ProtiSen™

Catalytic Hydrogen Gas Sensor

FEATURES

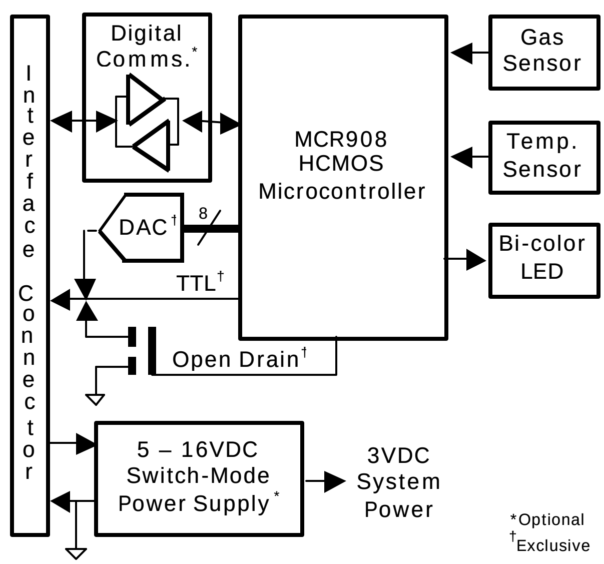
- Catalytic Sensor & HCMOS microcontroller
- 0-40,000 ppm hydrogen in air measurement
- 200 ppm logical resolution
- 2 seconds start-up time
- 2 secs. T90 response time
- 5 secs. T10 recovery time
- Normal, Warning, Alarm & Error states
- Bi-color LED status indicator
- Optional 0-to-3V proportional output (8 bit)
- Optional 0-to-3V Encoded State output
- Optional binary operation (TTL output)
- Optional 60V at 2 amps open drain output
- Latching or auto-resetting operation
- *PK-Port™* compatible digital communications
- User-settable alarm/warning via *PK-Port™*
- Digital FLASH-based calibration
- Each device factory pre-calibrated
- -40 to +80 Celsius operation
- Sensor & temperature error detection
- 750mW power consumption
- Optional 3VDC input power version (I1)
- Optional 5-16VDC input power version (I2)
- 51mm x 51mm x 19mm size

ProtiSen™ front view

DESCRIPTION

ProtiSen™ is an intelligent hydrogen gas sensor intended for safety applications in hydrogen fueled vehicles and power generation equipment. The sensor has a VOC filter, cannot be damaged by overexposure, and has increased tolerance of silicone-based contaminants. Linear measurement of hydrogen (in air) concentrations is possible up to 40,000 ppm with 200 ppm resolution. Each device is factory calibrated to a user-specified alarm point. Calibration values are FLASH memory-based and are field-adjustable via Neodym's *PK-Port™* PC interface. The device may be powered from 5 to 16VDC and consumes about 750mW. Custom form factors, connector types and mounting provisions are available by special request.

BLOCK DIAGRAM



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1 – FUNCTIONAL DESCRIPTION

1.1 - OVERVIEW

ProtiSen™ gas sensors comprise of an HCMOS microcontroller, a catalytic gas-sensing element and amplifier, a semiconductor temperature sensor, a bi-color indicator LED and various optional signaling devices such as a D-to-A converter or an open drain FET.

Standard devices operate with an input supply of 5 to 16 VDC. Special lower cost and more power efficient versions are available that operate at 3VDC (regulated).

A one-wire bi-directional digital interface (*PK-Port*™) may be used for set-up, calibration and remote monitoring via a PC serial port.

Each time that power is applied the device enters a brief warm-up state after which active gas sensing functions commence. Gas concentrations and sensing state indications become available after the warm-up period has elapsed.

Gas sensor signals are continuously sampled by an 8-bit A-D subsystem and are digitally filtered to reject burst noise and other spurious events. The filtered signal is then stripped of its baseline component and is spanned according to its memory-resident calibration values. The scaled signal is used to produce linear readings of gas concentration that may be accessed in real-time via the output signal DAC or the *PK-Port*™ interface.

1.2 – SYSTEM COMPONENTS

This section describes the function of various ProtiSen™ system components. Certain items may not be present depending on the options selected at order time.

SENSOR

The employed gas-sensing element is a catalytic type offering high sensitivity to hydrogen, rapid response/recovery time, no "inverted response" at high gas concentrations, modest power requirements and long life.

The sensor has an in-line VOC filter, good long- term stability characteristics, increased tolerance of silicones, and is immune to overexposure damage.

Gas sensing is performed on a diffusion basis and materials that would impede the convection of the sampled atmosphere to the sensor should therefore never obstruct the sensor opening.

LED

A bi-color (red/green) light-emitting diode is used to provide visual indication of the detector's state. For more details, please see the section titled DEVICE STATES.

OUTPUT SIGNAL

The output signal is accessible via the INTERFACE CONNECTOR. Depending on device options, the output signal may be binary (TTL or Open Drain), proportional analog (0-3V), or a voltage-encoded representation of the current device state.

The TTL or Open Drain output function may be configured at order time (or using PK-Port™) as normally high (or on) or normally low (or off); latching or auto-resetting. It may further be configured to respond to the Warning level, the Alarm level, or both.

Latch-mode output signals are reset via power cycling.

For more details on interpreting the 0-3V and Encoded State output functions, please see the section titled OUTPUT INDICATION.

INTERFACE CONNECTOR

This connection permits application of input power and connection to the output signal. For pin details, please see the section titled ELECTRICAL INTERFACE.

1.3 - DEVICE STATES

Five device states are supported, viz. warm-up, normal, warning, alarm and error. Each state asserts specific signaling conditions.

WARM-UP STATE

The warm-up state is entered whenever the device is powered-on and lasts approximately 2 seconds. This period permits the gas sensor to reach its proper operating temperature and allows the sensor signal to stabilize after periods of inactivity. During the warm-up state gas sensing is not active and zero value gas readings are returned. The LED blinks green/off during the warm-up period.

NORMAL STATE

The normal state is entered upon the expiry of the warm-up period. During the normal state the LED remains steady green. The normal state is maintained while the power level is valid and while there is an absence of error conditions or actionable gas concentrations. All other states return to the normal state upon their expiry or resolution.

WARNING STATE

The warning state reports a gas concentration that is a specific percentage of the alarm state. This action percentage is stored in memory and is usually configured at order time. *PK-Port*™ may be used to modify the action level. During the warning state the LED blinks red/green.

ALARM STATE

The alarm state is entered when the gas concentration reaches or exceeds a predetermined threshold. The action level is stored in memory and is usually configured at order time, although it may be reconfigured using *PK-Port*™. During the alarm state the LED blinks red/off.

ERROR STATE

The error state is asserted whenever the device is prevented from providing reliable readings. The error sources are gas sensor failure/removal, temperature out of bounds and loss of firmware integrity (detectable via a checksum failure). During the error state gas concentration readings are invalid and return full-scale values for failsafe operation. During the error state the LED remains off and briefly pulses red about every 10 seconds. Normal device operation resumes dynamically when the error condition is resolved.

Please note: The device features a Low Voltage Inhibit function and a Computer Operating Properly watchdog timer. A fault from either source does not produce an error state but rather device reset. If such faults should persist then they are detectable via continuous return to the warm-up state.

TABLE 1.3.1 – Device States Summary

State	Stimulus	Reading	LED
Warm-up	Power-on, software error	Zero	Blink green/off
Normal	Ambient conditions	Valid	Steady green
Warning	Warning threshold reached	Valid	Blink red/green
Alarm	Alarm threshold reached	Valid	Blink red
Error	Sensor failure, temperature error	Full scale	Off, pulse red

1.4 – OUTPUT INDICATION

Gas concentration indications are available as a proportional output voltage in devices with the 0-3V output option, or as voltage-encoded representations of the device state in models with the Encoded State option.

1.4.1 – 0 - 3V ANALOG OUTPUT

Devices with a 0-3V output signal (“O5” option) encode the measured gas concentration as one step per 200 ppm hydrogen where each reading step is about 12 mV.

The output signal is produced by a 10-bit DAC with a resolution of 3V/1023 steps = 2.93255 mV. While the DAC resolution is 10 bits (~50 ppm), the gas reading resolution is 8 bits (200 ppm) – which means that the output signal steps by four DAC units for each 200 ppm (11.73mV).

A 500mV (170 DAC steps) safety offset (trouble threshold) is applied to the output signal and needs to be subtracted when calculating the gas reading. The absence of this offset voltage may be used to indicate a system error condition, power loss, or that there has been a break/short in the output signal wiring.

OUTPUT VOLTAGE INTERPRETATION

The output signal voltage may be converted to a gas concentration using the following formula:

$$ppm = ((V_{OUT} - V_{OFS}) / StepSize) \times Resolution$$

where

ppm	is the gas concentration
V_{OUT}	is the total output signal voltage
V_{OFS}	is the offset voltage (500mV)
StepSize	is the reading step size (11.73mV)
Resol.	is 200 ppm

For example:

An output signal voltage of 2.26V would be indicating the following gas concentration:

$$((2.26V - 0.5V) / 0.01173V) \times 200 \text{ ppm}$$

$$= 30{,}000 \text{ ppm}$$

i.e. 150 net steps of 200 ppm each

1.4.2 – ENCODED STATE OUTPUT

Devices with encoded state outputs (“O6” option) represent the current state (normal, alarm, etc.) via a unique output voltage for each state, as shown below.

STATE	V_{MIN}	V_{TYP}	V_{MAX}
Fault	0	0	0.1
Normal	0.25	0.50	0.75
Warning	1.00	1.25	1.50
Alarm	1.75	2.00	2.25
Fault	2.50	2.75	3.00

Two fault states are defined (0V and 3V) in order to detect output signals that are open, shorted to ground, or shorted to a power rail.

1.4.3 – TTL OUTPUT SIGNAL

Devices with the TTL output signal (“T1” option) indicate the alarm state by activating this binary output that can be configured to be normally high or normally low. The signal can also be configured to reset automatically when the alarm concentration is removed, or to remain latched until the monitor is power cycled.

1.4.4 – OPEN DRAIN OUTPUT SIGNAL

Devices with the Open Drain output signal (“T2” option) indicate the alarm state by activating or deactivating a power FET. This transistor can be configured to be normally on or normally off. This output can also be configured to reset automatically when the alarm concentration is removed, or to remain latched until the monitor is power cycled.

1.5 – SENSING PERFORMANCE

Sensing performance is only guaranteed over the range of electrical and environmental conditions cited in the specifications sections. The following remarks are provided for general guidance.

ACCURACY

Sensing accuracy is dependent on proper device calibration and the absence of abusive handling. Please see the Use, Care & Maintenance section for recommended handling and usage procedures.

Accuracy is defined as the ability of the sensor to correctly indicate the real gas concentration. Please see SPECIFICATIONS section for detailed sensing parameters.

The specified accuracy error budget takes into account the following factors: Sensor, amplifier, A-to-D, and D-to-A linearity; Supply voltage variation; Sensing and calibration resolution; Sampling jitter due to electrical noise; Math rounding-off errors.

RESPONSE TIME

Whereas the raw gas signal response and recovery time is virtually immediate, the system employs software averaging and state debouncing to filter out spurious events and to prevent metastable indications. Please refer to the Electrical Specifications section for these AC characteristics.

CALIBRATION

All devices are individually factory calibrated prior to delivery. Calibration is performed digitally with values stored in FLASH memory. Baseline offsets (zero) may be captured via PK-Port™. User modification of the Span value may be performed via the *PK-Port*™ interface and requires exposure of the device to known reference concentration of hydrogen in air.

1.6 – RELIABILITY FEATURES

Various fault detection features have been implemented to provide indication of unacceptable sensing conditions. Devices are configured at order time (or via *PK-Port*™) to respond to error conditions by simply asserting the error state, or by triggering the alarm state.

SENSOR ERROR

This error is triggered by the removal of the sensor, or a break in the sensor's bonding wires. The error state is released when the sensor is replaced.

TEMPERATURE ERROR

This error is triggered when the operating temperature is above or below permissible levels. The error state is released automatically when the temperature returns to the acceptable range.

COP TIME-OUT

Electrostatic discharges or other electrical events that may alter system RAM and cause improper program operation will cause the Computer Operating Properly watchdog timer to reset the system (return to the warm-up state).

LOW VOLTAGE INHIBIT

The device will remain in the reset state if the system voltage is below 2.6 VDC (nominal). Unstable system power levels manifest themselves as a continuous return to the warm-up state.

MEMORY CHECKSUMS

Abnormal electrical conditions that may cause a loss of integrity of the FLASH memory are detected via checksum calculations after each power-up. If the firmware checksum value is incorrect then the system will remain in the error state. A similar check and response applies to calibration and configuration values.

Damaged firmware is in-circuit field reprogrammable via *PK-Port*™ adapters and a Neodym utility program.

BOUND OFFSET VALUE

The system prevents "zeroing-to-death" conditions by rejecting attempts to capture an offset in high gas concentrations.

1.7 – USE, CARE & MAINTENANCE

ProtiSen™ sensors can provide reliable readings for many years if properly handled and maintained. To derive the maximum serviceable lifetime from the device, please observe the following recommendations.

CHECK CALIBRATION PRIODICALLY

Although the devices feature several self-diagnosing functions, the only direct method to check accuracy and proper operation is via exposure of the sensor to a reference gas concentration and observing it to read correctly. Devices are delivered factory calibrated, but the accuracy of the unit can and will degrade over time – especially if used in corrosive or hostile environments. It is recommended that calibration checking should be performed as often as is practical and no less frequently than once every six months.

GENERATING REFERENCE GAS

The recommended method for generating calibration test gas mixtures is to dilute pure target gas with clean, normal air in a leak-free chamber of fixed, known volume. A simple procedure is to inject a specific amount of pure target gas using a syringe into a sealed plastic lunch container. EG 50cc of pure target gas injected into a chamber with a net volume of 5 liters produces a concentration of 10,000 ppm. Gentle shaking or an enclosed fan may be used to assure proper dispersion of the gas mixture. In applications where it is impractical to immerse the module in such a gas mixture, a pump or aspirator may be used to flow the gas mixture over the sensor.

INTEFERENCE GASES

The employed catalytic sensor is not specific to any one combustible gas. ProtiSen™ monitors will read accurately in the presence of homogeneous hydrogen gas/air mixtures, but will also produce readings in the presence of other combustible vapors. Heterogeneous gas mixtures generally have a synergistic effect on the sensor, and in the absence of a target gas presence, the interference gases will manifest themselves as 'false' readings.

AVOID SENSOR OBSTRUCTION

The sensor samples the atmosphere based on the diffusion of gas through the filter/mesh into the internal cavity. Please locate the sensor such that it is not pressed against a surface that will obstruct gas flow, and prevent materials such as dust and lint from clogging the sensor opening.

PROPER PLACEMENT

For earliest warning of a possible gas hazard, locate the detector nearest to the most likely source of the gas leak.

AVOID EXPOSURE TO SILICONE VAPORS

Sealants such as caulking compounds, lubricants, hoses, etc. may contain silicones. These items may continue to off-gas silicone vapors indefinitely, even after full curing – and especially under high temperature conditions. Extra care should be taken when testing the sensor in environmental chambers – many of which use silicones for thermal insulation. While the sensor has higher resistance to silicone poisoning than many other catalytic sensors, concentrations of silicone higher than those specified as permissible may lead to a loss of hydrogen sensitivity.

NO STRONG ELECTROMAGNETIC FIELDS

While the circuit is relatively low impedance, avoid locating the sensor in the immediate vicinity (<10 cm) of strong and fluctuating field sources such as fans, pumps, motors, RF transmitters, etc. Close proximity to such fields may result in spurious gas readings. Also, make sure that the detector's power supply is adequately decoupled from fluctuations caused by the switching of large external loads.

2 - SPECIFICATIONS

2.1 – SENSING PERFORMANCE

These parameters apply under the Functional Operating Conditions stipulated in the Electrical Specifications section.

TABLE 2.1.1 – Hydrogen sensing characteristics

Parameter	Min	Typ	Max	Unit	Note
Sensing range	-	-	40,000	**ppm**	
Logical resolution	-	-	200	**ppm**	
Accuracy	5	3	-	**%**	**1**
Linearity	5	3	-	**%**	**2**
Air velocity error	-	1	1.5	**%**	**4**
HMDS tolerance	100/50 10/500	-	-	**PPM/hrs**	
Start-up time	-	2	6	**Sec.**	
Response time (T90)	-	2	3	**Sec.**	
Recovery time (T10)	-	5	10	**Sec.**	

TABLE 2.1.2 – Hydrogen sensing environmental requirements

Parameter	Min	Typ	Max	Unit	Note
Relative humidity	0	-	99	**% R.H.**	**3**
Operating temperature	-40	-	+80	**Deg. C.**	
Flow rate	-	-	3	**m/sec.**	**4**
Atmospheric oxygen	5	21	-	**% vol.**	

Notes: 1. Accuracy specified at the alarm point. Please see Sensing Performance for error budget items.
2. Linearity specified at the warning point.
3. Non-condensing
4. Devices are factory calibrated in static air flow conditions

2.2 – ELECTRICAL SPECIFICATIONS

ABSOLUTE MAXIMUM RATINGS

Note: Maximum ratings are the extreme limits to which the device can be exposed without permanent damage. The devices are not guaranteed to operate properly at maximum ratings.

TABLE 2.2.1 - Absolute Maximum Ratings

Parameter	Symbol	Value	Unit
Supply voltage I1 Models: I2 Models:	V_{SUP}	 3.1 25	**VDC**

FUNCTIONAL OPERATING RANGE

Note: Sensing accuracy deteriorates rapidly outside the specified operating voltage range. Permanent device damage may occur above the specified operated voltage range.

TABLE 2.2.2 – Operating Voltage Range

Parameter	Symbol	Value	Unit
Operating voltage range I1 Models: **I2 Models:**	V_{SUP}	 2.9 to 3.1 **5 to 16**	**VDC**
Undervoltage lockout I1 Models: **I2 Models:**	V_{INH}	 2.6V 4.0	**VDC**

TEMPERATURE RATINGS

TABLE 2.2.3 - Temperature Ratings

Parameter	Symbol	Value	Unit
Storage temperature	t_{STG}	**-40 to +125**	**Deg. C.**
Operating temperature range	t_{OP}	**-40 to +80**	**Deg. C.**

POWER CONSUMPTION

TABLE 2.2.4 – Supply current

Parameter	Symbol	Min	Typ	Max	Unit
I1 models: V_{SUP} = 3.0VDC	I_{SC}	-	210	225	**mA**
I2 models: V_{SUP} = 12VDC	I_{SC}	-	62	67	**mA**

DC CHARACTERISTICS

TABLE 2.2.5 – DC Parameters

Parameter	Symbol	Min	Typ	Max	Unit
TTL high voltage (I_{LOAD}=-5.0mA)	V_{OH}	2.0	-	-	**V**
TTL low voltage (I_{LOAD}=5.0mA)	V_{OL}	-	-	0.2	**V**
0-3VDC output signal loading	PS_{LOAD}	-	-	3	**mA**
Encoded State output signal loading	ES_{LOAD}	-	-	5	**mA**
Open drain output voltage	DS_{VDS}	-	-	60	**V**
Open drain output current	DS_{IO}	-	-	2	**A**
Open drain resistance	$R_{DS(ON)}$	**-**	0.30	0.35	**Ohm**

AC CHARACTERISTICS

TABLE 2.2.6 – AC Parameters

Parameter	Symbol	Min	Typ	Max	Unit
Fundamental operating frequency	f_{OP}	5.8	7.3	8.7	**MHz**
Power-on reset time	T_{PRES}	0.9	1	1.1	**mS**
COP watchdog time-out time	T_{CTO}	**29**	32	35	**mS**
COP time-out reset time	T_{CRES}	90	100	110	**uS**
Warm-up time	T_{WARM}	**1.8**	2.0	2.2	**S**
ADC sampling rate	T_{SAMP}	**9**	10	11	**mS**
Signal averaging period	T_{AVG}	**450**	500	550	**mS**
State debounce period	T_{DEB}	**1.8**	2	2.2	**S**
LED blink rate	T_{LBR}	**180**	200	220	**mS**
LED pulse on/off rate	T_{LPR}	**0.18/9**	0.2/10	0.22/11	**S**

3 - INTERFACE

3.1 – INTERFACE CONNECTOR

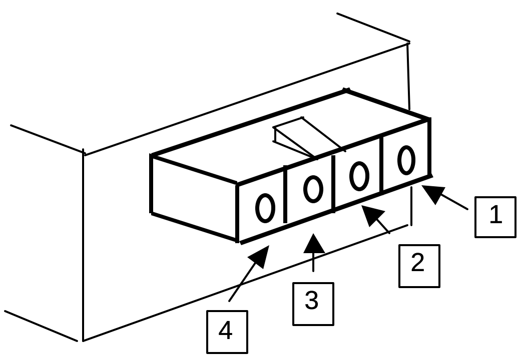
SIGNAL DEFINITIONS

TABLE 3.1.1 – Input/Output Signals

Name	Description
V_{SUP}	I1 models: Positive 3VDC regulated input voltage I2 models: Positive unregulated input voltage
PKP	PK-Port™ single-wire bi-directional digital communications port. Connect only to HCTTL compatible PK-Port™ communications adapter, or leave unconnected.
SIGNAL	Output signal. Proportional (analog) 0-to-3VDC in “O5” models. Encoded State signal in “O6” models. TTL or Open Drain output in case of O1/O2/O3/O4 models.
GND	Common power and output signal ground.

PIN CONNECTIONS

FIGURE 3.1.1 – Pin connections



Connector (shown) part no. 39-30-3045 (Molex)

Mating receptacle part no. 39-01-4040 (Molex)

Pin	Symbol	Function
1	V_{SUP}	Input power (+)
2	PKP	PK-Port™ digital I/O[1]
3	SIGNAL	Output signal[2]
4	GND	Common ground return

Notes: 1. Proprietary protocol. Requires adapter.
2. 0-3V, State, TTL or Open Drain – per options.

4 – MECHANICAL DRAWINGS

4.1 – PHYSICAL DIMENSIONS

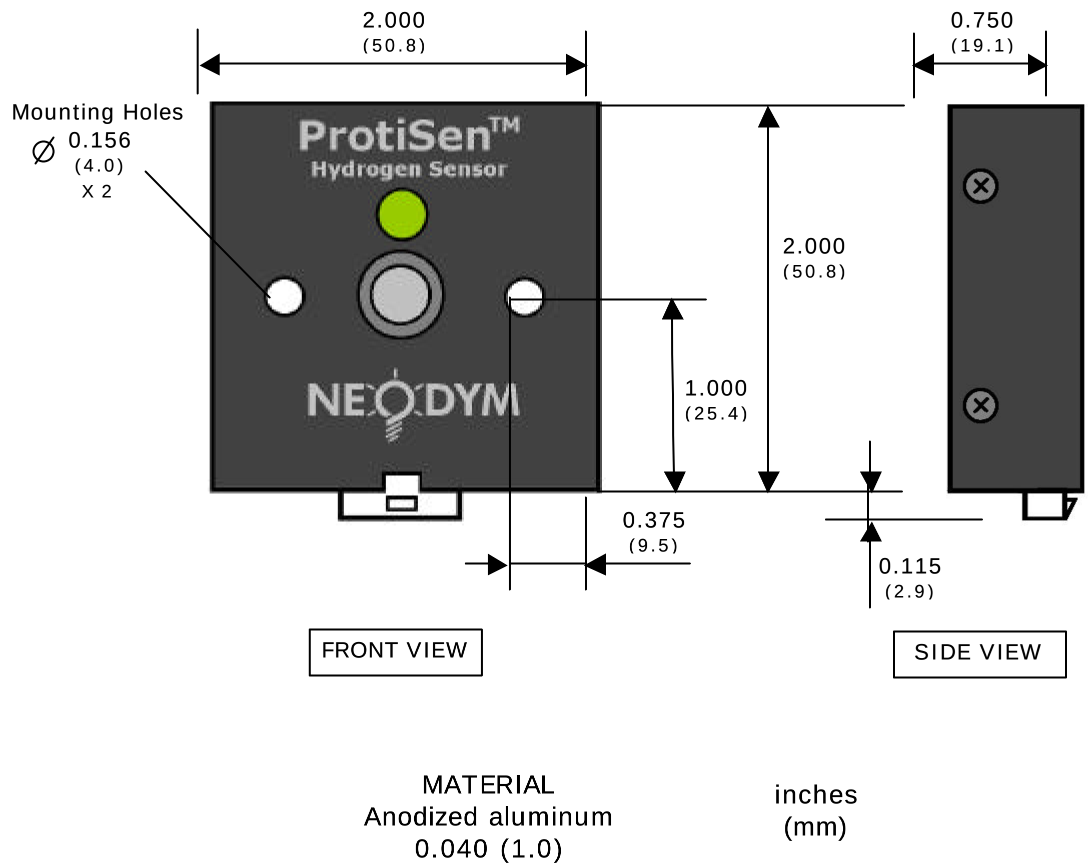


FIGURE. 4.1.1 – Enclosure dimensions

5 – PART NUMBERING

5.1 – PART NUMBER FIELD DESCRIPTIONS

Device ID	ProtiSen™
Target gas	GH – Hydrogen
Alarm level	AnnnX, "nnn"=Alarm ppm/200 X=A, no alarm trigger X=C, alarm triggers signal
Warning level	WnnnX, "nnn"=Warn ppm/200 X=A, no warning trigger X=B, warning triggers signal
Output signal type	O1 – Binary N-HI/ON Auto O2 – Binary N-LO/OFF Auto O3 – Binary N-HI/ON Latch O4 – Binary N-LO/OFF Latch O5 – Proportional 0-to-3V O6 – Voltage-encoded state
Binary Signal type	T1 – TTL T2 – Open Drain
Error handling	E1 – Error state E2 – Errors trigger alarm
Input Power	I1 – 3VDC regulated I2 – 5-to-16VDC
Harness connector	J0 – None J1 – Include
AC adapter	Z0 – None Z1 – Include

PS-Gx-AnnnX-WnnnY-On-Tn-En-In-Jn-Zn

6 – CONTACT INFORMATION

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7 – DOCUMENT REVISION HISTORY

DATE	VERSION	AUTHOR	DESCRIPTION
2007.04.18	1.0.0	JK	First release
2008.12.19	1.0.1	JK	Correct part number warning spec. Revise contact information Revise I2 input power range