FES Sensor
Technology GmbH

H2-CNI I2C-E-ULTD

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High-precision Hydrogen Sensor

1. FEATURES

- Detection of hydrogen levels up to 100% LEL with 0.25 % resolution in air
- Extended temperature range from -40 °C to +120 °C
- Ultralow thermal drift
- No sensitivity against typical catalyst poisons such as volatile siloxanes and carbon monoxide
- Fast response and recovery times
- No humidity-induced base line drift
- Applicable in relative humidity (rh) between 0 % to 100 %
- Linear output up to 100 % LEL
- No cross-sensitivity against hydrocarbons such as methane and ethane
- On-board digital temperature sensor and EEPROM with I2C®bus connectivity

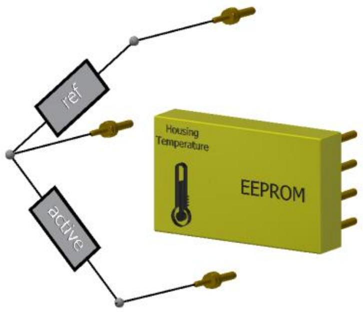
2. APPLICATION

- Hydrogen warning systems in a wide temperature range
- Hydrogen measuring instrumentation

3. DESCRIPTION

H2-CNI I2C-E-ULTD is a calorimetric hydrogen sensor with a catalytically highly active and siloxane-resistant sensor element and is based on a non-isothermal calorimetric operation principle. It contains a digital temperature sensor and an EEPROM for an advanced control of sensor characteristics in a wide temperature range of -40 to +120°C. As a result of high-precision adjustment, the thermal drift of the zero-signal is very small.

4. SIMPLIFIED SCHEMATIC



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5. REVISION HISTORY

Date	Rev.	
Nov 3, 2022	1.0	Initial Version
July 23, 2024	1.1	Changes to Table 4

6. PIN CONFIGURATION AND FUNCTION

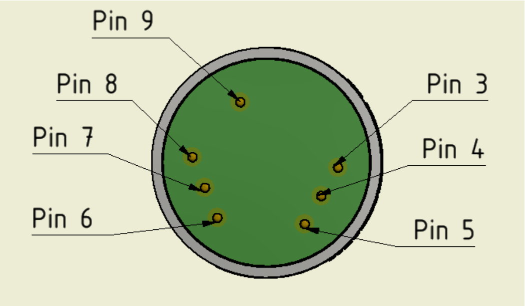

Figure 1: Bottom view of sensor

Table 1		
PIN NO.	SIGNAL NAME	DESCRIPTION
3	SCL	SCL line of I2C bus
4	VBRIDGE	Bridge excitation voltage connected to 1st junction of reference sensing element
5	INP	Junction between active sensor element and reference element
6	IN-CURR	1st junction of sensing element
7	AGND	I2C ground
8	SDA	SDA line of I^2C bus
9	VPOW	Supply voltage of internal electronics

7. SPECIFICATIONS

7.1. ABSOLUTE MAXIMUM RATINGS

Values are given for an ambient temperature of $T_{ambient}$ = 20 °C.

Table 2	
Supply voltage	+15 V
Bridge excitation voltage at pin 4	+10 V
Storage temperature	-40°C to 135 °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 is fabricated using a high-precision adjustment of the thermal coupling of its sensor elements and 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

Values are given for an ambient temperature of $T_{ambient}$ = 20 °C (unless otherwise noted).

Table 3

	MIN	NOM	MAX	UNIT
Input supply voltage at pin 9	+5.5	+12	+15	V
Bridge excitation voltage at pin 4		+8.0	+10	V

7.5. MECHANICAL

Table 4

Housing material	Stainless steel (1.4404; SUS316L)
Potting	Polyurethane
Bottom side cover	FR-4
Weight	15 g
Diameter	20.0 mm
Height (housing)	16.6 mm
Height (overall)	20.0 mm
Pins	Gold over nickel
Pin diameter	1.0 mm
Pin length	4.7 mm

7.6. ELECTRICAL

Table 5

	Ambient temperature	*Supply Current@ 8V*
Supply current	-40 °C	44 mA
	-20 °C	44 mA
	0 °C	44 mA
	20 °C	43 mA
	40 °C	41 mA
	60 °C	40 mA
	80°C	37 mA
	100 °C	36 mA
	120 °C	35 mA

7.7. ENVIRONMENTAL

Table 6	
Ambient temperature range during operation	-40 to +120 °C
Operation humidity	0 to 100 % r.h.

7.8. SENSOR PARAMETERS

Table 7	
Signal at 50% LEL between pin 5 and VBRIDGE/2	80 mV (typical)
Linearity	Typical value: 40 mV/(1 vol-% H_2) at 20 °C
Response time	≈ 1 s
Thermal zero point drift	0.10 mV/°C
Cross sensitivity for humidity	negligible

7.9. SENSOR CROSS SENSITIVITIES

Table 8

Gas / Vapor	Chemical Formula	Concentration Applied	Signal between pin 5 and VOUT/2
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). Ambient temperatures are adjusted in a cooled or heated test chamber at which the sensor is assembled. Data are collected with the evaluation kit PrecVS-PGA-ADC 3.6, set at a gain of 8V/V of the signal voltage between pin 5 and the internal reference point of the second branch of the Wheatstone bridge (see chapters 9 and 10).

8.1. GENERAL FEATURES

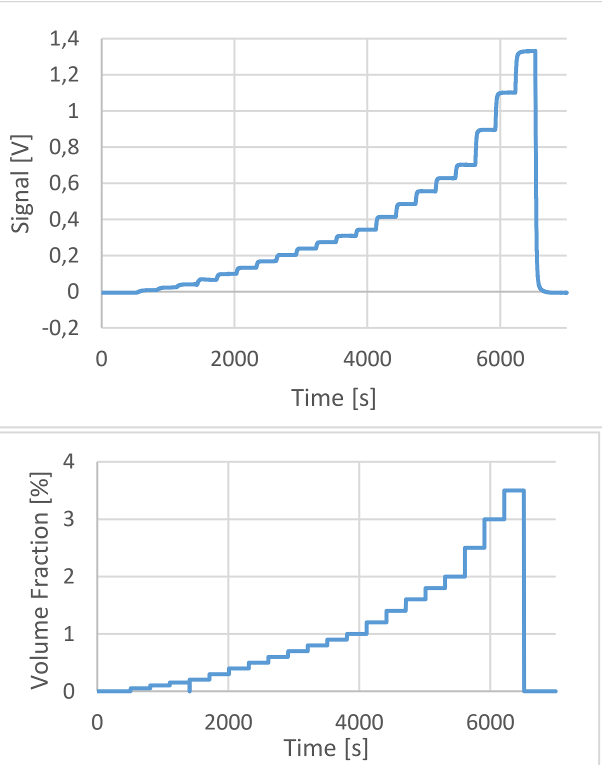

Figure 3. Top: Typical values of the signal (at gain 8 V/V) as a function of time at 8,0 V bridge excitation voltage. Conditions: 20 °C ambient temperature, dry air, 50 sccm/min volume flow. Bottom: Corresponding changes of the hydrogen volume fraction as a function of time.

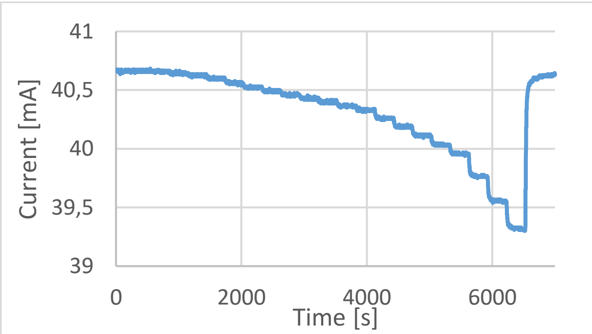

Figure 4. Corresponding values of the supply current between pin 6 and ground (pin 4).

8.2. LOW DETECTION LIMIT AND RESOLUTION

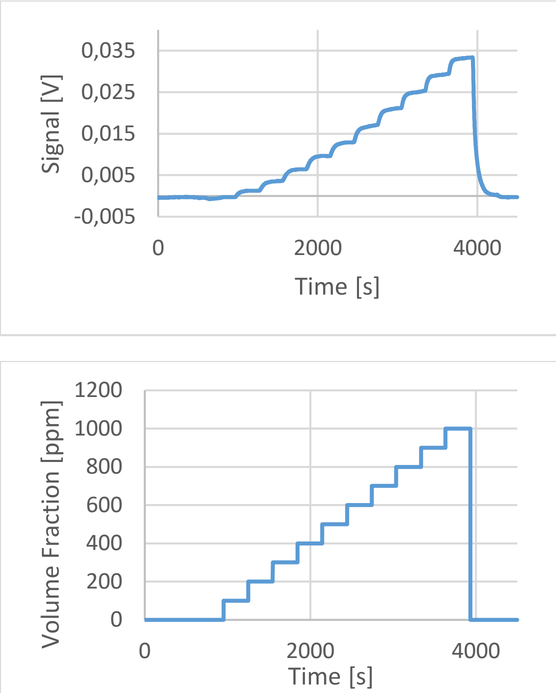

Figure 5. Top: Sensor signal as a function of the time (top) in dry air at 20 °C at low volume fractions of hydrogen. Total flow 100 sccm/min. Bottom: Corresponding changes of H_2 volume fractions.

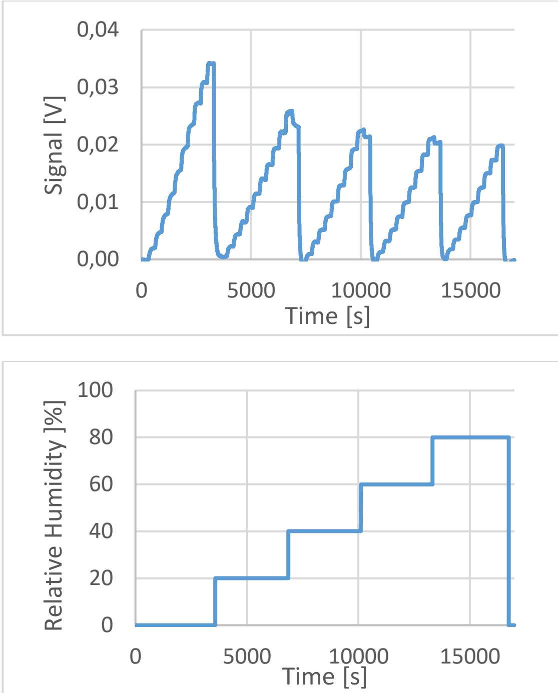

Figure 6. Top: Sensor signal as a function of the time at low volume fractions of hydrogen (0 to 1000 ppm, each step 100 ppm) at various various of humidity (0, 20, 40, 60, and 80% at 20 °C at low volume fractions of hydrogen. Bottom: Corres-ponding changes of relative humidity.

8.3. LINEARITY AND TEMPERATURE-DEPENDENCE

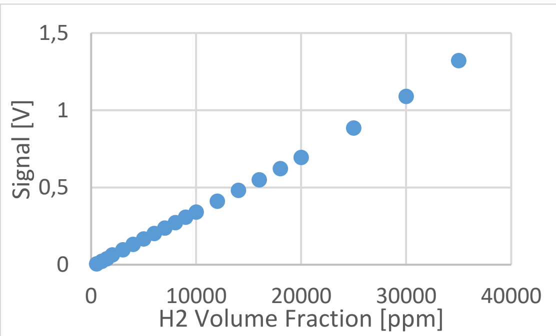

Figure 7. Sensor signal (gain 8 V/V) as a function of hydrogen volume fractions in the range of 500 to 40.000 ppm = 4 % in dry air at 20 °C (8 V bridge excitation voltage, total flow = 50 sscm/min).

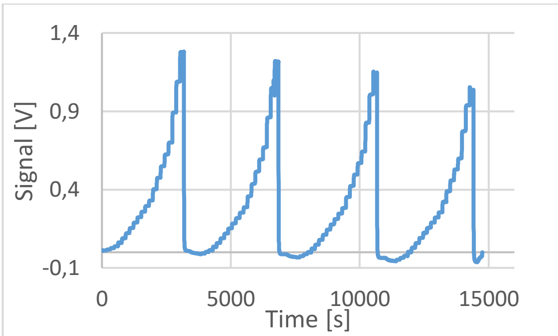

Figure 8. Transient of sensor signal at four different temperatures 20 °C, 50 °C, 70 °C 90 °C (from left to right). Each data set is collected at stepwisely increased H_2 volume fractions from 500 to 35.000 ppm (see figure 3, bottom).

8.4. EFFECT OF RELATIVE HUMIDITY ON THE BASE LINE

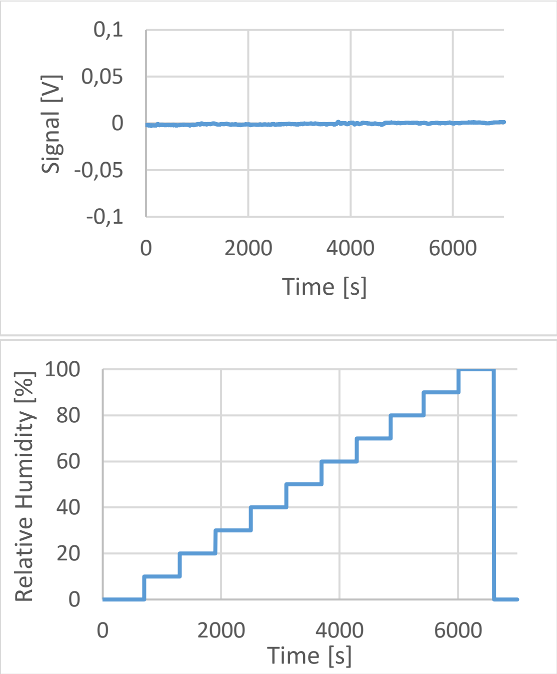

Figure 9. Top: Sensor signal (gain 8 V/V) as a function of time at different levels of relative humidity from dry air to 100 % at 20 °C (8 V bridge excitation voltage, total flow = 50 sscm/min). Bottom: Corresponding changes of the relative humidity in the test chamber as a function of time.

8.5. EFFECT OF RELATIVE HUMIDITY ON THE SIGNAL

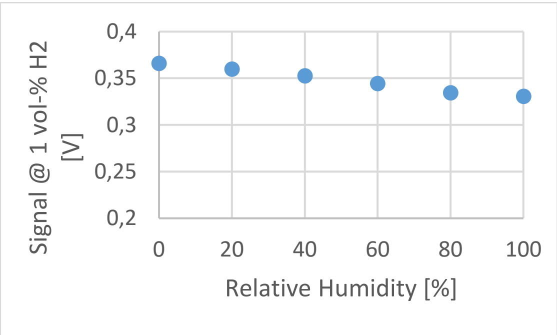

Figure 10. Sensor signal (gain 8 V/V) at 1 vol-% H_2 in air of varying relative humidity at 20 °C (8 V bridge excitation voltage, total flow = 50 sccm/min).

8.6. EFFECT OF FLOW RATES

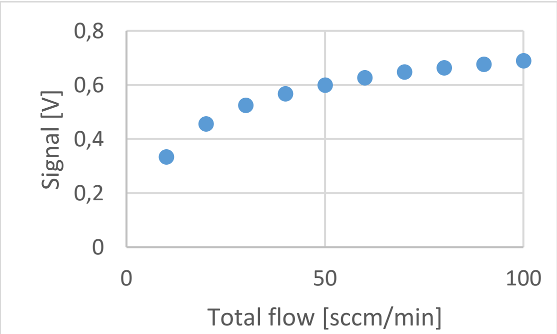

Figure 11. Sensor signal (gain 8 V/V) as a function of at low values of the total flow for 2 vol-% H2 in dry air at 20 °C (8 V bridge excitation voltage).

8.7. RESPONSE AND DECAY TIMES

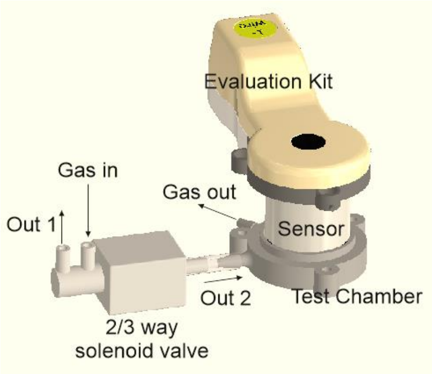

Figure 12. Special setup to determine the response and decay time of the sensor. A flow of 1 vol-% H_2 in air with 100 sccm/min flows into the system at the "Gas in" port. The flow can be switched electrically between Out 1 and Out 2. The voltage, applied to the valve, and the sensor signal are recorded. At zero valve voltage, the gas flows to a small test chamber and the sensor.

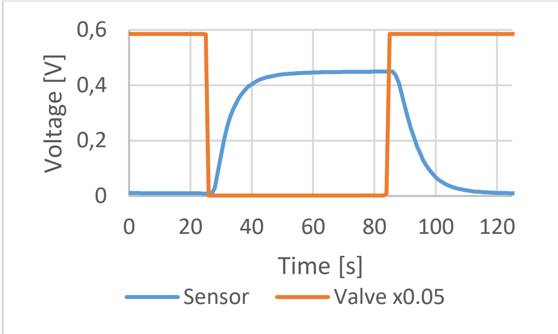

Figure 13. Sensor signal (blue, gain 8 V/V) and valve voltage (orange) as a function of time after applying 1 vol-% H_2 in dry air at 20 °C (8 V bridge excitation voltage). The time delay is approx. 1 s. The sensor signal reaches a steady-state signal with a t_{90} response time of 10 s. After re-directing 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.

8.8. EFFECT OF THERMAL SURROUNDING

As with all devices based on calorimetric concepts, the hydrogen sensor H2-CNI I2C-E-ULTD is sensitive against changes of its thermal surrounding. This gives rise to noticeable variations of the base line of such devices. H2-CNI I2C-E-ULTD has precisely adjusted sensor and reference elements that operate at virtually identical temperatures when a voltage is connected between pins 4 and 6. Consequently, the signal, which is the balance voltage of the full Wheatstone bridge (see chapter 9), alters only little with the bridge excitation voltage. 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 in the mV range under good conditions. Consider a vertical upside or upside-down direction of the sensor if possible.

9. THEORY OF OPERATION

The hydrogen sensor H2-CNI I2C-E-ULTD comprises two temperature-sensitive transducers that form one branch of a Wheatstone bridge configuration (Figure 14). One transducer (the so-called active sensor element R_{active}) is covered with an advanced highly stable catalytic layer that promotes the hydrogen-to-water oxidation while the second transducer forms the inactive element R_{ref} and is used as a reference. Its purpose is to compensate variations of the out-of-balance voltage with changing ambient temperature which is accomplished to a large extent. Both transducers are directly heated by passing a current through if a voltage V_{bridge} is applied at pin 4 with respect to pin 6. The second branch of the bridge consists of high-ohmic resistors and hence the current through the bridge equals approximately $I = V_{\mathrm{bridge}}/(R_{\mathrm{ref}} + R_{\mathrm{active}})$.

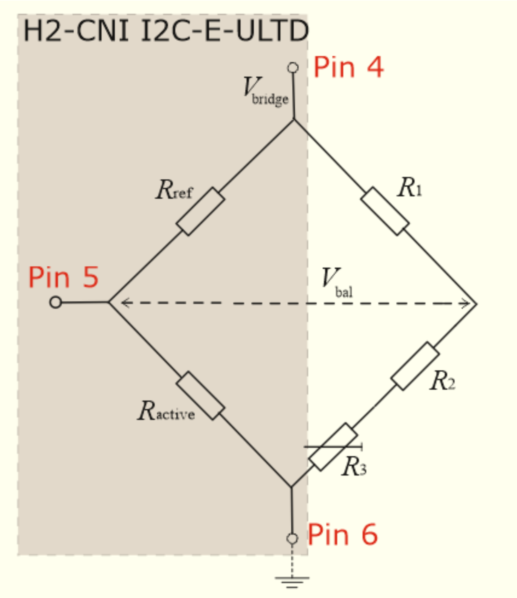

Figure 14. Wheatstone bridge configuration with H2-CNI I2C-E-ULTD (schematic).

The out-of-balance voltage V_{bal}, measured between pin 5 and the midpoint of the second branch of the bridge, is set to zero by means of an external trimmer or digital rheostat R_3 (like, e.g., in our evaluation kit PrecVS-PGA-ADC for H2-CNI I2C and H2-CNI I2C-E-ULTD Hydrogen Sensors, see corresponding Manual Sheet). An additional resistor R_2 in series to the digital rheostat allows a well-resolved zero-setting even with a 64-step rheostat. Note that V_{bal} depends linearly on V_{out} due to Kirchhoff´s rules applied to a Wheatstone bridge configuration.

Exposure of the sensor to hydrogen and oxygen-containing atmospheres results in the generation of a chemical reaction heat that causes a temperature increase and hence a resistance change of the active sensor element R_{active}. This effect can be detected by the variation of the out-of-balance voltage V_{bal}. Typical gains of the amplification of V_{bal} should be in the range of 10 to 50, depending on the desired hydrogen sensitivity and detection range. Since the absolute voltage at both midpoints of the Wheatstone bridge are approximately V_{bridge} /2, the amplifier must have appropriate voltage level shifting components to avoid an overload of the input stage of the analog-to-digital converter.

10.APPLICATION AND IMPLEMENTATION

For most applications, H2-CNI I2C-E-ULTD can be operated with a few external components as shown in Figure 15. The low-impedance voltage source delivers sufficient power to heat up the active and reference elements and to adjust a stable midpoint voltage at INP.

Two additional resistors form the second branch of the Wheatstone bridge, one of them should be adjustable to set the balance voltage to zero. This voltage can be measured and digitalized, e.g. with a programmable gain amplifier (PGA) and a subsequent analog-to-digital converter that yields an appropriate sensor signal for the detection of hydrogen. Use a constant voltage V_{bridge} = 8 V for operation of the sensor at room temperature or near-room temperature condition.

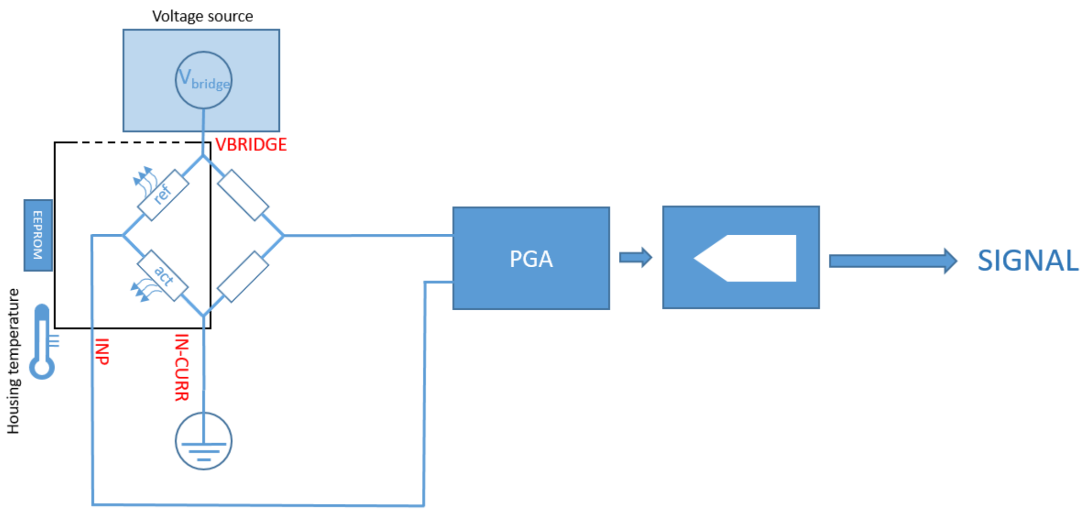

Figure 15. Components of the circuitry for operation of H2-CNI I2C-E-ULTD hydrogen sensors.

11.FOOTPRINT AND RECOMMENDED PLUG-IN SOCKETS

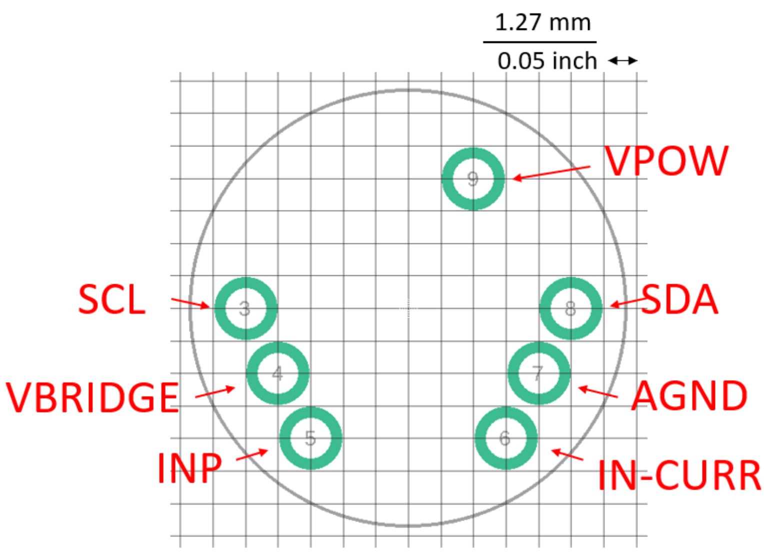

Figure 8: Footprint

Table 12	
Recommended plug-in sockets	450-3704-01-03-00 (Cambion)
Drill hole:	1.6 mm

12.ORDERING INFORMATION

Hydrogen sensor H2- CNI I2C-E-ULTD

13. PACKAGING/SHIPPING INFORMATION

This sensor is shipped individually in an antistatic bag.

14. WARNINGS

Warnings: The sensor H2-CNI I2C-E-ULTD 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.

15.NOTES

16.DEVICE SUPPORT

An evaluation kit (PrecVS-PGA-ADC 3.6 with SBPS-eFuse-LDO 3.12 and additional accessories) is available to support customers in the performance evaluation of our H2-CNI I2C-E-ULTD sensors. The related user's manual can be requested at the website www.fes-sensor.com through the product folders.

17.WORLDWIDE SALES AND CUSTOMER SUPPORT

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