OPERATING & INSTRUCTION MANUAL

P/N
6/30/2011
ECO #

IMPORTANT NOTICES

Read and understand this operating manual before installing or using the unit. Only use cables from Model 2230R with this unit. If this equipment is used in a manner not specified by Model 2230R, the protection provided by this equipment may be impaired.

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Warranty

This equipment is sold subject to the mutual agreement that it is warranted by us free from defects of material and of construction, and that our liability shall be limited to replacing or repairing at our factory (without charge, except for transportation), or at customer plant at our option, any material or construction in which defects become apparent within one year from the date of shipment, except in cases where quotations or acknowledgements provide for a shorter period. Components manufactured by others bear the warranty of their manufacturer. This warranty does not cover defects caused by wear, accident, misuse, neglect or repairs other than those performed by Teledyne or an authorized service center. We assume no liability for direct or indirect damages of any kind and the purchaser by the acceptance of the equipment will assume all liability for any damage which may result from its use or misuse.

We reserve the right to employ any suitable material in the manufacture of our apparatus, and to make any alterations in the dimensions, shape or weight of any parts, in so far as such alterations do not adversely affect our warranty.

Voided Warranty:

- The unit is opened and the manufacturing seal is broken.
- Unauthorized repair work performed at the customer's location or carried out by anyone other than Teledyne Analytical Instrument factory trained technicians.
- Equipment or parts that have been tampered with, misused, neglected, mishandled, improperly adjusted, or modified in any way without the written consent of Model 2230R.
- Equipment or parts that have been damaged due to shipping, misuse, accidents, mishandling, neglect, or problems with electrical power sources.
- Repair work performed during the warranty period does not prolong the warranty period past the original period.
- System operation in incorrect or inappropriate environments.
- Usage that is not in accordance with system guidelines or an operator's failure to follow manual instructions.

Important Notice

This instrument provides measurement readings to its user, and serves as a tool by which valuable data can be gathered. The information provided by the instrument may assist the user in eliminating potential hazards caused by his process; however, it is essential that all personnel involved in the use of the instrument or its interface be properly trained in the process being measured, as well as all instrumentation related to it.

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The safety of personnel is ultimately the responsibility of those who control process conditions. While this instrument may be able to provide early warning of imminent danger, it has no control over process conditions, and it can be misused. In particular, any alarm or control systems installed must be tested and understood, both as to how they operate and as to how they can be defeated. Any safeguards required such as locks, labels, or redundancy, must be provided by the user or specifically requested of Teledyne at the time the order is placed.

Therefore, the purchaser must be aware of the hazardous process conditions. The purchaser is responsible for the training of personnel, for providing hazard warning methods and instrumentation per the appropriate standards, and for ensuring that hazard warning devices and instrumentation are maintained and operated properly.
Teledyne Analytical Instruments, the manufacturer of this instrument, cannot accept responsibility for conditions beyond its knowledge and control. No statement expressed or implied by this document or any information disseminated by the manufacturer or its agents, is to be construed as a warranty of adequate safety control under the user's process conditions.

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SAFETY MESSAGES

Your safety and the safety of others is very important. We have provided many important safety messages in this manual. Please read these messages carefully.

A safety message alerts you to potential hazards that could hurt you or others. Each safety message is associated with a safety alert symbol. These symbols are found in the manual and inside the instrument. The definition of these symbols is described below:

IMPORTANT NOTICES

Read and understand this operating manual before installing or using the unit. Only use cables from Model 2230R with this unit. If this equipment is used in a manner not specified by Model 2230R, the protection provided by this equipment may be impaired.

Hydrogen is flammable at 4% in air. Take indications seriously and be prepared to take action. In the event of detection of 4% or higher of a hydrogen gas concentration there is a high probability of a hazard to safety. Inform local emergency response personnel immediately.

LIMITATION OF LIABILITY

In the event of a defect in a product, Model 2230R shall not be responsible for any direct, indirect, incidental or consequential damages resulting therefore, including, but not limited to, loss of revenue and/or profit.

This manual provides information designed to guide you through the installation, calibration and operation of your new analyzer. Please read this manual and keep it available.

Occasionally, some instruments are customized for a particular application or features and/or options added per customer requests. Please check the front of this manual for any additional information in the form of an Addendum which discusses specific information, procedures, cautions and warnings that may be specific to your instrument.

Manuals do get misplaced. Additional manuals can be obtained from Teledyne at the address given in the Appendix. Some of our manuals are available in electronic form via the internet. Please visit our website at: www.teledyne-ai.com

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If there are any questions concerning this equipment, please contact your local TAI representative, or the factory directly at:

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1. DESCRIPTION

The Model 2230R Process Hydrogen Analyzer is designed to detect and/or measure hydrogen as a component of a gas mixture. The hydrogen specific solid-state sensing element is designed for ease of use, interface flexibility and true process control. The electronics contains all the circuitry necessary to operate the sensor and present calibrated hydrogen readings to a voltage or current analog output and an RS232 or RS422 digital output. The monitor can be implemented in humidity and in process gas streams with temperatures up to 100°C. The Model 2230R is ideal for hydrogen production and petrochemical applications where real-time measurements can enhance process plant efficiencies, diagnostics, and maintenance management.

Product Name	Process Hydrogen Analyzer
Product Model	Model 2230R
Purchase Date	
Serial No	
Contact Details, Your Distributor	
Contact Details, TELEDYNE ANALYTICAL INSTRUMENTS	TELEDYNE INSTRUMENTS *Analytical Instruments* 16830 Chestnut Street City of Industry, CA 91749-1580 Telephone: (626) 934-1500 Fax: (626) 961-2538 Web: www.teledyne-ai.com Or your local representative. Email: ask_tai@teledyne.com

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2. SPECIFICATIONS

Process Gas Stream	Temperature: -20°C to 100°C Flow Rate: 0 to 50 slpm
Ambient Temperature	Operating: -20°C to 40°C Storage: -40°C to 50°C
Power Supply	8 VDC to 13 VDC, 1.0 A
Environmental	Indoor/Outdoor Use Altitude up to 2000 meters Pollution degree 2 environment
Ingress Protection	IP64 capable
Analog Outputs	Output Voltages OR • 0 VDC to 5 VDC • 1 VDC to 5 VDC Output Currents • 4 mA to 20 mA • 0 mA to 20 mA User-specific ranges available
Serial Communications	RS-232 or RS-422
Relay Contacts (Optional)	(Two programmable 60 VDC / 1 A SPDT relays with both normally open N.O.) and normally closed (N.C.) contacts.
Dimensions	See following figure (dimensions in inches [mm])
Weight	0.37 kg (0.82 lb.)
Product Life Expectancy	10 years
Certifications	CE

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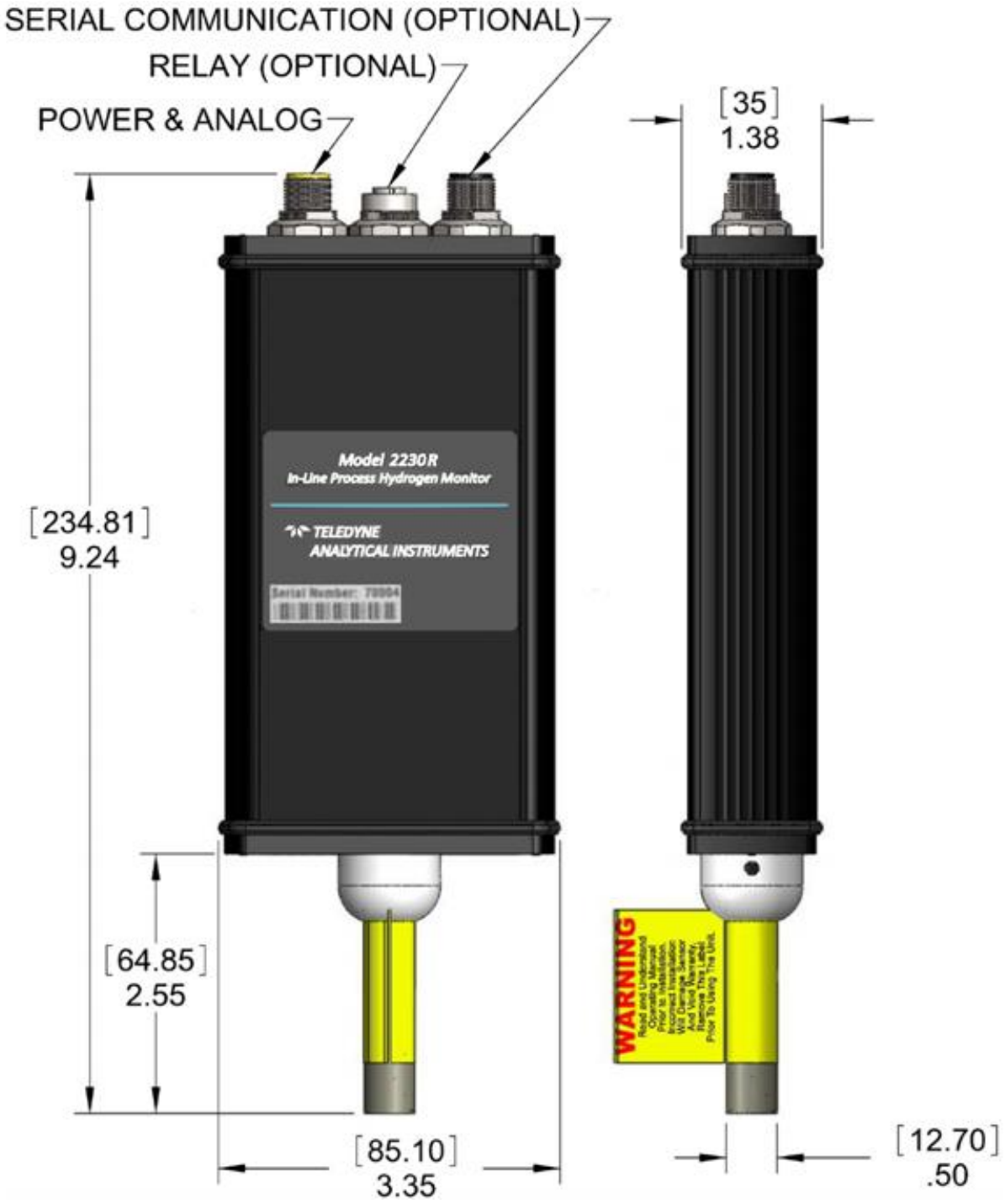

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3. OPERATION

3.1 UNIT LOCATION

The unit can be mounted in any orientation or position, however vertical mounting (unit above process connection) should be made in process streams containing liquids or potentially condensing gases.

3.1.1 WARNING LABEL

Remove sensor tube warning label prior to using the unit.

3.2 MOUNTING

Mounting is achieved by securing the sensor tube into the supplied fitting directly in the process piping as shown below. Optional mounting brackets that attach to the instrument housing are also available.

WARNING: DO NOT CINCH DOWN OR TIGHTEN FERRULES OUTSIDE OF THE FERRULE REGION OF THE LONG TUBE OR YOU WILL RISK PERMANENTLY DAMAGING THE LONG TUBE AND SENSOR ASSEMBLY WITHIN.

1.0 inches is the maximum distance that the fitting mount can be from the end plate of the Model 2230R unit. This is referred to as the Ferrule Region of the long tube which has a wall thickness of 0.065 in. Any distance exceeding 1.0 in. will be in the Sensor Assembly Region where the tube wall thickness is only 0.038 in. Cinching down a fitting outside the Ferrule Region and in the Sensor Assembly Region may result in permanent damage to the long tube and the sensor assembly within.

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3.3 PROCESS CONNECTION

Model 2230R offer a variety of fittings to mate the unit to a process stream. The following table lists our standard fitting selections. Others are available upon request.

- ½" MNPT thread
- ½" FNPT thread
- -8 SAE/MS thread size

... and many other industry standards.

3.4 PROCESS CONNECTION

Power (8 to 13 VDC) is connected via the Power/Analog connector as shown in *Section 4.1*. Once power is applied, the unit executes a warm-up sequence lasting five minutes. The status LED will be amber in color during the warm-up sequence. When the unit is ready for operation, the status LED will change to green (if the measured hydrogen concentration is under the first relay set point) and to red (if it exceeds the second relay set point). The following operations will be completed in this warm-up sequence:

- Heat the sensor to operating temperature
- Perform system self-test

WARNING: MODEL 2230R PROCESS HYDROGEN ANALYZERS ARE CALIBRATED IN A HYDROGEN/NITROGEN (H_2/N_2) BACKGROUND AND SHOULD NEVER BE OPERATED IN AN AIR OR OXYGEN BACKGROUND.

After warm-up, the Model 2230R Analyzer should be run in a hydrogen concentration exceeding 5% by volume for at least an hour. Oxygen will readily adsorb on the Model 2230R Analyzer and can confound the hydrogen measurements. If the sensors are left in oxygen, air or any environment without hydrogen for long periods of time, they must be conditioned in hydrogen to remove adsorbed oxygen and taken through the Verification process to check accuracy. Failure of the Verification will require that the sensors go through Calibration. Both procedures are described later in this manual.

The Model 2230R Analyzer can be exposed to oxygen for short periods of time without adverse effects if the unit is turned off. If the units are operated in oxygen or stored in air for longer than a week, the units' hydrogen readings may be high due to oxygen adsorption on the sensor. Hydrogen exposure will then cause the readings to drift lower as adsorbed oxygen is slowly removed and the unit recovers to normal steady behavior.

If this drift behavior is observed, the sensor should be conditioned by operating in a hydrogen concentration exceeding 5% until the readings are stable. The required hydrogen conditioning may vary from several hours to several days depending on the level of oxygen exposure. Higher hydrogen concentrations used during conditioning may accelerate the process. Once stable, the unit should be taken through Verification to check accuracy and Calibration if needed.

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Step	Description
1	Power units on in 5% H_2/N_2 by volume or greater
2	Operate the Model 2230R Analyzer in the 5% H_2/N_2 or greater gas for six hours or longer
3	Check to see if the sensor readings were accurate and stable over that time
4	If the readings are not accurate and stable, condition the sensor in 5% H_2/N_2 or greater gas overnight and perform the Verification and Calibration described later in this manual.

3.5 SETTINGS

The unit's operational and output settings have been configured at the manufacturer with settings specified at the time of purchase. Settings may be changed through the use of Serial Communication as described in section 4, or through the use of an Optional User Interface Module.

WARNING: IF SETTINGS ARE CHANGED FROM THOSE SET BY THE MANUFACTURER THEN IT IS THE USER'S RESPONSIBILITY TO UNDERSTAND THE IMPLICATIONS TO THE CONNECTING EQUIPMENT MONITORING THE UNIT.

3.6 VISUAL STATUS INDICATOR

Located on the front of the unit next to model number marking, the Status Indicator LED displays basic unit function as described below.

Status	Indicator Color
Normal operation / Hydrogen Detected below R1 set point	GREEN
Warm-up / Hydrogen Detected above R1 and below R2 set points	AMBER
Hydrogen Detected above R2 set point/ Unit fault detected	RED

3.7 OPTIMUM UNIT PERFORMANCE

For maximizing the performance of the sensor, the following steps are recommended.

- Verify that all electrical connections and made as recommended. Switching the polarity can cause damage to the unit. Ensure that the DC power supply utilized is appropriate and does not have large peak-to-peak noise.
- Perform a Field Calibration after installation and conditioning steps described in the Start-up section are completed.

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- If the unit gets exposed to extended periods of no H_2 (or some Oxygen), condition the sensor as described in the Start-up section and follow-up with a Field Verification (and Field Calibration, if needed).
- Effect of pressure: The Model 2230R Analyzer is hydrogen specific and sensitive to only the hydrogen partial pressure in the gas stream. Since changes in total gas pressure will affect the hydrogen partial pressure, they will also affect the sensor readings. For instance, at one atmosphere pressure, a 50% H_2/N_2 mixture will be reported as 50% from the unit. At 1.1 atm, the reading will increase to 55% and two atms will result in a reading of 100%. In fact, the Model 2230R Analyzer are capable of measuring multiple atmospheres of hydrogen and readings above 100% H_2 are interpreted as hydrogen pressures above one atmosphere. So, for example, a reading of 150% H_2 means 1.5 times the hydrogen pressure of a 100% H_2 concentration at one atmosphere. At the factory, the units are calibrated at one atmosphere pressure. Performing the Field Calibration at the operating pressure will display the pressure corrected reading. For example, if the local atmospheric pressure is 0.97 atm, doing a Field Calibration will correct for this.
- Verification/Calibration gas bottle accuracy: The inaccuracy of the gas bottle concentration will directly affect the measured accuracy by the units. During factory calibration, the units are calibrated with high accuracy gases (as high as ± 0.02% accurate). It is strongly recommended that the user perform calibration with similar high accuracy gases to maintain the accuracy specified in the manual.

4. ELECTRICAL & COMMUNICATION

WARNING: IF THE UNIT IS INSTALLED IN A CLASSIFIED LOCATION THEN IT IS THE RESPONSIBILITY OF THE USER AND INSTALLER TO MAKE CONNECTIONS TO RELATED EQUIPMENT IN A MANNER CONSISTENT WITH THE LOCATION CLASSIFICATION.

4.1 CONNECTIONS

Power/Analog Output - Connector 1

Supplied Cable – 4m (12 ft.) standard length (Other lengths available)

Wire Color	Description
Brown	+8 VDC to +13 VDC
White	VDC Return
Black	Positive Analog Output
Blue	Analog Output Return

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Relays (Optional) - Connector 2

Supplied Cable – 4m (12 ft.) standard length (Other lengths available).

Wire Color	Description
Grey	Relay 1 Common
Pink	Relay 1 Normally Closed (NC)
Black	Relay 1 Normally Open (NO)
White	Relay 2 Common
Blue	Relay 2 Normally Closed (NC)
Brown	Relay 2 Normally Open (NO)

Serial Interface (Optional) / Remote User Interface Module (Optional) - Connector 3

Supplied Cable – 4m (12 ft.) standard length (Other lengths available).

Wire Color	RS232 (standard)			RS422 (Optional)		
	Description	DB9 Pin	DB25 Pin	Description	DB9 Pin	DB25 Pin
Brown	+6V (N.C.)					
White	TxD (Device Transmit)	3	2	TxD- (Device Transmit, -Ve)	3	2
Blue	-	-	-	TxD+ (Device Transmit, +Ve)	4	3
Black	RxD (Device Receive)	2	3	RxD- (Device Receive, -Ve)	2	20
Grey	-	-	-	RxD+ (Device Receive, +Ve)	6	8
Pink	Ground	5	7	Ground	5	7

4.2 ANALOG OUTPUT

The user can request for a specific output current or voltage range or there are a number of standard analog output ranges the user can select from, which are listed below. The analog output the user selects is scaled to the user's hydrogen range of interest. All of this is initially set at the factory per customer specification at the time of order.

Below is the table for standard analog output current ranges:

Current Analog Output Range	Power-On Self Diagnostic	Error
4 mA to 20 mA	2 mA	3 mA
0 mA to 20 mA	0 mA	20 mA

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The user can change to another current range of the analog output in the field. Please refer to the "I" command in *Section 4.3 SERIAL COMMUNICATION*.
Below is the table for standard analog output voltage ranges:

Voltage Analog Output Range	Power-On Self Diagnostic	Error
0 V to 5 V	**0 V**	**5 V**
1 V to 5 V	**0.5 V**	**0 V**
0 V to 4 V	**5 V**	**4.5 V**
0.5 V to 4.5 V	**0 V**	**5 V**

The user can change to another voltage range of the analog output in the field. Please refer to the "V" command in *Section 4.3 SERIAL COMMUNICATION*.

WARNING: THE USER CANNOT CHANGE FROM A CURRENT RANGE TO A VOLTAGE RANGE OR FROM A VOLTAGE RANGE TO A CURRENT RANGE OUT IN THE FIELD. THIS REQUIRES A FACTORY MODIFICATION.

4.3 SERIAL COMMUNICATION

The user can monitor output and interface with the unit to perform calibration or adjust user settings via the serial communication connector. The serial communication is accomplished via an RS232 (optional RS422) interface.

Serial Communications Software	Any serial port two-way communications software such as terminal emulators (HyperTerminal, Telnet, etc.) and purpose-built software (using LabView, Visual Basic, C++, etc.) can be used to establish serial communication with the unit.
Format and Settings	RS232 (RS422 optional) • 19200 Baud • 8 bit data • 1 stop bit • No parity • Xon/Xoff
Data Display	Streaming data is presented in column format. Once serial communication is established and the unit is operating in normal mode, data will be displayed in the user specified format. The display output options are configured via a serial command as described in the following sections (refer to the *SERIAL COMMUNICATION COMMANDS*, *FORMAT <fmt>*, and *OPTIONS <opt>* sections). Columnated data available are as follows:

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	<fmt> Format (these appear in their own columns) • Timestamp (an integer count at 0.25 sec intervals) • Printed Circuit Board (PCB) Temperature in • Sensor Temperature in °C • Raw Analog Data Converter (ADC) Values • Calibrated Hydrogen Values • Peak Hydrogen Values <opt> Options (these status data appear in the MESSAGES column) • Calculation Errors • Heater State

What follows are examples of typical user specified outputs:
Example 1:
Sample serial data with column headers – Calibrated H_2% and Messages only

Display	User Response
H2scan:	Type “g 02 06”

%H_2	Messages
0.0000	
0.0000	
0.0000	

Example 2:
Sample serial data with column headers– Multiple Outputs Specified

Display	User Response
H2scan:	Type “g b2 06”

Time stamp	Pcb Temp	Snsr Temp	%H_2	Messages
264	28.8530	124.50800	0.0000	
280	29.1979	124.50910	0.0000	
296	29.5169	124.51110	0.0000	
312	29.7951	124.51320	0.0000	

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Serial Communication Commands	The unit can be communicated with and configured via the use of commands as described below. Two levels of communication outputs are available: • Level 0 – Default level used for data monitoring and basic functions providing a continuous stream of data readings • Level 1 – Password protected level used for configuration of user-settable parameters; interactive single-line data output per command

Command Summary	The RETURN or ENTER key is the last character of the command string. If either key is pressed without a command string the result is an invalid command and will resume continuous display if in Level 0 or return to prompt if in Level 1.

Level 0 Commands	
Keystroke	Description
ESC	Stops continuous display to enter a password or command. If in level zero, the continuous display will resume after executing one command.
sp(spacebar)	Pressing the Space key while the serial output is active will display a label line showing the heading for each column of data.
A	Average readings.
C	Clear peak hydrogen value.
=<password>	Enter the password to change security level. A null or invalid password returns to the default security level. Level 0 password = "0" Level 1 password = "h2scan"

Level 1 Commands	
Keystroke	Description
A <R1> <R2>	Set the R1 and R2 set points for the relay contacts in $\%H_2$.
C	Clear peak hydrogen value.
D <page>	Display Product Information. Enter page number 0-6 or A for all pages, default is page 0. 0 – Product information 1 – User configuration 2 – Manufacturing information 3 – Product configuration 4 – Sensor characterization data 5 – Hydrogen calibration data

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	6 – Temperature calibration data A – All of the above
E	Field Verify (refer to the *Section 5.4 VERFICATION*).
F	Field Calibration (refer to the *Section 5.5 CALIBRATION*).
G < fmt> <opt>	Start or resume the sensor operation: if needed, heat the ASIC, setup the sensor, and output data on serial port; this restores default settings (refer to the *FORMAT <fmt>* and *OPTIONS <opt>* sections).
H <low> <high>	Set the hydrogen reporting range: <low> to <high> in $\%H_2$.
I <low> <high> <err> <not rdy>	Set the DAC current output range: <low> to <high>; error output <err>; and not ready output <not rdy> milliamps. Possible range from 0 to 20 milliamps.
L < fmt> <opt>	Print current hydrogen reading. Used to poll for hydrogen readings. Default format <fmt> is current setting (refer to the *FORMAT <fmt>* and *OPTIONS <opt>* sections).
P <atm>	Select atmospheric pressure of gas. Factory default pressure is 1 ATM.
S	Stop the sensor: turn off heater, set Bias to zero, set DAC outputs to zero, and stop reporting data on the serial output.
V <low> <high> <err> <not rdy>	Set the DAC voltage output range: <low> to <high>; error output <err>; and not ready output <not rdy> in volts. Possible range from 0 to 5 volts.
X	Clear field calibration data (returns to last factory calibration data).

Format <fmt>	The Format <fmt> string is a two character hexadecimal representation of an 8 bit value derived from the following table. The user determines which data is needed and selects that bit value. Once all selections are made the values are summed bitwise and then converted to a two place hexadecimal value. To aid in the conversion, a 4 bit to hexadecimal conversion table follows in *EXAMPLE 3*.

Format: Bit Value Identifiers

Serial output Format <fmt> parameter: select the desired columns of data from this list, add the bit value for each column bitwise, and convert into two hexadecimal characters using the 4 bit-to-Hexadecimal table in *EXAMPLE 3*.

Description	Bit Value							
Include time stamp	1	0	0	0	0	0	0	0
Include raw ADC values	0	1	0	0	0	0	0	0
Include PCB temperature	0	0	1	0	0	0	0	0
Include sensor temperature	0	0	0	1	0	0	0	0
Include capacitor reading	0	0	0	0	1	0	0	0

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Include resistor reading	0	0	0	0	0	1	0	0
Include overall hydrogen reading	0	0	0	0	0	0	1	0
Include peak hydrogen reading	0	0	0	0	0	0	0	1

Options <opt>	The Options <opt> string is a two character hexadecimal representation of an 8 bit value derived from the following table. The user determines which data is needed and selects that bit value. Once all selections are made the values are summed bitwise and then converted to a two place hexadecimal value. To aid in the conversion, a 4 bit-to-Hexadecimal conversion table follows in *EXAMPLE 3*.

Options: Bit Value Identifiers

Serial output Options <opt> parameter: select the desired status messages from this list which will appear in the MESSAGES column, add the bit value for each column bitwise, and convert into two hexadecimal characters using the 4 bit-to-Hexadecimal table in *EXAMPLE 3*.

Description	Bit Value							
Calculation Errors	0	0	0	0	0	1	0	0
Heater State	0	0	0	0	0	0	1	0

Example 3:

The user wishes to implement the "G" command ("Go"command, refer to *LEVEL 1 COMMANDS* table) to have the following serial output columns reported from the monitor: Time Stamp, Capacitor Reading, Overall Hydrogen Reading, the Peak Hydrogen Reading, Calculation Errors, and the Heater state.

From the *FORMAT <fmt>* table above, you identify your desired columns with its corresponding bit value:

<fmt> Descriptions	<fmt> Bit Value
Time Stamp	1000 0000
Capacitor Reading	0000 1000
Overall Hydrogen Reading	0000 0010
Peak Hydrogen Reading	0000 0001
<fmt> 4 Bit Value Combination:	1000 1011

4 bit value	Hexadecimal Character
0000	0
0001	1
0010	2
0011	3
0100	4
0101	5
0110	6
0111	7
1000	8
1001	9
1010	A
1011	B
1100	C
1101	D
1110	E
1111	F

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Now use the *4 BIT-TO-HEXADECIMAL* table above to convert this 4 bit value combination into a two place hexadecimal value:
<fmt> Two Place Hexadecimal Value : 8b

From the *OPTIONS* <*opt*> table above, you identify your desired columns with its corresponding bit value:

<opt> Descriptions	<opt> Bit Value
Calculations Errors	0000 0100
Heater State	0000 0010
<opt> 4 Bit Value Combination:	0000 0110

Again, use the *4 BIT-TO-HEXADECIMAL* table to convert this 4 bit value combination into a two place hexadecimal value:
<opt> Two Place Hexadecimal Value : 06

Conclusion: To have the Time Stamp, Capacitor Reading, Overall Hydrogen Reading, the Peak Hydrogen Reading, Calculations Errors and Heater State columns continuously reported, you will implement the "G" serial command ("Go" Command, refer to *LEVEL 1 COMMANDS* table) as follows at the H2scan:
command prompt: G < fmt> <opt> = g 8b 06

Display	User Response
H2scan:	Type "g 8b 06"

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5. MAINTENANCE

5.1 CLEANING

If the unit is exposed to process streams containing debris, condensates or other material that may collect over the sensor tip then the unit should be removed from the stream periodically and the tip cleaned by a gentle wiping with a clean lint-free cloth or paper.

5.2 CALIBRATION INTERVAL

TELEDYNE ANALYTICAL INSTRUMENTS recommends that the system calibration be carried out if the unit fails Verification. Field Verification can occur as often as needed and is recommended when the tolerated sensor drift may result in unacceptably high errors. Anticipated drift rates and error calculations are explained in the Verification section of this manual. The user has two choices in calibrating the unit:

Factory Calibration	Contact TELEDYNE ANALYTICAL INSTRUMENTS to make arrangements for a comprehensive Factory Calibration using high accuracy gases by TELEDYNE ANALYTICAL INSTRUMENTS's factory trained technicians; optional NIST traceable certificate available upon request. An annual Factory Calibration is advisable to optimize performance.
Field Calibration	Refer to *Sections 4.4 and 4.5* for the operational procedure. Customer-specific Field Calibration Kits for the Model 2230R analyzer is available from TELEDYNE ANALYTICAL INSTRUMENTS. Field Calibration is a 3 stage process: 1. Run Field Verification, 2. Run Field Calibration, 3. Repeat the Field Verification to confirm a successful Field Calibration.

In the event the Field Calibration procedure seems to not be effective, TELEDYNE ANALYTICAL INSTRUMENTS recommends the unit be shipped back to the factory for a comprehensive evaluation and Factory Calibration.

5.3 FIELD VERIFICATION & FIELD CALIBRATION GASES

Field Verification and Field Calibration require the availability of at least two certified known gases at values specific to the user's application. For optimization, the hydrogen concentrations of the gases implemented in Field Verification and Field Calibration must be the same. Flow rate recommended is 0.5 ± 0.2 slpm.

Verification / Calibration in an Inert (i.e. nitrogen) Background Gas:
For a unit calibrated in an inert gas (i.e. nitrogen) background, carry out Verification and Calibration in an inert (i.e. nitrogen) gas background.
Gas Connection
Gases are applied to the unit through user's piping.

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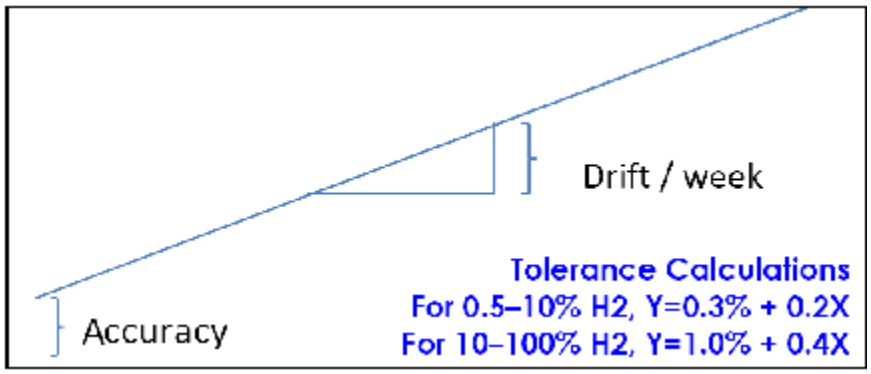
5.4 VERIFICATION

Verification Interval

Verification is a process to compare the sensor output to a known hydrogen concentration. Verifications do not cause any wear on the sensor and can be accomplished as often as desired. The recommended interval to perform Verification depends solely on the user's desired tolerance for the specific application in question. If the user does not have a specific desired tolerance, TELEDYNE ANALYTICAL INSTRUMENTS recommends that Verification be performed every three months.

The tolerance (error) in measuring hydrogen has two primary components: the initial accuracy number (offset) and a weekly drift value (slope). The chart below is provided as a guideline for tolerance estimation for the Model 2230R and can be a useful tool in determining the initial verification frequency. The subsequent verification frequencies can be decided based on the actual weekly drift observed. The tolerance chart may be used in accordance with TELEDYNE ANALYTICAL INSTRUMENTS Model 2230R accuracy specifications.

Tolerance Chart (Gas Temperature <65°c)



Number of Weeks after Field Calibration, X

Model	Accuracy(*):	Drift/week:
2230R	± 0.3% absolute for 0.5 to 10% H_2	± 0.2% absolute for 0.5 to 10% H_2
	± 1.0% absolute for 10 to 100% H_2	± 0.4% absolute for 10 to 100% H_2

* Sensor performance specifications are only valid for units configured for a maximum 65°C dry process stream temperature. All figures assume pressure compensation, operating in ambient that do not contain Oxygen and are in addition to any errors in the gasses used. The accuracy is specified for serial port output only.

The drift chart can be used to determine the maximum recommended Verification interval to maintain a required level of accuracy. For instance, if ± 1% accuracy in a 5% H2/N2 gas is needed; Verification should be typically performed every 3.5 weeks. If ± 2% accuracy is needed in the same gas, the recommended Verification interval can be extended to 8.5 weeks. Verifications may be done more frequently than these intervals if desired and should always be performed if the sensor readings are unusual or suspected to have large errors.

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The Model 2230R Analyzer should be conditioned by operation in hydrogen exceeding 5% by volume until stable and taken through the Field Calibration, if exposed to oxygen or operated without hydrogen for an extended period. If the unit continues to exhibit errors in excess of the published accuracy specification and drift rate, please contact TELEDYNE ANALYTICAL INSTRUMENTS for factory evaluation and repair.

Verification Procedure

Verification can only be accomplished through interface with the unit via the serial port (refer to the previous *Serial Communication Commands* section and the *LEVEL 1 COMMANDS* table in Section 4.3). Verification of sensor output should be conducted on a regular basis to insure proper unit operation. Analog outputs can be monitored through the user's system. As part of this sequence the date of verification is stored in the unit's memory.

WARNING: IN ORDER FOR VERIFICATION TO SUCCESSFULLY TAKE PLACE, THE SENSOR MUST BE IN NORMAL RUNNING MODE.

Verification Using Serial Interface – After establishing serial communication then follow the sequence below:

1) Press "Esc"
2) The unit will return the command prompt "H2scan:"
3) Type "e" then hit "Enter" and follow prompts to field verify sensor calibration at two gas concentrations

These steps will implement the following specification values as an example; for values in bold, please substitute appropriate values relative to your specific operational conditions:

- Local atmospheric pressure: 0.969 ATM
- Hydrogen range: 0% to 30% hydrogen, balance nitrogen
- Field Verification Gas #1: 1% hydrogen, balance nitrogen (instead of gas #1 being 0% hydrogen, H2scan recommends Field Verification gases always have a hydrogen concentration)
- Field Verification Gas #2: 30% hydrogen, balance nitrogen
- Settle Time: 30 minutes (TELEDYNE ANALYTICAL INSTRUMENTS recommends this duration for field verification)
- Tolerance of Field Verification Gas #1 (1% hydrogen by volume): For example, ± 0.30% absolute hydrogen by volume (refer to the *TOLERANCE CHART* above or enter user desired tolerance) NOTE: Poor accuracy of the verification gases will influence the achievable accuracy from the unit.
- Tolerance of Field Verification Gas #2 (30% hydrogen by volume): ± 1.0% absolute hydrogen by volume (refer to the *TOLERANCE CHART* above or enter user desired tolerance)

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FIELD VERIFICATION STEPS		
Step	Display	User response
1	*H2scan:*	Type " e" to run field verification
2	*Ready to Verify (Y/N)?*	Type " y"
3	*Pressure is 1.000 atm (Y/N)?*	Type " n"
4	*Enter new pressure:*	Type " .969" for the local atmospheric pressure
5	*Pressure is 0.9690 atm (Y/N)?*	Type " y"
6	*Save as default (Y/N)?*	Type " n"
7	*Verify Sensor (Y/N)?*	Type " y"
8	*Enter Gas (%H2):*	Type " 1" for gas #1, 1% hydrogen by volume
9	*Settle time (min):*	Type " 30" for a 30 minute duration for gas #1
10	*Tolerance (%H2):*	Type "0.3%" absolute from the for 1% hydrogen by volume
11	*Apply 1.000%H2: Ready (Y/N)?*	Type " y"
	Streaming data…	
12	*Taking Average…*	An average will be calculated. Verification Gas1 finished
13	*Continue test Verify Sensor (Y/N)?*	Type " y"
14	*Enter Gas (%H2):*	Type " 30" for gas #2, 30% hydrogen by volume
15	*Settle time (min):*	Type " 30" for a 30 minute duration for gas #2
16	*Tolerance (%H2):*	Type "1.0%" absolute from the *TOLERANCE CHART* for 30% hydrogen by volume
17	*Apply 30.000%H2: Ready (Y/N)?*	Type " y"
	Streaming data…	
18	*Taking Average…*	An average will be calculated. Verification Gas2 finished.
19	*Continue test Verify Sensor (Y/N)?*	Type "n" to end field verification. Verification complete.

4). If the unit passes Verification, Calibration is not required at this time.

5). If the unit fails Verification, you will see the following:

18	*Taking Average…*	An average will be calculated.
19	*Verify Failed*	Verification complete.

6). If the unit fails Verification, TELEDYNE ANALYTICAL INSTRUMENTS recommends Calibration, detailed in the following section.

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5.5 CALIBRATION

Calibration Interval

Calibration is used to correct any offset that exist between the sensor output and a known hydrogen concentration. Calibrations do not cause any wear on the sensor and can be accomplished as often as desired. It is recommended that Calibration be performed if a unit fails Verification.

Calibration Procedure

IMPORTANT NOTE: During the Calibration process any previously completed Field Calibrations are cancelled. As a result, during the routine the unit may display a hydrogen concentration that is different from the applied gas concentration. This is normal. Once the procedure is completed, the readings will be corrected to display the right concentrations for all subsequent exposures.

Calibration can only be accomplished through interface with the unit via the serial port (refer to the previous *Serial Communication Commands* section and the *LEVEL 1 COMMANDS* table in Section 4.3). Analog outputs can be monitored through the user's system.

Calibration Using Serial Interface (firmware version 0.47) – Follow the sequence below:

1) Press "Esc"
2) The unit will return the command prompt "H2scan:"
3) Type "f" then hit "Enter" and follow prompts to field calibrate the sensor with two gas concentrations

These steps will implement the following specification values as an example; for values in bold, please substitute appropriate values relative to your specific operational conditions:

- Local atmospheric pressure: 0.969 ATM
- Hydrogen range: 0% to 30% hydrogen, balance nitrogen
- Field Verification Gas #1: 1% hydrogen, balance nitrogen (instead of gas #1 being 0% hydrogen, H2scan recommends Field Verification gases always have a hydrogen concentration)
- Field Verification Gas #2: 30% hydrogen, balance nitrogen
- Settle Time: 30 minutes (TELEDYNE ANALYTICAL INSTRUMENTS recommends this duration for field calibration)

WARNING: AS IN THIS EXAMPLE, FOR OPTIMIZATION, THE HYDROGEN CONCENTRATIONS OF THE GASES IMPLEMENTED IN FIELD CALIBRATION AND FIELD VERIFICATION MUST BE THE SAME.

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FIELD CALIBRATION STEPS		
Step	Display	User response
1	*H2scan:*	Type " f" to run field calibration
2	*Ready to Calibrate (Y/N)?*	Type " y"
3	*Pressure is 0.9690 atm (Y/N)?*	Type " y" Please note that the firmware has remembered the atmospheric pressure from the preceding Verification procedure. Type "n" if a change is required and enter the correct pressure.
4	*Save as default (Y/N)?*	Type " n"
5	*Gas1 is 0%H2 (Y/N)?*	Type " n"
6	*Gas1 for res (Y/N)?*	Type " y"
7	*Cal Gas: 2.000%H2 (Y/N)?*	Type " n"
8	*Enter gas:*	Type " 1" for gas #1, 1% hydrogen by volume
9	*Cal Gas: 1.000%H2 (Y/N)?*	Type " y"
10	*Settle time: 3 min (Y/N)? n*	Type " n"
11	*Enter time:*	Type " 30" for a 30 minute duration for gas #1
12	*Settle time: 30 min (Y/N)?*	Type " y"
13	*Apply 1.000%H2: Ready (Y/N)? y*	Type " y"
	Streaming data…	
14	*Taking Average…* cap=0.00000 res=x.xxxxx	Calibration Gas #1 finished
15	*Gas2 for res (Y/N)?*	Type " y"
16	*Cal Gas: 100.000%H2 (Y/N)?*	Type " n"
17	*Enter gas:*	Type " 30" for gas #2, 30% hydrogen by volume
18	*Cal Gas: 30.000%H2 (Y/N)?*	Type " y"
19	*Settle time: 1 min (Y/N)?*	Type " n"
20	*Enter time:*	Type " 30" for a 30 minute duration for gas #2

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21	*Settle time: 30 min (Y/N)?*	Type " y"
22	*Apply 30.000%H2: Ready (Y/N)?*	Type " y"
	Streaming data…	
23	*Taking Average…* cap=0.00000 res=x.xxxxx	Calibration Gas #2 finished. Calibration complete.

4) Per TELEDYNE ANALYTICAL INSTRUMENTS's recommendation, upon completion of Calibration, conduct the Verification sequence as described in the previous section to verify that the calibration process was executed correctly.

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