FES SENSOR
TECHNOLOGY GMBH

H2-CNI I2C

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Hydrogen Sensor with Implemented Digital Temperature Sensor and EEPROM

1. FEATURES

- Detection of hydrogen levels up to 100% LEL with 0.25 % resolution in air
- 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 %
- Industrial temperature range from -40 °C to +90 °C
- Linear output up to 100 % LEL
- On-board digital temperature sensor and EEPROM with I2C®bus connectivity

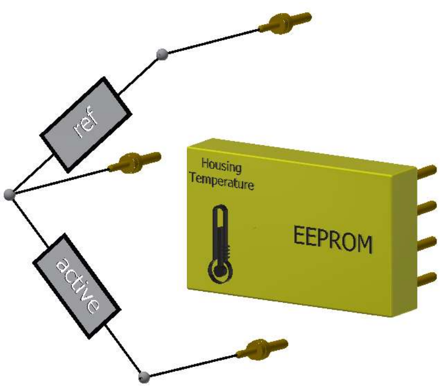
2. APPLICATION

- Hydrogen warning systems in a wide temperature range

3. DESCRIPTION

H2-CNI I2C 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 +90°C.

4. SIMPLIFIED SCHEMATIC



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5. REVISION HISTORY

Date	Rev.	
Aug 10, 2021	1.0	Initial Version
Nov. 3, 2021	1.1	Table 7.5: steel grade added
Mai 8, 2022	1.2	Figures 5 to 12 added

6. PIN CONFIGURATION AND FUNCTION

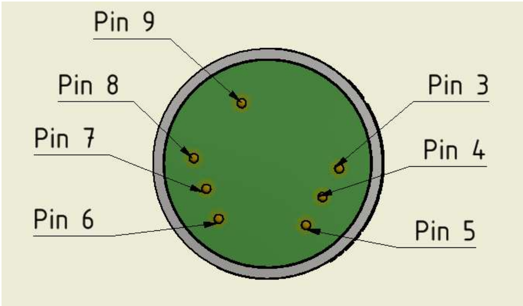

Figure 1: Bottom view of sensor

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^{2}C 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
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

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	+9.8 (@90 °C)	V

7.5. MECHANICAL

Table 4

Housing material	Stainless steel (1.4404; SUS316L)
Potting	Polyurethane
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*
Supply current	-40 °C	46.4 mA
	-20 °C	44.3 mA
	0 °C	42.5 mA
	20 °C	40.5 mA
	40 °C	39.6 mA
	60 °C	39.4 mA
	80°C	40.7 mA
	90 °C	41.3 mA

7.7.ENVIRONMENTAL

Table 6	
Ambient temperature range during operation	-40 to +90 °C
Operation humidity	0 … 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	< 5 s
Thermal zero point drift	0.15 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 climatic test chamber.

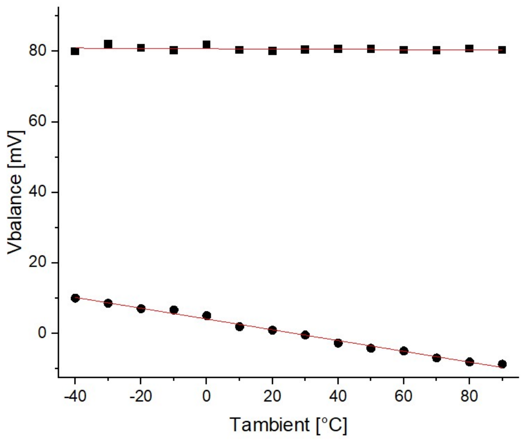

Figure 3. Typical values of the balance voltage between pin 5 and VBRIDGE/2 (V_{Bal}) as a function of the ambient temperature in dry air (circles) and 2 vol% hydrogen H_2 (squares).

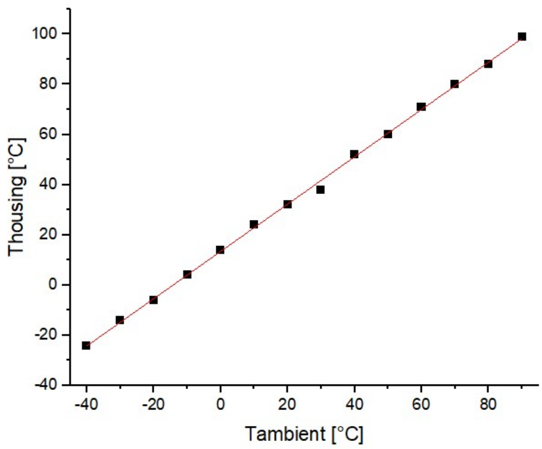

Figure 4. Sensor housing temperature as a function of the ambient temperature in calm air.

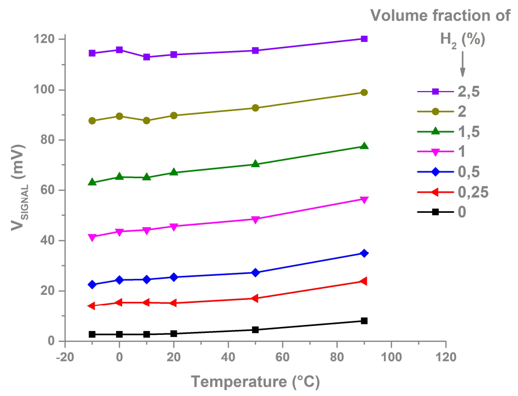

Figure 5. Sensor signal as a function of the ambient temperature in air and at different volume fractions of hydrogen.

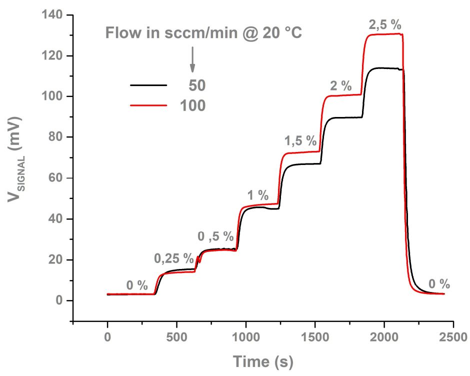

Figure 8. Transient of sensor signal during changes of hydrogen levels at air flows of 50 and 100 sccm/min at 20 °C.

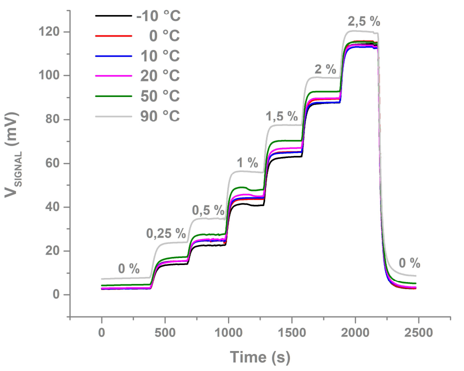

Figure 6. Transient of sensor signal during changes of hydrogen levels at different ambient temperatures.

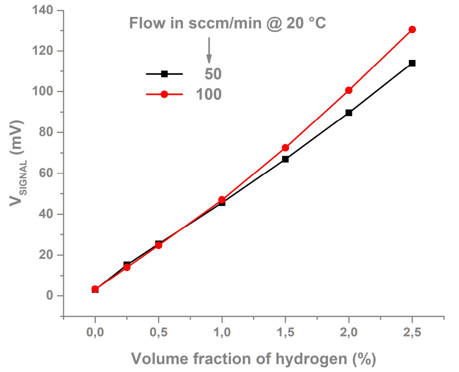

Figure 9. Sensor signal as a function of hydrogen volume fractions at air flows of 50 and 100 sccm/min at 20 °C.

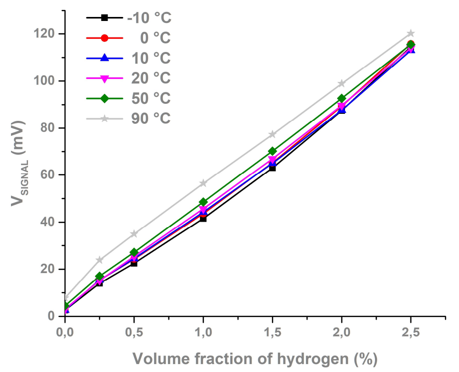

Figure 7. Sensor signal as a function of hydrogen volume fractions at different ambient temperatures.

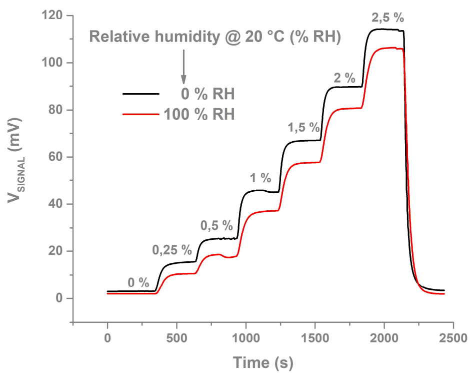

Figure 10. Transient of sensor signal during changes of hydrogen levels at 0 % and 100 % relative humidity at 20 °C.

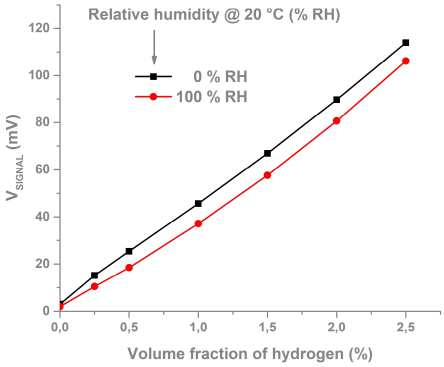

Figure 11. Sensor signal as a function of hydrogen volume fractions at 0 % and 100 % relative humidity at 20 °C.

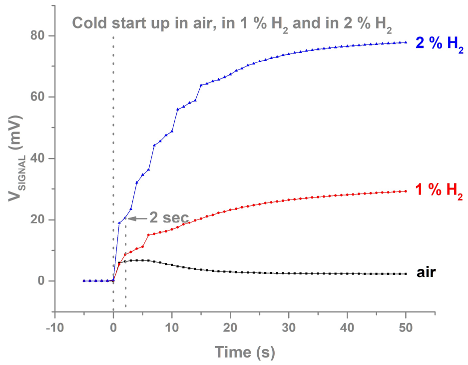

Figure 12. Transient of sensor signal after powering the sensor in air and at hydrogen levels at 1 % and 2 % in the first minute of operation.

9. THEORY OF OPERATION

The hydrogen sensor H2-CNI I2C comprises two temperature-sensitive transducers that form one branch of a Wheatstone bridge configuration (Figure 5). 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 $I = V_{\mathrm{bridge}}/(R_{\mathrm{ref}} + R_{\mathrm{active}})$.

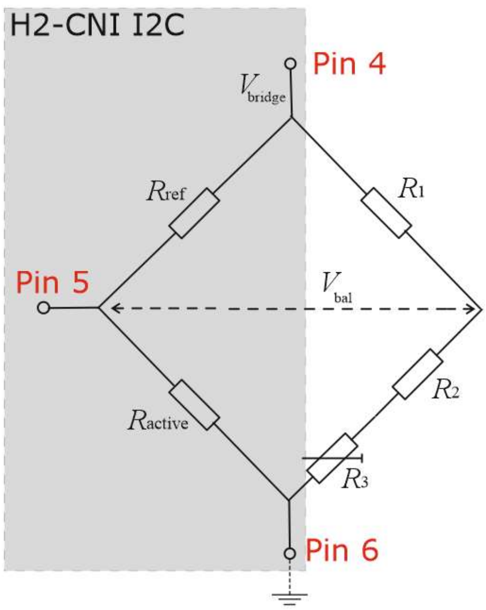

Figure 5. Wheatstone bridge configuration with H2-CNI I2C (schematic).

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 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 can be operated with a few external components as shown in Figure 6. 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 temperarture or near-room temperature condition.

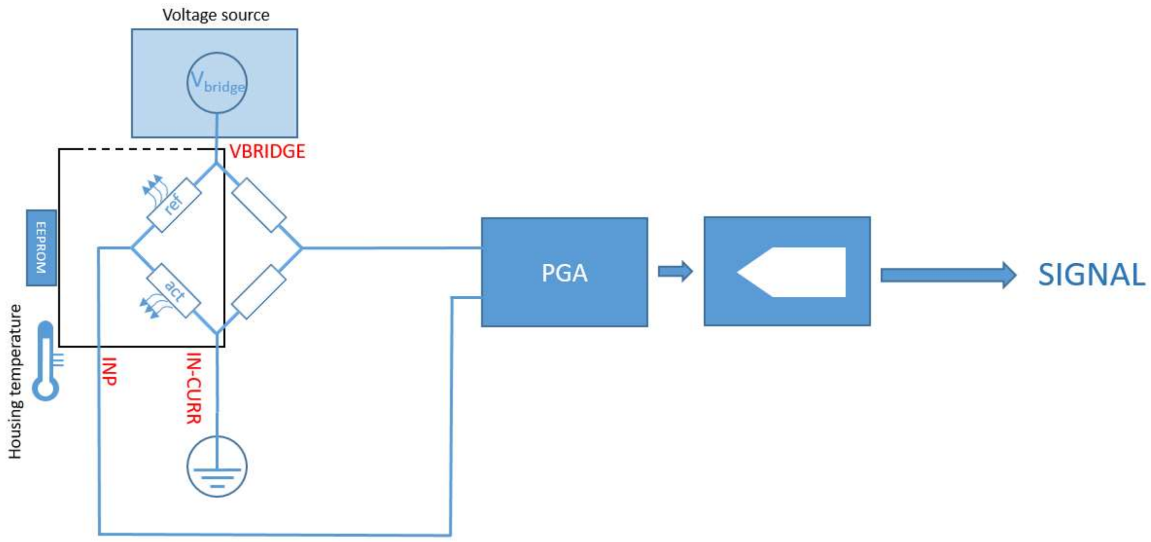

Figure 6. Components of the circuitry for operation of H2-CNI I2C hydrogen sensors.

The balance voltage may alter if H2-CNI I2C is applied in areas in which the ambient temperature varies in a wide range. This effect may not be compensated by R_{ref} and is due to small differences between the active and reference elements. You can use the advanced features of H2-CNI I2C sensors to achieve an optimum sensor characteristics even if large changes of the ambient conditions occur with respect to temperature as well as air flow. This is explained in the following.

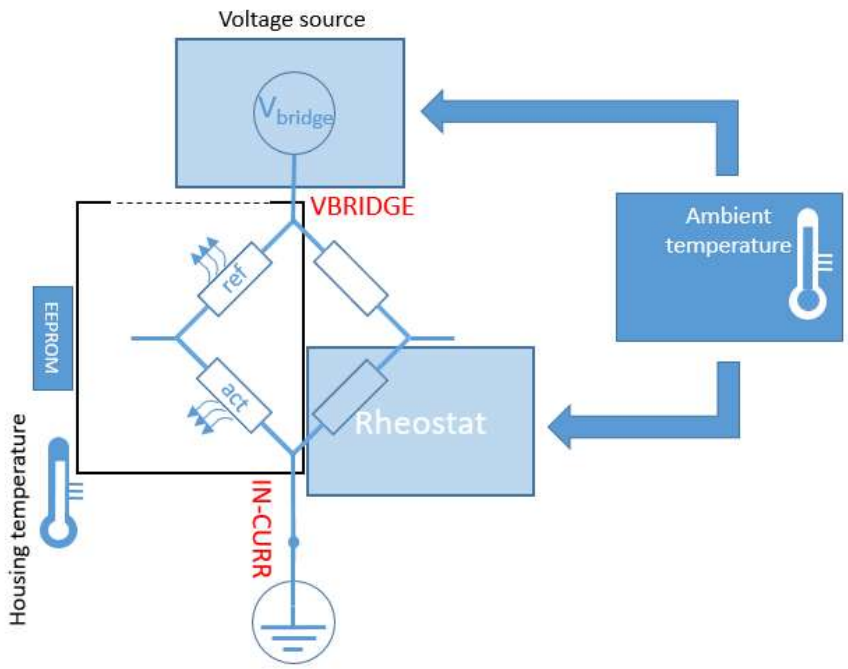

Figure 7. Recommended main elements of the controller for making use of the advanced features of H2-CNI I2C sensors (schematic).

Table 9	
TEMPERATURE T_{ambient}	VOLTAGE V_{bridge}
-40 °C	8.2
-30 °C	8.2
-20 °C	8.1
-10 °C	8.1
0 °C	8.1
10 °C	8.0
20 °C	8.0
30 °C	8.1
40 °C	8.2
50 °C	8.4
60 °C	8.7
70 °C	9.0
80 °C	9.4
90 °C	9.8

This can be achieved by changing the voltage V_{bridge} in dependence of T_{ambient}. Table 9 summarizes the recommended voltages V_{out} of the source at different ambient temperatures. The data are stored in the sensor´s EEPROM (Microchip Technology Inc., 24C01C) (see Reference Sheet of EEPROM).

Another useful approach is, however, to use a software-controlled automatic mode for both the voltage and rheostat control. Such a mode is implemented in our software program SensorControl which can be used with our evaluation kit PrecVS-PGA-ADC for H2-CNI I2C Hydrogen Sensors. This LabVIEW® program is also available as an executable code for Windows® platforms (refer to the Manual Sheet "Prec-PGA-ADC for H2-CNI I2C Hydrogen Sensors" for more details). Apart from other components, the kit contains an adjustable voltage source for bridge excitation with V_{bridge}, a digital temperature sensor for T_{ambient} measurement as well the PGA/ADC amplifier for precisely determining the balance voltage V_{bal}. Note that the ambient and the sensor housing temperature are related to each other by a linear function (compare figure 4). Hence, the housing temperature can also be used to control V_{bridge}.

11.FOOTPRINT AND RECOMMENDED PLUG-IN SOCKETS

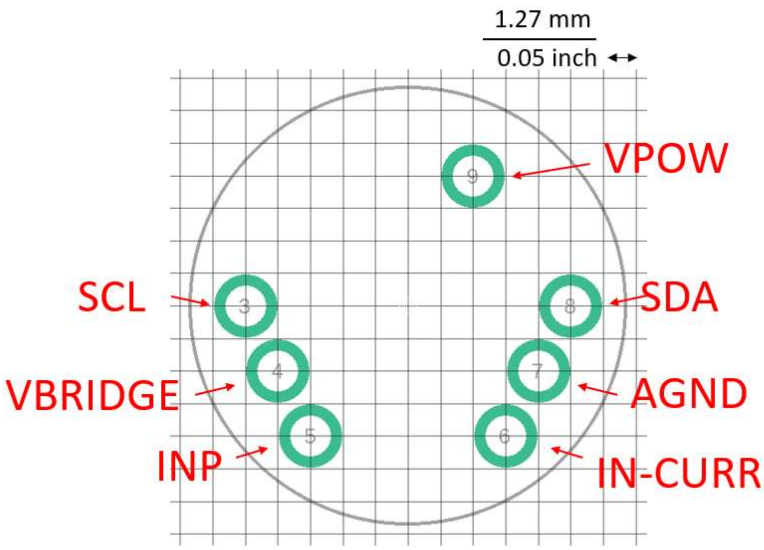

Figure 8: Footprint

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

13. PACKAGING/SHIPPING INFORMATION

This sensor is shipped individually in an antistatic bag.

14. WARNINGS

⚠ **Warnings:** The sensor H2-CNI I2C 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 3.8 and additional accessories) is available to support customers in the performance evaluation of our H2-CNI I2C 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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