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TECHNOLOGY GMBH

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H2-CNI 4-20MA-I

H2-CNI 4-20MA-I ULTD

Precision Hydrogen Sensor with 4-20 mA Transmitter for Industrial Applications

1. FEATURES

- Accurate detection of hydrogen levels up to 100% LEL with 100 ppm resolution in air
- Negligible sensitivity against typical catalyst poisons such as volatile siloxanes and carbon monoxide
- Fast response and recovery times
- Negligible humidity-induced base line drift
- Applicable in relative humidity (rh) between 0 % to 100 %
- Industrial temperature range -40 °C to +80 °C
- Linear output up to 100 % LEL
- Available with ultra-low thermal drift (ULTD) and test protocol
- 4-20 mA current-loop transmitter with reverse voltage operation and over-voltage surge protection
- Supply voltage with reversed bias protection

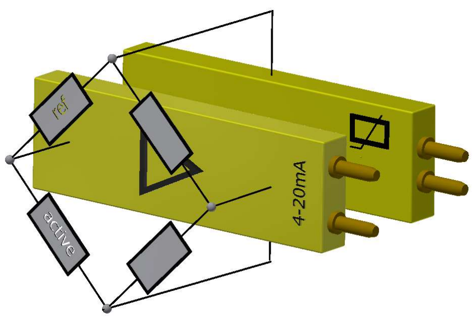
2. APPLICATION

- Precision hydrogen meters

3. DESCRIPTION

H2-CNI 4-20mA-I and H2-CNI 4-20mA-I ULTD are four-pin calorimetric hydrogen sensors with a catalytically highly active and siloxane-resistant sensor element and is based on a non-isothermal calorimetric operation principle. The sensor contains on-board electronics to reduce the effect of ambient temperature changes on hydrogen sensitivity, featuring a secure 4-20 mA current interface. It is designed for use in a variety of applications which require an accurate hydrogen determination in air.

4. SIMPLIFIED SCHEMATIC



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5. REVISION HISTORY

Date	Rev.	
April 22, 2023	1.0	Initial Version

6. PIN CONFIGURATION AND FUNCTION

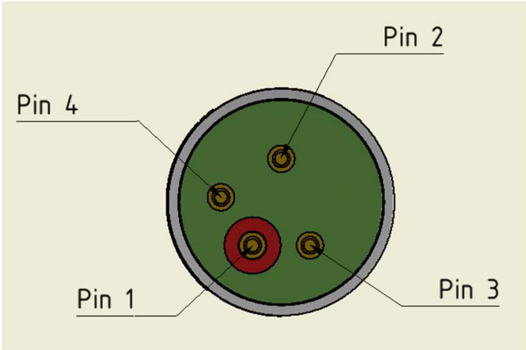

Figure 1: Bottom view of sensor

PIN NO.	DESCRIPTION
1	+12 V positive supply voltage with respect to ground
2	Current output connect to 0 V of the current loop
3	Ground of the internal electronics. The pin is electrically not connected to the housing
4	Current input connect to +24 V of the current loop*
⚠	* The current loop must be galvanically decoupled from the 12 V supply voltage. No common mass is allowed. The current loop <u>must</u> contain a driving voltage source (recommended value: +24 V).

7. SPECIFICATIONS

7.1. ABSOLUTE MAXIMUM RATINGS

At ambient temperature T_a = 20 °C.

Input supply voltage	+15 V
Storage temperature	-40°C to 100 °C

7.2. ESD CAUTION

ESD (electrostatic discharge) sensitive device. Although this product features protection circuitry, proper ESD precautions should be taken to avoid performance degradation or loss of functionality.

7.3. HANDLING RATINGS

The sensor must not subjected to severe shocks which might result from suddenly applied forces or abrupt changes in motion. They may cause permanent damage to the device.

7.4. RECOMMENDED OPERATING CONDITIONS

At ambient temperature T_a = 20 °C (unless otherwise noted).

	MIN	NOM	MAX	UNIT
Input supply voltage	+9	+12	+15	V
Serial load resistor of the current loop connected to pin 2 and pin 4		≥ 100		Ω

7.5. MECHANICAL

Housing material	Stainless steel
Potting	Epoxy
Weight	15 g
Diameter	20.0 mm
Height (housing)	16.6 mm
Height (overall)	21.0 mm
Pins	Gold over nickel
Pin diameter	1.57 mm
Pin length	4.78 mm

7.6. ELECTRICAL

Supply current	43 mA @ 20 °C
Current loop voltage	≤ 24 V

7.7. ENVIRONMENTAL

Ambient temperature range during operation	-40 to +80 °C
Operation humidity	0 … 100 % r.h.

7.8. SENSOR PARAMETERS

Signal at 50% LEL	14 mA (typical)
Resolution	100 ppm H_2
Linearity	5 mA/(1 vol-% H_2) at 20 °C
Response time	< 5 s
Thermal zero point drift	< 0.01 mA/°C

7.9. SENSOR CROSS SENSITIVITIES

Gas / Vapor	Chemical Formula	Concentration Applied	Output $I_{Signal, Gas} - I_{Signal, air}$ (mA)
Methane	CH_4	0 to 99.99 vol-%	0
Ethane	C_2H_6	0 to 99.95 vol-%	0
Propane	C_3H_8	0 to 30 vol-%	0
Butane	C_4H_{10}	0 to 70 vol-%	0
Ammonia	NH_3	0 to 5 vol-%	0
Chlorine	Cl_2	0 to 5 vol-%	0
Carbon dioxide	CO_2	1 vol-%	0
Carbon monoxide	CO	1500 ppm	0
Nitrogen dioxide	NO_2	5 ppm	0
Nitrogen monoxide	NO	15 ppm	0

7.10. EFFECT OF PRETREATMENTS OF THE SENSOR TO SILOXANES

OCTAMETHYLCYCLOTETRASILOXANE ($C_8H_{24}O_4SI_4$)

A laboratory beaker with 100 g $C_8H_{24}O_4Si_4$ (98%) is heated to 250 °C in a 2-liter glass together with the sensor for one hour. The sensor is tested with 2 vol-% H_2. A 12% decline of the sensor signal is found with respect to the initial signal.

HEXAMETHYLDISILOXANE ($C_6H_{18}OSI_2$)

A laboratory beaker with 40 ml $C_6H_{18}OSi_2$ is placed with in a 2-liter glass together with the sensor for one hour. The sensor is tested with 2 vol-% H_2. A 15% decline of the sensor signal is found with respect to the initial signal.

8. TYPICAL PERFORMANCE CHARACTERISTICS

All data presented below are acquired in an automated gas mixing system with mass flow controllers and pressurized gas bottles with synthetic air (21 vol-% oxygen in nitrogen) and calibrated hydrogen mixtures (5 vol-% H_2 in nitrogen). Room temperature data are determined with the sensor attached to our test chamber TC 2x1/4". Ambient temperatures are adjusted in a cooled or heated test chamber. Data for figures 3 to 11 are collected with a 7 ½ digit precision multimeter with RS232 interface in series with a 24 V supply and a 100 Ω resistance. For figures 13 the evaluation kit DCC-PGA-ADC 3.2 and a stabilized 12 V power supply are used.

8.1. INITIAL WARM-UP PHASE

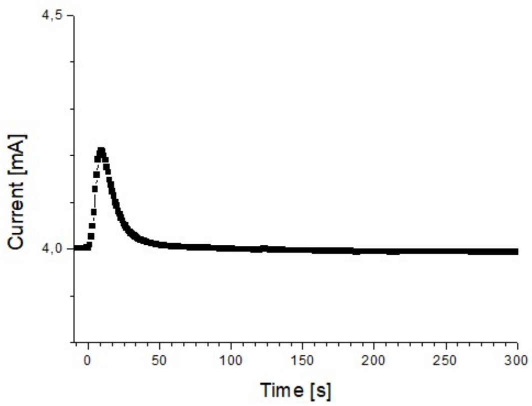

Figure 3. Typical signal characteristics (curent through pin 2 and pin 4) of the sensor after applying the operational voltage of 12 V between pin 1 and 3 at time 0.

8.2. CALIBRATION CURVE AND LINEARITY

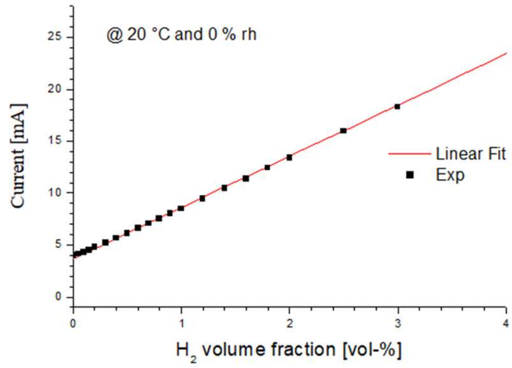

Figure 4. Typical values of the current (sensor signal) as a function of hydrogen volume fraction in synthetic dry air at 20 °C. Data (Exp) are determined for a total flow of 50 sccm/min. Red: Linear fit with a slope of 5 mA/1 vol-%.

8.1. LOW DETECTION LIMIT AND RESOLUTION

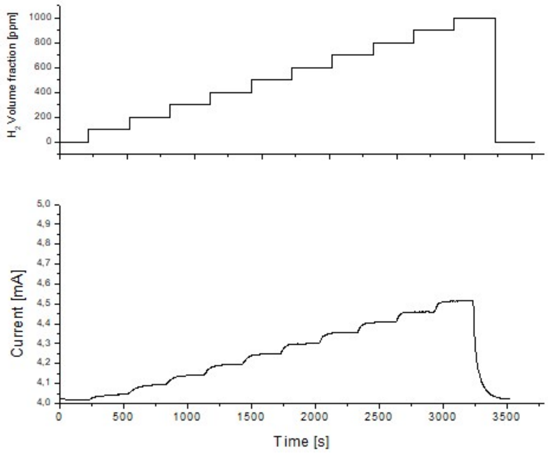

Figure 5. Top: Test protocol with an automated procedure of low hydrogen exposures (H_2 volume fractions between 100 and 1000 ppm) in the test chamber (dry air at 20 °C, total flow 100 sccm/min). Bottom: Sensor signal (current) as a function of the time.

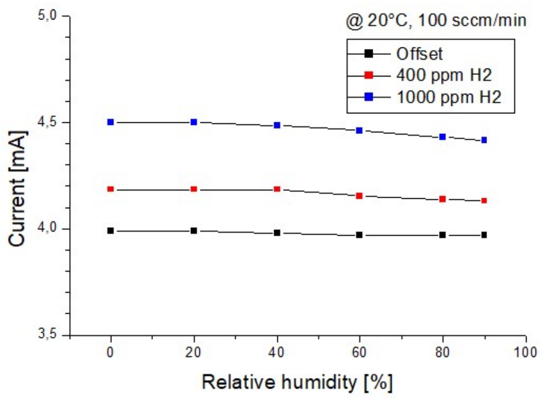

Figure 6. Bottom: Sensor signal as a function of humidity (0, 20, 40, 60, 80, and 90 % at 20 °C at low volume fractions of hydrogen.

8.1. TEMPERATURE-DEPENDENCE

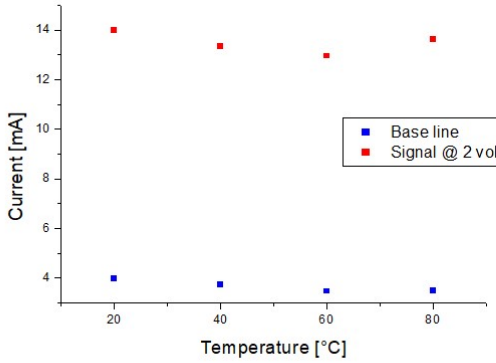

Figure 7. Red: Sensor signal (current) for a hydrogen volume fraction of 2 vol% at temperatures of 20 °C, 40 °C, 60 °C, and 80 °C. Blue: Base line current at 0 vol% H_2.

8.1. EFFECT OF RELATIVE HUMIDITY ON THE BASE LINE

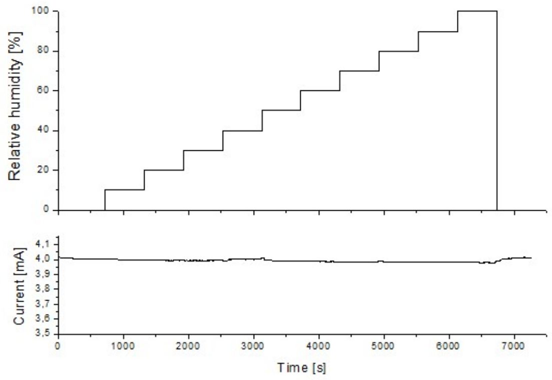

Figure 8. Top: Test protocol with an automated procedure of relative humidity changes in the test chamber, ranging from dry air to 100 % (temperature = 20 °C, total flow = 50 sscm/min). Bottom: Sensor signal (current) as a function of time.

8.2. EFFECT OF RELATIVE HUMIDITY ON THE SIGNAL

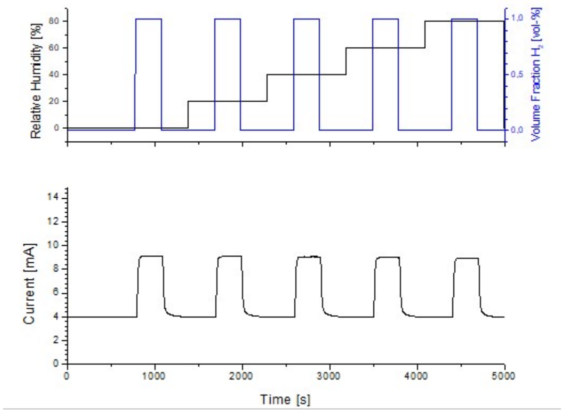

Figure 9. Top: Test protocol with an automated hydrogen exposure (1 vol-%) and variations of the relative humidity (0 to 80 %) at 20 °C (total flow = 50 sscm/min). Bottom: Sensor signal (current) as a function of time.

8.3. EFFECT OF FLOW RATES ON THE BASE LINE

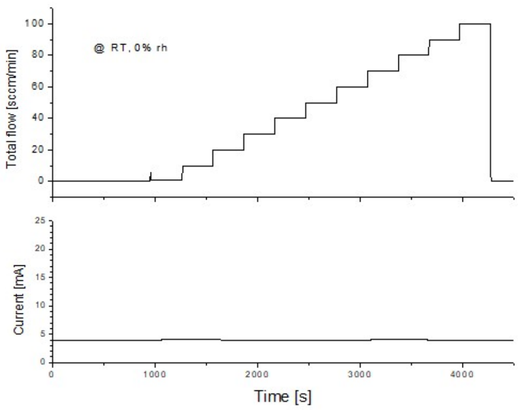

Figure 10. Top: Test protocol with an automated total flow variation between 0 and 100 sccm/min at 20 °C and 0 % rh. Bottom: Sensor signal (current) as a function of time.

8.4. EFFECT OF FLOW RATES ON THE SIGNAL

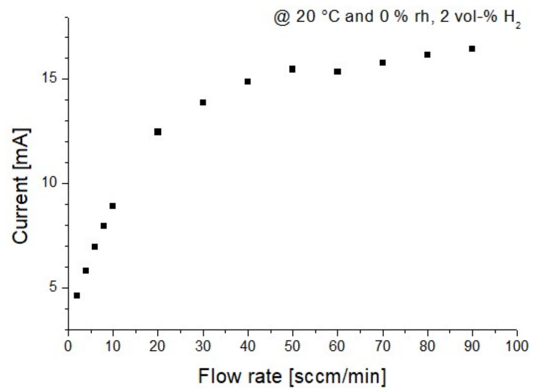

Figure 11. Sensor signal as a function of the total flow for 2 vol-% H_2 in dry air at 20 °C. Because of the catalytic sensing principle and the hydrogen-to-water oxidation, a steady-state signal cannot be generated at a zero-flow.

8.5. RESPONSE AND DECAY TIMES

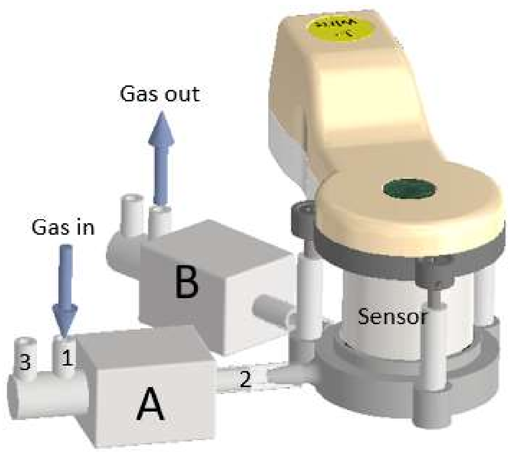

Figure 12. Special setup to determine the response and decay time of the sensor. Here, the evaluation kit DCC-PGA-ADC 3.2 is used to apply both, the 12 V supply voltage and the 24 V loop voltage to determine the current of the sensor. A flow of 2 vol-% H_2 in air with 50 sccm/min flows into the system at the "gas in" through port 1 of valve A. The valve can be switched electrically to pass the flow through port 3 to the ambient air or port 2 to the sensor, attached to a small test chamber. Valve B is operated together with valve A and cut off the test chamber from the outlet if A is switched into the 1-3 position.

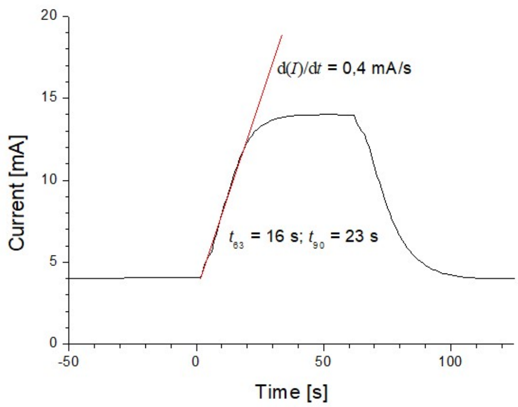

Figure 13. Sensor signal as a function of time after applying 2 vol-% H_2 in dry air at 20 °C. The sensor signal reaches a steady-state signal with a t_{63} response time of 16 s and a t_{90} response time of 44 s. The slope dI/dt is approx. 0,4 mA/s, i.e., a 2 mA change of the signal is found after 5 s. After re-directing the test gas to the port "Out 1", the signal decays to zero due to an oxidation and consumption of the hydrogen molecules at the sensor´s catalytic layer.

8.6. CALIBRATION PROCEDURE

The sensor contains a precision 12-turn trimmer for adjusting the offset voltage of the Wheatstone bridge, that consists of the sensing element, the reference element and two constant resistors (see Figure 8 in Chapter 9), as well as a second 12-turn trimmer for adjusting the gain of the instrumentation amplifier. The trimmers are factory-set to provide a zero point at 4 mA, a low detection limit of better than 500 ppm hydrogen and a sensitivity of 5 mA/1-vol % H_2. Both holes in the housing are closed with an adhesive foil and it is usually not necessary to make any changes of the trimmer settings. See Chapter 8.7 for further information.

Figure 14. Adjustment the Wheatstone bridge offset (zero point of calibration straight line) and amplifier gain (slope of calibration straight line). If necessary, trimmer settings can be altered by means of a srew driver. Note, that both holes have a diameter of 1.8 mm. A ceramic type instrument (e.g., CD-15) is recommended. The srew drivers should be oriented to the middle of the opposite side of the housing and not to the center of the sensor. A counter-clock wise rotation increases the gain (i.e. leads to larger currents) and shifts the offset to higher currents.

8.7. MECHANICAL TESTS

The electronic board of the sensor has been tested in shock tests with the sensor placed on a vibrating plate (50 Hz) and on an alternating acceleration test stand with 8 G.

8.8. EFFECT OF THERMAL SURROUNDING

H2-CNI 4-20mA-I and H2-CNI 4-20mA-I ULTD have precisely adjusted sensor and reference elements that operate at virtually identical temperatures when a voltage is connected between pins 1 and 3. As with all devices based on calorimetric concepts, the sensor is, however, sensitive against changes of its thermal surrounding. This gives rise to noticeable variations of the base line of such devices. The variations are very small for the ULTD type sensors. The best assembly place for the sensor should provide a constant thermal surrounding to minimize variations of the signal´s base line which can be low under good conditions. If the sensor is in contact to metals (e.g. supports) corrections of the offset adjustment can be necessary to provide a base line just below 4 mA. Consider a vertical upside or upside-down direction of the sensor if possible.

9. THEORY OF OPERATION

The hydrogen sensors H2-CNI 4-20mA-I and H2-CNI 4-20mA-I ULTD comprise two temperature-sensitive transducers that form a Wheatstone bridge arrangement together with precision resistors R_2 and R_3. One transducer (the so-called active sensor element R_{active}) is covered with an advanced catalytic layer that promotes the hydrogen-to-water oxidation while the second transducer (the so-called inactive sensor element R_{ref}) is used as a reference to compensate variations of the out-of-balance voltage with changing ambient temperatures. The out-of-balance voltage is set to zero by means of R_5. Exposure of the sensor to hydrogen and oxygen containing atmospheres results in the generation of a chemical reaction heat that causes a temperature change and hence a resistance change of the active sensor element R_{active}. This leads to a non-zero out-of-balance voltage of the bridge which is amplified by means of a built-in amplifier and lead to the internal 4-20mA current-loop transmitter. The transmitter is protected against reverse voltage operation and overvoltages above 24 V. The output current is limited to approximately 32mA. Pin 4 should be connected to the positive pole of the current loop through a load resistor of 100 Ω and pin 2 to the negative pole. The current loop must be galvanically decoupled from the supply voltage and driven by a 24 V voltage.

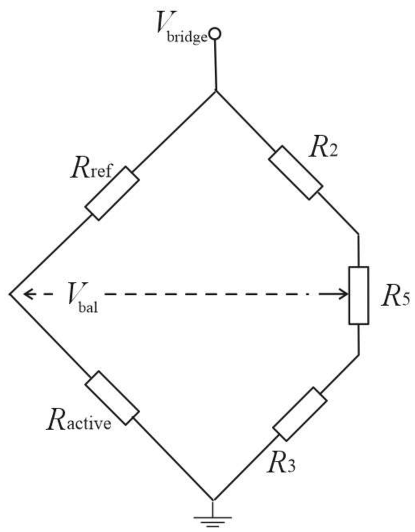

Figure 15. Wheatstone bridge with active and reference sensor element (schematic).

10. APPLICATION AND IMPLEMENTATION

The device contains a special circuitry that reduces the effect of ambient temperature changes on the sensor sensitivity in a range of -40 to +80 °C. Temperature variations may affect the base line of the sensor signal. If the operation requires larger temperature ranges in which only very small or negligible base-line variations can be accepted, we recommend the use of the version *H2 CNI I2C-E* of this hydrogen sensor. It contains the same sensing and reference elements, an electrically erasable PROM and a ±1.0°C accurate digital temperature sensor but no temperature stabilization circuitry. It gives a high flexibility in adjusting the bridge voltage and out-of-balance voltage as a function of ambient temperature variations. A practical hardware-software solution is available as evaluation kit. Contact our distributor for further support. It is our intention to provide you with the best solution to ensure successful use of the hydrogen sensor *H2 CNI* for your application.

11. FOOTPRINT AND RECOMMENDED PLUG-IN SOCKETS

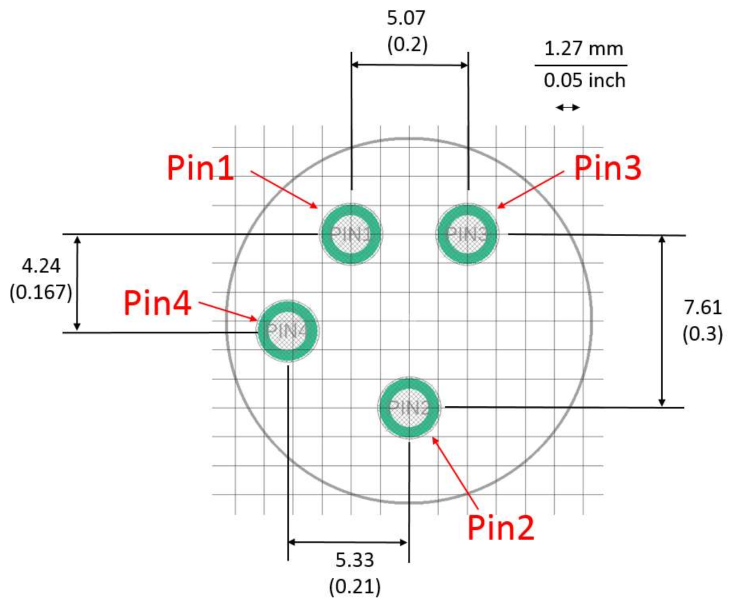

Figure 16: Footprint (dimensions shown in millimeter and inch)

Recommended plug-in sockets	450-3326-01-03-00 (Cambion Electronics LTD)
Drill hole:	2.6 mm

12. ORDERING INFORMATION

Hydrogen sensor H2- CNI 4-20mA-I

Hydrogen sensor H2- CNI 4-20mA-I ULTD

13. PACKAGING/SHIPPING INFORMATION

This sensor is shipped individually in an antistatic bag.

14.QUALITY CONTROL

Each sensor is tested before delivery. The test includes standard protocols and an exposure of the sensor to a hydrogen/air mixture with H_2 volume fractions above the low-explosion limit, performed at ambient temperature and pressure.

15. WARNINGS

Warnings: The sensor H2-CNI 4-20mA is intended to be part of a customer safety system, enabling audible alarms, system shutdown, ventilation, or other measures to ensure safe handling and use of hydrogen gas. The sensor itself does not provide protection from hydrogen/air explosion. Make sure that your application meets applicable standards, and any other safety, security, or other requirements.

16.NOTES

17.WORLDWIDE SALES AND CUSTOMER SUPPORT

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