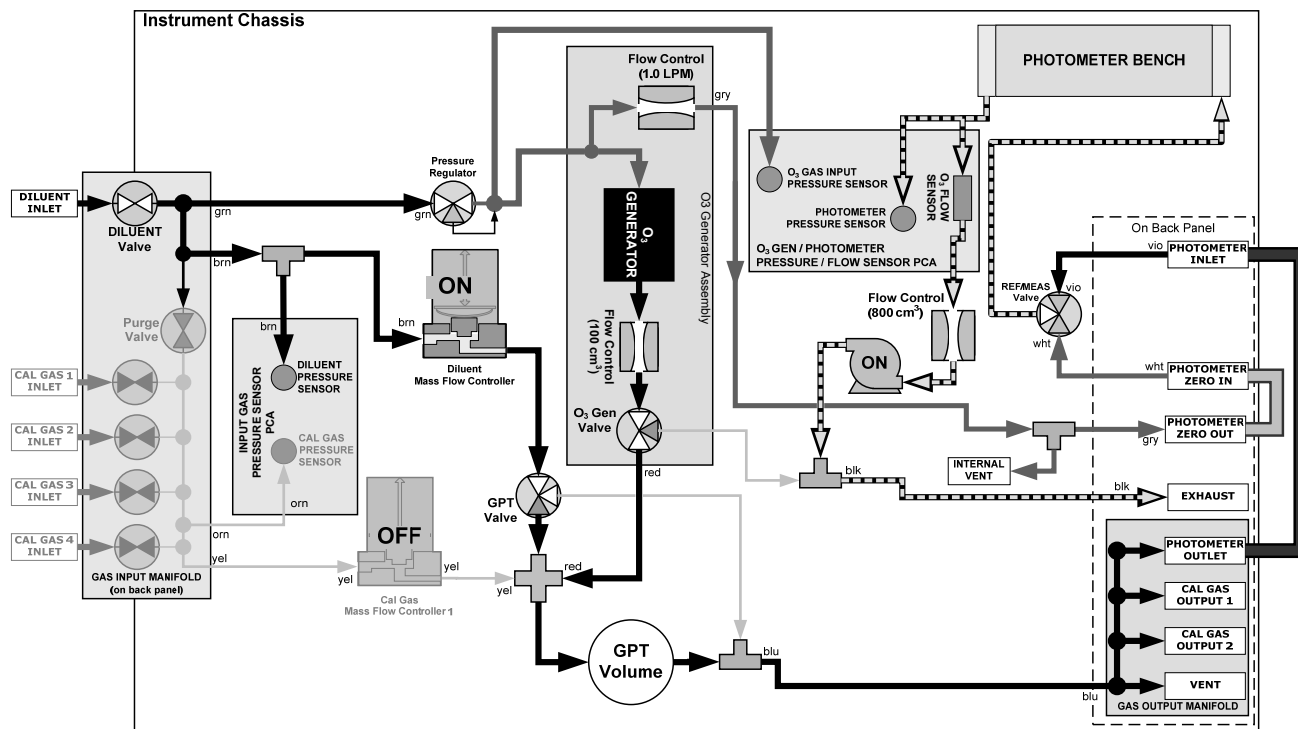


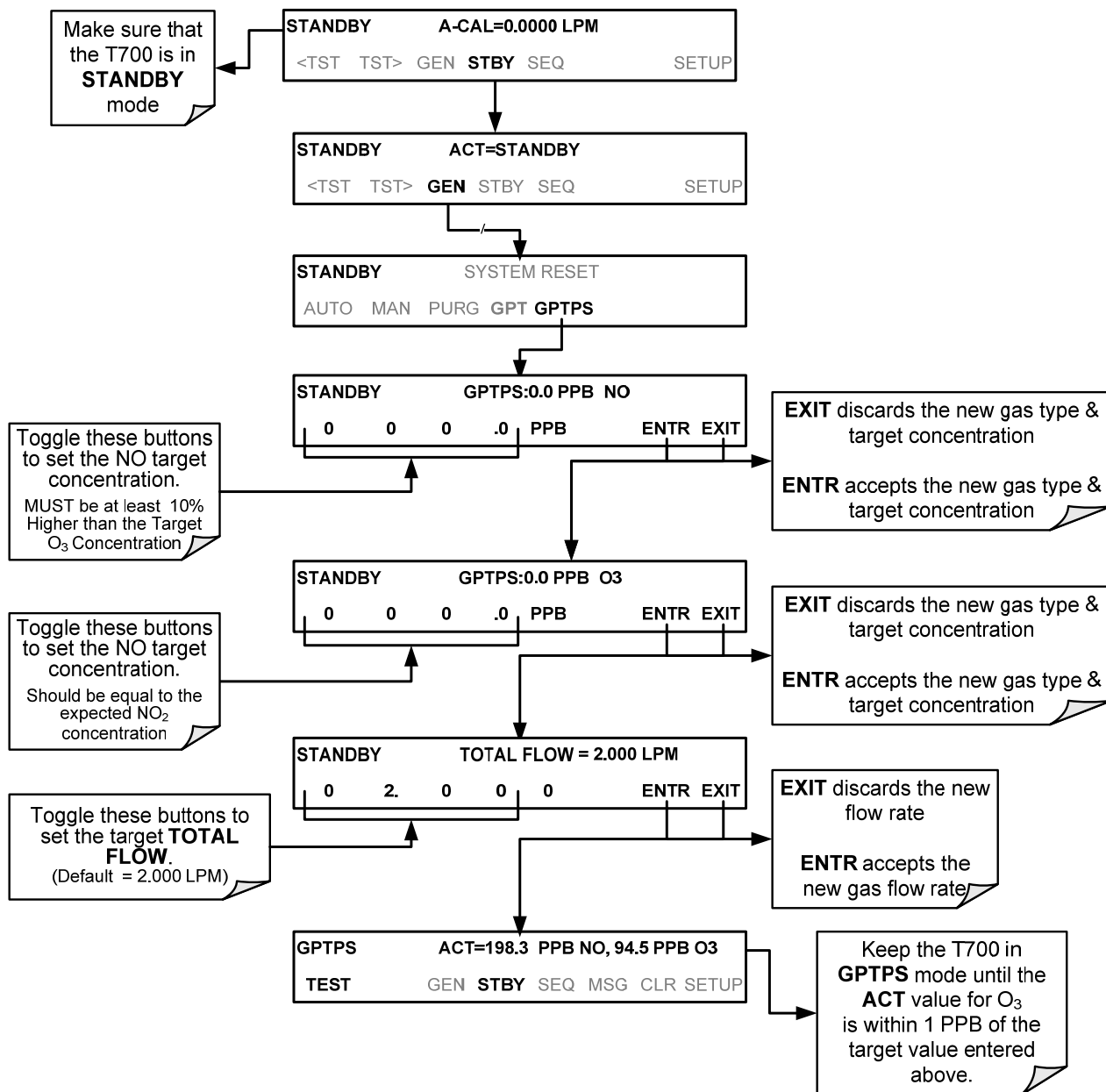
Figure 4-8: Gas Flow through T700 with O₃ Options when in GTPS Mode

4.2.4.2. Initiating a GPT Pre-Set

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

- The **TOTAL GAS FLOW** for the mixture output;
- The Target O₃ concentration (equal to the target NO₂ concentration being simulated), and;
- The NO source gas concentration.

Then, press:



4.2.5. GENERATE → PURGE: ACTIVATING THE T700'S PURGE FEATURE

The T700 calibrator's PURGE feature clears residual source gases and calibration mixtures gases from the previous generated steps from the instruments internal pneumatics as well as any external pneumatic lines down stream from the calibrator.

When activated, the **PURGE** feature:

- Opens the Diluent (zero air) inlet valve allowing zero air to flow into the calibrator from 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 T700.

The **PURGE** air is vented through the VENT port of the rear panel of the instrument (see Figure 3-4).

Table 4-7: Internal Pneumatics During Purge Mode

MODE	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	
PURGE	X	X	X	X	O	O	O	O	Switching	ON³	ON³	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.

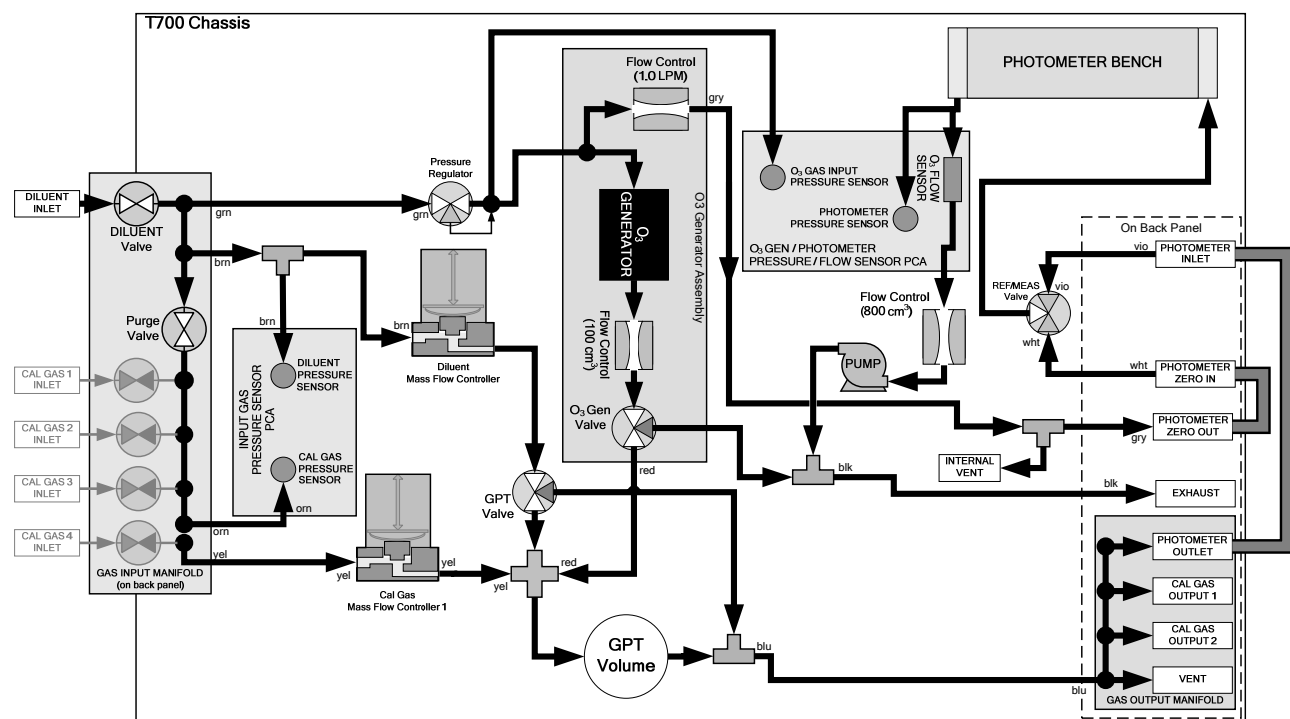
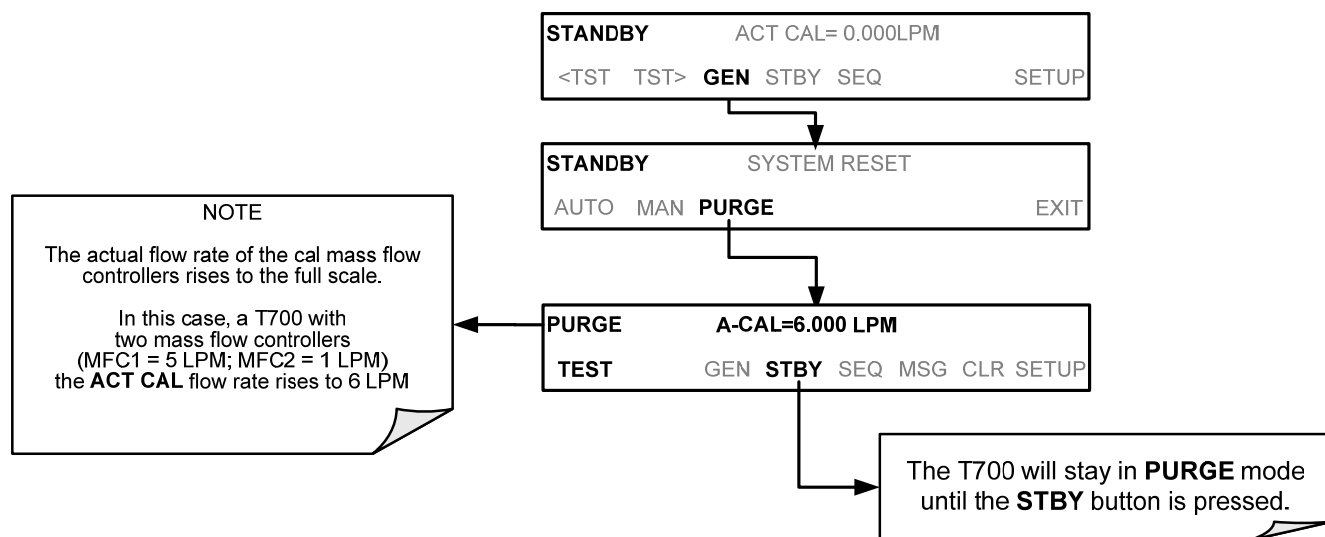


Figure 4-9: Gas Flow through T700 with O₃ Options when in PURGE mode

To activate the **PURGE** feature, press:



IMPORTANT

IMPACT ON READINGS OR DATA

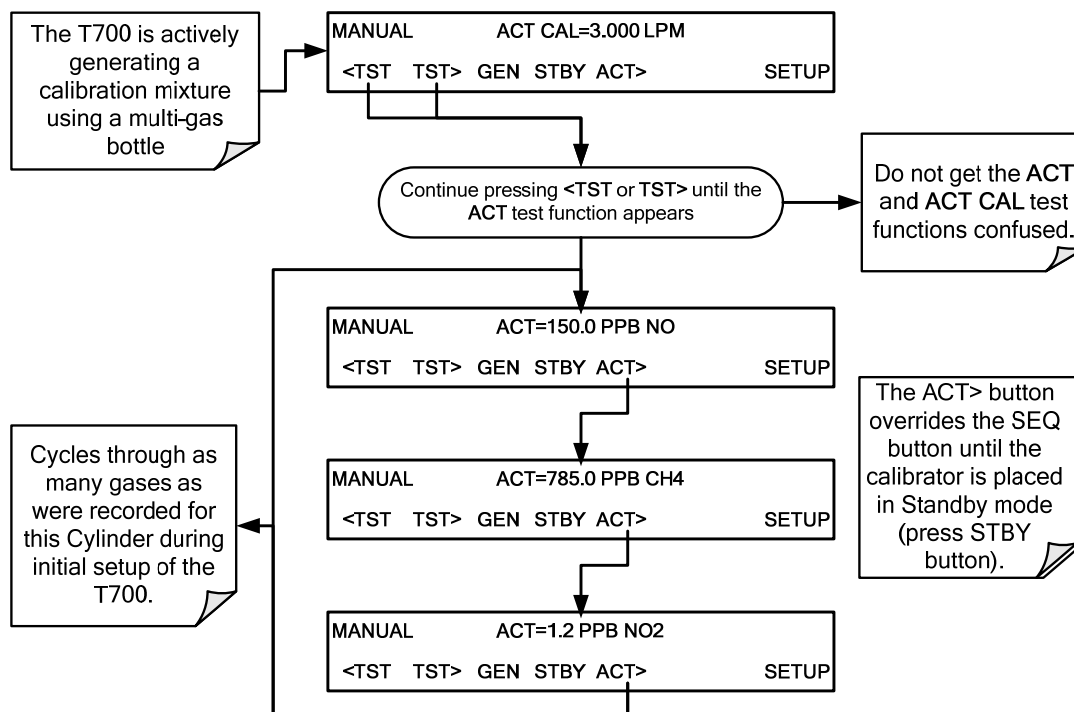
This **PURGE** feature does not stop automatically. Manually press the **STBY** button to stop the purging process..

4.2.6. GENERATE → ACT>: VIEWING CONCENTRATIONS GENERATED FROM MULTI-GAS CYLINDERS

When a concentration mixture is being generated, using a multiple-gas cylinder as a source the software uses the Diluent and Cal gas flow rates to calculate the actual concentration for each gas in the cylinder so that it is possible to see the concentrations of all of the gases being output by the T700 calibrator.

EXAMPLE: For a cylinder containing a blend of CH₄, NO and NO₂, a common contaminant is present in small quantities in bottles containing NO: This will display the actual concentration being generated for each gas in the multiple-gas cylinder.

When generating a concentration of one of the two primary gases in the cylinder (e.g. NO or CH₄) using the GEN → AUTO, GEN → MANUAL buttons or a preprogrammed calibration SEQUENCE, press:



Note

The ACT> button only appears if the T700 is generating gas from a multiple-gas cylinder. To start any preprogrammed calibration SEQUENCES, first place the calibrator in STANDBY mode (the SEQ button replaces the ACT> button)

For NO cylinders, the instrument will only display the amount of NO₂ in the calibration mixture if the concentration of NO₂ present in the bottle is known and was programmed into the bottle's definition (see Section 3.4.7).

4.2.6.1. Using the T700 Calibrator as an O₃ Photometer

If the T700 calibrator is equipped with the optional O₃ photometer the ACT> test function allows it to be used as an O₃ photometer to measure external sources of O₃.

4.3. AUTOMATIC CALIBRATION SEQUENCES

The T700 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

4.3.1. SETUP → SEQ: PROGRAMMING CALIBRATION SEQUENCES

A sequence is a database of single or multiple steps where each single step is an instruction that causes the instrument to perform an operation. These steps are grouped under a user defined SEQUENCE NAME.

For each sequence, there are seven attributes that must be programmed. They attributes are listed in Table 4-8.

Table 4-8: Automatic Calibration SEQUENCE Set Up Attributes

ATTRIBUTE NAME	DESCRIPTION
NAME	Allows the user to create a text string of up to 10 characters identifying the sequence.
REPEAT COUNT	Number of times, between 0 and 100, to execute the same sequence. A value of 0 (zero) causes the sequence to execute indefinitely.
CC INPUT	Specifies which of the T700's Digital Control Inputs will initiate the sequence.
CC OUTPUT	Specifies which of the T700's Digital Control Outputs will be set when the sequence is active.
TIMER ENABLE	Enables or disables an internal automatic timer that can initiate sequences using the T700's built in clock.
STEPS	A series of submenus for programming the activities and instructions that make up the calibration sequence.
PROGRESS MODE	Allows the user to select the reporting style the calibrator uses to report the progress of the sequences , on the front panels display, as it runs.

The types of instruction steps available for creating calibration sequences are listed in Table 4-9.

Table 4-9: Calibration SEQUENCE Step Instruction

INSTRUCTION NAME	DESCRIPTION
GENERATE	Puts the instrument into GENERATE mode. Similar in operation and effect to the GENERATE → AUTO function used at the front panel.
GPT	Initiates a Gas Phase Titration operation.
GPTPS	Initiates a Gas Phase Titration Preset procedure.
PURGE	Puts the calibrator into PURGE mode.
DURATION	Adds a period of time between the previous instruction and the next
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.
SETCCOUTPUT	Allows the sequence to activate the T700's digital control outputs. Similar to the CC OUPUT attribute, but can be set and reset by individual steps.
MANUAL	Puts the instrument into GENERATE mode. Similar in operation and effect to the GENERATE → MAN function used at the front panel.

Note

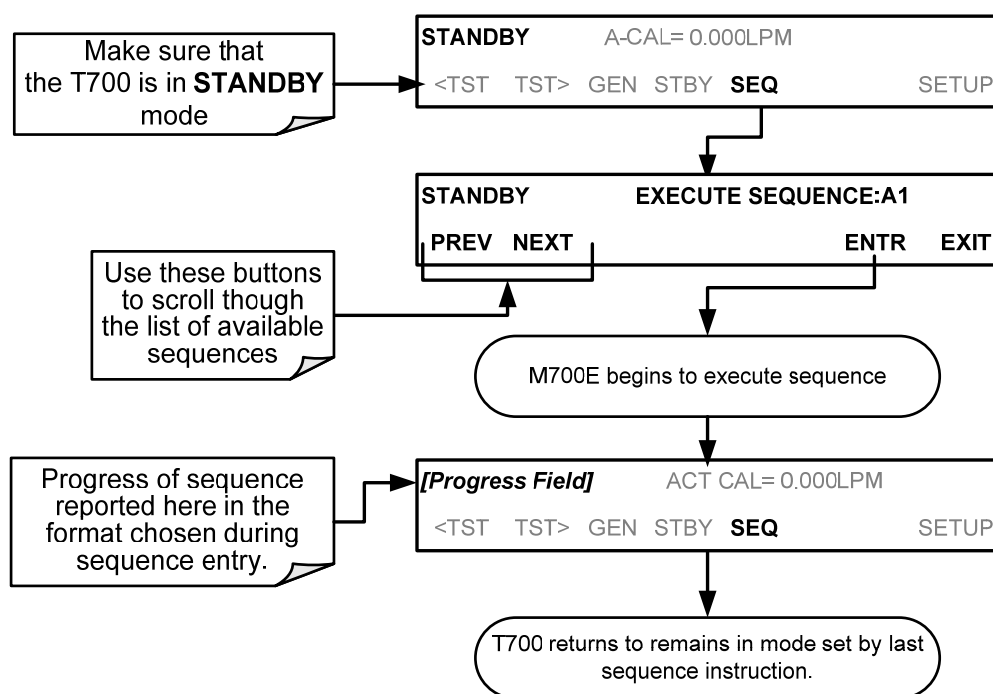
It is generally a good idea to end each calibration sequence with a **PURGE** instruction followed by an instruction to return the instrument to **STANDBY** mode.

Even if a **PURGE** is not included, the last instruction in a sequence should always be to place the T700 in **STANDBY** mode.

To create a sequence, use the instructions in the following sections to name the sequence, set its associated parameters and define the steps to be included.

4.3.1.1. Activating a Sequence from the T700 Front Panel

To activate an already programmed sequence from the front panel, press:



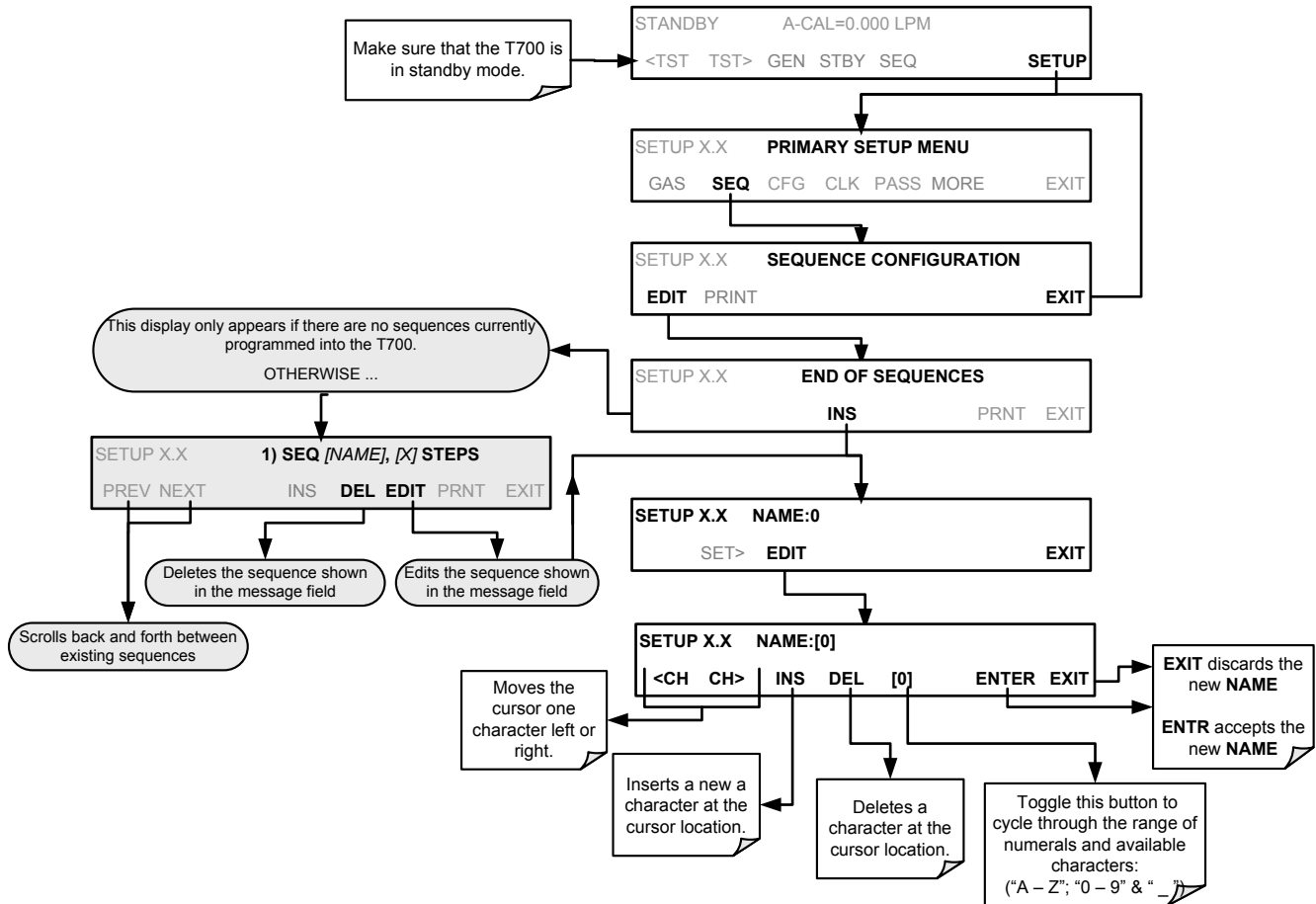
4.3.1.2. Naming a Sequence

The first step of creating a calibration sequence is to assign it a name. The name can be up to 10 characters and can be comprised of any alpha character (A to Z), and numeral (0 to 9) or the underscore character (“_”).

Note

All sequences should be assigned a unique name.

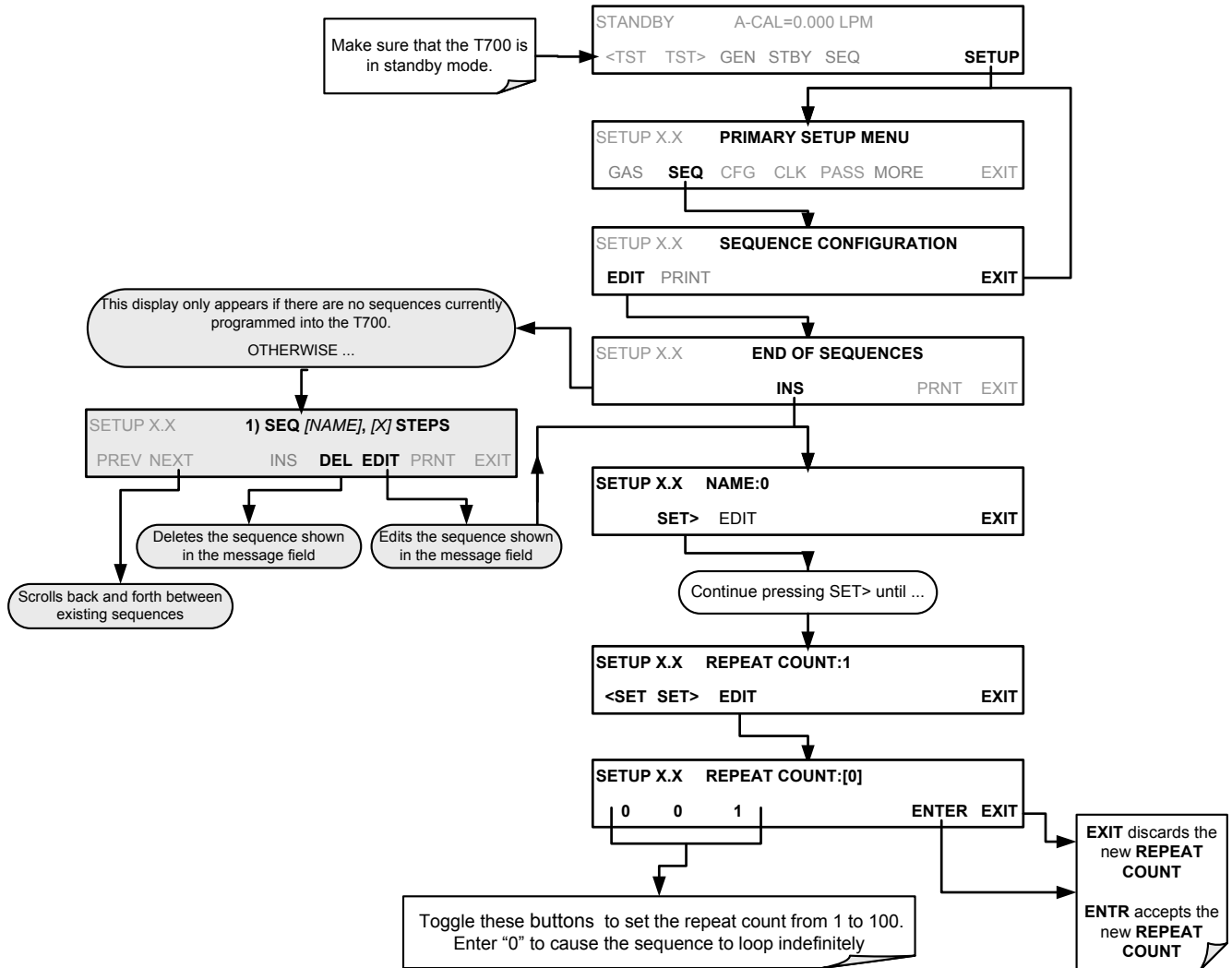
To assign a name to a sequence, press:



4.3.1.3. Setting the Repeat Count for a Sequence

The sequence can be set to repeat a certain number of times, from 1 to 100. It can also be set to repeat indefinitely by inputting a zero (0) into the **REPEAT COUNTER**.

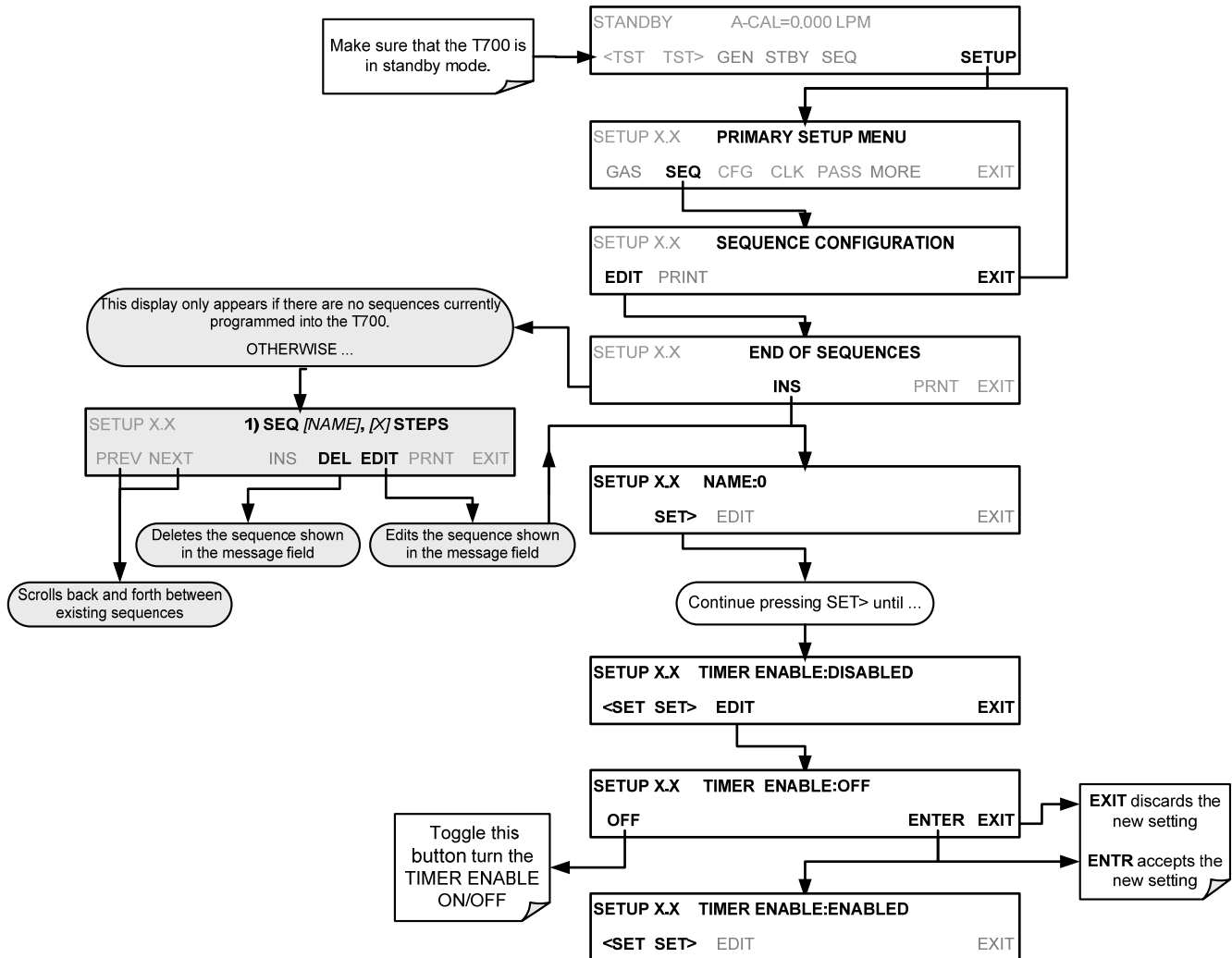
To set the **REPEAT COUNTER**, press:



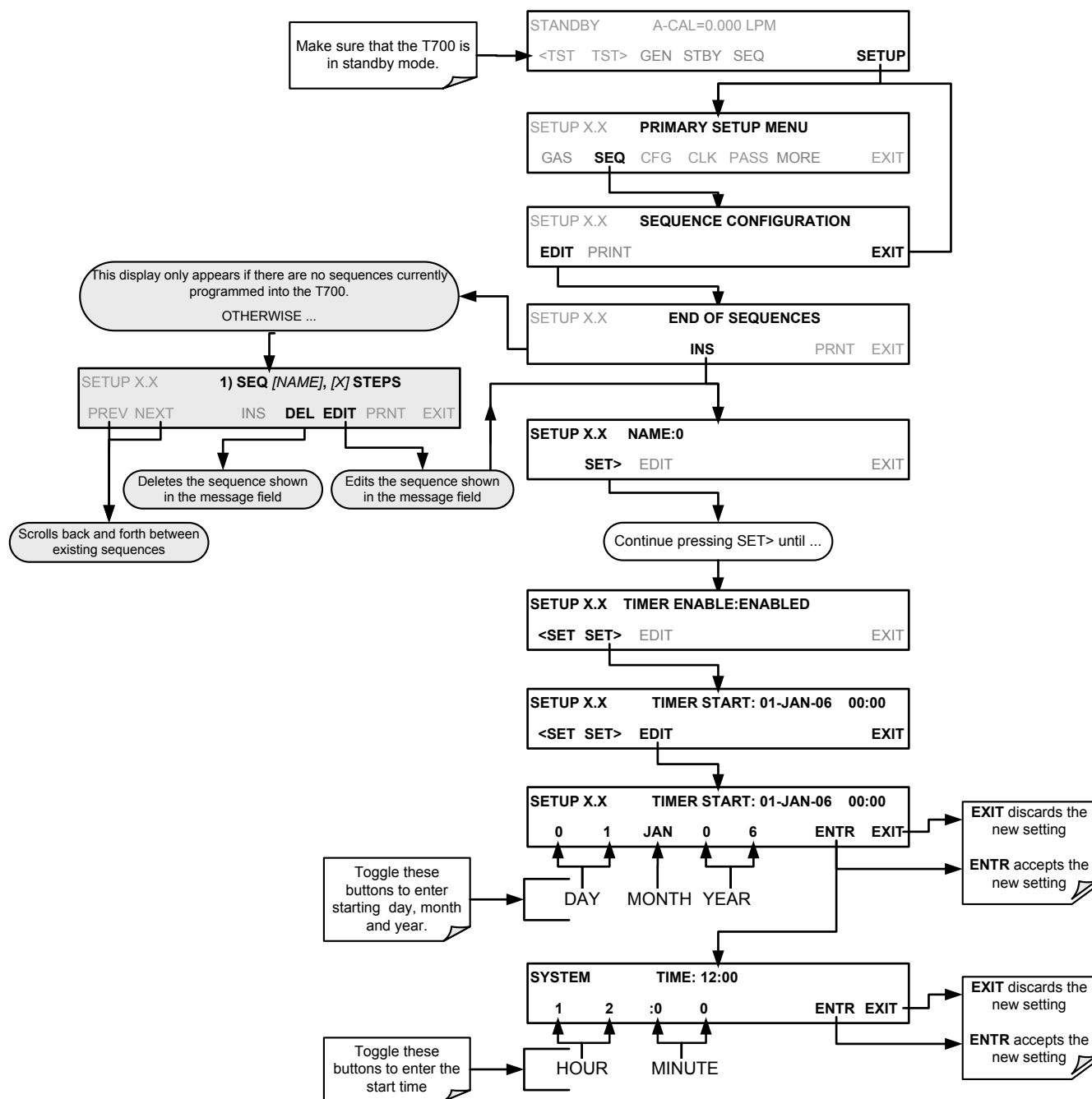
4.3.1.4. Using the T700's Internal Clock to Trigger Sequences

Sequences can be set to trigger based on the T700's internal clock. The sequence can be set up to start at a predetermined date and time. It can also be set to repeat after a predetermined delay time.

So activate and sequence timer, press:



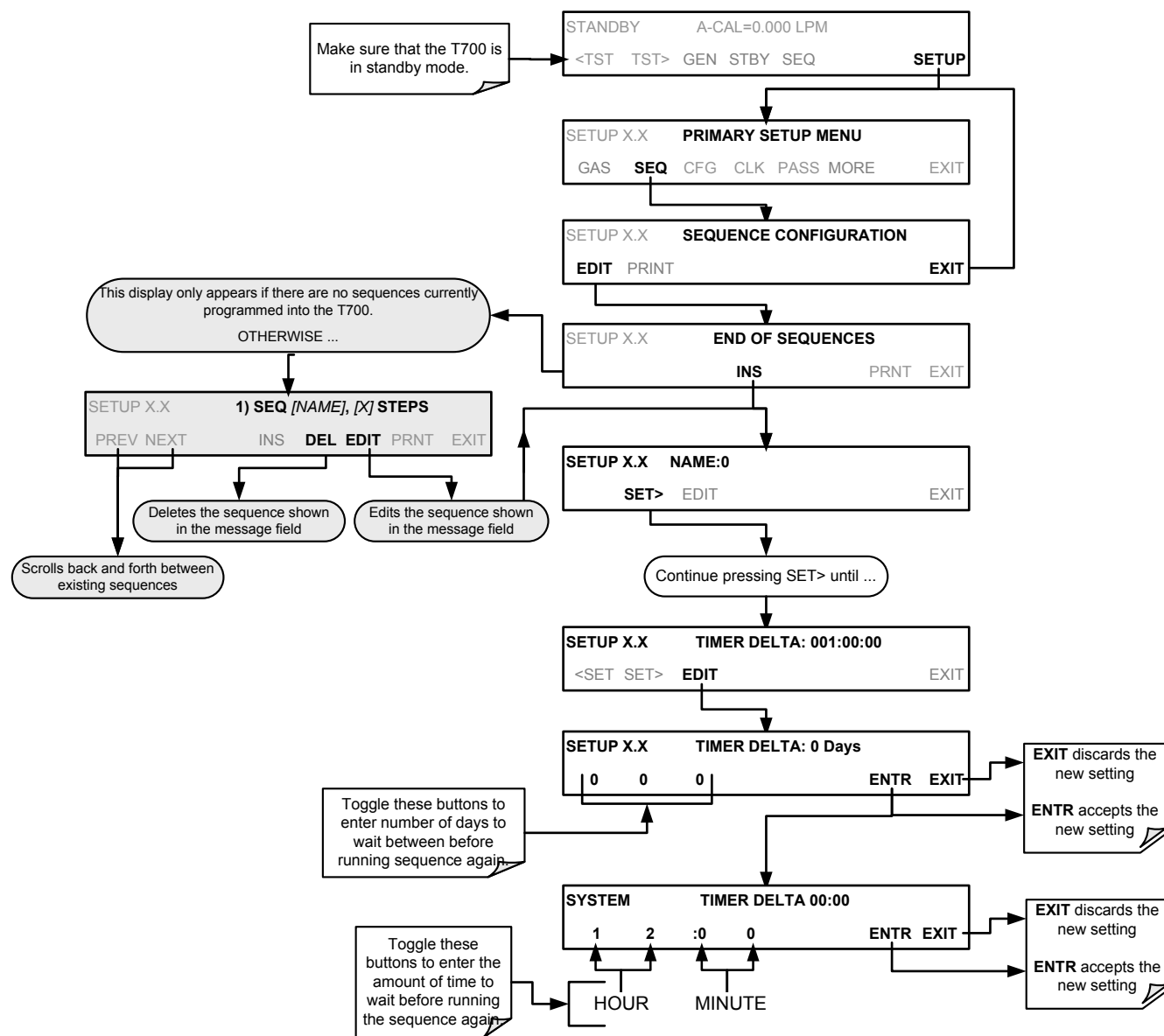
To specify a starting date and time for the sequence, press:



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.

To set the delta timer, press:



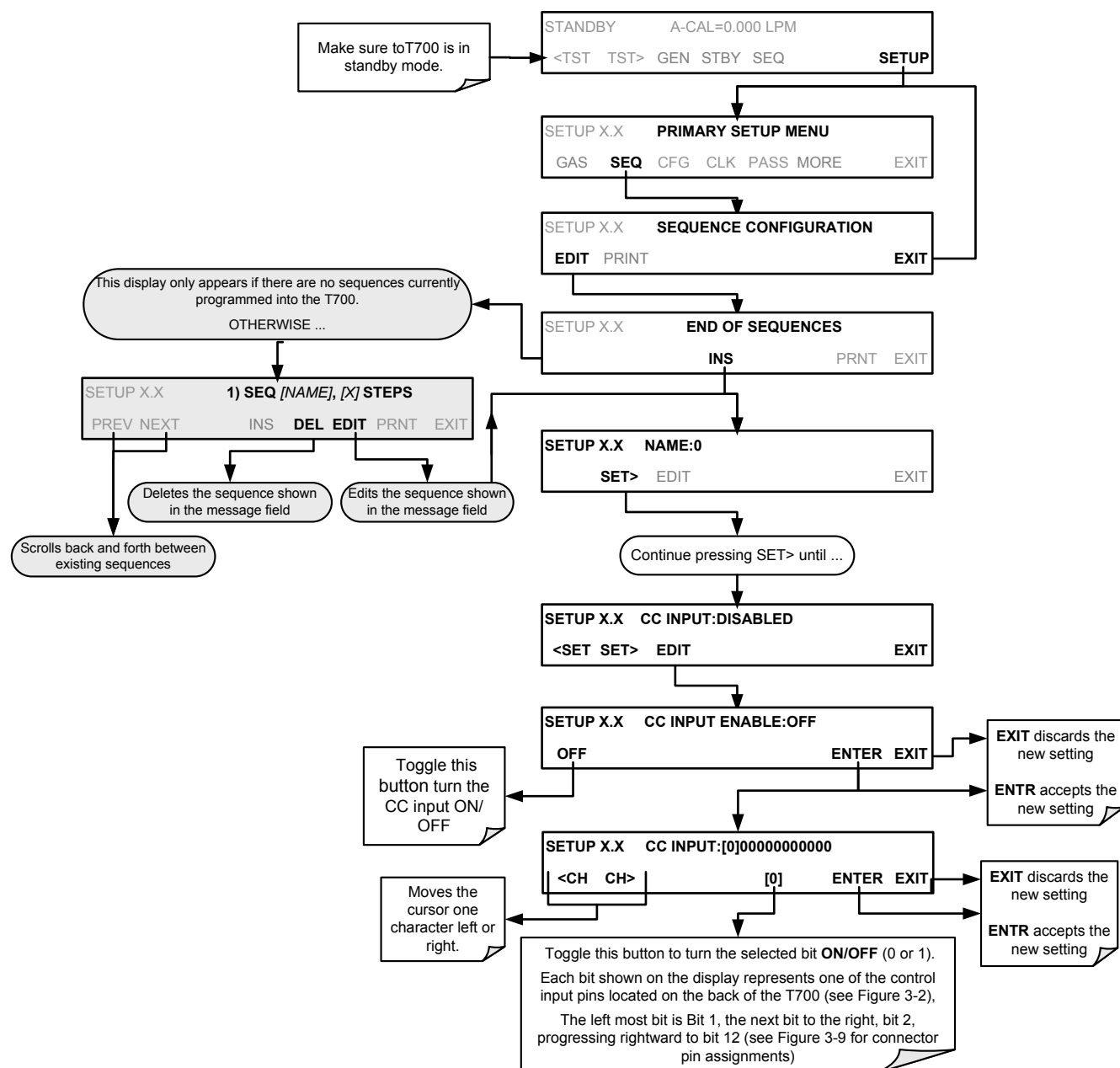
4.3.1.5. Setting Up Control Inputs for a Sequence

The T700 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.

Each of the T700 calibrator's control outputs is located on the back of the instrument (see Figure 3-4).

- 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, press:



4.3.1.6. Setting Up Control Outputs for a Sequence

The T700 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.

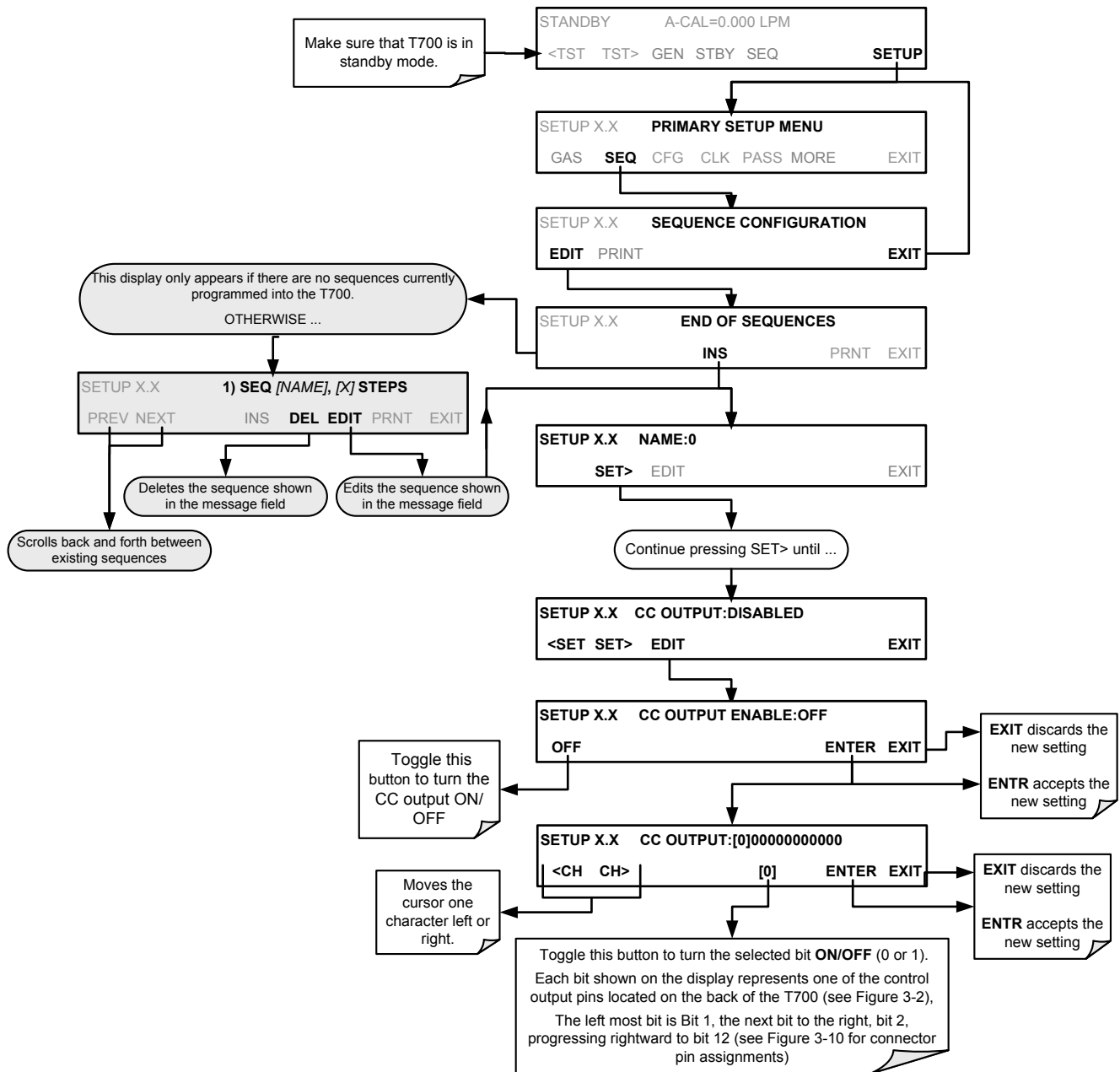
They can be used as:

- 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 to:

- Be active whenever a particular calibration sequence is operating, or;
- Activate/deactivate as individual steps within a calibration sequence are run (see Section 4.3.2.8).

To assign a **CC OUTPUT** pattern/code to a particular sequence, press:



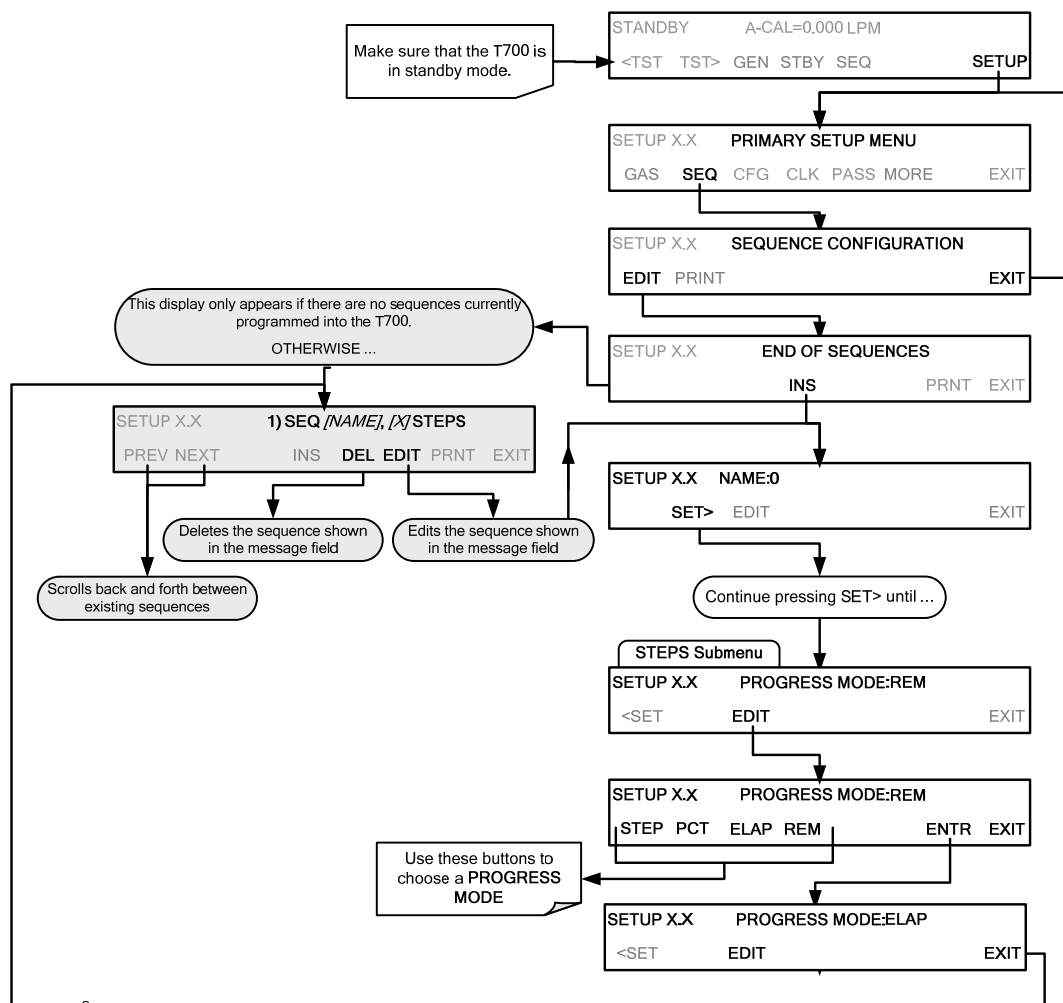
4.3.1.7. Setting the PROGRESS Reporting Mode for the Sequences

As sequences run, the T700 calibrator reports progress by displaying a message in the MODE field of the front panel display (See Figure 3-1). There are several types of report modes available (see Table 4-10).

Table 4-10: Sequence Progress Reporting Mode

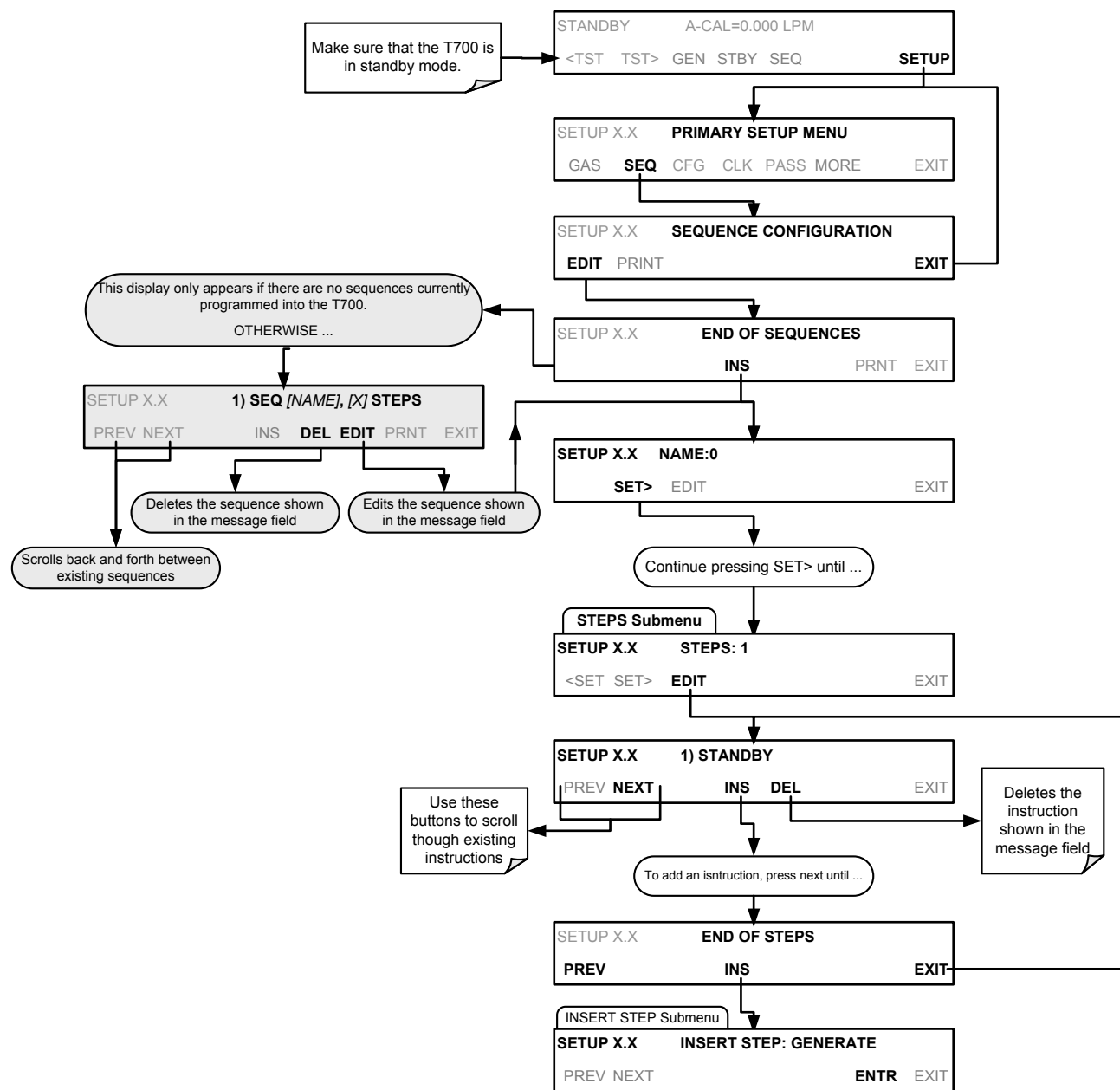
MODE	DESCRIPTION
STEP	Shows the progress as the sequence name and step number. This is the traditional display. Example: Progress for a sequence named "SO2_Test" would appear as "SO2_Test-2", indicating that it is currently executing step 2.
PCT	Shows the progress as a percent (0–100%) of each duration step. Example: "SEQ 48%"
ELAP	Shows the progress as time elapsed in hours, minutes and seconds, counting upward from 0. Example: "T+01:30:25" (i.e. 1 hour, 30 minutes, 25 seconds have elapsed)
REM	Shows the progress as time remaining in hours, minutes, and seconds remaining, counting downward to 0. Example: "T-01:30:25" (i.e. 1 hour, 30 minutes, 25 seconds are remaining)

To select a PROGRESS report mode, press:



4.3.2. ADDING SEQUENCE STEPS

To insert an instruction step into a sequence, navigate to the **INSERT STEP** submenu by pressing:

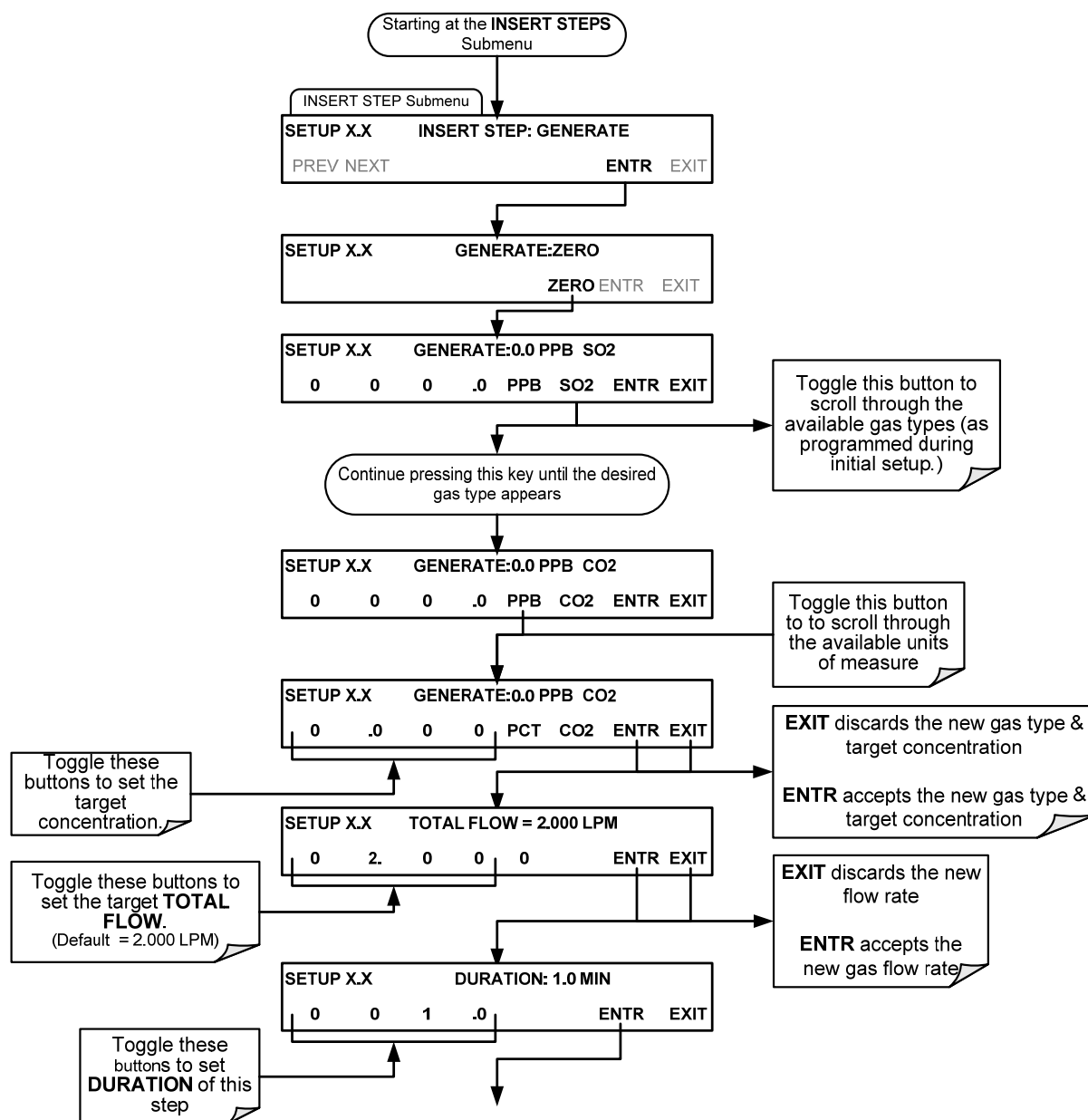


4.3.2.1. The GENERATE Step

This step operates and is programmed similarly to the **GENERATE → AUTO**.

At the end of the programming sequence, the T700 firmware will automatically insert a **DURATION** step that needs to be defined.

To insert a **GENERATE** step into a sequence, press:



Note

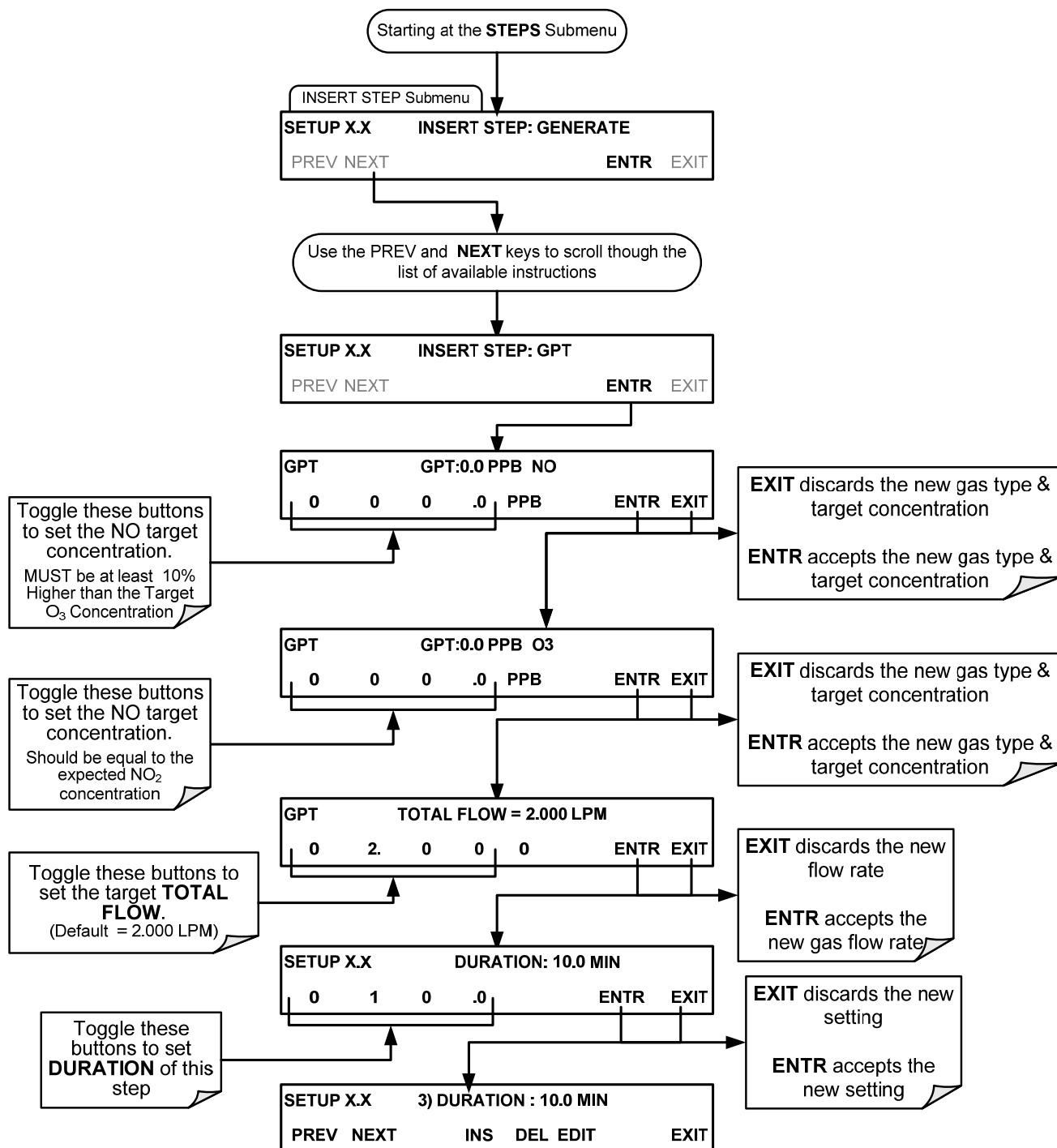
If the user attempts to generate a source gas type that has not been entered into the T700's gas library, the sequence will freeze and after a certain time-out period, stop running.

4.3.2.2. The GPT Step

This step operates and is programmed similarly to the **GENERATE → GPT** (see Section 4.2.3 for information on choosing the correct input values for this step).

At the end of the programming sequence, the T700 firmware will automatically insert a **DURATION** step that needs to be defined.

To insert a **GPT** step into a sequence, press:

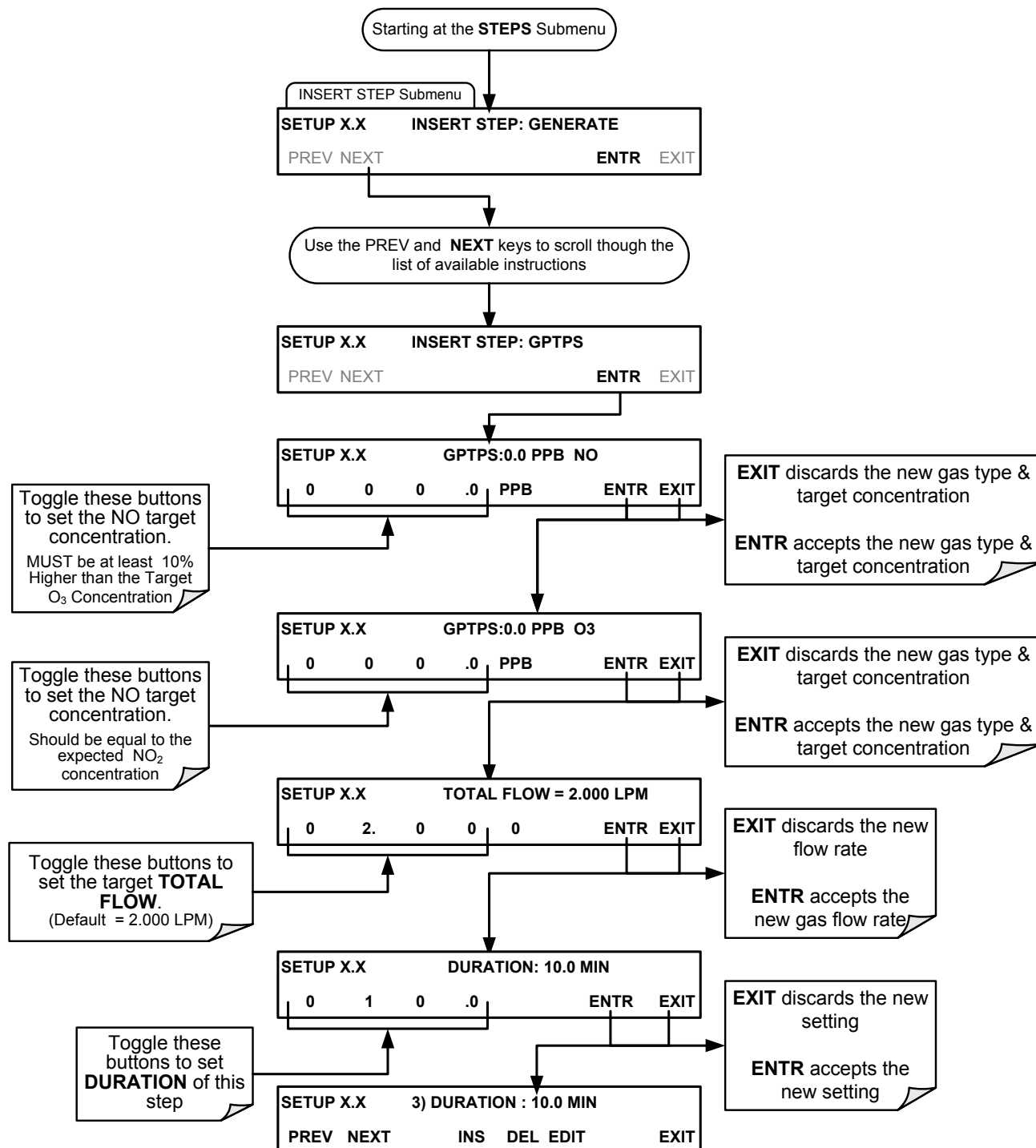


4.3.2.3. The GPTPS Step

This step operates and is programmed similarly to the **GENERATE** → **GPTPS** (see Section 4.2.4 for information on choosing the correct input values for this step).

At the end of the programming sequence, the T700 firmware will automatically insert a **DURATION** step that needs to be defined.

To insert a **GPTPS** step into a sequence, press:

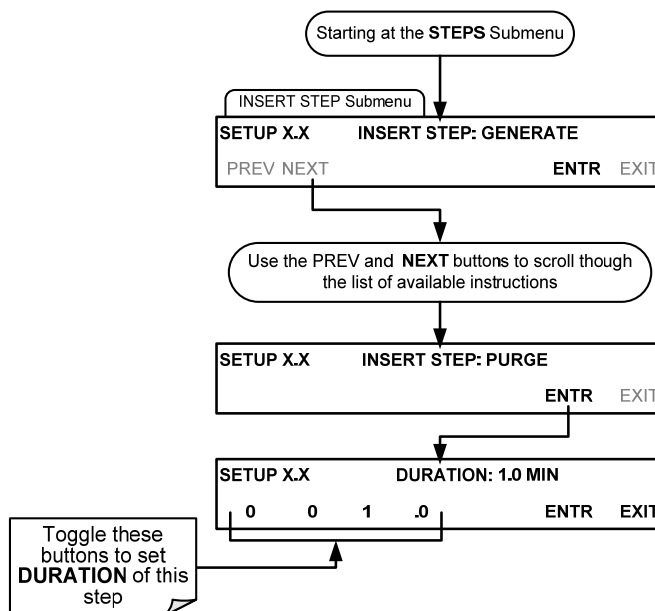


4.3.2.4. The PURGE Step

This step places the T700 into **PURGE** mode.

At the end of the programming sequence, the T700 firmware will automatically insert a **DURATION** step that needs to be defined.

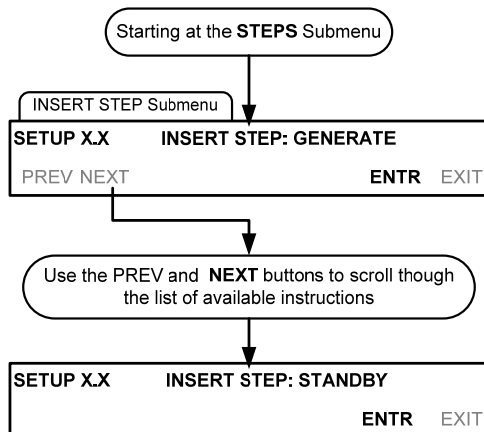
To insert a **PURGE** step into a sequence, press:



4.3.2.5. The STANDBY Step

The **STANDBY** step places the T700 into **STANDBY** mode. It is recommended, but not required to follow this with a **DURATION** step.

To insert a **STANDBY** step into a sequence, press:

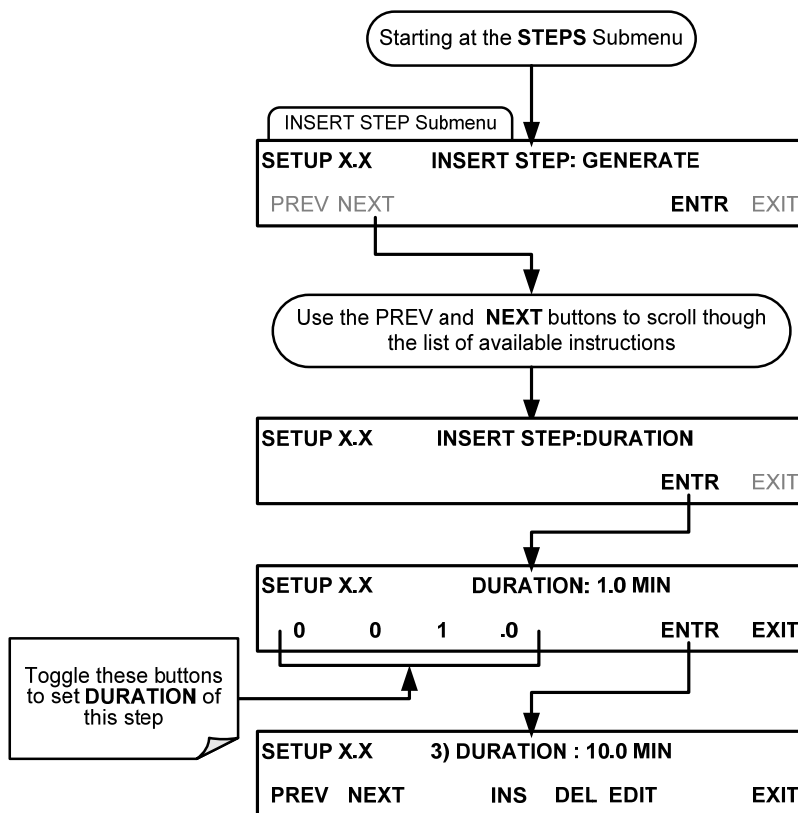


4.3.2.6. The DURATION Step

The duration step causes the T700 to continue performing whatever action was called for by the preceding step of the sequence.

- If that step put the instrument into **STANDBY** mode, the calibrator stays in **STANDBY** mode for the period specified by the **DURATION** step,
- If that step put the instrument into **GENERATE** mode, the will continue to **GENERATE** whatever calibration mixture was programmed into that step for the period specified by the **DURATION** step.

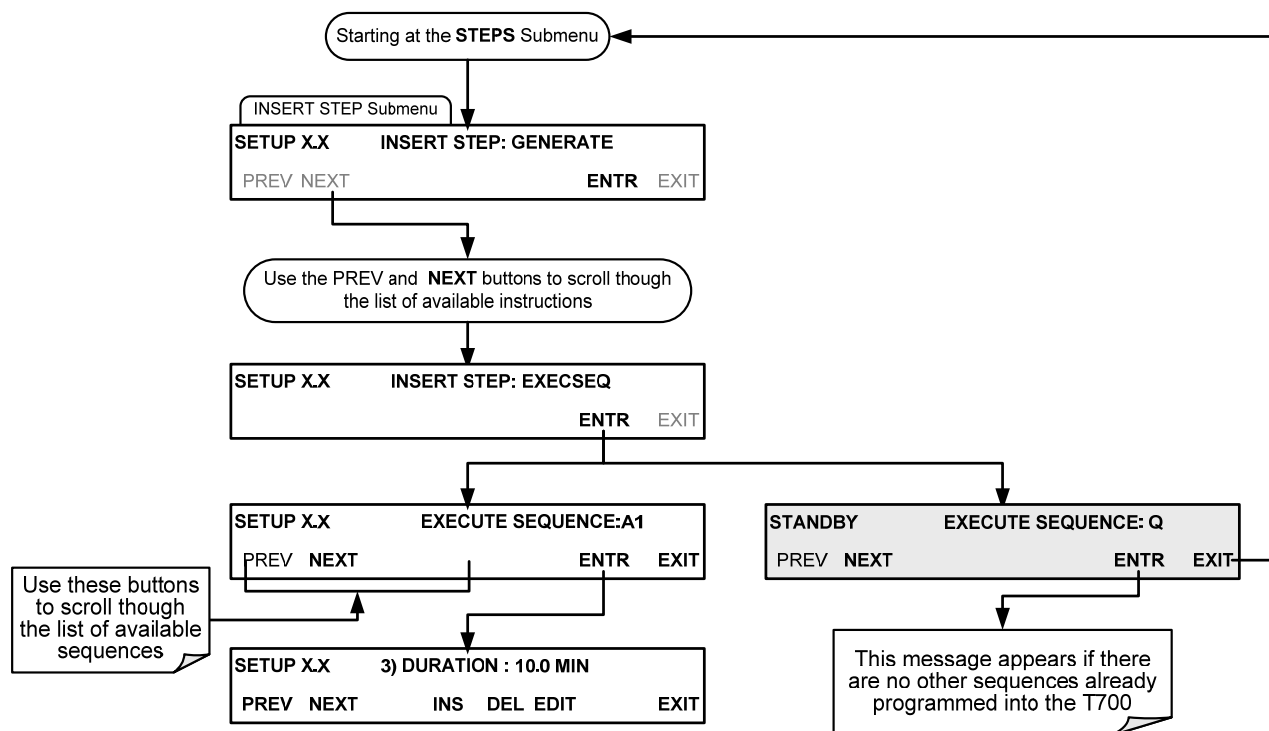
To insert a **DURATION** step into a sequence, press:



4.3.2.7. The EXECSEQ Step

The **EXECSEQ** step allows the sequence to call another, already programmed sequence. This is a very powerful tool in that it allows the user to create a “toolbox” of often-used operations that can then be mixed and matched by an overhead sequence.

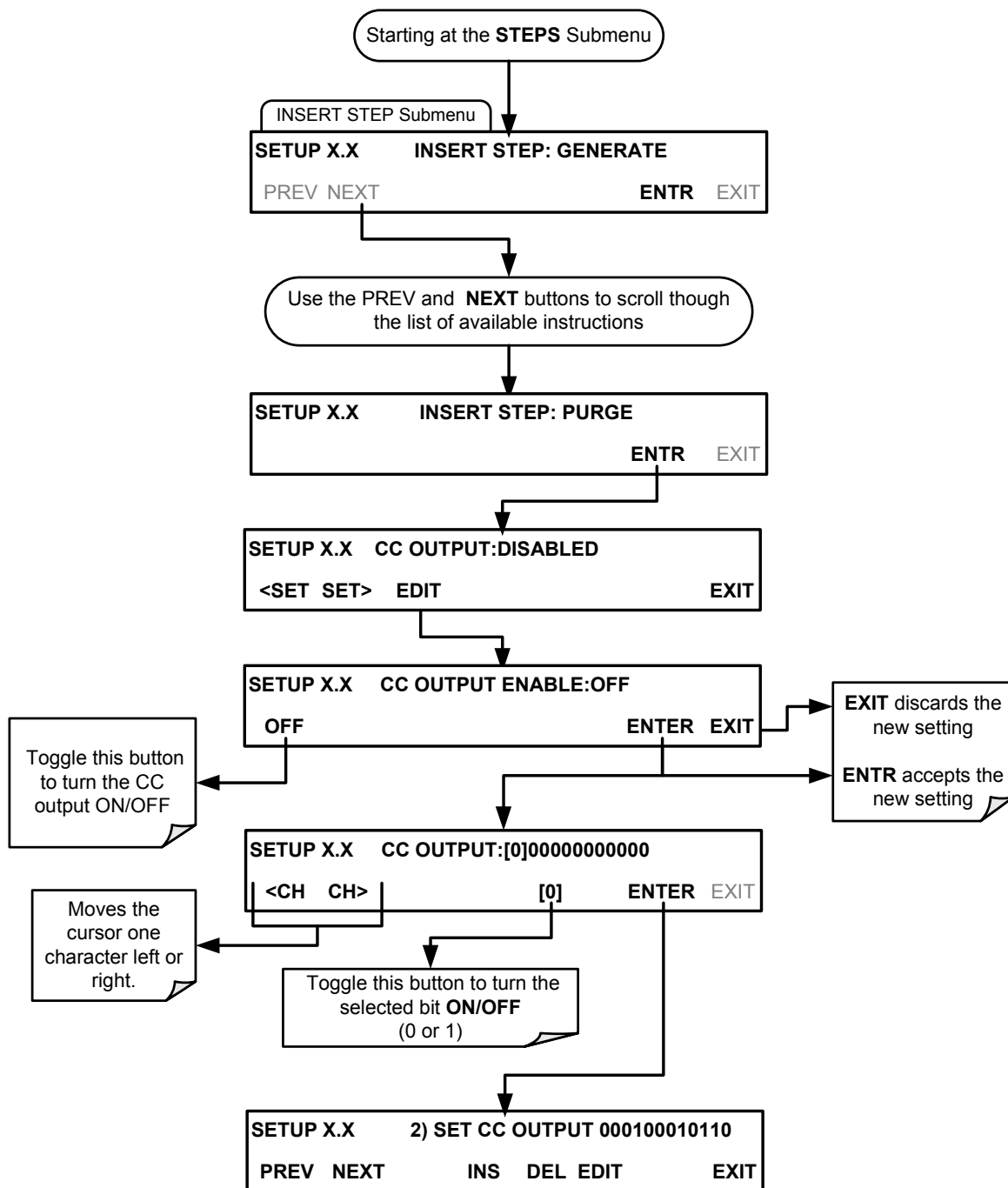
To insert an **EXECSEQ** step into a sequence, press:



4.3.2.8. The CC OUTPUT Step

This instruction causes the sequence to set or reset the T700's digital control outputs. 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 synch with the operation of the calibrator as it progress through the sequence.

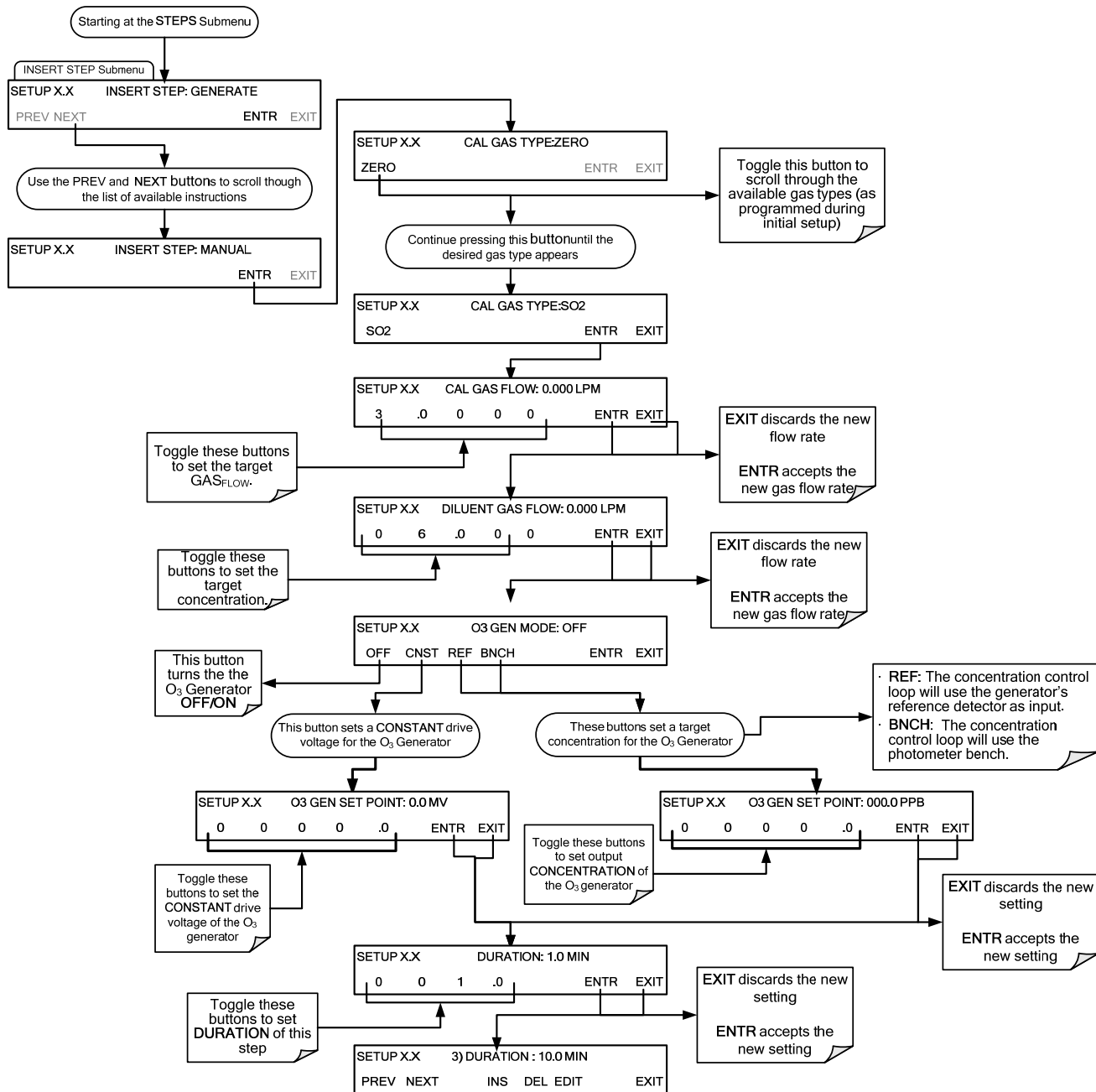
To insert a **CC OUTPUT** step into a sequence, press:



4.3.2.9. The MANUAL Gas Generation Step

The **MANUAL** step causes the T700 calibrator to enter **MANUAL CALIBRATION MODE**. It is programmed in a similar manner to the calibrator's **GENERATE** → **MANUAL** function. AT the end of the programming sequence, the T700 firmware will automatically insert a **DURATION** step that needs to be defined.

To insert a **MANUAL** step into a sequence, press:

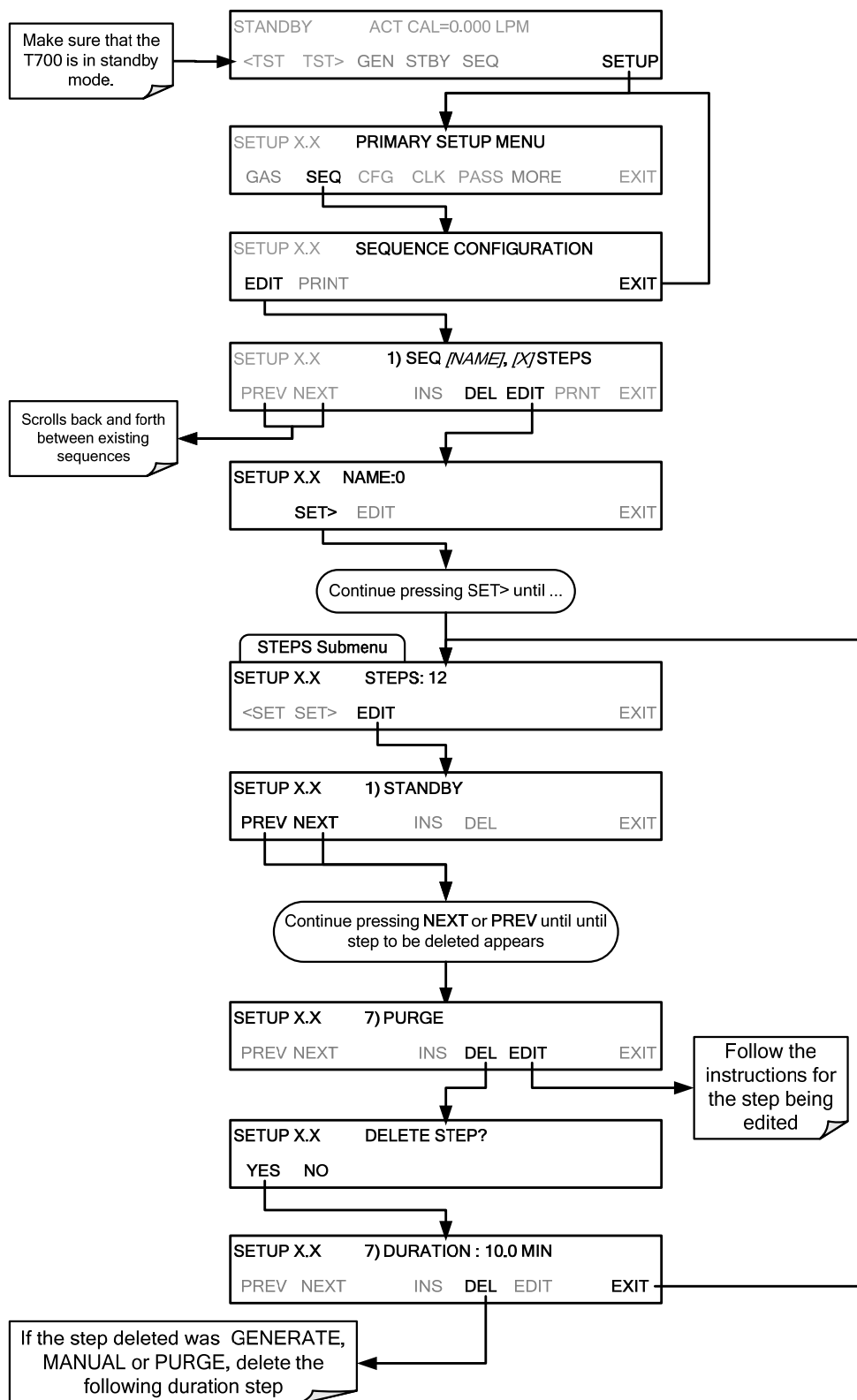


Note

If the user attempts to generate a source gas type that has not been entered into the T700's gas library, the sequence will freeze and after a certain time-out period, stop running.

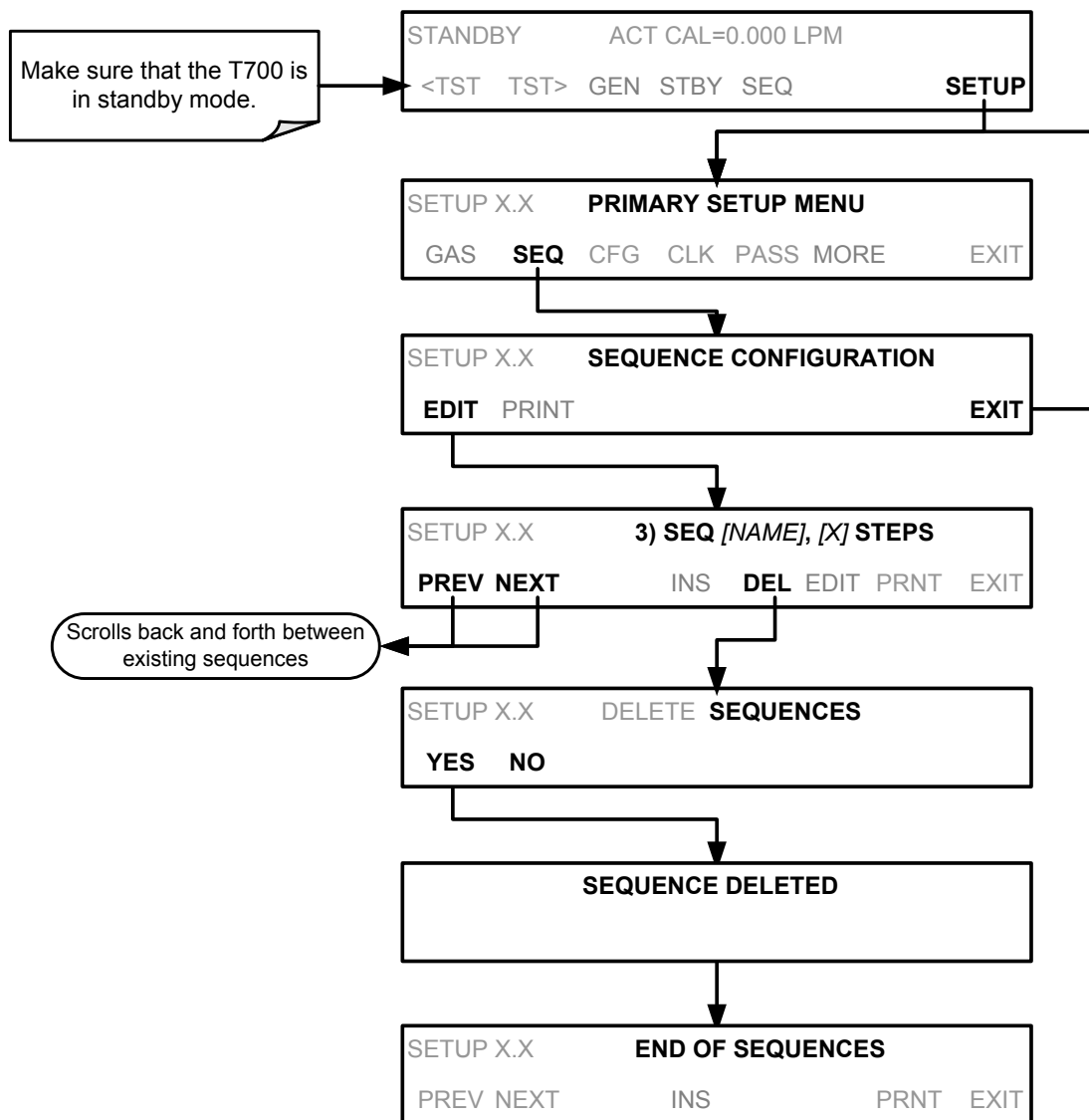
4.3.2.10. Deleting or Editing an Individual Step in a Sequence

To delete or edit an individual step in an existing Sequence, press:



4.3.3. DELETING A SEQUENCE

To delete a sequence from the T700 calibrator's memory, press:

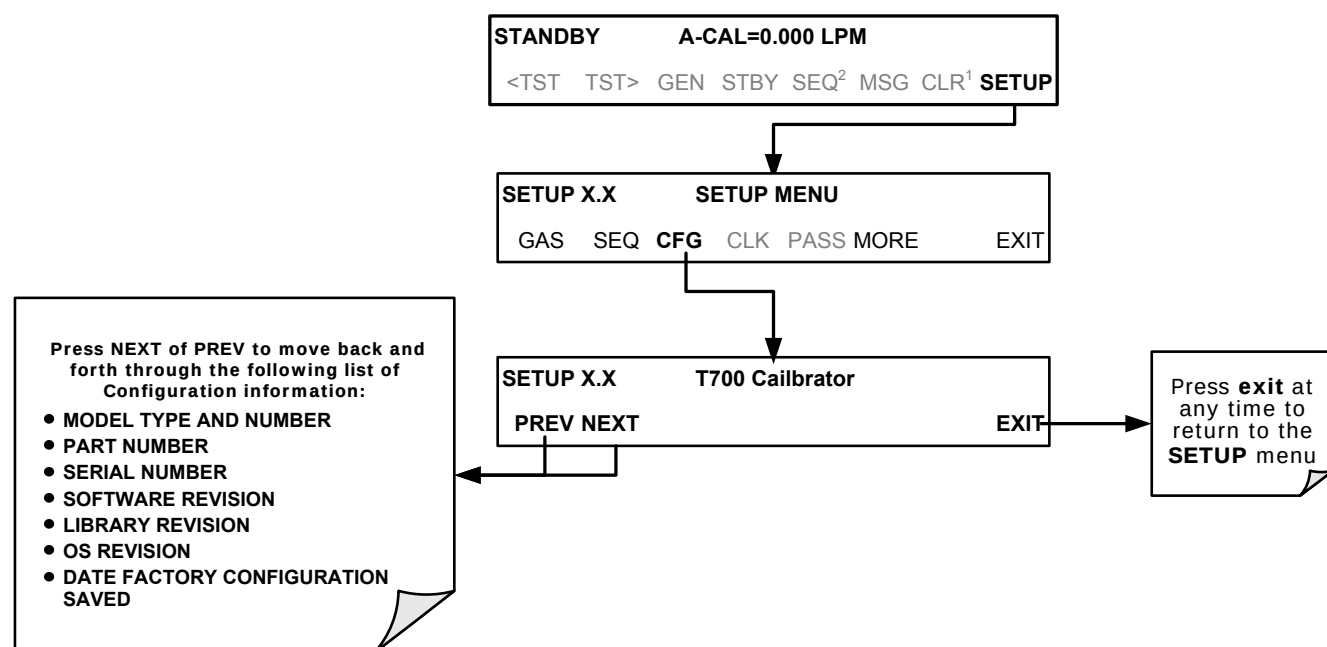


4.4. SETUP → CFG

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

Use this information to identify the software and hardware when contacting Customer Service.

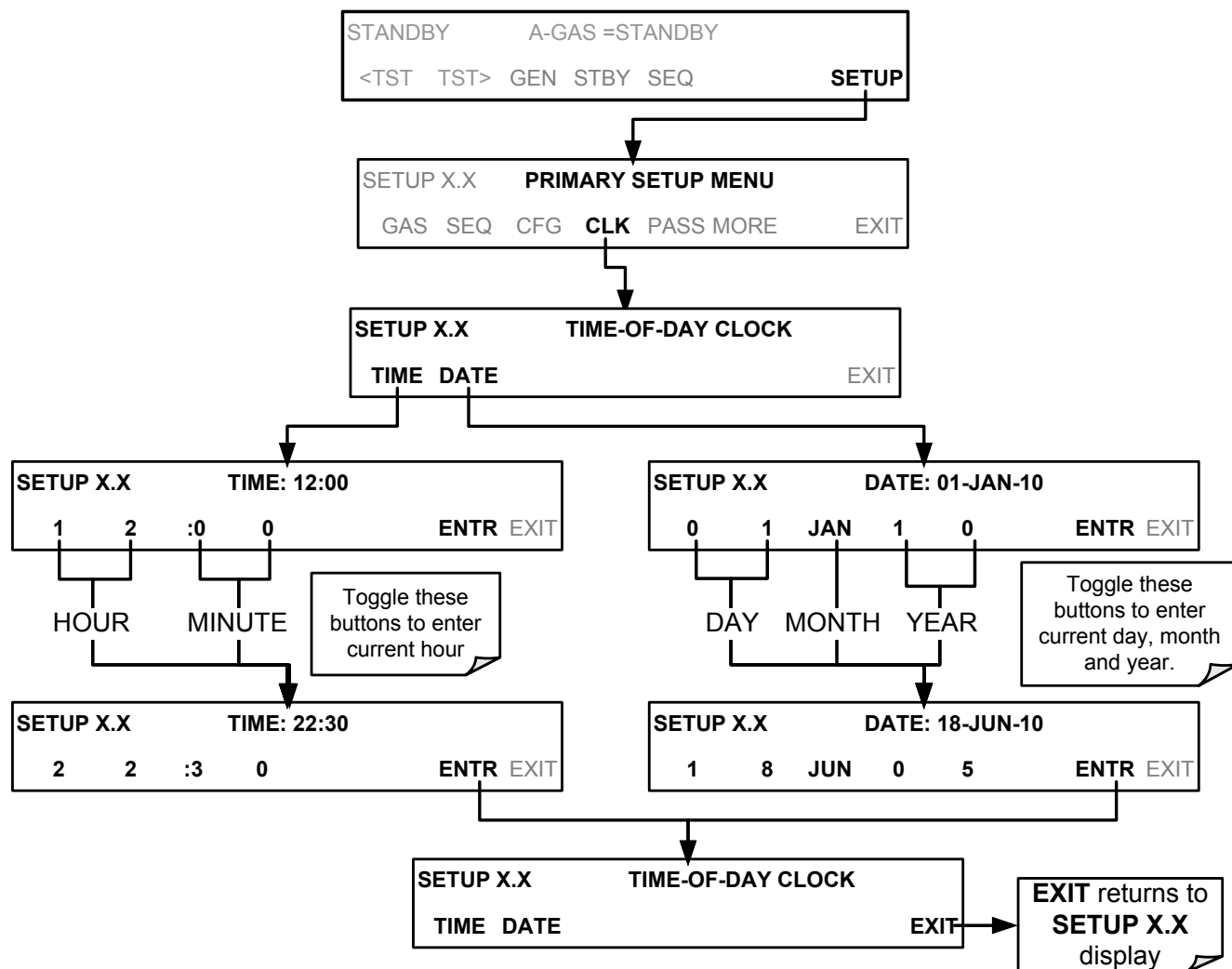
Special instrument or software features or installed options may also be listed here.



4.5. SETUP → CLK: SETTING THE INTERNAL TIME-OF-DAY CLOCK AND ADJUSTING SPEED

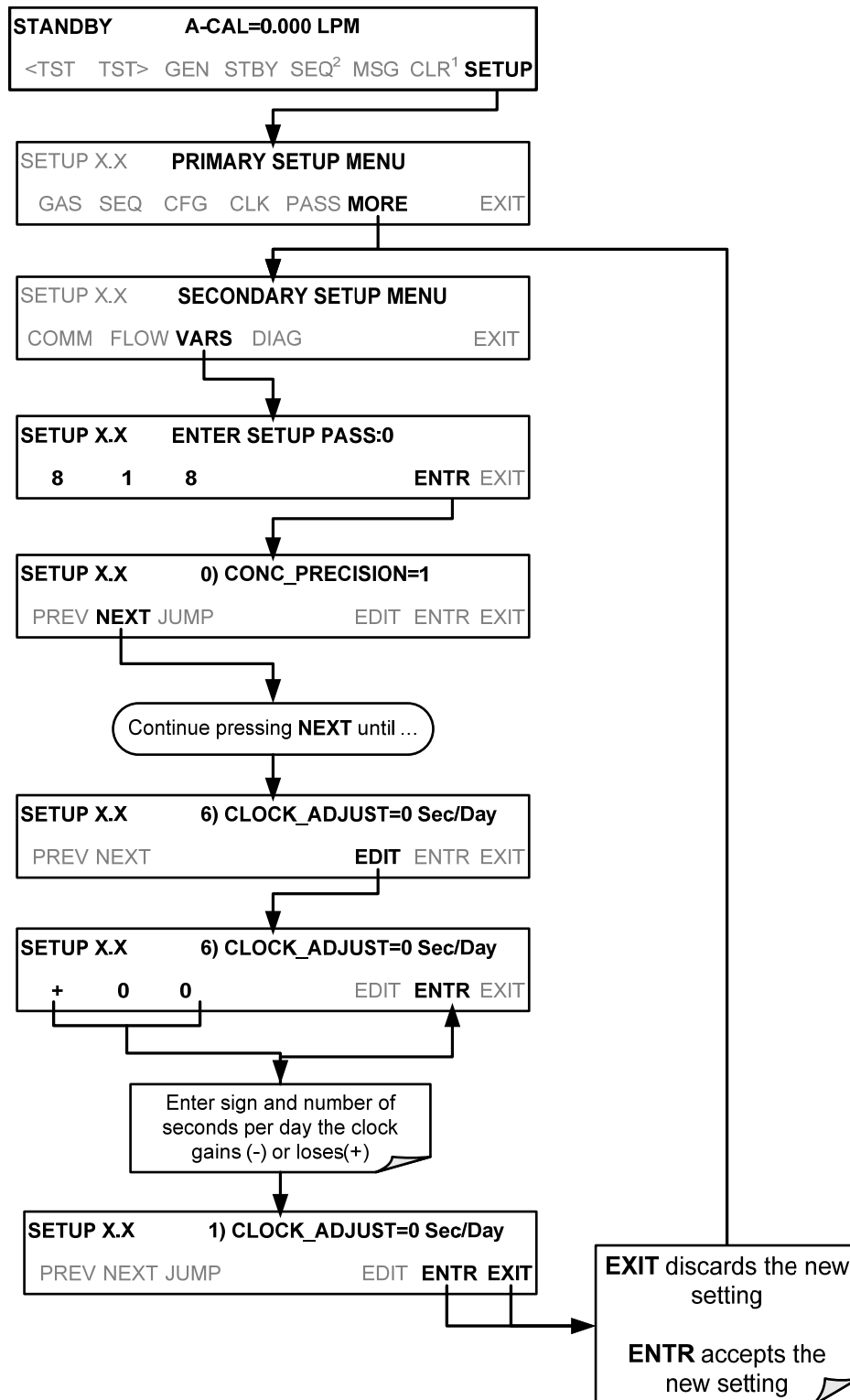
4.5.1. SETTING THE INTERNAL CLOCK'S TIME AND DAY

The T700 has a time of day clock that supports the **DURATION** step of the calibration sequence feature, time of day TEST function, and time stamps on most COMM port messages. To set the clock's time and day, press:



4.5.2. ADJUSTING THE INTERNAL CLOCK'S SPEED

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



4.6. SETUP → PASS

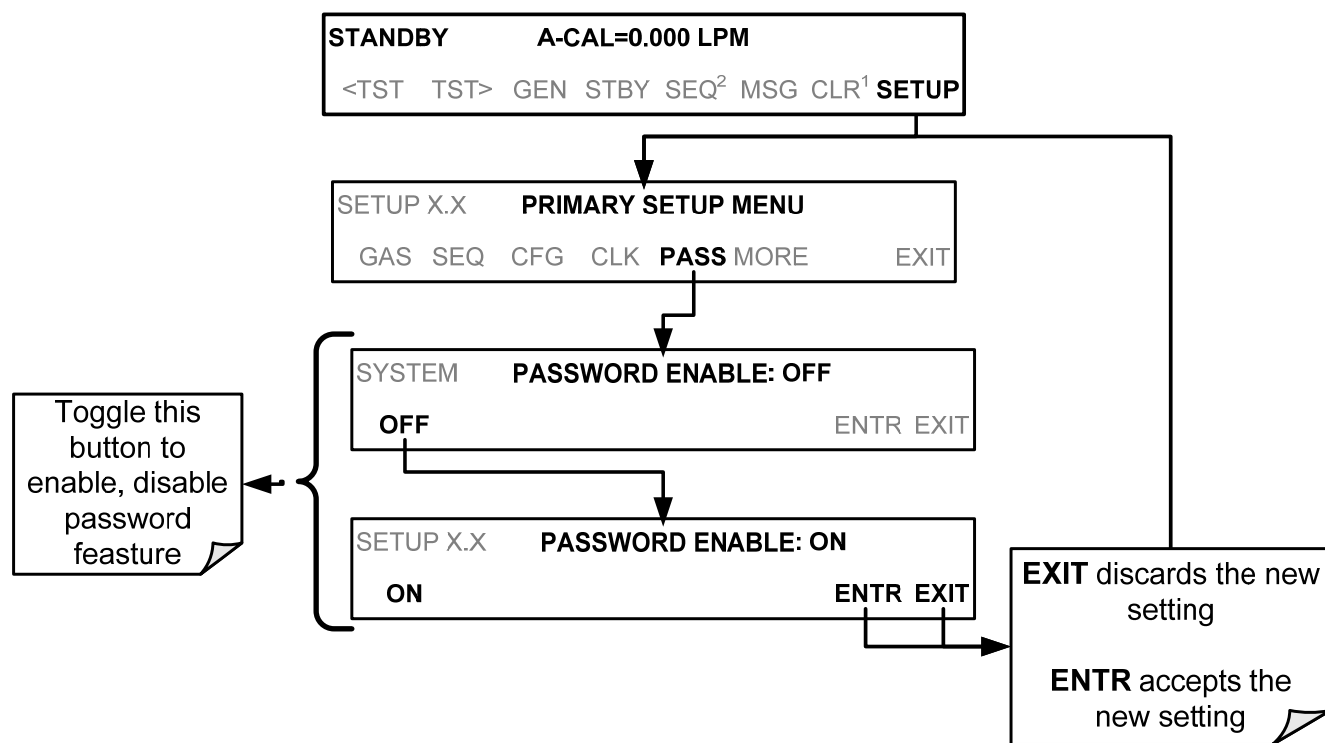
The T700 provides password protection of the calibration and setup functions to prevent unauthorized adjustments. When the passwords have been enabled in the **PASS** menu item, the system will prompt the user for a password anytime a password-protected function is requested.

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

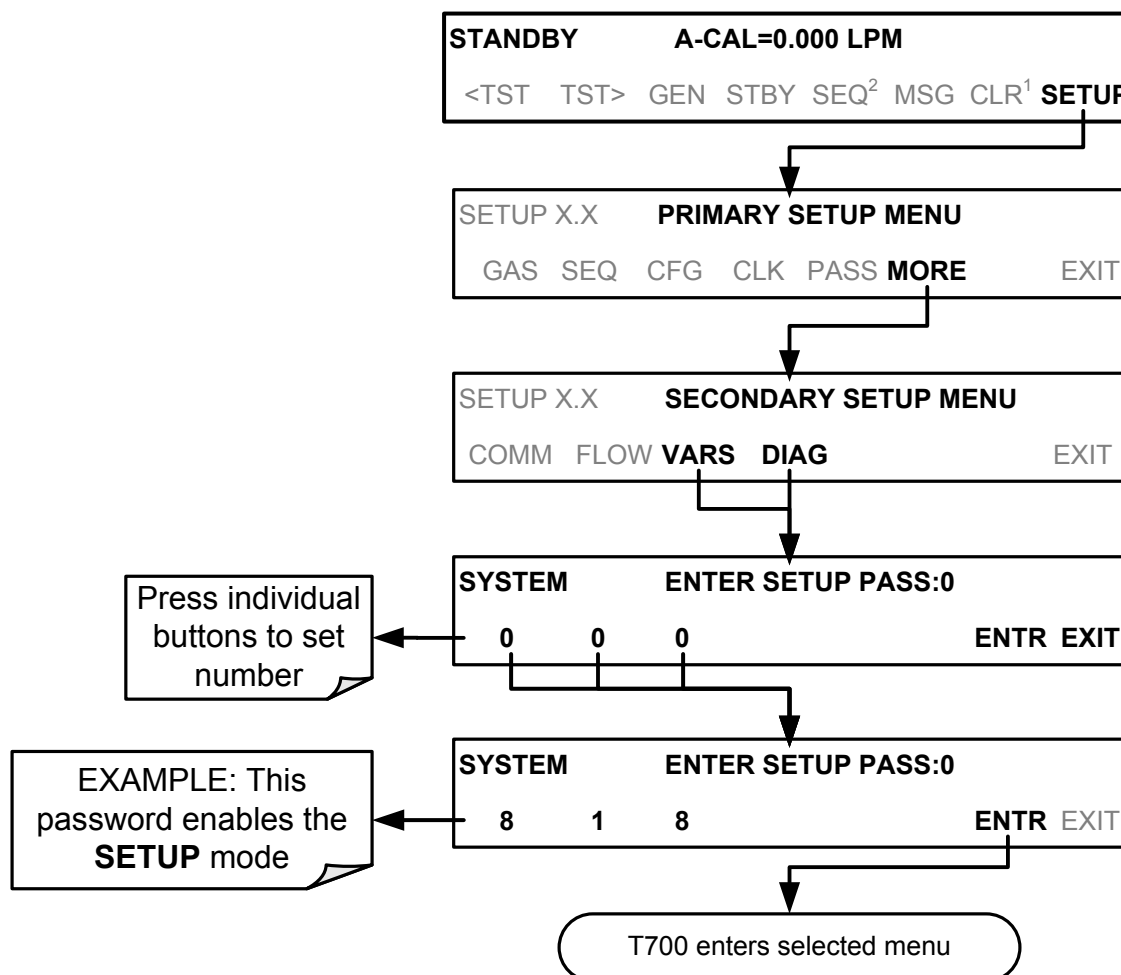
Table 4-11: Password Levels

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

To enable or disable passwords, press:



Example: If all passwords are enabled, the following touch screen button sequence would be required to enter the VARS or DIAG submenus:



Note

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

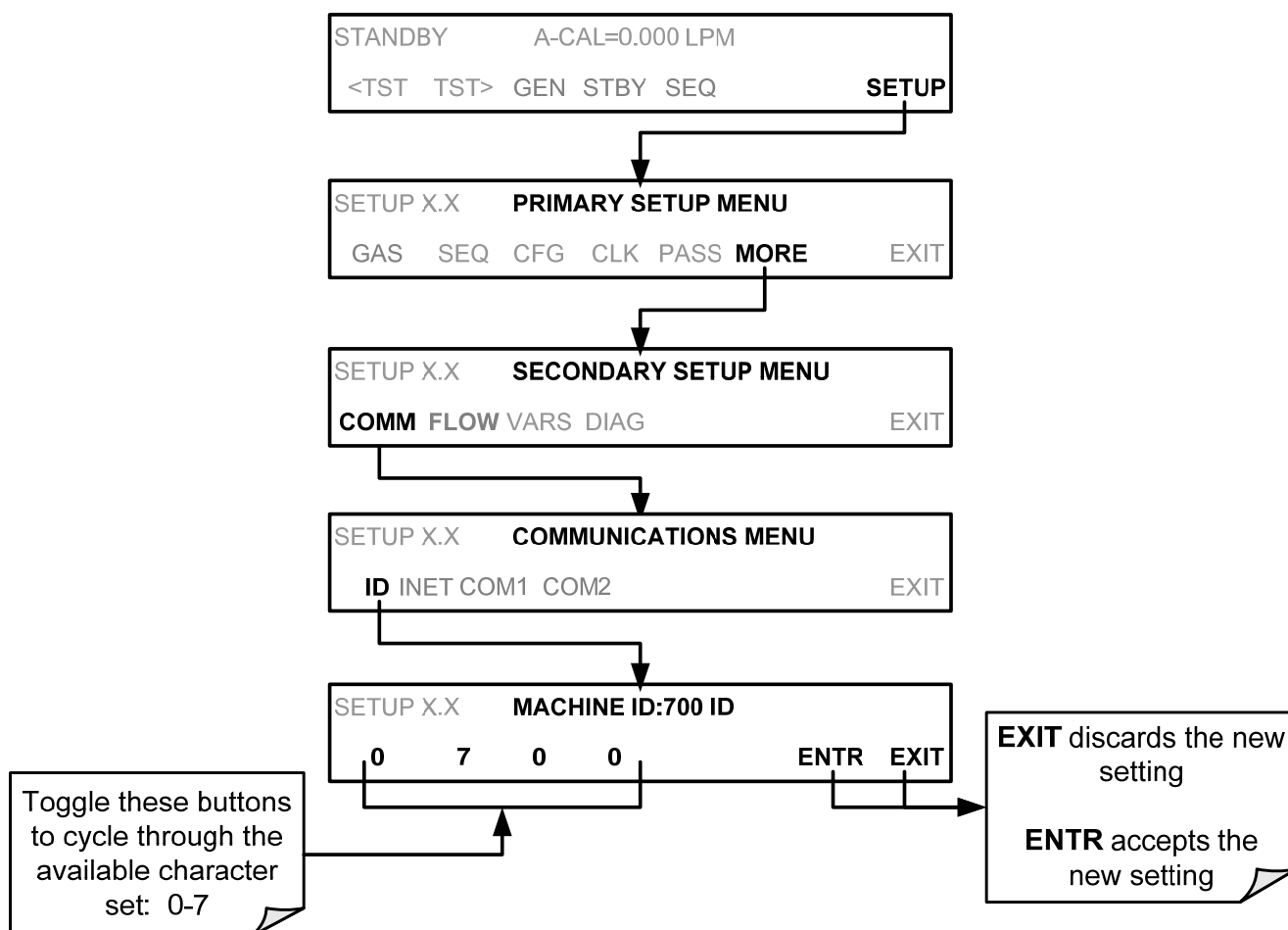
4.7. SETUP → COMM: COMMUNICATIONS PORTS

This section introduces the communications setup menu; Section 5 provides the setup instructions and operation information. Press **SETUP>MORE>COMM** to arrive at the communications menu.

4.7.1. ID (MACHINE IDENTIFICATION)

Each type of Teledyne API's calibrator is configured with a default ID code. The default ID code for all T700 calibrators is typically **700** (or **0**). The ID number is only important if more than one calibrator is connected to the same communications channel such as when several calibrators are on the same Ethernet LAN (See Section 5.4); in an RS-232 multi-drop chain (See Section 3.3.1.7) or operating over a RS-485 network (see Section 5.3). If two calibrators of the same model type are used on one channel, the ID codes of one or both of the instruments need to be changed.

To edit the instrument's ID code, press:



The ID number is only important if more than one calibrator is connected to the same communications channel (e.g., a multi-drop setup). Different models of Teledyne API's calibrators have different default ID numbers, but if two calibrators of the same model type are used on one channel (for example, two T700's), the ID of one instrument needs to be changed.

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

4.7.2. INET (ETHERNET)

Use SETUP>COMM>INET to configure Ethernet communications, whether manually or via DHCP. Please see Section 5.4 for configuration details.

4.7.3. COM1 AND COM2 (MODE, BAUD RATE AND TEST PORT)

Use the SETUP>COMM>COM1[COM2] menus to:

- configure communication modes (Section 5.2.1)
- view/set the baud rate (Section 5.2.2)
- test the connections of the com ports (Section 5.2.3).

Configuring COM1 or COM2 requires setting the DCE DTE switch on the rear panel. Section 5.1 provides DCE DTE information.

4.8. SETUP → MORE → FLOW

The Flow menu allows you to view the performance statistics for the Mass Flow Controllers (MFCs). See Section 7.1 for more information and details on setting up for MFC flow verification and calibration.

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

The T700 has several user-adjustable software variables, which define certain operational parameters. Usually, these variables are automatically set by the instrument's firmware, but can be manually redefined using the VARS menu.

The following table lists all variables that are available within the 818 password protected level. See Appendix A2 for a detailed listing of all of the T700 variables that are accessible through the remote interface.

Table 4-12: Variable Names (VARS)

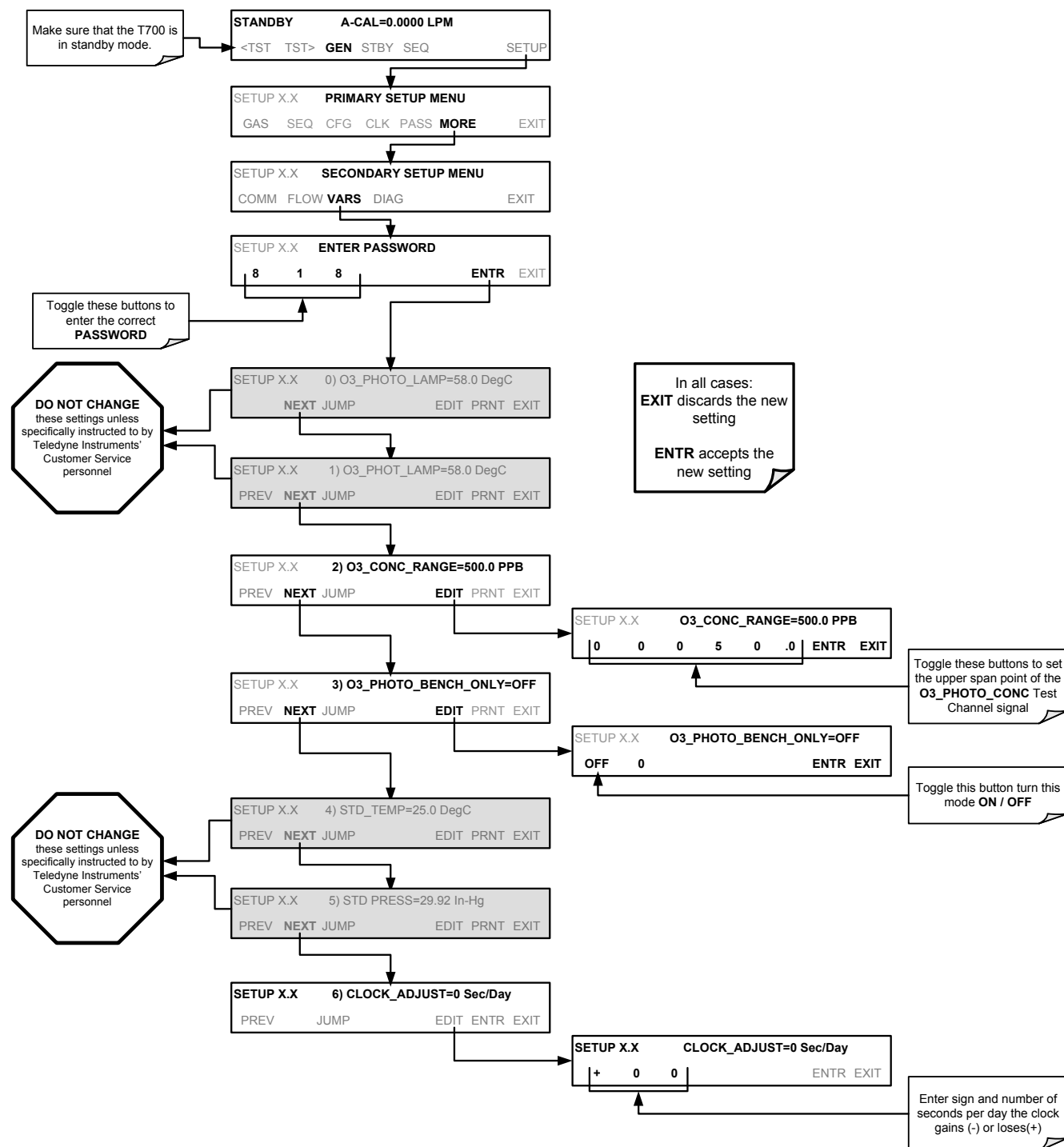
NO.	VARIABLE	DESCRIPTION	ALLOWED VALUES	DEFAULT VALUES
0	PHOTO_LAMP ^{1,2}	Sets the photometer lamp temperature set point and warning limits.	0°C and 100°C	58°C Warning limits 56°C - 61°C
1	O3_GEN LAMP ^{1,2}	Sets the O ₃ generator lamp temperature set point and warning limits.	0°C and 100°C	48°C Warning limits 43°C - 53°C
2	O3_CONC_RANGE	Set the upper span point of the O ₃ concentration range for TEST CHANNEL analog signal O3_PHOTO_CONC.	0.1–20000 ppb	500 ppb

NO.	VARIABLE	DESCRIPTION	ALLOWED VALUES	DEFAULT VALUES
3	O3_PHOTO_BENCH_ONLY ²	O ₃ bench control flag. • ON turns on the photometer pump and switches measure/reference valve only when the O ₃ mode is set for BNCH (See Section 3.4.8).	ON/OFF	OFF
4	STD_TEMP ¹	Sets the standard Temperature used in calculating O ₃ flow rates and concentrations.	0°C and 100°C	25°C
5	STD PRESSURE ¹	Sets the standard pressure used in calculating O ₃ flow rates and concentrations.	15.00 – 50.00 in-Hg-A	29.92 in-Hg-A
6	CLOCK_ADJ	Adjusts the speed of the analyzer's clock. Choose the + sign if the clock is too slow, choose the - sign if the clock is too fast (See Section 4.5).	-60 to +60 s/day Default=0	0
¹ DO NOT ADJUST OR CHANGE these values unless instructed to by Teledyne API's customer service personnel.				
² Only available in calibrators with O ₃ photometer and generator options installed.				

IMPORTANT**IMPACT ON READINGS OR DATA**

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

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



4.10. SETUP → MORE → DIAG: DIAGNOSTICS FUNCTIONS

A series of diagnostic tools is grouped together under the **SETUP→MORE→DIAG** menu, as these parameters are dependent on firmware revision (see Appendix A). These tools can be used in a variety of troubleshooting and diagnostic procedures and are referred to in many places of the maintenance and troubleshooting sections of this manual (see Sections 9.1 and 9.2).

This section shall focus on the test channel analog output.

4.10.1. → TEST CHAN OUTPUT: USING THE TEST CHANNEL ANALOG OUTPUT

The T700 calibrator comes equipped with one analog output. It can be set by the user to carry the current signal level of any one of the parameters listed in Table 4-14 and will output an analog VDC signal that rises and falls in relationship with the value of the parameter.

Pin-outs for the analog output connector at the rear panel of the instrument are:

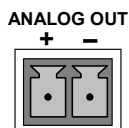


Figure 4-10: T700 the TEST CHANNEL Connector

4.10.1.1. Configuring the Test Channel Analog Output

Table 4-13 lists the analog I/O functions that are available in the T700 calibrator.

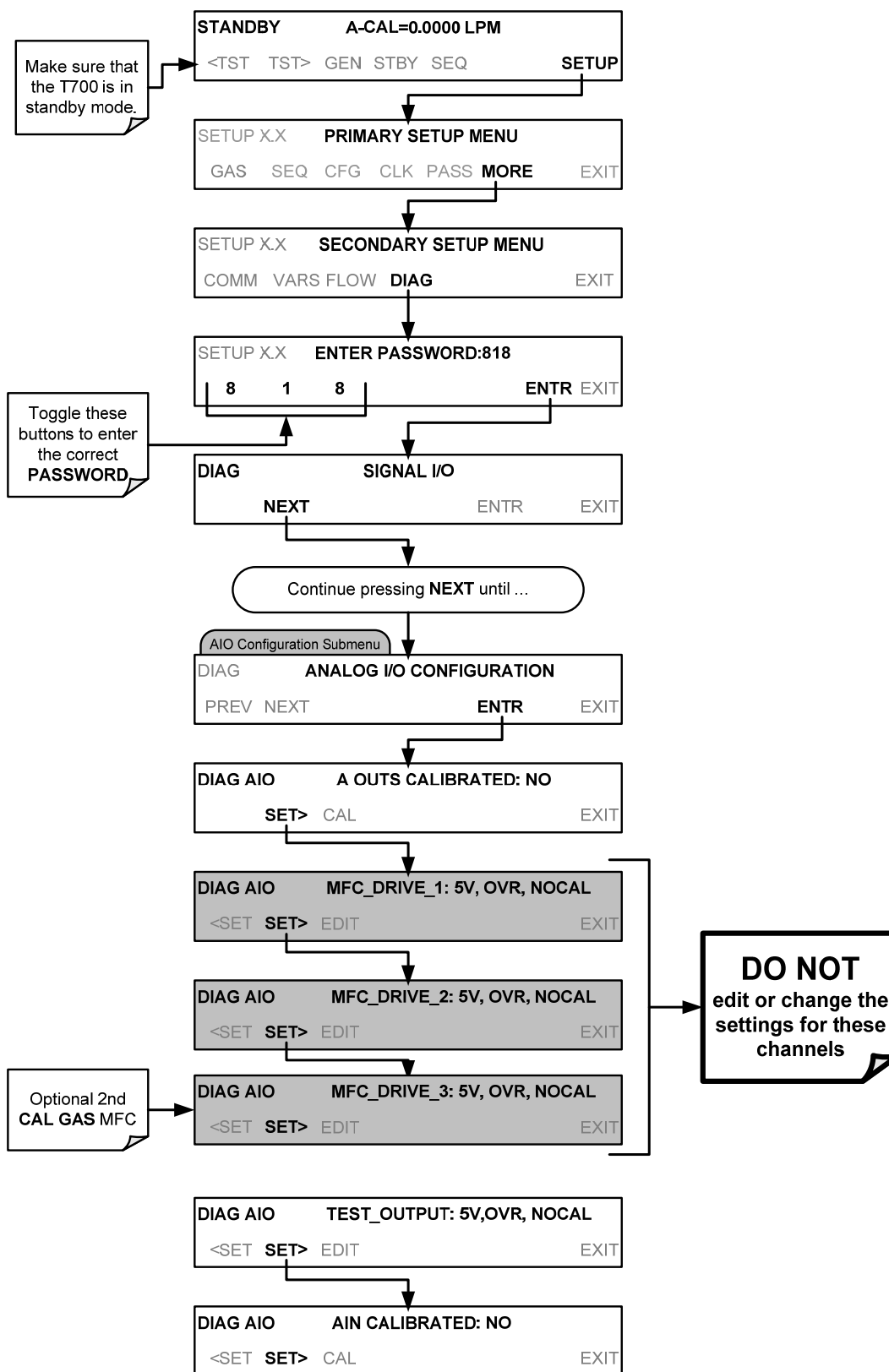
Table 4-13: DIAG – Analog I/O Functions

SUB MENU	FUNCTION
AOUTS CALIBRATED:	Shows the status of the analog output calibration (YES/NO) and initiates a calibration of all analog output channels.
MFC_DRIVE_1	These channels are used by the T700 calibrator internally as drive voltages for instruments with analog MFCs. DO NOT alter the settings for these channels.
MFC_DRIVE_2	
MFC_DRIVE_3 (OPTIONAL)	
TEST OUTPUT	Configures the analog output: RANGE¹ : Selects the signal type (voltage or current loop) and full-scale value of the output. OVERRANGE : Turns the $\pm 5\%$ over-range feature ON/OFF for this output channel. REC_OFS¹ : Sets a voltage offset (not available when RANGE is set to CURRENT loop. AUTO_CAL¹ : Sets the channel for automatic or manual calibration CALIBRATED¹ : Performs the same calibration as AOUT CALIBRATED , but on this one channel only.
AIN CALIBRATED	Shows the calibration status (YES/NO) and initiates a calibration of the analog to digital converter circuit on the motherboard.
¹ Changes to RANGE or REC_OFS require recalibration of this output.	

To configure the calibrator's **TEST CHANNEL**, set the electronic signal type of each channel and calibrate the outputs. This consists of:

- Choosing a Test Channel function to be output on the channel (Table 4-14).
- Selecting a signal level that matches the input requirements of the recording device attached to the channel (Section 4.10.1.3).
- Determining if the over-range feature is needed and turn it on or off accordingly (Section 4.10.1.4).
- Adding a bipolar recorder offset to the signal if required (Section 4.10.1.5).
- Calibrating the output channel. This can be done automatically or manually for each channel (Section 4.10.1.6).

To access the analog I/O configuration sub menu, press:



4.10.1.2. Selecting a Test Channel Function to Output

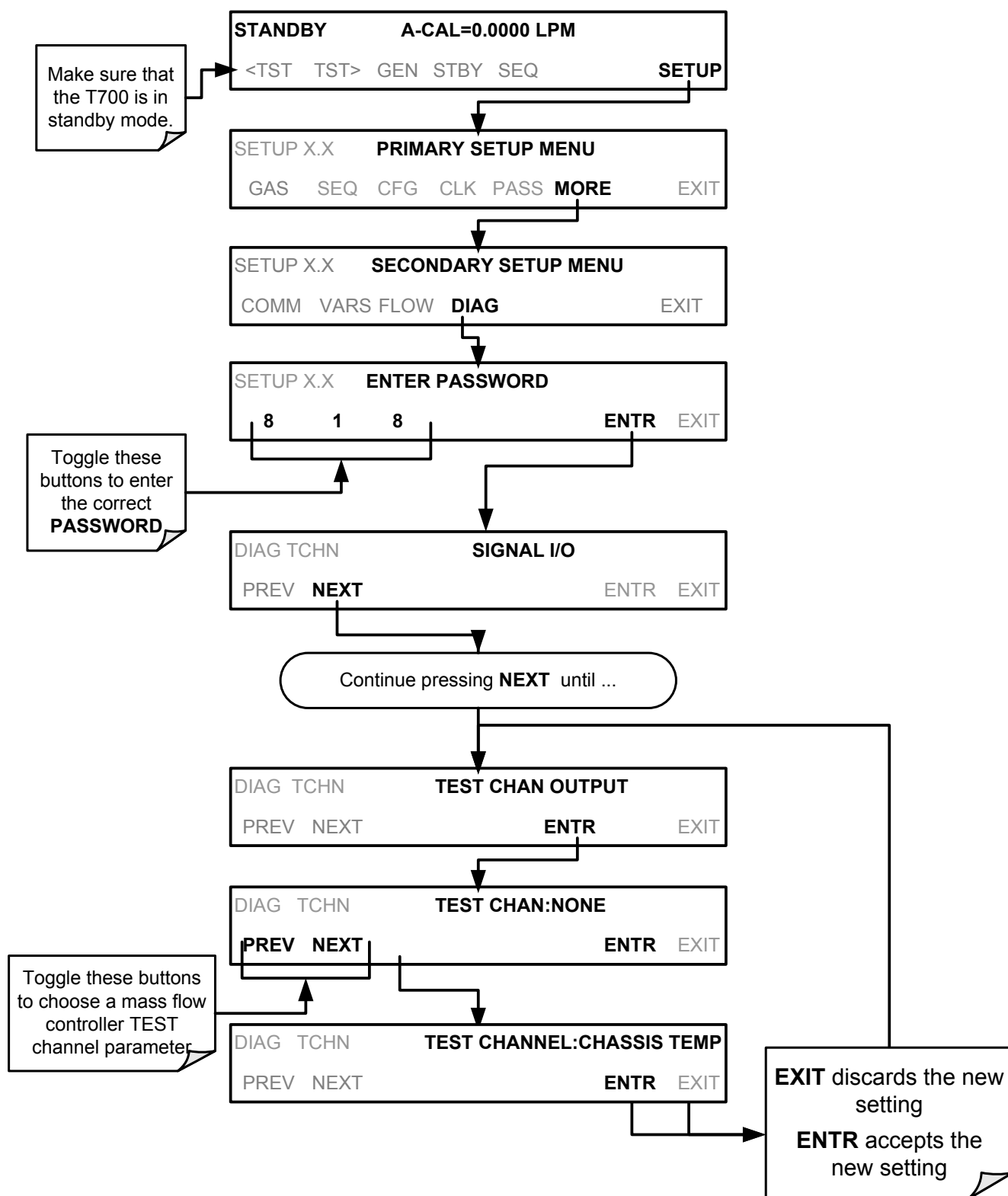
The Test Functions available to be reported are listed on Table 4-14:

Table 4-14: Test Channels Functions available on the T700's Analog Output

TEST CHANNEL	DESCRIPTION	ZERO	FULL SCALE
NONE	TEST CHANNEL IS TURNED OFF		
O3 PHOTO MEAS	The raw output of the photometer during its measure cycle	0 mV	5000 mV
O3 PHOTO REF	The raw output of the photometer during its reference cycle	0 mV	5000 mV
O3 GEN REF	The raw output of the O ₃ generator's reference detector	0 mV	5000 mV
REGULATOR PRESSURE	The gas pressure of the pressure regulator on the O ₃ generator supply line	PSIG	PSIG
SAMPLE PRESSURE	The pressure of gas in the photometer absorption tube	0" Hg-In-A	40" Hg-In-A
SAMPLE FLOW	The gas flow rate through the photometer	0 cm ³ /min	1000 cm ³ /min
SAMPLE TEMP	The temperature of gas in the photometer absorption tube	0 C°	70 C°
PHOTO LAMP TEMP	The temperature of the photometer UV lamp	0 C°	70 C°
O3 LAMP TEMP	The temperature of the O ₃ generator's UV lamp	0 mV	5000 mV
CHASSIS TEMP	The temperature inside the T700's chassis (same as BOX TEMP)	0 C°	70 C°
O3 PHOTO CONC	The current concentration of O ₃ being measured by the photometer.	0 PPM	1 ppm

Once a function is selected, the instrument not only begins to output a signal on the analog output, but also adds **TEST** to the list of Test Functions viewable via the Front Panel Display.

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



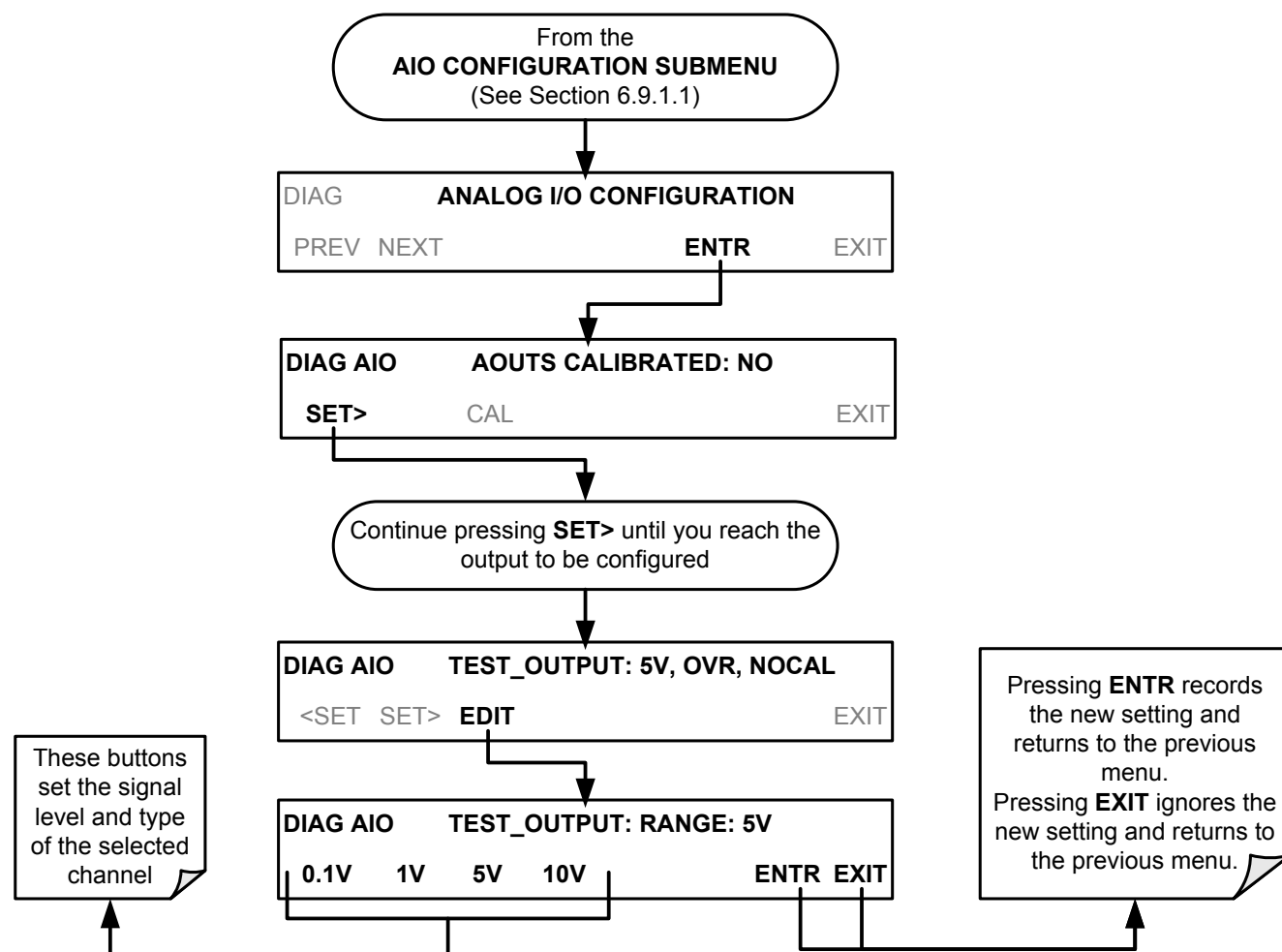
4.10.1.3. Test Channel Voltage Range Configuration

In its standard configuration, the analog outputs is set to output a 0 – 5 VDC signals. Several other output ranges are available (see Table 4-15). Each range is usable from -5% to +5% of the rated span.

Table 4-15: 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.		

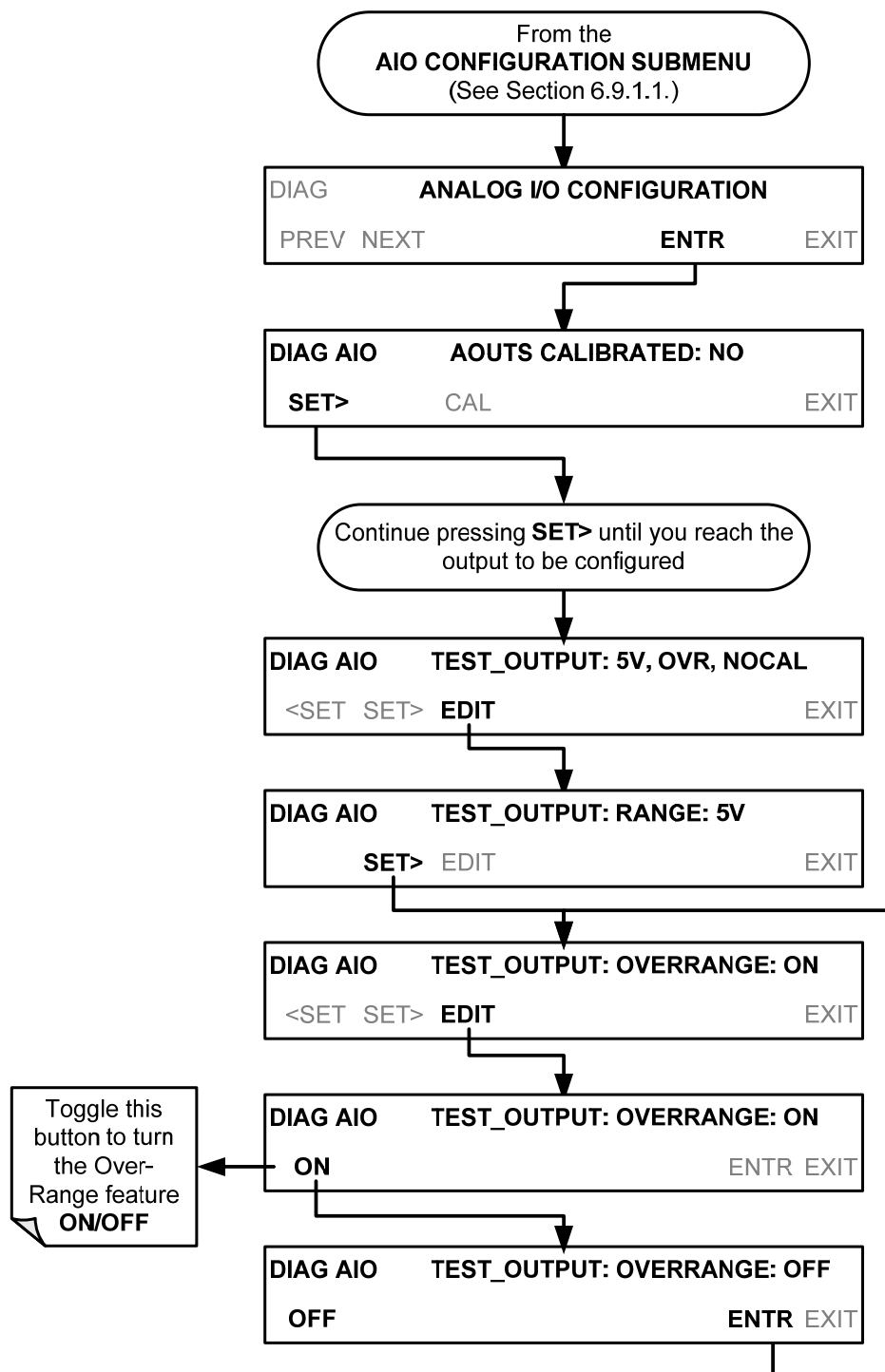
To change the output range, press:



4.10.1.4. Turning the Test Channel Over-Range Feature ON/OFF

In its default configuration, a $\pm 5\%$ over-range is available on each of the T700's **TEST CHANNEL** output. This over-range can be disabled if your recording device is sensitive to excess voltage or current.

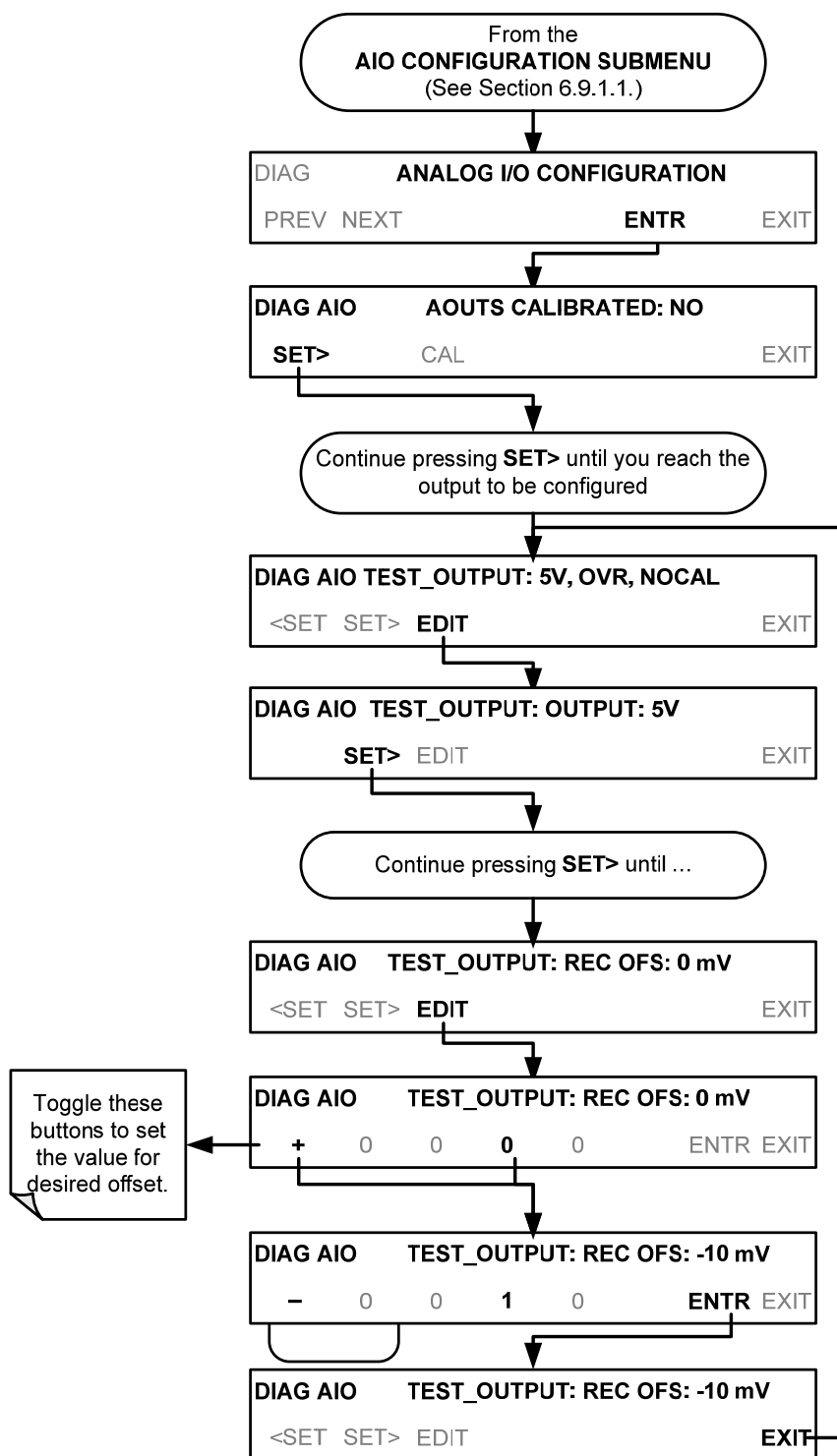
To turn the over-range feature on or off, press:



4.10.1.5. Adding a Recorder Offset to the Test Channel

Some analog signal recorders require that the zero signal is 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 T700 by defining a zero offset, a small voltage (e.g., 10% of span).

To add a zero offset to a specific analog output channel, press:



4.10.1.6. Test Channel Calibration

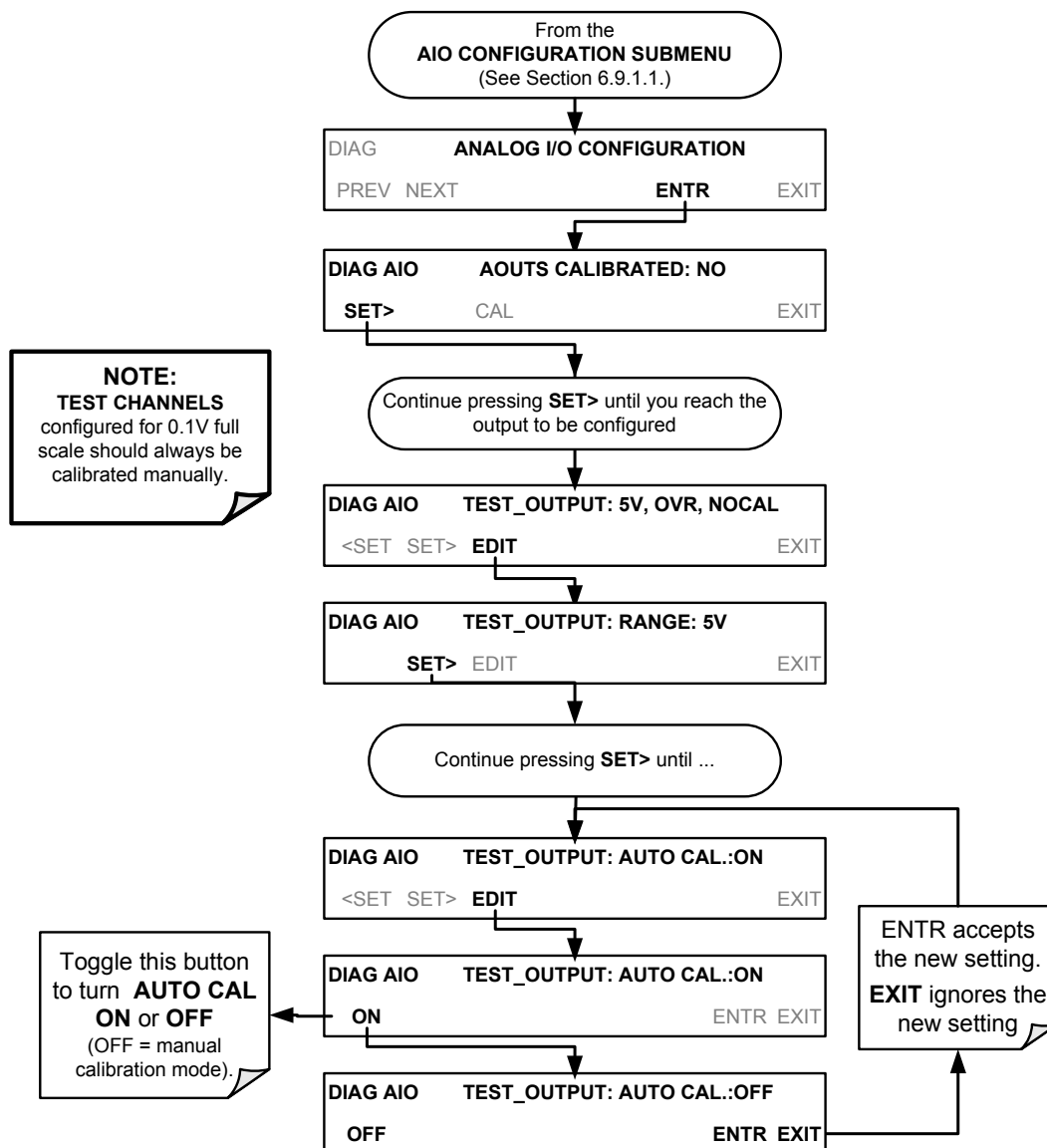
TEST CHANNEL calibration needs to be carried out on first startup of the calibrator (performed in the factory as part of the configuration process) or whenever recalibration is required. The analog outputs can be calibrated automatically or adjusted manually.

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.

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 requires the AUTOCAL feature to be disabled.

ENABLING OR DISABLING THE TEST CHANNEL AUTOCAL FEATURE

To enable or disable the AUTOCAL feature for the **TEST CHANNEL**, press:

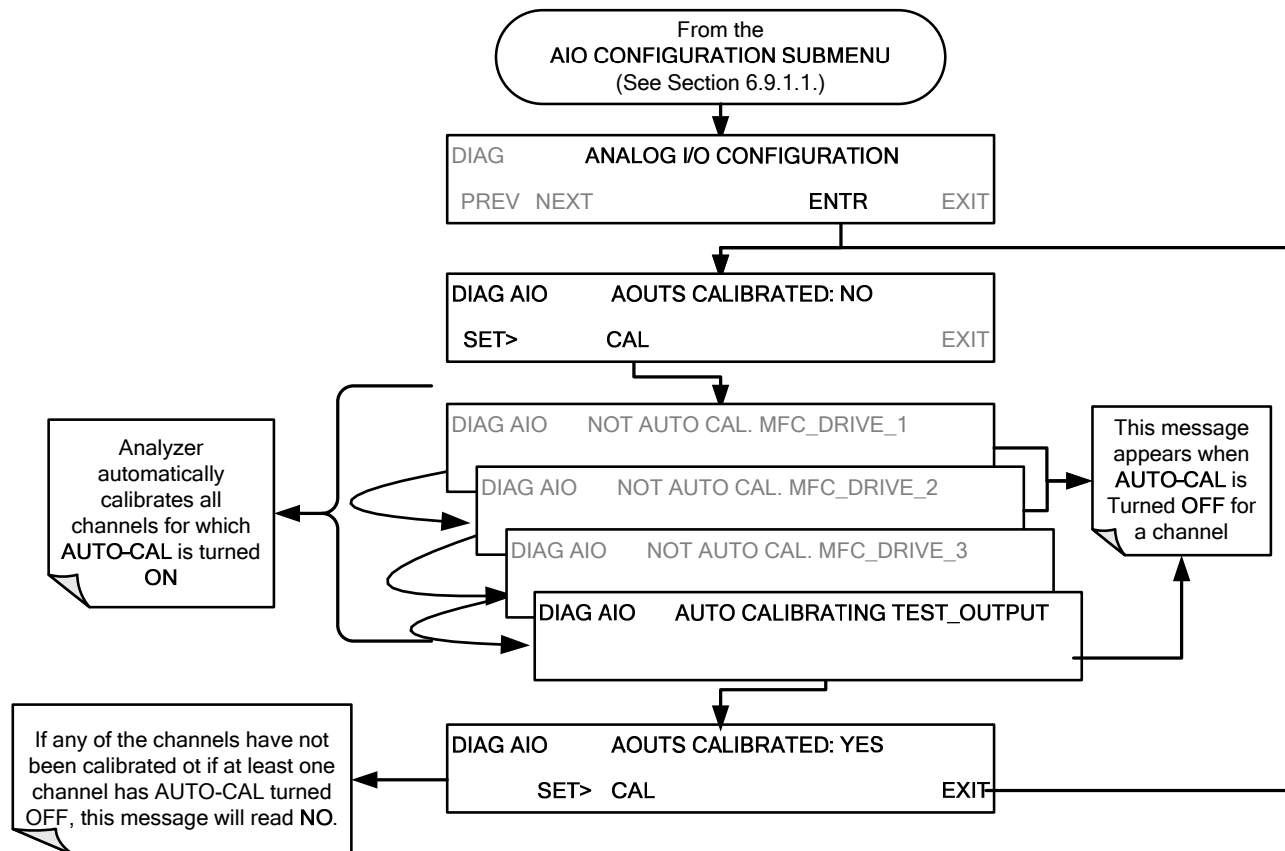


AUTOMATIC TEST CHANNEL CALIBRATION

Note

Before performing this procedure, ensure that the **AUTO CAL** feature is turned **OFF** for **MFC_DRIVE_1**, **MFC_DRIVE_2** and **MFC_DRIVE_3** if installed). Ensure that the **AUTO CAL** feature is turned **ON** for the **TEST CHANNEL** (see Section 4.10.1.6).

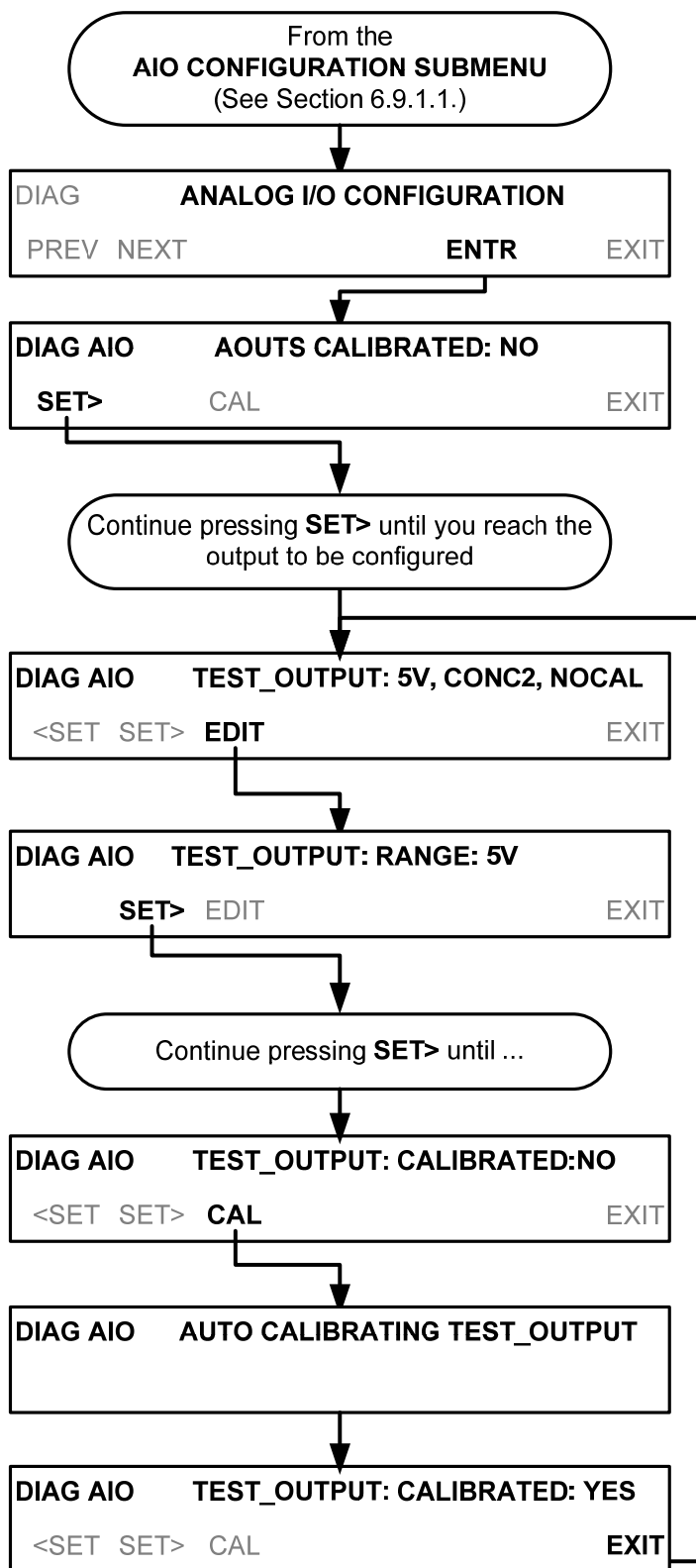
To calibrate the outputs as a group with the **AOUTS CALIBRATION** command, press:



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 requires that the **AUTOCAL** feature be disabled.

To initiate an automatic calibration from inside the **TEST CHANNEL** submenu, press:



MANUAL CALIBRATION OF THE TEST CHANNEL CONFIGURED FOR VOLTAGE RANGES

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

Note

The menu for manually adjusting the analog output signal level will only appear if the AUTO-CAL feature is turned off for the channel being adjusted (see Section 4.10.1.6).

Calibration is performed with a voltmeter connected across the output terminals and by changing the actual output signal level using the front panel buttons in 100, 10 or 1 count increments.

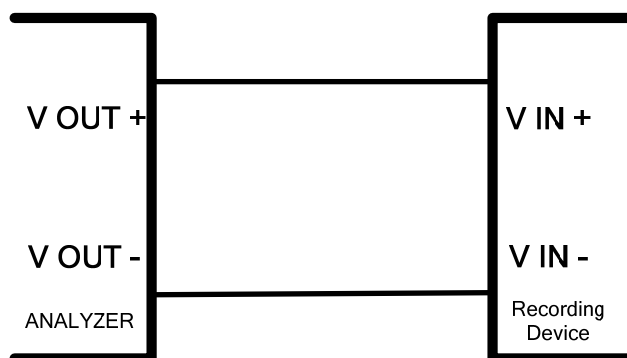
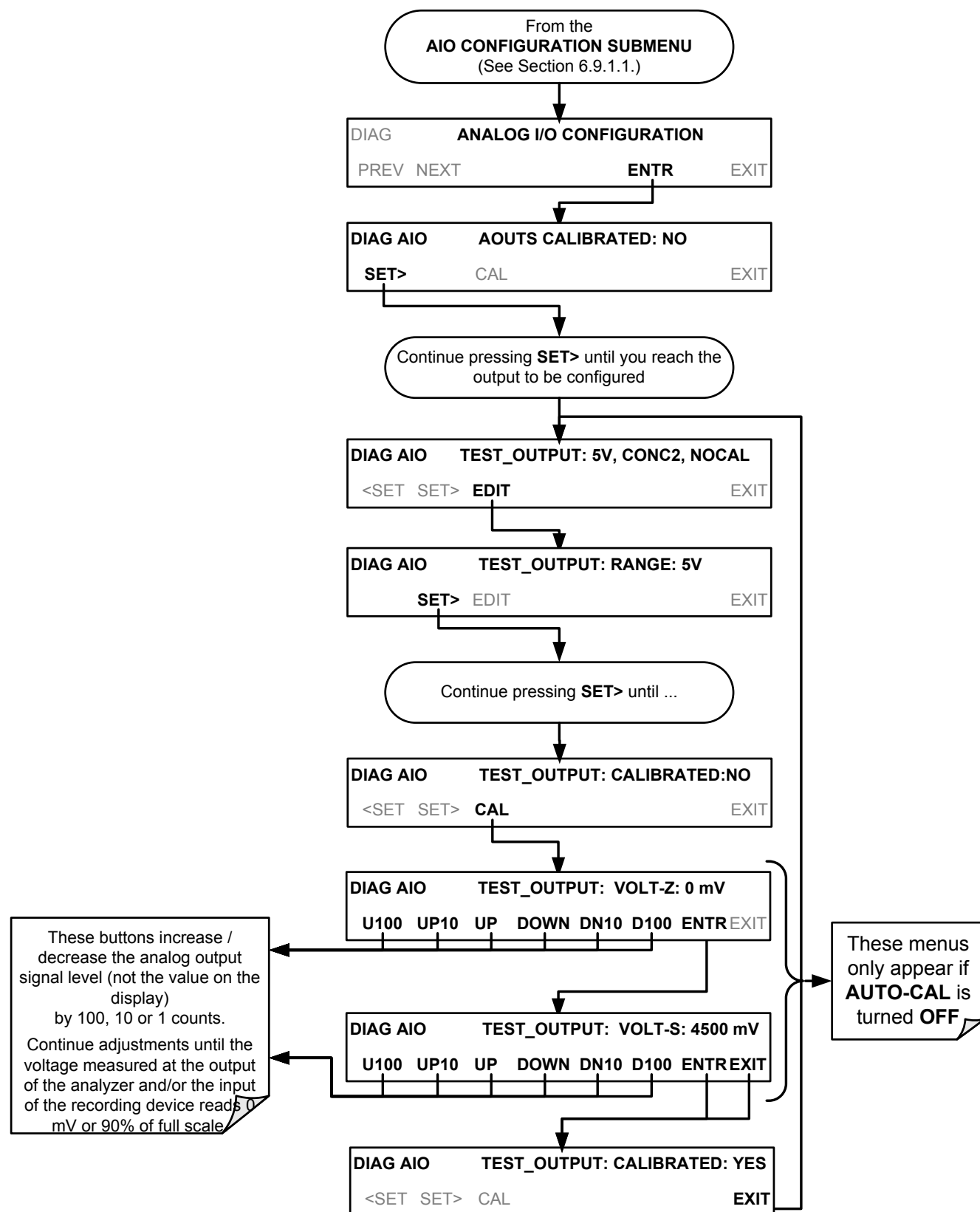


Figure 4-11: Setup for Calibrating the TEST CHANNEL

Table 4-16: Voltage Tolerances for the TEST CHANNEL Calibration

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

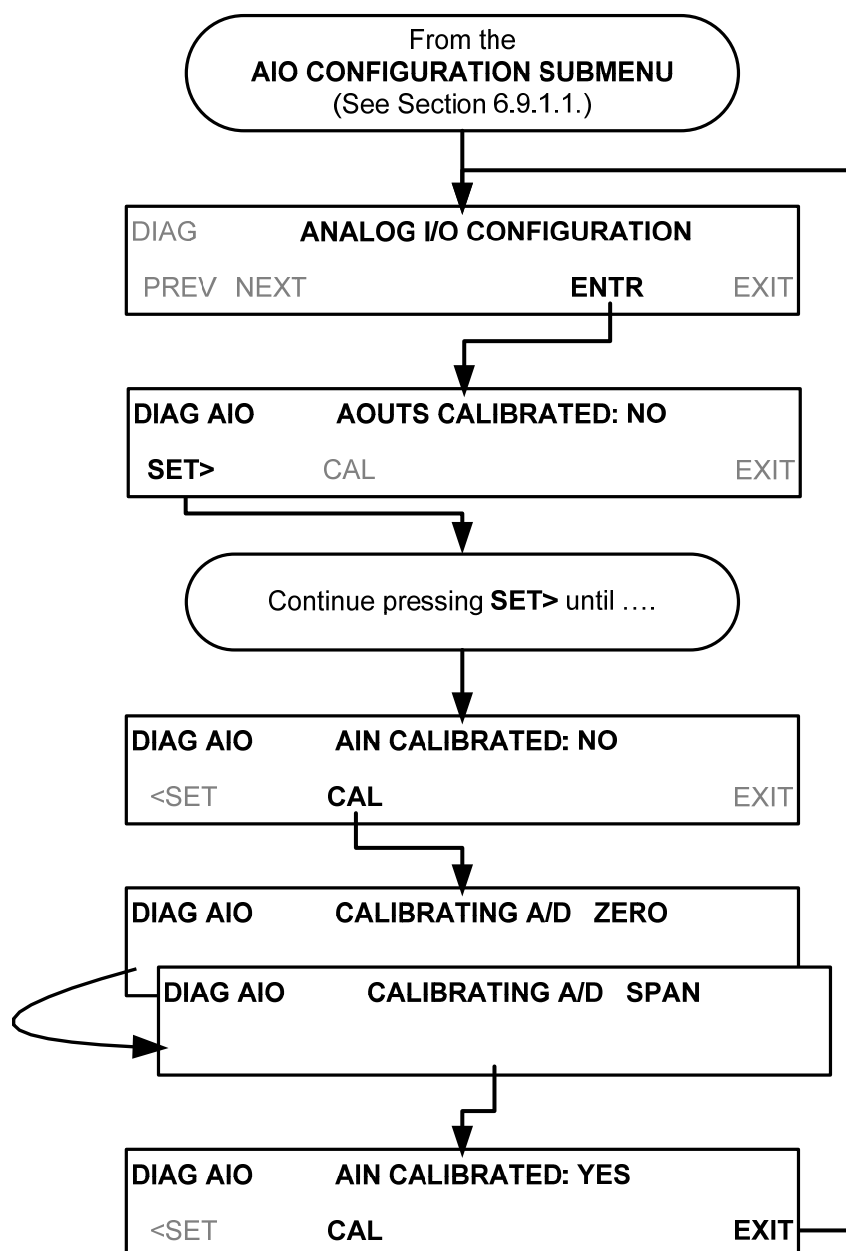
To adjust the signal levels of an analog output channel manually, press:



4.10.1.7. AIN Calibration

This is the sub-menu in which to calibrate the A-to-D conversion circuitry (Sections 9.4.11.1 and 10.3.5.1). This calibration is only necessary after a major repair such as the replacement of a CPU, a motherboard or a power supply.

To perform an **AIN CALIBRATION**, press:



4.11. SETUP → LVL: SETTING UP AND USING LEADS (DASIBI) OPERATING LEVELS

4.11.1. GENERAL INFORMATION ABOUT LEADS LEVELS

The T700 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 an T700 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 T700 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 3.3.1.6).

Note

For more information on the LEADS system, please go to <http://www.meteostar.com/>.

4.11.2. 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 Customer Service.

A T700 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.

4.11.3. LEVELS

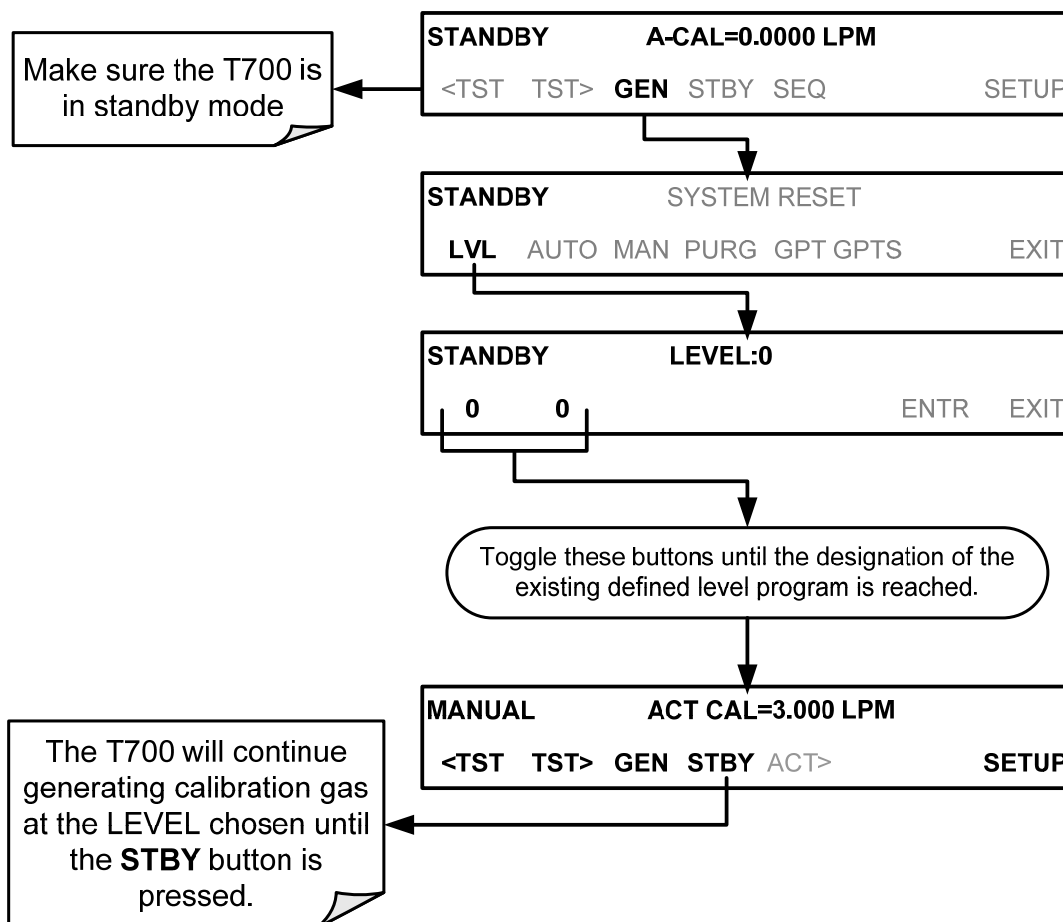
A **LEVEL** is a combination of several parameters:

- An ID number for the LEVEL
- An action, (e.g. GENERATE, GPT, GPTPS & MANUAL)
- A target concentration value
- An output flow rate (if applicable)
- Configuration for one or both of two status output blocks.

Up to twenty levels can be defined and used with the T700 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 can not 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.

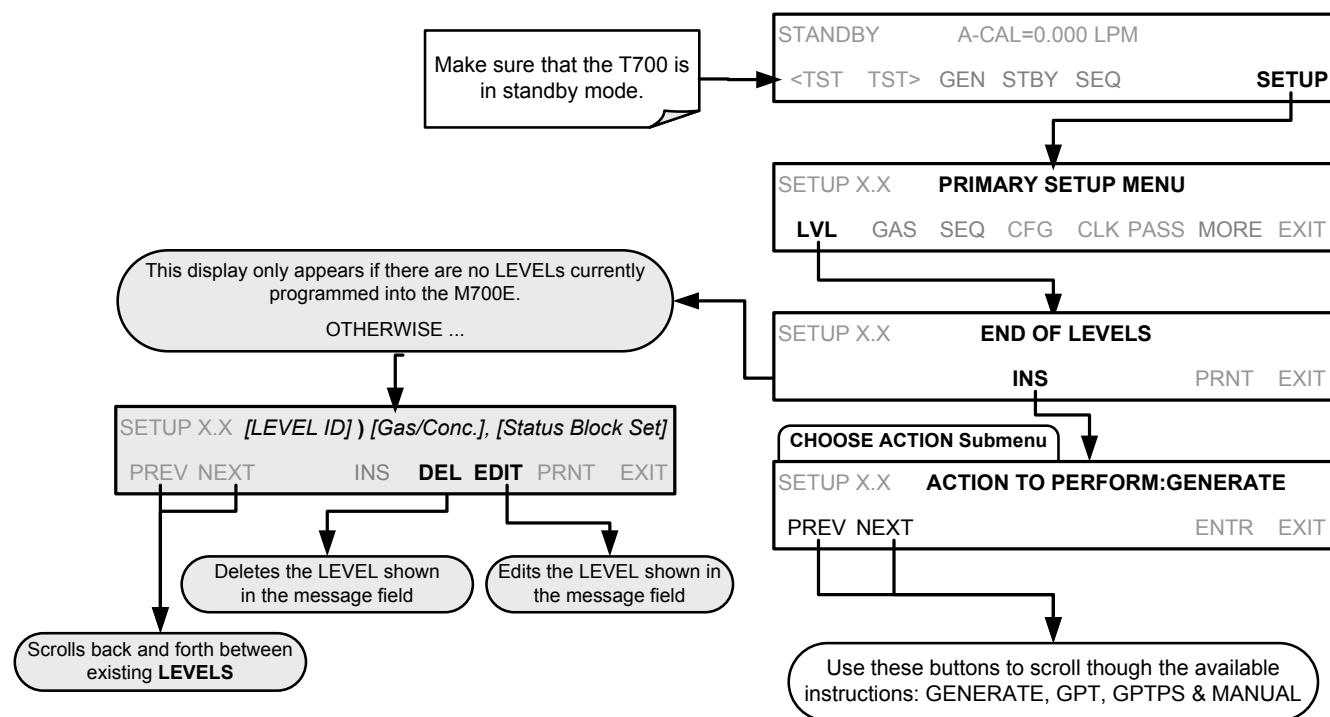
4.11.4. ACTIVATING AN EXISTING LEVEL

To activate an existing defined **LEVEL**, press:



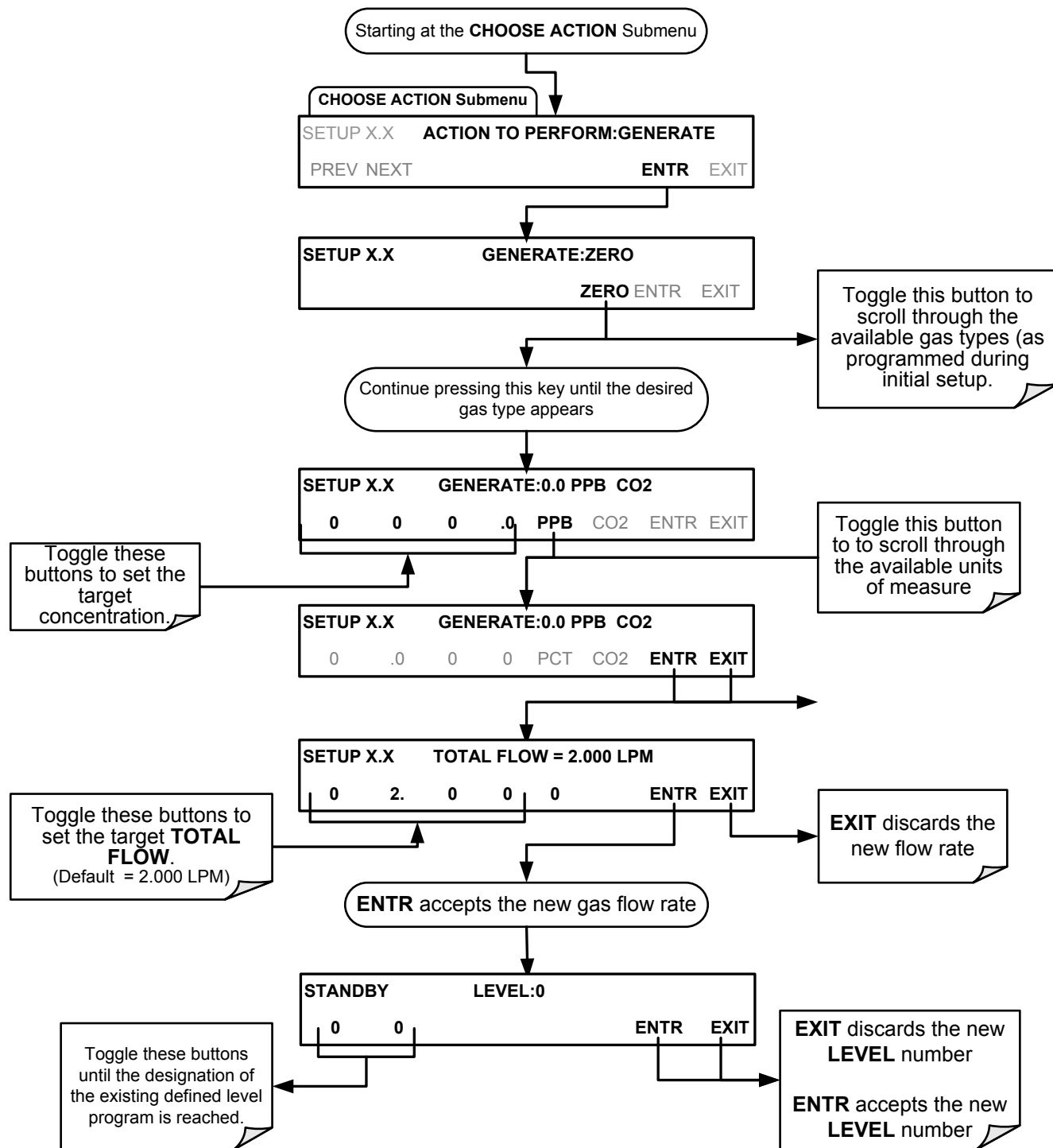
4.11.5. PROGRAMMING NEW LEVELS

To begin programming a new **LEVEL** find the **LVL** submenu by pressing:



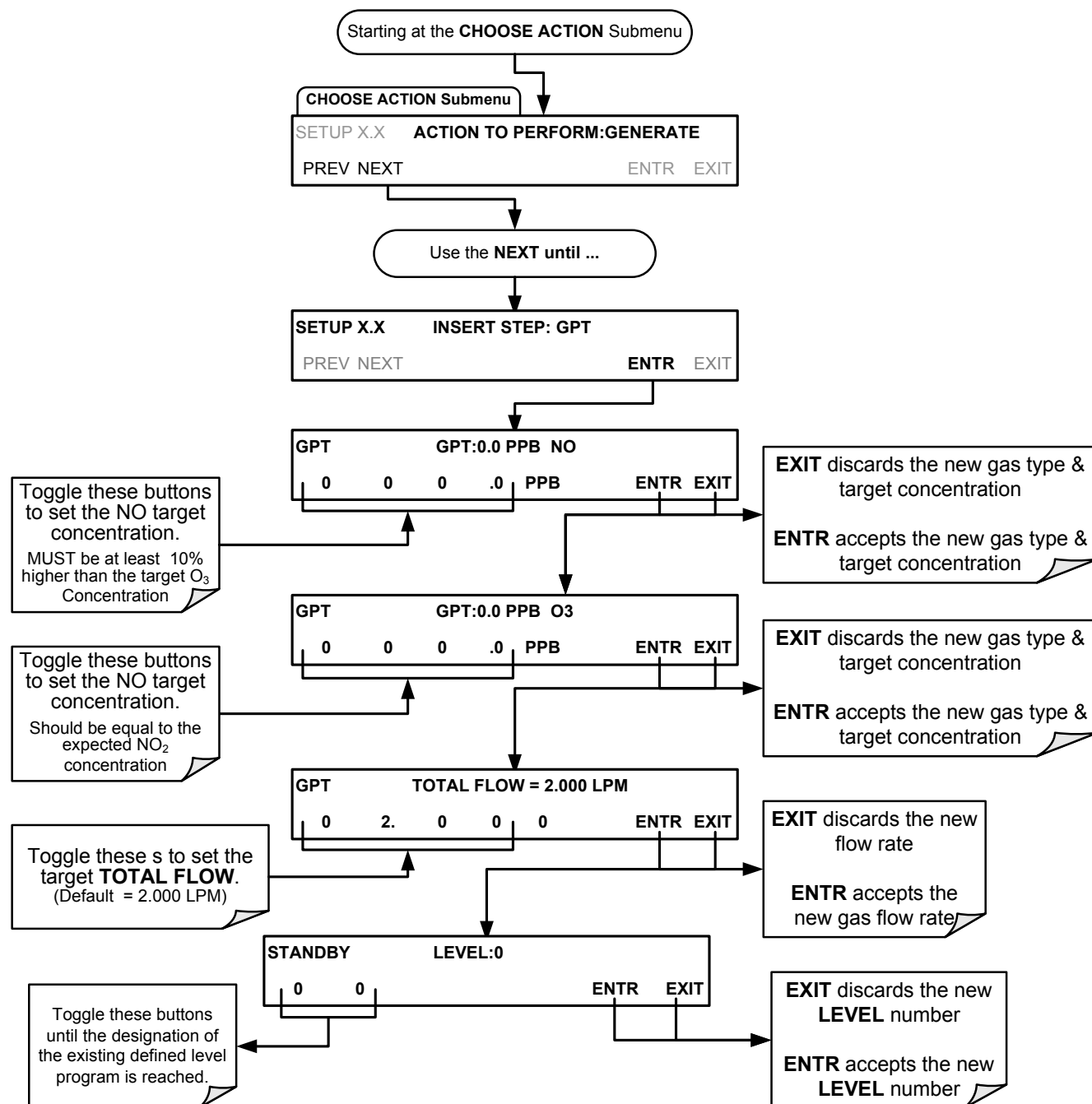
4.11.5.1. Creating a GENERATE LEVEL

To create a **LEVEL** using the T700's **AUTO** generation function, press:



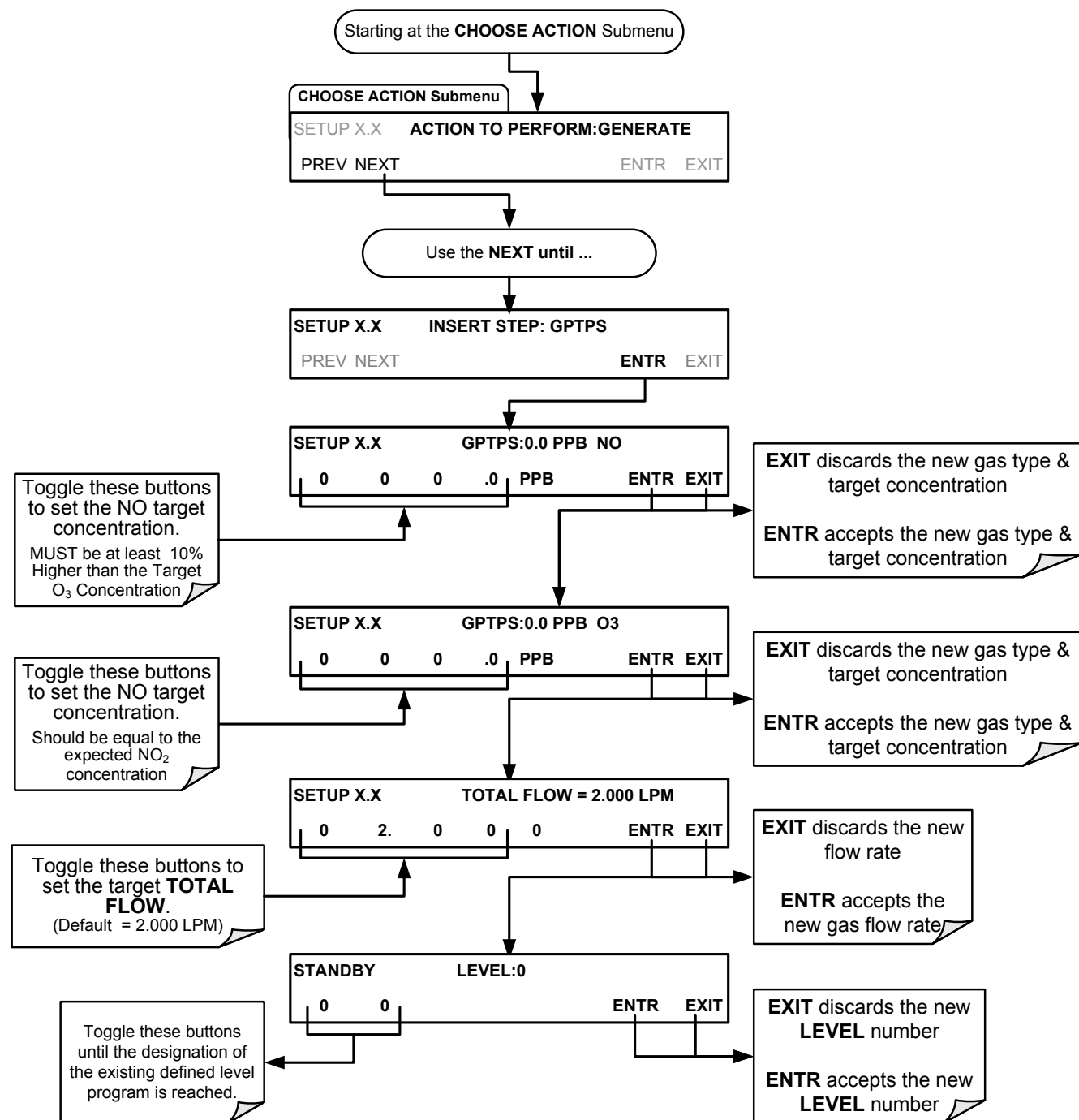
4.11.5.2. Creating a GPT LEVEL

To create a **LEVEL** using the T700's **GPT** function, press:



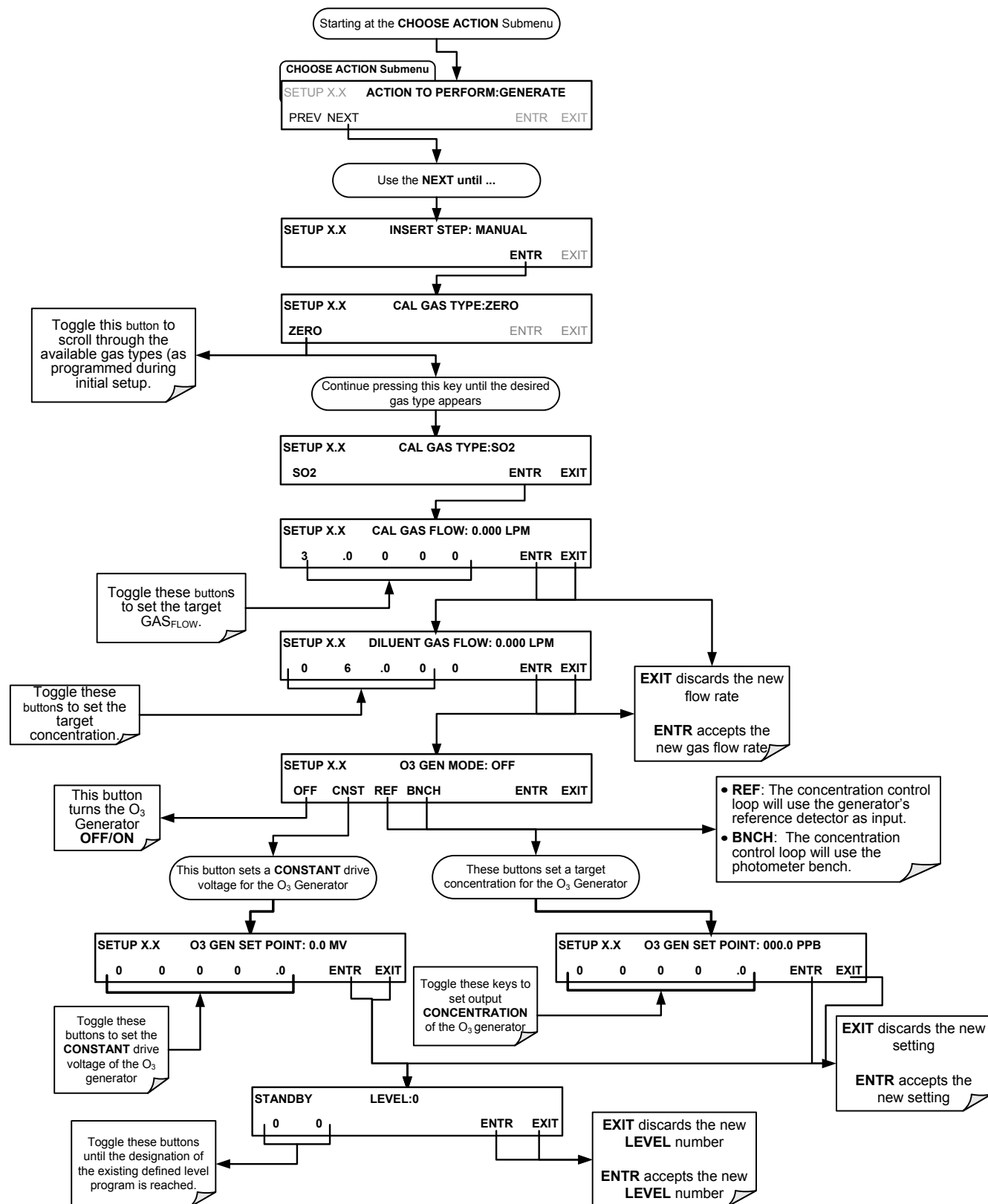
4.11.5.3. Creating a GPTPS LEVEL

To create a **LEVEL** using the T700's **GPTPS** function, press:



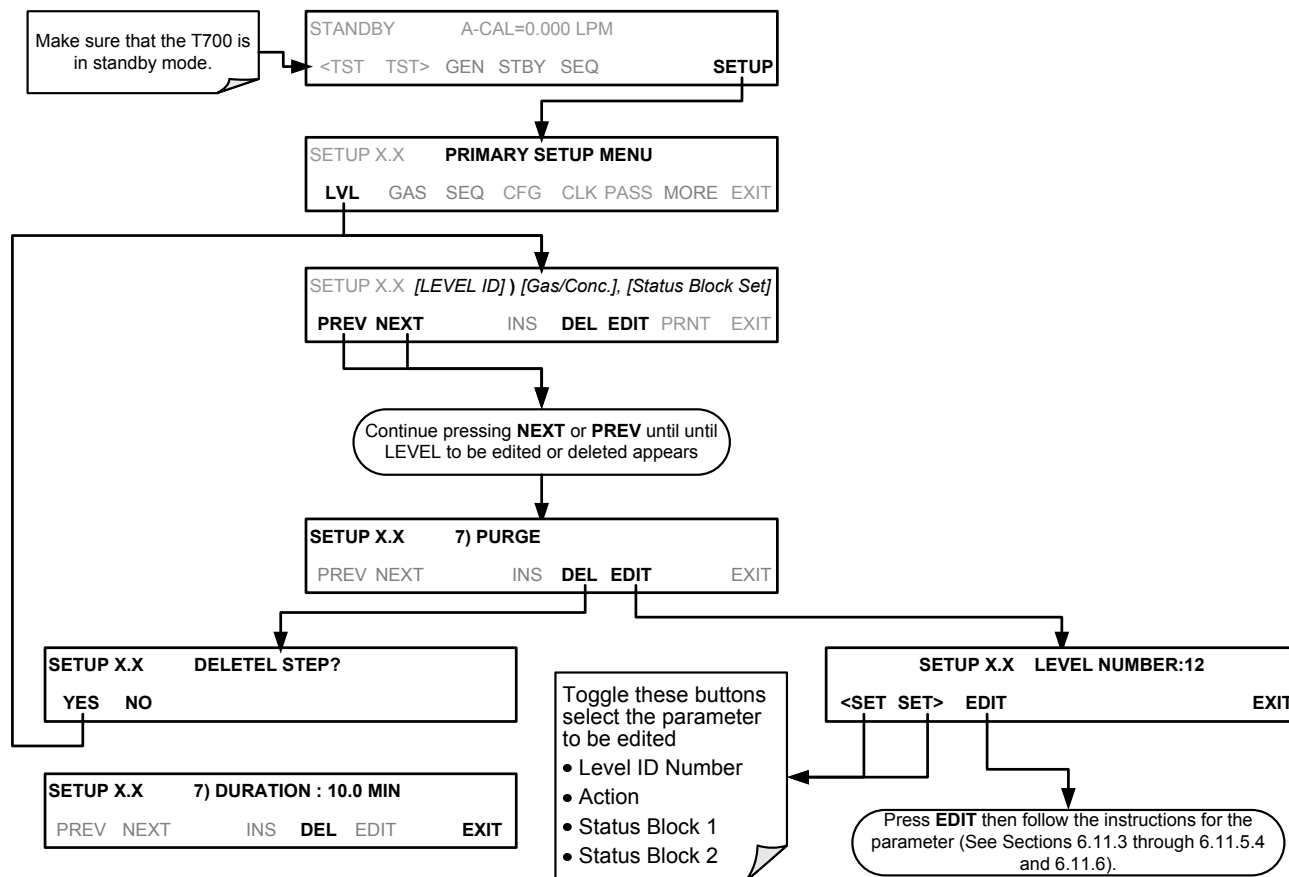
4.11.5.4. Creating a MANUAL LEVEL

To create a level using the T700's **MANUAL** generation function, press:



4.11.5.5. Editing or Deleting a LEVEL

To edit or delete an existing **LEVEL**, press:

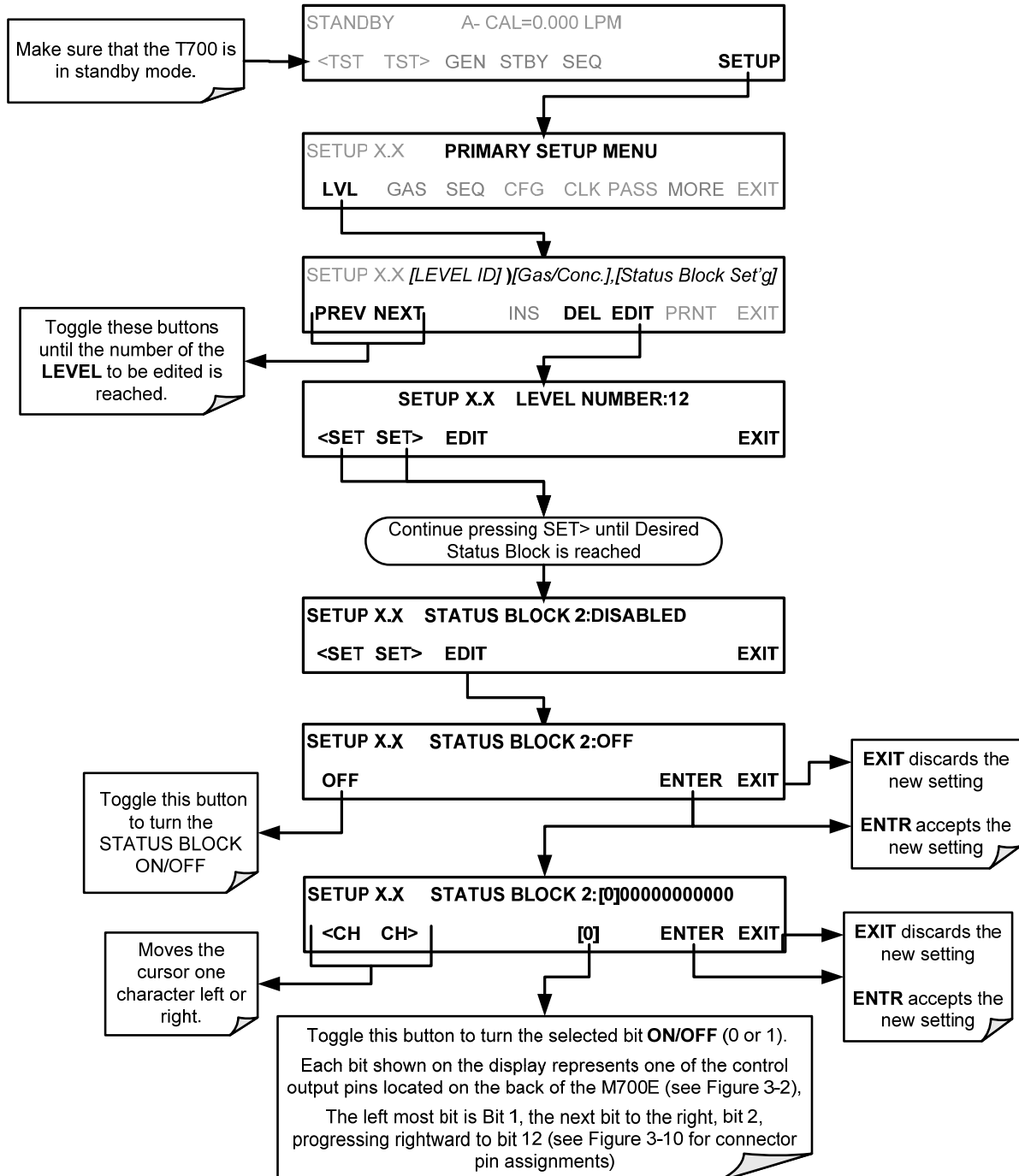


4.11.6. CONFIGURING LEVEL STATUS BLOCKS

There are two **STATUS BLOCKS** associated with **LEADS LEVELS**.

- **BLOCK 1:** This block corresponds to the physical CONTROL OUTPUT connections located on the back panel of the T700 (see Figure 3-4 and Section 3.3.1.5).
- **BLOCK 2:** The second status block does not correspond to any physical output but is used to communicate status over the serial data port.

To configure the either of the **STATUS BLOCKS**, press:



5. COMMUNICATIONS SETUP AND 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 3-4). These ports give the user 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, describes the instrument's communications modes, presents configuration instructions for the communications ports, and provides instructions for their use.

5.1. 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 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.

The T700 is equipped with two serial communication ports (labeled **RS232** and **COM2**), a USB com port and an Ethernet port located on the rear panel. The two serial ports are accessible via two DB-9 connectors (see Figure 3-4): RS232 (COM1), a male DB-9 connector, and COM2, a female DB9 connector.

The RS232 and COM2 ports operate similarly and give the user the ability to communicate with, issue commands to, and receive data from the calibrator through an external computer system or terminal.

- The RS-232 port (COM1) can also be configured to operate in single or RS-232 multi-drop mode (option 62, Sections 3.3.1.7 and 5.2).
- The COM2 port can be configured for standard RS-232 operation, half-duplex RS-485 communication. (Contact the factory for RS-485 communication configuration).

The Ethernet connector allows the analyzer to be connected to a network running TCP/IP or to the public Internet if access is available. The network must have routers

capable of operating at 10BaseT or 100BaseT. DHCP is enabled by default (Section 5.4.1). This configuration is useful for quickly getting an instrument up and running on a network. However, for permanent Ethernet connections, a static IP address should be used (Section 5.4.1.1). Edit the Instrument and Gateway IP addresses and Subnet Mask to the desired settings. Then, from the computer, enter the same information through an application such as HyperTerminal.

The USB port is for optional direct communication between the calibrator and a desktop or laptop computer. This configuration can be used when the **COM2** port is not in use except for multidrop communication. For setup instructions, please refer to Sections 3.3.1.7 and 5.2.1.

5.2. COMMUNICATION MODES, BAUD RATE AND PORT TESTING

Use the **SETUP>MORE>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/or port testing for correct connection.

5.2.1. COMMUNICATION MODES

Each of the calibrator's serial ports can be configured to operate in a number of different modes, listed in Table 5-1. As modes are selected, the calibrator sums the Mode ID numbers and displays this combined number on the front panel display. For example, if quiet mode (01), computer mode (02) and Multi-Drop-enabled mode (32) are selected, the Calibrator would display a combined **MODE ID** of 35.

Table 5-1: COMM Port Communication Modes

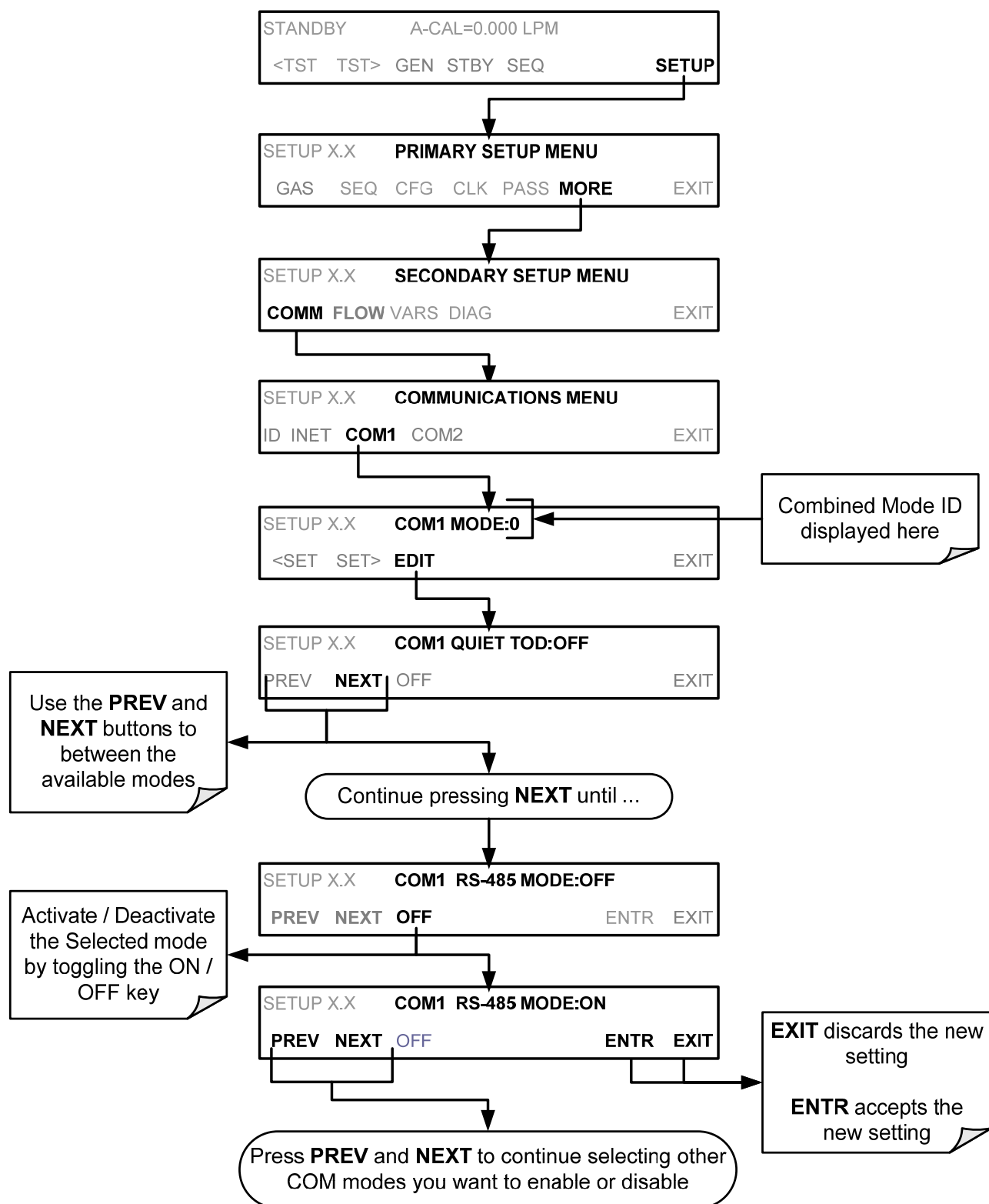
MODE ¹	ID	DESCRIPTION
QUIET	1	Quiet mode suppresses any feedback from the calibrator (such as warning messages) to the remote device and is typically used when the port is communicating with a computer program where such intermittent messages might cause communication problems. Such feedback is still available but a command must be issued to receive them.
COMPUTER	2	Computer mode inhibits echoing of typed characters and is used when the port is communicating with a computer operated control program.
E,8,1 / E,7,1	2048	When turned on this mode switches the COMM port settings from No parity; 8 data bits; 1 stop bit to Even parity; 7 data bits; 1 stop bit
SECURITY	4	When enabled, the serial port requires a password before it will respond. The only command that is active is the help screen (? CR).
RS-485	1024	Configures the COM2 Port for RS-485 communication. RS-485 mode has precedence over multi-drop mode if both are enabled.
MULTI-DROP PROTOCOL	32	Multi-drop protocol allows a multi-instrument configuration on a single communications channel. Multi-drop requires the use of instrument IDs.
ENABLE MODEM	64	Enables to send a modem initialization string at power-up. Asserts certain lines in the RS-232 port to enable the modem to communicate.
ERROR CHECKING ²	128	Fixes certain types of parity errors at certain Hessen protocol installations.
XON/XOFF	256	Disables XON/XOFF data flow control also known as software handshaking.

HANDSHAKE²		
HARDWARE HANDSHAKE	8	Enables CTS/RTS style hardwired transmission handshaking. This style of data transmission handshaking is commonly used with modems or terminal emulation protocols as well as by Teledyne Instrument's APICOM software.
HARDWARE FIFO²	512	Disables the HARDWARE FIFO (First In – First Out), When FIFO is enabled it improves data transfer rate for that COMM port.
COMMAND PROMPT	4096	Enables a command prompt when in terminal mode.
¹ Modes are listed in the order in which they appear in the SETUP → MORE → COMM → COM[1 OR 2] → MODE menu ² The default setting for this feature is ON . Do not disable unless instructed to by Teledyne API's Customer Service personnel.		

Note

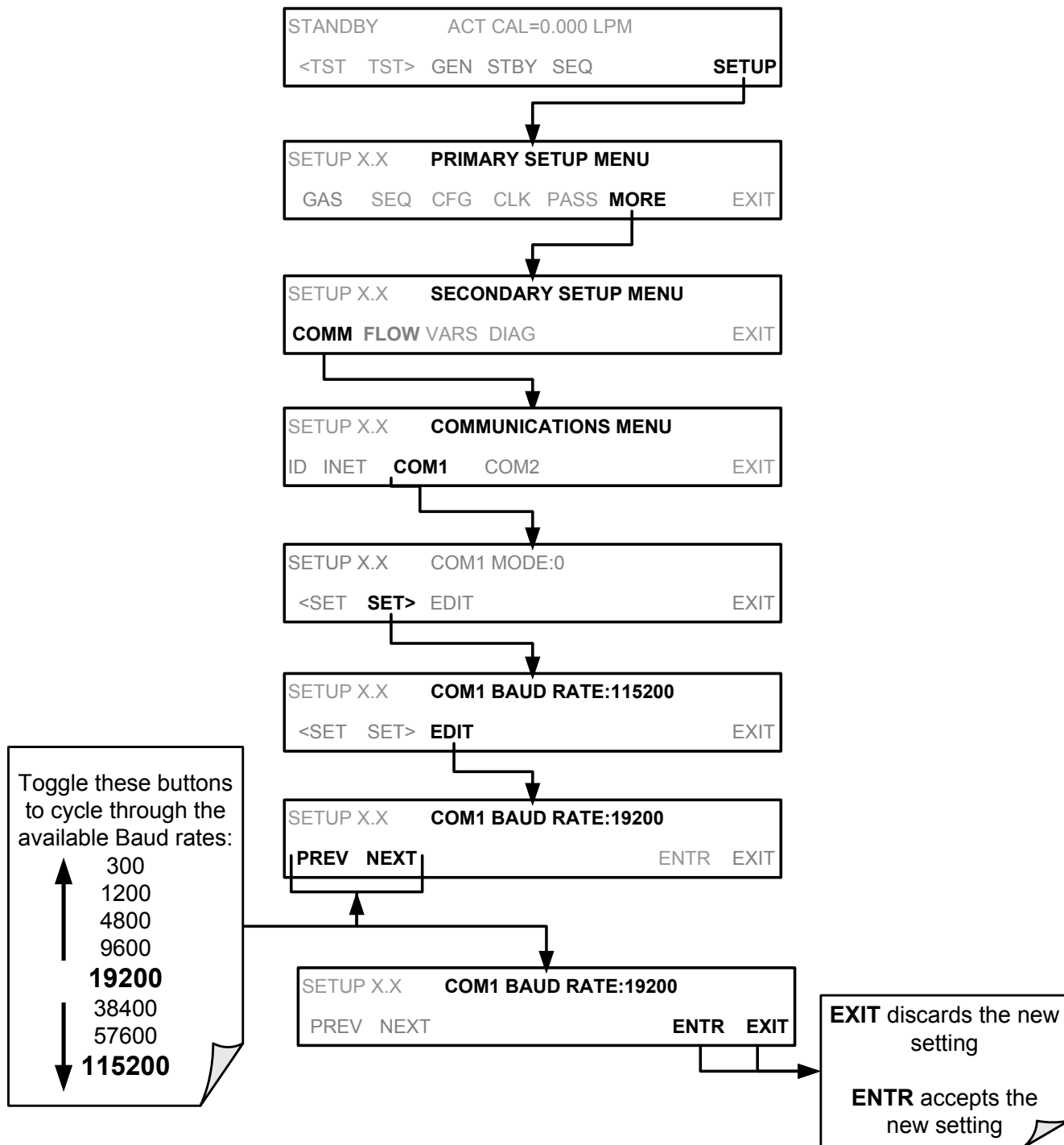
Communication Modes for each COMM port must be configured independently.

Press the following buttons to select communication modes for a one of the COMM Ports, such as the following example where **RS-485** mode is enabled:



5.2.2. COM PORT BAUD RATE

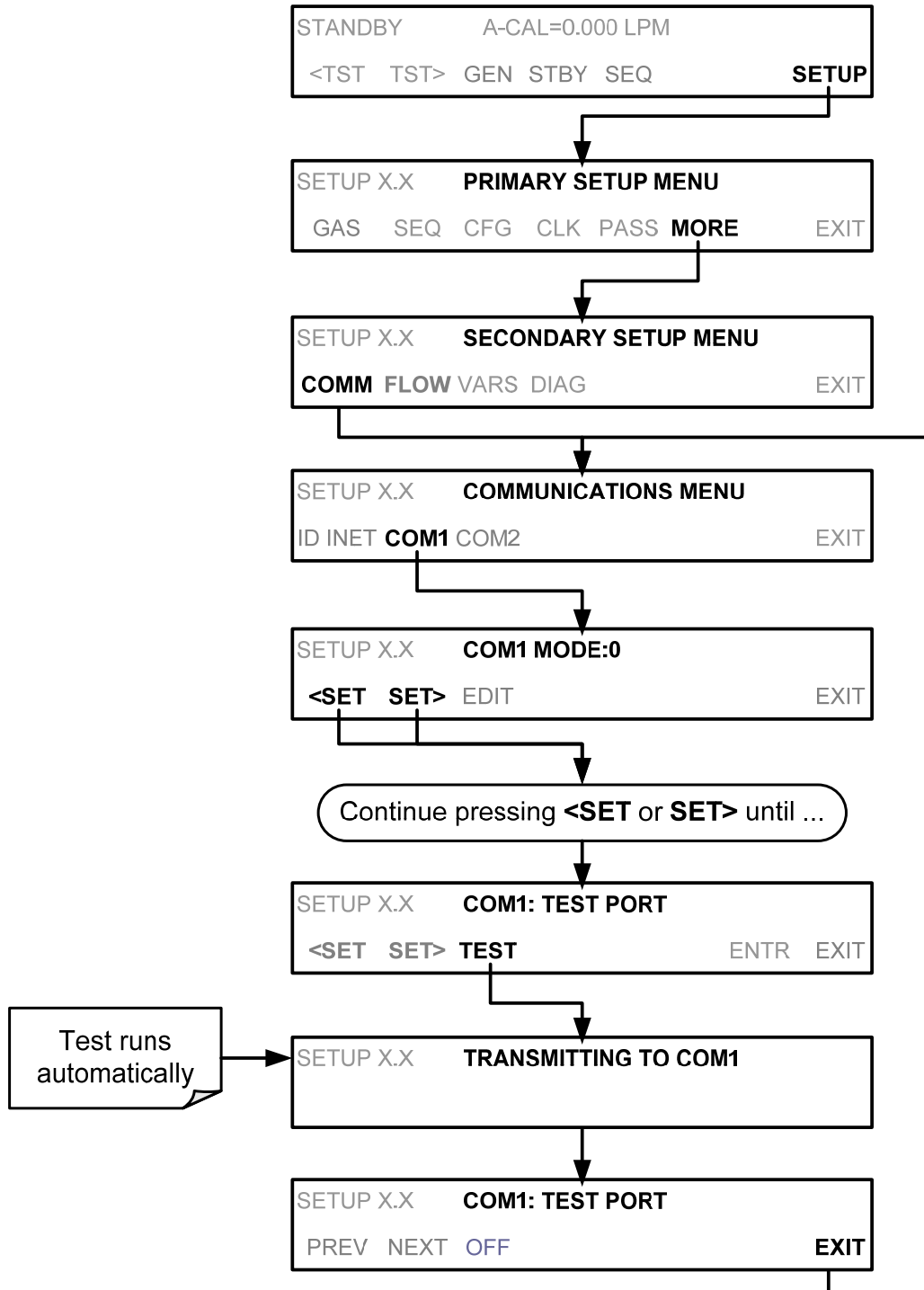
To select the baud rate of either COM Port, go to **SETUP>MORE>COMM** and select either COM1 or COM2 as follows (use COM2 to view/match your personal computer baud rate when using the USB port):



5.2.3. COM PORT TESTING

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

To initiate the test, press the following button sequence:



5.3. 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 Customer Service. If this option was elected at the time of purchase, the rear panel was preconfigured at the factory. Choosing this option disallows use of the USB port.

5.4. REMOTE ACCESS VIA THE ETHERNET

Via the Ethernet interface, the calibrator 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 Internet to the calibrator using APICOM, terminal emulators or other programs.

Under the SETUP>MORE>COMM menu the **INET** submenu is used to manage and configure the Ethernet interface with your LAN or Internet Server(s). The calibrator is shipped with DHCP enabled by default. This allows the instrument to be connected to a network or router with a DHCP server (Section 5.4.1), but for a permanent Ethernet connection, configure the instrument with a static IP address (Section 5.4.1.1).

The Ethernet LEDs located on the connector indicate the Ethernet connection status.

Table 5-2: Ethernet Status Indicators

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

5.4.1. CONFIGURING THE ETHERNET INTERFACE USING DHCP

The Ethernet feature for your T700 uses Dynamic Host Configuration Protocol (DHCP) to configure its interface with your LAN automatically. This requires your network servers also be running DHCP. The calibrator will do this the first time you turn the instrument on after it has been physically connected to your network. Once the instrument is connected and turned on, it will appear as an active device on your network without any extra set up steps or lengthy procedures.

Note

Check the **INET** settings the first time you power up your calibrator after it has been physically connected to the LAN/Internet to ensure that the DHCP has successfully downloaded the appropriate information from your network server(s).

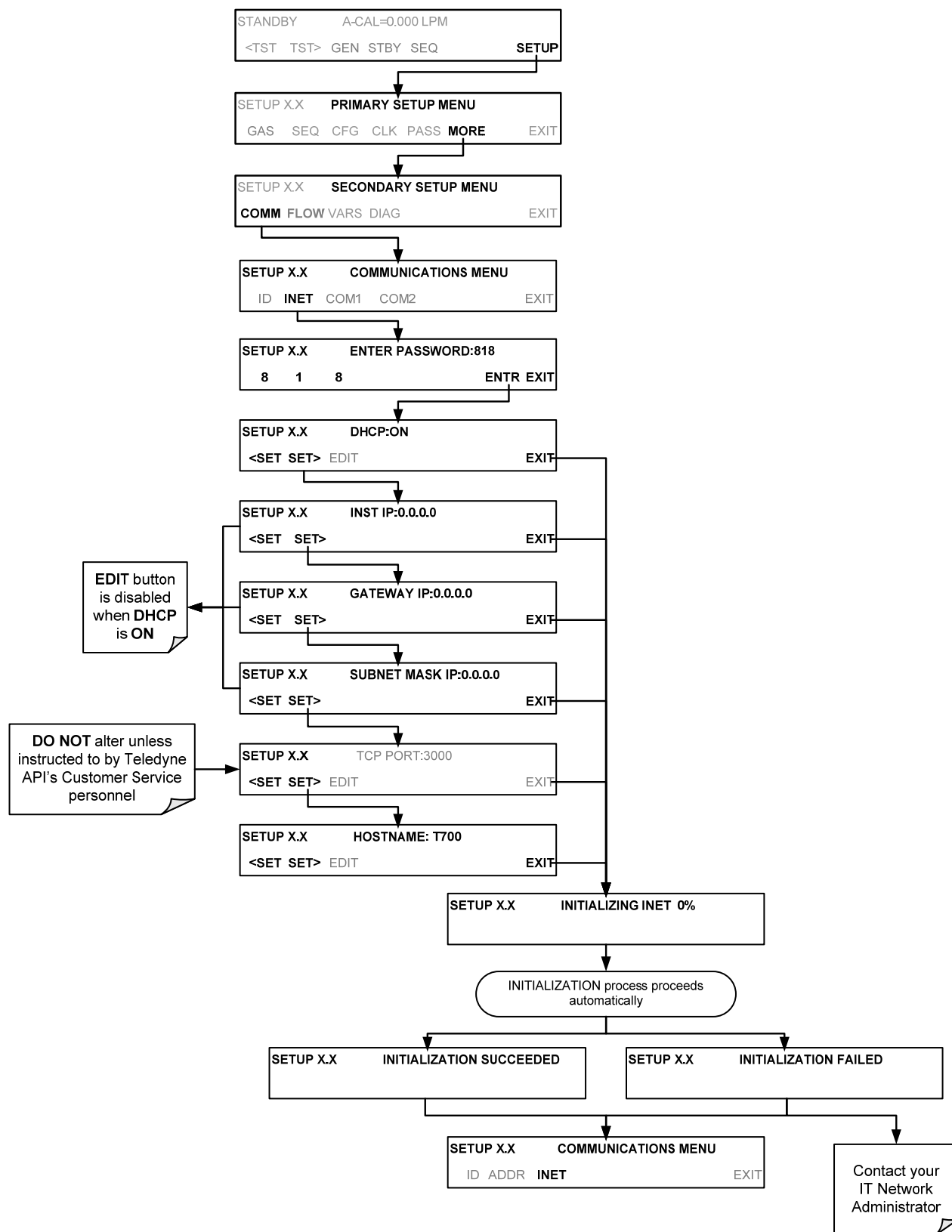
Table 5-3: LAN/Internet Configuration Properties

PROPERTY	DEFAULT STATE	DESCRIPTION
DHCP STATUS	On	This displays whether the DHCP is turned ON or OFF.
INSTRUMENT IP ADDRESS	0.0.0.0	This string of four packets of 1 to 3 numbers each (e.g. 192.168.76.55.) is the address of the calibrator itself.
GATEWAY IP ADDRESS	0.0.0.0	A string of numbers very similar to the Instrument IP address (e.g. 192.168.76.1.) that is the address of the computer used by your LAN to access the Internet.
SUBNET MASK	0.0.0.0	Also, a string of four packets of 1 to 3 numbers each (e.g. 255.255.252.0) that defines that identifies the LAN to which the device is connected. All addressable devices and computers on a LAN must have the same subnet mask. Any transmissions sent devices with different subnet masks are assumed to be outside of the LAN and are routed through a different gateway computer onto the Internet.
TCP PORT¹	3000	This number defines the terminal control port by which the instrument is addressed by terminal emulation software, such as Internet or Teledyne API's APICOM.
HOST NAME	T700	The name by which your calibrator will appear when addressed from other computers on the LAN or via the Internet. While the default setting for all Teledyne API's T700 calibrators is "T700", the host name may be changed to fit customer needs.
¹ Do not change the setting for this property unless instructed to by Teledyne API's Customer Service personnel.		

Note

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

To view the above properties listed in Table 5-3, press:

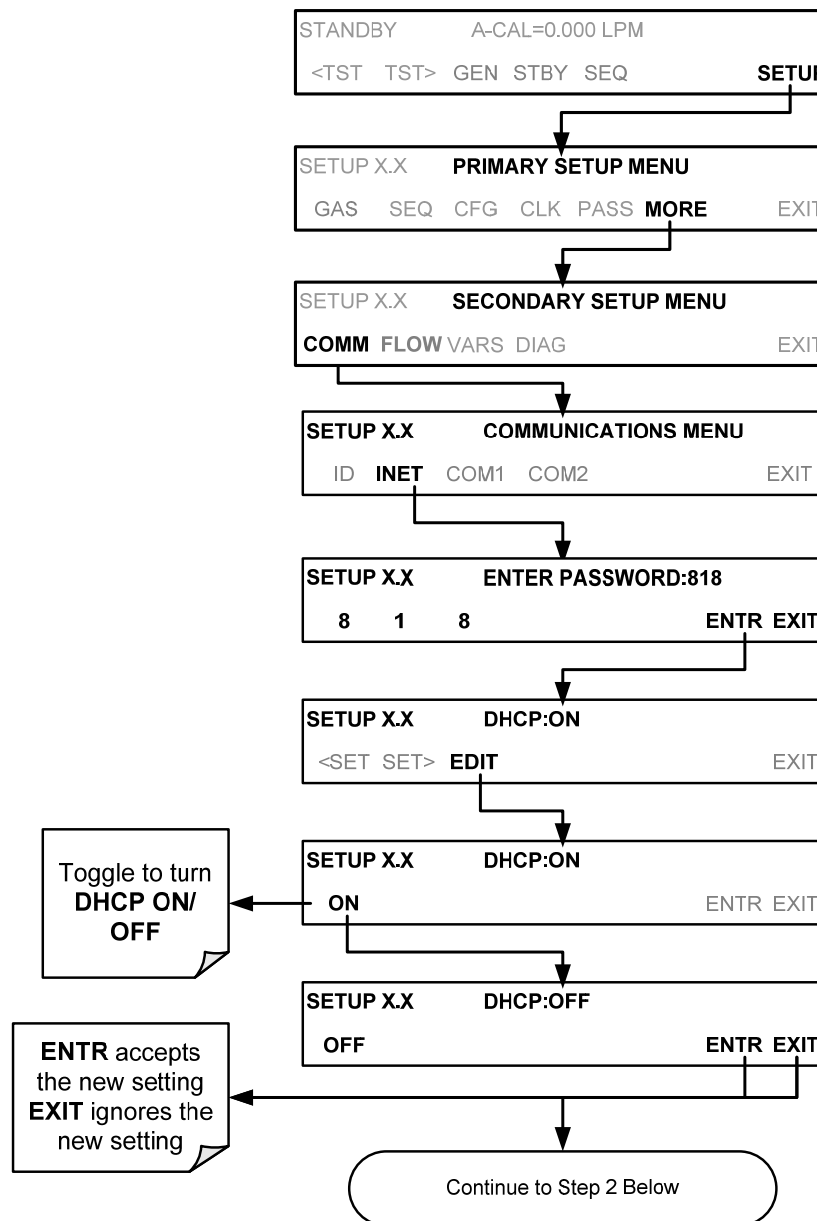


5.4.1.1. Manually Configuring the Network IP Addresses

There are several circumstances when you may need to manually set the Ethernet configuration:

- Your LAN is not running a DHCP software package,
- The DHCP software is unable to initialize the calibrator's interface;
- You wish to configure the interface with a specific IP address, such as for a permanent Ethernet connection..

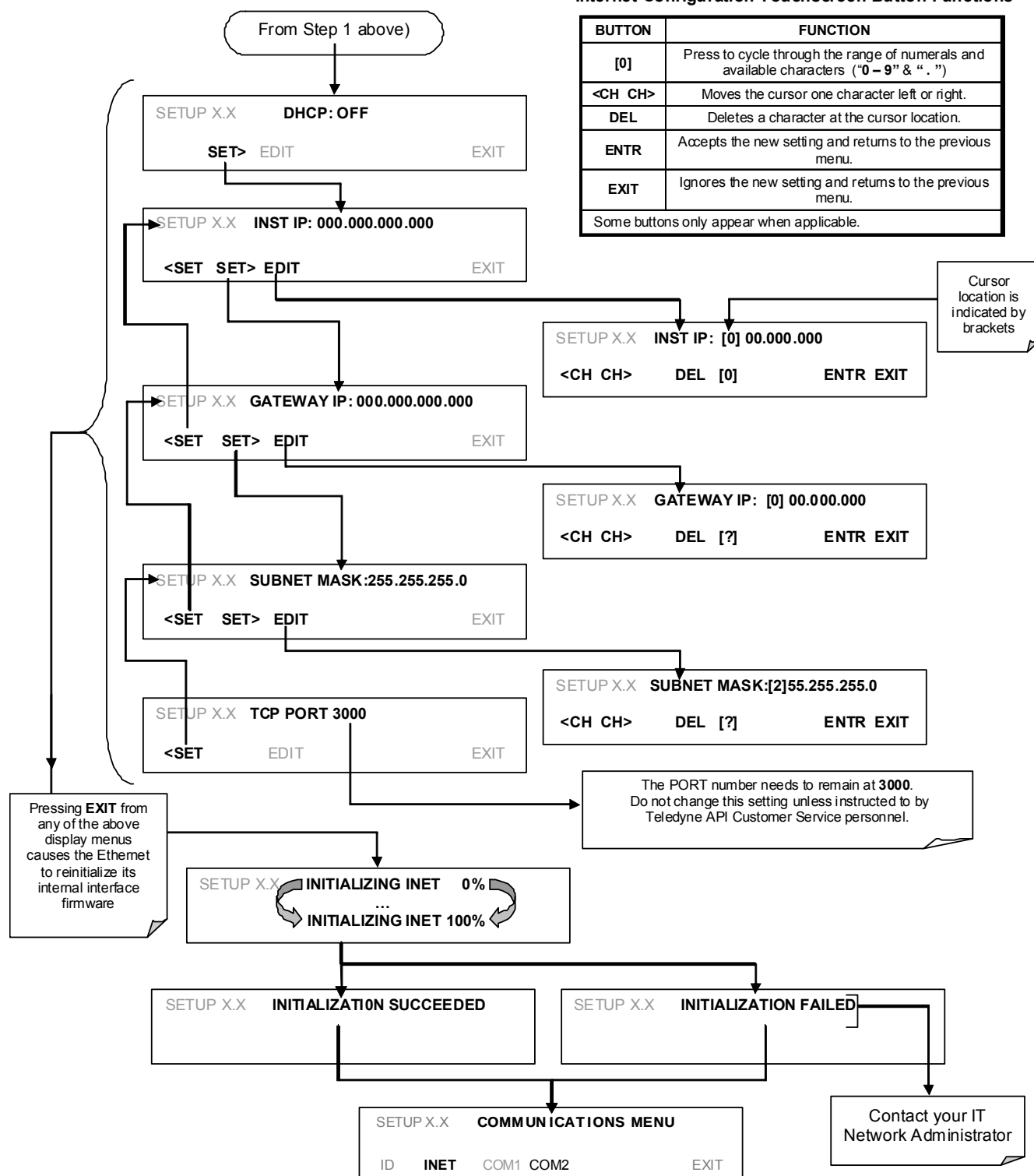
Manually configuring the Ethernet interface requires that you first turn DHCP to OFF before setting the **INSTRUMENT IP**, **GATEWAY IP** and **SUBNET MASK** parameters:



Internet Configuration Touchscreen Button Functions

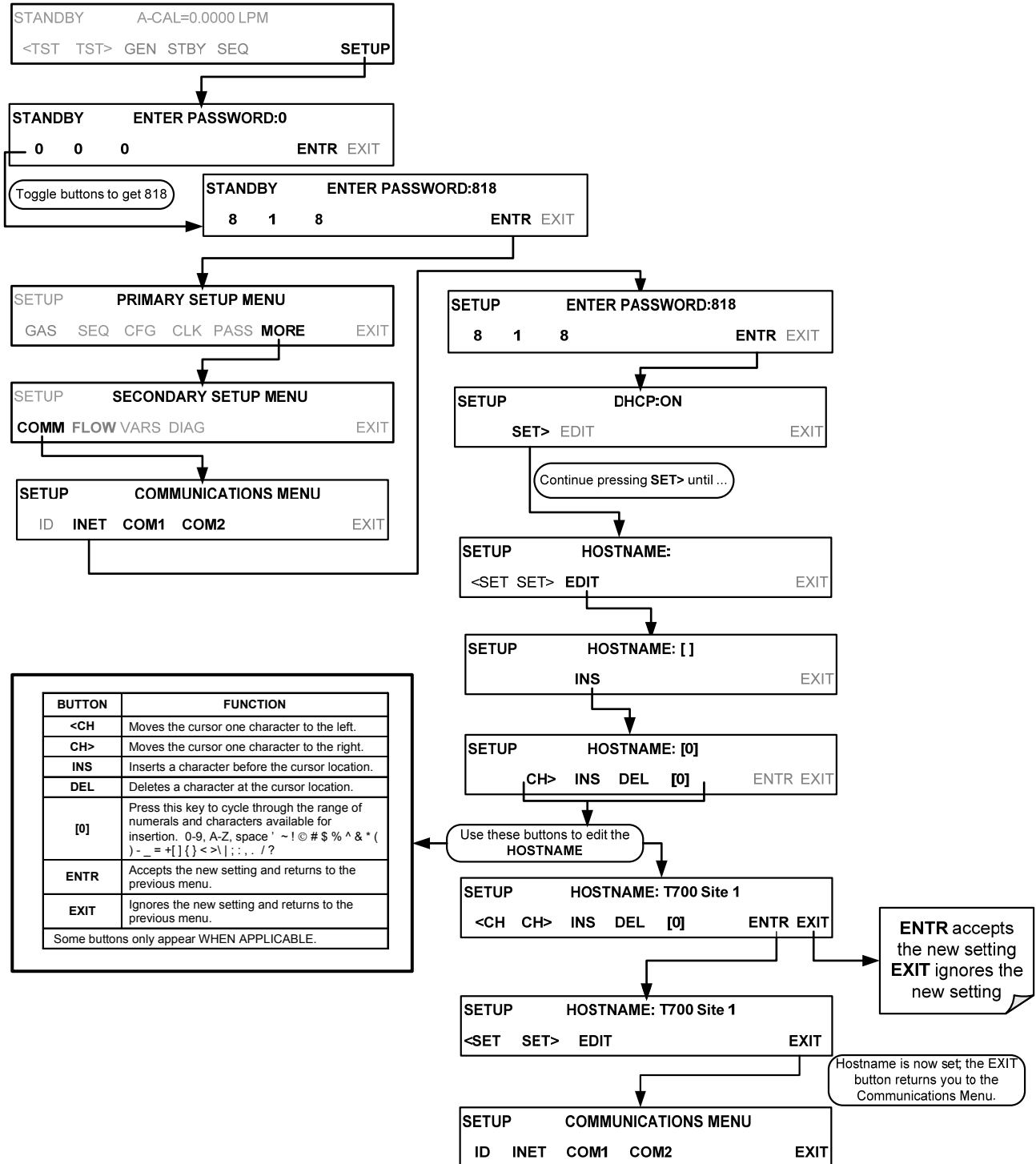
BUTTON	FUNCTION
[0]	Press to cycle through the range of numerals and available characters ("0–9" & ".")
<CH CH>	Moves the cursor one character left or right.
DEL	Deletes a character at the cursor location.
ENTR	Accepts the new setting and returns to the previous menu.
EXIT	Ignores the new setting and returns to the previous menu.

Some buttons only appear when applicable.



5.4.2. CHANGING THE CALIBRATOR'S HOSTNAME

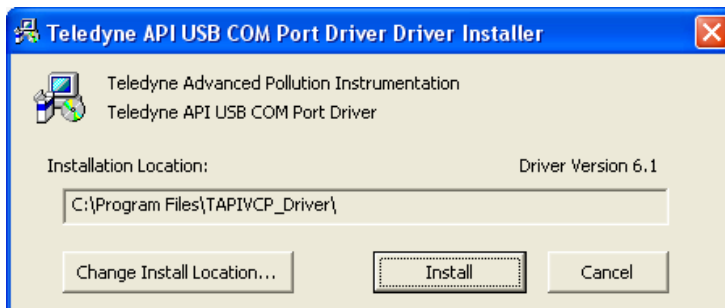
The **HOSTNAME** is the name by which the calibrator appears on your network. The default name for all Teledyne API's T700 calibrators is **T700**. To change this name (particularly if you have more than one T700 calibrator on your network), press.



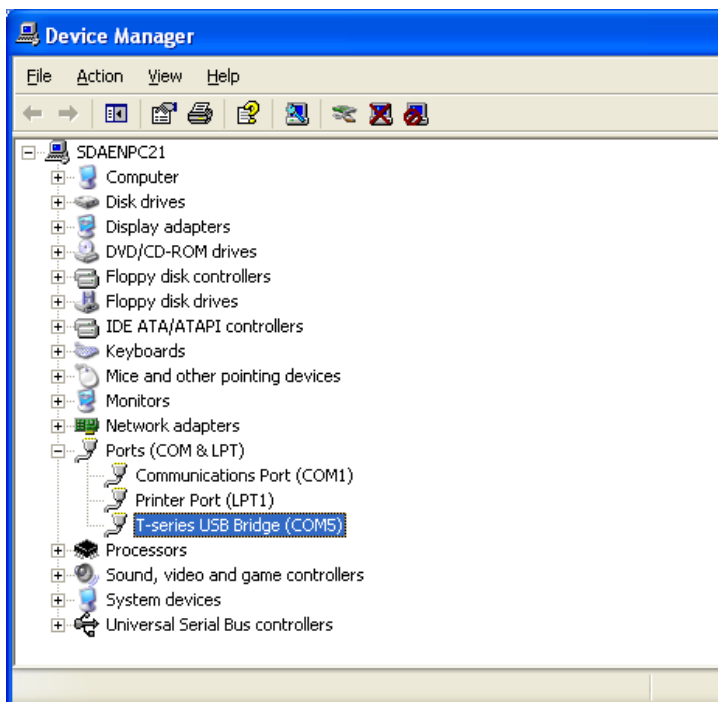
5.4.3. USB PORT (OPTION) FOR REMOTE ACCESS

The analyzer can be operated through a personal computer by downloading the TAPI USB driver and directly connecting their respective USB ports.

1. Install the Teledyne T-Series USB driver on your computer, downloadable from the Teledyne API website under Help Center>Software Downloads (www.teledyne-api.com/software).
2. Run the installer file: "TAPIVCPInstaller.exe"



3. Connect the USB cable between the USB ports on your personal computer and your analyzer. The USB cable should be a Type A – Type B cable, commonly used as a USB printer cable.
4. Determine the Windows XP Com Port number that was automatically assigned to the USB connection. (Start → Control Panel → System → Hardware → Device Manager). This is the com port that should be set in the communications software, such as APIcom or Hyperterminal.



Refer to the Quick Start (*Direct Cable Connection*) section of the Teledyne APIcom Manual, PN 07463.

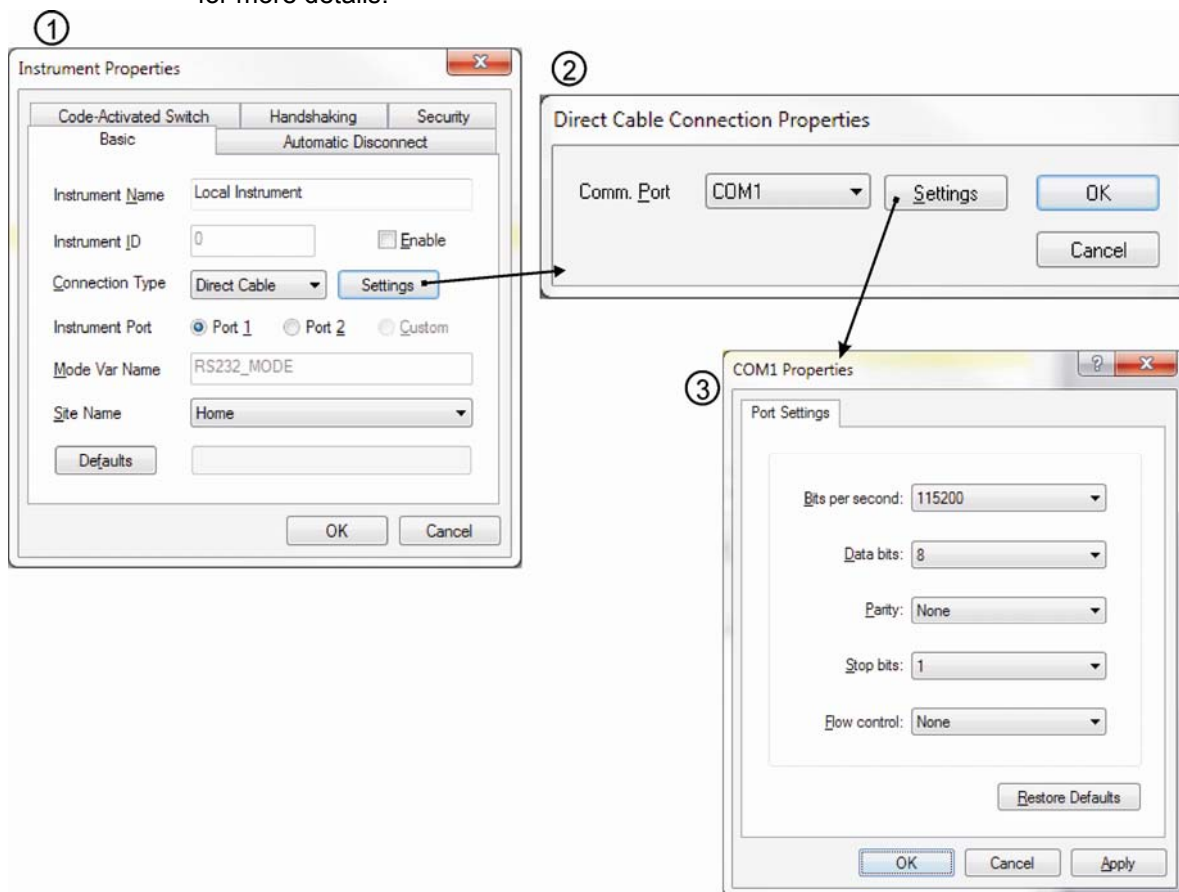
5. In the instrument's SETUP>MORE>COMM>COM2 menu, make the following settings:

Baud Rate: 115200

COM2 Mode Settings:

Quiet Mode	ON	Computer Mode	ON
MODBUS RTU	OFF	MODBUS ASCII	OFF
E,8,1 MODE	OFF	E,7,1 MODE	OFF
RS-485 MODE	OFF	SECURITY MODE	OFF
MULTIDROP MODE	OFF	ENABLE MODEM	OFF
ERROR CHECKING	ON	XON/XOFF HANDSHAKE	OFF
HARDWARE HANDSHAKE	OFF	HARDWARE FIFO	ON
COMMAND PROMPT	OFF		

6. Next, configure your communications software, such as APIcom. Use the COM port determined in Step 4 and the baud rate set in Step 5. The figures below show how these parameters would be configured in the Instrument Properties window in APIcom when configuring a new instrument. See the APIcom manual (PN 07463) for more details.



Note

- USB configuration requires that the baud rates of the instrument and the PC match; check the PC baud rate and change if needed.
- Using the USB port disallows use of the rear panel COM2 port except for multidrop communication.

6. REMOTE OPERATION

This section provides information needed when using external digital and serial I/O for remote operation. It assumes that the electrical connections have been made as described in Section 3.3.1.

The T700 can be remotely configured, calibrated or queried for stored data through the rear panel serial ports, via either **Computer mode** (using a personal computer with a dedicated interface program) or **Interactive mode** (using a terminal emulation program).

6.1. COMPUTER MODE

Computer mode is used when the analyzer is connected to a computer with a dedicated interface program such as APICOM.

6.1.1. REMOTE CONTROL VIA APICOM

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

- Establish a link from a remote location to the T700 through direct cable connection via RS-232 modem or Ethernet.
- View the instrument's front panel and remotely access all functions that could be accessed when standing in front of the instrument.
- Remotely edit system parameters and set points.
- Download, view, graph and save data for predictive diagnostics or data analysis.
- Check on system parameters for trouble-shooting and quality control.

APICOM is very helpful for initial setup, data analysis, maintenance and trouble-shooting. Figure 6-1 shows an example of APICOM's main interface, which emulates the look and functionality of the instrument's actual front panel. Refer to the APICOM manual available for download from <http://www.teledyne-api.com/software/apicom/>.

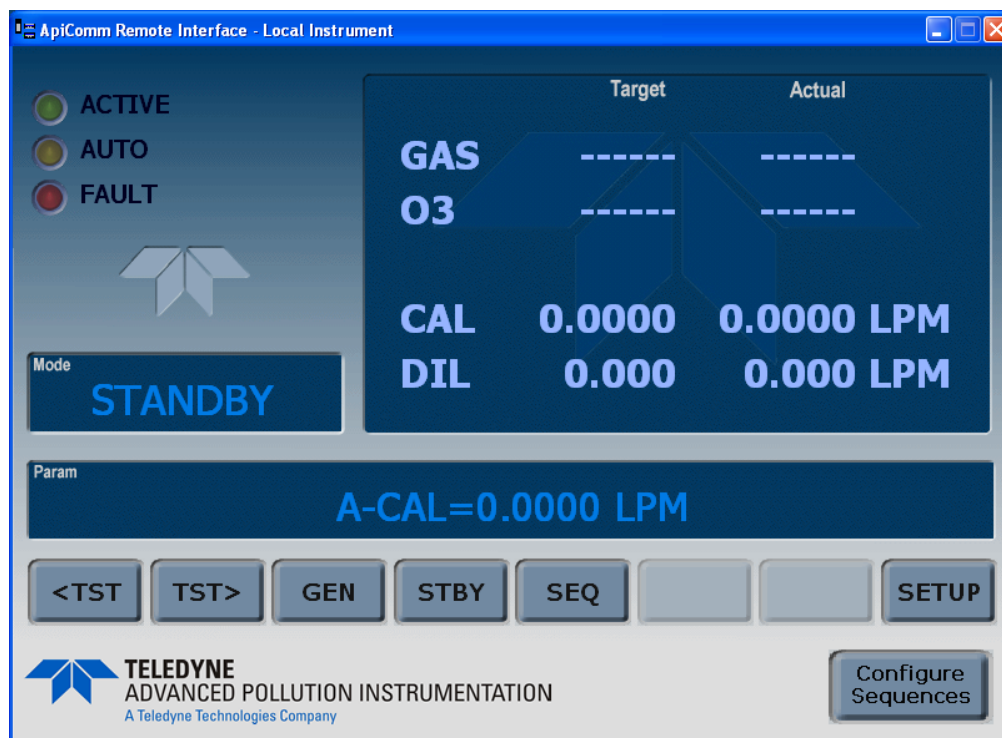


Figure 6-1: APICOM Remote Control Program Interface

6.2. INTERACTIVE MODE

Interactive mode is used with a terminal emulation programs or a “dumb” computer terminal.

6.2.1. REMOTE CONTROL VIA A TERMINAL EMULATION PROGRAM

Start a terminal emulation program such as HyperTerminal. All configuration commands must be created following a strict syntax or be pasted in from an existing text file, which was edited offline and then uploaded through a specific transfer procedure. The commands that are used to operate the analyzer in this mode are listed in Table 6-1.

6.2.1.1. Help Commands in Interactive Mode

Table 6-1: Terminal Mode Software Commands

COMMAND	Function
Control-T	Switches the calibrator to terminal mode (echo, edit). If mode flags 1 & 2 are OFF, the interface can be used in interactive mode with a terminal emulation program.
Control-C	Switches the calibrator to computer mode (no echo, no edit).
CR (carriage return)	A carriage return is required after each command line is typed into the terminal/computer. The command will not

COMMAND	Function
	be sent to the calibrator to be executed until this is done. On personal computers, this is achieved by pressing the ENTER button.
BS (backspace)	Erases one character to the left of the cursor location.
ESC (escape)	Erases the entire command line.
? [ID] CR	This command prints a complete list of available commands along with the definitions of their functionality to the display device of the terminal or computer being used. The ID number of the calibrator is only necessary if multiple calibrators are on the same communications line, such as the multi-drop setup.
Control-C	Pauses the listing of commands.
Control-P	Restarts the listing of commands.

6.2.1.2. Command Syntax

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

All Commands follow the syntax:

X [ID] COMMAND <CR>

Where

X is the command type (one letter) that defines the type of command. Allowed designators are listed in Table 6-2 and Appendix A-6.

[ID] is the machine identification number (Section 4.7.1). Example: the Command “? 700” followed by a carriage return would print the list of available commands for the revision of software currently installed in the instrument assigned ID Number 700.

COMMAND is the command designator: This string is the name of the command being issued (LIST, ABORT, NAME, EXIT, etc.). Some commands may have additional arguments that define how the command is to be executed. Press ? <CR> or refer to Appendix A-6 for a list of available command designators.

<CR> is a carriage return. All commands must be terminated by a carriage return (usually achieved by pressing the ENTER button on a computer).

Table 6-2: Teledyne API Serial I/O Command Types

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

6.2.1.3. Data Types

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

- Integer data are used to indicate integral quantities such as a number of records, a filter length, etc. They consist of an optional plus or minus sign, followed by one or more digits. For example, +1, -12, 123 are all valid integers.
- Hexadecimal integer data are used for the same purposes as integers. They consist of the two characters "0x," followed by one or more hexadecimal digits (0-9, A-F, a-f), which is the 'C' programming language convention. No plus or minus sign is permitted. For example, 0x1, 0x12, 0x1234abcd are all valid hexadecimal integers.
- Floating-point numbers are used to specify continuously variable values such as temperature set points, time intervals, warning limits, voltages, etc. They consist of an optional plus or minus sign, followed by zero or more digits, an optional decimal point and zero or more digits. (At least one digit must appear before or after the decimal point.) Scientific notation is not permitted. For example, +1.0, 1234.5678, -0.1, 1 are all valid floating-point numbers.
- Boolean expressions are used to specify the value of variables or I/O signals that may assume only two values. They are denoted by the keywords ON and OFF.
- Text strings are used to represent data that cannot be easily represented by other data types, such as data channel names, which may contain letters and numbers. They consist of a quotation mark, followed by one or more printable characters, including spaces, letters, numbers, and symbols, and a final quotation mark. For example, "a", "1", "123abc", and "()/<>" are all valid text strings. It is not possible to include a quotation mark character within a text string.
- Some commands allow you to access variables, messages, and other items. When using these commands, you must type the entire name of the item; you cannot abbreviate any names.

6.2.1.4. Status Reporting

Reporting of status messages as an audit trail is one of the three principal uses for the RS-232 interface (the other two being the command line interface for controlling the instrument and the download of data in electronic format). You can effectively disable the reporting feature by setting the interface to quiet mode (Section 5.2.1, Table 5-1).

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

6.2.1.5. General Message Format

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

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

Where:

X	is a command type designator, a single character indicating the message type, as shown in the Table 6-2.
DDD:HH:MM	is the time stamp, the date and time when the message was issued. It consists of the Day-of-year (DDD) as a number from 1 to 366, the hour of the day (HH) as a number from 00 to 23, and the minute (MM) as a number from 00 to 59.
[ID]	is the calibrator ID, a number with 1 to 4 digits.
MESSAGE	is the message content that may contain warning messages, test measurements, variable values, etc.
<CRLF>	is a carriage return / line feed pair, which terminates the message.

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

6.3. REMOTE ACCESS BY MODEM

The T700 can be connected to a modem for remote access. This requires a cable between the calibrator's COMM port and the modem, typically a DB-9F to DB-25M cable (available from Teledyne API with P/N WR0000024).

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

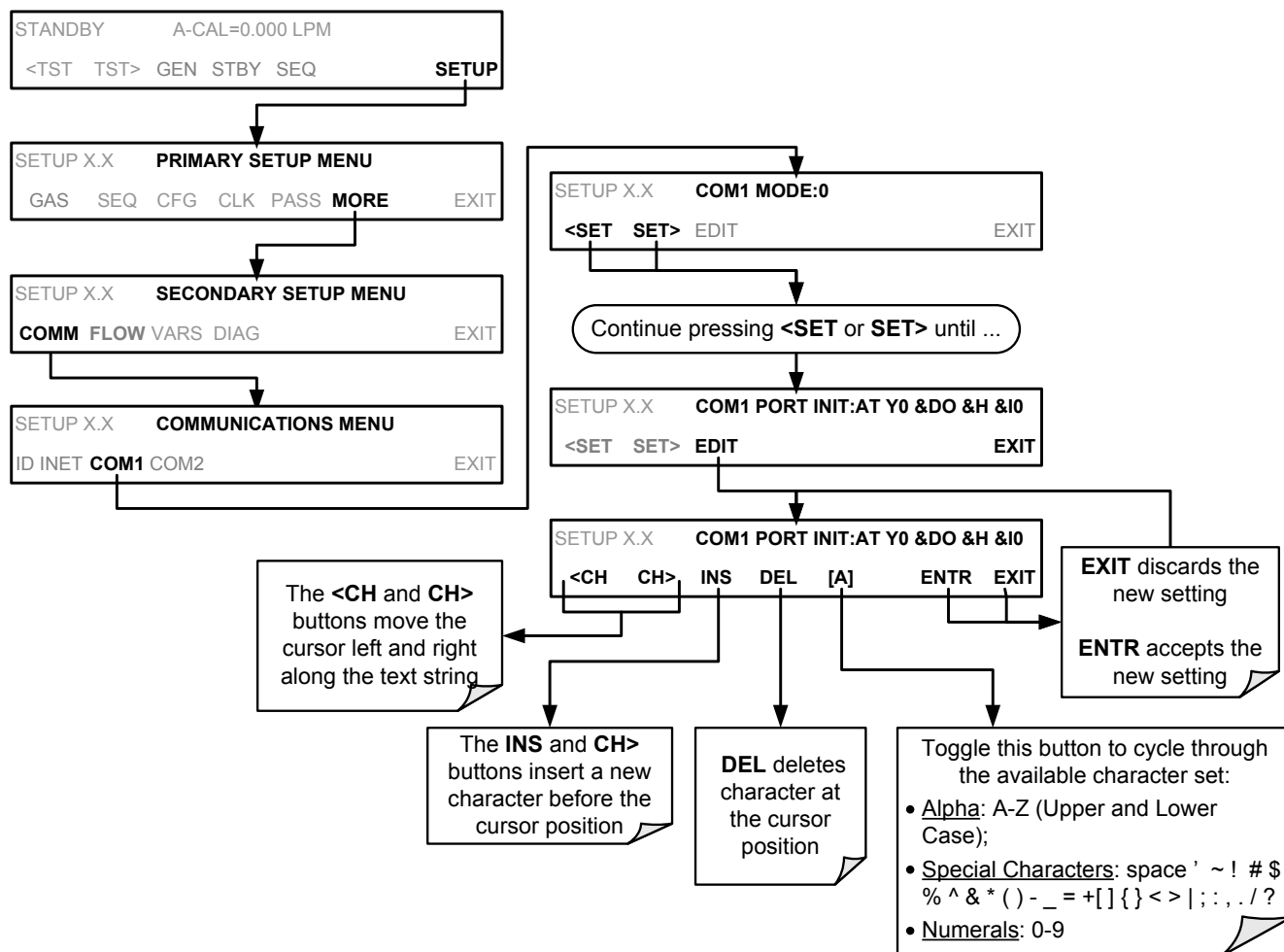
- The DTE-DCE is in the DCE position.
- The T700 COMM port is set for a baud rate that is compatible with the modem.
- The Modem is designed to operate with an 8-bit word length with one stop bit.
- The **MODEM ENABLE** communication mode is turned **ON** (Mode 64, see Section 5.2.1).

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

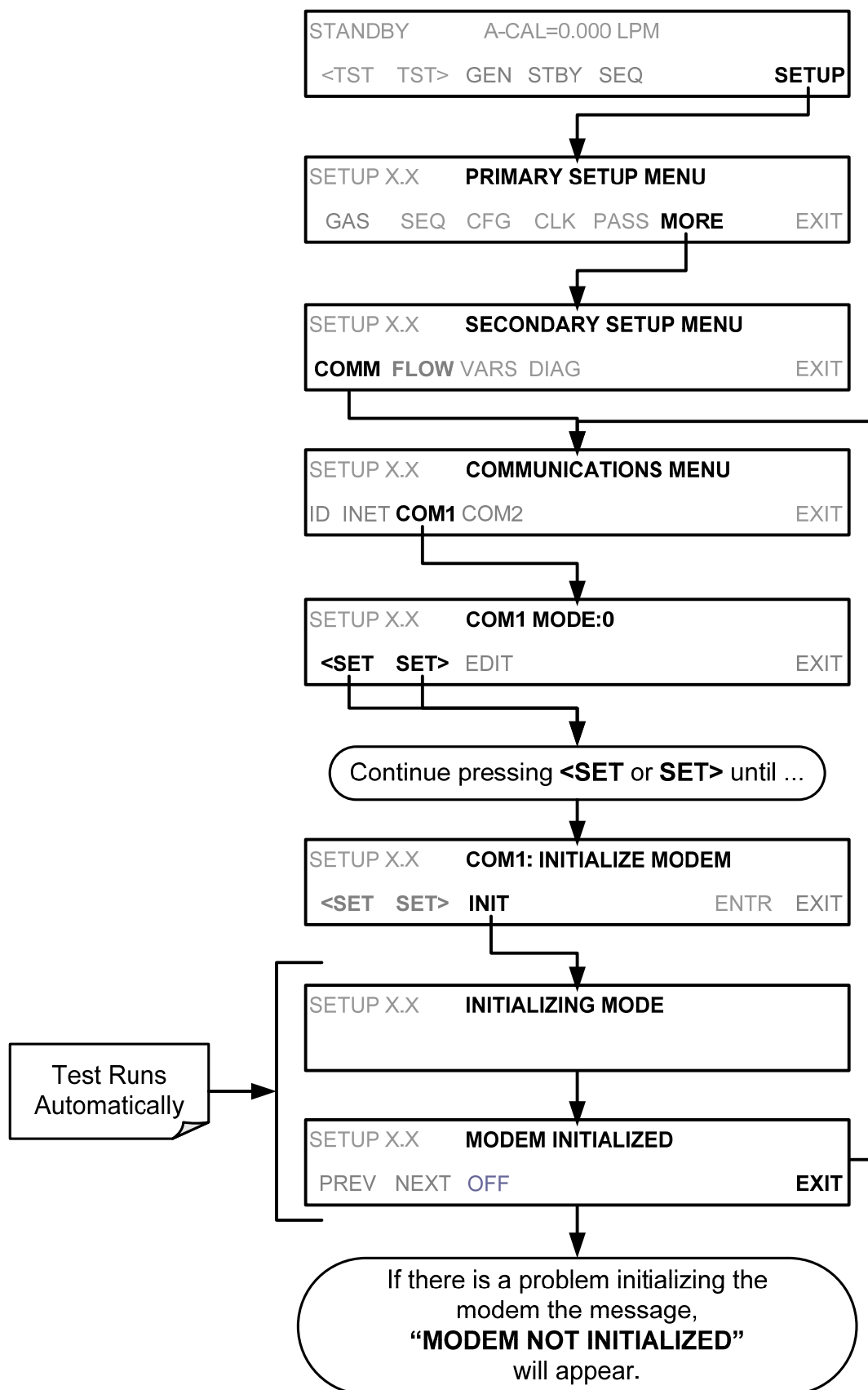
AT Y0 &D0 &H0 &I0 S0=2 &B0 &N6 &M0 E0 Q1 &W0

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

To change this setting, press:



To initialize the modem, press:



6.4. PASSWORD SECURITY FOR SERIAL REMOTE COMMUNICATIONS

In order to provide security for remote access of the T700, a LOGON feature can be enabled to require a password before the instrument will accept commands. This is done by turning on the **SECURITY MODE** (Mode 4, Section 5.2.1). Once the **SECURITY MODE** is enabled, the following items apply.

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

To log on to the T700 calibrator with **SECURITY MODE** feature enabled, type:

LOGON 940331

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

V RS232_PASS=NNNNNN

Where N is any numeral between 0 and 9.

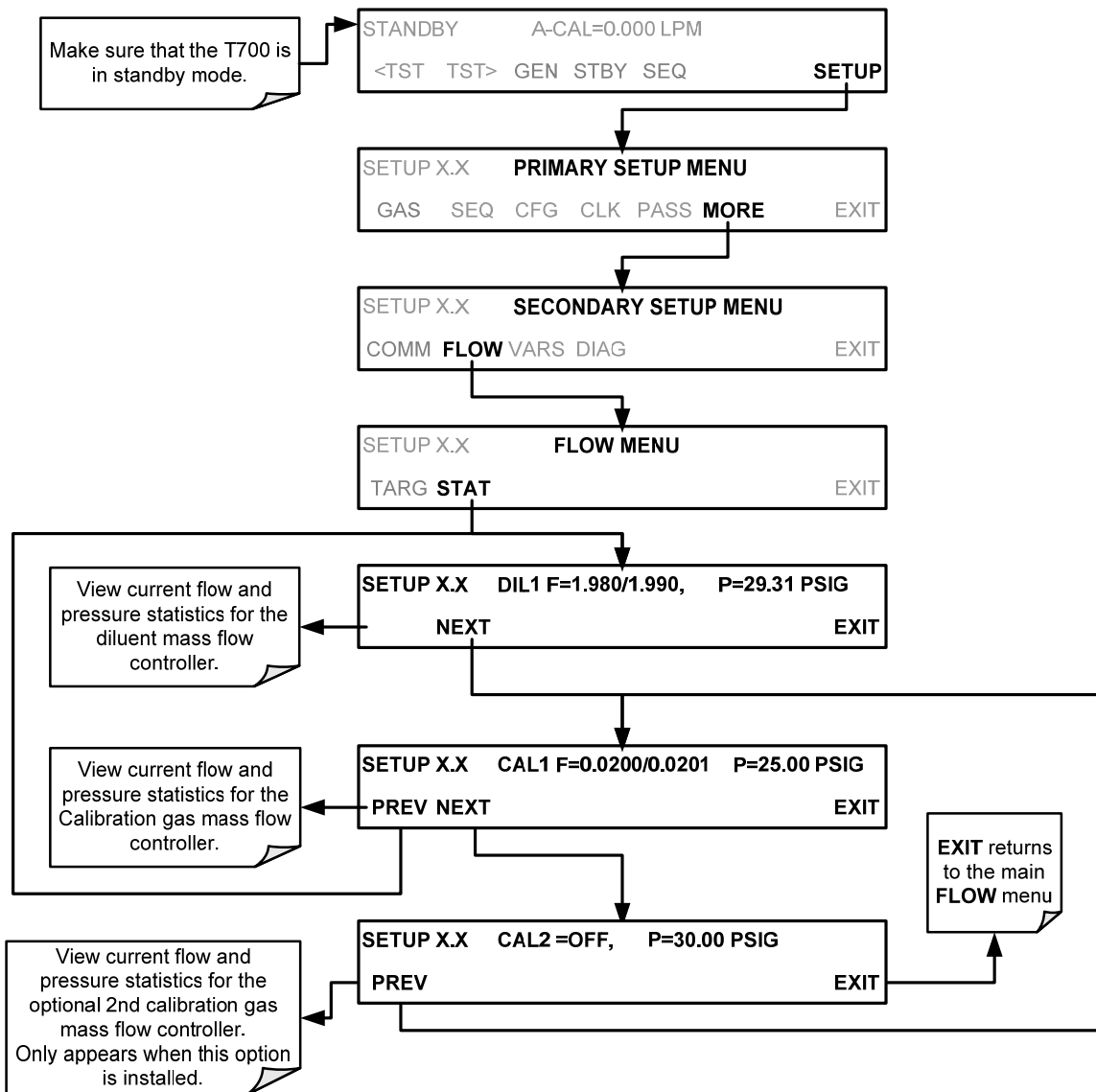
7. CALIBRATION AND VERIFICATION

Basic electronic calibration of the T700 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 if necessary adjusted. 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 Sections 7.1 and 7.2).
- O₃ Photometer: If your T700 is equipped with the optional O₃ photometer its performance should be periodically verified against an external transfer standard (see Section 7.3).
- O₃ Generator: If your T700 is equipped with the optional O₃ generator, it should be periodically calibrated (see Section 7.4).

7.1. VIEWING THE PERFORMANCE STATISTICS FOR THE T700'S MFC'S

It is possible to view the target flow rate, actual flow rate and actual gas pressure for each MFC via the **FLOW** submenu in the T700 calibrator (in real time). To access this information, press:



In the displays associated with the **FLOW → STAT** submenu:

- The numbers after “F=” are the flow.
 - The first number is the target flow.
 - The second is the actual flow.
- The number after “P=” is pressure in PSIG.
- If an MFC is off, its flows are displayed as OFF.

7.2. CALIBRATING THE OUTPUT OF THE T700'S MFC'S

A table exists in the memory of the T700's for each MFC that sets the output of the MFC at each of 20 equally spaced control points along its entire performance range. This table may be accessed via the **DIAG → MFC CONFIGURATION** submenu (see Section 7.2.2).

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 to 1/20th 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 7.2.2).

Table 7-1: 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

7.2.1. SETUP FOR VERIFICATION AND CALIBRATION OF THE T700'S MFC'S

Note

A separate flow meter is required for the procedure.

1. Turn off the T700 Dynamic Dilution Calibrator.
2. Open the front panel to the T700 calibrator. This is the easiest access to the MFC output ports.
 - A locking screw located at the top center of the front panel (See Figure 3-1) must be removed before the panel can be opened.
3. Attach the flow meter directly to the output port of the MFC to be checked/tested.

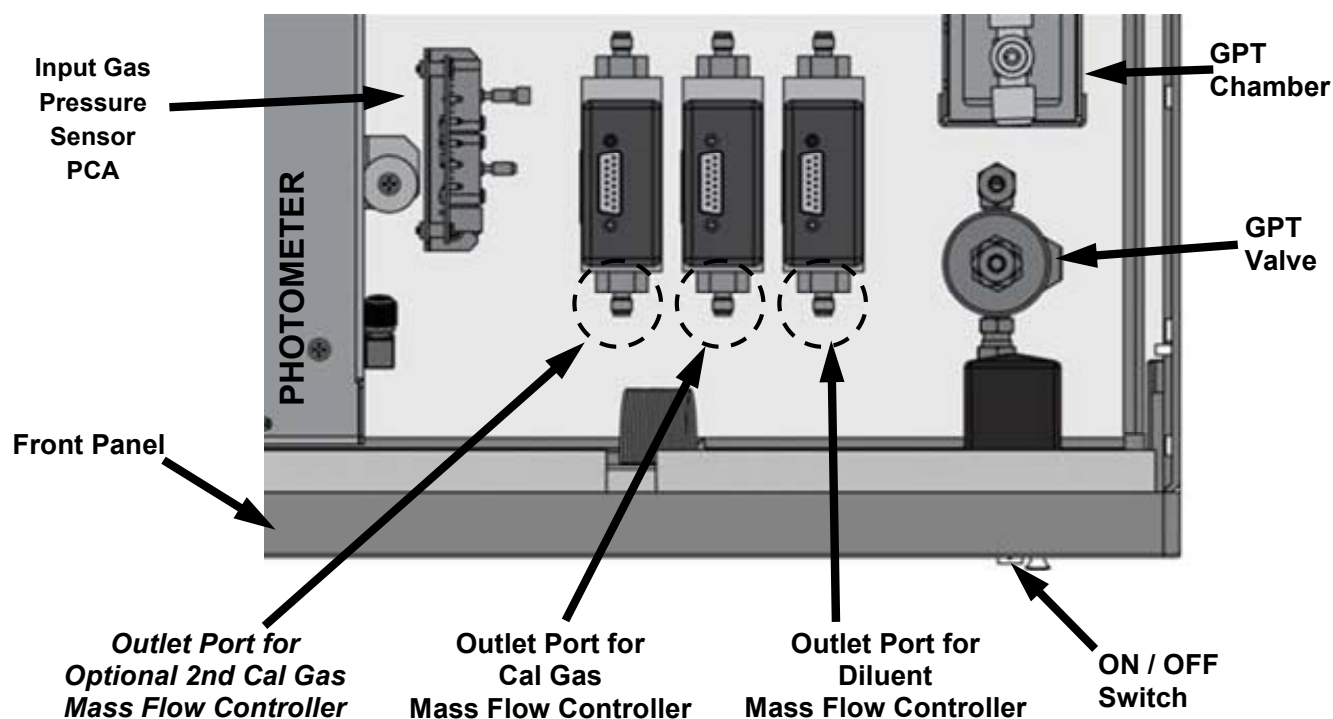
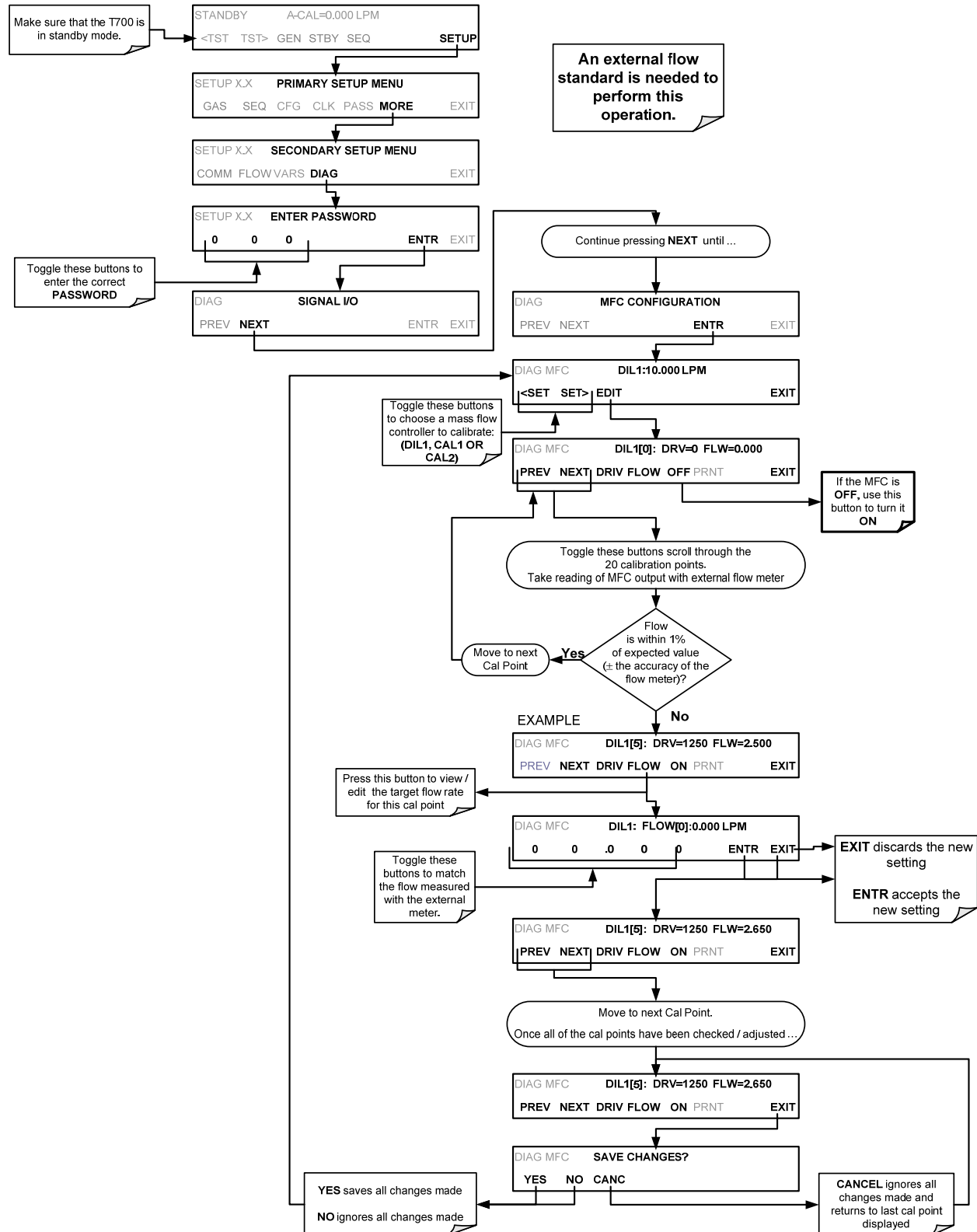


Figure 7-1: Location of MFC Outlet Ports

4. Turn the T700 Dynamic Dilution Calibrator ON.

7.2.2. VERIFYING AND CALIBRATING THE T700'S MFC'S

Once the external flow meter is connected to the output of the MFC being verified/calibrated, perform the following steps:



7.3. VERIFYING AND CALIBRATING THE T700'S OPTIONAL O₃ PHOTOMETER

For calibrators equipped with the O₃ photometer, the accuracy of calibration mixtures involving O₃ produced by the T700 depends entirely on the accuracy of the photometer, therefore it is very important that the photometer is operating properly and accurately. Setup for Verifying O₃ Photometer Performance is shown in Section 7.3.1.

7.3.1. SETUP FOR VERIFYING O₃ PHOTOMETER PERFORMANCE

Note

This operation requires an external reference photometer.

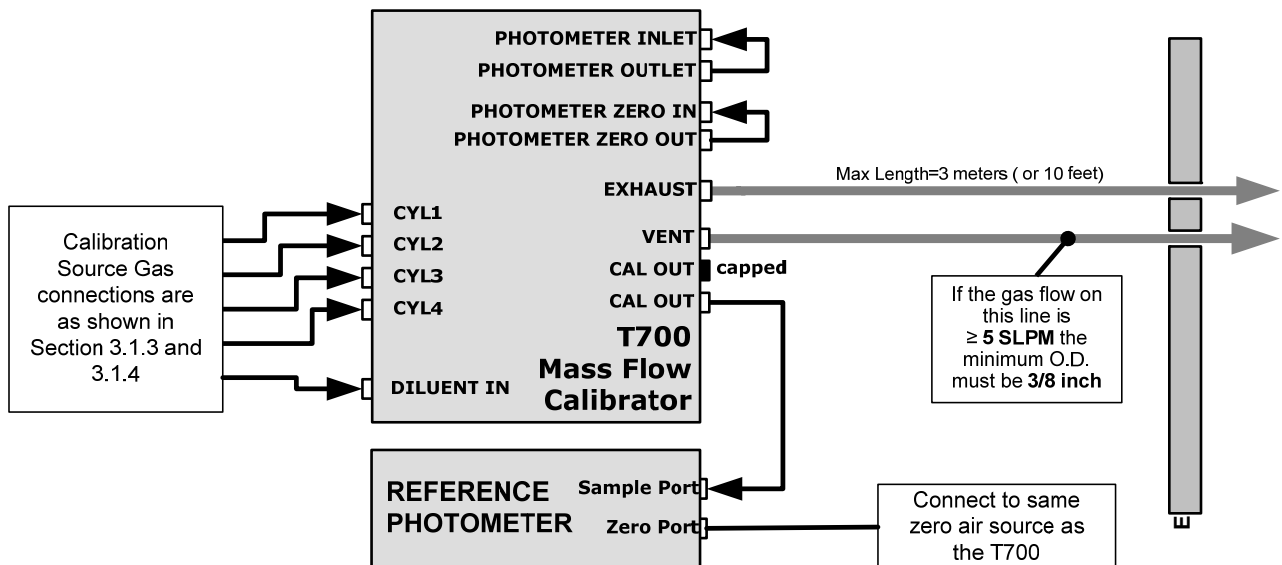
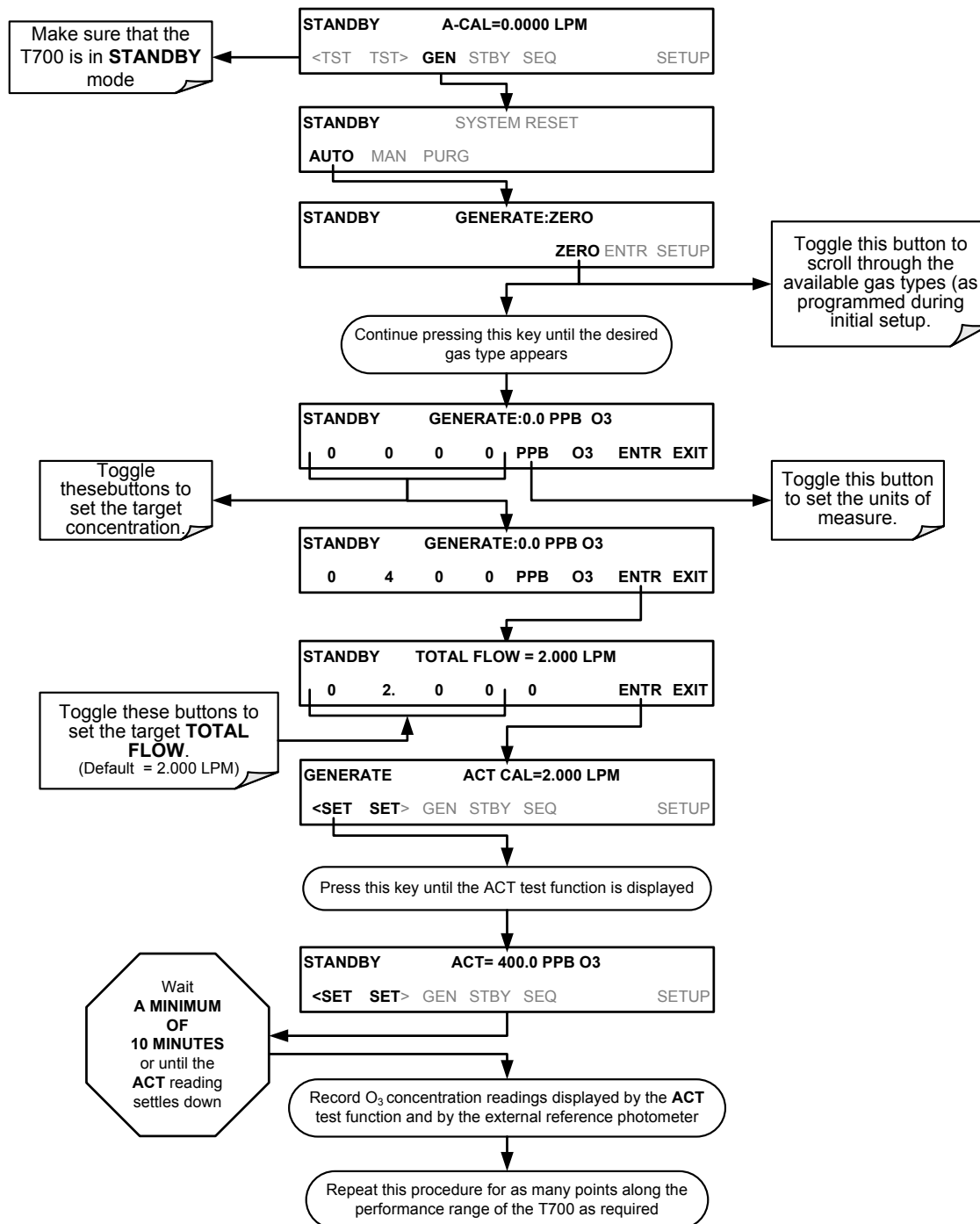


Figure 7-2: Set up for Verifying Optional O₃ Photometer

7.3.2. VERIFYING O₃ PHOTOMETER PERFORMANCE

To verify the performance of the T700's optional internal photometer perform the following steps:



Note

The readings recorded from the T700's ACT test function and the reference photometer should be within 1% of each other.

7.3.3. SETUP FOR CALIBRATION OF THE O₃ PHOTOMETER

Note

This procedure requires external sources for zero air and O₃ as an external reference photometer.

Calibrating the T700 calibrator's 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 T700 calibrator: either with direct connections or calibration manifolds

7.3.3.1. Setup Using Direct Connections

Figure 7-3 shows the external zero air and O₃ sources as well as the reference photometer connected directly to the fixtures on the back of the T700 Calibrator.

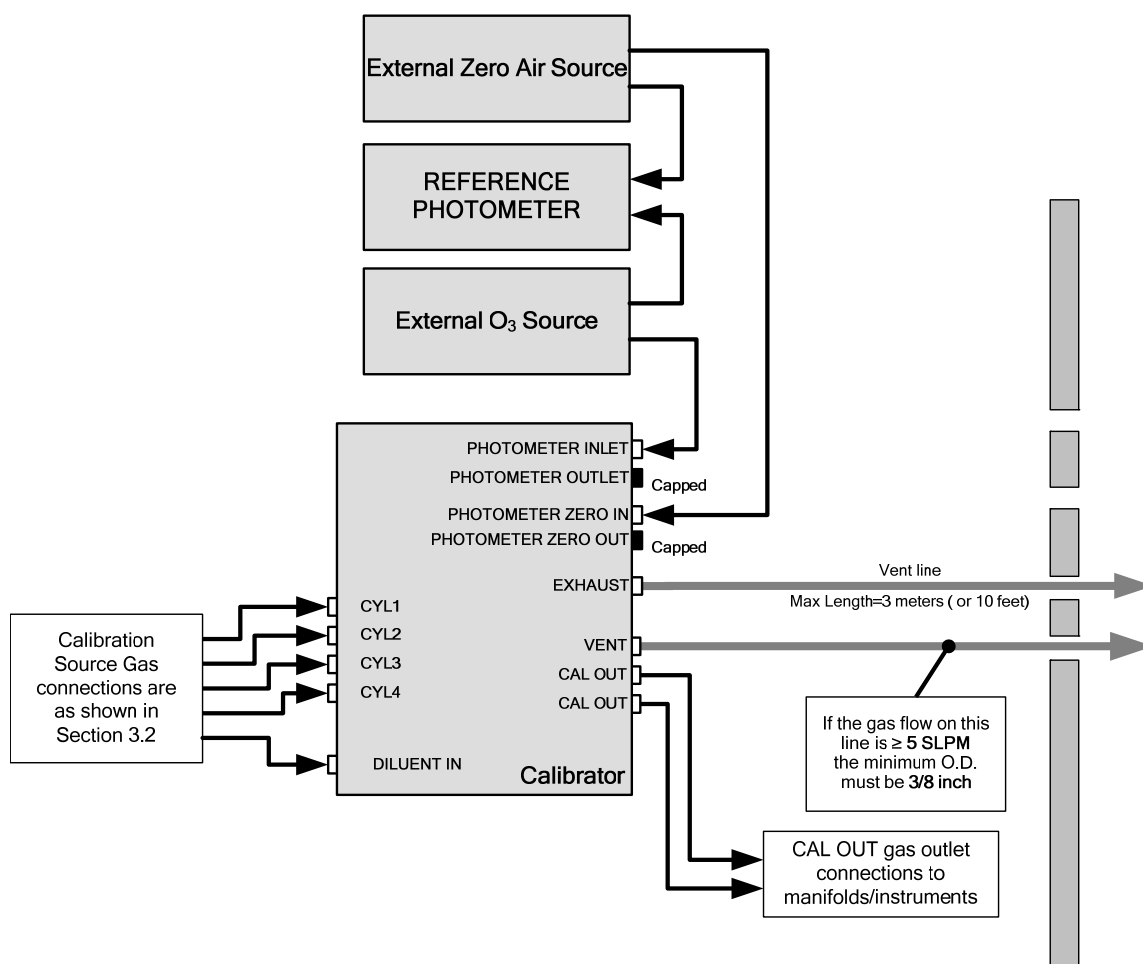


Figure 7-3: External Photometer Validation Setup – Direct Connections

Note

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

7.3.3.2. Setup Using a Calibration Manifold

Figure 7-4 shows the external zero air and O₃ sources as well as the reference photometer connected to the T700 Calibrator via calibration manifolds for both zero air and O₃.

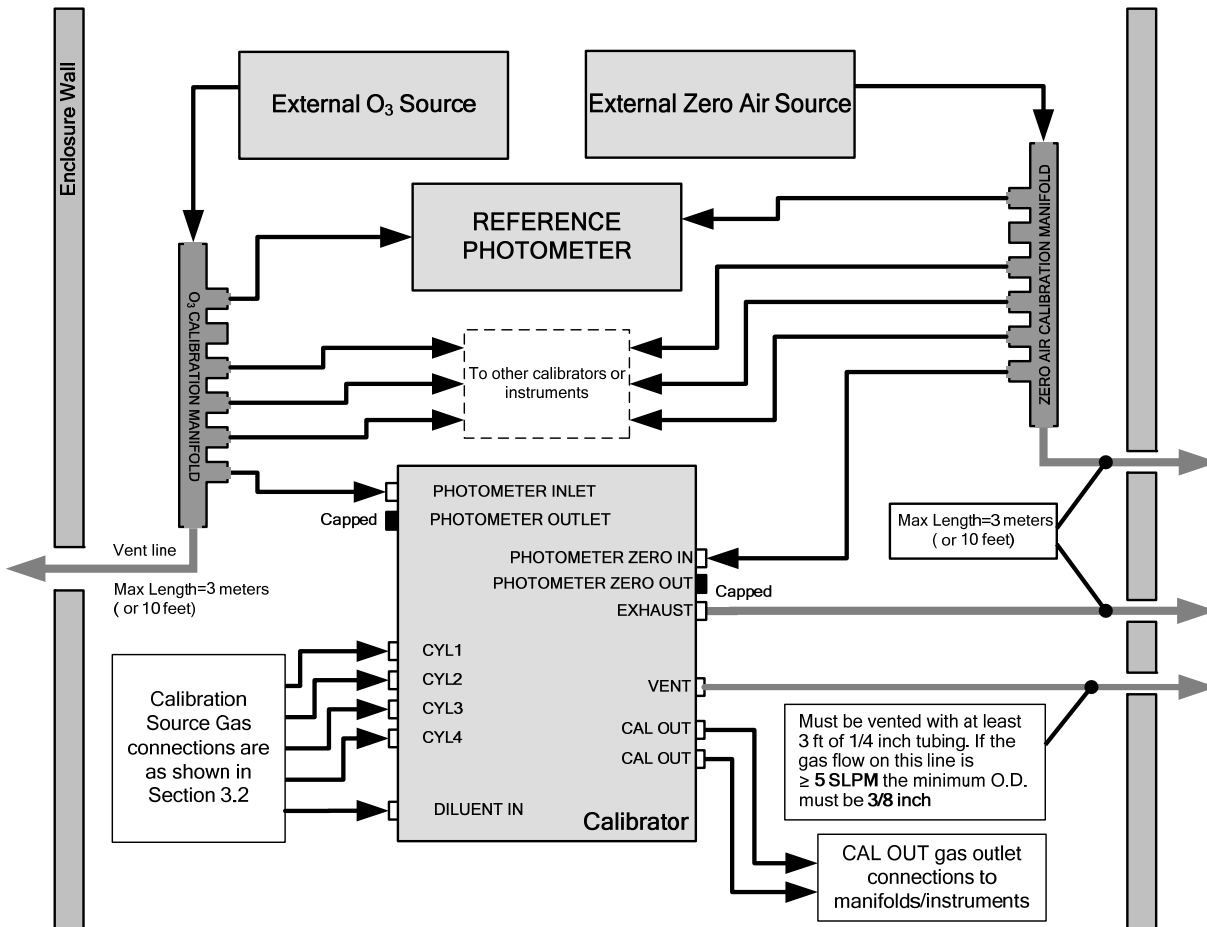


Figure 7-4: External Photometer Validation Setup with Calibration Manifolds

Note

The manifolds as shown in the above drawing 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.

7.3.3.3. Calibration Manifold Exhaust/Vent Line

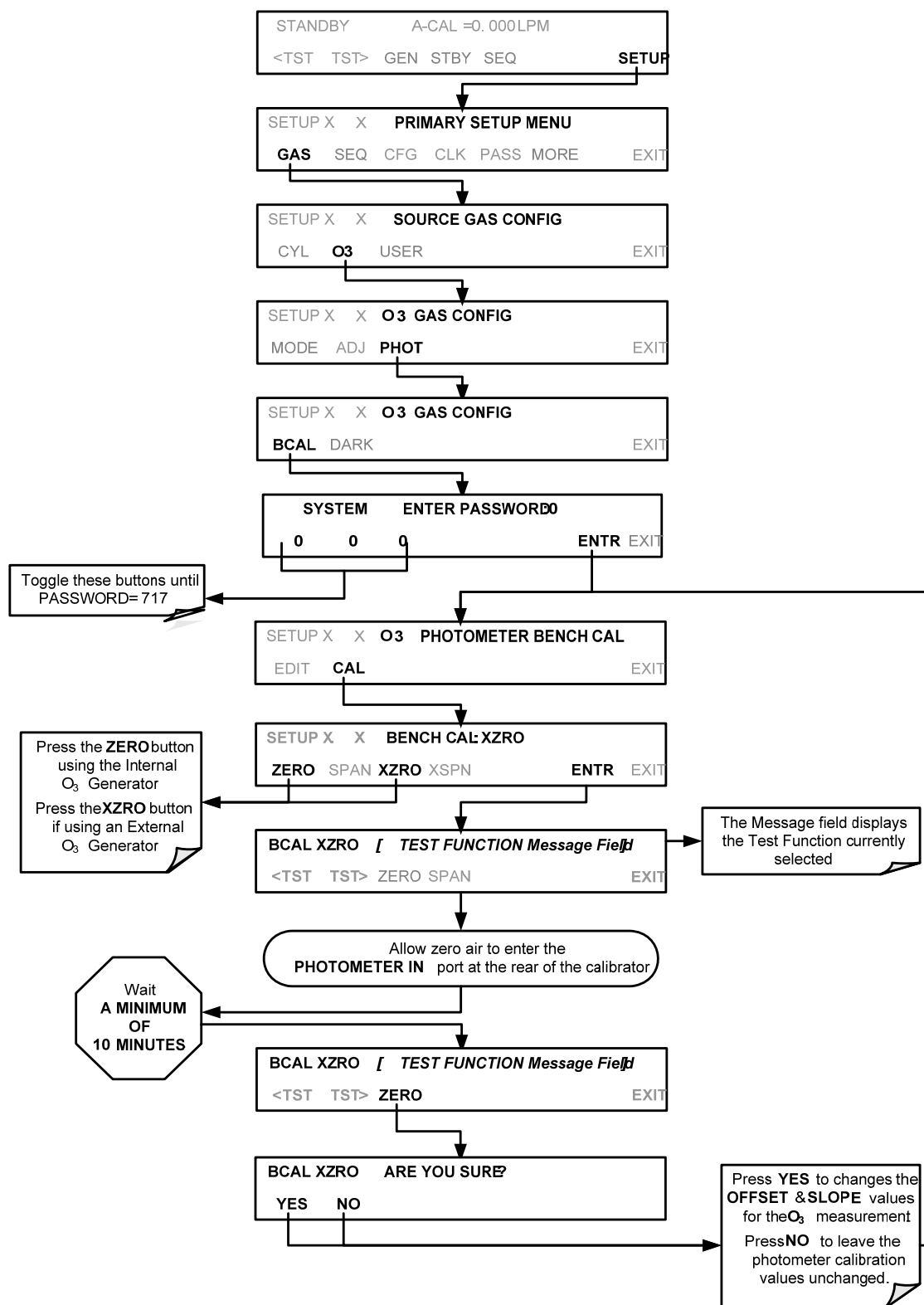
The manifold's excess gas should be vented to a suitable vent outside of the room. The internal diameter of this vent should be large enough to avoid any appreciable pressure drop, and it must be located sufficiently downstream of the output ports to ensure that no ambient air enters the manifold due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

7.3.4. PERFORMING AN O₃ PHOTOMETER EXTERNAL CALIBRATION

The following procedure sets values held in the calibrator's memory for zero point **OFFSET** and **SLOPE**.

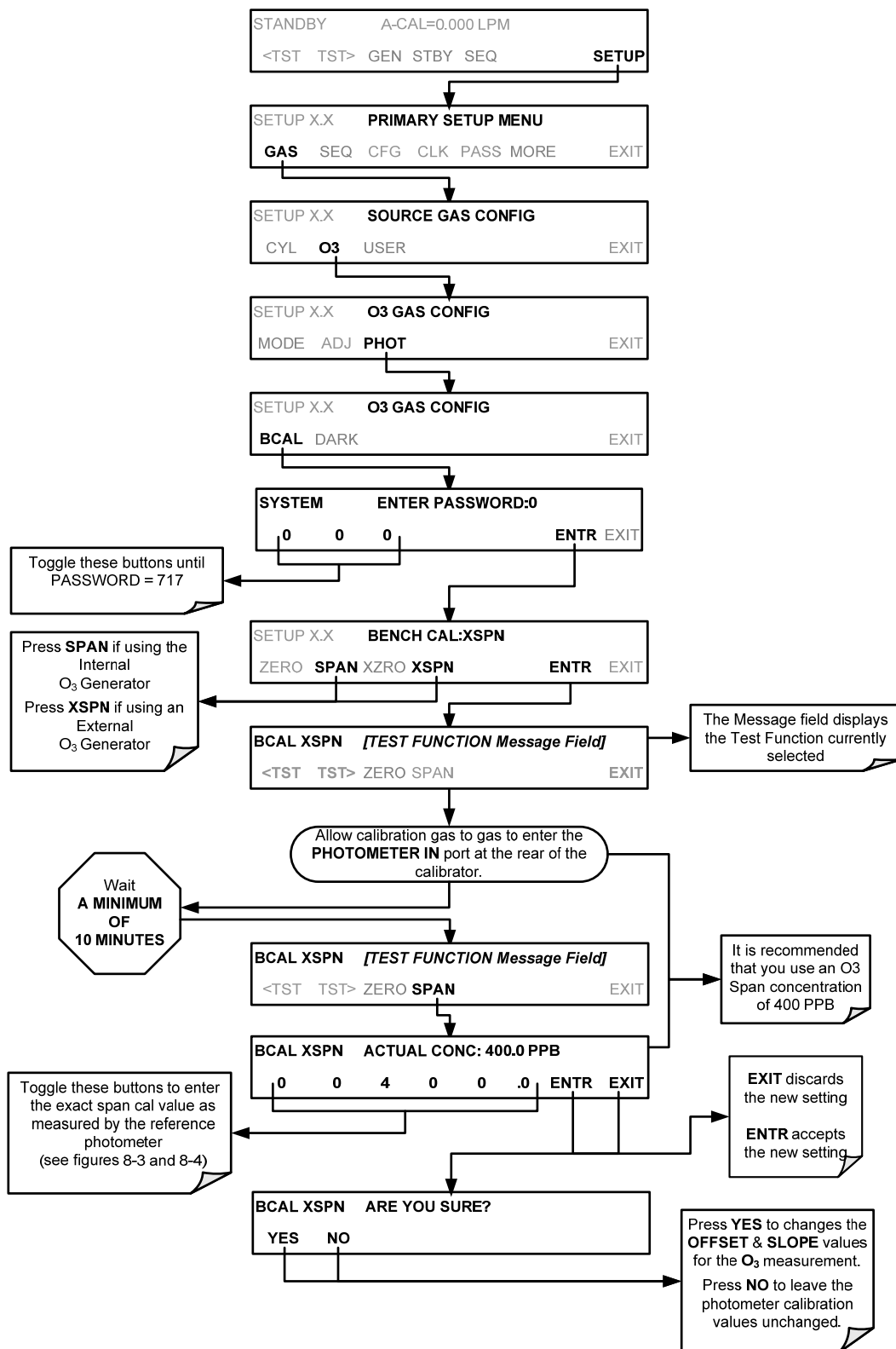
7.3.4.1. Photometer Zero Calibration

To set the zero point offset for the T700 Dynamic Dilution Calibrator's photometer, press:



7.3.4.2. Photometer Span Calibration

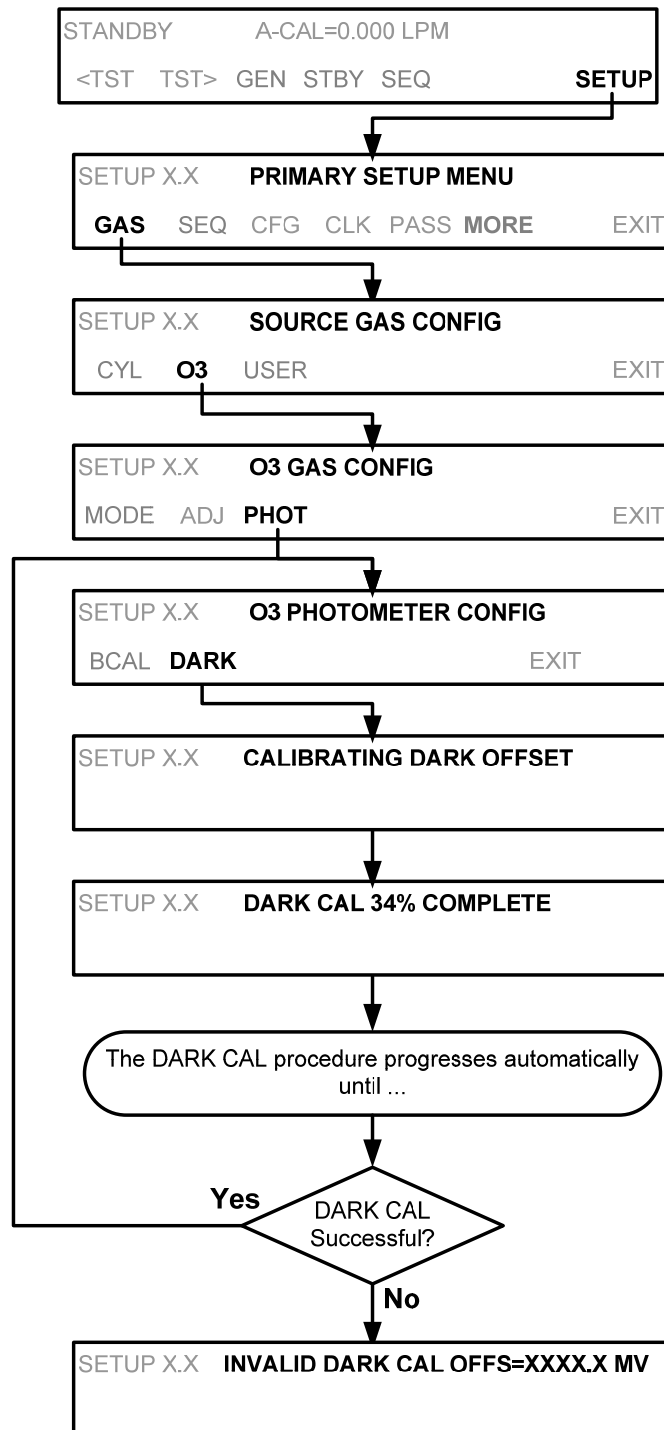
To set the response SLOPE for the T700 Dynamic Dilution Calibrator's photometer, press:



7.3.5. O₃ PHOTOMETER DARK CALIBRATION

The Dark Calibration Test turns off the Photometer UV Lamp and records any offset signal level of the UV Detector-Preamplifier-Voltage to Frequency Converter circuitry. This allows the instrument to compensate for any voltage levels inherent in the Photometer detection circuit that might affect the output of the detector circuitry and therefore the calculation of O₃ concentration.

To activate the Dark Calibration feature:



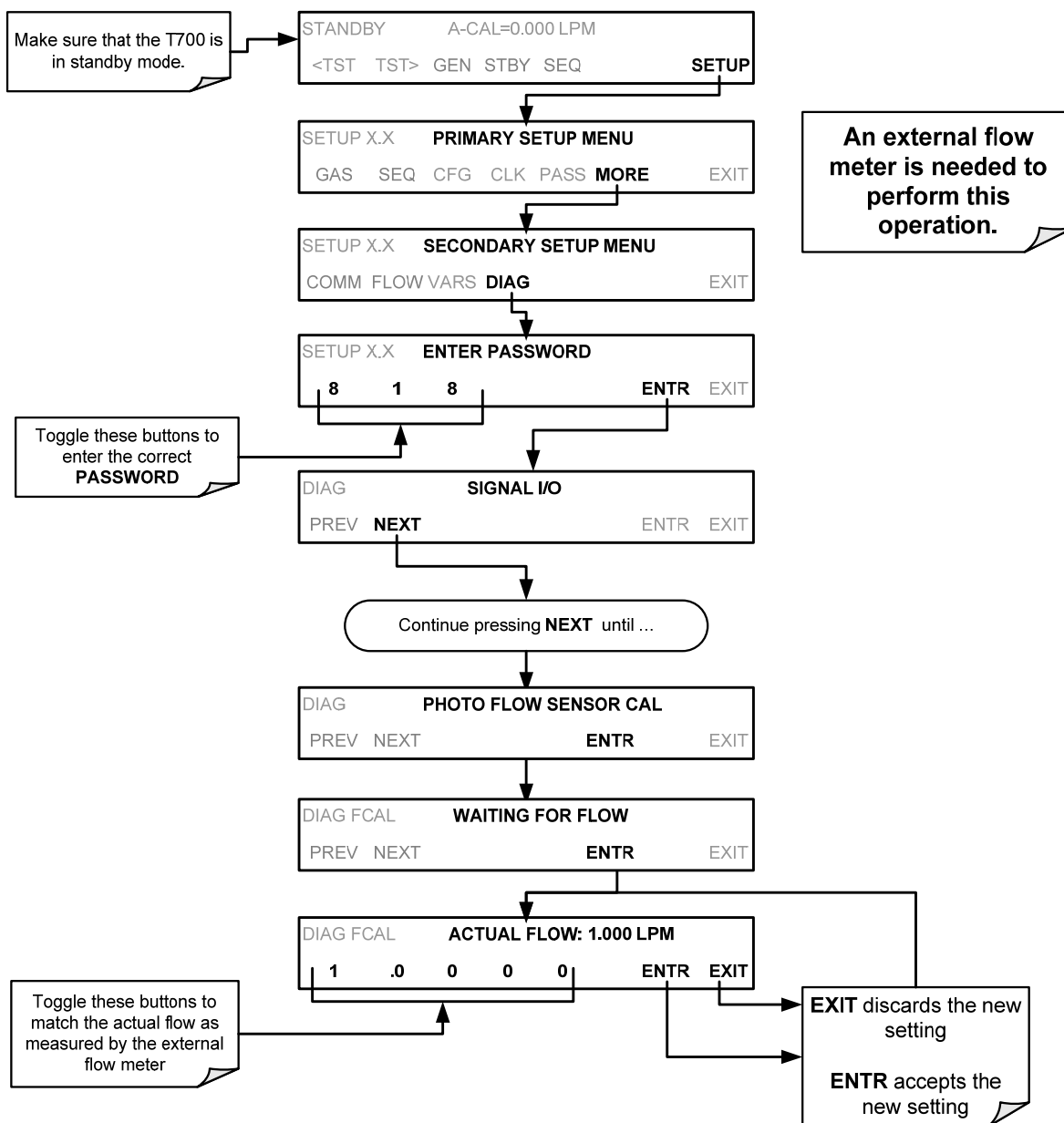
7.3.6. O3 PHOTOMETER GAS FLOW CALIBRATION

Note

A separate flow meter is required for the procedure.

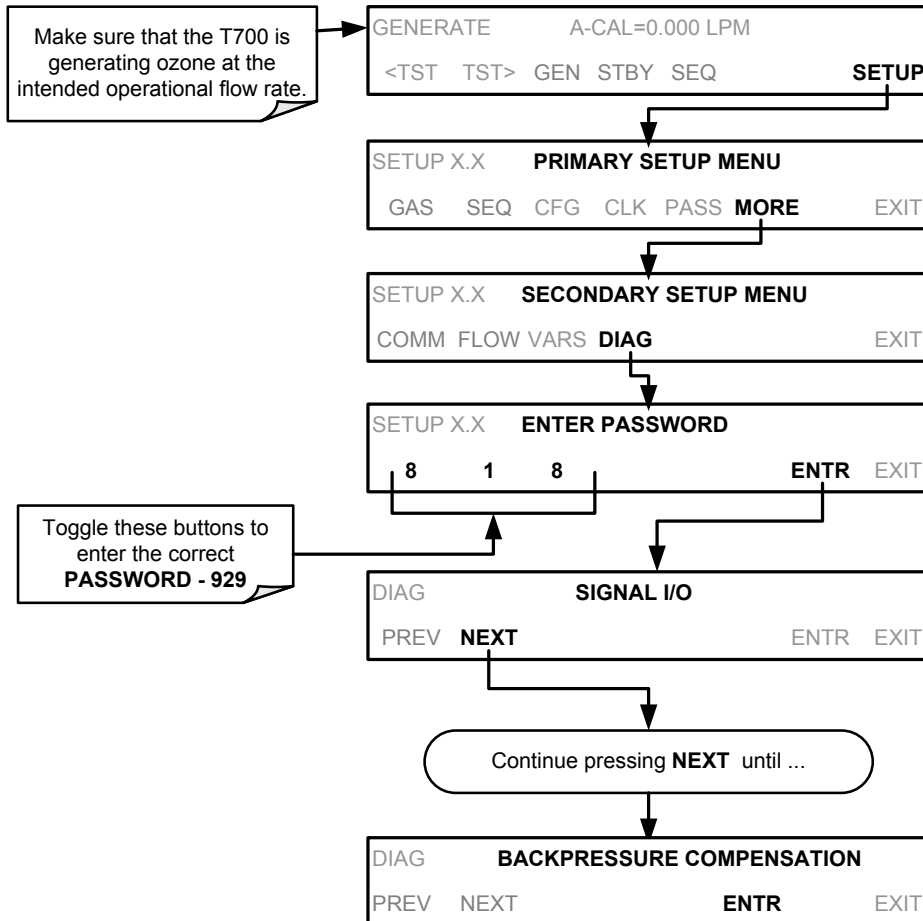
To calibrate the flow of gas through the T700 calibrator's optional photometer bench.

1. Turn OFF the T700 Dynamic Dilution Calibrator.
2. Attach the flow meter directly to the EXHAUST port of the T700 calibrator.
3. Turn the T700 Dynamic Dilution Calibrator ON.
4. Perform the following steps:



7.3.7. O3 PHOTOMETER BACKPRESSURE COMPENSATION CALIBRATION

Any time there is a pneumatic configuration change, there is risk of impacting the internal measure/reference pressure. To compensate for this, a backpressure compensation calibration is required each time. Set the calibrator to generate ozone at the flow rate intended for operation. While the instrument is generating ozone, go to the **SETUP>MORE>DIAG>929>...>BACKPRESSURE COMPENSATION** menu and press **ENTR**, shown in the following illustration, to initiate the calibration; the operation will take a few minutes:



7.4. CALIBRATING THE O₃ GENERATOR

7.4.1. SETUP FOR VERIFICATION AND CALIBRATION THE O₃ GENERATOR

Note

An external reference photometer is required for the procedure.

7.4.1.1. Setup Using Direct Connections

Figure 7-5 shows the reference photometer connected directly to the fixtures on the back of the T700 Calibrator.

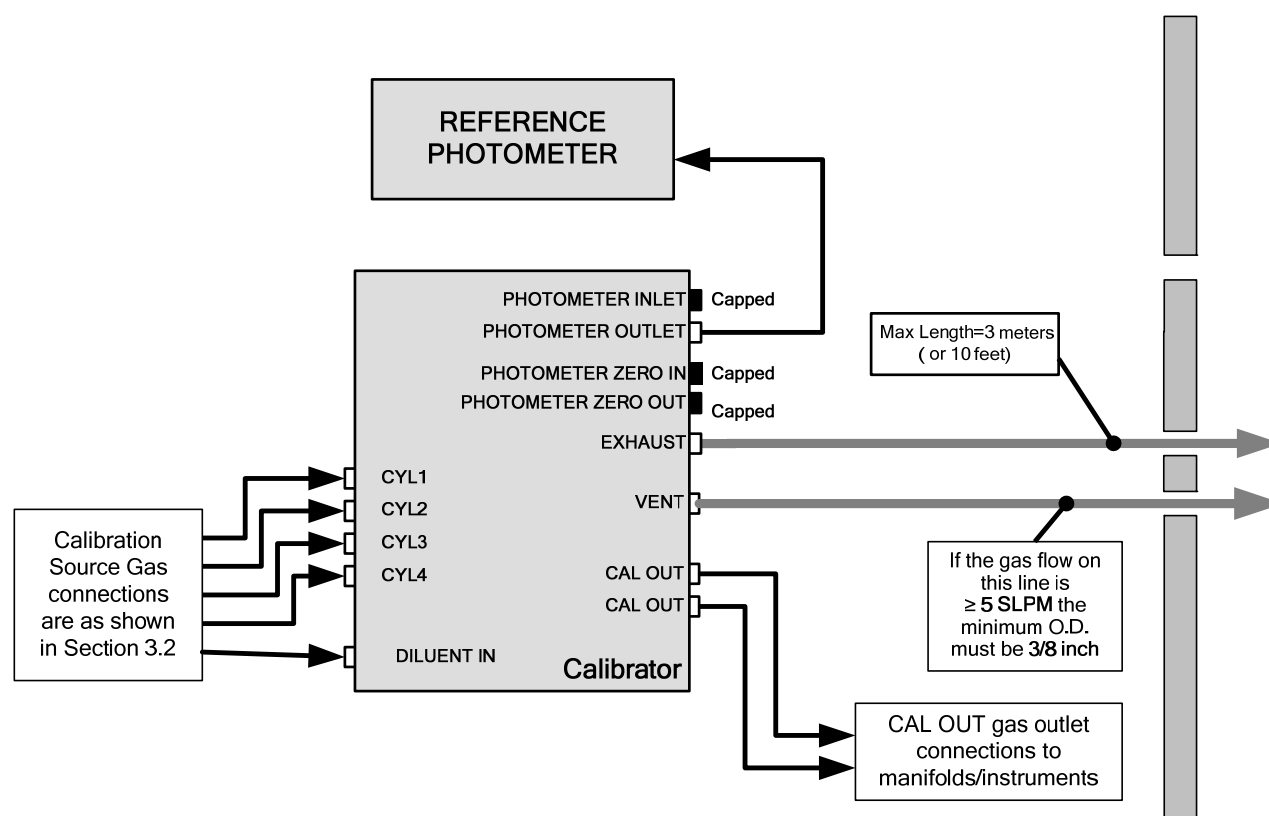
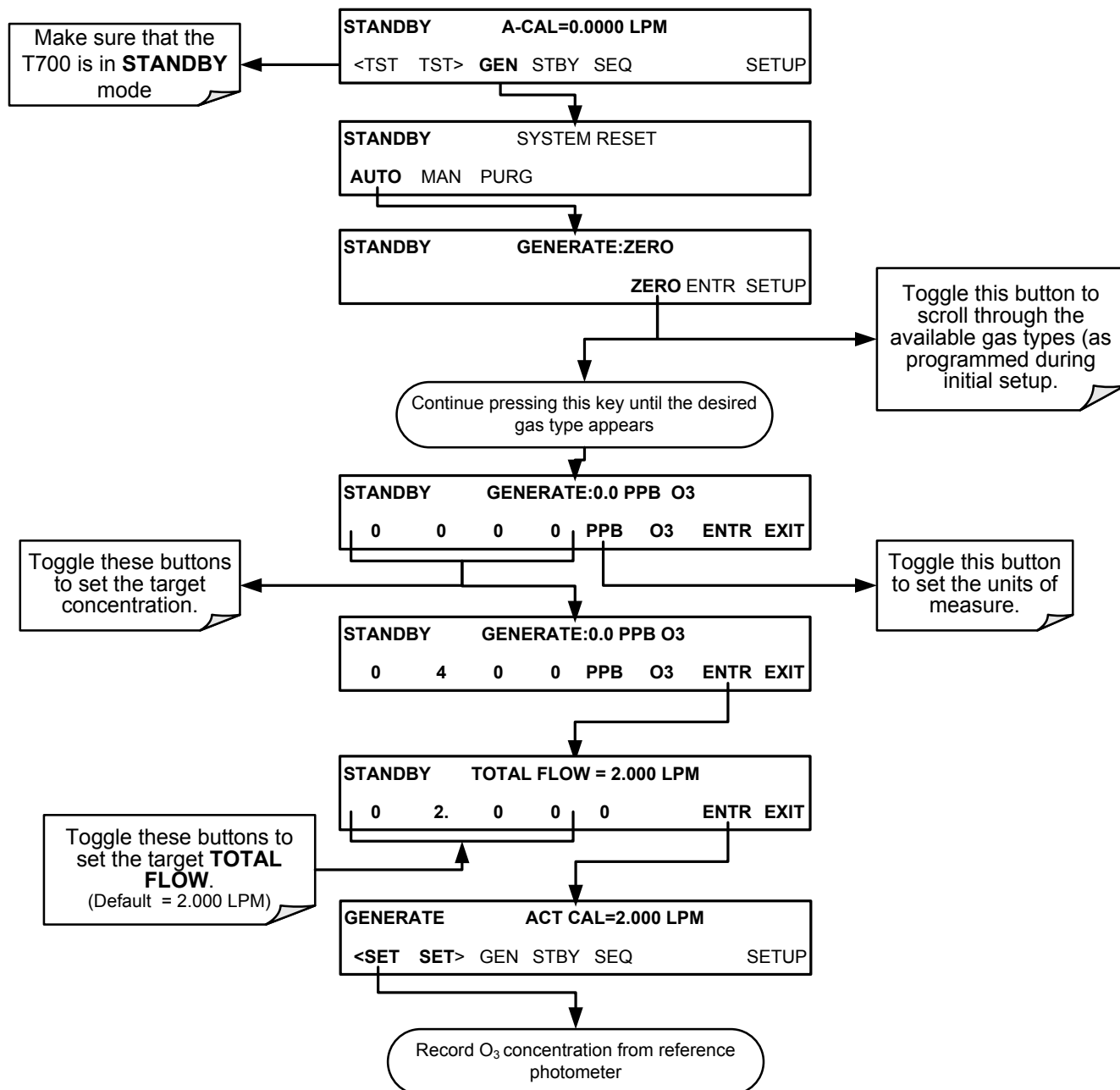


Figure 7-5: O₃ Generator Calibration Setup – Direct Connections

Verifying O₃ Generator Performance

Using the set up shown in Figure 8-4, perform the following steps:

**Note**

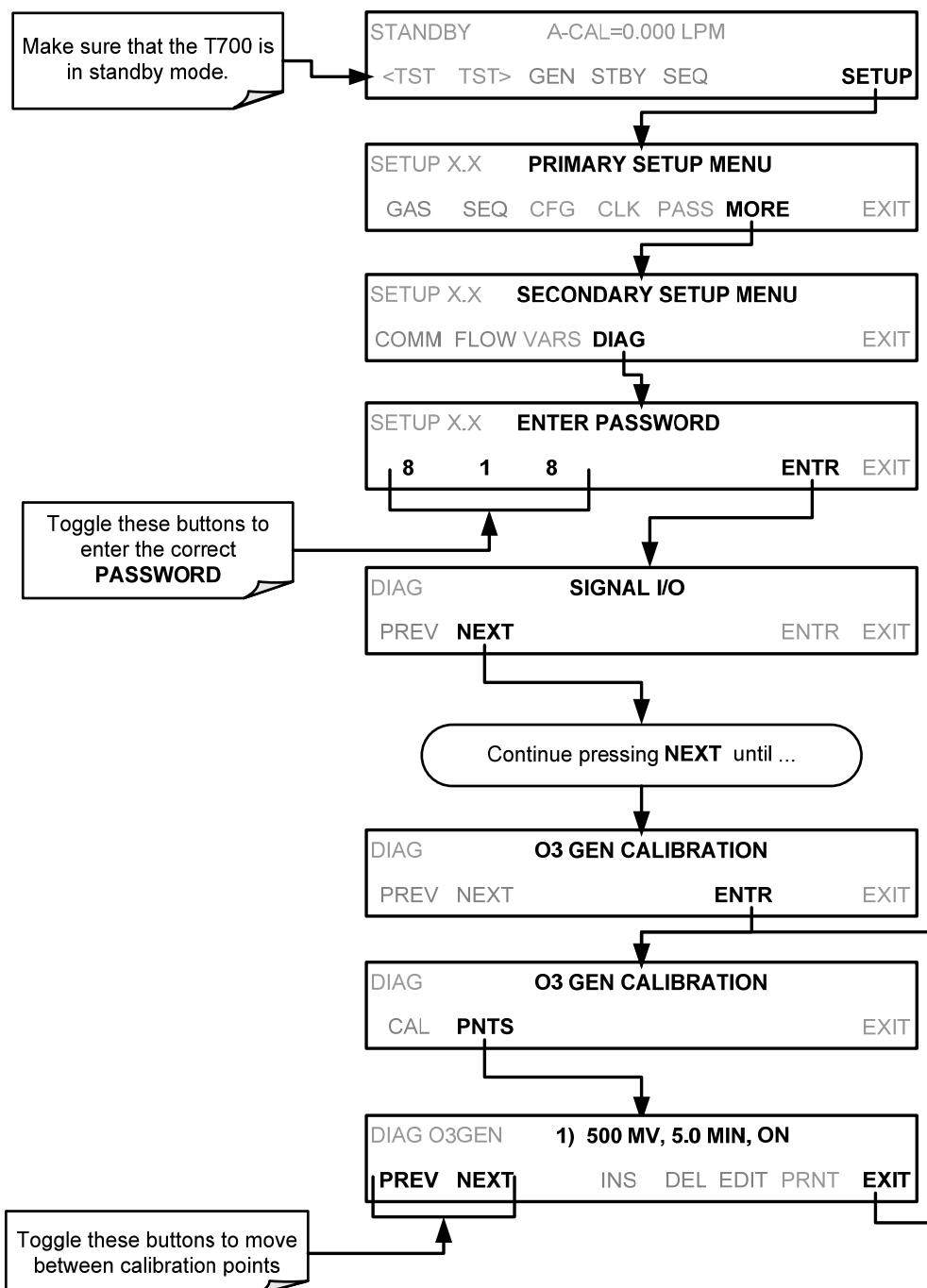
The readings recorded from the T700's A-CAL test function and the reference photometer should be within 1% of each other.

7.4.2. O₃ GENERATOR CALIBRATION PROCEDURE

The T700 calibrator's software includes a routine for automatically calibrating the O₃ generator. A table of drive voltages stored in the T700's memory is the basis for this calibration. For each point included in the table used by the T700 to calibrate the optional O₃ generator the user can set a drive voltage and a dwell time for that point. Each point can also be individually turned OFF or ON.

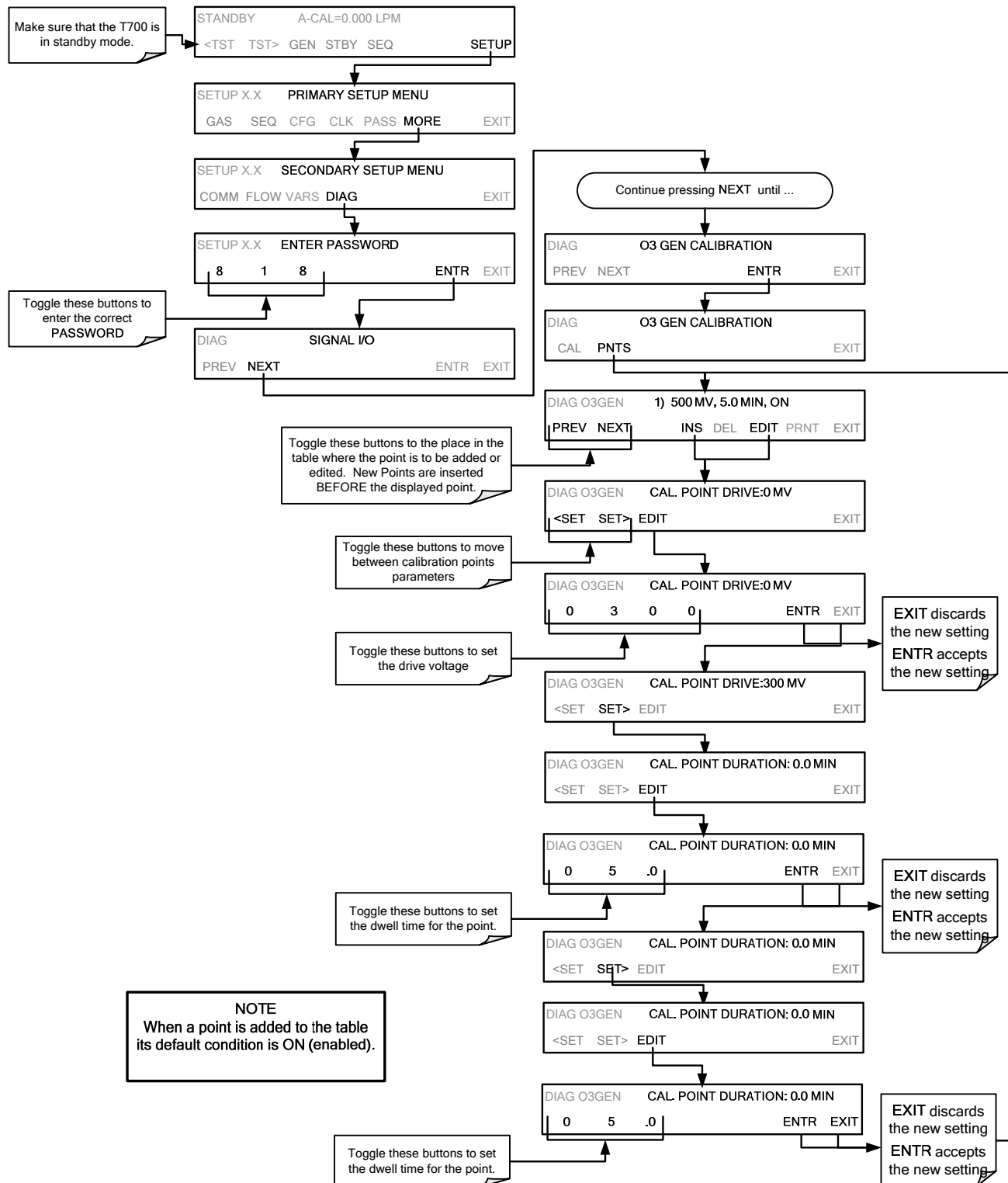
7.4.2.1. Viewing O₃ Generator Calibration Points

To view these calibration points, press:



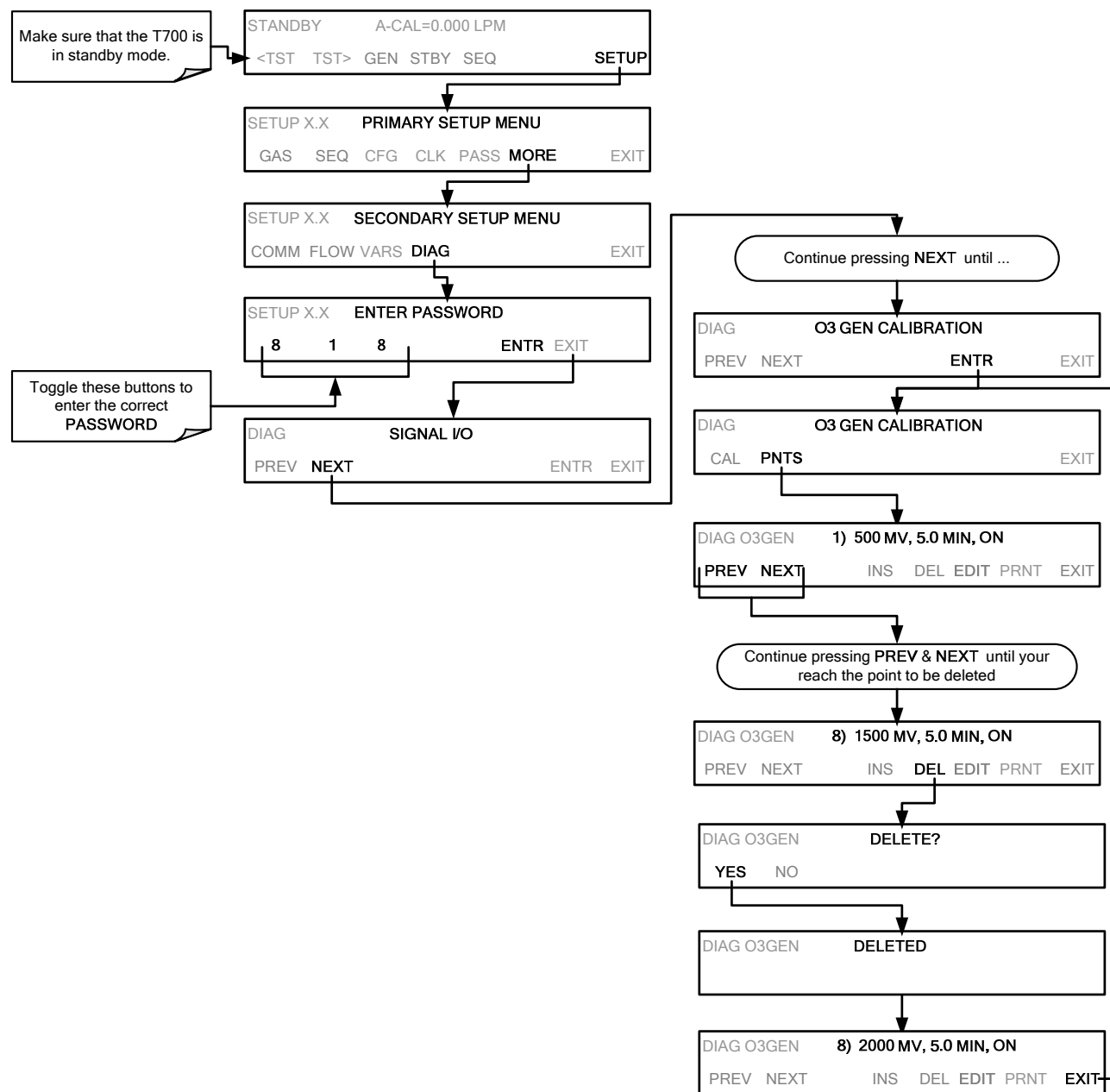
7.4.2.2. Adding or Editing O₃ Generator Calibration Points

To add a calibration point to the table or edit an existing point, press:



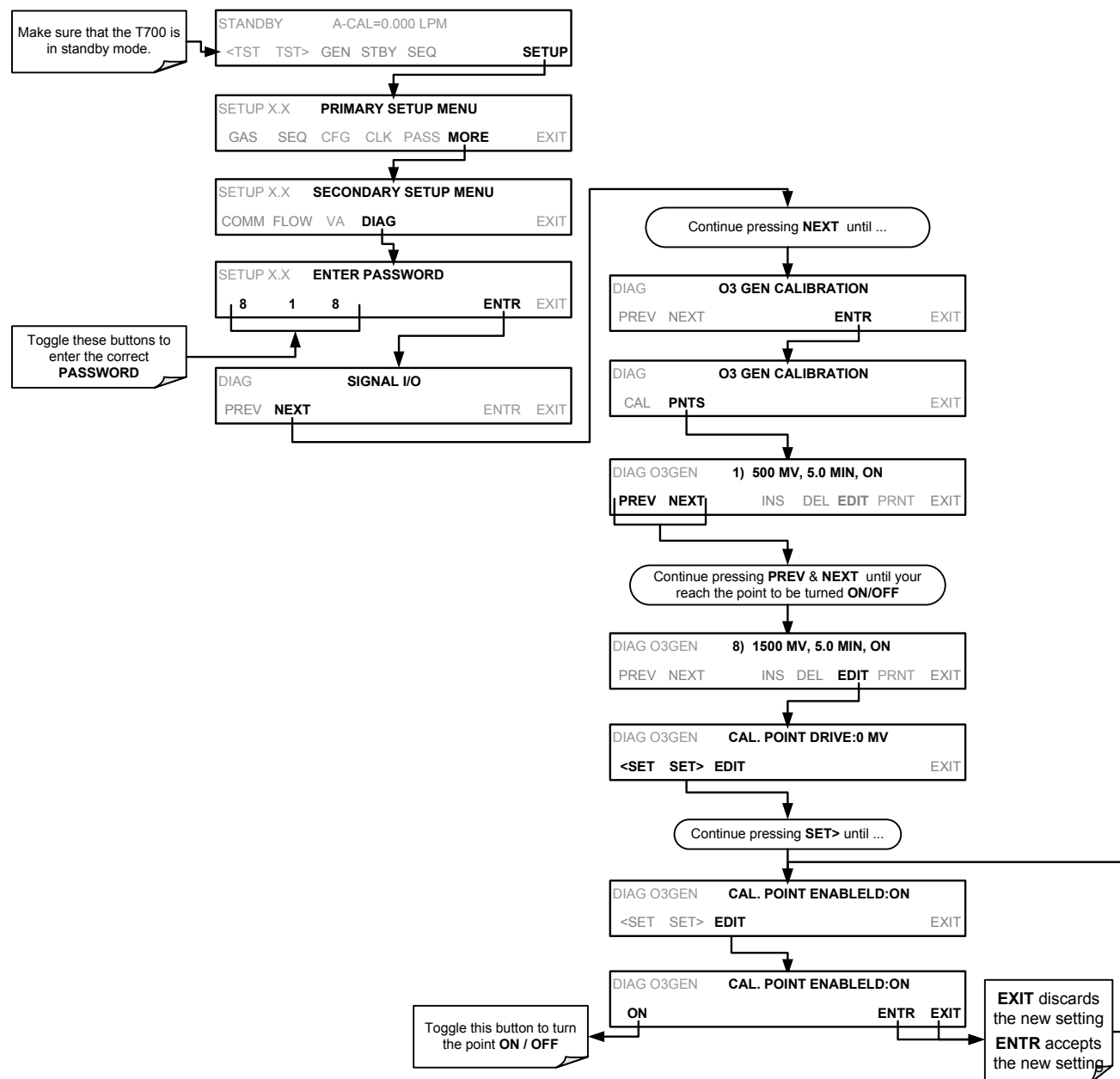
7.4.2.3. Deleting O₃ Generator Calibration Points

To delete an existing calibration point, press:



7.4.2.4. Turning O₃ Generator Calibration Points ON / OFF

To enable or disable an existing calibration point, press:

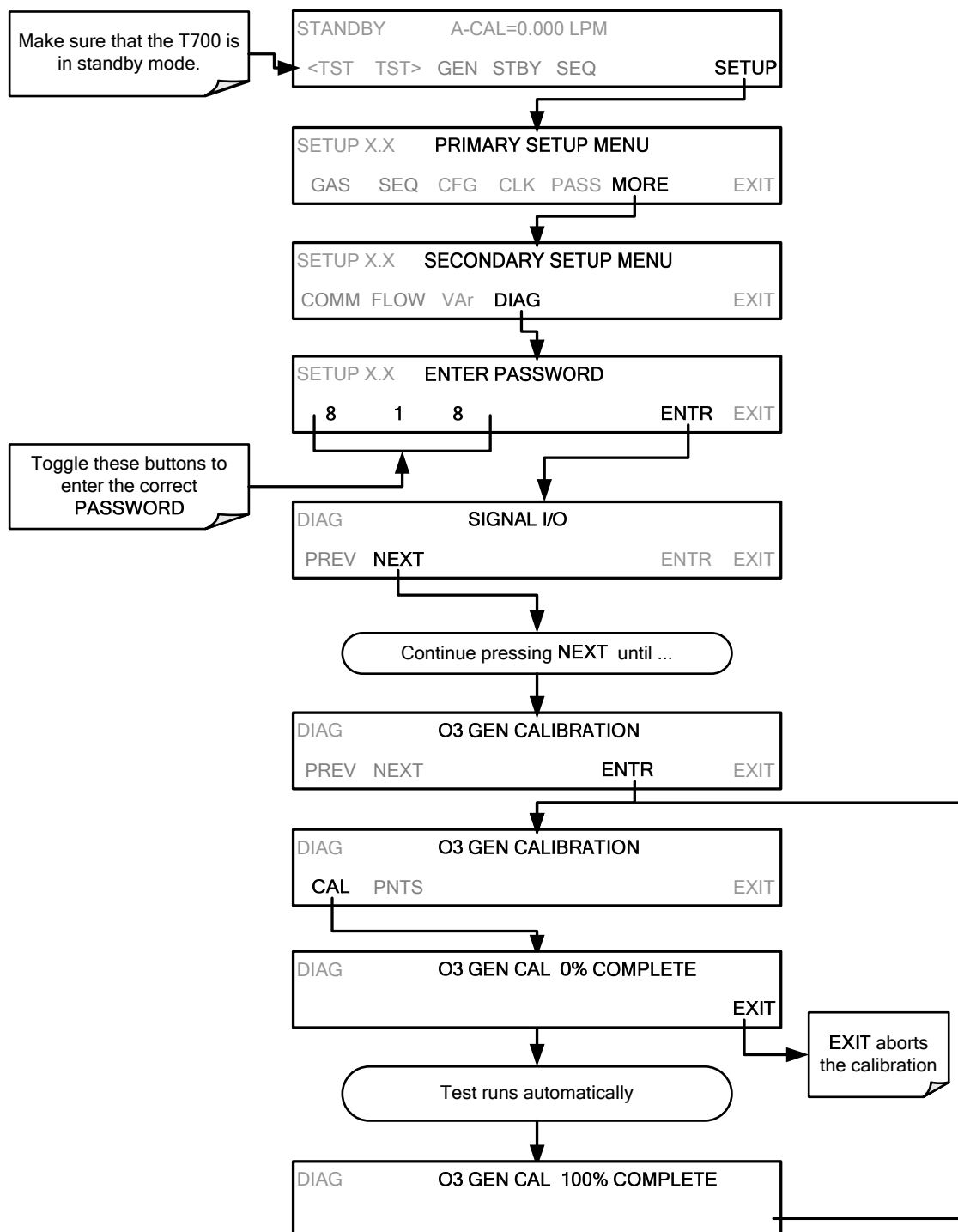


7.4.2.5. Performing an Automatic Calibration of the Optional O₃ Generator

Note

This procedure requires that the T700 calibrator have an optional photometer installed.

To run the automatic O₃ generator calibration program, press:



7.5. T700 GAS PRESSURE SENSOR CALIBRATION

Note

The procedures described in this section require a separate pressure meter/monitor.

The T700 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 7-2: T700 Pressure Sensor Calibration Setup

SENSOR	ASSOCIATED TEST FUNCTION	UNITS	PRESSURE MONITOR MEASUREMENT POINT
Diluent Pressure Sensor	DIL PRESSURE	PSIG	Insert monitor just before the inlet port of the diluent MFC
Cal Gas Pressure Sensor	CAL PRESSURE	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 SPRESS	IN-HG-A	Use monitor to measure ambient atmospheric pressure at the calibrator's location.

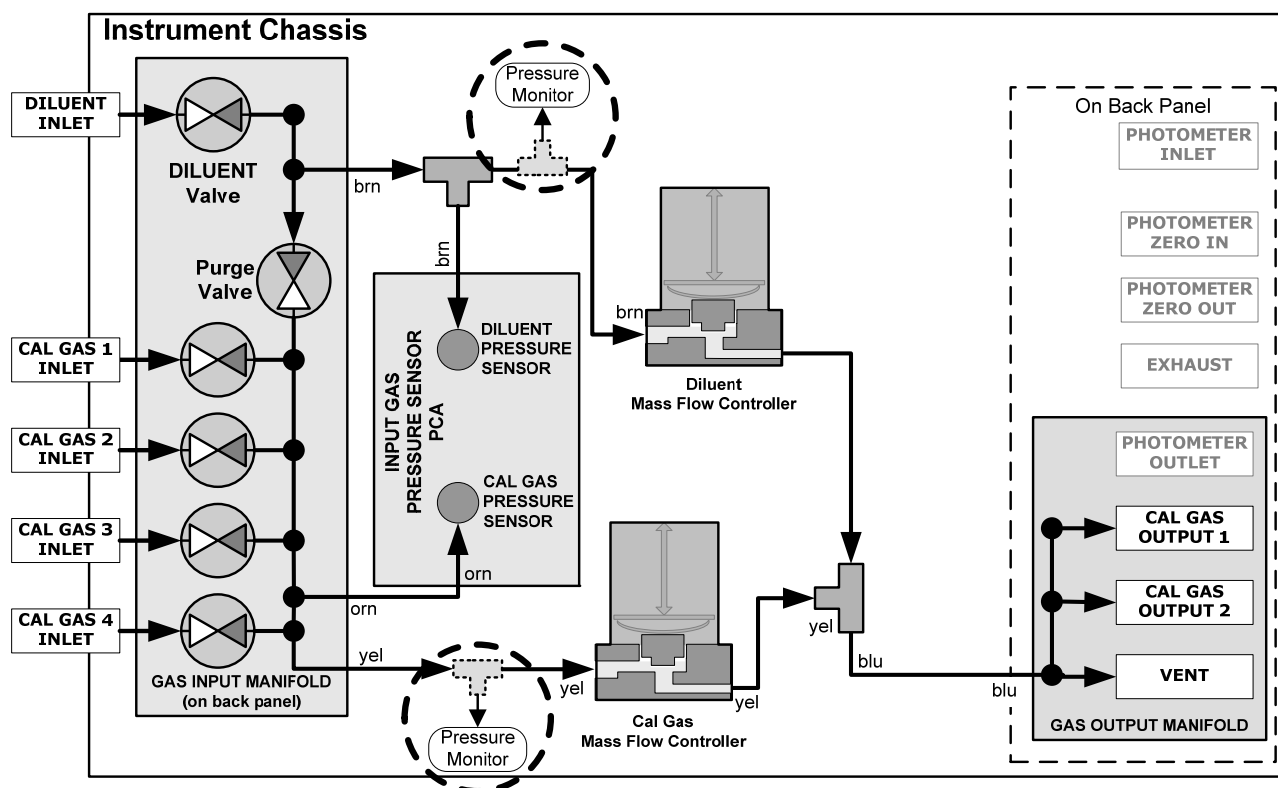
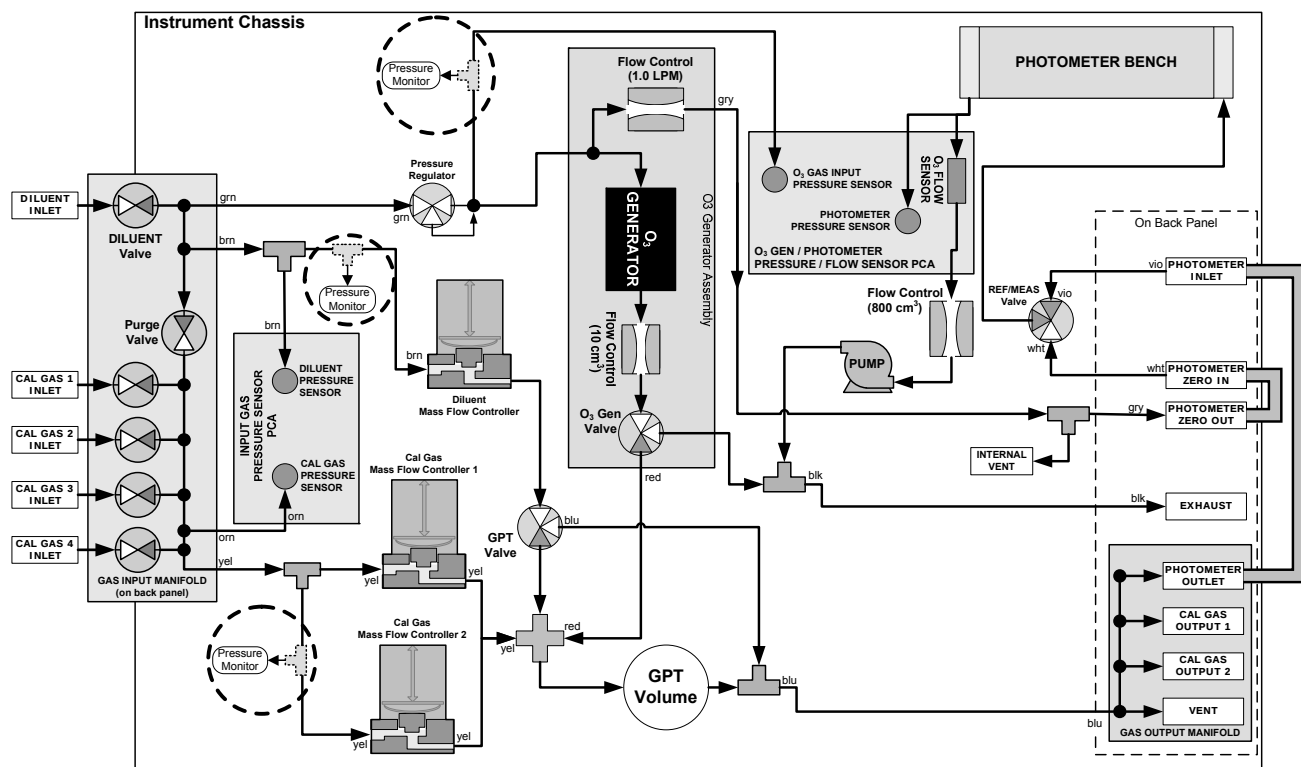
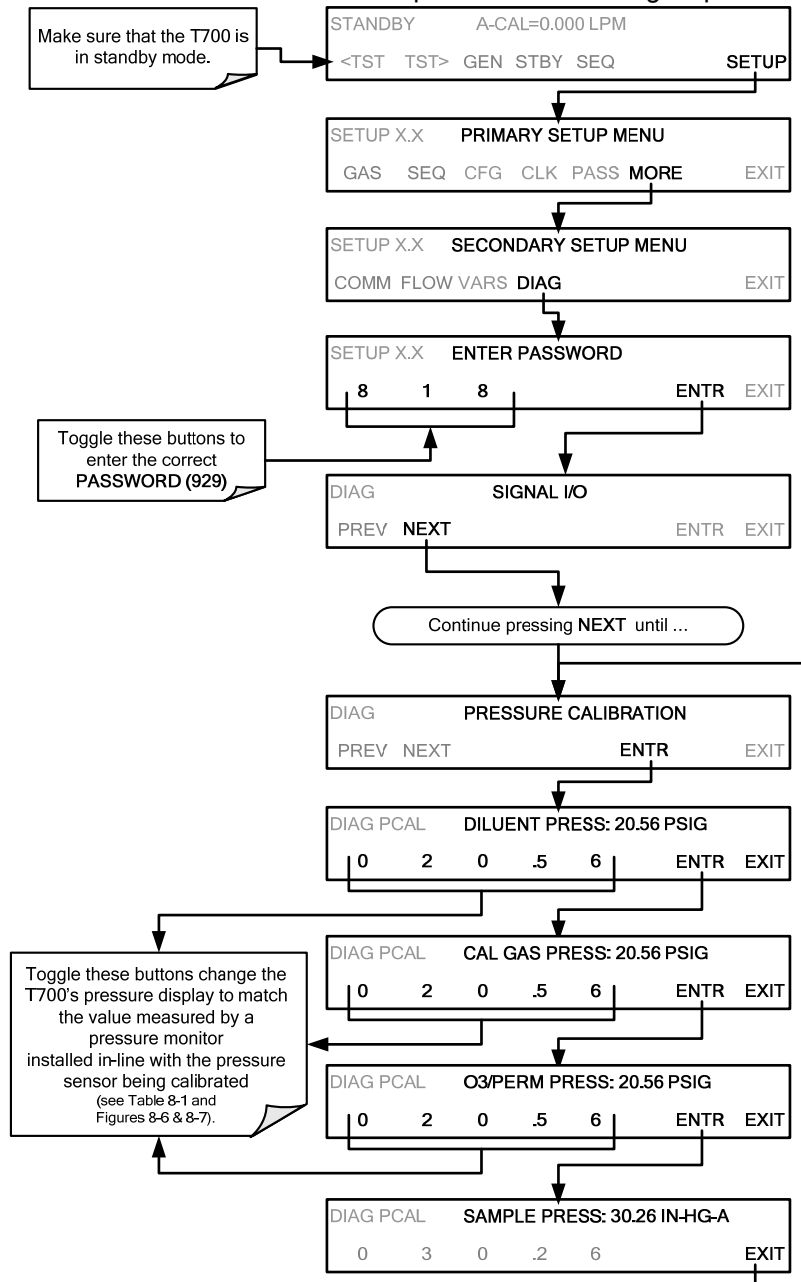


Figure 7-6: Pressure Monitor Points – T700 – Basic Unit

Figure 7-7: Pressure Monitor Points – T700 with O₃ Options and Multiple Cal MFCs Installed

7.5.1.1. Calibrating the Diluent, Cal Gas Optional O₃ Generator Pressure Sensors

1. Turn off the calibrator and open the top cover.
2. For the sensor being calibrated, insert a “T” pneumatic connector at the location described in Table 7-2 and shown in Figure 7-6 and Figure 7-7.
3. Turn on the calibrator and perform the following steps:



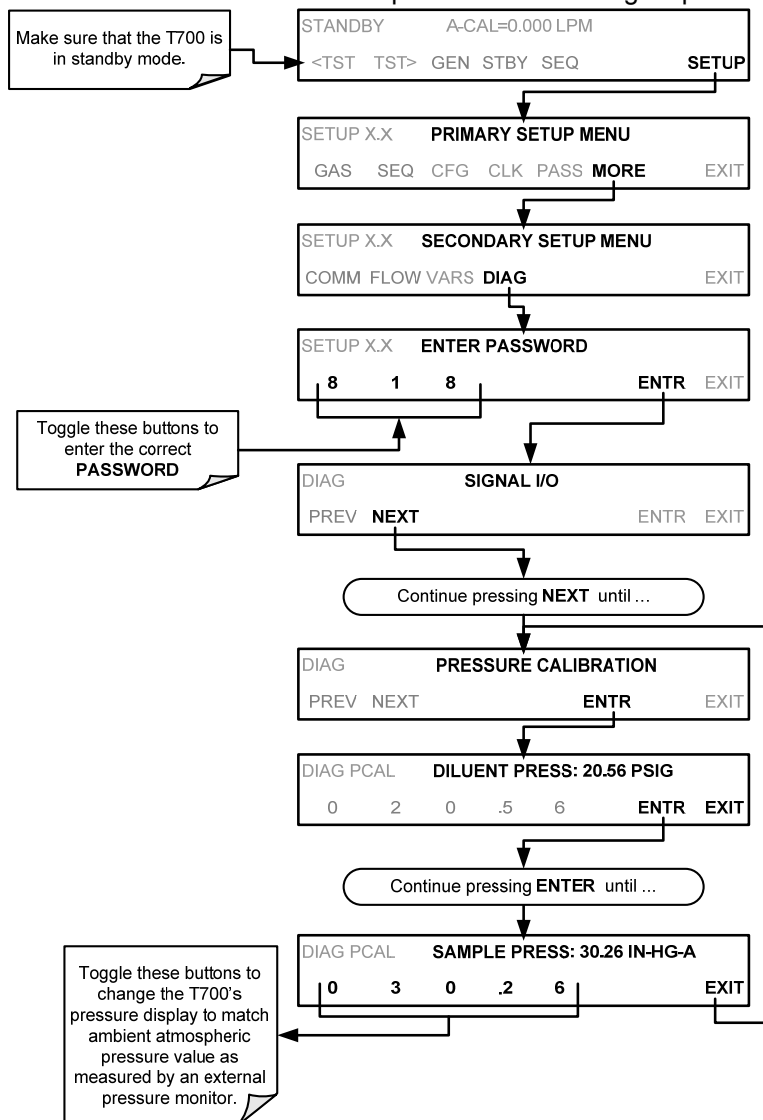
4. Turn OFF the T700.
5. Remove the pressure monitor.
6. Restore the pneumatic lines to their proper connections.
7. Close the calibrator's cover.

7.5.1.2. Calibrating the Optional O₃ Photometer Sample Gas Pressure Sensors

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. Measure the ambient atmospheric pressure of T700's location in In-Hg-A.
4. Turn on the calibrator and perform the following steps:



5. Turn OFF the T700.
6. Reconnect the internal pump.
7. Close the calibrator's cover.

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PART III
—
MAINTENANCE AND SERVICE

8. 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.

For the most part, the T700 calibrator is maintenance free, there are, however, a minimal number of simple procedures that when performed regularly will ensure that the T700 photometer continues to operate accurately and reliably over its lifetime.

Repairs and troubleshooting are covered in Section 11 of this manual.

8.1. MAINTENANCE SCHEDULE

Table 8-1 shows a typical maintenance schedule for the T700. 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 O₃ photometer installed, a Span and Zero Calibration Check must be performed on the photometer following some of the maintenance procedure listed below. See Section 7.3 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 8-1: T700 Maintenance Schedule

Item	Action	Freq	Cal Check Req'd. ¹	Manual Section	Date Performed							
Verify Test Functions	Record and analyze	Weekly or after any Maintenance or Repair	No									
Pump Diaphragm ¹	No Replacement Required. Under Normal Circumstances this Pump Will Last the Lifetime of the Instrument.											
Absorption Tube ¹	Inspect --- Clean	As Needed	Yes after cleaning	8.2.2	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 T700 Calibrator							
Perform Flow Check	Verify Flow of MFCs	Annually or any time the T700's internal DAC is recalibrated	No	7.1 & 7.2								
Perform Leak Check	Verify Leak Tight	Annually or after any Maintenance or Repair	Yes	8.2.1								
Pneumatic lines	Examine and clean	As needed	Yes if cleaned	---								
¹ Only applies to T700 Calibrator's with O ₃ photometer options installed.												

8.2. MAINTENANCE PROCEDURES

The following procedures are to be performed periodically as part of the standard maintenance of the T700 calibrator.

8.2.1. AUTO LEAK CHECK

8.2.1.1. 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

8.2.1.2. Setup Auto Leak Check

To perform a leak-check on the T700 calibrator:

1. Remove the cover from the calibrator.
2. On Instruments with the optional O3 photometer installed, the photometer flow sensor PCA and pump must be bypassed:
 - Using a #6 nut driver, remove the hexagonal nut located at the top of the gas outlet of the photometer (see Figure 8-1).
 - Using a #6 nut driver, remove the hexagonal nut located on the fitting on the back side of the Flow/Pressure sensor board (see Figure 8-1).
 - Connect the end of the line removed from the Sensor PCA in Step 3 to the Photometer Outlet Fitting.

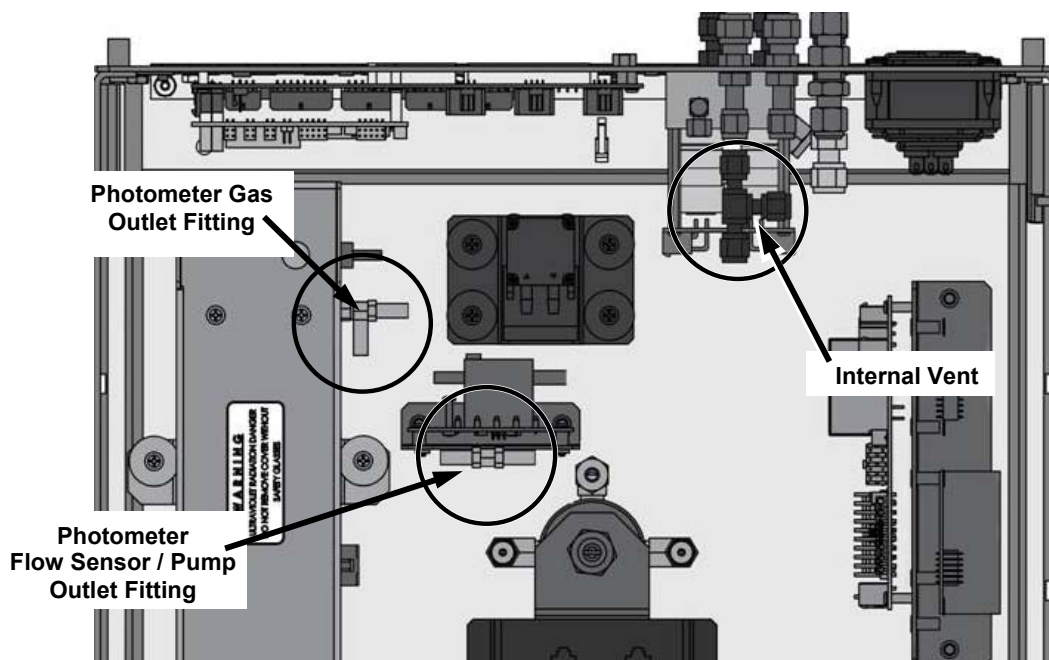


Figure 8-1: Bypassing the Photometer Sensor PCA and Pump

3. Using the 1/8" cap, securely cover the outlet of the internal vent located just behind the valve relay PCA (see Figure 8-1).
4. Use the 1/4" caps to cover the following gas outlet ports on the back of the T700 (see Figure 8-2).
 - Exhaust (Only required for calibrators with O3 generators install).
 - Both Cal Gas 1 outlet ports.
 - The Vent port.

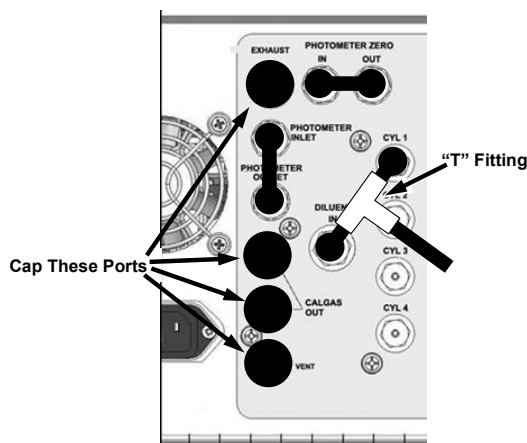


Figure 8-2: Gas Port Setup for Auto-Leak Check Procedure

5. If a bottle of source gas is connected to the CYL 1 port, remove it.

Note

Ensure that the gas outlet of the bottle is CLOSED before disconnecting the gas line from the CYL 1 port..

6. Connect a gas line from the zero air gas source to the Diluent In and to the CYL 1 port using a "T" type pneumatic fitting (see Figure 8-2).

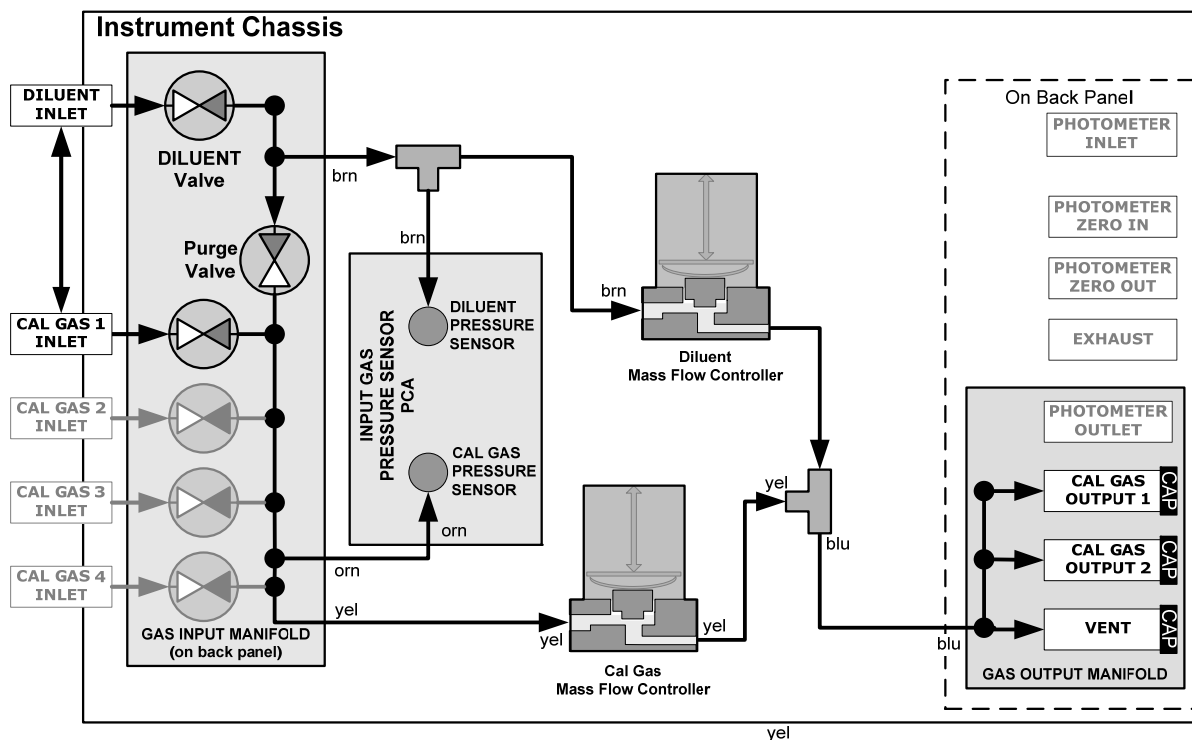


Figure 8-3: Gas Flow for Auto-Leak Check Procedure of Base Model T700's

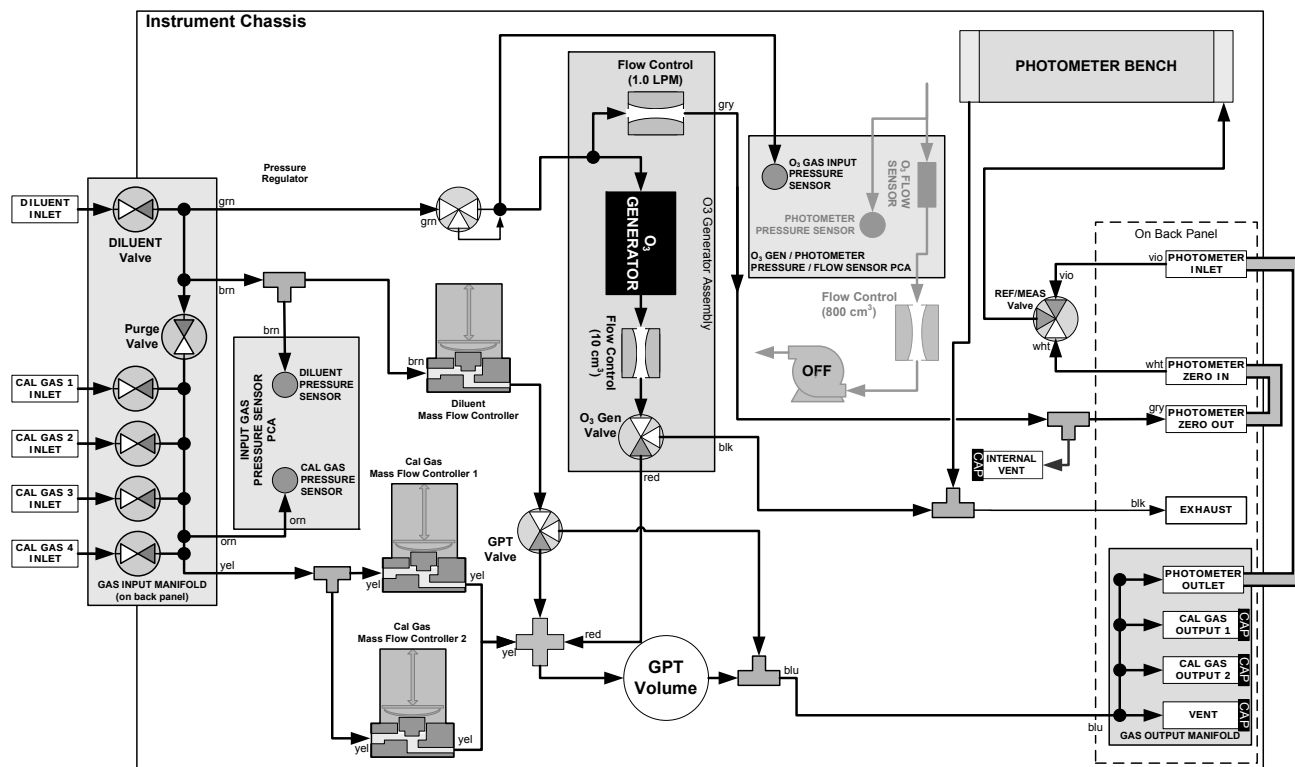
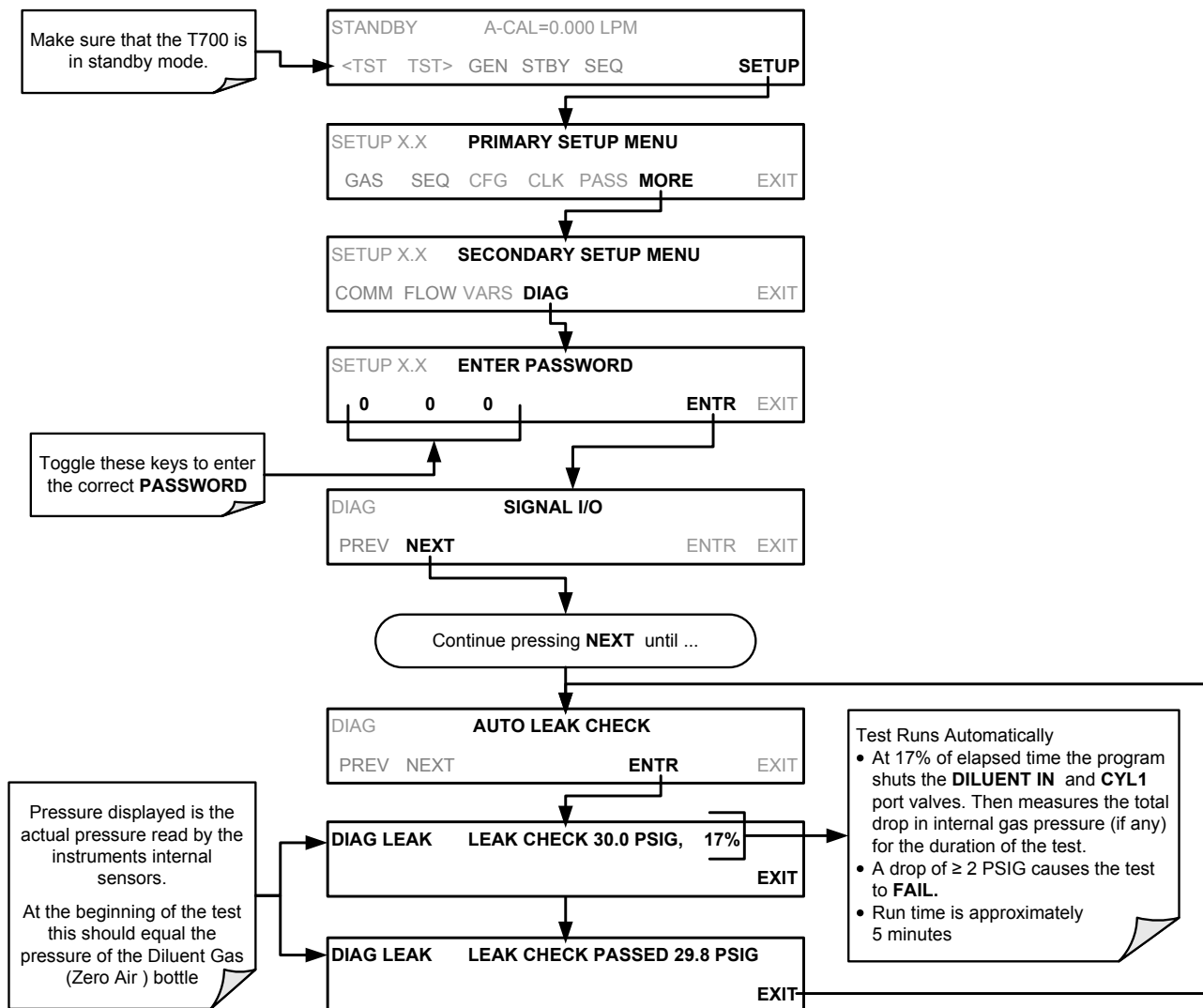


Figure 8-4: Gas Flow for Auto-Leak Check Procedure of T700's with Optional Photometer

8.2.1.3. Performing the Auto Leak Check Procedure

To perform an **AUTO LEAK CHECK**, press:



8.2.1.4. Returning the T700 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 O3 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 bottles outlet port.
6. Replace the calibrator's top cover.
7. The calibrator is now ready to be used.

8.2.2. 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.

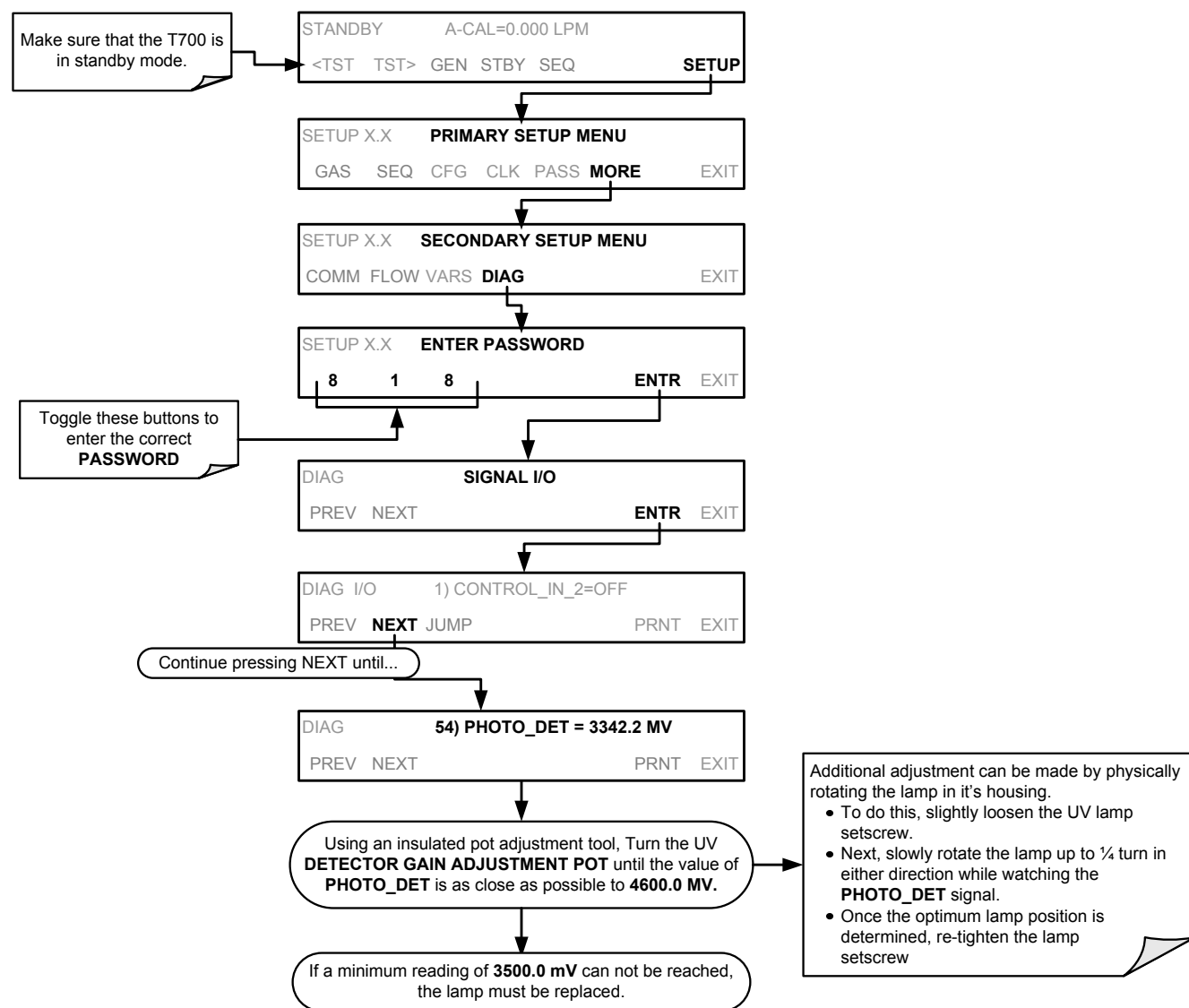
Note

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.

8.2.3. 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** test function 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 optional Photometer (see Figure 3-6).
4. Locate the UV detector gain adjust pot on the photometer assembly (see Figure 8-5).
5. Perform the following procedure:



6. Replace the cover on the calibrator.

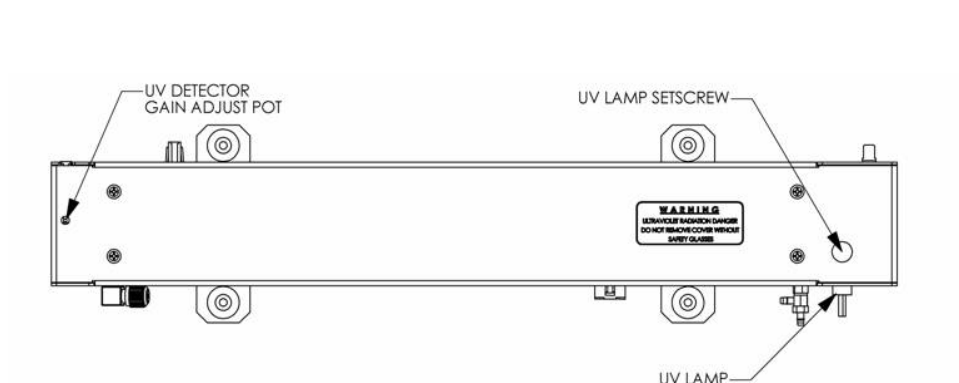


Figure 8-5: Photometer Assembly – Lamp Adjustment / Installation

8.2.4. 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 8.2.3.

1. Turn the calibrator off.
2. Remove the cover from the calibrator.
3. Locate the Optical Bench Assembly (see Figure 3-6).
4. Locate the UV lamp at the front of the optical bench assembly (see Figure 8-5).
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 8-5) 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 8.2.3, with the following exceptions:
 - a) Slowly rotate the lamp in its housing (up to $\frac{1}{4}$ 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_DET will not drop below 5000 mV while performing this rotation, contact Teledyne API'S Customer Service for assistance.
 - b) Once a lamp position is found that corresponds to a minimum observed value for **PHOTO_DET**, tighten the lamp setscrew at the approximate minimum value observed.

c) Adjust PHOTO_DET 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.

8.2.5. 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 O₃ generator (see Figure 3-6).

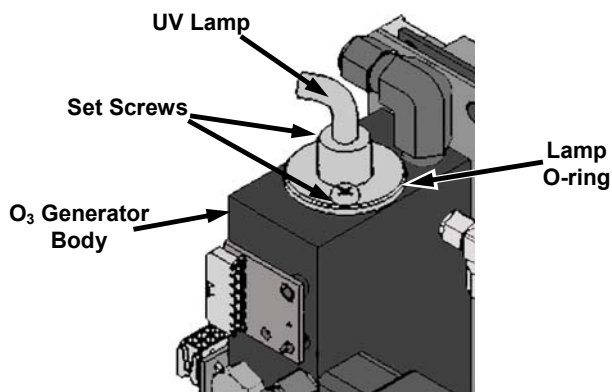


Figure 8-6: O₃ Generator Temperature Thermistor and DC Heater Locations

4. Remove the two setscrews on the top of the O₃ 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 O₃ generator housing.
 - Do not fully tighten the setscrews.
 - The lamp should be able to be rotated in the assembly by grasping the lamp cable.
7. Turn on calibrator and allow it to stabilize for at least 30 minutes.
8. Locate the potentiometer used to adjust the O₃ generator UV output.

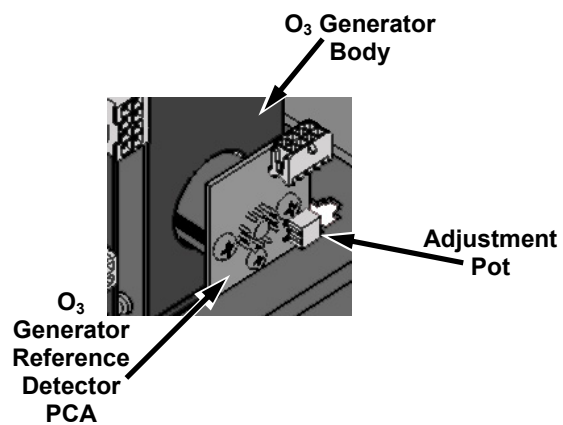
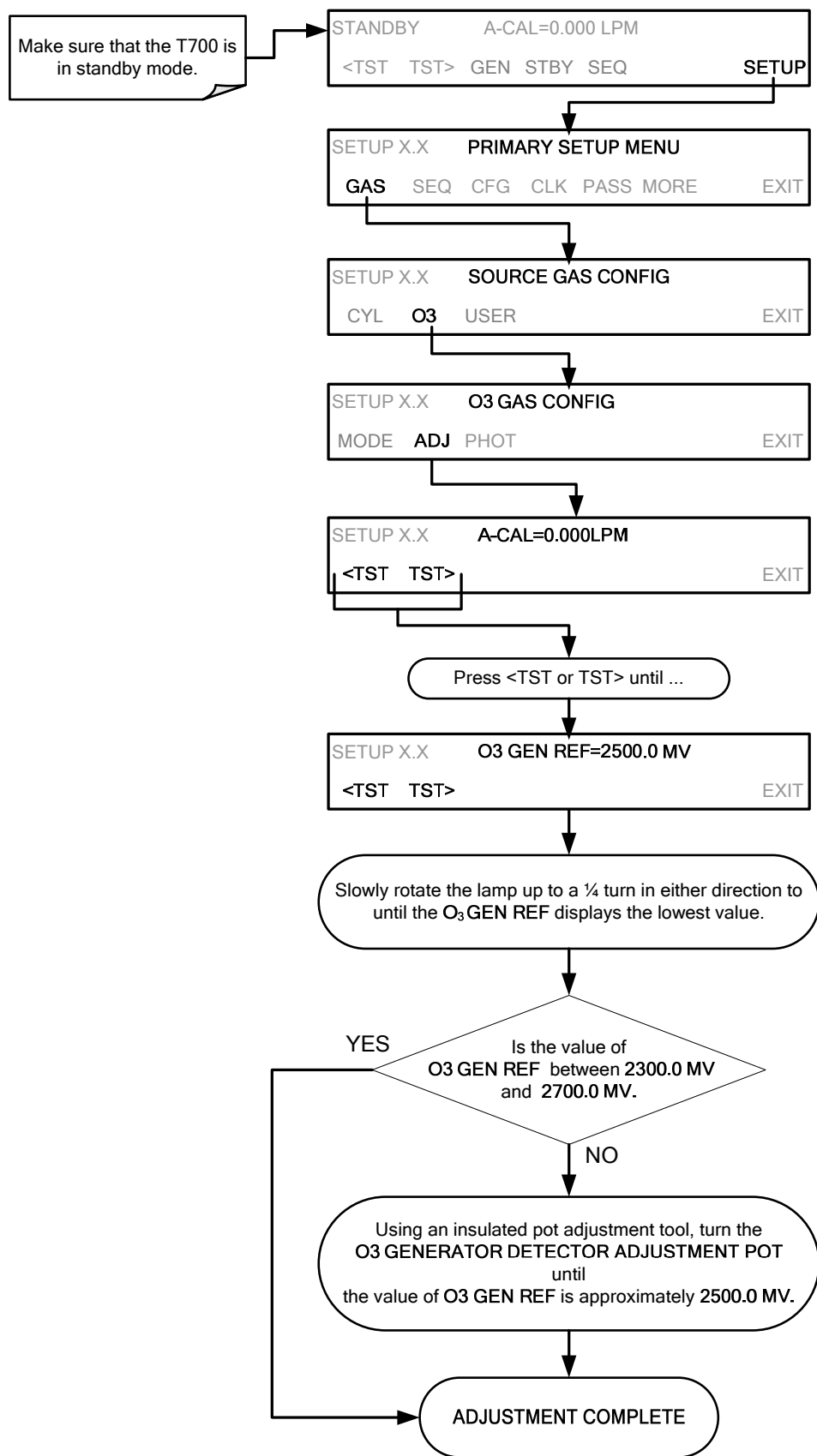


Figure 8-7: Location of O₃ Generator Reference Detector Adjustment Pot

9. Perform the following procedure:



10. Tighten the two setscrews.

11. Replace the calibrator's cover.
12. Perform an auto-leak check (See Section 8.2.1).
13. Perform an Ozone Generator calibration (see Section 7.4).

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9. 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.

9.1. GENERAL TROUBLESHOOTING

The T700 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. Examine the values of all TEST functions and compare them to factory values. Note any major deviations from the factory values and take corrective action.
3. Use the internal electronic status LEDs to determine whether the electronic communication channels are operating properly.

- Verify that the DC power supplies are operating properly by checking the voltage test points on the relay PCA.
 - Note that the calibrator's DC power wiring is color-coded and these colors match the color of the corresponding test points on the relay PCA.
4. Follow the procedures defined in Section 3.4.3 to confirm that the calibrator's vital functions are working (power supplies, CPU, relay PCA, etc.).
 - See Figure 3-5 and Figure 3-6 for general layout of components and sub-assemblies in the calibrator.
 - See the wiring interconnect diagram and interconnect list in Appendix D.

9.1.1. FAULT DIAGNOSIS WITH WARNING MESSAGES

The most common and/or serious instrument failures will result in a warning message being displayed on the front panel. Table 9-1 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 9.4.3), the relay PCA (See Section 9.4.7), and the motherboard (See Section 9.4.11) be confirmed before addressing the specific warning messages.

The T700 will alert the user that a Warning Message is active by flashing the FAULT LED, displaying the Warning message in the Param field along with the **CLR** button (press to clear Warning message). The **MSG** button displays if there is more than one warning in queue or if you are in the TEST menu and have not yet cleared the message. The following display/touchscreen examples provide an illustration of each:



The calibrator will also alert the user via the Serial I/O COMM port(s) and cause the FAULT LED on the front panel to blink.

To view or clear the various warning messages press:

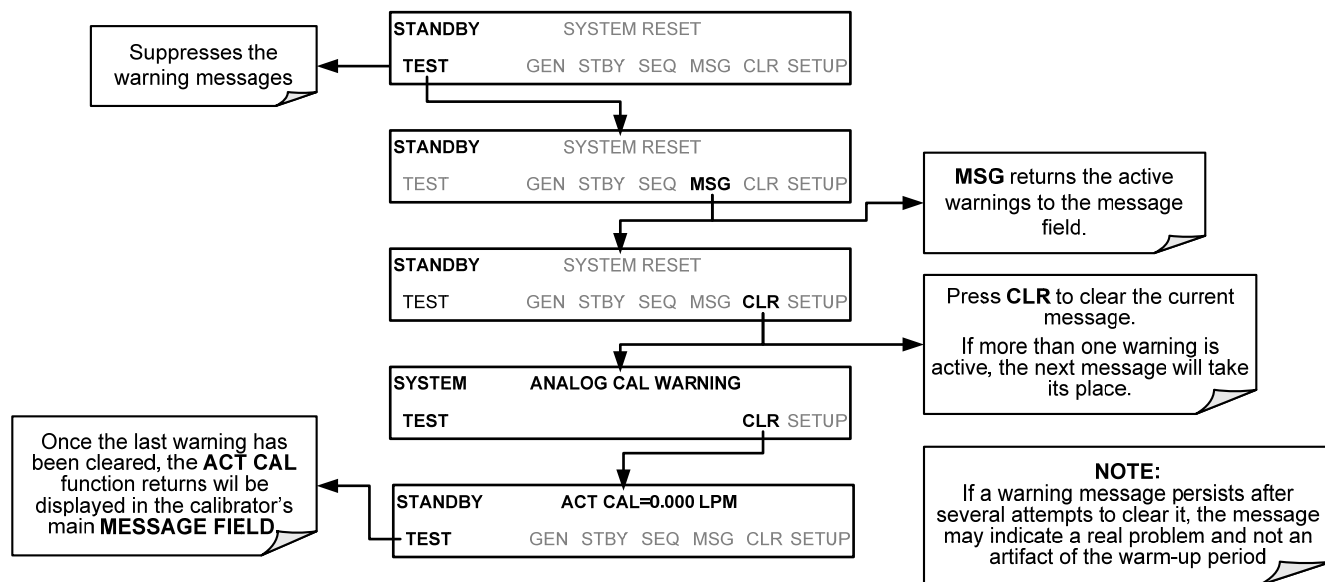


Table 9-1: Warning Messages in Front Panel Display Param Field

WARNING	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 ² C driver chip.	- I²C has failed
MFC COMMUNICATION WARNING	Firmware is unable to communicate with any MFC.	- I²C 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 T700'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 - O₃ generator heater - O₃ generator temperature sensor - Relay controlling the O₃ generator heater - Entire Relay PCA - I²C Bus
O3 GEN REFERENCE WARNING ¹	The O ₃ generator's reference detector output has dropped below 50 mV. ¹	Possible failure of: - O₃ generator UV Lamp - O₃ generator reference detector - O₃ generator lamp power supply - I²C 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 - I²C Bus - Hot Lamp
PHOTO LAMP STABILITY WARNING	Value output during the Photometer's reference cycle changes from measurements to measurement more than 25% of the time.	- Faulty UV source lamp - Noisy UV detector - Faulty UV lamp power supply - Faulty ± 15 VDC power supply
PHOTO REFERENCE WARNING ²	Occurs when Ref is <2500 mVDC or >4950 mVDC.	Possible failure of: - UV Lamp - UV Photo-Detector Preamp

WARNING	FAULT CONDITION	POSSIBLE CAUSES
REAR BOARD NOT DET	Mother Board 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 Mother Board
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 O₃ zero air pressure regulator - Leak or blockage exists in the T700's internal pneumatics - Failed O₃ Generator Input pressure sensor
RELAY BOARD WARN	The CPU cannot communicate with the Relay PCA.	- I²C 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.	- I²C 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).		

9.1.2. FAULT DIAGNOSIS WITH TEST FUNCTIONS

Besides being useful as predictive diagnostic tools, the test 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 calibrators Theory of Operation (see Section 10).

The acceptable ranges for these test functions are listed in the "Nominal Range" column of the calibrator Final 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.

A worksheet has been provided in Appendix C to assist in recording the values of these Test Functions.

Table 9-2 contains some of the more common causes for these values to be out of range.

Table 9-2: Test Functions – Indicated Failures

TEST FUNCTION	DIAGNOSTIC RELEVANCE AND CAUSES OF FAULT CONDITIONS.
O3GENREF¹	Particularly important in calibrators without the optional O ₃ photometer since the reference detector is the primary input for controlling O ₃ concentration. Possible causes of faults are the same as O3 GEN REFERENCE WARNING from Table 9-1.
O3FLOW¹	Gas flow problems directly affect the concentration accuracy of the T700's calibration gas mixtures. - Check for Gas Flow problems.
O3GENDRV¹	Check the O ₃ generator heater and temperature sensors. Possible causes of faults are the same as O3 GEN LAMP TEMP WARNING from Table 9-1.
O3LAMPTMP¹	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 9-1.
CAL PRES	Affects proper flow rate of Cal gas MFCs. Possible causes of faults are the same as MFC PRESSURE WARNING from Table 9-1.
DIL PRES	Affects proper flow rate of Diluent gas MFCs. Possible causes of faults are the same as MFC PRESSURE WARNING from Table 9-1.
REG PRES	Same as REGULATOR PRESSURE WARNING from Table 9-1.
BOX TMP	If the Box Temperature is out of range, ensure that the: Box Temperature typically runs ~7°C warmer than ambient temperature. - The Exhaust-Fan is running. - Ensure there is sufficient ventilation area to the side and rear of instrument to allow adequate ventilation.
PH MEAS² & PH REF²	If the value displayed is too high the UV Source has become brighter. Adjust the variable gain potentiometer on the UV Preamp Board in the optical bench. If the value displayed is too low: - < 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 ² C Bus. If the PHOTO REFERENCE value changes by more than 10mV between zero and span gas: - Defective/leaking switching valve.
PH FLW²	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.
PH LTEMP²	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 9-1.
PH PRES²	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 9-1.

TEST FUNCTION	DIAGNOSTIC RELEVANCE AND CAUSES OF FAULT CONDITIONS.
PH STEMP ²	The temperature of the gas in the photometer's sample chamber is used to calculate the concentration of O₃ 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 - I²C Bus malfunction - Hot Lamp
PH 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.
PH OFFST ²	Values outside range indicate: ▪ Contamination of the Zero Air supply.
TIME	Time of Day clock is too fast or slow. ▪ To adjust see Section 4.5. ▪ Battery in clock chip on CPU board may be dead.
¹ Only appears when the optional O₃ generator is installed. ² Only appears when the optional O₃ photometer is installed	

9.1.3. USING THE DIAGNOSTIC SIGNAL I/O FUNCTION

The Signal I/O parameters found under the DIAG Menu combined with a thorough understanding of the instrument's Theory of Operation (found in Section 10) 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. Figure 9-1 is an example of how to use the Signal I/O menu to view the raw voltage of an input signal or to control the state of an output voltage or control signal. The specific parameter will vary depending on the situation.

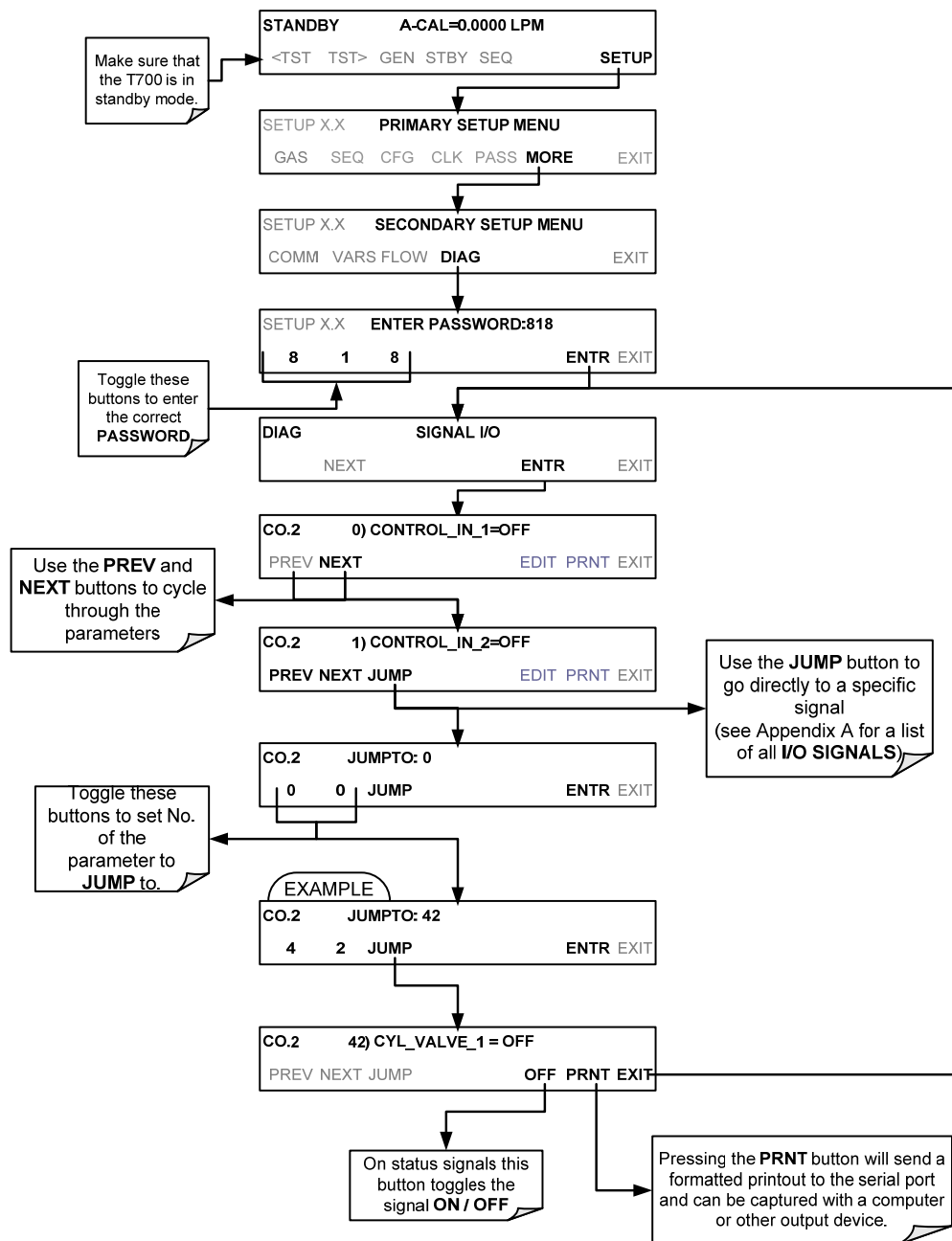


Figure 9-1: Example of Signal I/O Function

9.2. USING THE ANALOG OUTPUT TEST CHANNEL

The signals available for output over the T700's analog output channel can also be used as diagnostic tools. See Section 4.7 for instruction on activating the analog output and selecting a function.

Table 9-3: Test Channel Outputs as Diagnostic Tools

TEST CHANNEL	DESCRIPTION	ZERO	FULL SCALE	CAUSES OF EXTREMELY HIGH / LOW READINGS
NONE	TEST CHANNEL IS TURNED OFF			
O3 PHOTO MEAS	The raw output of the photometer during its measure cycle	0 mV	5000 mV*	If the value displayed is: - >5000 mV: The UV source has become brighter; adjust the UV Detector Gain potentiometer. - < 100mV – 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 I²C Bus. If the PHOTO REFERENCE value changes by more than 10mV between zero and span gas: - Defective/leaking M/R switching valve.
O3 PHOTO REF	The raw output of the photometer during its reference cycle	0 mV	5000 mV	
O3 GEN REF	The raw output of the O ₃ generator's reference detector	0 mV	5000 mV	Possible causes of faults are the same as O3 GEN REFERENCE WARNING from Table 9-1.
SAMPLE PRESSURE	The pressure of gas in the photometer absorption tube	0 "Hg	40 "Hg-In-A	Check for Gas Flow problems.
SAMPLE FLOW	The gas flow rate through the photometer	0 cm ³ /min	1000 cm ³ /m	Check for Gas Flow problems.
SAMPLE TEMP	The temperature of gas in the photometer absorption tube	0 C°	70 C°	Possible causes of faults are the same as PHOTO STEMP from Table 9-2.
PHOTO LAMP TEMP	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 - I²C Bus - Hot Lamp
O3 LAMP TEMP	The temperature of the O ₃ generator's UV lamp	0 mV	5000 mV	Same as PHOTO LAMP TEMP WARNING from Table 9-1.
CHASSIS TEMP	The temperature inside the T700's chassis (same as BOX TEMP)	0 C°	70 C°	Possible causes of faults are the same as BOX TEMP from Table 9-2.
O3 PHOTO CONC	The current concentration of O ₃ being measured by the photometer.	---	---	- I²C 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 O₃ generator. - Internal A/D converter problem.

9.3. USING THE INTERNAL ELECTRONIC STATUS LEDS

Several LEDs are located inside the instrument to assist in determining if the calibrators CPU, I²C bus and Relay PCA are functioning properly.

9.3.1. CPU STATUS INDICATOR

DS5, a red LED, that is located on upper portion of the motherboard, just to the right of the CPU board, flashes when the CPU is running the main program loop. After power-up, approximately 30 – 60 seconds, DS5 should flash on and off. If DS5 does not flash then the program files may have become corrupted; contact customer service 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.

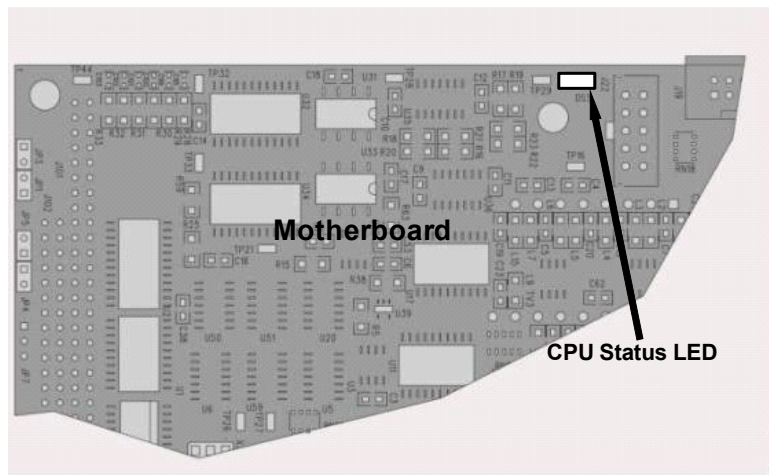


Figure 9-2: CPU Status Indicator

9.3.2. RELAY PCA STATUS LEDS

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

9.3.2.1. I²C Bus Watchdog Status LEDS

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

Table 9-4: Relay PCA Watchdog LED Failure Indications

LED	Function	Fault Status	Indicated Failure(s)
D1 (Red)	I ² C bus Health (Watchdog Circuit)	Continuously ON or Continuously OFF	Failed/Halted CPU Faulty Mother Board, Valve Driver board or Relay PCA Faulty Connectors/Wiring between Mother Board, 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.

9.3.2.2. O₃ Option Status LEDs

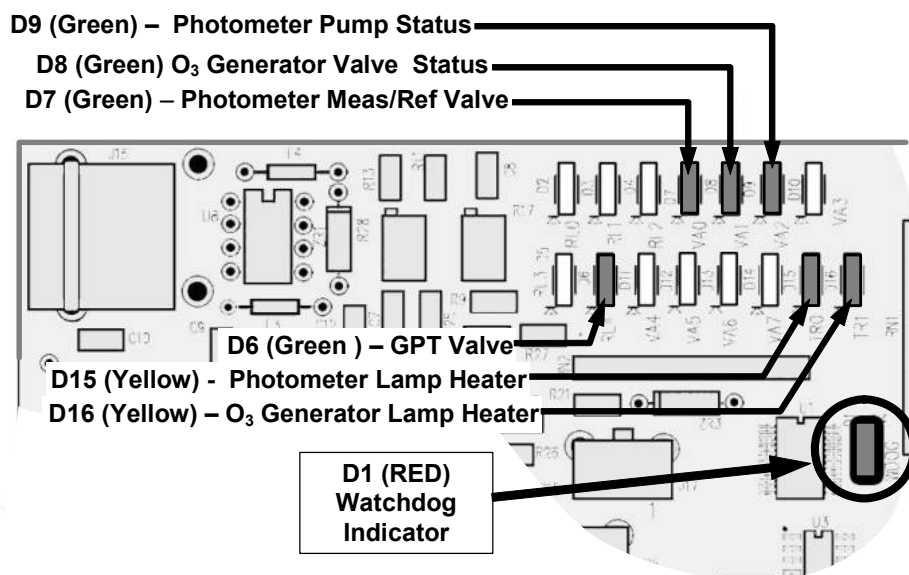


Figure 9-3: Relay PCA Status LEDs Used for Troubleshooting

Table 9-5: 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 O₃ generator options installed.

9.3.3. 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.

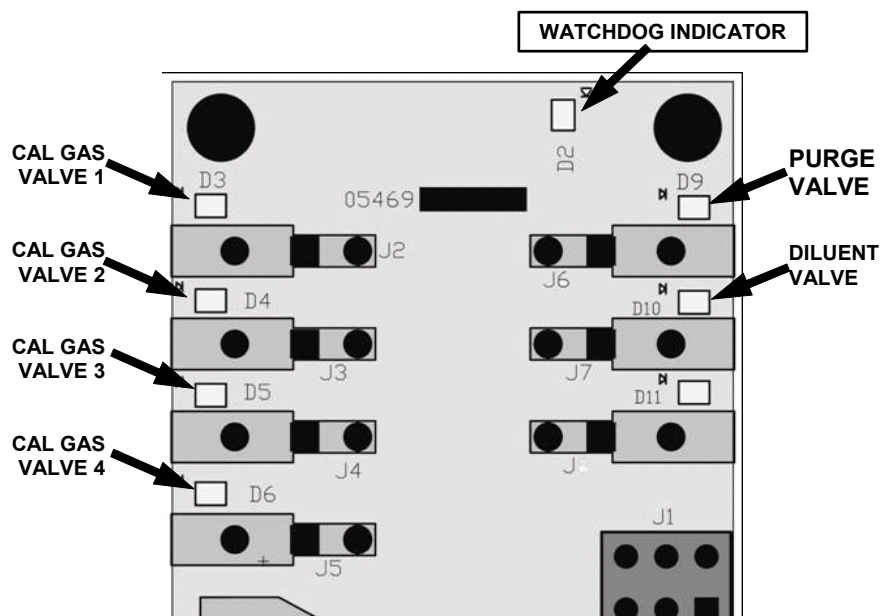


Figure 9-4: Valve Driver PCA Status LEDs Used for Troubleshooting

Table 9-6: Valve Driver Board Watchdog LED Failure Indications

LED	Function	Fault Status	Indicated Failure(s)
D1 (Red)	I ² C bus Health (Watchdog Circuit)	Continuously ON or Continuously OFF	- Failed/Halted CPU - Faulty Mother Board, Valve Driver board or Relay PCA - Faulty Connectors/Wiring between Mother Board, Valve Driver board or Relay PCA - Failed/Faulty +5 VDC Power Supply (PS1)

Table 9-7: 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
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	- Failed Valve Driver Board - Faulty +12 VDC Supply (PS2) - Faulty Connectors/Wiring
D10	Diluent Valve Status	INPUT_VALVE	

9.4. SUBSYSTEM CHECKOUT

The preceding sections of this manual discussed a variety of methods for identifying possible sources of failures or performance problems within the T700 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.

9.4.1. VERIFY SUBSYSTEM CALIBRATION

A good first step when troubleshooting the operation of the T700 calibrator is to verify that its major subsystems are properly calibrated. These are:

- The mass flow controllers (see Section 7.2).
- Test Channel D → A conversion (see Sections 4.10.1.7, 9.4.11.1, and 10.3.5.1).
- Gas pressure calibration (see Section 7.5).

When optional O₃ components are installed, you should also check:

- Photometer calibration (see Section 7.3).
- O₃ generator calibration (see Section 7.4).

9.4.2. AC MAIN POWER

The T700 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.

9.4.3. 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 9-5 and Table 9-8.

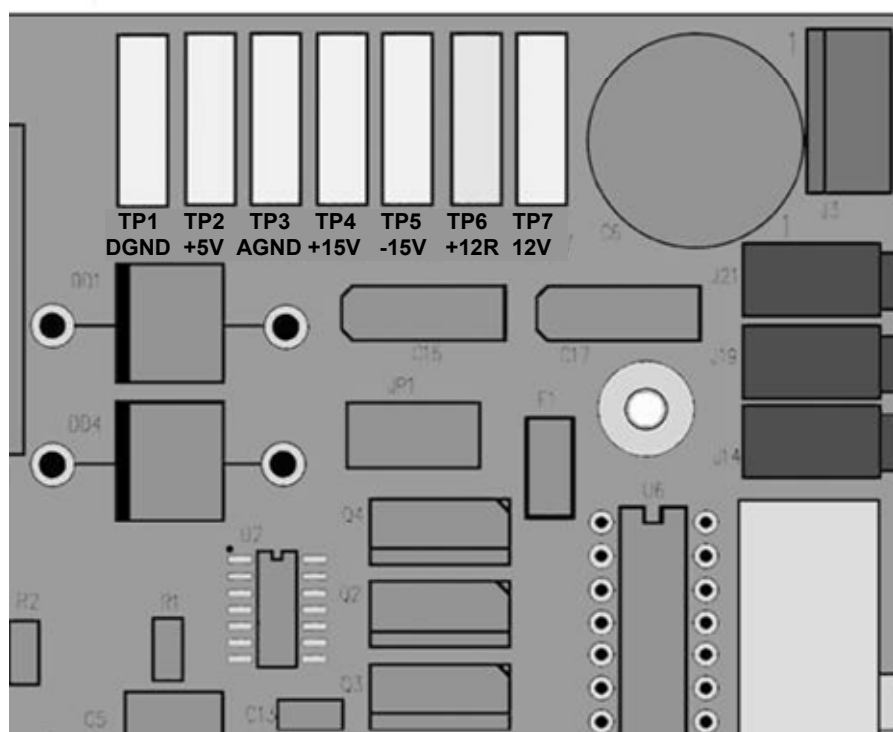


Figure 9-5: Location of DC Power Test Points on Relay PCA

Table 9-8: 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 9-9, 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 9-9: 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

9.4.4. I²C BUS

Operation of the I²C 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 I²C 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 I²C bus if both D1 on the relay PCA and D2 of the Valve Driver PCA are ON/OFF constantly.

9.4.5. 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.

9.4.6. 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.

9.4.7. RELAY PCA

The Relay PCA can be most easily checked by observing the condition of the status LEDs on the Relay PCA (see Section 9.3.2), and using the **SIGNAL I/O** submenu under the **DIAG** menu (see Section 4.10) 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 9-10 lists the control device associated with a particular function.

Table 9-10: Relay PCA Control Devices

FUNCTION	CONTROL DEVICE	IN SOCKET
UV Lamp Heater	Q2	No
O ₃ Gen Heater	Q3	No
All Valves	U5	Yes

9.4.8. 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 9.3.2), and using the **SIGNAL I/O** submenu under the **DIAG** menu (see Section 9.1.3) 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.

9.4.9. 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 3-6) 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:

BASIC PCA OPERATION:

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

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:

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

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.

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.
 - Evaluate the reading in the same manner as for the cal gas pressure sensor.

9.4.10. PHOTOMETER O₃ GENERATOR PRESSURE/FLOW SENSOR ASSEMBLY

This assembly is only present in calibrators with O₃ generator and/or photometer options installed. The pressure/flow sensor PCA, located at the rear of the instrument between the O₃ generator and the photometer pump (see Figure 3-6) 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:

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.

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:

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

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.

O₃ 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 9.4.9).

PHOTOMETER FLOW SENSOR

- 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.

9.4.11. MOTHERBOARD

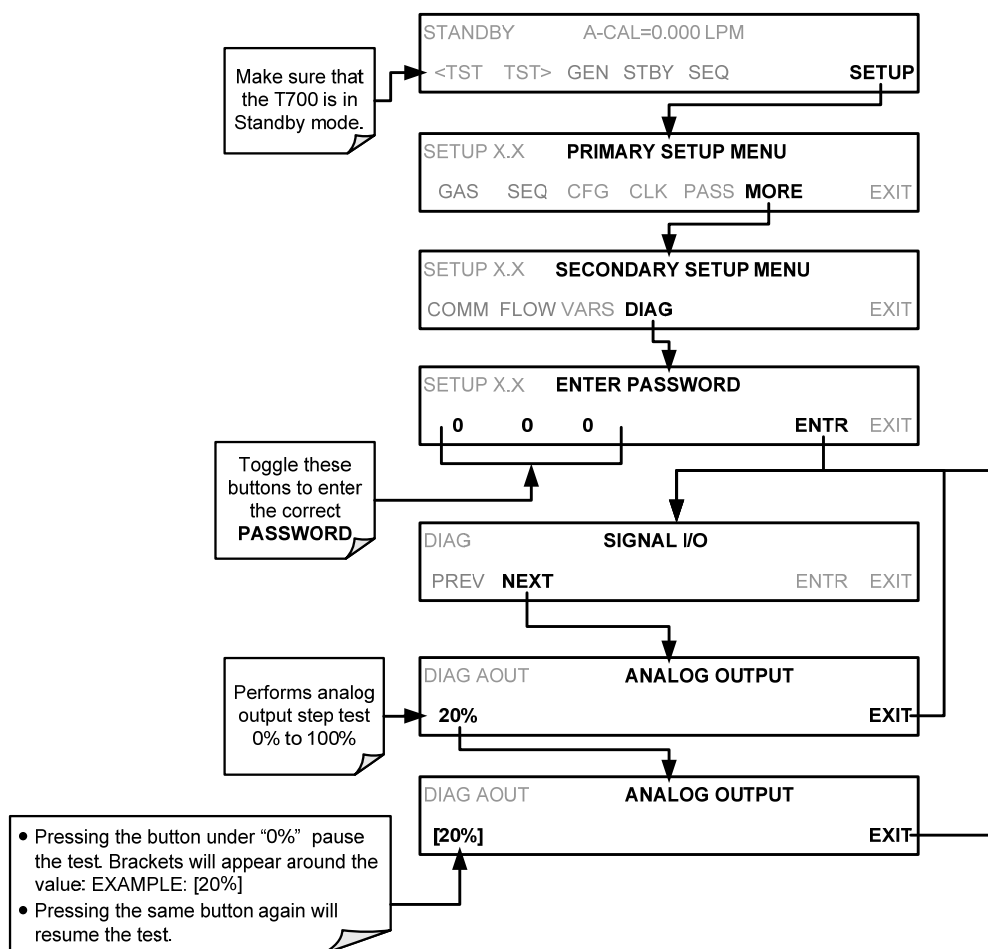
9.4.11.1. A/D Functions

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

1. Use the Signal I/O function (See Section 9.1.3 and Appendix A) to view the value of REF_4096_MV and REF_GND. If both are within 3 mV of nominal (4096 and 0), and are stable, ± 0.5 mV then the basic A/D is functioning properly. If not then the motherboard is bad.
2. Choose a parameter in the Signal I/O function such as Dil_Press, MFC_FLOW_1 or SAMPLE_FLOW.
 - Compare these voltages at their origin (see the interconnect drawing and interconnect list in Appendix D) with the voltage displayed through the signal I/O function.
 - If the wiring is intact but there is a large difference between the measured and displayed voltage (± 10 mV) then the motherboard is bad.

9.4.11.2. Test Channel / Analog Outputs Voltage

To verify that the analog output is working properly, connect a voltmeter to the output in question and perform an analog output step test as follows:



For each of the steps the output should be within 1% of the nominal value listed in the table below except for the 0% step, which should be within $0\text{mV} \pm 2$ to 3 mV . Ensure you take into account any offset that may have been programmed into channel (See Section 4.10.1.5).

Table 9-11: Analog Output Test Function – Nominal Values Voltage Outputs

		FULL SCALE OUTPUT OF VOLTAGE RANGE (see Section 4.10.1.3)			
		100MV	1V	5V	10V
STEP	%	NOMINAL OUTPUT VOLTAGE			
1	0	0	0	0	0
2	20	20 mV	0.2	1	2
3	40	40 mV	0.4	2	4
4	60	60 mV	0.6	3	6
5	80	80 mV	0.8	4	8
6	100	100 mV	1.0	5	10

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

9.4.11.3. Status Outputs

To test the status output electronics:

1. Connect a jumper between the “D” pin and the “▽” pin on the status output connector.
2. Connect a 1000 ohm resistor between the “+” pin and the pin for the status output that is being tested.
3. Connect a voltmeter between the “▽” pin and the pin of the output being tested (see table below).
4. Under the DIAG→ Signal I/O menu (See Section 9.1.3), scroll through the inputs and outputs until you get to the output in question.
5. Alternatively, 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 9-12: Status Outputs Check

PIN (LEFT TO RIGHT)	STATUS
1	ST_SYSTEM_OK
2	SPARE
3	ST_CAL_ACTIVE
4	ST_DIAG_MODE
5	ST_TEMP_ALARM
6	ST_PRESS_ALARM
7	PERM_VALVE_1
8	PERM_VALVE_2

9.4.11.4. Control Inputs

Table 9-13: T700 Control Input Pin Assignments and Corresponding Signal I/O Functions

CONNECTOR	INPUT	CORRESPONDING I/O SIGNAL
Top	A	CONTROL_IN_1
Top	B	CONTROL_IN_2
Top	C	CONTROL_IN_3
Top	D	CONTROL_IN_4
Top	E	CONTROL_IN_5
Top	F	CONTROL_IN_6
Bottom	G	CONTROL_IN_7
Bottom	H	CONTROL_IN_8
Bottom	I	CONTROL_IN_9
Bottom	J	CONTROL_IN_10
Bottom	K	CONTROL_IN_11
Bottom	L	CONTROL_IN_12

The control input bits can be tested by applying a trigger voltage to an input and watching changes in the status of the associated function under the SIGNAL I/O submenu:

EXAMPLE: to test the “A” control input:

1. Under the DIAG→ Signal I/O menu (See Section 9.1.3), scroll through the inputs and outputs until you get to the output named 0) CONTROL_IN_1.
2. Connect a jumper from the “+” pin on the appropriate connector to the “U” on the same connector.
3. Connect a second jumper from the “▽” pin on the connector to the “A” pin.
4. The status of 0) CONTROL_IN_1 should change to read “ON”.

9.4.11.5. 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 9-14).
4. Under the DIAG→ Signal I/O menu (See Section 9.1.3), scroll through the inputs and outputs until you get to the output in question.
5. Alternately, turn on and off the output noting the voltage on the voltmeter.
 - It should vary between 0 volts for ON and 5 volts for OFF.

Table 9-14: Control Outputs Pin Assignments and Corresponding Signal I/O Functions Check

PIN (LEFT TO RIGHT)	STATUS
1	CONTROL_OUT_1
2	CONTROL_OUT_2
3	CONTROL_OUT_3
4	CONTROL_OUT_4
5	CONTROL_OUT_5
6	CONTROL_OUT_6
7	CONTROL_OUT_7
8	CONTROL_OUT_8
9	CONTROL_OUT_9
10	CONTROL_OUT_10
11	CONTROL_OUT_11
12	CONTROL_OUT_12

9.4.12. 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.

9.4.13. 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.

9.4.14. RS-232 COMMUNICATIONS

9.4.14.1. 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 3.3.1.7 for connector and pin-out information.
- The BAUD rate and protocol are incorrectly configured. See Section 5.2.
- If a modem is being used, additional configuration and wiring rules must be observed. See Section 6.3.
- Incorrect setting of the DTE-DCE Switch is set correctly. See Section 5.1.
- Verify that the cable (P/N 03596) that connects the serial COMM ports of the CPU to J12 of the motherboard is properly seated.

9.4.14.2. Troubleshooting Calibrator/Modem or Terminal Operation

These are the general steps for troubleshooting problems with a modem connected to a Teledyne API calibrator.

1. Check cables for proper connection to the modem, terminal or computer.
2. Check to ensure the DTE-DCE is in the correct position as described in Section 5.1.
3. Check to ensure the set up command is correct. See Section 6.2.
4. Verify that the Ready to Send (RTS) signal is at logic high. The T700 sets pin 7 (RTS) to greater than 3 volts to enable modem transmission.
5. Ensure the BAUD rate, word length, and stop bit settings between modem and calibrator match. See Section 5.2.1.
6. Use the RS-232 test function to send “w” characters to the modem, terminal or computer. See Section 5.2.3.
7. Get your terminal, modem or computer to transmit data to the calibrator (holding down the space bar is one way); the green LED should flicker as the instrument is receiving data.
8. Ensure that the communications software or terminal emulation software is functioning properly.

Note

Further help with serial communications is available in a separate manual “RS-232 Programming Notes” Teledyne API’s P/N 013500000.

9.4.15. 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 T700 will perform poorly.

9.4.15.1. Box / Chassis Temperature

The box temperature sensor is mounted to the Motherboard and cannot be disconnected to check its resistance. Rather check the **BOX TEMP** signal using the **SIGNAL I/O** function under the **DIAG** Menu (see Section 9.1.3). This parameter will vary with ambient temperature, but at ~30°C (6-7° above room temperature) the signal should be ~1450 mV.

9.4.15.2. Photometer Sample Chamber Temperature

The temperature of the gas in the photometer sample chamber should read approximately 5.0°C higher than the box temperature.

9.4.15.3. 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 I²C 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°C set point is ~8.1k ohms.

9.4.15.4. 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 I²C 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_HEATER** parameter under the **SIGNAL I/O** submenu of the **DIAG** 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.

9.5. TROUBLESHOOTING THE OPTIONAL O₃ PHOTOMETER

9.5.1. DYNAMIC PROBLEMS WITH THE OPTIONAL O₃ PHOTOMETER

Dynamic problems are problems that only manifest themselves when the photometer is measuring O₃ 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.

9.5.1.1. Noisy or Unstable O₃ Readings at Zero

- Check for leaks in the pneumatic system as described in Section 8.2.1.
- 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 8.2.2.
- 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.

9.5.1.2. Noisy, Unstable, or Non-Linear Span O₃ Readings

- Check for leaks in the pneumatic systems as described in Section 8.2.1.
- Check for proper operation of the meas/ref switching valve as described in Section 9.5.2.
- Check for dirty absorption cell and clean or replace as necessary as described in Section 8.2.2.
- Check for operation of the A/D circuitry on the motherboard. See Section 9.4.11.1.
- Confirm the Sample Temperature, Sample Pressure and Sample Flow readings are correct. Check and adjust as required.

9.5.1.3. Slow Response to Changes in Concentration

- Check for dirty absorption cell and clean or replace as necessary as described in Section 8.2.2.
- Check for pneumatic leaks as described in Section 8.2.1.
- 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 3.4.9).

9.5.1.4. The Analog Output Signal Level Does Not Agree With Front Panel Readings

- Confirm that the recorder offset (see Section 4.10.1.5) is set to zero.
- Perform an AIO calibration (see Section 4.10.1.6) and photometer dark calibration (see Section 7.3.5).

9.5.1.5. Cannot Zero

- Check for leaks in the pneumatic system as described in Section 8.2.1.
- Confirm that the Zero gas is free of Ozone.
- 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 3.4.9).

9.5.1.6. Cannot Span

- Check for leaks in the pneumatic systems as described in Section 8.2.1.
- Check for proper operation of the meas/ref switching valve as described in Section 9.5.2.
- Check for dirty absorption cell and clean or replace as necessary as described in Section 8.2.2.
- Check for operation of the A/D circuitry on the motherboard. See Section 9.4.11.1.
- 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 3.4.9).

9.5.2. CHECKING MEASURE / REFERENCE VALVE

1. To check the function of the photometer's measure / reference valve:
2. Set the calibrator's front panel display to show the PHOTO REFERENCE test function (see Section 4.1.1).
3. Follow the instruction in Sections 7.3.3 and 7.3.4.1 for performing a zero point calibration of the photometer.
 - Press XZro and allow the calibrator to stabilize.
4. Before completing the calibration by pressing the ZERO button, note of the displayed value.
5. Press the final Zero button then press "NO" when asked, "ARE YOU SURE".
6. Follow the instruction in Sections 7.3.4.2 for performing a span point calibration of the photometer.
 - Press XSPN and allow the calibrator to stabilize.
7. Before completing the calibration by pressing the SPAN button, note of the displayed value of PHOTO REFERENCE.
 - If the O3 REF value has decreased by more than 2 mV from its value with Zero-gas, then there is a "cross-port" leak in the M/R valve.
8. Press the final Zero button then press "NO" when asked, "ARE YOU SURE".

9.5.3. CHECKING THE UV LAMP POWER SUPPLY

Note

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

**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 9.4.3.
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 10-20):
 - +4500 mVDC $\pm$ 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.

9.6. TROUBLESHOOTING THE OPTIONAL O₃ GENERATOR

The only significant components of the O₃ generator that might reasonable malfunction is the power supply assembly for the UV source lamp and the lamp itself.

9.6.1. CHECKING THE UV SOURCE LAMP POWER SUPPLY

Note

Appendix D 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 9.4.3.
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 10-20):
 - +800 mVDC $\pm$ 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.

9.7. SERVICE PROCEDURES

9.7.1. DISK-ON-MODULE REPLACEMENT PROCEDURE

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.

9.8. TECHNICAL ASSISTANCE

If this manual and its service & repair section do not solve your problems, technical assistance may be obtained from:

**TELEDYNE API, CUSTOMER SERVICE,
9480 CARROLL PARK DRIVE
SAN DIEGO, CALIFORNIA 92121-5201
USA**

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

Before you contact customer service, fill out the problem report form in Appendix C, which is also available online for electronic submission at <http://www.teledyne-api.com/forms/>.

9.9. FREQUENTLY ASKED QUESTIONS (FAQs)

The following list of FAQs is from the Teledyne API's Customer Service Department's most commonly asked questions relating to the T700 Dynamic Dilution Calibrator.

Question	Answer
My ozone ACT =XXXX 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 number until finally stabilizing.	Perform an O ₃ Gen Adjust (Section 8.2.5), and then an O ₃ Gen Calibration (Section 7.4). Re-run points.
Why does the ENTR button sometimes disappear on the front panel display?	Once you adjust the setting to an allowable value, the ENTR button will re-appear.
How do I make the RS-232 Interface Work?	See Sections 3.3.1.7, 5, and 9.4.14
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 Customer Service.
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.

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10. PRINCIPLES OF OPERATION

10.1. BASIC PRINCIPLES OF DYNAMIC DILUTION CALIBRATION

The T700 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 T700 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 is known (and therefore the density of the gases).

The CPU calculates both the required source gas and diluent gas flow rates and controls the corresponding mass flow controllers by the following equation.

Equation 10-1

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

WHERE:

C_f = final concentration of diluted gas

C_i = source gas concentration

GAS_{flow} = source gas flow rate

$Totalflow$ = the total gas flow through the calibrator

Totalflow is determined as:

Equation 10-2a

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

WHERE:

GAS_{flow} = source gas flow rate

$Diluent_{flow}$ = zero air flow rate

For instrument with multiple source gas MFC total Flow is:

Equation 10-2b

$$TOTALFLOW = GAS_{flow\ MFC1} + GAS_{flow\ MFC2} \dots + GAS_{flow\ MFCn} + Diluent_{flow\ rate}$$

This dilution process is dynamic. The T700's 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 T700 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 T700, it will create an exact output concentration of any of the gases in the bottle.

10.1.1. GAS PHASE TITRATION MIXTURES FOR O₃ AND NO₂

Because ozone is a very reactive and therefore under normal ambient conditions a short-lived gas, it cannot be reliably bottled, however, an optional O₃ generator can be included in the T700 calibrator that allows the instrument to be used to create calibration mixtures that include O₃.

This ability to generate O₃ internally also allows the T700 Dynamic Dilution Calibrator to be used to create calibration mixture containing NO₂ using a gas phase titration process (GPT) by precisely mixing bottled NO of a known concentration with O₃ of a known concentration and diluent gas (zero air).

The principle of GPT is based on the rapid gas phase reaction between NO and O₃ that produces quantities of NO₂ as according to the following equation:

Equation 10-3



Under controlled circumstances, the NO-O₃ reaction is very efficient (<1% residual O₃), therefore the concentration of NO₂ resulting from the mixing of NO and O₃ can be accurately predicted and controlled as long as the following conditions are met:

- The amount of O₃ used in the mixture is known.
- The amount of NO used in the mixture is **AT LEAST** 10% greater than the amount O₃ in the mixture.
- The volume of the mixing chamber is known.
- The NO and O₃ 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 NO₂ being output by the T700 will be equal to (at a 1:1 ratio) the amount of O₃ added.

Since:

- The O₃ flow rate of the T700's O₃ 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 **TOTALFLOW** is determined and entered into the T700's memory and target concentration for the O₃ generator are entered into the calibrator's software, the T700 adjusts the NO flow rate and diluent (zero air) flow rate to precisely create the appropriate NO₂ concentration at the output.

In this case, **Totalflow** is calculated as:

Equation 10-4

$$DIL_{flow} = Totalflow - NOGAS_{flow} - O_{3flow}$$

WHERE:

$NOGAS_{flow}$ = NO source gas flow rate (For calibrator's 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_{3flow} = 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 the T700 calibrator that allows the CPU to tracks 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.

10.2. PNEUMATIC OPERATION

The T700 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 purges 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 3-21 and Section 3.3.2 for descriptions of the internal pneumatics for the T700 calibrator.

10.2.1. GAS FLOW CONTROL

The precision of gas flow through the T700 Dynamic Dilution Calibrator is centrally critical to its ability to mix calibration gases accurately. This control is established in several ways.

10.2.1.1. Diluent and Source Gas Flow Control

Diluent and source gas flow in the T700 calibrator is a directly and dynamically controlled by using highly accurate Mass Flow Controller. These MFCs include internal sensors that determine the actual flow of gas through 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 flow through the sensor is always laminar.

The MFCs 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 this decrease and increase of temperature in the capillary tube and produces a mVDC output signal proportional to that change that is proportional to the rate of flow through the MFCs 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 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 T700's 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 MFCs 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.

The entire control loop is set up so that as solenoid valve opens and closes to vary the flow of gas through the shunt, valve and sensor in an attempt to minimize the differential between the control voltage for the target flow rate and the flow sensor output voltage generated by the actual flow rate of gas through the controller.

This process is heavily dependant 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 (see Section 3.4.6.3). 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.

10.2.1.2. Flow Control Assemblies for Optional O₃ 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 orifices 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.

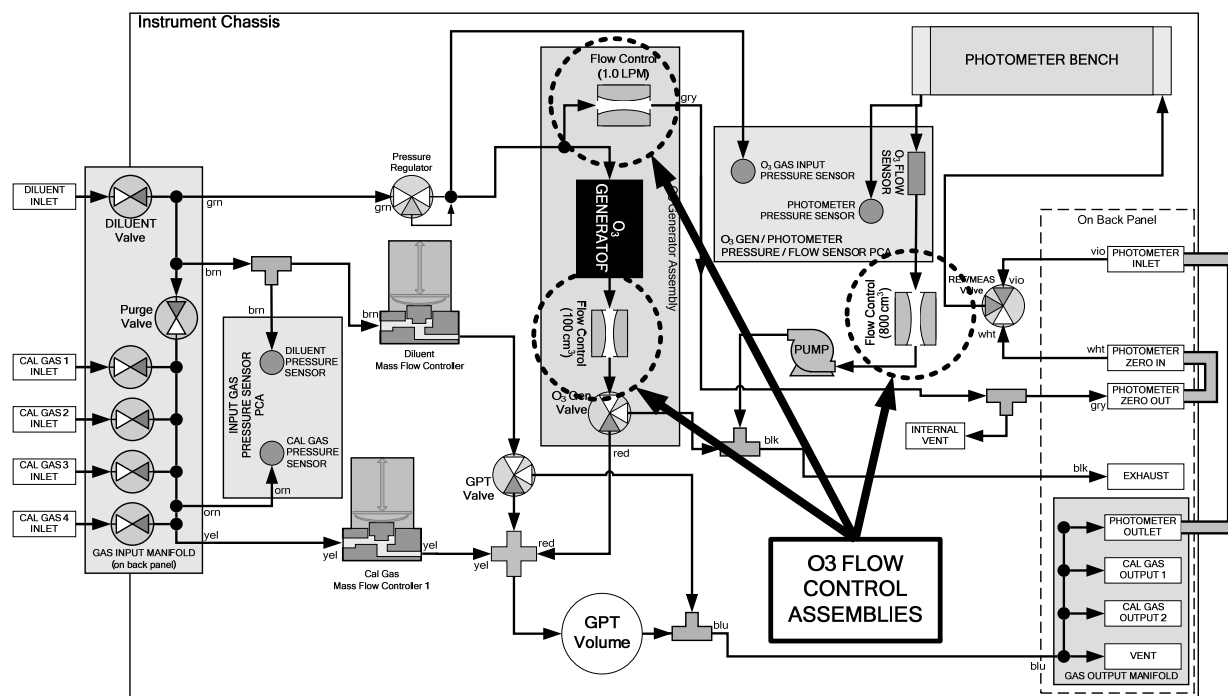


Figure 10-1: Location of Gas Flow Control Assemblies for T700's with O₃ Options Installed

The flow orifice 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.

10.2.1.3. 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 through 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 through 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.

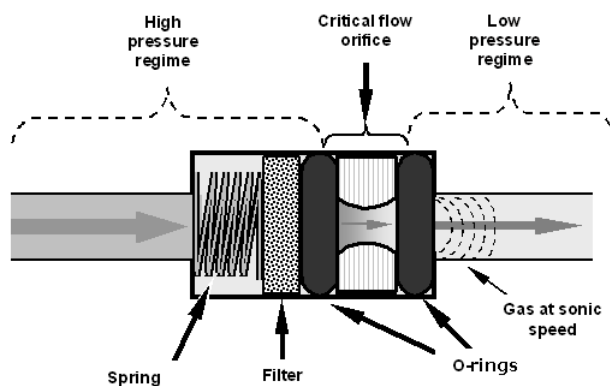


Figure 10-2: Flow Control Assembly & Critical Flow Orifice

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.

10.2.2. INTERNAL GAS PRESSURE SENSORS

The T700 includes a single pressure regulator. Depending upon how many and which options are installed in the T700 calibrator, 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 O₃ 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 O₃ 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 O₃ 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 O₃ concentration inside the absorption tube.

10.3. ELECTRONIC OPERATION

10.3.1. OVERVIEW

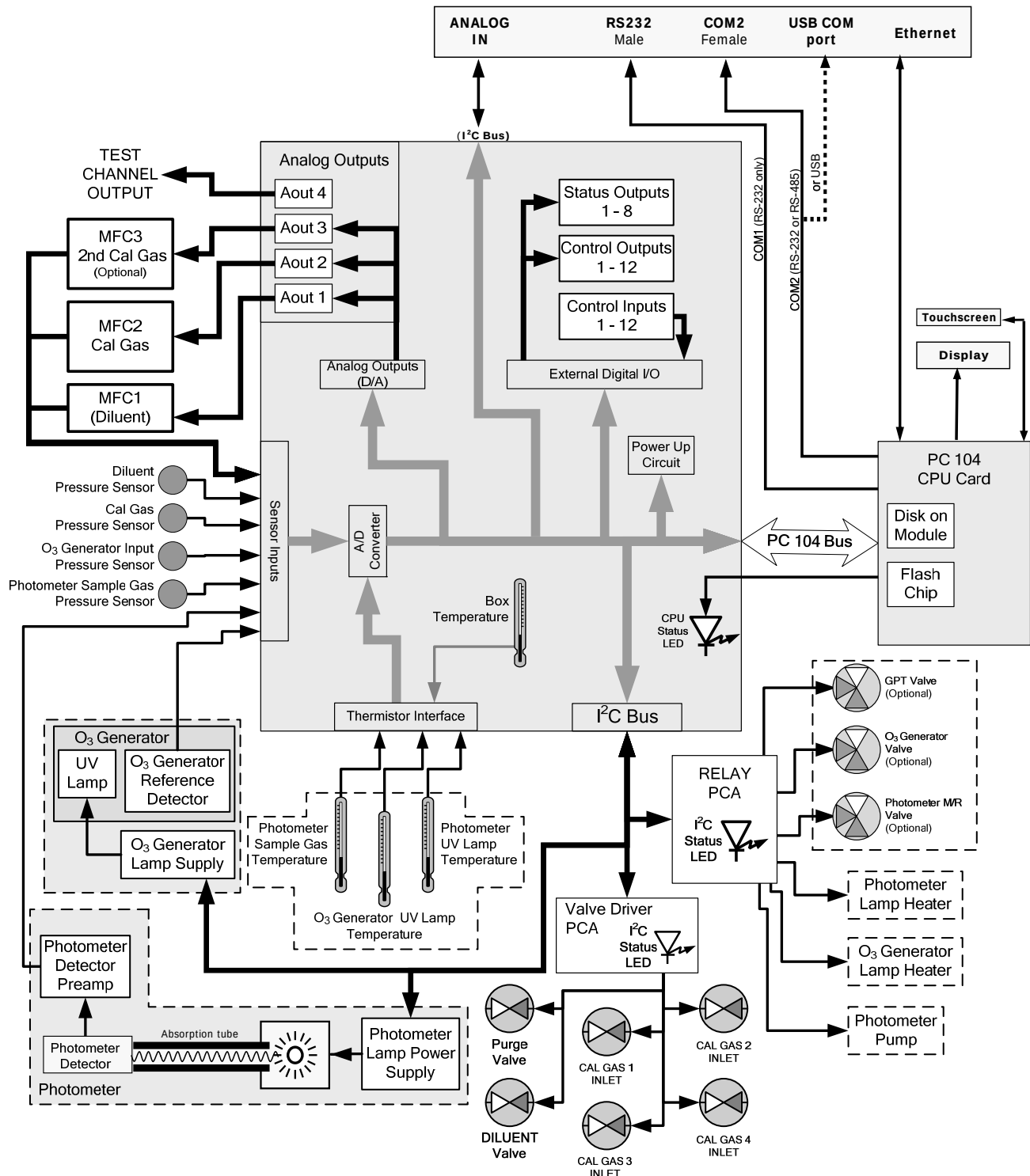


Figure 10-3: T700 Electronic Block Diagram

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 sub components of the T700 (e.g. flow data from the MFCs, O₃ 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;
- RS 232 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 I²C bus) located on a separate printed circuit assembly to control the function of key electromechanical devices such as heaters, motors and valves.

10.3.2. CPU

The unit's CPU card (Figure 10-4) 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:

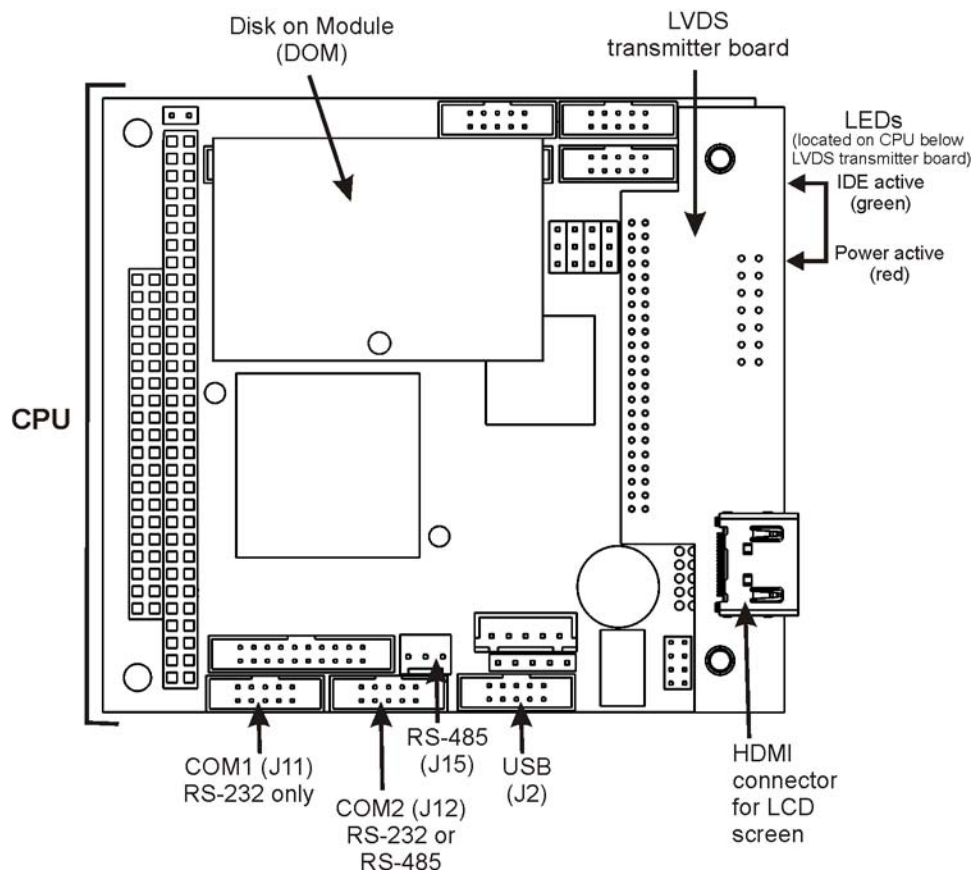


Figure 10-4: T700 CPU Board Annotated

The CPU includes two types of non-volatile data storage: an embedded 2MB flash chip and a Disk on Module (DOM).

10.3.2.1. Disk-on-Module (DOM)

The DOM is a 44-pin IDE flash chip with a storage capacity up to 256 MB. It is used to store the computer's operating system, the Teledyne API firmware, and most of the operational data. The LEDs on the DOM indicate power and reading/writing to or from the DOM.

10.3.2.2. Flash Chip

This non-volatile, embedded flash chip includes 2MB of storage for calibration data as well as a backup of the analyzer configuration. Storing these key data on a less heavily accessed chip significantly decreases the chance of data corruption.

In the unlikely event that the flash chip should fail, the calibrator will continue to operate with just the DOM. However, all configuration information will be lost, requiring the unit to be recalibrated.

10.3.3. RELAY PCA

The relay PCA is one of the central switching and power distribution units of the calibrator. It contains power relays, valve drivers and status LEDs for all heated zones and valves, as well as thermocouple amplifiers, power distribution connectors and the two switching power supplies of the calibrator. The relay PCA communicates with the motherboard over the I²C bus and can be used for detailed trouble-shooting of power problems and valve or heater functionality.

Generally, the relay PCA is located in the right-rear quadrant of the calibrator and is mounted vertically on the back of the same bracket as the instrument's DC power supplies, however the exact location of the relay PCA may differ from model to model (see Figure 3-5 or Figure 3-6).

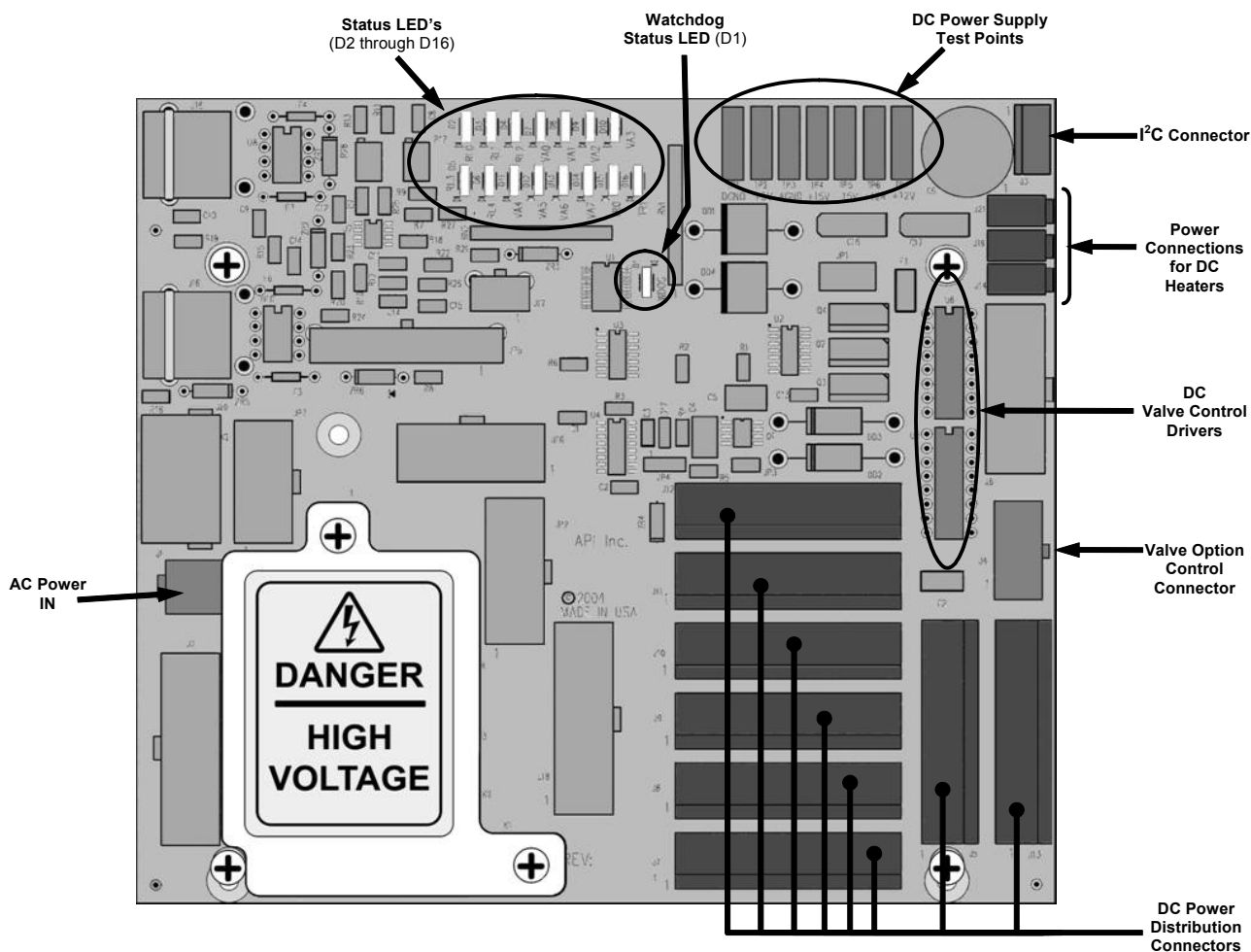


Figure 10-5: Relay PCA

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

10.3.3.1. Valve Control

The relay PCA also hosts two valve driver chips, each of which can drive up four valves. In the T700, the relay PCA controls only those valves associated with the O₃ generator and photometer options. All valves related to source gas and diluent gas flow are controlled by a separate valve driver PCA (see Section 10.3.4).

10.3.3.2. Heater Control

The relay PCA controls the various DC heaters related to the O₃ generator and photometer options.

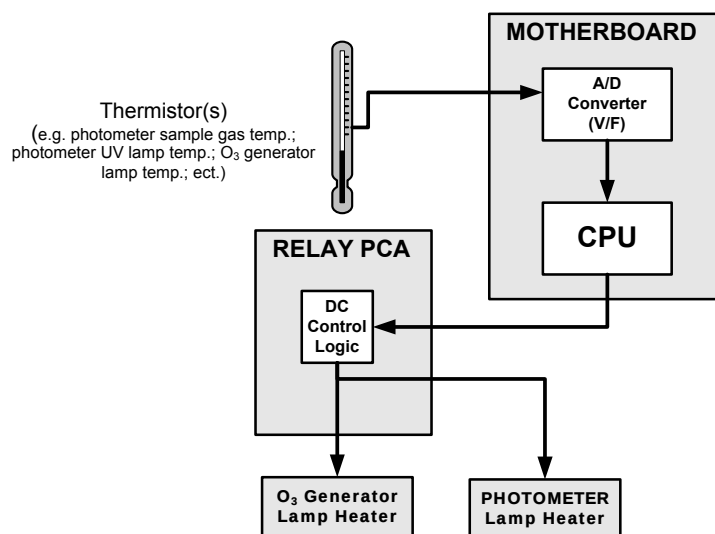


Figure 10-6: Heater Control Loop Block Diagram.

10.3.3.3. Relay PCA Status LEDs & Watch Dog Circuitry

Thirteen LEDs are located on the calibrator's relay PCA to indicate the status of the calibrator's heating zones and some of its valves as well as a general operating watchdog indicator. Table 10-1 shows the status of these LEDs and their respective functionality.

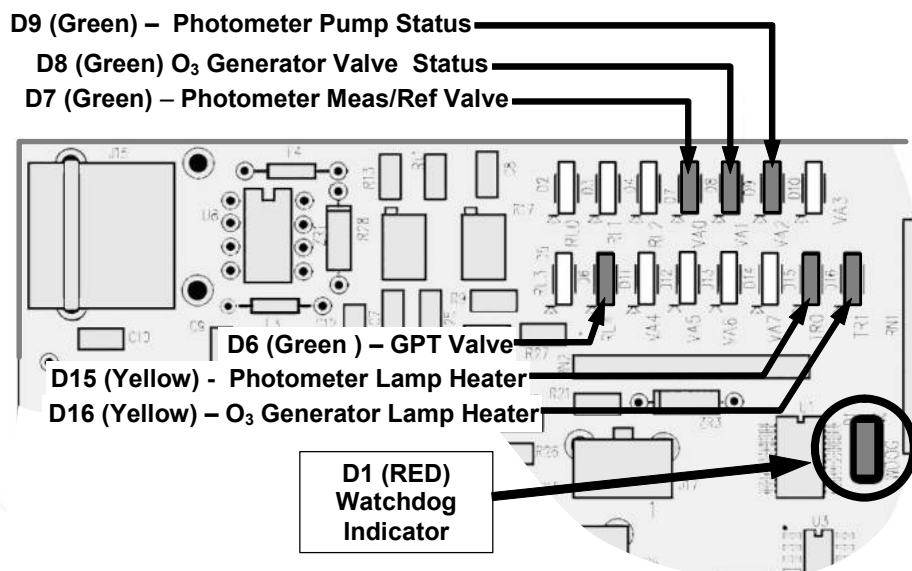


Figure 10-7: Status LED Locations – Relay PCA

Table 10-1: Relay PCA Status LEDs

LED	COLOR	DESCRIPTION	FUNCTION
D1	Red	Watchdog Circuit; I ² C bus operation.	Blinks when I ² C 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.			

10.3.3.4. Relay PCA Watchdog Indicator (D1)

The most important of the status LEDs on the relay PCA is the red I²C Bus watchdog LED. It is controlled directly by the calibrator's CPU over the I²C bus. Special circuitry on the relay PCA watches the status of D1. Should this LED ever stay ON or OFF for 30 seconds (indicating that the CPU or I²C bus has stopped functioning) this Watchdog Circuit automatically shuts all valves and turns off all heaters and lamps.

10.3.4. VALVE DRIVER PCA

The valves that operate the T700 calibrator's main source gas and diluent gas inputs are controlled by a PCA that is attached directly to the input valve manifold (see Figure 3-5 or Figure 3-6). Like the relay PCA, the valve driver PCA communicates with T700's CPU through the motherboard over the I²C bus.

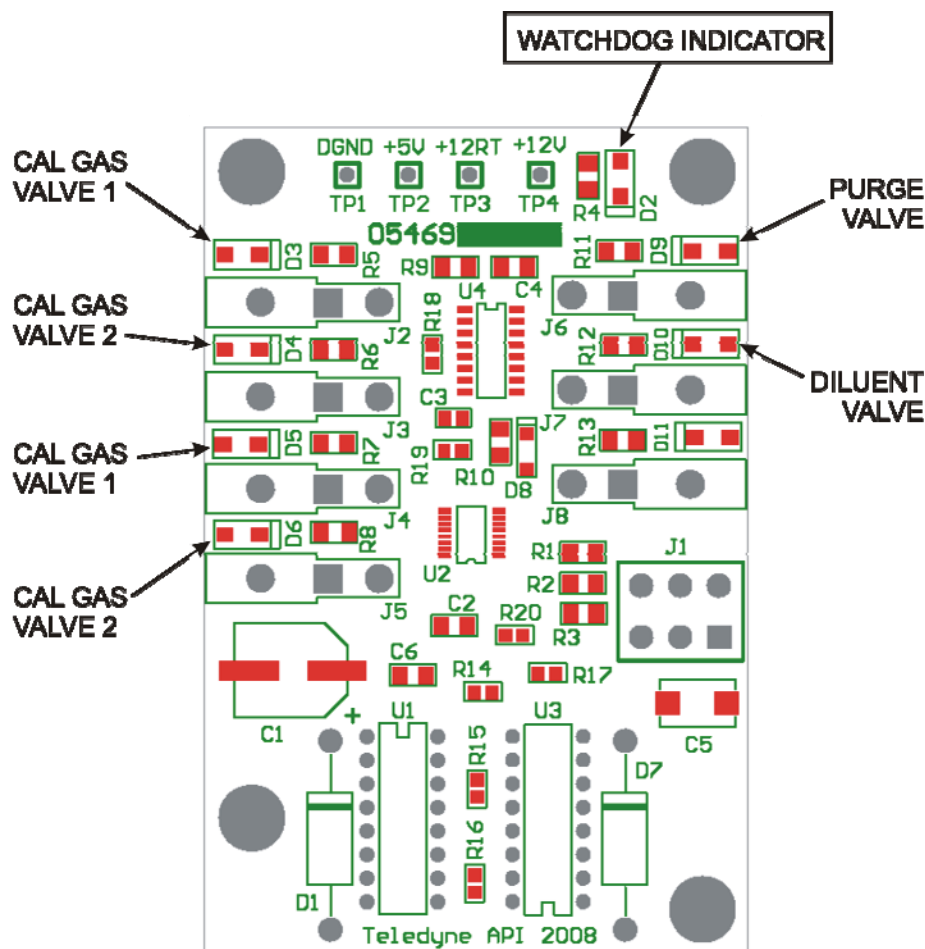


Figure 10-8: Status LED Locations – Valve Driver PCA

10.3.4.1. Valve Driver PCA Watchdog Indicator

The most important of the status LEDs on the relay PCA is the red I²C Bus watchdog LED. It is controlled directly by the calibrator's CPU over the I²C bus. Like the watchdog LED on the relay PCA, should this LED ever stay ON or OFF for 30 seconds if the CPU or I²C bus has stopped functioning, this Watchdog Circuit automatically shuts all valves and turns off all heaters and lamps.

10.3.5. MOTHERBOARD

This is the largest electronic assembly in the calibrator and is mounted to the rear panel as the base for the CPU board and all I/O connectors. This printed circuit assembly provides a multitude of functions including A/D conversion, digital input/output, PC-104 to I²C translation, temperature sensor signal processing and is a pass through for the RS-232 and RS-485 signals.

10.3.5.1. A to D Conversion

Analog signals, such as the voltages received from the calibrator's various sensors, are converted into digital signals that the CPU can understand and manipulate by the analog to digital converter (A/D). Under the control of the CPU, this functional block selects a particular signal input and then converts the selected voltage into a digital word.

The A/D consists of a voltage-to-frequency (V-F) converter, a programmable logic device (PLD), three multiplexers, several amplifiers and some other associated devices. The V-F converter produces a frequency proportional to its input voltage. The PLD counts the output of the V-F during a specified time 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, two reference voltages are supplied to the A/D converter: Reference ground and +4.096 VDC. During calibration, the device measures these two voltages and outputs their digital equivalent to the CPU. The CPU uses these values to compute the converter's offset and slope, then uses these factors for subsequent calculations.

10.3.5.2. 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.

10.3.5.3. Thermistor Interface

This circuit provides excitation, termination and signal selection for several negative-coefficient, thermistor temperature sensors located inside the calibrator.

10.3.5.4. Analog Outputs

The T700 calibrator comes equipped with one analog output. It can be set by the user to output a signal level representing any one of the test parameters (see Table 4-14) and will output an analog VDC signal that rises and falls in relationship with the value of the chosen parameter.

10.3.5.5. 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 of the calibrator. These outputs convey on/off information about certain calibrator conditions such as **SYSTEM OK**. They 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 (see Section 4.3.2.8).

The **CONTROL** inputs can be initiated by applying 5V DC power from an external source such as a PLC or data logger (Section 4.3.1.5). Zero and span calibrations can be initiated by contact closures on the rear panel.

10.3.5.6. I²C Data Bus

I²C is a two-way, clocked, bi-directional, digital serial I/O bus that is used widely in commercial and consumer electronic systems. A transceiver on the motherboard converts data and control signals from the PC-104 bus to I²C. The data is then fed to the relay board, optional analog input board and valve driver board circuitry.

10.3.5.7. Power-up Circuit

This circuit monitors the +5V power supply during calibrator start-up and sets the analog outputs, external digital I/O ports, and I²C circuitry to specific values until the CPU boots and the instrument software can establish control.

10.3.6. INPUT GAS PRESSURE SENSOR PCA

This PCA, physically located 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 from the associated MFC.

This data is used in calculating the concentration of calibration mixtures.

The following TEST functions are viewable from the instrument's front panel:

- **CALPRESS** - the pressure of the selected calibration gas input reported in **PSIG**.
- **DILPRESS** - the pressure of the diluent gas (zero air) input also reported in **PSIG**.

10.3.7. POWER SUPPLY AND CIRCUIT BREAKER

The T700 calibrator operates in two main AC power ranges: 100-120 VAC and 220-240 VAC (both $\pm 10\%$) 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.



WARNING

The T700 calibrator is equipped with a universal power supply that allows it to accept any AC power configuration, within the limits specified in Table 2-2.

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

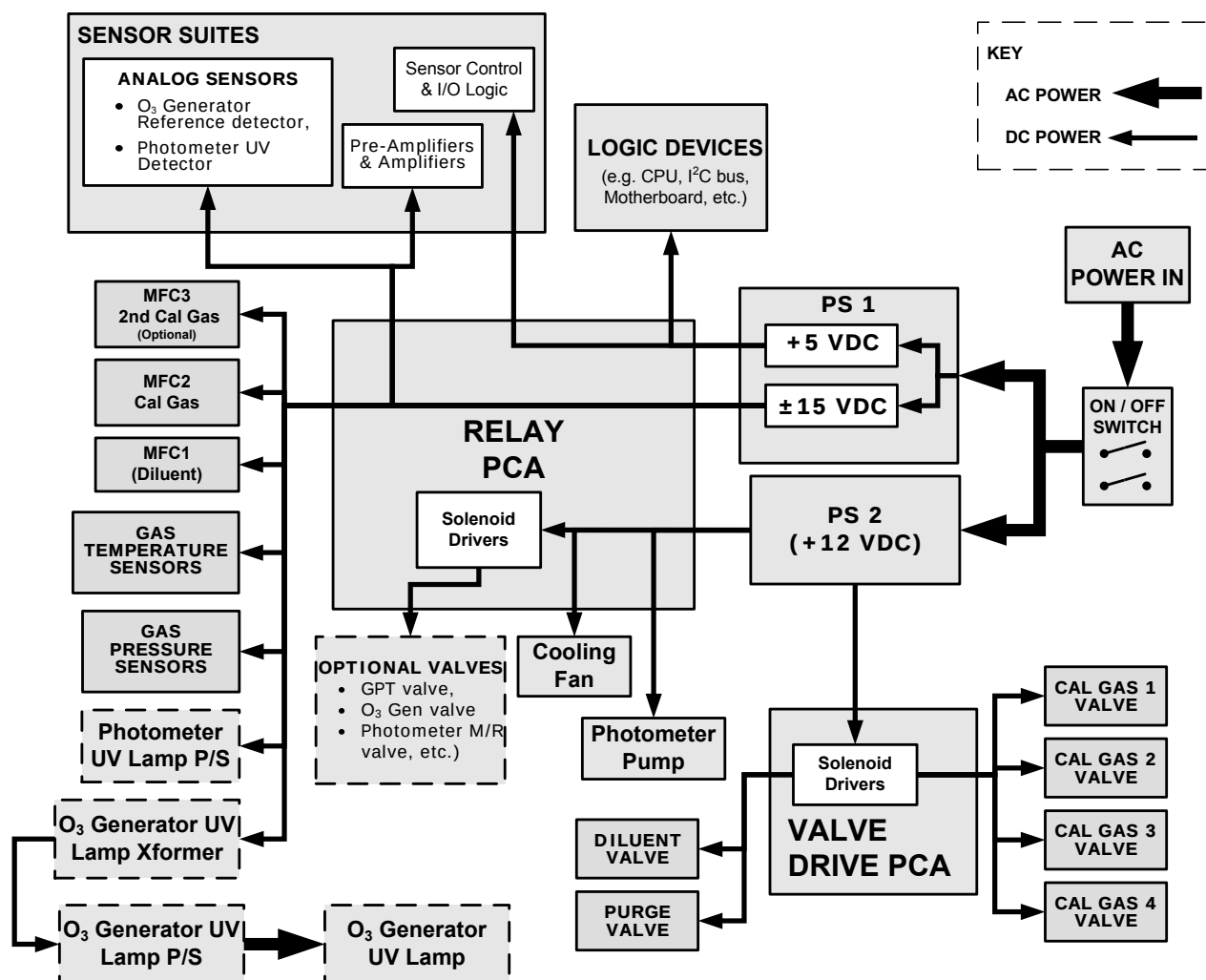


Figure 10-9: T700 Power Distribution Block diagram

10.4. FRONT PANEL TOUCHSCREEN/DISPLAY INTERFACE

The most commonly used method for communicating with the T700 Dynamic Dilution Calibrator is via the instrument's front panel LCD touchscreen display from where users can input data and receive information directly.

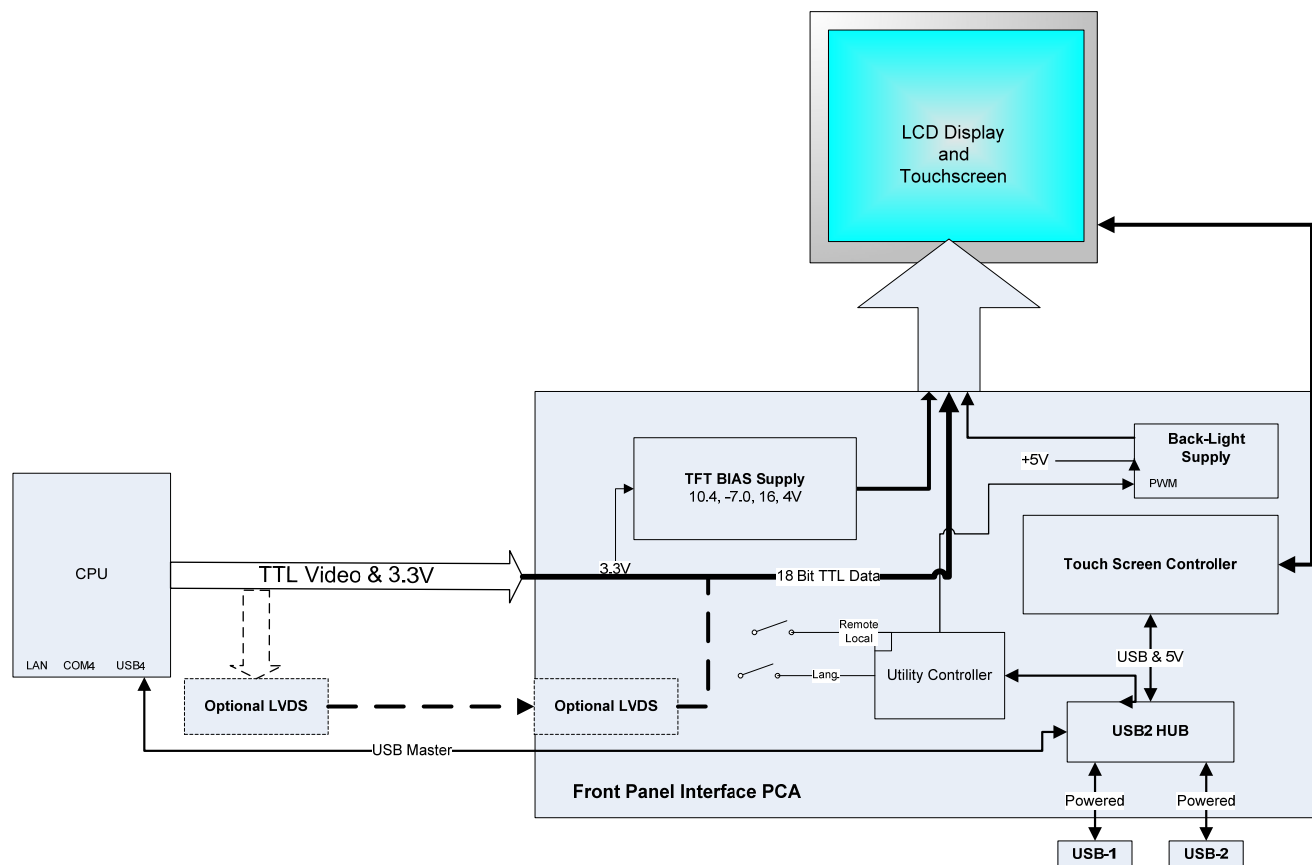


Figure 10-10: Front Panel Display Interface Block Diagram

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.

10.4.1.1. 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

10.6. O₃ GENERATOR OPERATION

10.6.1. PRINCIPLE OF PHOTOLYTIC O₃ GENERATION

Ozone is a naturally occurring substance that is sometimes called "activated oxygen". It contains three atoms of oxygen (O₃) instead of the usual two found in normal oxygen (O₂) 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 O₃ concentration is poor. Also, the corona-discharge method produces a small amount of NO₂ 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 (O₂) in the gas into individual oxygen atoms that attach to other existing oxygen molecules (O₂), forming ozone (O₃).

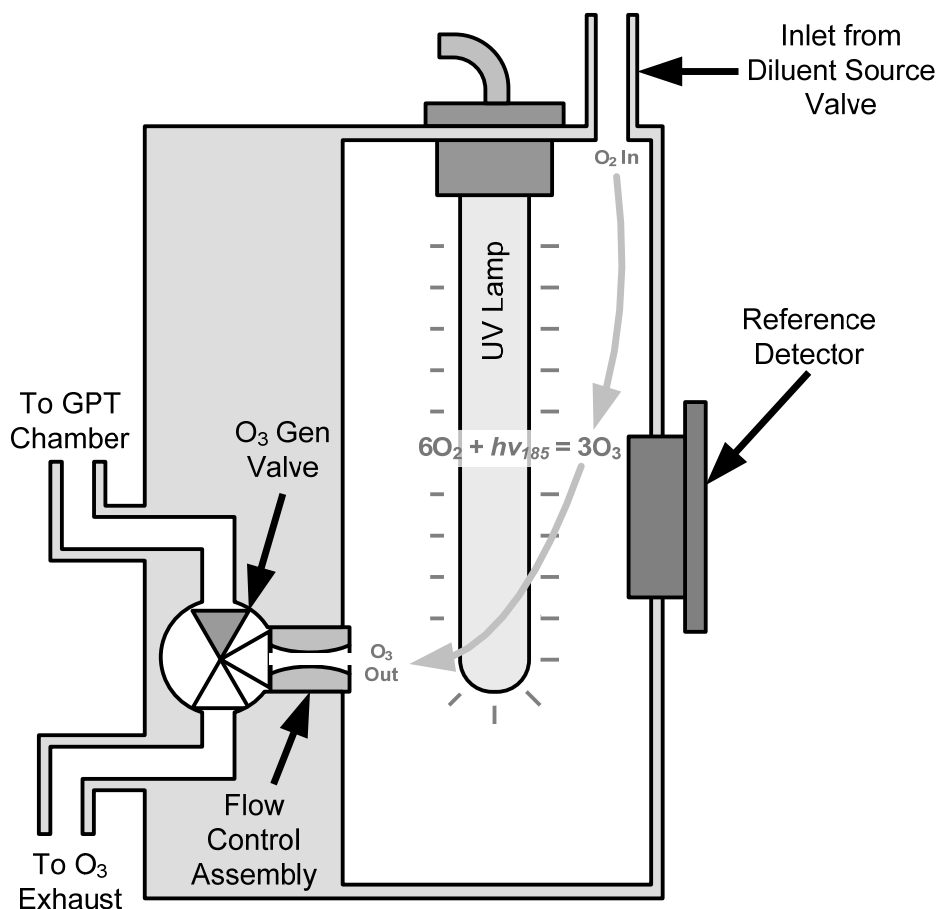


Figure 10-12: O₃ Generator Internal Pneumatics

10.6.2. O₃ GENERATOR – PNEUMATIC OPERATION

Pneumatic flow through the O₃ 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 cm³/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 O₃ generation valve: This valve is located on the body of the O₃ 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 O₃ generator is controlled by a 100 cm³/min flow control assembly positioned between the O₃ generation chamber and the O₃ 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 10.2.1.3).

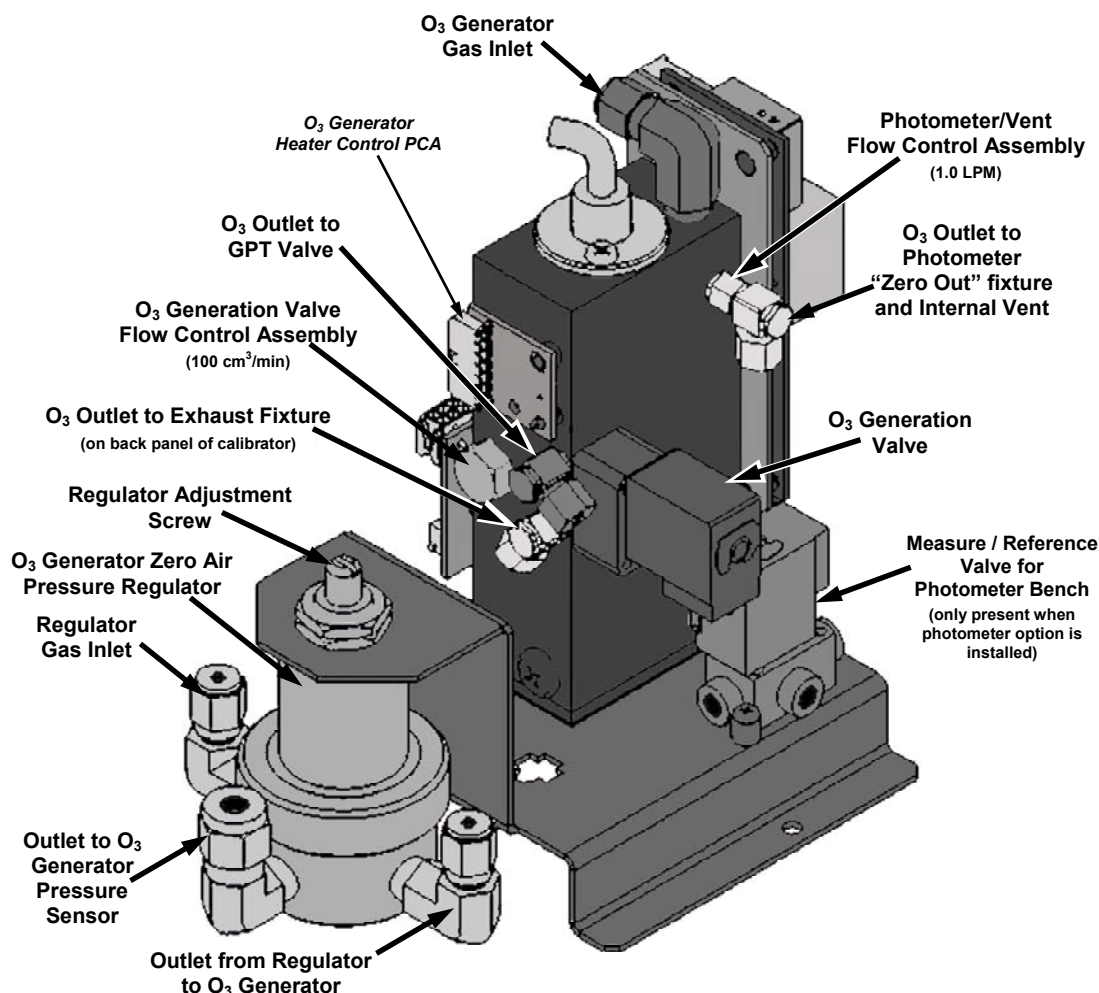


Figure 10-13: O₃ Generator Valve and Gas Fixture Locations

10.6.3. O₃ GENERATOR – ELECTRONIC OPERATION

Electronically the O₃ 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 calibrator's I²C bus.

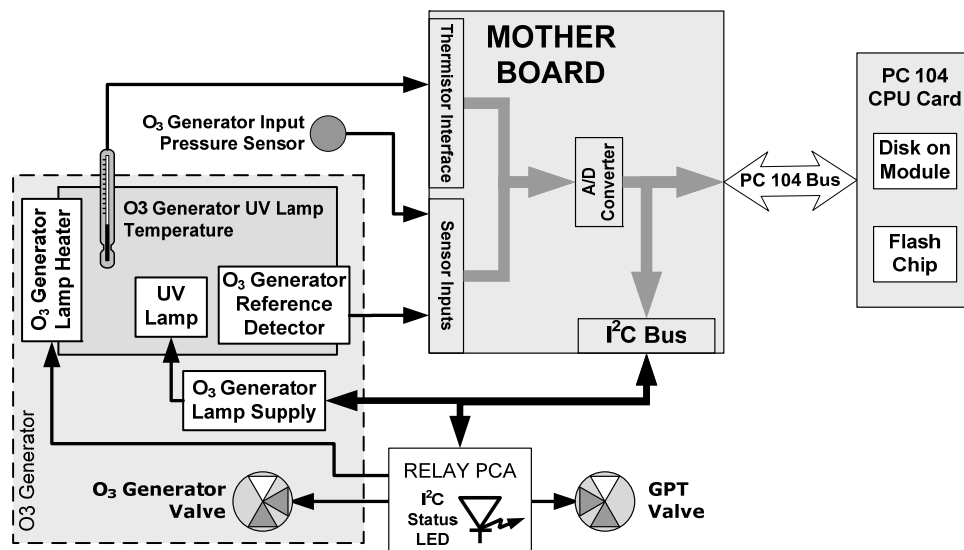


Figure 10-14: O₃ Generator – Electronic Block Diagram

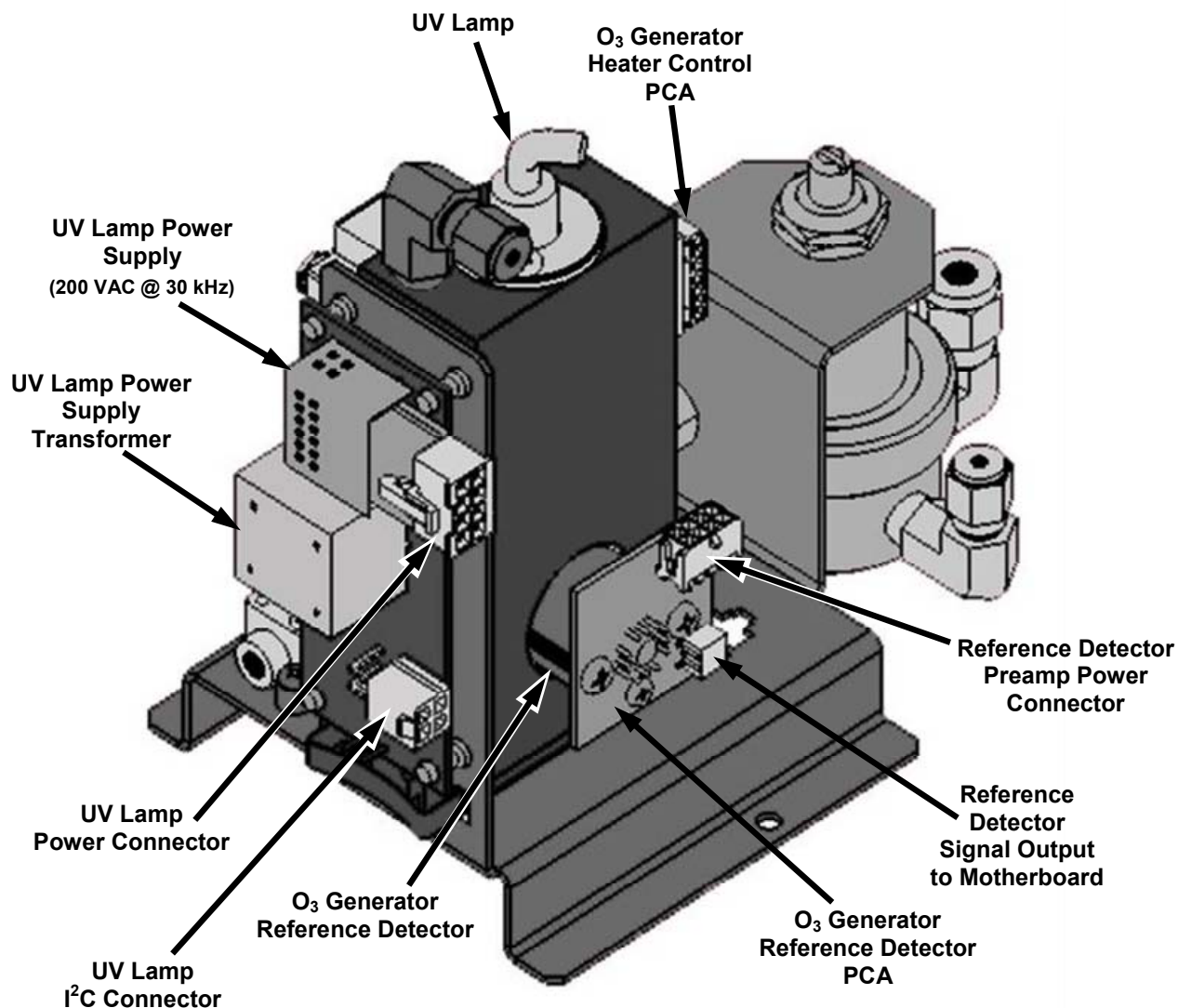


Figure 10-15: O₃ Generator Electronic Components Location

10.6.3.1. O₃ Generator Temperature Control

In order to operate at peak efficiency the UV lamp of the T700's O₃ generator is maintained at a constant 48°C. If the lamp temperature falls below 43°C or rises above 53°C a warning is issued by the calibrators CPU.

This temperature is controlled as described in the section on the relay PCA (Section 10.3.3). The location of the thermistor and heater associated with the O₃ generator is shown in Figure 10-16:

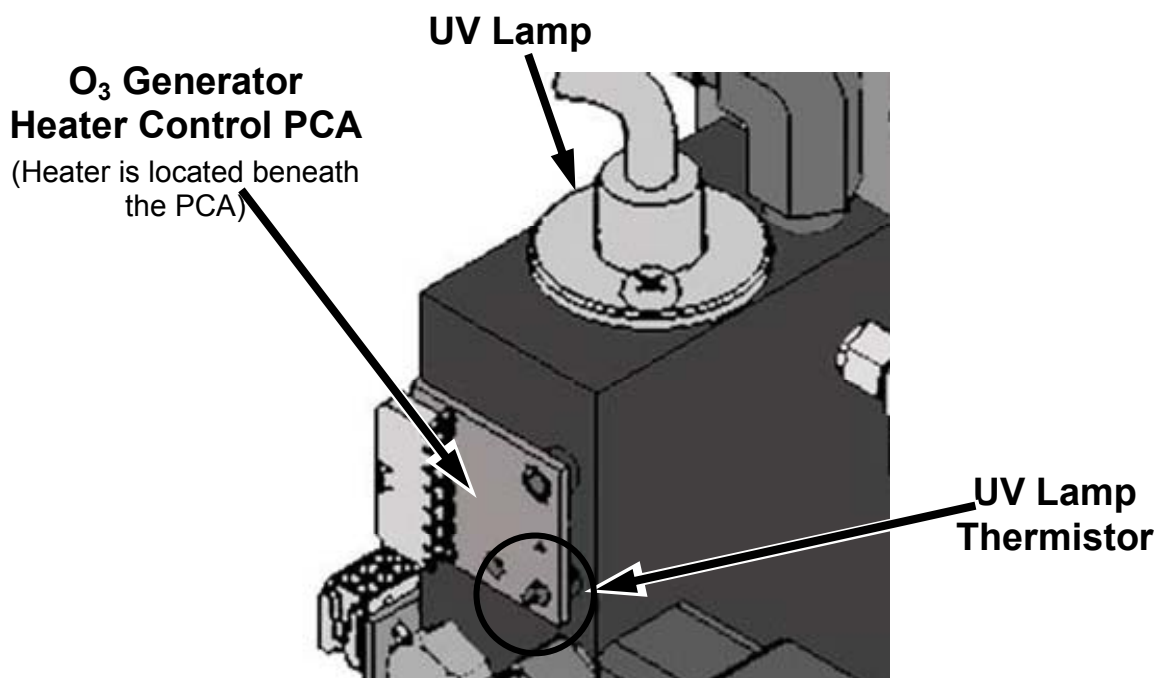


Figure 10-16: O₃ Generator Temperature Thermistor and DC Heater Locations

10.6.3.2. Pneumatic Sensor for the O₃ Generator

A pressure sensor, located on the O₃ generator and photometer, pressure/flow sensor PCA (see Figure 3-6), monitors the output gas pressure of the regulator on the O₃ 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.

10.7. PHOTOMETER OPERATION

The Model T700 calibrator's optional photometer determines the concentration of Ozone (O₃) in a sample gas drawn through it. Sample and calibration gases must be supplied at ambient atmospheric pressure in order to establish a stable gas flow through the absorption tube where the gas' ability to absorb ultraviolet (UV) radiation of a certain wavelength (in this case 254 nm) is measured.

Gas bearing O₃ and zero air are alternately routed through the photometer's absorption tube. Measurements of the UV light passing through the sample gas with and without O₃ present are made and recorded.

Calibration of the photometer is performed in software and does not require physical adjustment. During calibration, the CPU's microprocessor measures the current state of the UV Sensor output and various other physical parameters of the calibrator and stores them in memory. The CPU uses these calibration values, the UV absorption

measurements made on the sample gas in the absorption tube along with data regarding the current temperature and pressure of the gas to calculate a final O₃ concentration.

10.7.1. MEASUREMENT METHOD

10.7.1.1. Calculating O₃ Concentration

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

Equation 10-5

$$I = I_0 e^{-\alpha L C} \quad \text{at STP}$$

Where:

I_0 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 T700, Ozone (O₃).

α is the absorption coefficient that tells how well O₃ absorbs light at the specific wavelength of interest.

To solve this equation for C , the concentration of the absorbing Gas (in this case O₃), the application of algebra is required to rearrange the equation as follows:

Equation 10-6

$$C = \ln \frac{I_0}{I} \times \frac{1}{\alpha L} \quad \text{at STP}$$

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 10-7

$$C = \ln \frac{I_0}{I} \times \frac{1}{\alpha L} \times \frac{T}{273^\circ K} \times \frac{29.92 \text{ inHg}}{P}$$

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 10-8

$$C = \ln \frac{I_o}{I} \times \frac{10^9}{\alpha L} \times \frac{T}{273^\circ K} \times \frac{29.92 \text{ inHg}}{P}$$

The T700 photometer:

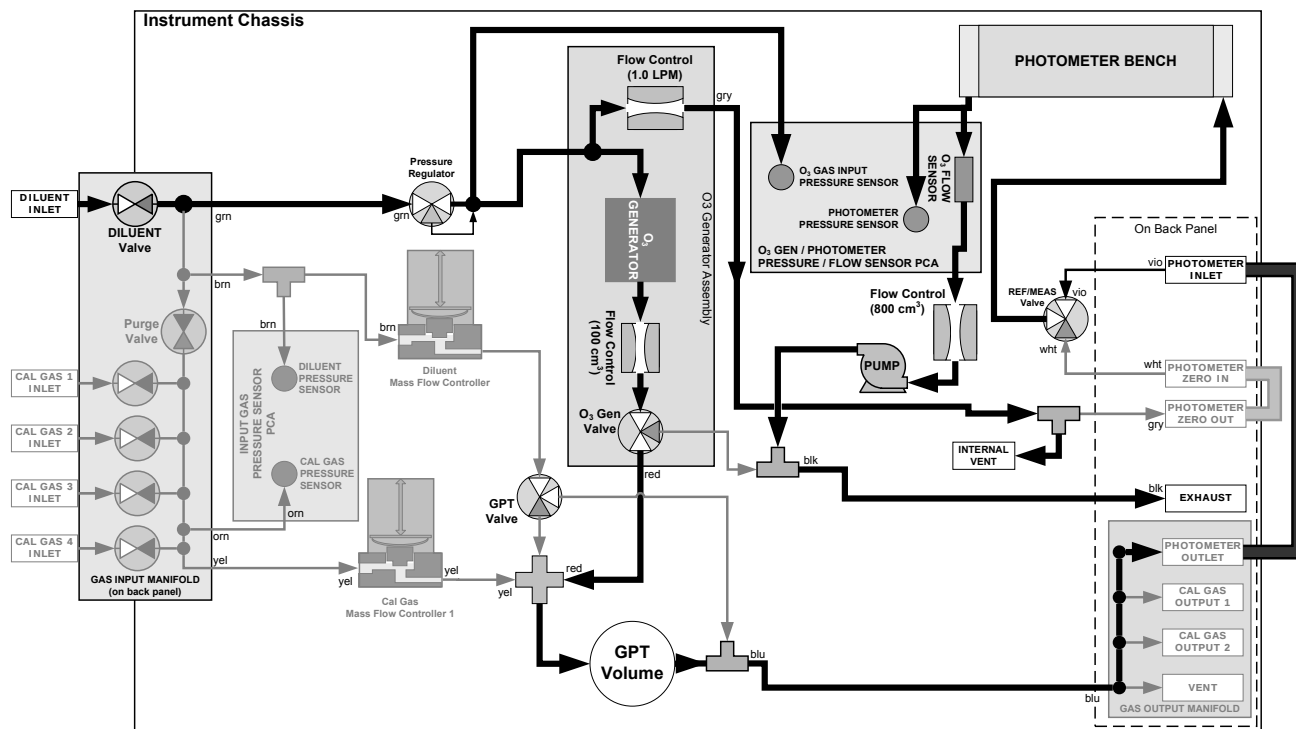
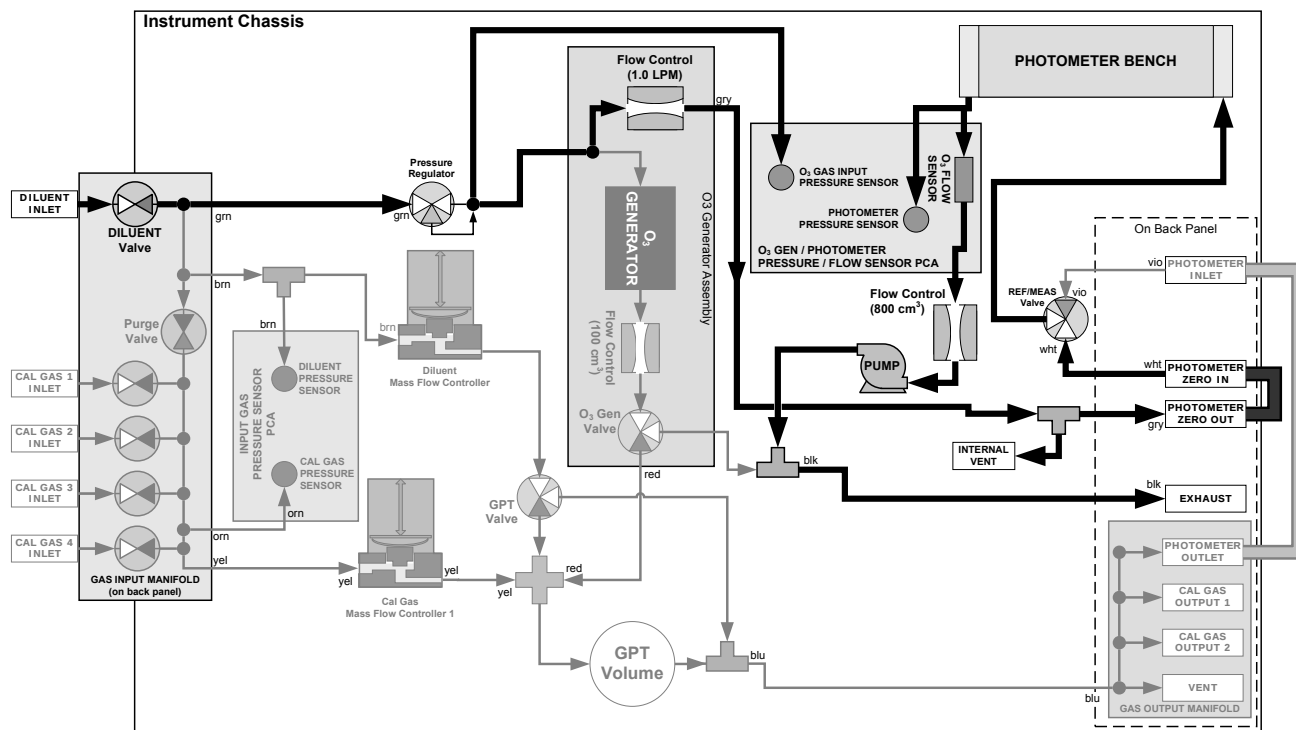
- Measures each of the above variables: ambient temperature; ambient gas pressure; the intensity of the UV light beam with and without O₃ present;
- Inserts know values for the length of the absorption path and the absorption coefficient, and:
- Calculates the concentration of O₃ present in the sample gas.

10.7.1.2. 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 O₃ is present and when it is not. A valve called the measure/reference valve, physically located on front-left corner of the O₃ generator assembly (see Figure 3-6 and Figure 10-13) alternates the gas stream flowing to the photometer between zero air (diluent gas) and the O₃ output from the O₃ generator. This cycle takes about 6 seconds.

Table 10-2: T700 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 (I₀) during this period.
CYCLE REPEAT EVERY 6 SECONDS	

Figure 10-17: O₃ Photometer Gas Flow – Measure CycleFigure 10-18: O₃ Photometer Gas Flow – Reference Cycle

10.7.1.3. The Absorption Path

In the most basic terms, the T700 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.

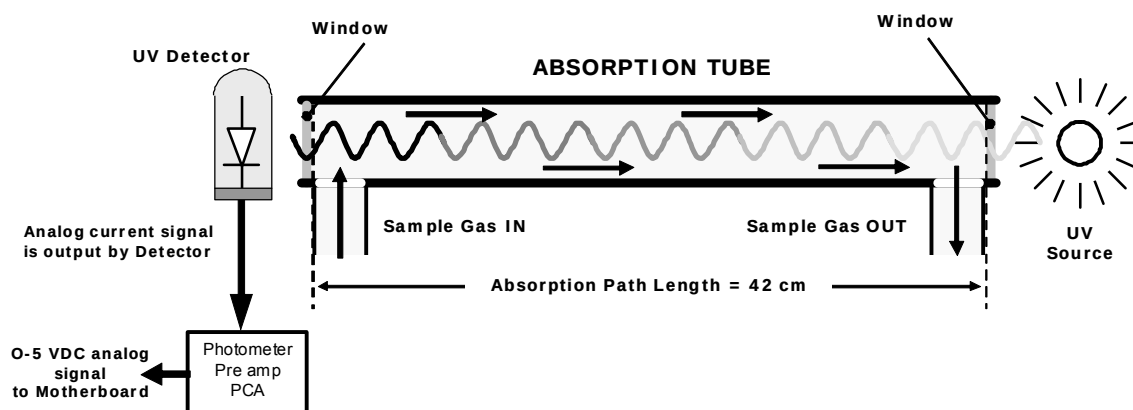


Figure 10-19: O_3 Photometer Absorption Path

10.7.1.4. Interferent Rejection

It should be noted that the UV absorption method for detecting ozone is subject to interference from a number of sources. The T700'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 T700 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.

10.7.2. 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.

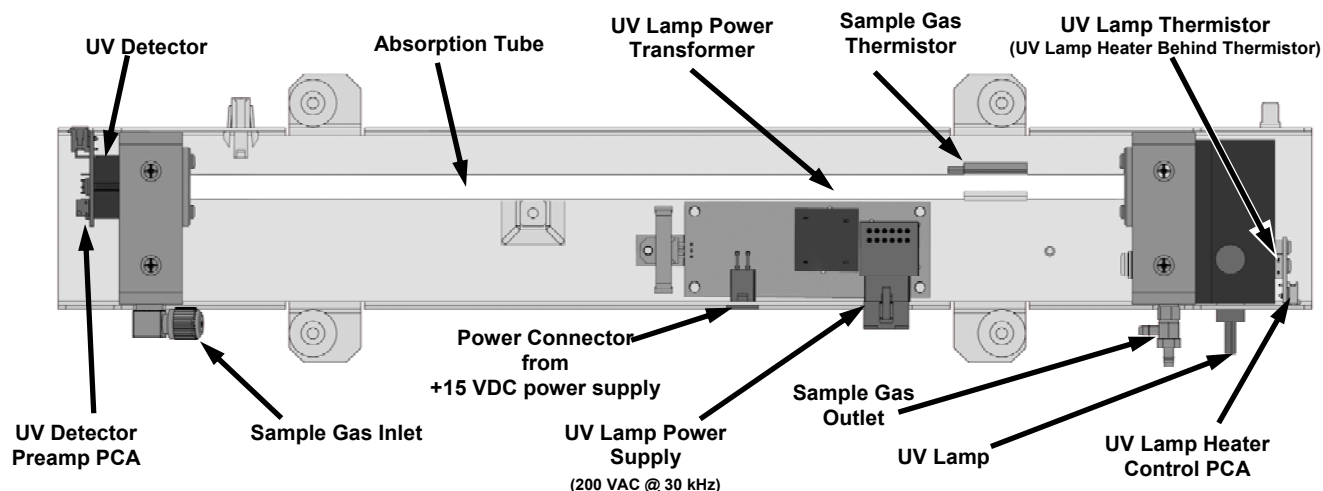


Figure 10-20: O_3 Photometer Layout – Top Cover Removed

10.7.3. PHOTOMETER PNEUMATIC OPERATION

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

In order to 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 cm³/min. A pressure sensor and a flow sensor, located on the O₃ generator/photometer pressure flow sensor PCA, monitor the pressure and flow rate of the gas passing through the photometers absorption tube.

See Figure 10-17 and Figure 10-18 for depictions of the airflow related to the photometer.

10.7.4. PHOTOMETER ELECTRONIC OPERATION

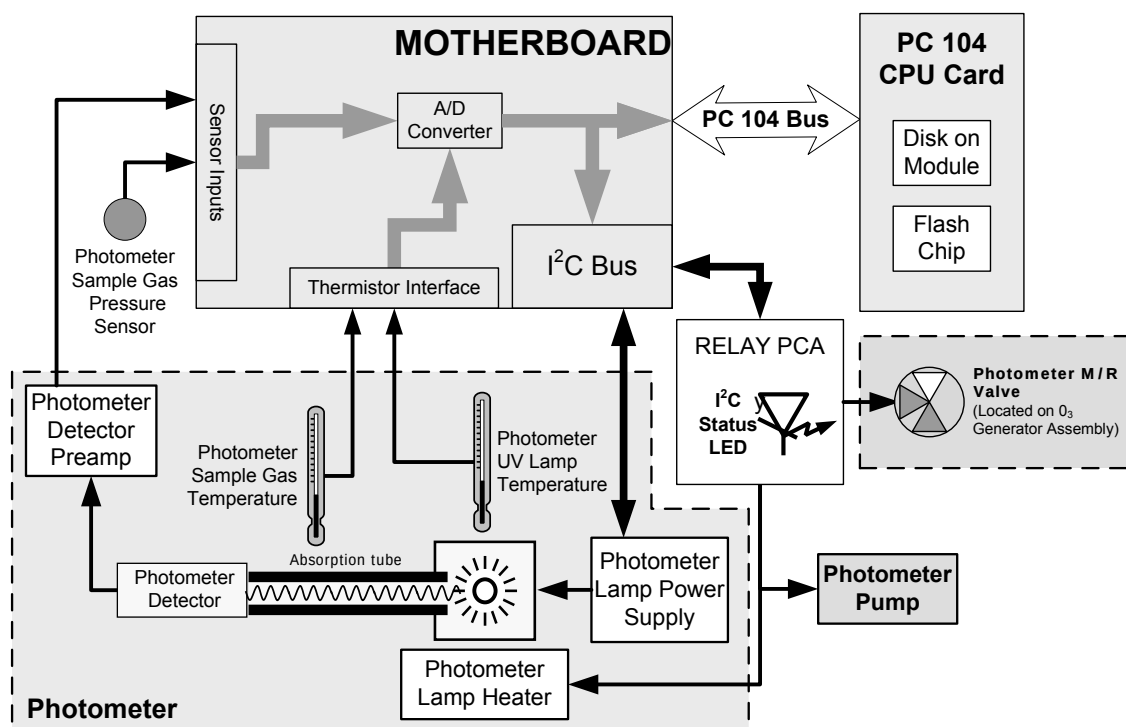


Figure 10-21: O₃ Photometer Electronic Block Diagram

Like the O₃ generator, the O₃ 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 I²C bus to circuitry on the relay PCA which turns them ON/OFF. The CPU also issues commands over the I²C 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 photometers temperature sensors is also amplified and converted to digital data by the motherboard. The O₃ concentration of the sample gas is computed by the CPU using this data (along with gas pressure and flow data received from the T700's pressure sensors).

10.7.4.1. O₃ Photometer Temperature Control

In order to operate at peak efficiency the UV lamp of the T700's O₃ photometer is maintained at a constant 58°C. This is intentionally set at a temperature higher than the ambient temperature of the T700's operating environment to ensure that local changes in temperature do not affect the UV Lamp. If the lamp temperature falls below 56°C or rises above 61°C a warning is issued by the calibrators CPU.

This temperature is controlled as described in the section on the relay PCA (Section 10.3.3.2).

The following TEST functions report these temperatures and are viewable from the instrument's front panel:

- **PHOTOLTEMP** - The temperature of the UV Lamp reported in °C.
- **PHOTOSTEMP** - The temperature of the Sample gas in the absorption tube reported in °C.

10.7.4.2. Pneumatic Sensors for the O₃ Photometer

The sensors located on the pneumatic sensor just to the left rear of the O₃ 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 O₃ 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 cm³/min.

The following TEST functions are viewable from the instrument's front panel:

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

11. A PRIMER ON ELECTRO-STATIC DISCHARGE

Teledyne API considers the prevention of damage caused by the discharge of static electricity to be extremely important part of making sure that your analyzer continues to provide reliable service for a long time. This section describes how static electricity occurs, why it is so dangerous to electronic components and assemblies as well as how to prevent that damage from occurring.

11.1. HOW STATIC CHARGES ARE CREATED

Modern electronic devices such as the types used in the various electronic assemblies of your analyzer, are very small, require very little power and operate very quickly. Unfortunately, the same characteristics that allow them to do these things also make them very susceptible to damage from the discharge of static electricity. Controlling electrostatic discharge begins with understanding how electro-static charges occur in the first place.

Static electricity is the result of something called triboelectric charging which happens whenever the atoms of the surface layers of two materials rub against each other. As the atoms of the two surfaces move together and separate, some electrons from one surface are retained by the other.

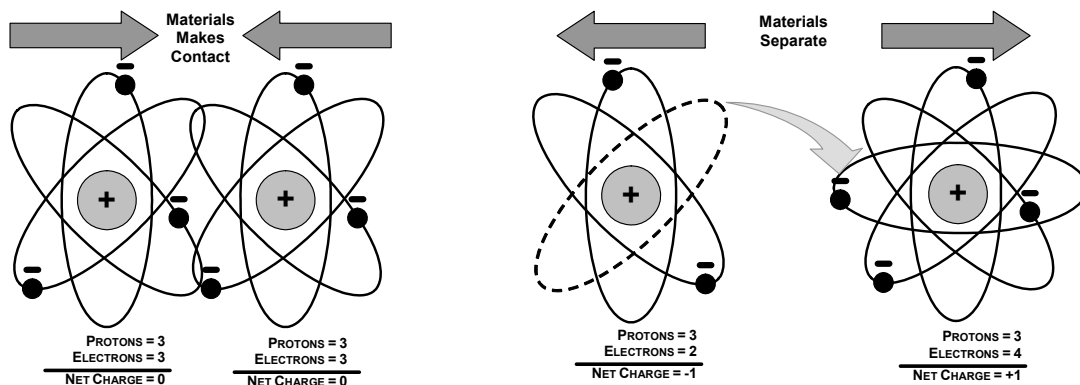


Figure 11-1: Triboelectric Charging

If one of the surfaces is a poor conductor or even a good conductor that is not grounded, the resulting positive or negative charge cannot bleed off and becomes trapped in place, or static. The most common example of triboelectric charging happens when someone wearing leather or rubber soled shoes walks across a nylon carpet or linoleum tiled floor. With each step, electrons change places and the resulting electro-static charge builds up, quickly reaching significant levels. Pushing an epoxy printed circuit board across a

workbench, using a plastic handled screwdriver or even the constant jostling of Styrofoam™ pellets during shipment can also build hefty static charges

Table 11-1: Static Generation Voltages for Typical Activities

MEANS OF GENERATION	65-90% RH	10-25% RH
Walking across nylon carpet	1,500V	35,000V
Walking across vinyl tile	250V	12,000V
Worker at bench	100V	6,000V
Poly bag picked up from bench	1,200V	20,000V
Moving around in a chair padded with urethane foam	1,500V	18,000V

11.2. HOW ELECTRO-STATIC CHARGES CAUSE DAMAGE

Damage to components occurs when these static charges come into contact with an electronic device. Current flows as the charge moves along the conductive circuitry of the device and the typically very high voltage levels of the charge overheat the delicate traces of the integrated circuits, melting them or even vaporizing parts of them. When examined by microscope the damage caused by electro-static discharge looks a lot like tiny bomb craters littered across the landscape of the component's circuitry.

A quick comparison of the values in Table 11-1 with the those shown in the Table 11-2, listing device susceptibility levels, shows why *Semiconductor Reliability News* estimates that approximately 60% of device failures are the result of damage due to electro-static discharge.

Table 11-2: Sensitivity of Electronic Devices to Damage by ESD

DEVICE	DAMAGE SUSCEPTIBILITY VOLTAGE RANGE	
	DAMAGE BEGINS OCCURRING AT	CATASTROPHIC DAMAGE AT
MOSFET	10	100
VMOS	30	1800
NMOS	60	100
GaAsFET	60	2000
EPROM	100	100
JFET	140	7000
SAW	150	500
Op-AMP	190	2500
CMOS	200	3000
Schottky Diodes	300	2500
Film Resistors	300	3000
This Film Resistors	300	7000
ECL	500	500
SCR	500	1000
Schottky TTL	500	2500

Potentially damaging electro-static discharges can occur:

- Any time a charged surface (including the human body) discharges to a device. Even simple contact of a finger to the leads of a sensitive device or assembly can allow enough discharge to cause damage. A similar discharge can occur from a charged conductive object, such as a metallic tool or fixture.
- When static charges accumulated on a sensitive device discharges from the device to another surface such as packaging materials, work surfaces, machine surfaces or other device. In some cases, charged device discharges can be the most destructive.
- A typical example of this is the simple act of installing an electronic assembly into the connector or wiring harness of the equipment in which it is to function. If the assembly is carrying a static charge, as it is connected to ground a discharge will occur.
- Whenever a sensitive device is moved into the field of an existing electro-static field, a charge may be induced on the device in effect discharging the field onto the device. If the device is then momentarily grounded while within the electrostatic field or removed from the region of the electrostatic field and grounded somewhere else, a second discharge will occur as the charge is transferred from the device to ground.

11.3. COMMON MYTHS ABOUT ESD DAMAGE

- **I didn't feel a shock so there was no electro-static discharge:** The human nervous system isn't able to feel a static discharge of less than 3500 volts. Most devices are damaged by discharge levels much lower than that.
- **I didn't touch it so there was no electro-static discharge:** Electro Static charges are fields whose lines of force can extend several inches or sometimes even feet away from the surface bearing the charge.
- **It still works so there was no damage:** Sometimes the damage caused by electro-static discharge can completely sever a circuit trace causing the device to fail immediately. More likely, the trace will be only partially occluded by the damage causing degraded performance of the device or worse, weakening the trace. This weakened circuit may seem to function fine for a short time, but even the very low voltage and current levels of the device's normal operating levels will eat away at the defect over time causing the device to fail well before its designed lifetime is reached.

These latent failures are often the most costly since the failure of the equipment in which the damaged device is installed causes down time, lost data, lost productivity, as well as possible failure and damage to other pieces of equipment or property.

- **Static Charges can't build up on a conductive surface:** There are two errors in this statement.

Conductive devices can build static charges if they are not grounded. The charge will be equalized across the entire device, but without access to earth ground, they are still trapped and can still build to high enough levels to cause damage when they are discharged.

A charge can be induced onto the conductive surface and/or discharge triggered in the presence of a charged field such as a large static charge clinging to the surface of a nylon jacket of someone walking up to a workbench.

- **As long as my analyzer is properly installed, it is safe from damage caused by static discharges:** It is true that when properly installed the chassis ground of your analyzer is tied to earth ground and its electronic components are prevented from

building static electric charges themselves. This does not prevent discharges from static fields built up on other things, like you and your clothing, from discharging through the instrument and damaging it.

11.4. BASIC PRINCIPLES OF STATIC CONTROL

It is impossible to stop the creation of instantaneous static electric charges. It is not, however difficult to prevent those charges from building to dangerous levels or prevent damage due to electro-static discharge from occurring.

11.4.1. GENERAL RULES

Only handle or work on all electronic assemblies at a properly set up ESD station. Setting up an ESD safe workstation need not be complicated. A protective mat properly tied to ground and a wrist strap are all that is needed to create a basic anti-ESD workstation.

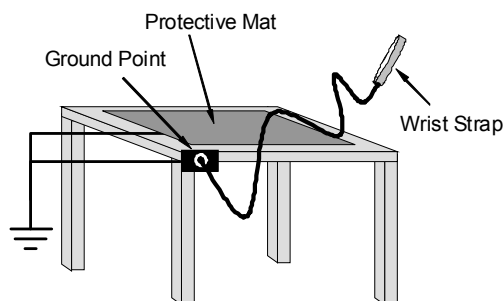


Figure 11-2: Basic Anti-ESD Work Station

For technicians that work in the field, special lightweight and portable anti-ESD kits are available from most suppliers of ESD protection gear. These include everything needed to create a temporary anti-ESD work area anywhere.

- **Always wear an Anti-ESD wrist strap when working on the electronic assemblies of your analyzer.** An anti-ESD wrist strap keeps the person wearing it at or near the same potential as other grounded objects in the work area and allows static charges to dissipate before they can build to dangerous levels. Anti-ESD wrist straps terminated with alligator clips are available for use in work areas where there is no available grounded plug.

Also, anti-ESD wrist straps include a current limiting resistor (usually around one meg-ohm) that protects you should you accidentally short yourself to the instrument's power supply.

- **Simply touching a grounded piece of metal is insufficient.** While this may temporarily bleed off static charges present at the time, once you stop touching the grounded metal new static charges will immediately begin to re-build. In some conditions, a charge large enough to damage a component can rebuild in just a few seconds.
- **Always store sensitive components and assemblies in anti-ESD storage bags or bins:** Even when you are not working on them, store all devices and assemblies in a closed anti-Static bag or bin. This will prevent induced charges from building up on the device or assembly and nearby static fields from discharging through it.

- **Use metallic anti-ESD bags for storing and shipping ESD sensitive components and assemblies rather than pink-poly bags.** The famous, pink-poly bags are made of a plastic that is impregnated with a liquid (similar to liquid laundry detergent) which very slowly sweats onto the surface of the plastic creating a slightly conductive layer over the surface of the bag.

While this layer may equalizes any charges that occur across the whole bag, it does not prevent the build up of static charges. If laying on a conductive, grounded surface, these bags will allow charges to bleed away but the very charges that build up on the surface of the bag itself can be transferred through the bag by induction onto the circuits of your ESD sensitive device. Also, the liquid impregnating the plastic is eventually used up after which the bag is as useless for preventing damage from ESD as any ordinary plastic bag.

Anti-Static bags made of plastic impregnated with metal (usually silvery in color) provide all of the charge equalizing abilities of the pink-poly bags but also, when properly sealed, create a Faraday cage that completely isolates the contents from discharges and the inductive transfer of static charges.

Storage bins made of plastic impregnated with carbon (usually black in color) are also excellent at dissipating static charges and isolating their contents from field effects and discharges.

- **Never use ordinary plastic adhesive tape near an ESD sensitive device or to close an anti-ESD bag.** The act of pulling a piece of standard plastic adhesive tape, such as Scotch[®] tape, from its roll will generate a static charge of several thousand or even tens of thousands of volts on the tape itself and an associated field effect that can discharge through or be induced upon items up to a foot away.

11.4.2. BASIC ANTI-ESD PROCEDURES FOR ANALYZER REPAIR AND MAINTENANCE

11.4.2.1. Working at the Instrument Rack

When working on the analyzer while it is in the instrument rack and plugged into a properly grounded power supply

1. Attach your anti-ESD wrist strap to ground before doing anything else.
 - Use a wrist strap terminated with an alligator clip and attach it to a bare metal portion of the instrument chassis.
 - This will safely connect you to the same ground level to which the instrument and all of its components are connected.
2. Pause for a second or two to allow any static charges to bleed away.
3. Open the casing of the analyzer and begin work. Up to this point, the closed metal casing of your analyzer has isolated the components and assemblies inside from any conducted or induced static charges.
4. If you must remove a component from the instrument, do not lay it down on a non-ESD preventative surface where static charges may lie in wait.
5. Only disconnect your wrist strap after you have finished work and closed the case of the analyzer.

11.4.2.2. Working at an Anti-ESD Work Bench

When working on an instrument or an electronic assembly while it is resting on an anti-ESD work bench

1. Plug your anti-ESD wrist strap into the grounded receptacle of the work station before touching any items on the work station and while standing at least a foot or so away. This will allow any charges you are carrying to bleed away through the ground connection of the workstation and prevent discharges due to field effects and induction from occurring.
2. Pause for a second or two to allow any static charges to bleed away.
3. Only open any anti-ESD storage bins or bags containing sensitive devices or assemblies after you have plugged your wrist strap into the workstation.
 - Lay the bag or bin on the workbench surface.
 - Before opening the container, wait several seconds for any static charges on the outside surface of the container to be bled away by the workstation's grounded protective mat.
4. Do not pick up tools that may be carrying static charges while also touching or holding an ESD Sensitive Device.
 - Only lay tools or ESD-sensitive devices and assemblies on the conductive surface of your workstation. Never lay them down on any non-ESD preventative surface.
5. Place any static sensitive devices or assemblies in anti-static storage bags or bins and close the bag or bin before unplugging your wrist strap.
6. Disconnecting your wrist strap is always the last action taken before leaving the workbench.

11.4.2.3. Transferring Components from Rack to Bench and Back

When transferring a sensitive device from an installed Teledyne API analyzer to an anti-ESD workbench or back:

1. Follow the instructions listed above for working at the instrument rack and workstation.
2. Never carry the component or assembly without placing it in an anti-ESD bag or bin.
3. Before using the bag or container allow any surface charges on it to dissipate:
4. If you are at the instrument rack, hold the bag in one hand while your wrist strap is connected to a ground point.
5. If you are at an anti-ESD workbench, lay the container down on the conductive work surface.
6. In either case wait several seconds.
7. Place the item in the container.
8. Seal the container. If using a bag, fold the end over and fastening it with anti-ESD tape.
9. Folding the open end over isolates the component(s) inside from the effects of static fields.
10. Leaving the bag open or simply stapling it shut without folding it closed prevents the bag from forming a complete protective envelope around the device.
11. Once you have arrived at your destination, allow any surface charges that may have built up on the bag or bin during travel to dissipate:
12. Connect your wrist strap to ground.
13. If you are at the instrument rack, hold the bag in one hand while your wrist strap is connected to a ground point.
14. If you are at a anti-ESD work bench, lay the container down on the conductive work surface.
15. In either case wait several seconds.
16. Open the container.

11.4.2.4. Opening Shipments from Teledyne API's Customer Service

Packing materials such as bubble pack and Styrofoam pellets are extremely efficient generators of static electric charges. To prevent damage from ESD, Teledyne API ships all electronic components and assemblies in properly sealed anti-ESD containers.

Static charges will build up on the outer surface of the anti-ESD container during shipping as the packing materials vibrate and rub against each other. To prevent these static charges from damaging the components or assemblies being shipped ensure that you:

Always unpack shipments from Teledyne API's Customer Service by:

1. Opening the outer shipping box away from the anti-ESD work area.
2. Carry the still sealed ant-ESD bag, tube or bin to the anti-ESD work area.
3. Follow steps 6 and 7 of Section 11.4.2.3 above when opening the anti-ESD container at the work station.
4. Reserve the anti-ESD container or bag to use when packing electronic components or assemblies to be returned to Teledyne API.

11.4.2.5. Packing Components for Return to Teledyne API's Customer Service

Always pack electronic components and assemblies to be sent to Teledyne API's Customer Service in anti-ESD bins, tubes or bags.



WARNING

- **DO NOT** use pink-poly bags.
- **NEVER** allow any standard plastic packaging materials to touch the electronic component/assembly directly
 - This includes, but is not limited to, plastic bubble-pack, Styrofoam peanuts, open cell foam, closed cell foam, and adhesive tape
- **DO NOT** use standard adhesive tape as a sealer. Use **ONLY** anti-ESD tape

1. Never carry the component or assembly without placing it in an anti-ESD bag or bin.
2. Before using the bag or container allow any surface charges on it to dissipate:
 - If you are at the instrument rack, hold the bag in one hand while your wrist strap is connected to a ground point.
 - If you are at an anti-ESD workbench, lay the container down on the conductive work surface.
 - In either case wait several seconds.
3. Place the item in the container.
4. Seal the container. If using a bag, fold the end over and fastening it with anti-ESD tape.
 - Folding the open end over isolates the component(s) inside from the effects of static fields.
 - Leaving the bag open or simply stapling it shut without folding it closed prevents the bag from forming a complete protective envelope around the device.

Note

If you do not already have an adequate supply of anti-ESD bags or containers available, Teledyne API's Customer Service department will supply them (see Section 9.8 for contact information). Follow the instructions listed above for working at the instrument rack and workstation.

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	<i>Assembly</i>
CAS	<i>Code-Activated Switch</i>
CD	<i>Corona Discharge</i> , 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	<i>Converter Efficiency</i> , the percentage of light energy that is actually converted into electricity
CEM	<i>Continuous Emission Monitoring</i>
Chemical formulas that may be included in this document:	
CO2	carbon dioxide
C3H8	propane
CH4	methane
H2O	water vapor
HC	general abbreviation for hydrocarbon
HNO3	nitric acid
H2S	hydrogen sulfide
NO	nitric oxide
NO2	nitrogen dioxide
NOX	nitrogen oxides, here defined as the sum of NO and NO2
NOy	nitrogen oxides, often called odd nitrogen: the sum of NOX plus other compounds such as HNO3 (definitions vary widely and may include nitrate (NO3), PAN, N2O and other compounds as well)
NH3	ammonia
O2	molecular oxygen
O3	ozone

Term	Description/Definition
SO ₂	sulfur dioxide
cm ³	metric abbreviation for <i>cubic centimeter</i> (replaces the obsolete abbreviation “cc”)
CPU	<i>Central Processing Unit</i>
DAC	<i>Digital-to-Analog Converter</i>
DAS	<i>Data Acquisition System</i>
DCE	<i>Data Communication Equipment</i>
DFU	<i>Dry Filter Unit</i>
DHCP	<i>Dynamic Host Configuration Protocol.</i> 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	<i>Diagnostics</i> , the diagnostic settings of the analyzer.
DOM	<i>Disk On Module</i> , a 44-pin IDE flash drive with up to 256MB storage capacity for instrument’s firmware, configuration settings and data
DOS	<i>Disk Operating System</i>
DRAM	<i>Dynamic Random Access Memory</i>
DR-DOS	<i>Digital Research DOS</i>
DTE	<i>Data Terminal Equipment</i>
EEPROM	<i>Electrically Erasable Programmable Read-Only Memory</i> also referred to as a FLASH chip or drive
ESD	<i>Electro-Static Discharge</i>
ETEST	<i>Electrical Test</i>
Ethernet	a standardized (IEEE 802.3) computer networking technology for local area networks (LANs), facilitating communication and sharing resources
FEP	<i>Fluorinated Ethylene Propylene</i> polymer, one of the polymers that Du Pont markets as <i>Teflon</i> ®
Flash	non-volatile, solid-state memory
FPI	<i>Fabry-Perot Interface</i> : a special light filter typically made of a transparent plate with two reflecting surfaces or two parallel, highly reflective mirrors
GFC	<i>Gas Filter Correlation</i>
I ² C bus	a clocked, bi-directional, serial bus for communication between individual analyzer components
IC	<i>Integrated Circuit</i> , 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

Term	Description/Definition
IP	<i>Internet Protocol</i>
IZS	<i>Internal Zero Span</i>
LAN	<i>Local Area Network</i>
LCD	<i>Liquid Crystal Display</i>
LED	<i>Light Emitting Diode</i>
LPM	<i>Liters Per Minute</i>
MFC	<i>Mass Flow Controller</i>
M/R	<i>Measure/Reference</i>
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	<i>Non-Dispersive Infrared</i>
NIST-SRM	<i>National Institute of Standards and Technology - Standard Reference Material</i>
PC	<i>Personal Computer</i>
PCA	<i>Printed Circuit Assembly</i> , the PCB with electronic components, ready to use
PC/AT	<i>Personal Computer / Advanced Technology</i>
PCB	<i>Printed Circuit Board</i> , the bare board without electronic component
PFA	<i>Per-Fluoro-Alkoxy</i> , an inert polymer; one of the polymers that <i>Du Pont</i> markets as <i>Teflon</i> ®
PLC	<i>Programmable Logic Controller</i> , a device that is used to control instruments based on a logic level signal coming from the analyzer
PLD	<i>Programmable Logic Device</i>
PLL	<i>Phase Lock Loop</i>
PMT	<i>Photo Multiplier Tube</i> , a vacuum tube of electrodes that multiply electrons collected and charged to create a detectable current signal
P/N (or PN)	<i>Part Number</i>
PSD	<i>Prevention of Significant Deterioration</i>
PTFE	<i>Poly-Tetra-Fluoro-Ethylene</i> , a very inert polymer material used to handle gases that may react on other surfaces; one of the polymers that <i>Du Pont</i> markets as

Term	Description/Definition
	<i>Teflon[®]</i>
PVC	<i>Poly Vinyl Chloride</i> , 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	<i>Storage and Retrieval of Aerometric Data</i>
SLAMS	<i>State and Local Air Monitoring Network Plan</i>
SLPM	<i>Standard Liters Per Minute</i> of a gas at standard temperature and pressure
STP	<i>Standard Temperature and Pressure</i>
TCP/IP	<i>Transfer Control Protocol / Internet Protocol</i> , the standard communications protocol for Ethernet devices
TEC	<i>Thermal Electric Cooler</i>
TPC	<i>Temperature/Pressure Compensation</i>
USB	<i>Universal Serial Bus</i> : 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	<i>Variables</i> , the variable settings of the instrument
V-F	<i>Voltage-to-Frequency</i>
Z/S	<i>Zero / Span</i>

APPENDIX A – Version Specific Software Documentation

APPENDIX A-1: Models T700 and 700E Software Menu Trees

APPENDIX A-2: Models T700 and 700E Setup Variables Available Via Serial I/O

APPENDIX A-3: Models T700 and 700E Warnings and Test Measurements Via Serial I/O

APPENDIX A-4: Models T700 and 700E Signal I/O Definitions

APPENDIX A-5: MODBUS Register Map

APPENDIX A-6: Terminal Command Designators

APPENDIX A-1: Software Menu Trees, Revision D.3

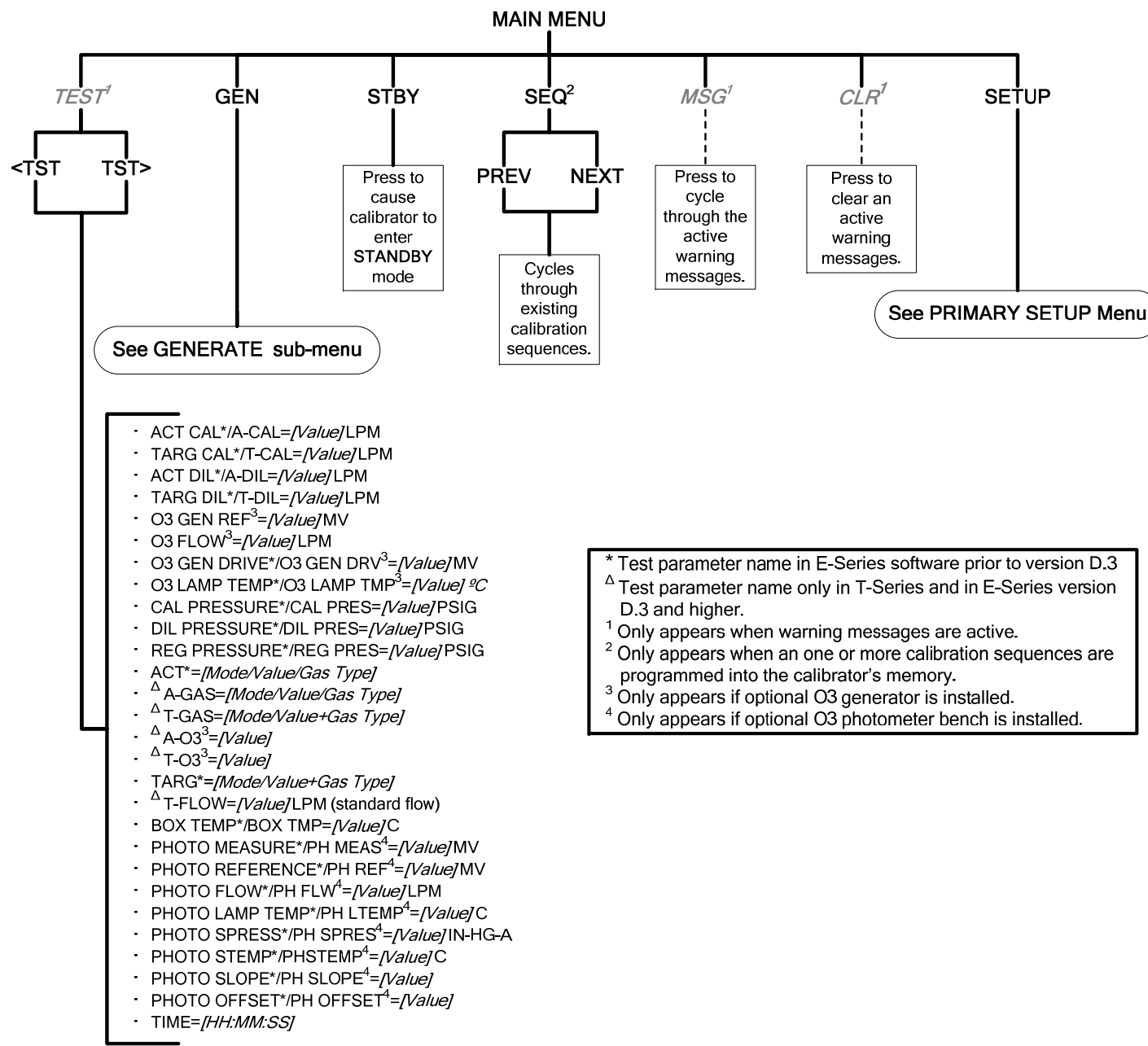


Figure A-1: Main Menu

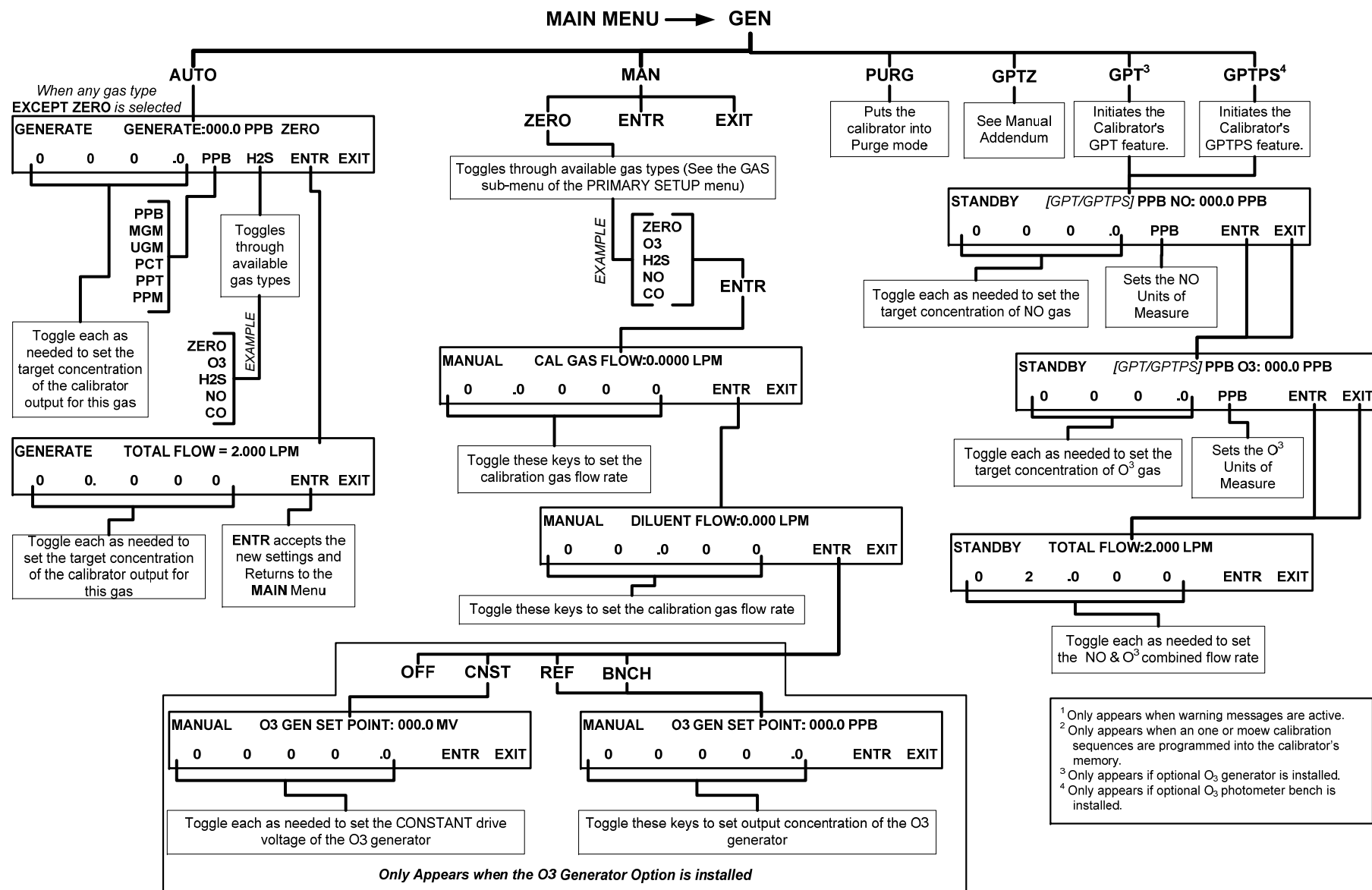


Figure A-2: MAIN Menu - GENERATE Submenu

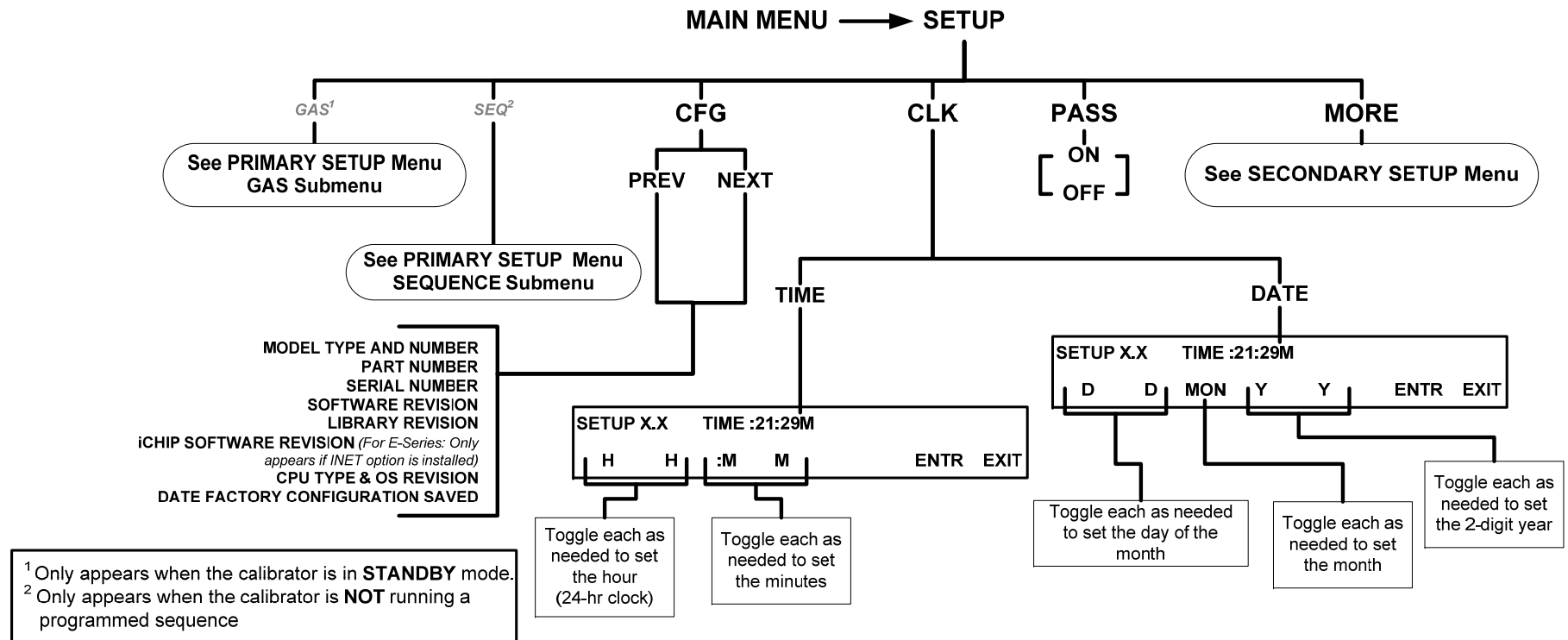


Figure A-3: PRIMARY SETUP MENU - Basics

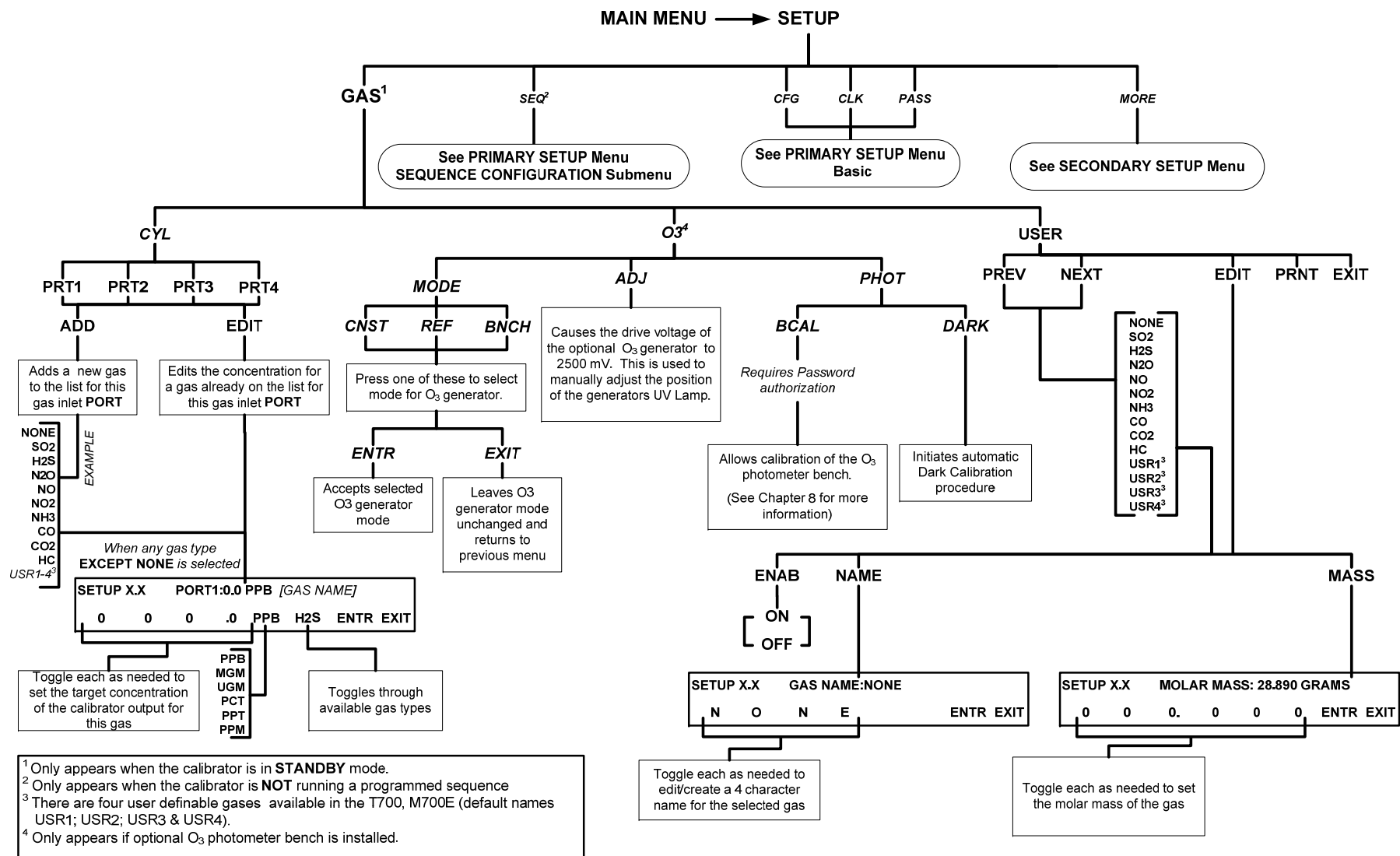


Figure A-4: PRIMARY SETUP Menu - SOURCE GAS CONFIGURATION Submenu

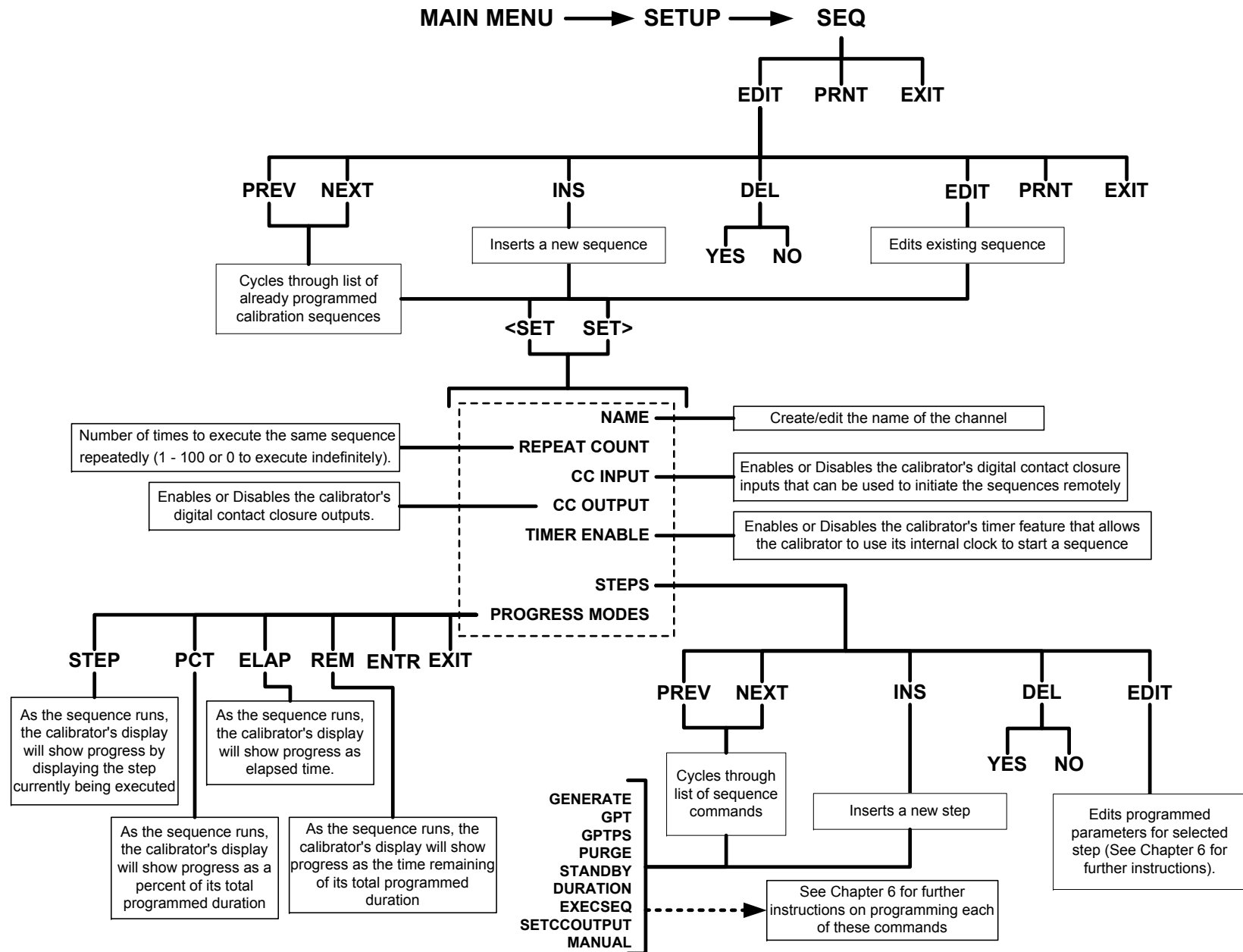


Figure A-5: PRIMARY SETUP Menu - SEQUENCE CONFIGURATION Submenu

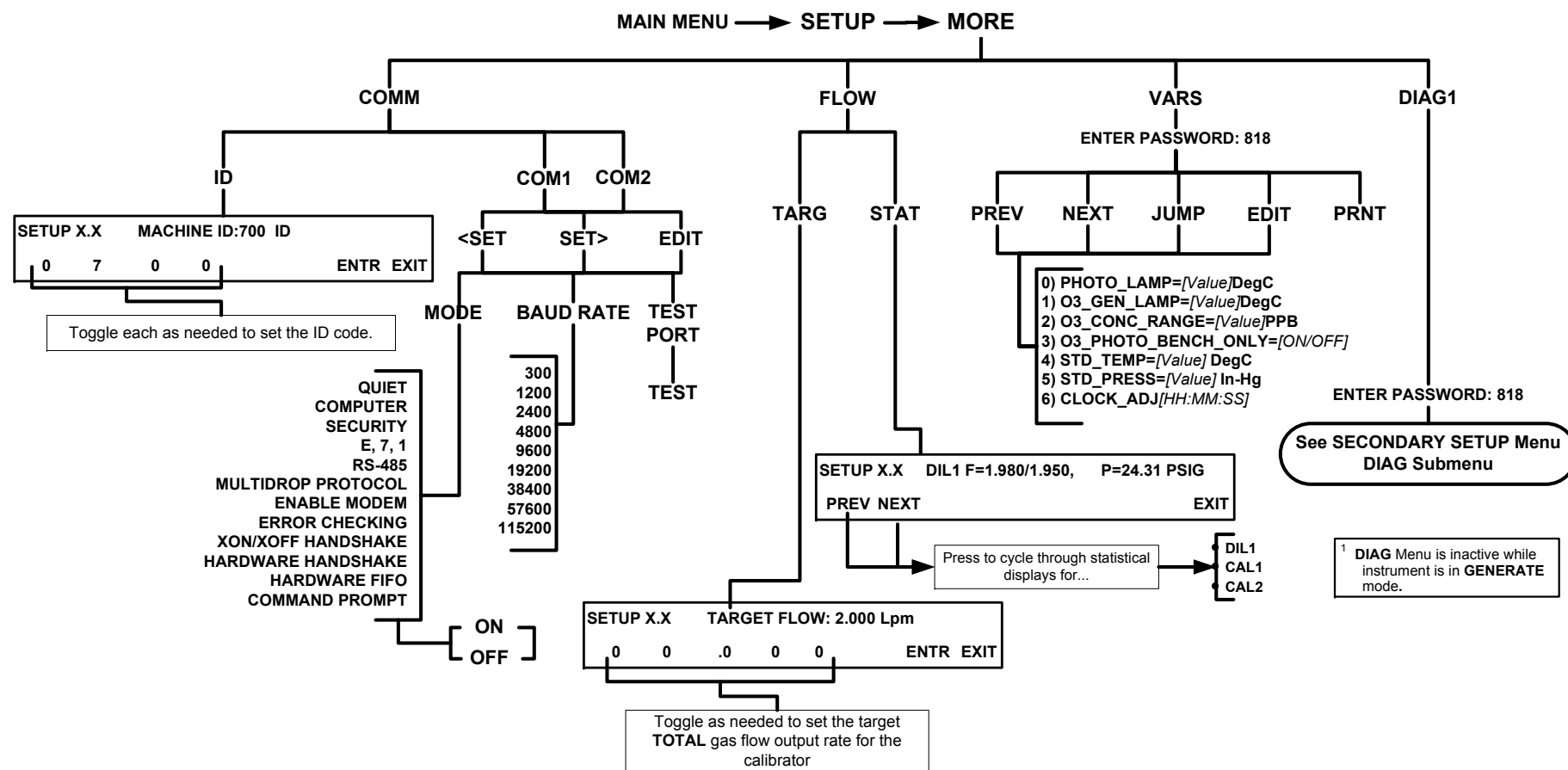


Figure A-6: SECONDARY SETUP Menu - Basic

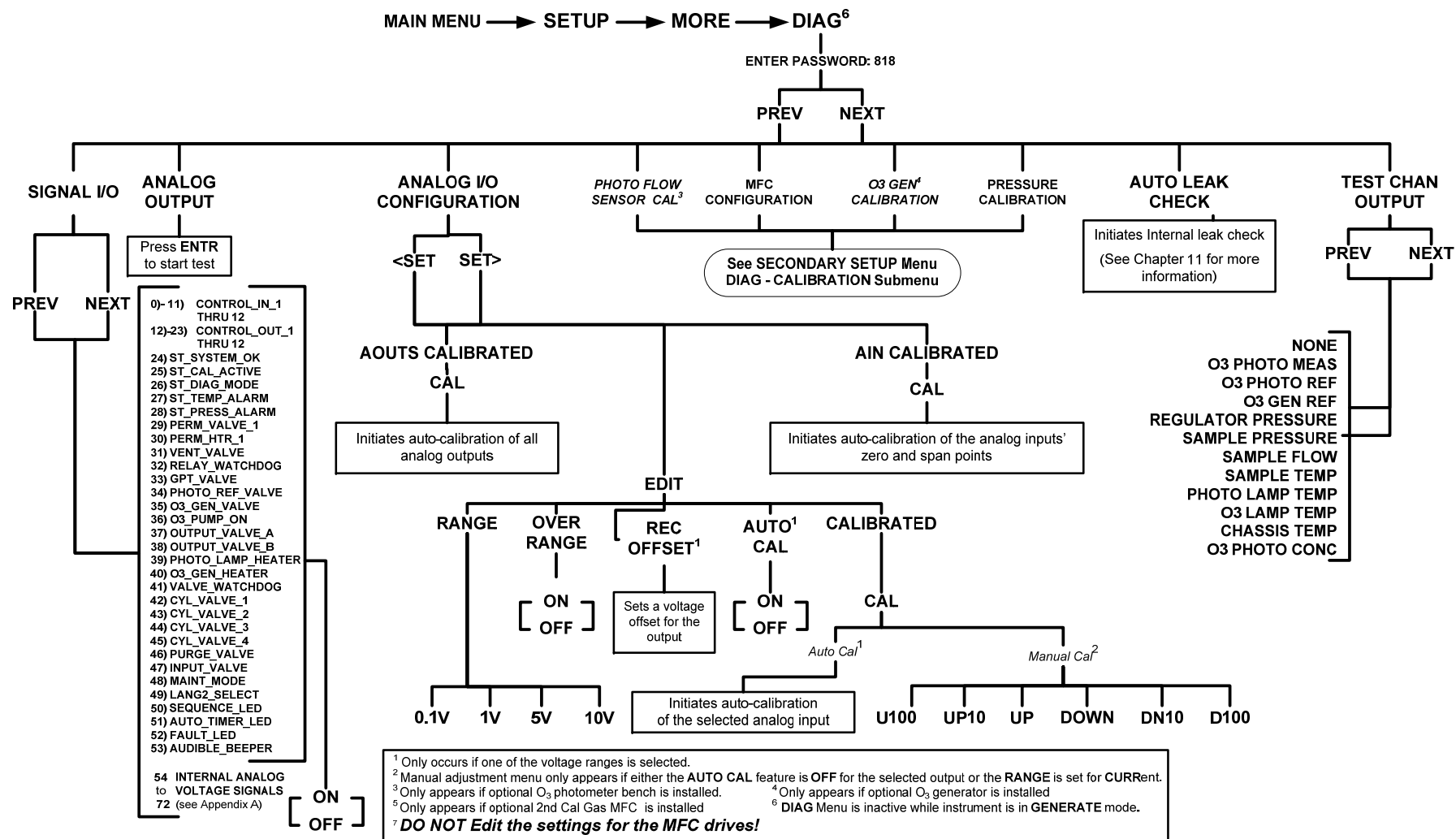


Figure A-7: SECONDARY SETUP Menu; DIAG Submenu – Basics

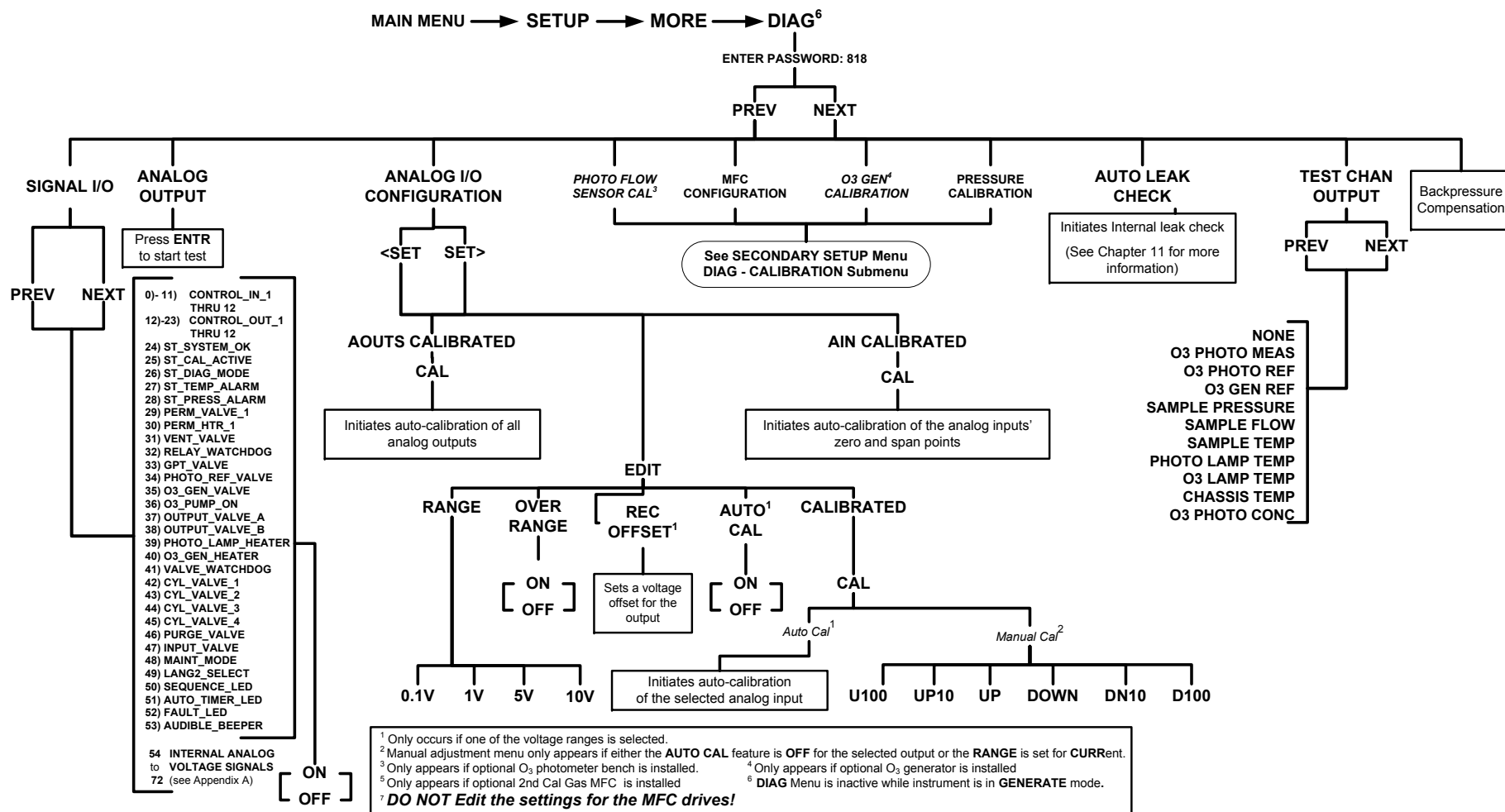


Figure A-8: SECONDARY SETUP Menu; DIAG Submenu – GAS CONFIGURATION

APPENDIX A-2: Setup Variables For Serial I/O, Revision D.3

Table A-1: Setup Variables, Revision D.3

Setup Variable	Numeric Units	Default Value	Value Range	Description
Low Access Level Setup Variables (818 password)				
PHOTO_LAMP	°C	58	0–100	Photometer lamp temperature set point and warning limits.
		Warnings: 56–61		
O3_GEN_LAMP	°C	48	0–100	O ₃ generator lamp temperature set point and warning limits.
		Warnings: 43–53		
O3_CONC_RANGE	PPB	500	0.1–20000	O ₃ concentration range for test channel analog output.
O3_PHOTO_BENCH_ONLY	—	ON	OFF, ON	O ₃ bench control flag. ON turns on pump and switches measure/reference valve only in bench generation mode.
STD_TEMP	°C	25	0–100	Standard temperature for unit conversions.
STD_PRESS	"Hg	29.92	15–50	Standard pressure for unit conversions.
CLOCK_ADJ	Sec./Day	0	-60–60	Time-of-day clock speed adjustment.
Medium Access Level Setup Variables (929 password)				
LANGUAGE_SELECT	—	ENGL	ENGL, SECD, EXTN	Selects the language to use for the user interface. Enclose value in double quotes (") when setting from the RS-232 interface.
MAINT_TIMEOUT	Hours	2	0.1–100	Time until automatically switching out of software-controlled maintenance mode.
O3_DWELL	Seconds	2.5	0.1–30	Dwell time after switching measure/reference valve.
O3_SAMPLE	Samples	1	1–30	Number of O ₃ detector readings to sample.
DARK_OFFSET	mV	0	-1000–1000	Photometer dark offset for measure and reference readings.
FILT_SIZE	Samples	32	1–100	Moving average filter size.
FILT_ASIZE	Samples	6	1–100	Moving average filter size in adaptive mode.
FILT_DELTA	PPB	20	1–1000	Absolute concentration difference to trigger adaptive filter.
FILT_PCT	Percent	5	1–100	Percent concentration difference to trigger adaptive filter.
FILT_DELAY	Seconds	60	0–60	Delay before leaving adaptive filter mode.
FILT_ADAPT	—	ON	OFF, ON	ON enables adaptive filter; OFF disables it.

Setup Variable	Numeric Units	Default Value	Value Range	Description
PDELTA_GAIN	PPB/dIn-Hg	0	-200–200	Multiplied by difference between measure and reference pressure and added to concentration.
PDELTA_CAL_DUR	Minutes	5	0.1–20	Duration of pressure compensation calibration procedure.
O3_SLOPE_CONST	—	1.0	0.1–10	Constant factor to keep visible slope near 1.
O3_SLOPE	—	1	0.850–1.150	O ₃ photometer slope.
O3_OFFSET	PPB	0	-1000–1000	O ₃ photometer offset.
O3_BCAL_SET	PPB	400	0.1–10000	Target O ₃ concentration during bench span calibration.
O3_PUMP_STARTUP	—	ON	OFF, ON	O ₃ pump startup enable. ON enables startup procedure.
O3_PUMP_MIN_FLOW	LPM	0.2	0–1	Minimum flow rate that indicates O ₃ pump is on.
O3_PUMP_TIMEOUT	Seconds	30	1–180	O ₃ pump startup timeout.
O3_PUMP_PULSE	Seconds	0.5	0.1–10	O ₃ pump power off pulse duration.
PHOTO_CYCLE	Seconds	10	0.5–30	Photometer lamp temperature control cycle period.
PHOTO_PROP	—	0.5	0–10	Photometer lamp temperature PID proportional coefficient.
PHOTO_INTEG	—	0.05	0–10	Photometer lamp temperature PID integral coefficient.
PHOTO_DERIV	—	0.2	0–10	Photometer lamp temperature PID derivative coefficient.
PHOTO_FLOW_SLOPE	—	1	0.001–100	Slope term to correct photometer sample flow rate.
O3_DEF_DRIVE	mV	800	0–5000	O ₃ generator default drive setting.
O3_GEN_FLOW	LPM	0.105	0.001–1.000	O ₃ generator nominal flow rate.
O3_GEN_MODE	—	CNST	CNST, REF, BNCH	O ₃ generator control mode. Enclose value in double quotes (") when setting from the RS-232 interface.
O3_MIN_CONC	PPB	25 ⁵	0–100	O ₃ generator minimum reliable concentration. Less than this is treated as zero.
LOW_RANGE_THRESH ⁵	PPB	100	10–2500	O ₃ generator concentration threshold for low range switch.
LOW_RANGE_FRAC ⁵	—	.5	.01–1.0	Fraction of O ₃ generator flow used in low range mode.

Setup Variable	Numeric Units	Default Value	Value Range	Description
REF_DELAY	Seconds	60	1–300	O ₃ generator reference feedback control delay.
REF_FREQ	Seconds	1	1–60	O ₃ generator reference adjustment frequency.
REF_FSIZE	Samples	4	1–10	O ₃ generator reference filter size.
REF_INTEG	—	0.1	0–10	O ₃ generator reference PID integral coefficient.
REF_DERIV	—	0.2	0–10	O ₃ generator reference PID derivative coefficient.
BENCH_DELAY	Seconds	120	1–300	O ₃ generator bench feedback control delay.
BENCH_FREQ	Seconds	10	1–60	O ₃ generator bench adjustment frequency.
BENCH_FSIZE	Samples	3	1–10	O ₃ generator bench filter size.
BENCH_INTEG	—	0.2	0–10	O ₃ generator bench PID integral coefficient.
BENCH_DERIV	—	0.5	0–10	O ₃ generator bench PID derivative coefficient.
DRIVE_STABIL	mV	10	0.1–100	O ₃ generator drive stability limit to update concentration cache.
CACHE_RESOL	PPB	2	0.1–20	O ₃ generator cache un-normalized concentration resolution.
O3_LAMP_CYCLE	Seconds	2	0.5–30	O ₃ generator lamp temperature control cycle period.
O3_LAMP_PROP	1/DegC	0.2	0–10	O ₃ generator lamp temperature PID proportional coefficient.
O3_LAMP_INTEG	Gain	0.01	0–10	O ₃ generator lamp temperature PID integral coefficient.
O3_LAMP_DERIV	Gain	0.2	0–10	O ₃ generator lamp temperature PID derivative coefficient.
MFC_PRESS_LIMIT	PSIG	25	0–50	MFC pressure warning limits. Set point not important.
		Warnings: 15–36		
REG_PRESS_LIM	PSIG	20 8 ⁵	0–50	Regulator pressure warning limits. Set point not important.
		Warnings: 15–25 5–11 ⁵		
PERM_SET1	°C	50	0–100	Permeation tube #1 temperature set point and warning limits.
		Warnings: 49–51		
PERM_SET2 ²	°C	50	0–100	Permeation tube #2 temperature set point and warning limits.
		Warnings: 49–51		
TARGET_FLOW	Lpm	2	0.01–20.00	Default total output flow rate, if flow not specified in individual actions or steps.

Setup Variable	Numeric Units	Default Value	Value Range	Description
RS232_MODE	BitFlag	0	0–65535	RS-232 COM1 mode flags. Add values to combine flags. 1 = quiet mode 2 = computer mode 4 = enable security 8 = enable hardware handshaking 32 = enable multi-drop 64 = enable modem 128 = ignore RS-232 line errors 256 = disable XON / XOFF support 512 = disable hardware FIFOs 1024 = enable RS-485 mode 2048 = even parity, 7 data bits, 1 stop bit 4096 = enable command prompt 8192 = even parity, 8 data bits, 1 stop bit
BAUD_RATE	—	115200	300, 1200, 2400, 4800, 9600, 19200, 38400, 57600, 115200	RS-232 COM1 baud rate. Enclose value in double quotes (") when setting from the RS-232 interface.
MODEM_INIT	—	"AT Y0 &D0 &H0 &I0 S0=2 &B0 &N6 &M0 E0 Q1 &W0" ⁰	Any character in the allowed character set. Up to 100 characters long.	RS-232 COM1 modem initialization string. Sent verbatim plus carriage return to modem on power up or manually.

Setup Variable	Numeric Units	Default Value	Value Range	Description
RS232_MODE2	—	0	0–65535	RS-232 COM2 mode flags. (Same settings as RS232_MODE, plus these when MODBUS option is installed:) 8192 = enable dedicated MODBUS ASCII protocol 16384 = enable dedicated MODBUS RTU or TCP protocol
BAUD_RATE2	—	19200	300, 1200, 2400, 4800, 9600, 19200, 38400, 57600, 115200	RS-232 COM2 baud rate.
MODEM_INIT2	—	"AT Y0 &D0 &H0 &I0 S0=2 &B0 &N6 &M0 E0 Q1 &W0" ⁰	Any character in the allowed character set. Up to 100 characters long.	RS-232 COM2 modem initialization string. Sent verbatim plus carriage return to modem on power up or manually.
RS232_PASS	Password	940331	0–999999	RS-232 log on password.
LINE_DELAY ¹	ms.	0	0–1000	RS-232 inter-line transmit delay (0=disabled).
MACHINE_ID	ID	700	0–9999	Unique ID number for instrument.
COMMAND_PROMPT	—	"Cmd> "	Any character in the allowed character set. Up to 100 characters long.	RS-232 interface command prompt. Displayed only if enabled with RS232_MODE variable. Enclose value in double quotes (") when setting from the RS-232 interface.

Setup Variable	Numeric Units	Default Value	Value Range	Description
TEST_CHAN_ID			NONE, O3 PHOTO MEAS, O3 PHOTO REF, O3 GEN REF, REGULATOR PRESSURE SAMPLE PRESSURE, SAMPLE FLOW, SAMPLE TEMP, PHOTO LAMP TEMP, O3 LAMP TEMP, CHASSIS TEMP, DCPS VOLTAGE, O3 PHOTO CONC	Diagnostic analog output ID. Enclose value in double quotes (") when setting from the RS-232 interface.
PASS_ENABLE	—	ON	OFF, ON	ON enables passwords. OFF disables them.
DEF_CC_OUTPUT	—	"000000000000"	Any string of exactly 12 characters consisting of the digits 0 and 1 only.	Default contact closure output pattern when not executing a sequence. Enclose value in double quotes (") when setting from the RS-232 interface.
PHOTO_LAMP_POWER	mV	4500	0–5000	Photometer lamp power setting.
LAMP_PWR_ENABLE	—	ON	OFF, ON	ON enables photometer lamp power cycling. OFF disables it.
LAMP_PWR_PERIOD	Hours	24	0.01–1000	Photometer lamp power cycling period.
LAMP_OFF_DELAY	Seconds	0.1	0.02–5	Length of time photometer lamp is turned off.
DET_VALID_DELAY	Seconds	20	1–300	Delay until valid concentration is computed.
REF_SDEV_LIMIT	mV	3	0.1–100	Photometer reference standard deviation must be below this limit to switch out of startup mode.
PATH_LENGTH	cm	41.96	0.01–99.999	Photometer detector path length.

Setup Variable	Numeric Units	Default Value	Value Range	Description
BOX_SET	°C	30 Warnings: 5–45	0–100	Internal box temperature set point and warning limits.
GAS_MOL_WEIGHT	MolWt	32	1–99.999	Molar mass of sample gas for computing concentrations by weight instead of volume.
SERIAL_NUMBER	—	“00000000 ”	Any character in the allowed character set. Up to 100 characters long.	Unique serial number for instrument.
DISP_INTENSITY	—	HIGH	HIGH, MED, LOW, DIM	Front panel display intensity. Enclose value in double quotes (") when setting from the RS-232 interface.
I2C_RESET_ENABLE	—	ON	OFF, ON	I ² C bus automatic reset enable.
MFC_BUSY_TIME ⁴	ms.	20	10–1000	Time it takes for MFC to process command.
CLOCK_FORMAT	—	“TIME=%H:%M:%S”	Any character in the allowed character set. Up to 100 characters long.	Time-of-day clock format flags. Enclose value in double quotes (") when setting from the RS-232 interface. “%a” = Abbreviated weekday name. “%b” = Abbreviated month name. “%d” = Day of month as decimal number (01 – 31). “%H” = Hour in 24-hour format (00 – 23). “%I” = Hour in 12-hour format (01 – 12). “%j” = Day of year as decimal number (001 – 366). “%m” = Month as decimal number (01 – 12). “%M” = Minute as decimal number (00 – 59). “%p” = A.M./P.M. indicator for 12-hour clock. “%S” = Second as decimal number (00 – 59). “%w” = Weekday as decimal number (0 – 6; Sunday is 0). “%y” = Year without century, as decimal number (00 – 99). “%Y” = Year with century, as decimal number. “%%” = Percent sign.

Setup Variable	Numeric Units	Default Value	Value Range	Description
FACTORY_OPT	—	0	0–65535	Factory option flags. Add values to combine options. 1 = permeation tube #1 installed (do not enable dual gas outputs option) 2 = O₃ generator installed 4 = O₃ photometer installed 8 = enable high concentration 16 = enable high pressure diluent sensor 32 = O₃ generator reference detector installed (implies that O₃ generator is installed) 64 = enable MFC flow correction 128 = enable dual gas outputs (do not enable permeation tube option) 256 = enable dual diluent inputs 512² = permeation tube #2 installed (do not enable O₃ photometer option) 1024 = enable software-controlled maintenance mode 2048³ = enable Internet option 4096 = enable switch-controlled maintenance mode
¹ Dasibi emulation version only. ² Dual permeation tube option. ³ iChip option (E-Series only). ⁴ I²C MFC option. ⁵ Low range option.				

APPENDIX A-3: Warnings and Test Functions, Revision D.3

Table A-2: Warning Messages, Revision D.3

Name ¹	Message Text	Description
Warnings		
WSYSRES	SYSTEM RESET	Instrument was power-cycled or the CPU was reset.
WDATAINIT	DATA INITIALIZED	Data storage was erased.
WCONFIGINIT	CONFIG INITIALIZED	Configuration storage was reset to factory configuration or erased.
WPHOTOLTEMP	PHOTO LAMP TEMP WARNING	Photometer lamp temperature outside of warning limits specified by <i>PHOTO_LAMP</i> variable.
WO3GENTEMP	O3 GEN LAMP TEMP WARNING	O ₃ generator lamp temperature outside of warning limits specified by <i>O3_GEN_LAMP</i> variable.
WPERMTEMP1	PERM TUBE #1 TEMP WARNING	Permeation tube #1 temperature outside of warning limits specified by <i>PERM_SET1</i> variable.
WPERMTEMP2 ³	PERM TUBE #2 TEMP WARNING	Permeation tube #2 temperature outside of warning limits specified by <i>PERM_SET2</i> variable.
WPHOTOREF	PHOTO REFERENCE WARNING	Photometer reference reading less than 2500 mV or greater than 4999 mV.
WLAMPSTABIL	PHOTO LAMP STABILITY WARNING	Photometer lamp reference step changes occur more than 25% of the time.
WO3GENREF	O3 GEN REFERENCE WARNING	O ₃ reference detector drops below 5 mV during reference feedback O ₃ generator control.
WREGPRESS	REGULATOR PRESSURE WARNING	Regulator pressure outside of warning limits specified by <i>REG_PRESS_LIM</i> variable.
WMFCPRESS	MFC PRESSURE WARNING	Any MFC pressure outside of warning limits specified by <i>PRESS_LIMIT</i> variable.
WMFCFLOW	MFC FLOW WARNING	Any MFC drive less than 10% of full scale or greater than full scale.
WMFCCAL	MFC CALIBRATION WARNING	Any MFC sensor offset greater than allowable limit.
WO3PUMP	O3 PUMP WARNING	O ₃ pump failed to turn on within timeout period specified by <i>O3_PUMP_TIMEOUT</i> variable.
WOUTPUT	INVALID OUTPUT WARNING	An invalid output has been selected for the requested gas generation. For example, output B was selected when generating ozone.
WREARBOARD	REAR BOARD NOT DET	Rear board was not detected during power up.
WRELAYBOARD	RELAY BOARD WARN	Firmware is unable to communicate with the relay board.
WVALVEBOARD	VALVE BOARD WARN	Firmware is unable to communicate with the valve board.
WLAMPDRIVER	LAMP DRIVER WARN	Firmware is unable to communicate with either the O ₃ generator or photometer lamp I ² C driver chip.

Name ¹	Message Text	Description
WFRONTPANEL ⁶	FRONT PANEL WARN	Firmware is unable to communicate with the front panel.
WMFCCOMM ⁴	MFC COMMUNICATION WARNING	Firmware is unable to communicate with any MFC.
WANALOGCAL	ANALOG CAL WARNING	The A/D or at least one D/A channel has not been calibrated.
¹ The name is used to request a message via the RS-232 interface, as in "T BOXTEMP". ² O ₃ photometer stability measurement option. ³ Dual permeation tube option. ⁴ I ² C MFCs. ⁵ Low range option. ⁶ E-Series only.		

Table A-3: Test Functions, Revision D.3

Name ¹	Message Text	Description
Test Measurements		
Parameter name in T-Series and in E-Series w/ software v. D.3 and higher.	Parameter name in earlier E-Series software versions and test meas value	
A-CAL	ACT CAL=0.0800 LPM	Actual cal. gas flow rate.
T-CAL	TARG CAL=0.0000 LPM	Target cal. gas flow rate.
A-DIL	ACT DIL=1.920 LPM	Actual diluent flow rate.
T-DIL	TARG DIL=0.000 LPM	Target diluent flow rate.
O3GENREF ⁶	O3 GEN REF=1000.0 MV	O ₃ generator reference detector reading.
O3FLOW ⁶	O3 FLOW=0.1050 LPM	O ₃ generator flow rate. Note: this is simply a constant, specified by the O3_GEN_FLOW variable.
O3GENDRV ⁶	O3 GEN DRIVE=800.0 MV	O ₃ generator lamp drive output.
O3LAMPTMP ⁶	O3 LAMP TEMP=49.7 C	O ₃ generator lamp temperature.
CAL PRES	CAL PRESSURE=25.1 PSIG	Cal. gas pressure.
DIL PRES	DIL PRESSURE=25.1 PSIG	Diluent pressure.
REG PRES	REG PRESSURE=20.1 PSIG	Regulator pressure.
(n/a)	ACT=GENERATE 37 PPB O3	Actual concentration being generated, computed from real-time inputs.
A-GAS	(n/a)	T-GAS ± 1%
T-GAS	(n/a)	
A-O3 ⁷	(n/a)	T-O3 ± 1%
T-O3 ⁷	(n/a)	
(n/a)	TARG=GENERATE 100 PPB O3	Target concentration to generate.
T-FLW	(n/a)	Target standard flow in LPM
BOX TMP	BOX TEMP=31.2 C	Internal chassis temperature.
PERM1 TMP	PERM TUBE #1 TEMP=50.4 C	Permeation tube #1 temperature.
PERM2 TMP ³	PERM TUBE #2 TEMP=50.4 C	Permeation tube #2 temperature.
PERMFLW ³	PERM FLOW=0.1050 LPM	Permeation tube flow rate. This is a property of the permeation tube (SETUP-GAS-PERM). Its value depends on which permeation tube is in use.
PH MEAS ⁷	PHOTO MEASURE=2998.8 MV	Photometer detector measure reading.
PH REF ⁷	PHOTO REFERENCE=3000.0 MV	Photometer detector reference reading.
PH FLW ⁷	PHOTO FLOW=0.2978 LPM	Photometer sample flow rate.
PH LTEMP ⁷	PHOTO LAMP TEMP=52.6 C	Photometer lamp temperature.
PH PRES ⁷	PHOTO SPRESS=29.9 IN-HG-A	Photometer sample pressure.
PHO STEMP ⁷	PHOTO STEMP=31.8 C	Photometer sample temperature.
PHO SLOPE ⁷	PHOTO SLOPE=1.000	Photometer slope computed during zero/span bench calibration.
PH OFFST ⁷	PHOTO OFFSET=0.0 PPB	Photometer offset computed during zero/span bench calibration.
PHOTOSTABIL ²	PHOTO STABIL=0.1 PPB	Photometer concentration stability (standard deviation of 25 bench concentration samples taken 10 seconds apart).

Name ¹	Message Text	Description
TESTCHAN	TEST=2753.9 MV	Value output to <i>TEST_OUTPUT</i> analog output, selected with <i>TEST_CHAN_ID</i> variable.
CLOCKTIME	TIME=14:48:01	Current instrument time of day clock.
¹ The name is used to request a message via the RS-232 interface, as in "T BOXTEMP". ² O ₃ photometer stability measurement option. ³ Dual permeation tube option. ⁴ I ² C MFCs. ⁵ Low range option. ⁶ O ₃ generator option. ⁷ Photometer option.		

APPENDIX A-4: Signal I/O Definitions**Table A-4: Signal I/O Definitions 3**

Signal Name	Bit or Channel Number	Description
U11, J1004, control inputs, pins 1-6 = bits 0-5, read, default I/O address 321 hex		
CONTROL_IN_1 – CONTROL_IN_6	0–5	0 = input asserted 1 = de-asserted
	6–7	Always 1
U14, J1006, control inputs, pins 1-6 = bits 0-5, read, default I/O address 325 hex		
CONTROL_IN_7 – CONTROL_IN_12	0–5	0 = input asserted 1 = de-asserted
	6–7	Always 1
U17, J1008, control outputs, pins 1-8 = bits 0-7, write, default I/O address 321 hex		
CONTROL_OUT_1 – CONTROL_OUT_8	0–7	0 = output asserted 1 = de-asserted
U21, J1008, control outputs, pins 9-12 = bits 0-3, write, default I/O address 325 hex		
CONTROL_OUT_9 – CONTROL_OUT_12	0–3	0 = output asserted 1 = de-asserted
U7, J108, internal inputs, pins 9-16 = bits 0-7, read, default I/O address 322 hex		
	0–7	Spare
U8, J108, internal outputs, pins 1-8 = bits 0-7, write, default I/O address 322 hex		
	0–7	Spare
U24, J1017, A status outputs, pins 1-8 = bits 0-7, write, default I/O address 323 hex		
ST_SYSTEM_OK	0	0 = system OK 1 = any alarm condition or in diagnostics mode
	1	Spare
ST_CAL_ACTIVE	2	0 = executing sequence 1 = not executing sequence
ST_DIAG_MODE	3	0 = in diagnostic mode 1 = not in diagnostic mode
ST_TEMP_ALARM	4	0 = any temperature alarm 1 = all temperatures OK
ST_PRESS_ALARM	5	0 = any pressure alarm 1 = all pressures OK
	6–7	Spare
U27, J1018, B status outputs, pins 1-8 = bits 0-7, write, default I/O address 324 hex		
	0–7	Spare

Signal Name	Bit or Channel Number	Description
Relay board digital output (PCF8575), write, default I²C address 44 hex		
RELAY_WATCHDOG	0	Alternate between 0 and 1 at least every 5 seconds to keep relay board active
VENT_VALVE	1	0 = vent valve open 1 = close
PERM_HTR_2 ²	2	0 = permeation tube #2 heater on 1 = off
	3–4	Spare
GPT_VALVE	5	0 = open GPT bypass valve 1 = close
PHOTO_REF_VALVE	6	0 = photometer valve in reference position 1 = measure position
O3_GEN_VALVE	7	0 = open O ₃ generator valve 1 = close
O3_PUMP_ON	8	0 = pump on for photometer to measure O ₃ 1 = off
O3_DIVERT_VALVE	9	0 = open O3 divert valve 1 = close
OUTPUT_VALVE_B ¹	10	0 = open output shut-off valve B 1 = close
PERM_VALVE_1	11	0 = open permeation tube #1 valve 1 = close
PERM_VALVE_2 ²	12	0 = open permeation tube #2 valve 1 = close
PERM_HTR_1	13	0 = permeation tube #1 heater on 1 = off
PHOTO_LAMP_HEATER	14	0 = O ₃ photometer lamp heater on 1 = off
O3_GEN_HEATER	15	0 = O ₃ generator lamp heater on 1 = off
Valve board digital output (PCA9557), write, default I²C address 3A hex		
VALVE_WATCHDOG	0	Alternate between 0 and 1 at least every 5 seconds to keep valve board active
CYL_VALVE_1	1	1 = open cylinder gas valve 1 0 = close
CYL_VALVE_2	2	1 = open cylinder gas valve 2 0 = close
CYL_VALVE_3	3	1 = open cylinder gas valve 3 0 = close
CYL_VALVE_4	4	1 = open cylinder gas valve 4 0 = close

Signal Name	Bit or Channel Number	Description
PURGE_VALVE	5	1 = open purge valve 0 = close
INPUT_VALVE	6	1 = open input (zero-air) shut-off valve 0 = close
DIL_VALVE_2 ⁵	7	1 = open diluent valve #2 0 = open diluent valve #1
Front panel I²C keyboard, default I²C address 4E hex		
MAINT_MODE	5 (input)	0 = maintenance mode 1 = normal mode
LANG2_SELECT	6 (input)	0 = select second language 1 = select first language (English)
SEQUENCE_LED	8 (output)	0 = sequence LED on (executing sequence) 1 = off
AUTO_TIMER_LED	9 (output)	0 = automatic timer LED on (automatic sequence timer enabled) 1 = off
FAULT_LED	10 (output)	0 = fault LED on 1 = off
AUDIBLE_BEEPER	14 (output)	0 = beeper on (for diagnostic testing only) 1 = off
Rear board primary MUX analog inputs		
PHOTO_DET	0	Photometer detector reading
O3_GEN_REF_DET	1	O ₃ generator reference detector reading
DIL_PRESS	2	Diluent pressure
CAL_PRESS	3	Cal. gas pressure
	4	Temperature MUX
O3_PERM_PRESS	5	Ozone/perm tube pressure
	6–7	Spare
MFC_FLOW_3 ⁴	8	MFC 3 (cal. gas #2) flow output
REF_4096_MV	9	4.096V reference from MAX6241
PHOTO_FLOW	10	Photometer flow
PHOTO_SAMP_PRES	11	Photometer sample pressure
MFC_FLOW_1	12	MFC 1 (diluent) flow output
MFC_FLOW_2	13	MFC 2 (cal. gas #1) flow output
	14	DAC loopback MUX
REF_GND	15	Ground reference
Rear board temperature MUX analog inputs		
BOX_TEMP	0	Internal box temperature
PHOTO_SAMP_TEMP	1	Photometer sample temperature
PHOTO_LAMP_TEMP	2	Photometer lamp temperature
O3_GEN_TEMP	3	O ₃ generator lamp temperature
PERM_TEMP_1	4	Permeation tube #1 temperature
PERM_TEMP_2 ²	5	Permeation tube #2 temperature

Signal Name	Bit or Channel Number	Description
	6–7	Spare
Rear board DAC MUX analog inputs		
DAC_CHAN_1	0	DAC channel 0 loopback
DAC_CHAN_2	1	DAC channel 1 loopback
DAC_CHAN_3	2	DAC channel 2 loopback
DAC_CHAN_4	3	DAC channel 3 loopback
Rear board analog outputs		
MFC_DRIVE_1	0	MFC 1 (diluent) flow drive
MFC_DRIVE_2	1	MFC 2 (cal. gas #1) flow drive
MFC_DRIVE_3 ⁴	2	MFC 3 (cal. gas #2) flow drive
TEST_OUTPUT	3	Test measurement output
I²C analog output (AD5321), default I²C address 18 hex		
PHOTO_LAMP_DRIVE	0	O ₃ photometer lamp drive (0–5V)
I²C analog output (AD5321), default I²C address 1A hex		
O3_GEN_DRIVE	0	O ₃ generator lamp drive (0–5V)
¹ Must be enabled with a factory option bit. ² Dual permeation tube option. ⁴ Triple-MFC option. ⁵ Dual diluent option.		

APPENDIX A-5: MODBUS Register Map

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	Ozone generator reference detector reading	mV
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	O ₃ generator reference detector warning	
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 ² C 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 <i>SYSTEM_OK</i> 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.	

APPENDIX A-6: Terminal Command Designators**Table A-5: Terminal Command Designators**

COMMAND	ADDITIONAL COMMAND SYNTAX	DESCRIPTION
? [ID]		Display help screen and commands list
LOGON [ID]	password	Establish connection to instrument
LOGOFF [ID]		Terminate connection to instrument
T [ID]	SET ALL name hexmask	Display test(s)
	LIST [ALL name hexmask] [NAMES HEX]	Print test(s) to screen
	name	Print single test
	CLEAR ALL name hexmask	Disable test(s)
W [ID]	SET ALL name hexmask	Display warning(s)
	LIST [ALL name hexmask] [NAMES HEX]	Print warning(s)
	name	Clear single warning
	CLEAR ALL name hexmask	Clear warning(s)
C [ID]	ZERO LOWSPAN SPAN [1 2]	Enter calibration mode
	ASEQ number	Execute automatic sequence
	COMPUTE ZERO SPAN	Compute new slope/offset
	EXIT	Exit calibration mode
	ABORT	Abort calibration sequence
D [ID]	LIST	Print all I/O signals
	name[=value]	Examine or set I/O signal
	LIST NAMES	Print names of all diagnostic tests
	ENTER name	Execute diagnostic test
	EXIT	Exit diagnostic test
	RESET [DATA] [CONFIG] [exitcode]	Reset instrument
V [ID]	LIST	Print setup variables
	name[=value [warn_low [warn_high]]]	Modify variable
	name="value"	Modify enumerated variable
	CONFIG	Print instrument configuration
	MAINT ON OFF	Enter/exit maintenance mode
	MODE	Print current instrument mode

The command syntax follows the command type, separated by a space character. Strings in [brackets] are optional designators. The following key assignments also apply.

Table A-6: Terminal Key Assignments

TERMINAL KEY ASSIGNMENTS	
ESC	Abort line
CR (ENTER)	Execute command
Ctrl-C	Switch to computer mode
COMPUTER MODE KEY ASSIGNMENTS	
LF (line feed)	Execute command
Ctrl-T	Switch to terminal mode

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APPENDIX B - Spare Parts

Note	Use of replacement parts other than those supplied by T-API may result in non compliance with European standard EN 61010-1.

Note	Due to the dynamic nature of part numbers, please refer to the Website or call Customer Service for more recent updates to part numbers.

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T700 Spare Parts List
PN 06852B DCN6014 03/10/2011
1 of 3 page(s)

Part Number	Description
000940100	ORIFICE, 3 MIL, 03 GEN
003290000	THERMISTOR, BASIC (VENDOR ASSY)(KB)
006120100	ASSY, UV LAMP, OZONE GENERATOR
014540300	CONTROLLER, MFC, HFC-212, 100SCCM *
014550300	CONTROLLER, MFC, HFC-212, 10 SLM *
014570100	ASSY, INLET MANIFOLD, (KB)
014900000	ASSY, GPT
016590100	ASSY, GPT VALVE
022710000	ABSORPTION TUBE, QUARTZ, (KB)
024710000	ASSY, TUBING, CLEAR FEP 1/8" (TU1), 6FT
024720000	ASSY, TUBING, (B/F) TU0000002, 6FT
024730000	ASSY, TUBING, TU0000005, 6FT
024750000	ASSY, TYGON TUBING (B/F) TU0000009, 6FT
040010000	ASSY, FAN REAR PANEL
040030500	PCA, PRESS SENSORS (2X)
040030600	PCA, PRESS SENSORS (1X), OZONE OPT
041200000	PCA, DET PREAMP w/OP20
041200200	PCA, DET PREAMP w/OP20
041240001	MANIFOLD, DETECTOR, (KB)
041270000	LAMP BLOCK, (KB)
041280000	LAMP SPACER, (KB)
041300000	EXHAUST MANIFOLD, (KB)
041440000	PCA, DC HEATER/TEMP SENSOR, OPTICAL BENCH
042010000	ASSY, SAMPLE THERMISTOR
045230100	PCA, RELAY CARD
046740000	ASSY, PUMP, 12VDC (OP63)
048190300	ASSY, RELAY/PS, CAL
049290000	CLIP, THERMISTOR HOLDER
050490000	ASSY, O3 GENERATOR W/BRKT & REG
050500000	ASSY, O3 GENERATOR, 5LPM
052400000	ASSY, BENCH UV LAMP, (BIR), CR *
052910200	ASSY, OPTICAL BENCH, CAL
054690000	PCA, VALVE DRIVER, M700E
055020000	ASSY, INLET MANIFOLD W/PCA
055210000	OPTION, PHOTOMETER
055220000	ASSY, VALVE, PHOTOMETER
055240000	OPTION, OZONE, CAL (KB)
055270000	ASSY, EXHAUST MANIFOLD, (KB)
055560000	ASSY, VALVE, VA59 W/DIODE, 5" LEADS
056440000	ASSY, VALVE (VA23)
056450000	ASSY, VALVE (VA32)
056970000	PCA, EXT O/P ADPTR, LDS, (OPT)
057230000	PCA, SINGLE VALVE DRIVER (OPTION)
057360000	ASSY, 3/8" VENT ADAPTER

T700 Spare Parts List
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2 of 3 page(s)

Part Number	Description
057400001	FRONT FERRULE,SS,1/4",SILCOSTEEL
057520001	FRONT FERRULE,SS, 1/8",SILCOSTEEL
057630000	ASSY, DUAL OUTPUT VALVE
058021400	PCA, E-SERIES MTHRBRD, M700E, GEN 5-I (ACCEPTS ACROSSER OR ICOP CPU)
058430001	FT 40 FITTING BODY, SILCOSTEEL COATED
058440001	FT 36 FITTING BODY, SILCOSTEEL COATED
060340001	FT 85 FITTING BODY, SILCOSTEEL COATED
061630000	ASSY, FILTER, DFU, DESORBER (SOAKED)
063110000	PCA, DC HEATER/THERM, 100W
064130000	ASSY, DC HEATER/THERM PCA, O3 GEN
066970000	PCA, INTRF. LCD TOUCH SCRIN, F/P
067240000	CPU, PC-104, VSX-6154E, ICOP *(KB)
067300000	PCA, AUX-I/O BD, ETHERNET, ANALOG & USB
067300100	PCA, AUX-I/O BOARD, ETHERNET
067300200	PCA, AUX-I/O BOARD, ETHERNET & USB
067900000	LCD MODULE, W/TOUCHSCREEN(KB)
068290100	DOM, w/SOFTWARE, STD, T700 *
068730000	MANUAL, T700, OPERATORS
068810000	PCA, LVDS TRANSMITTER BOARD
069500000	PCA, SERIAL & VIDEO INTERFACE BOARD
072150000	ASSY. TOUCHSCREEN CONTROL MODULE
CN0000073	POWER ENTRY, 120/60 (KB)
CN0000458	CONNECTOR, REAR PANEL, 12 PIN
CN0000520	CONNECTOR, REAR PANEL, 10 PIN
CN0000640	CONNECTOR, REAR PANEL, 14 PIN
FM0000004	FLOWMETER (KB)
FM0000007	REGULATOR, PRESSURE, 0-30PSI(KB)
FT0000013	CONNECTOR-M, T, 1/8" (KB)
FT0000036	TEE-TTT, SS, 1/4" (HK)
FT0000040	UNION, BULKHEAD, SS, 1/4" (HK)
FT0000056	TEE-TTT, SS, 1/8" (HK)
FT0000085	PORT CONNECTOR, SS, 1/4" (HK)
FT0000134	BLKHD, UNION, REDUCING, SS, 1/4-1/8 (HK)
FT0000151	UNION, CROSS, TFE, 2-1/4", 2-1/8" KB
FT0000192	ELBOW, B, 1/8 X 1/4 TUBING
FT0000278	FEMALE COUPLING, 10-32, BRASS
FT0000279	HEX EXTENSION, B, 10-32 M-F
FT0000321	PORT CONNECTOR, SS, 1/8" (HK)
FT0000332	FITTING, 9 MIL, ZERO AIR FLOW
FT0000364	.003 ORIFICE, 10-32 X 10-32 W/ORING, BRA
FT0000429	ORIFICE, BARB, SS, 0.012"
HW0000005	FOOT
HW0000120	SHOCKMOUNT, GROMMET ISOLATOR
HW0000149	SEALING WASHER, #10
HW0000327	HEATSINK CLIP, TO-220
HW0000328	INSULATING THERMAL PAD, TO-220

T700 Spare Parts List
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Part Number	Description
HW0000356	PAD, THERMAL, TO-220, W/ ADHV
HW0000453	SUPPORT, CIRCUIT BD, 3/16" ICOP
KIT000253	ASSY & TEST, SPARE PS37
KIT000289	AKIT, UV LAMP P/S PCA, 041660100
KIT000290	AKIT, UV LAMP P/S PCA, 041660500
OP0000014	LAMP WINDOW, OPTICAL BENCH
OP0000031	WINDOW, OPTICAL BENCH & OZONE GEN FEEDBACK
OR0000001	ORING, SAMPLE FLOW & OZONE GENERATOR
OR0000026	ORING, ABSORPTION TUBE
OR0000039	ORING, OPTICAL BENCH & OZONE GEN FEEDBACK
OR0000046	ORING, 2-019V
OR0000077	ORING, 2-018V
OR0000089	ORING, OPTICAL BENCH
PS0000037	PS, 40W SWITCHING, +5V, +/-15V(KB) *
PS0000039	PS, SWITCHING, 12V/7.5A (KB)
PS0000040	PS,EXT,AC/DC (90-264V/47-63HZ),12V/3.75A
SW0000025	SWITCH, POWER, CIRC BREAK, VDE/CE *(KB)
WR0000008	POWER CORD, 10A(KB)

T700
RECOMMENDED SPARES
STOCKING LEVELS

(Reference: 07565A DCN6306)

PART NO.	DESCRIPTION	UNITS				
		1	2-5	6-10	11-20	21-30
006120100	ASSY, OZONE GEN LAMP	*	*	1	2	4
014540300	MASS FLOW CONTROLLER, 100CCM	*	*	*	*	1
014550300	MASS FLOW CONTROLLER, 10LPM	*	*	*	*	1
040010000	ASS, FAN, REAR PANEL	1	1	2	4	8
040030500	PCA, ;PRESS SENSORS (2X), 700E	*	*	*	1	2
040030700	PCA, PRESS SENSOR PHOTO OPT	*	1	2	4	8
041200200	PCA, DET. PREAMP w/OP20, O3 GEN	*	*	*	1	2
041660100	PCA, UV POWER SUPPLY, O3 GEN	*	*	*	1	2
041660500	PCA, UV POWER SUPPLY, OPT BENCH	*	*	*	1	2
067240000	CPU, PC-104, VSX-6154E, ICOP *(KB)	*	*	*	1	2
045230100	PCA, RELAY CARD	*	*	1	2	4
047020000	ASSY, PUMP	*	*	*	*	1
056440000	VALVE, CYL PORTS, 2-WAY	1	1	2	4	8
056450000	VALVE, DILUTION PORT 2-WAY	*	*	*	1	2
058021400	PCA, MTHRBRD, CAL, GEN 5-I	*	*	*	1	2
PS0000037	POWER SUPPLY, +5, +15, -15	*	*	*	1	2
PS0000039	POWER SUPPLY, 12V	*	*	*	1	2
067900000	LCD MODULE, W/TOUCHSCREEN(KB)				1	2
066970000	PCA, INTRF. LCD TOUCH SCRIN, F/P				1	2
068810000	PCA, LVDS TRANSMITTER BOARD				1	2
072150000	TOUCHSCREEN CONTROL MODULE			1	2	3
	PHOTOMETER					
022710000	ABSORPTION TUBE, QUARTZ	*	1	2	4	8
041200000	PCA, DET. PREAMP w/OP20, BENCH	*	*	*	1	2
041440000	PCA, DC HEATER/TEMP SENSOR	1	1	2	4	8
042010000	THERMISTOR ASSEMBLY	1	1	2	4	8
052400000	ASSY, BENCH UV LAMP, (BIR), CR *	*	*	1	2	4

Appendix C
Warranty/Repair Questionnaire
T700, M700E
(05625B DCN5798)



TELEDYNE
ADVANCED POLLUTION INSTRUMENTATION
A Teledyne Technologies Company

CUSTOMER: _____ PHONE: _____

CONTACT NAME: _____ FAX NO. _____

SITE ADDRESS: _____

MODEL TYPE: _____ SERIAL NO.: _____ FIRMWARE REVISION: _____

Are there any failure messages? _____

(Continue on back if necessary)

PLEASE COMPLETE THE FOLLOWING TABLE (Depending on options installed, not all test parameters shown will be available in your calibrator):

PARAMETER		RECORDED VALUE	ACCEPTABLE VALUE
Name in E-Series software versions prior to v.C.1.	Name in T-Series and in E-series w/software v. D.3 and higher		
ACT CAL	A-CAL	LPM*	TARG CAL $\pm$ 1%
TARG CAL	T-CAL	LPM*	0.001 – 0.100 SLPM
ACT DIL	A-DIL	LPM*	TARG DIL $\pm$ 1%
TARG DIL	T-DIL	LPM*	0.01 – 10 SLPM
O3 GEN REF ¹	O3GENREF ¹	mV	0 – 5000mV
O3 FLOW ¹	O3FLOW ¹	LPM*	0.100 $\pm$ 0.025 SLPM
O3 GEN DRIVE ¹	O3GENDRV ¹	mV	0 – 5000mV
O3 LAMP TEMP ¹	O3LAMPTMP ¹	°C	48 $\pm$ 1°C
CAL PRESSURE	CAL PRES	PSI	25 – 35PSI
DIL PRESSURE	DIL PRES	PSI	25 – 35PSI
REG PRESSURE ¹	REG PRES ¹	PSI	20 $\pm$ 1PSI
ACT	(n/a)		TARG $\pm$ 1%
(n/a)	A-GAS		T-GAS $\pm$ 1%
(n/a)	T-GAS		
(n/a)	A-O3 ¹		T-O3 $\pm$ 1%
(n/a)	T-O3 ¹		
TARG	(n/a)		
(n/a)	T-FLW	LPM*	
BOX TEMP	BOX TMP	°C	AMBIENT $\pm$ 5°C
PERM TUBE #1 TEMP ³	PERM1 TMP ³	°C	50 $\pm$ 1°C
PERM FLOW ³	PERM FLW ³	LPM*	0.100 $\pm$ 0.025 SLPM
PHOTO MEASURE ²	PH MEAS ²	mV	2500 – 4800mV
PHOTO REFERENCE ²	PH REF ²	mV	2500 – 4800mV
PHOTO FLOW ²	PH FLW ²	LPM	0.720 – 0.880LPM
PHOTO LAMP TEMP ²	PH LTEMP ²	°C	58 $\pm$ 1°C
PHOTO SPRESS ²	PH PRES ²	IN-HG	AMBIENT $\pm$ 1 IN-HG
PHOTO STEMP ²	PH STEMP ²	°C	AMBIENT $\pm$ 3°C
PHOTO SLOPE ²	PH SLOPE ²		0.85-1.15
PHOTO OFFSET ²	PH OFFST ²	PPB	0 $\pm$ 10 PPB

¹ If ozone generator option installed. ² If photometer option installed. ³ If permeation tube installed. *Standard flow

TELEDYNE INSTRUMENTS CUSTOMER SERVICE

EMAIL: api-customerservice@teledyne.com

PHONE: (858) 657-9800

TOLL FREE: (800) 324-5190

FAX: (858) 657-9816

Appendix C
Warranty/Repair Questionnaire
T700, M700E
(05625B DCN5798)



TELEDYNE
ADVANCED POLLUTION INSTRUMENTATION
A Teledyne Technologies Company

What is measured photometer flow rate _____ cc/min

What is measured O₃ generator flow rate? _____ cc/min

what is the pressure change during the **AUTO LEAK CHECK** procedure? _____ psi

What are the failure symptoms? _____

What tests have you done trying to solve the problem? _____

Thank you for providing this information. Your assistance enables Teledyne Instruments to respond faster to the problem that you are encountering.

OTHER NOTES: _____

APPENDIX D – Wire List and Electronic Schematics

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Interconnect List T700

(Reference: 069140100A DCN5870)

Revision	Description					Checked	Date	DCN	
A	Production Release					KV	10/4/2010	5870	
CONNECTION FROM									
Cable Part #	Signal	Assembly	PN	J/P	Pin	Assembly	PN	J/P	Pin
036490100 CBL, AC POWER									
	AC Line	Power Entry	CN0000073		L	Power Switch	SW0000025		L
	AC Neutral	Power Entry	CN0000073		N	Power Switch	SW0000025		N
	Power Grnd	Power Entry	CN0000073			Shield	SW0000025		
	Power Grnd	Power Entry	CN0000073			Chassis			
	AC Line Switched	Power Switch	SW0000025		L	PS2 (+12)	PS0000039	J1	1
	AC Neutral Switched	Power Switch	SW0000025		N	PS2 (+12)	PS0000039	J1	3
	Power Grnd	Power Entry	CN0000073			PS2 (+12)	PS0000039	J1	2
	AC Line Switched	Power Switch	SW0000025		L	PS1 (+5, ±15)	PS0000037	J1	1
	AC Neutral Switched	Power Switch	SW0000025		N	PS1 (+5, ±15)	PS0000037	J1	3
	Power Grnd	Power Entry	CN0000073			PS1 (+5, ±15)	PS0000037	J1	2
	AC Line Switched	Power Switch	SW0000025		L	Relay Board	045230100	J1	1
	AC Neutral Switched	Power Switch	SW0000025		N	Relay Board	045230100	J1	3
	Power Grnd	Power Entry	CN0000073			Relay Board	045230100	J1	2
038290000 CBL, DC POWER TO MOTHERBOARD									
	DGND	Relay Board	045230100	J7	1	Motherboard	058021400	J15	1
	+5V	Relay Board	045230100	J7	2	Motherboard	058021400	J15	2
	AGND	Relay Board	045230100	J7	3	Motherboard	058021400	J15	3
	+15V	Relay Board	045230100	J7	4	Motherboard	058021400	J15	4
	AGND	Relay Board	045230100	J7	5	Motherboard	058021400	J15	5
	-15V	Relay Board	045230100	J7	6	Motherboard	058021400	J15	6
	+12V RET	Relay Board	045230100	J7	7	Motherboard	058021400	J15	7
	+12V	Relay Board	045230100	J7	8	Motherboard	058021400	J15	8
	Chassis Gnd	Relay Board	045230100	J7	10	Motherboard	058021400	J15	9
041050000 CBL, KEYBOARD TO MOTHERBOARD									
	Kbd Interrupt	LCD Interface Bd	066970000	J1	7	Motherboard	058021400	J106	1
	DGND	LCD Interface Bd	066970000	J1	2	Motherboard	058021400	J106	8
	SDA	LCD Interface Bd	066970000	J1	5	Motherboard	058021400	J106	2
	SCL	LCD Interface Bd	066970000	J1	6	Motherboard	058021400	J106	6
	Shld	LCD Interface Bd	066970000	J1	10	Motherboard	058021400	J106	5
041760100 CBL, DC POWER, TYPE 2									
	DGND	Relay Board	045230100	J8	1	PS1 (+5, ±15)	PS0000037	J2	3
	+5V	Relay Board	045230100	J8	2	PS1 (+5, ±15)	PS0000037	J2	1
	+15V	Relay Board	045230100	J8	4	PS1 (+5, ±15)	PS0000037	J2	6
	AGND	Relay Board	045230100	J8	5	PS1 (+5, ±15)	PS0000037	J2	4
	-15V	Relay Board	045230100	J8	6	PS1 (+5, ±15)	PS0000037	J2	5
	+12V RET	Relay Board	045230100	J8	7	PS2 (+12)	PS0000039	J2	5
	+12V	Relay Board	045230100	J8	8	PS2 (+12)	PS0000039	J2	3
042790100 CBL, HEATER/THERMISTOR									
	+12V RET	Relay Board	045230100	J19	1	Lamp HTR/Thrm	041440000		1
	+12V	Relay Board	045230100	J19	2	Lamp HTR/Thrm	041440000		2
	+5VAVA	Motherboard	058021400	J27	6	Lamp HTR/Thrm	041440000		3
	THERMISTOR 3	Motherboard	058021400	J27	13	Lamp HTR/Thrm	041440000		4
	+5VAVA	Motherboard	058021400	J27	7	Sample Therm	042010000		1
	THERMISTOR 2	Motherboard	058021400	J27	14	Sample Therm	042010000		2
	THERMISTOR 4	Motherboard	058021400	J27	12	O3 Gen HTR/Therm	041440100		6
	+5VAVA	Motherboard	058021400	J27	5	O3 Gen HTR/Therm	041440100		5
	+12V RET	Relay Board	045230100	J14	2	O3 Gen HTR/Therm	041440100		2
	+12V	Relay Board	045230100	J14	1	O3 Gen HTR/Therm	041440100		1
046710000 CBL, MOTHERBOARD TO XMITTER BD (MULTIDROP OPTION)									
	GND	Motherboard	058021100	P12	2	Xmitter bd w/Multidrop	069500000	J4	2
	RX0	Motherboard	058021100	P12	14	Xmitter bd w/Multidrop	069500000	J4	14
	RTS0	Motherboard	058021100	P12	13	Xmitter bd w/Multidrop	069500000	J4	13
	TX0	Motherboard	058021100	P12	12	Xmitter bd w/Multidrop	069500000	J4	12
	CTS0	Motherboard	058021100	P12	11	Xmitter bd w/Multidrop	069500000	J4	11
	RS-GND0	Motherboard	058021100	P12	10	Xmitter bd w/Multidrop	069500000	J4	10
	RTS1	Motherboard	058021100	P12	8	Xmitter bd w/Multidrop	069500000	J4	8
	CTS1/485-	Motherboard	058021100	P12	6	Xmitter bd w/Multidrop	069500000	J4	6
	RX1	Motherboard	058021100	P12	9	Xmitter bd w/Multidrop	069500000	J4	9
	TX1/485+	Motherboard	058021100	P12	7	Xmitter bd w/Multidrop	069500000	J4	7
	RS-GND1	Motherboard	058021100	P12	5	Xmitter bd w/Multidrop	069500000	J4	5
	RX1	Motherboard	058021100	P12	9	Xmitter bd w/Multidrop	069500000	J4	9
	TX1/485+	Motherboard	058021100	P12	7	Xmitter bd w/Multidrop	069500000	J4	7
	RS-GND1	Motherboard	058021100	P12	5	Xmitter bd w/Multidrop	069500000	J4	5

Interconnect List T700
(Reference: 069140100A DCN5870)

Cable Part #	Signal	CONNECTION FROM				CONNECTION TO			
		Assembly	PN	J/P	Pin	Assembly	PN	J/P	Pin
051790000 CBL, POWER & SIGNAL DISTRIBUTION									
	CH1	Motherboard	058021400	J109	6	Bench Det	041200000	J3	1
	AGND	Motherboard	058021400	J109	12	Bench Det	041200000	J3	4
	+15V	Relay Board	045230100	J11	4	Bench Det	041200000	J3	2
	-15V	Relay Board	045230100	J11	6	Bench Det	041200000	J3	3
	+12V RET	Relay Board	045230100	J11	7	Fan	040010000		1
	+12V	Relay Board	045230100	J11	8	Fan	040010000		2
	DGND	Relay Board	045230100	J11	1	LCD Interface Bd	066970000	J14	2
	VCC	Relay Board	045230100	J11	2	LCD Interface Bd	066970000	J14	3
	DGND	Relay Board	045230100	J12	1	LCD Interface Bd	066970000	J14	8
	VCC	Relay Board	045230100	J12	2	LCD Interface Bd	066970000	J14	1
	SDA	CAL1	Digital MFC		8	LCD Interface Bd	066970000	J14	5
	SCL	CAL1	Digital MFC		7	LCD Interface Bd	066970000	J14	6
	DGND	CAL1	Digital MFC		6	LCD Interface Bd	066970000	J14	10
	DGND	CAL1	Digital MFC		1	Relay Board	045230100	J9	1
	VCC	CAL1	Digital MFC		3	Relay Board	045230100	J9	2
	SDA	CAL1	Digital MFC		8	DIL1	Digital MFC		8
	SCL	CAL1	Digital MFC		7	DIL1	Digital MFC		7
	DGND	CAL1	Digital MFC		6	DIL1	Digital MFC		6
	SDA	CAL 2	Digital MFC		8	DIL1	Digital MFC		8
	SCL	CAL 2	Digital MFC		7	DIL1	Digital MFC		7
	DGND	CAL 2	Digital MFC		6	DIL1	Digital MFC		6
	VCC	Relay Board	045230100	J9	2	DIL1	Digital MFC		3
	DGND	Relay Board	045230100	J9	1	DIL1	Digital MFC		1
	VCC	Relay Board	045230100	J9	2	CAL 2	Digital MFC		3
	DGND	Relay Board	045230100	J9	1	CAL 2	Digital MFC		1
	-15V	Relay Board	045230100	J12	6	CAL1	Analog MFC		9
	AGND	Relay Board	045230100	J12	5	CAL1	Analog MFC		12
	+15V	Relay Board	045230100	J12	4	CAL1	Analog MFC		11
	AGND	Relay Board	045230100	J12	3	Photo Press/Flo	040030600	J1	3
	+15V	Relay Board	045230100	J12	4	Photo Press/Flo	040030600	J1	6
	CH6	Motherboard	058021400	J109	2	Photo Press/Flo	040030600	J1	4
	CH11	Motherboard	058021400	J110	4	Photo Press/Flo	040030600	J1	5
	CH12	Motherboard	058021400	J110	3	Photo Press/Flo	040030600	J1	2
	CH14	Motherboard	058021400	J110	1	CAL1	Analog MFC		6
	CH13	Motherboard	058021400	J110	2	DIL1	Analog MFC		6
	CH9	Motherboard	058021400	J110	5	CAL2	Analog MFC		6
		Chassis				CAL2	Analog MFC		7
	-15V	Relay Board	045230100	J9	6	CAL2	Analog MFC		9
	+15V	Relay Board	045230100	J9	4	CAL2	Analog MFC		11
	AGND	Relay Board	045230100	J9	3	CAL2	Analog MFC		12
	-15V	Relay Board	045230100	J9	6	DIL1	Analog MFC		9
	+15V	Relay Board	045230100	J9	4	DIL1	Analog MFC		11
	AGND	Relay Board	045230100	J9	5	DIL1	Analog MFC		12
	DAC0V	Motherboard	058021400	J22	5	DIL1	Analog MFC		14
	AGND	Motherboard	058021400	J22	7	DIL1	Analog MFC		5
		Chassis				DIL1	Analog MFC		7
	DAC2V	Motherboard	058021400	J22	3	CAL2	Analog MFC		14
	AGND	Motherboard	058021400	J22	8	CAL2	Analog MFC		5
	DAC1V	CAL1	Analog MFC		14	Motherboard	058021400	J22	4
	AGND	CAL1	Analog MFC		5	Motherboard	058021400	J22	9
		CAL1	Analog MFC		7	Chassis			
	CH2	Motherboard	058021400	J109	5	I/ZS DET	041200200	J3	1
	AGND	Motherboard	058021400	J109	11	I/ZS DET	041200200	J3	4
	-15V	Relay Board	045230100	J13	6	I/ZS DET	041200200	J3	3
	+15V	Relay Board	045230100	J13	4	I/ZS DET	041200200	J3	2
	AGND	Relay Board	045230100	J13	5	Gas Flow PCA	040030500	J1	3
	+15V	Relay Board	045230100	J13	4	Gas Flow PCA	040030500	J1	6
	CH3	Motherboard	058021400	J109	4	Gas Flow PCA	040030500	J1	4
	CH4	Motherboard	058021400	J109	3	Gas Flow PCA	040030500	J1	2
054840000 CBL, VALVE DRIVER & PUMP POWER									
	+12V	Relay Board	045230100	J4	1	Photo Ref Valve	055220000		1
	+12V RET	Relay Board	045230100	J4	2	Photo Ref Valve	055220000		2
	+12V	Relay Board	045230100	J4	3	O3 Valve	055220000		1
	+12V RET	Relay Board	045230100	J4	4	O3 Valve	055220000		2
	+12V	Relay Board	045230100	J4	5	Pump	047020000		1
	+12V RET	Relay Board	045230100	J4	6	Pump	047020000		2

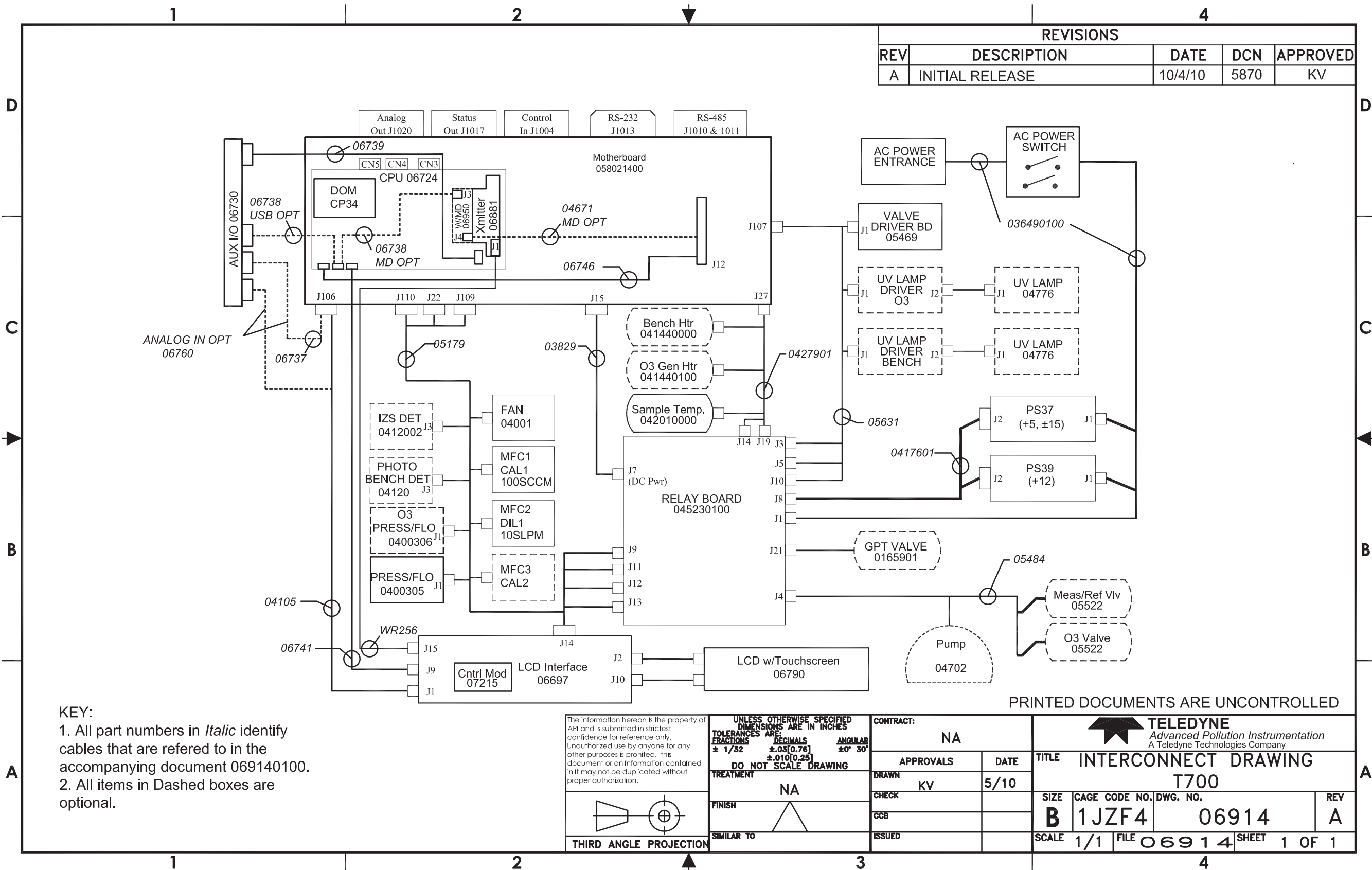
Interconnect List T700

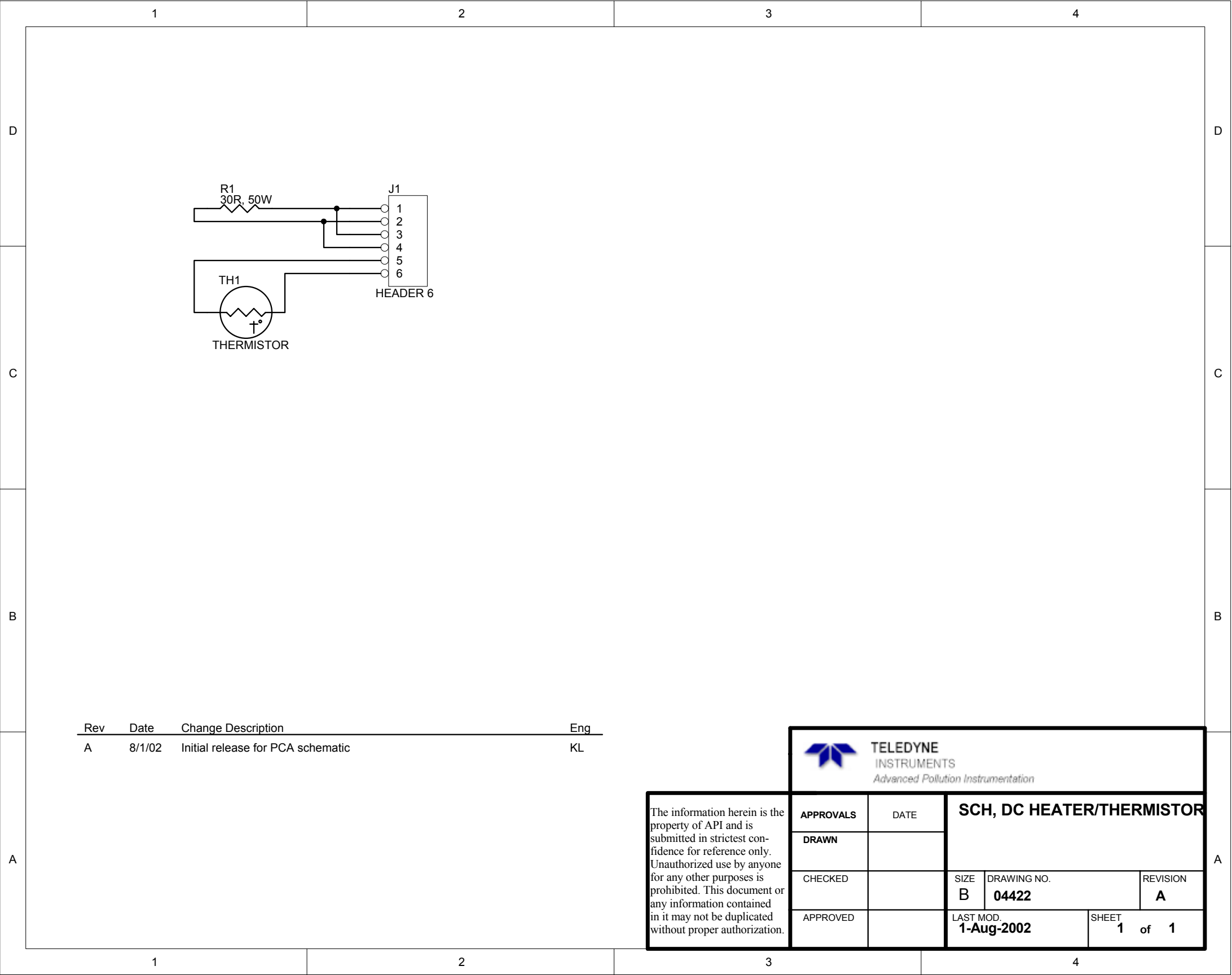
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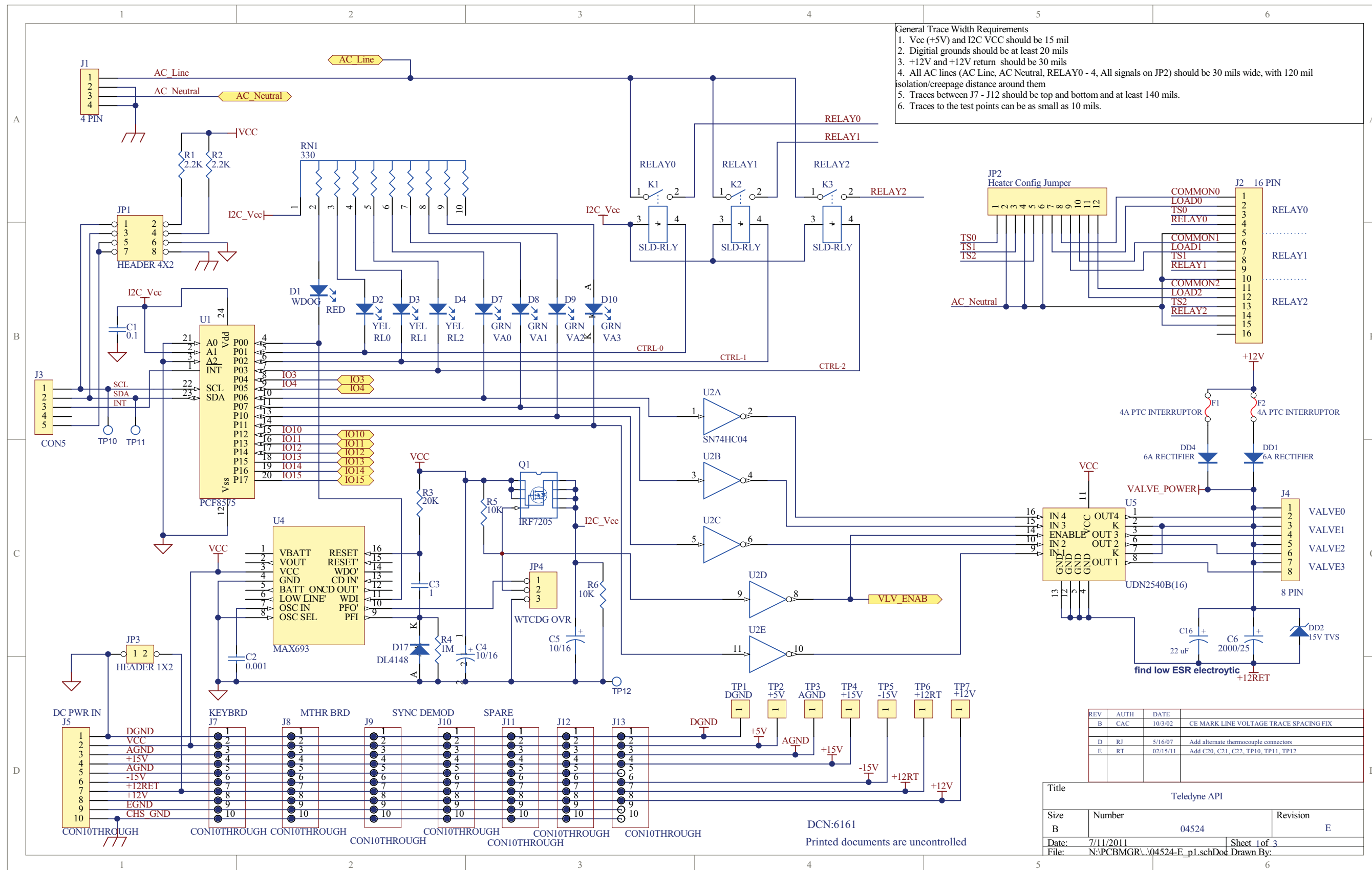
Cable Part #	Signal	CONNECTION FROM				CONNECTION TO			
		Assembly	PN	J/P	Pin	Assembly	PN	J/P	Pin
056310000 CBL, I2C SIGNAL									
	+15V	Relay Board	045230100	J5	4	IZS Lamp Supply	041660100	J1	1
	AGND	Relay Board	045230100	J5	3	IZS Lamp Supply	041660100	J1	2
	SCL	Bench Lamp Supply	041660500	J1	3	IZS Lamp Supply	041660100	J1	3
	SDA	Bench Lamp Supply	041660500	J1	4	IZS Lamp Supply	041660100	J1	4
	SCL	Bench Lamp Supply	041660500	J1	3	Motherboard	058021400	J107	3
	SDA	Bench Lamp Supply	041660500	J1	4	Motherboard	058021400	J107	5
	+15V	Bench Lamp Supply	041660500	J1	1	Relay Board	045230100	J10	4
	AGND	Bench Lamp Supply	041660500	J1	2	Relay Board	045230100	J10	3
	+12VRET	Valve Driver Board	054690000	J1	2	Relay Board	045230100	J10	7
	+12V	Valve Driver Board	054690000	J1	5	Relay Board	045230100	J10	8
	DGND	Valve Driver Board	054690000	J1	1	Relay Board	045230100	J10	1
	VCC	Valve Driver Board	054690000	J1	4	Relay Board	045230100	J10	2
	SCL	Valve Driver Board	054690000	J1	3	Relay Board	045230100	J3	1
	SDA	Valve Driver Board	054690000	J1	6	Relay Board	045230100	J3	2
	SCL	Valve Driver Board	054690000	J1	3	IZS Lamp Supply	041660100	J1	3
	SDA	Valve Driver Board	054690000	J1	6	IZS Lamp Supply	041660100	J1	4
	Shield	Motherboard	058021400	J107	6	Relay Board	045230100	J3	5
067370000 CBL, I2C TO AUX I/O PCA (ANALOG IN OPTION)									
	ATX-	Motherboard	058021400	J106	1	Aux I/O	067300000	J2	1
	ATX+	Motherboard	058021400	J106	2	Aux I/O	067300000	J2	2
	LED0	Motherboard	058021400	J106	3	Aux I/O	067300000	J2	3
	ARX+	Motherboard	058021400	J106	4	Aux I/O	067300000	J2	4
	ARX-	Motherboard	058021400	J106	5	Aux I/O	067300000	J2	5
	LED0+	Motherboard	058021400	J106	6	Aux I/O	067300000	J2	6
	LED1+	Motherboard	058021400	J106	8	Aux I/O	067300000	J2	8
067380000 CBL, CPU COM to AUX I/O (USB OPTION)									
	RXD1	CPU PCA	067240000	COM1	1	AUX I/O PCA	0673000 or -02	J3	1
	DCD1	CPU PCA	067240000	COM1	2	AUX I/O PCA	0673000 or -02	J3	2
	DTR1	CPU PCA	067240000	COM1	3	AUX I/O PCA	0673000 or -02	J3	3
	TXD1	CPU PCA	067240000	COM1	4	AUX I/O PCA	0673000 or -02	J3	4
	DSR1	CPU PCA	067240000	COM1	5	AUX I/O PCA	0673000 or -02	J3	5
	GND	CPU PCA	067240000	COM1	6	AUX I/O PCA	0673000 or -02	J3	6
	CTS1	CPU PCA	067240000	COM1	7	AUX I/O PCA	0673000 or -02	J3	7
	RTS1	CPU PCA	067240000	COM1	8	AUX I/O PCA	0673000 or -02	J3	8
	RI1	CPU PCA	067240000	COM1	10	AUX I/O PCA	0673000 or -02	J3	10
067380000 CBL, CPU COM to AUX I/O (MULTIDROP OPTION)									
	RXD	CPU PCA	067240000	COM1	1	Xmitter bd w/Multidrop	069500000	J3	1
	DCD	CPU PCA	067240000	COM1	2	Xmitter bd w/Multidrop	069500000	J3	2
	DTR	CPU PCA	067240000	COM1	3	Xmitter bd w/Multidrop	069500000	J3	3
	TXD	CPU PCA	067240000	COM1	4	Xmitter bd w/Multidrop	069500000	J3	4
	DSR	CPU PCA	067240000	COM1	5	Xmitter bd w/Multidrop	069500000	J3	5
	GND	CPU PCA	067240000	COM1	6	Xmitter bd w/Multidrop	069500000	J3	6
	CTS	CPU PCA	067240000	COM1	7	Xmitter bd w/Multidrop	069500000	J3	7
	RTS	CPU PCA	067240000	COM1	8	Xmitter bd w/Multidrop	069500000	J3	8
	RI	CPU PCA	067240000	COM1	10	Xmitter bd w/Multidrop	069500000	J3	10
067390000 CBL, CPU ETHERNET TO AUX I/O									
	ATX-	CPU PCA	067240000	LAN	1	Aux I/O	067300100	J2	1
	ATX+	CPU PCA	067240000	LAN	2	Aux I/O	067300100	J2	2
	LED0	CPU PCA	067240000	LAN	3	Aux I/O	067300100	J2	3
	ARX+	CPU PCA	067240000	LAN	4	Aux I/O	067300100	J2	4
	ARX-	CPU PCA	067240000	LAN	5	Aux I/O	067300100	J2	5
	LED0+	CPU PCA	067240000	LAN	6	Aux I/O	067300100	J2	6
	LED1	CPU PCA	067240000	LAN	7	Aux I/O	067300100	J2	7
	LED1+	CPU PCA	067240000	LAN	8	Aux I/O	067300100	J2	8
067410000 CBL, CPU USB TO LCD INTERFACE PCA									
	GND	CPU PCA	067240000	USB	8	LCD Interface PCA	066970000	JP9	
	LUSBD3+	CPU PCA	067240000	USB	6	LCD Interface PCA	066970000	JP9	
	LUSBD3-	CPU PCA	067240000	USB	4	LCD Interface PCA	066970000	JP9	
	VCC	CPU PCA	067240000	USB	2	LCD Interface PCA	066970000	JP9	

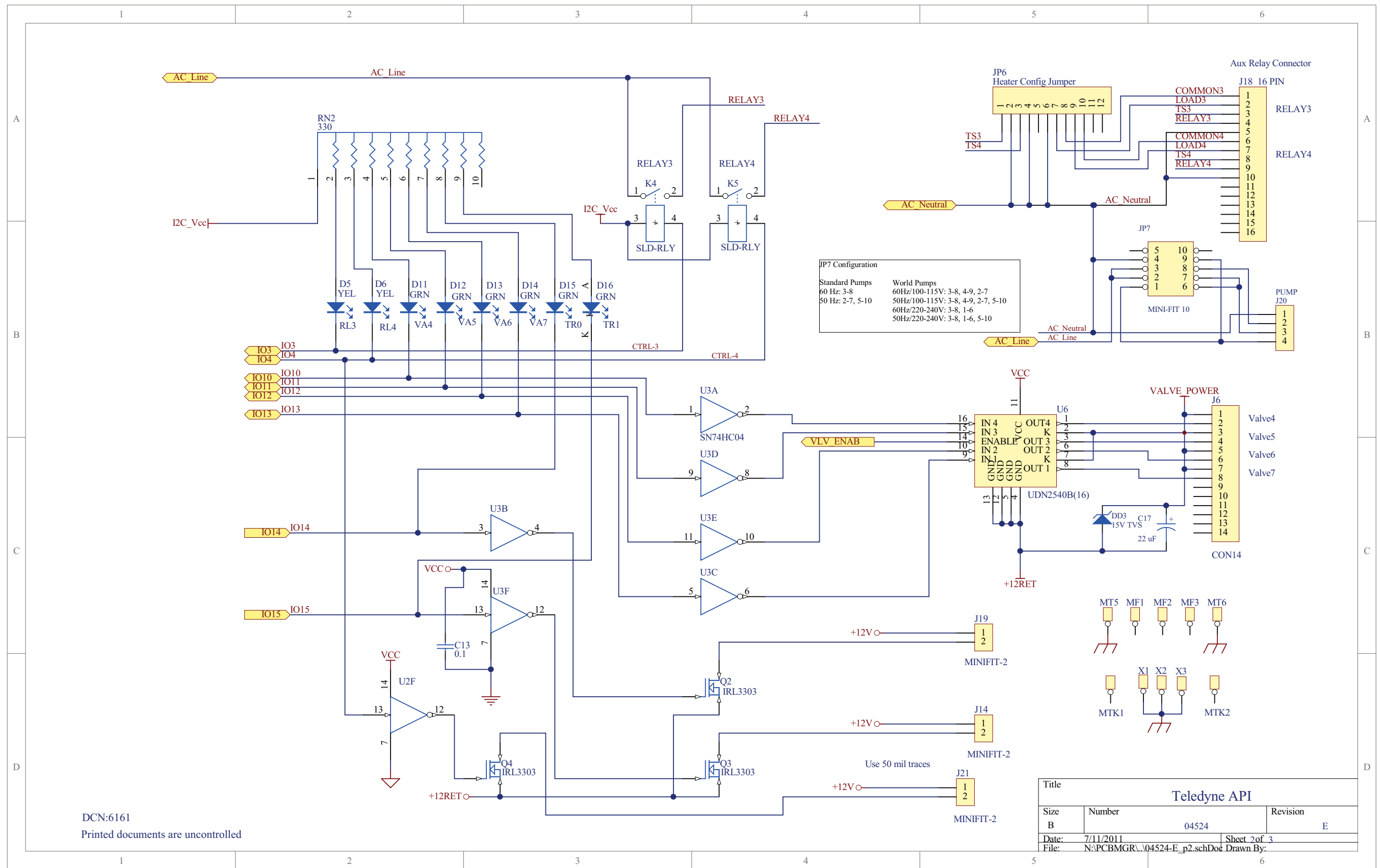
Interconnect List T700
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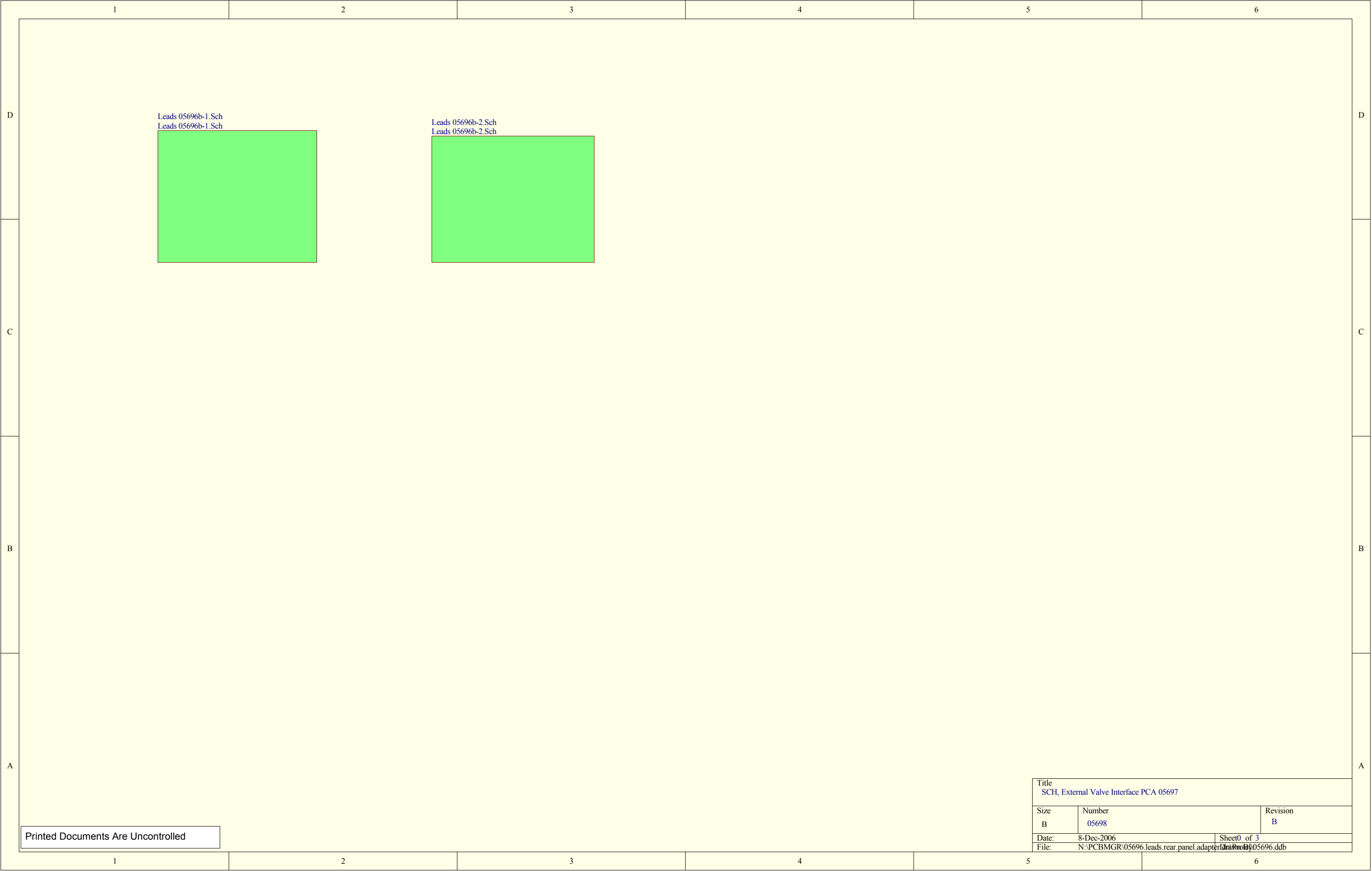
Cable Part #	Signal	CONNECTION FROM				CONNECTION TO			
		Assembly	PN	J/P	Pin	Assembly	PN	J/P	Pin
06746	CBL, MOTHERBOARD TO CPU								
	RXD(0)	CPU PCA	067240000	COM1	1	Motherboard	058021400	J12	14
	RTS(0)	CPU PCA	067240000	COM1	8	Motherboard	058021400	J12	13
	TXD(0)	CPU PCA	067240000	COM1	4	Motherboard	058021400	J12	12
	CTS(0)	CPU PCA	067240000	COM1	7	Motherboard	058021400	J12	11
	GND(0)	CPU PCA	067240000	COM1	6	Motherboard	058021400	J12	10
	RXD(1)	CPU PCA	067240000	COM2	1	Motherboard	058021400	J12	9
	RTS(1)	CPU PCA	067240000	COM2	8	Motherboard	058021400	J12	8
	TXD(1)	CPU PCA	067240000	COM2	4	Motherboard	058021400	J12	7
	CTS(1)	CPU PCA	067240000	COM2	7	Motherboard	058021400	J12	6
	GND(1)	CPU PCA	067240000	COM2	6	Motherboard	058021400	J12	5
	485+	CPU PCA	067240000	CN5	1	Motherboard	058021400	J12	9
	485-	CPU PCA	067240000	CN5	2	Motherboard	058021400	J12	7
	GND	CPU PCA	067240000	CN5	3	Motherboard	058021400	J12	5
	Shield					Motherboard	058021400	J12	2
WR256	CBL, XMITTER TO INTERFACE								
		LCD Interface	066970000	J15		Transmitter Board	068810000	J1	



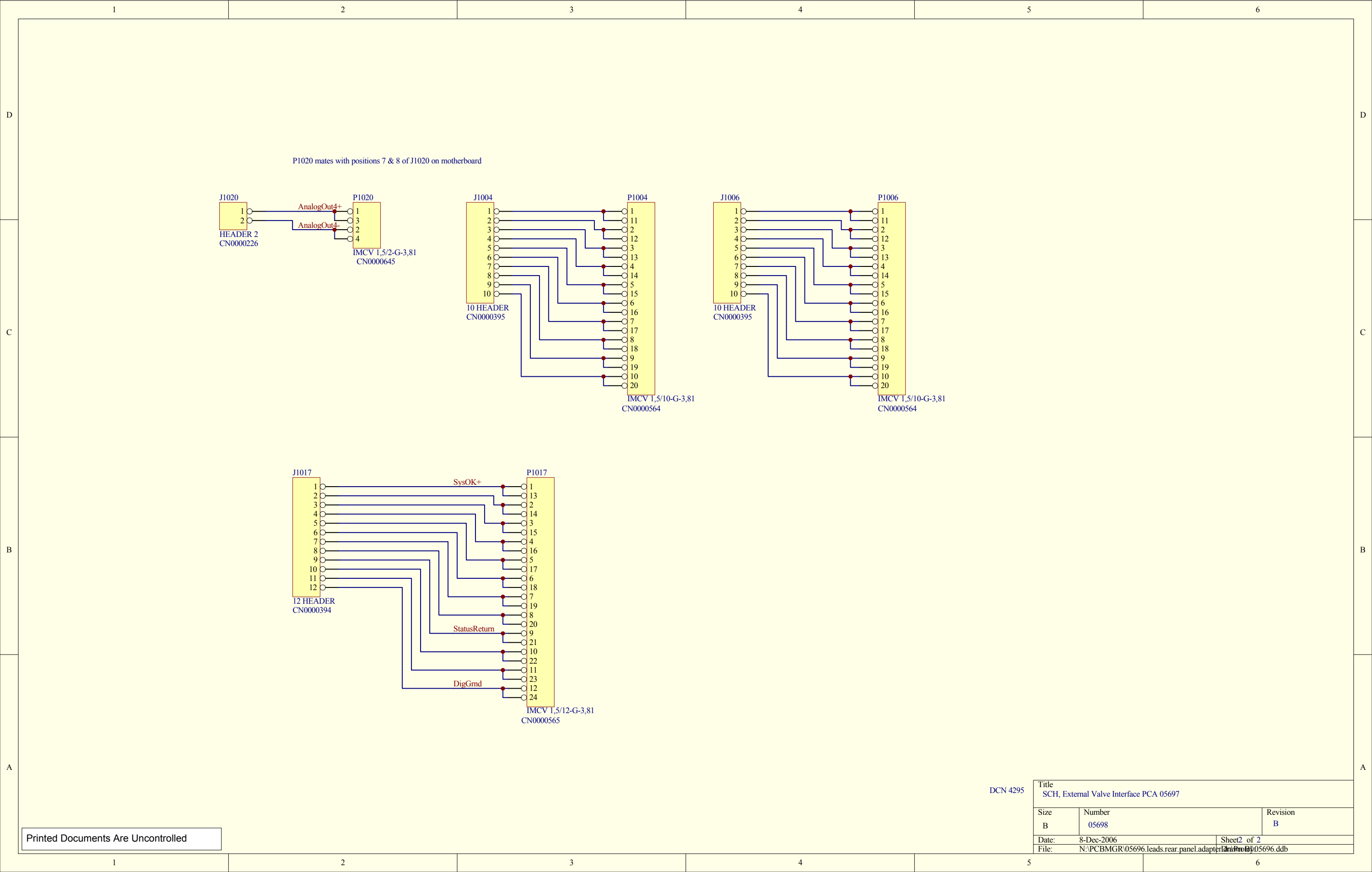


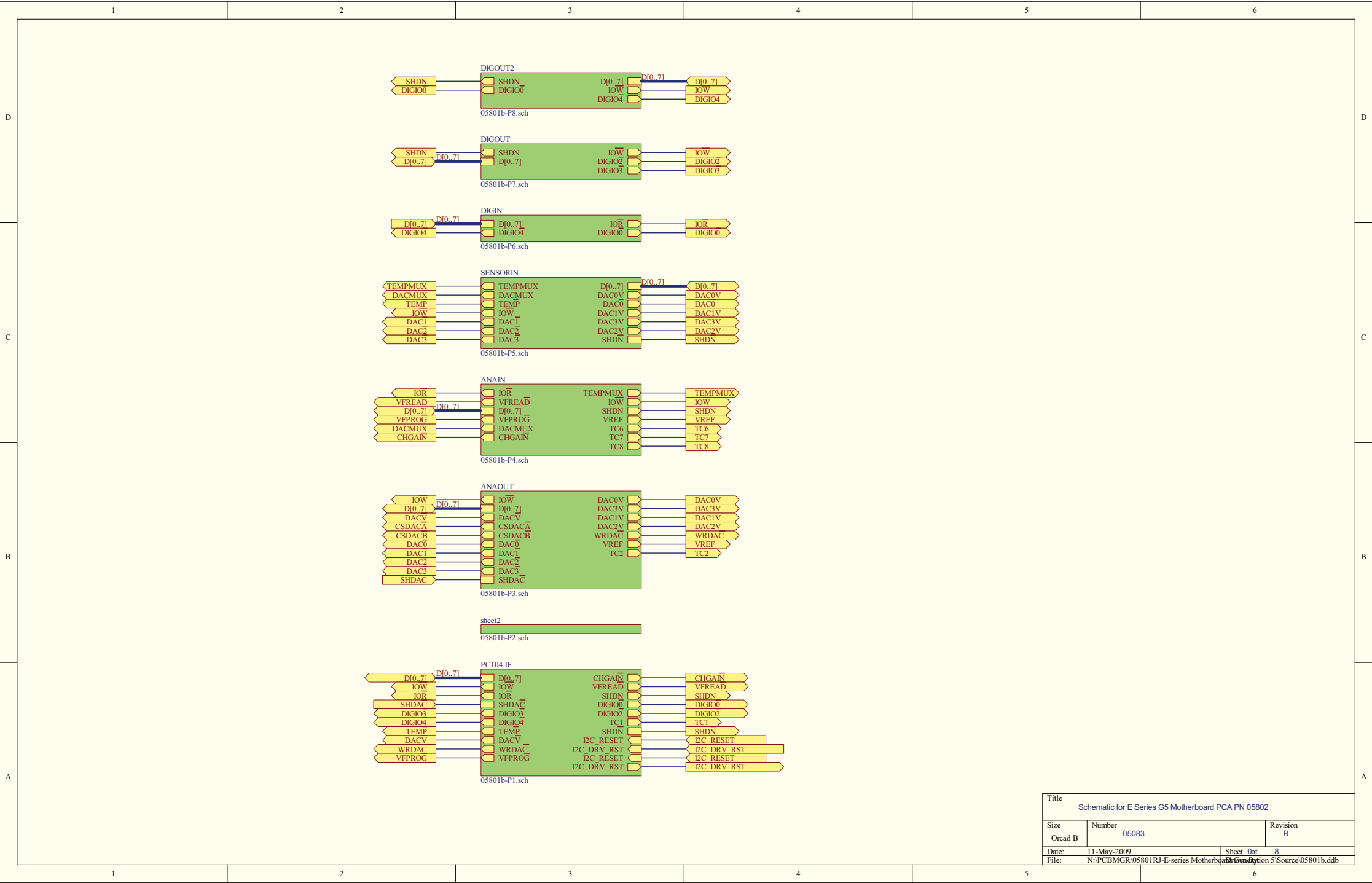




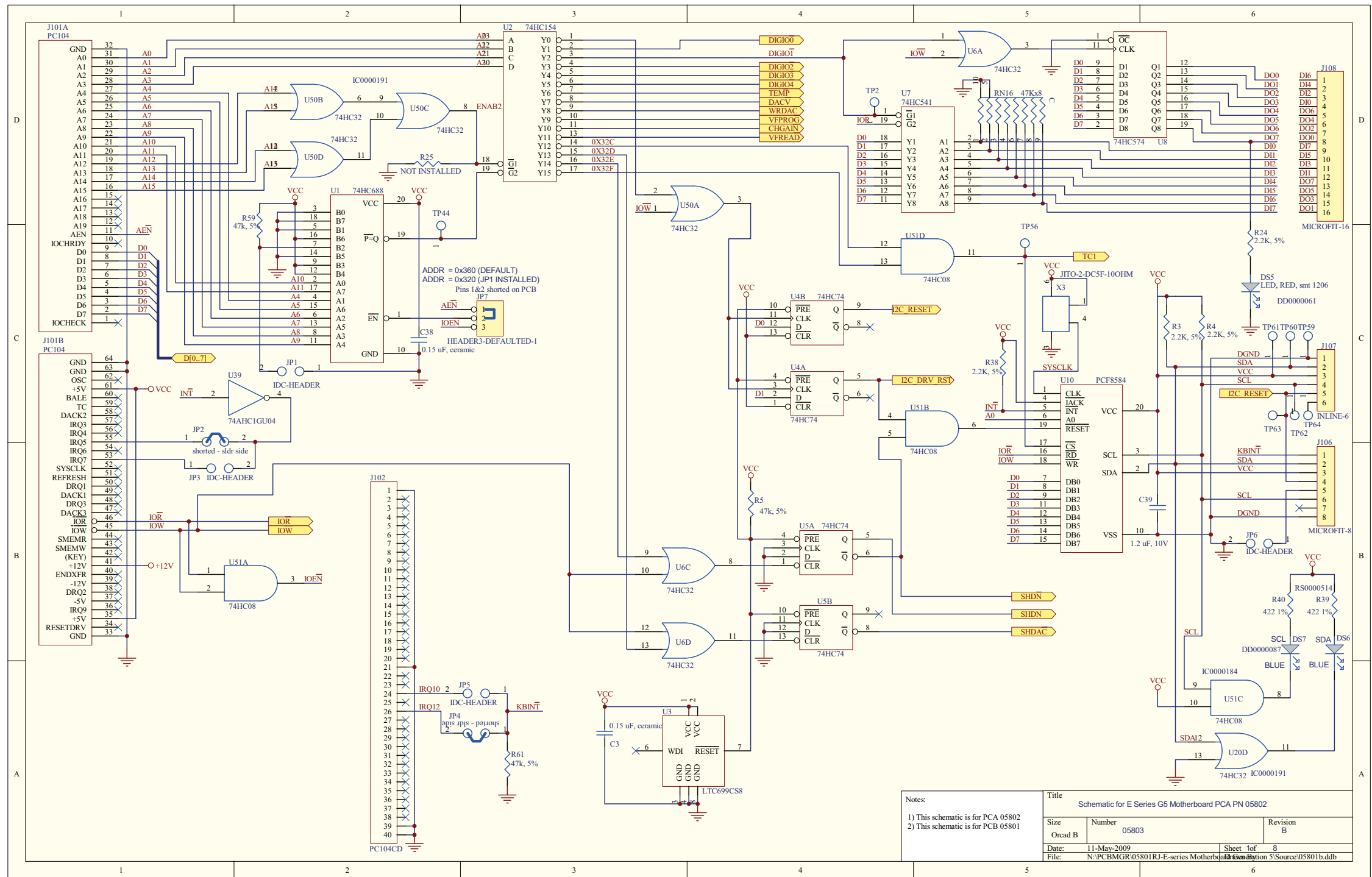


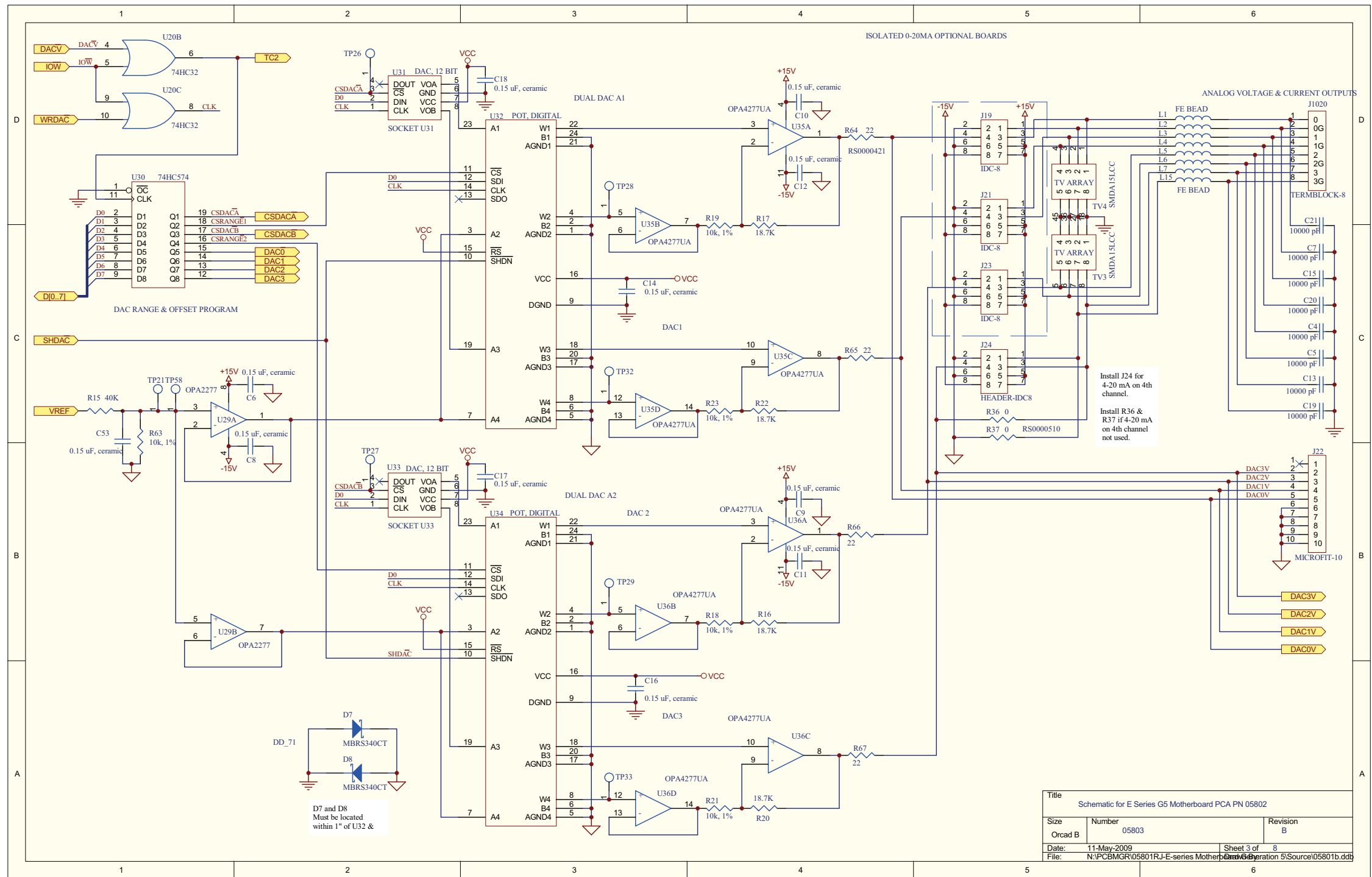
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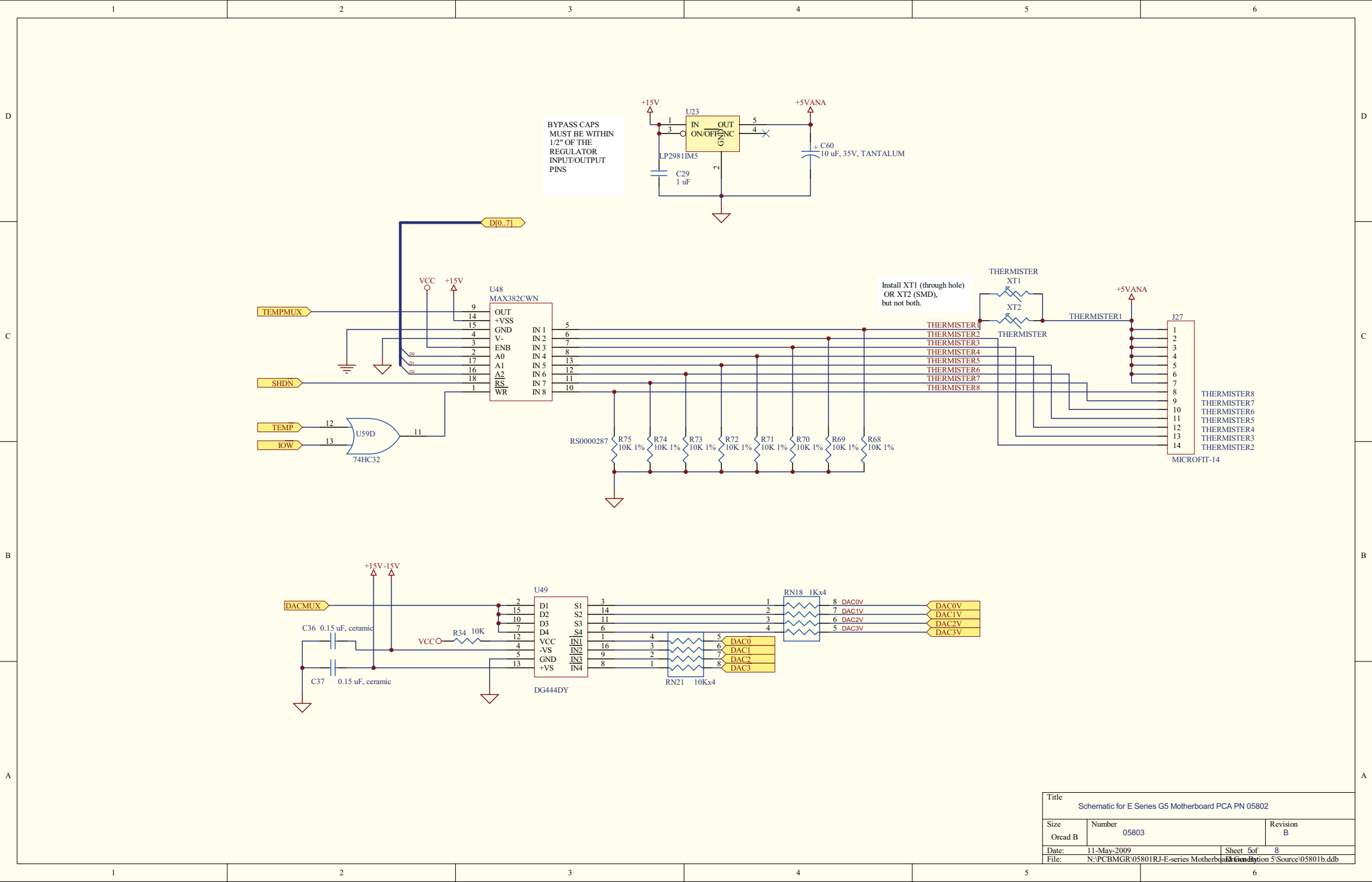




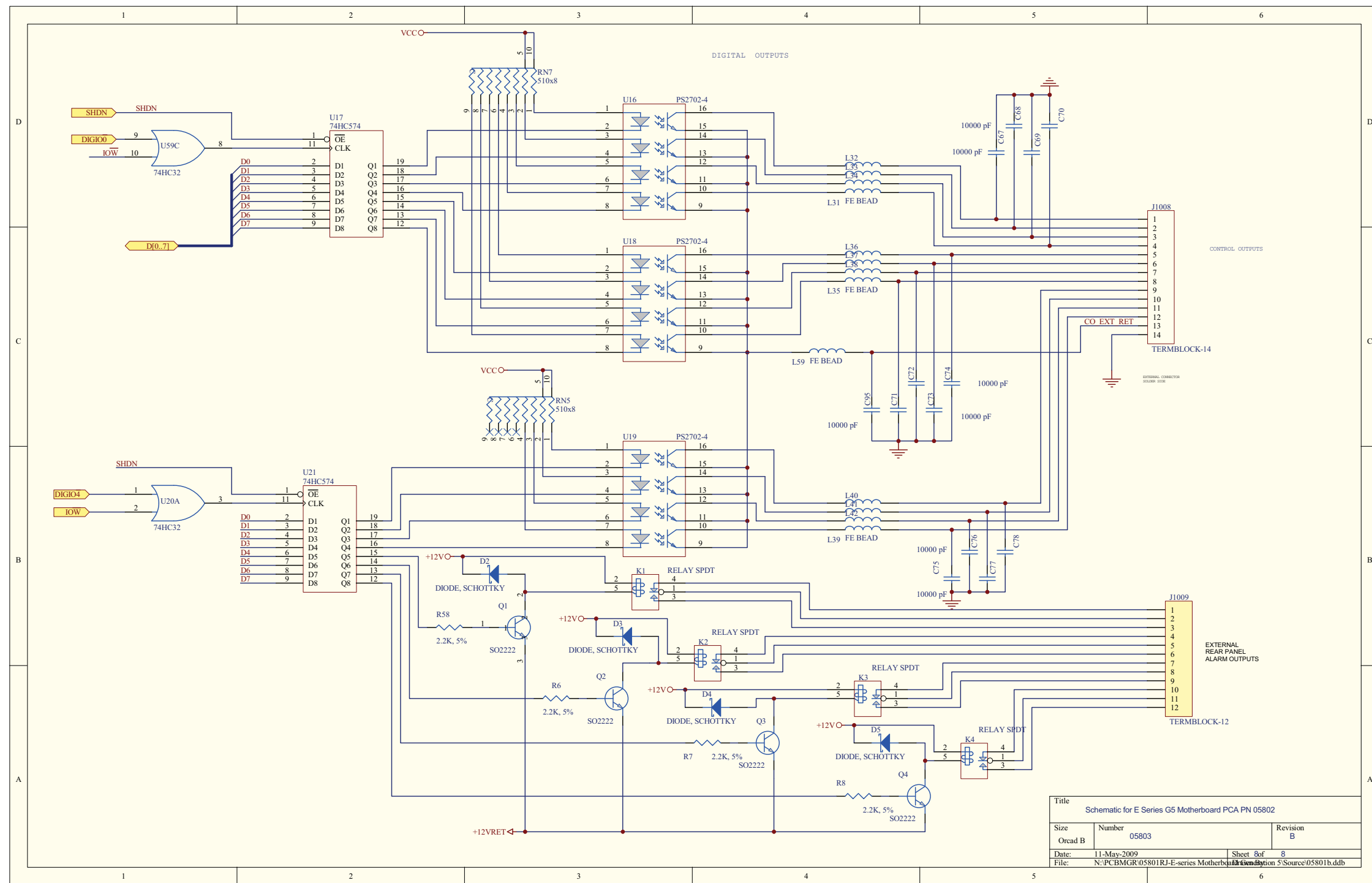
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Schematic for E Series G5 Motherboard PCA PN 05802		
Size	Number	Revision
Orcad B	05083	B
Date:	11-May-2009	Sheet 0 of 8
File:	N:\PCBMGR\05801RLE-series Motherboard\05801b.ddb	

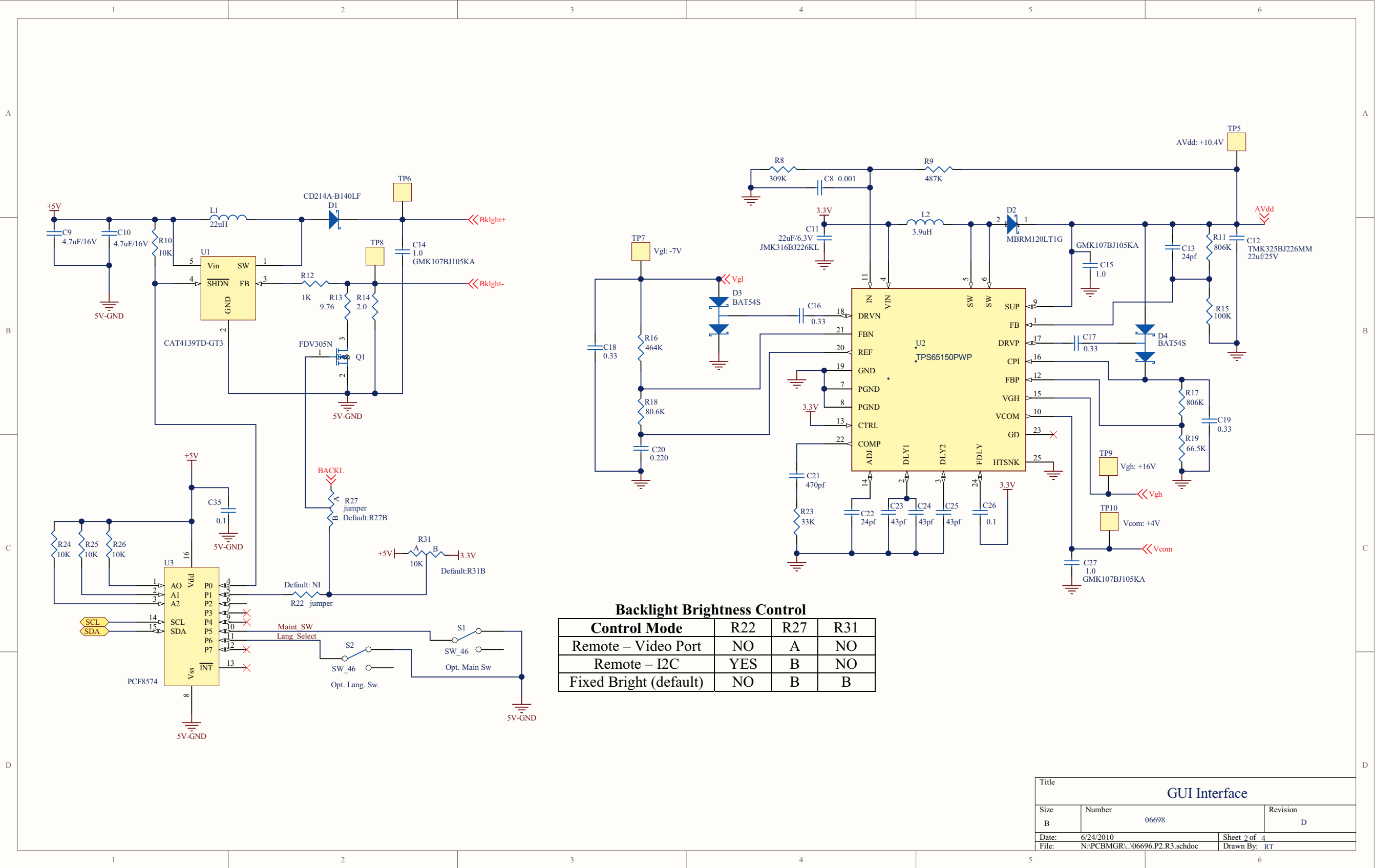


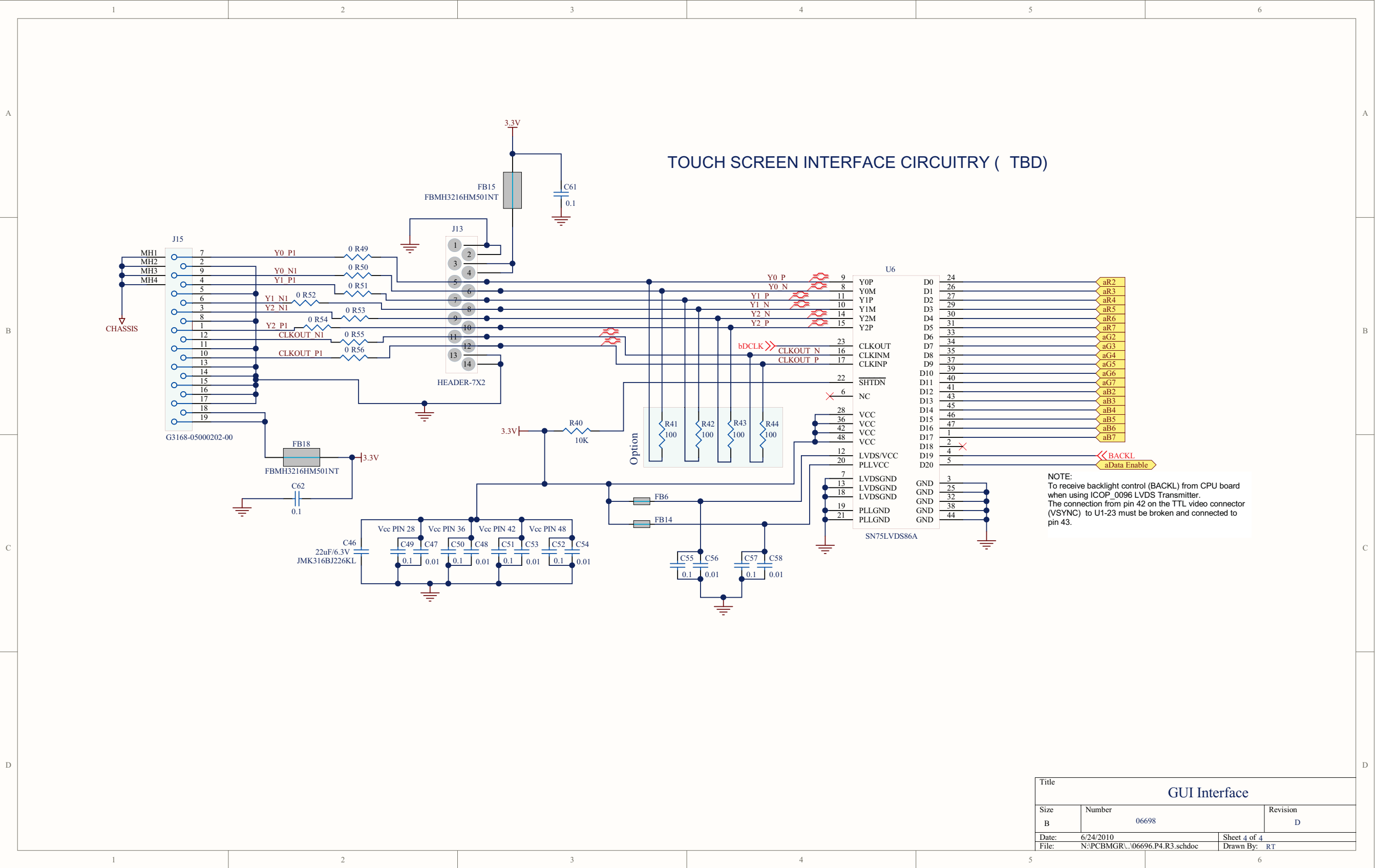




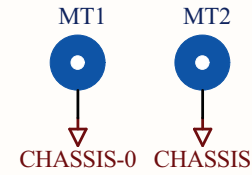
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Schematic for E Series G5 Motherboard PCA PN 05802		
Size	Number	Revision
Orcad B	05803	B
Date:	11-May-2009	Sheet 5 of 8
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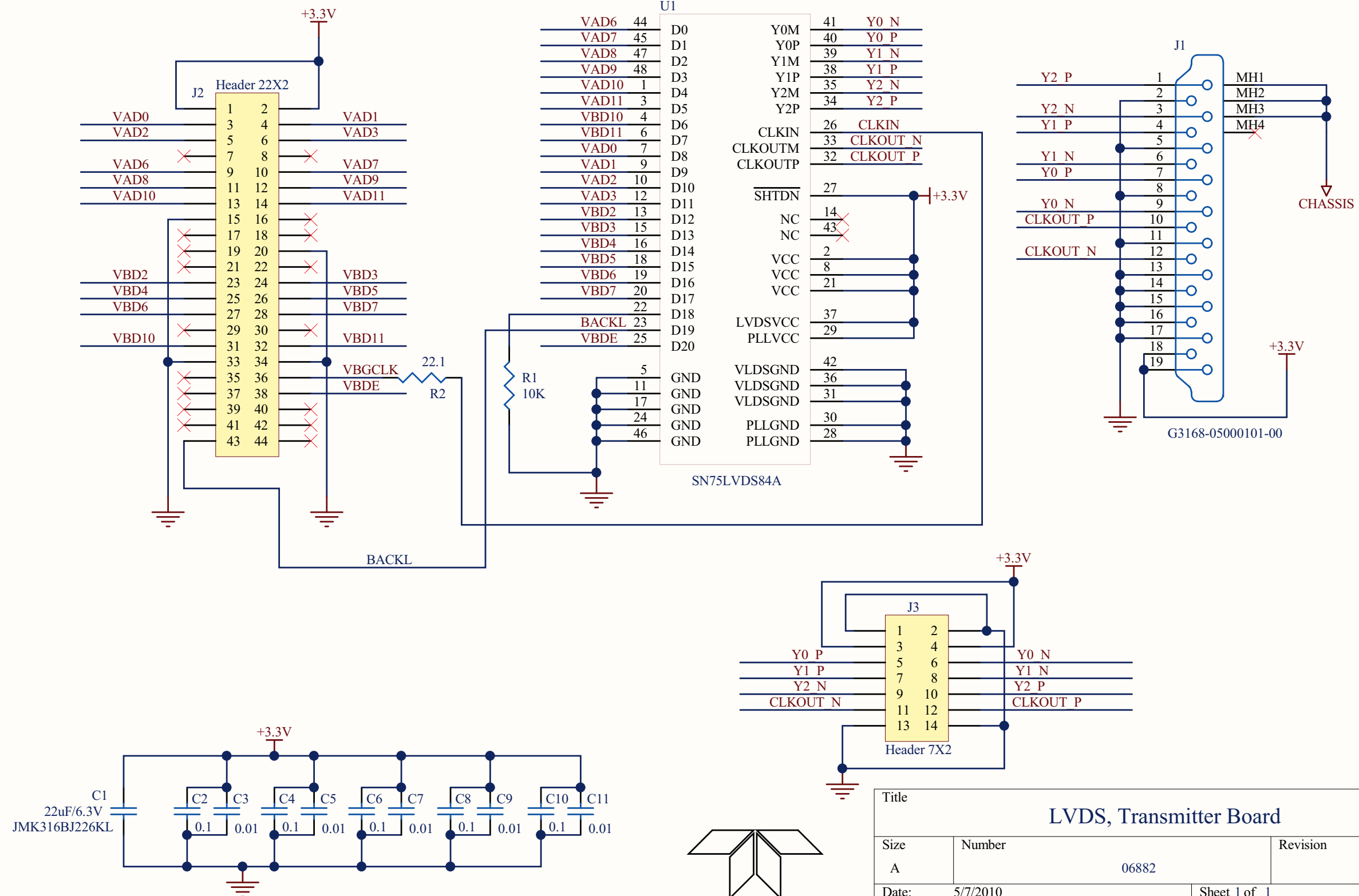




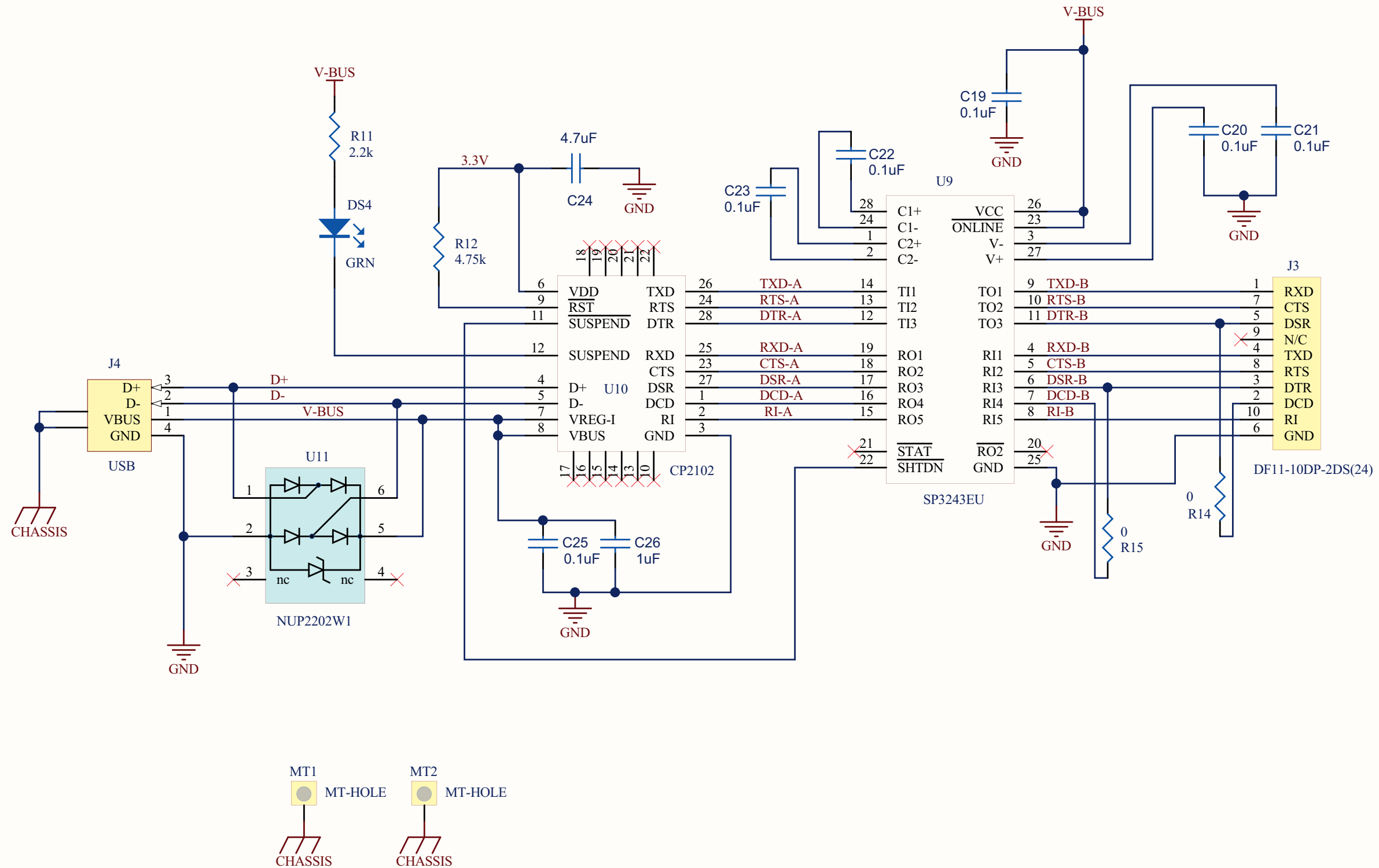
From ICOP CPU



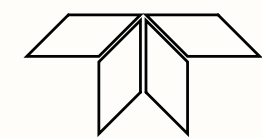
To LCD Display



Title		
LVDS, Transmitter Board		
Size	Number	Revision
A	06882	B
Date:	5/7/2010	Sheet 1 of 1
File:	N:\PCBMGR\...\06882-P1-R0.SchDoc	Drawn By: RT



DCN:6092
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Title		
Auxiliary I/O Board (USB)		
Size	Number	Revision
A	06731	B
Date:	5/6/2011	Sheet 2 of 3
File:	N:\PCBMGR\...\06731-2 USB.SchDoc	Drawn By: RT

