Thermal Conductivity Hydrogen Sensor with 4-20 mA Transmitter for Industrial Applications

1. FEATURES

- Accurate detection of hydrogen levels in air and nitrogen up to 15% vol-%
- Fast response and recovery times
- Applicable in relative humidity (rh) between 0 % to 100 %
- Temperature range -20 °C to +85 °C
- Linear output up to 5 % vol-%
- Very low power consumption < 10 mW
- 4-20 mA current-loop transmitter with reverse voltage operation and over-voltage surge protection
- Supply voltage with reversed bias protection

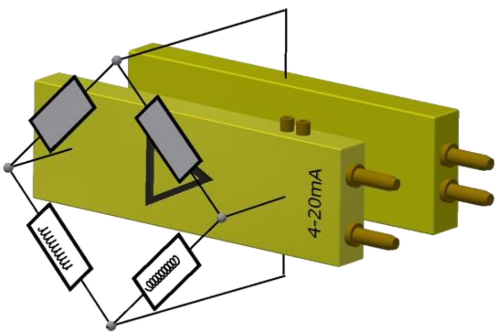
2. APPLICATION

- Precision hydrogen meters

3. DESCRIPTION

H2-meTCD 4-20mA is a hydrogen sensor for applications without oxygen and is based on a thermal conductivity operation principle. The sensor contains a Si-based heated transducer, fabricated by anisotropic etching, and on-board electronics, including the voltage sources for the transducer, a non-volatile digital rheostat for adjusting the Wheatstone bridge with the transducer, an instrumentation amplifier, and a secure 4-20 mA current interface. It is designed for use in a variety of applications which require an accurate hydrogen determination in nitrogen or other non-oxygen-containing atmospheres.

4. SIMPLIFIED SCHEMATIC



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5. REVISION HISTORY

Date	Rev.	
Aug 15, 2024	1.0	Initial Version
Sept 24, 2024	1.1	Table 4 updated, Chapter 13 revised
Nov 20, 2024	1.2	Changed sensor denotation

6. PIN CONFIGURATION AND FUNCTION

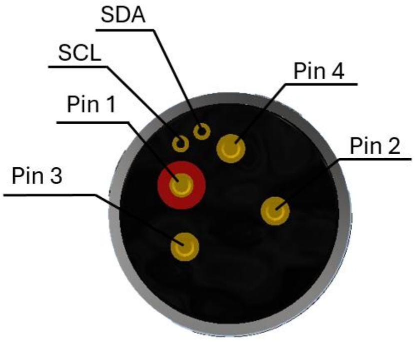

Figure 1: Bottom view of sensor

PIN NO.	DESCRIPTION
1	+7,5 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*
SCL	Clock line of the I2C bus**
SDA	Data line of the I2C bus**
	* 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).
	**If connected, provide necessary pull-up resistors to SCL and SDA (e.g. 4.7 kOhm).

7. SPECIFICATIONS

7.1. ABSOLUTE MAXIMUM RATINGS

At ambient temperature T_a = 20 °C.

Table 2	
Input supply voltage	+7.5 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 be 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).

Table 3

	MIN	NOM	MAX	UNIT
Input supply voltage	+6.5	+7.5	+9	V
Serial load resistor of the current loop connected to pin 2 and pin 4		≥ 100		Ω

7.5. MECHANICAL

Table 4

Housing material	Stainless steel (1.4404; SUS316L)
Potting	Epoxy
Base plate	FR4, flame retardant, according to UL-94
Weight	15 g
Diameter	20.0 mm
Height (housing)	16.6 mm
Height (overall)	21.6 mm
Pins	Gold over nickel
Pin diameter	1.57 mm
Pin length	4.78 mm

7.6. ELECTRICAL

Table 5	
Supply current	1 mA @ 20 °C
Current loop voltage	≤ 24 V

7.7. ENVIRONMENTAL

Table 6	
Ambient temperature range during operation	-20 to +80 °C
Operation humidity	0 … 100 % r.h.

7.8. SENSOR PARAMETERS

Table 7	
Signal at 50% LEL	7 mA (typical)
Resolution	100 ppm H_2
Linearity	1.5 mA/1 vol-% at 20 °C
Response time	< 5 s
Thermal zero point drift	< 0.01 mA/°C

7.9. SENSOR CROSS SENSITIVITIES

H2-meTDC 4-20mA sensors which are calibrated to measure hydrogen levels in air or nitrogen due to the large difference of of H_2 (0.15 W/mK) in comparison to nitrogen (0,02598 W/mK) and oxygen (0.02674 W/mK). Since for most gases and vapors thermal conductivity ranges between 0.01 and 0.03 W/mK at room temperature, cross-sensitivities are low in many applications. Among the light gases, which have high thermal conductivity, a notable interferent to hydrogen is helium (0.18 W/mK). Also, dense gases like xenon or others, which have low thermal conductivity, may affect the sensor´s output signal. The cross sensitivity of water vapor in humid air depends on the temperature and may be notably for ambient temperature well above room temperature.

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), calibrated hydrogen mixtures (5 vol-% H_2 in nitrogen), and pure hydrogen. 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 12 the evaluation kit DCC-PGA-ADC 3.2 and a stabilized 12 V power supply are used.

8.1. INITIAL WARM-UP PHASE

The sensors are operational immediately after the power supply is switched on without a relevant warm-up phase.

8.2. CALIBRATION CURVE

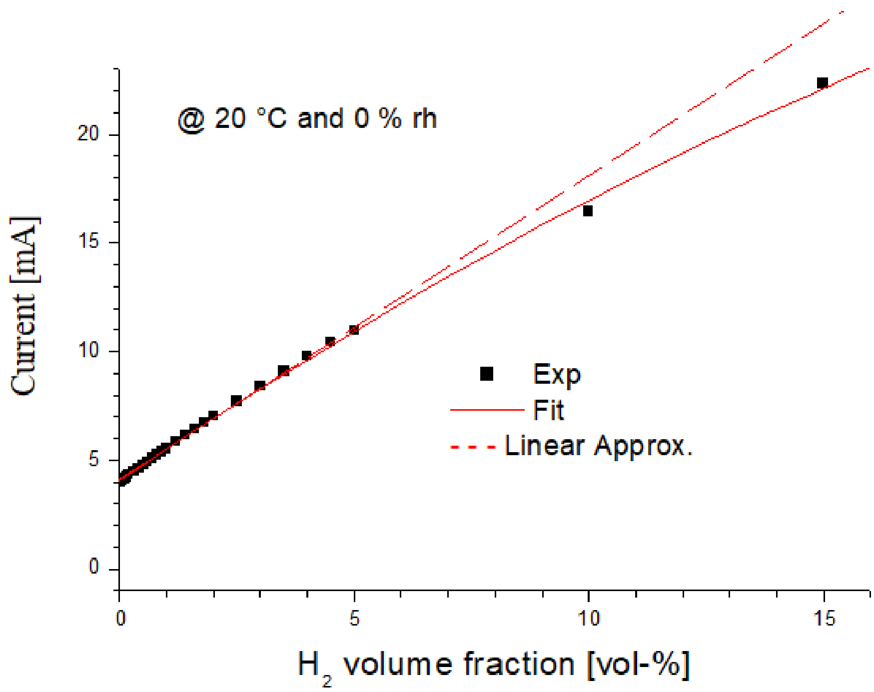

Figure 4. Typical values of the current (sensor signal) as a function of hydrogen volume fraction in synthetic dry air or nitrogen (for H2 volume fractions ≥ 5 vol-% at 20 °C. Data (Exp) are determined for a total flow of 50 sccm/min. Red: Polynomial fit of order 2. Red, broken line: Linear approximation with a slope of approx. 1.5 mA/1 vol-%.

8.3. LOW DETECTION LIMIT AND RESOLUTION

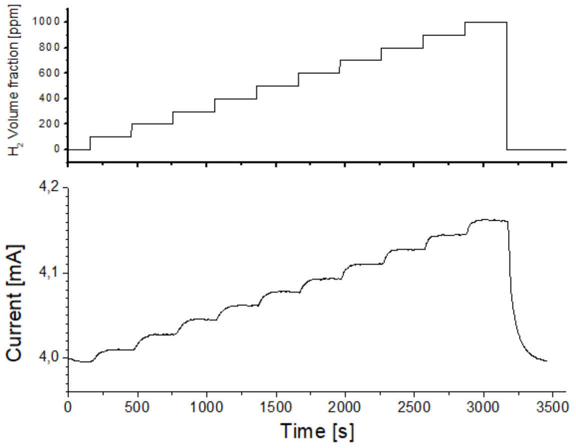

Figure 5. Top: Test protocol with an automated procedure of low hydrogen exposures (H_2 volume fractions between 100 and 1000 ppm) in the test chamber (dry air at 20 °C, total flow 100 sccm/min). Bottom: Sensor signal (current) as a function of the time.

8.4. TEMPERATURE-DEPENDENCE

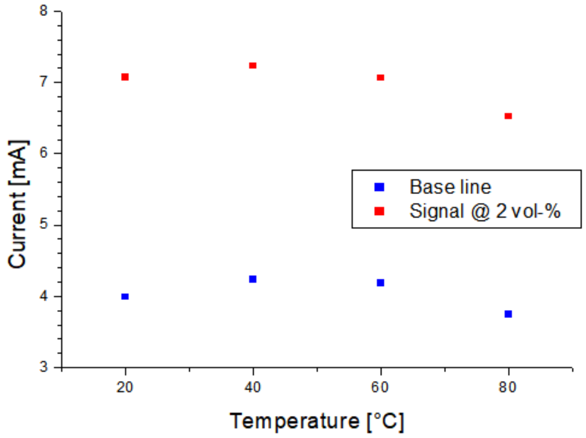

Figure 6. Red: Sensor signal (current) for a hydrogen volume fraction of 2 vol% at temperatures of 20 °C, 40 °C, 60 °C, and 80 °C. Blue: Base line current at 0 vol% H_2.

8.5. EFFECT OF RELATIVE HUMIDITY ON THE BASE LINE

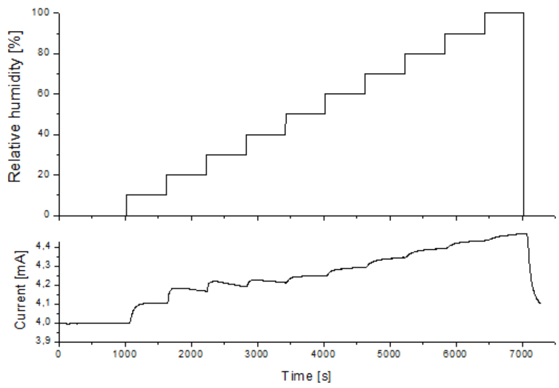

Figure 7. Top: Test protocol with an automated procedure of relative humidity changes in the test chamber, ranging from dry air to 100 % (temperature = 20 °C, total flow = 50 sscm/min). Bottom: Sensor signal (current) as a function of time.

8.6. EFFECT OF RELATIVE HUMIDITY ON THE SIGNAL

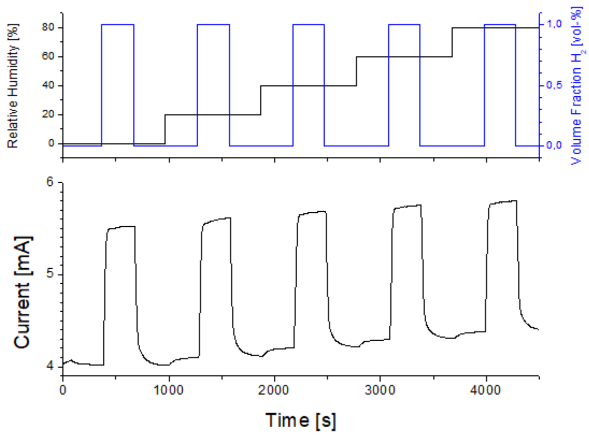

Figure 8. Top: Test protocol with an automated hydrogen exposure (1 vol-%) and variations of the relative humidity (0 to 80 %) at 20 °C (total flow = 50 sscm/min). Bottom: Sensor signal (current) as a function of time.

8.7. EFFECT OF FLOW RATES ON THE BASE LINE

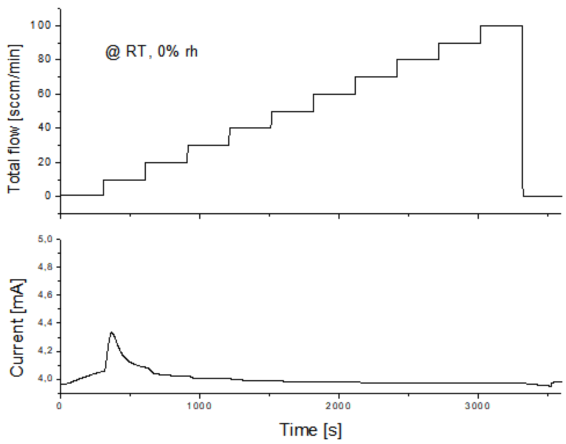

Figure 9. Top: Test protocol with an automated total flow variation between 0 and 100 sccm/min at 20 °C and 0 % rh. Bottom: Sensor signal (current) as a function of time.

8.8. EFFECT OF FLOW RATES ON THE SIGNAL

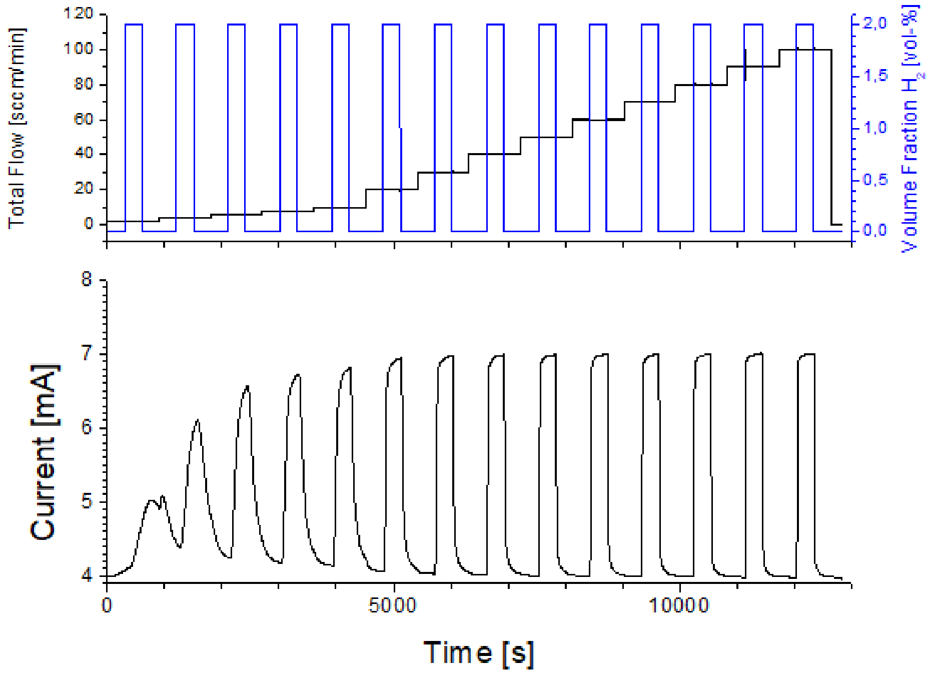

Figure 10. Top: Test protocol with an automated total flow variation between 1 and 100 sccm/min at 20 °C and 0 % rh (black) and repeated exposures with a hydrogen volume fraction of 2 vol-% (blue). Bottom: Sensor signal (current) as a function of time.

8.9. RESPONSE AND DECAY TIMES

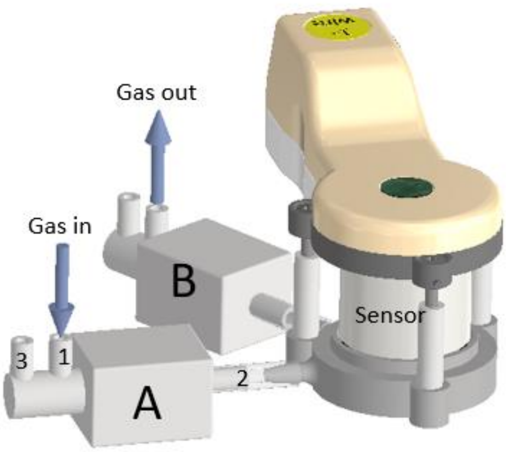

Figure 11. Special setup to determine the response and decay time of the sensor. Here, the evaluation kit DCC-PGA-ADC 3.3 is used to apply both, the 12 V supply voltage and the 24 V loop voltage to determine the current of the sensor. A flow of 2 vol-% H_2 in air with 50 sccm/min flows into the system 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.

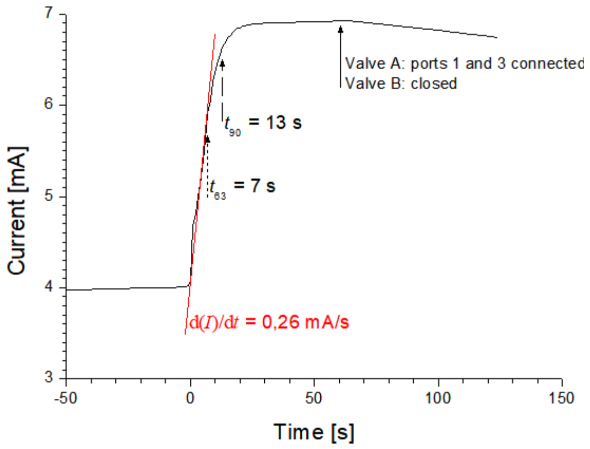

Figure 12. Sensor signal as a function of time after applying 2 vol-% H_2 in dry air at 20 °C. The sensor signal reaches a steady-state signal with a t_{63} response time of 7 s (dotted arrow) and a t_{90} response time of 13 s (dashed arrow). The slope dI/dt is approx. 0.26 mA/s. After re-directing the test gas to the port "Out 1" (solid arrow) and closing valve A, the signal does not decay to 4 mA since the sensor does not consume hydrogen.

8.10. CALIBRATION PROCEDURE

For offset adjustment, the sensor contains a digitally adjustable, non-volatile rheostat, controlled over the I2C bus. For changing the factory setting, a special PCB board is available. The number of possible changes of the offset settings, stored permanently in the rheostat, is limited to 50.

8.11. 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.

9. THEORY OF OPERATION

The hydrogen sensors H2-meTCD 4-20mA contains a Si-based heated transducer, fabricated by anisotropic etching, with a thin membrane that is heated by a thin-film resistor. The membrane´s temperature is higher than the temperature of the adjacent solid silicon chip which carries a second temperature-dependent resistor. Both resistors form a Wheatstone bridge arrangement together with additional resistors in the two branches of the bridge, one of them is made adjustable by a digital rheostat. The rheostat allows for nulling of the voltage decay across the bridge. Changes of the thermal conductivity of the surrounding atmosphere lead to the formation of an out-of-balance voltage that is amplified and converted into a 4-20 mA signal by means of an current transmitter The on-board electronics transmitter is protected against reverse voltage operation and over-voltages above 24 V. 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.

10.APPLICATION AND IMPLEMENTATION

The H2-meTCD 4-20mA sensors are optimized for the use as hydrogen detectors in nitrogen or air. The can be operated with only a few additional components (see section 12). A practical hardware-software solution is available as an evaluation kit. Contact our distributor for further support.

11. FOOTPRINT AND RECOMMENDED PLUG-IN SOCKETS

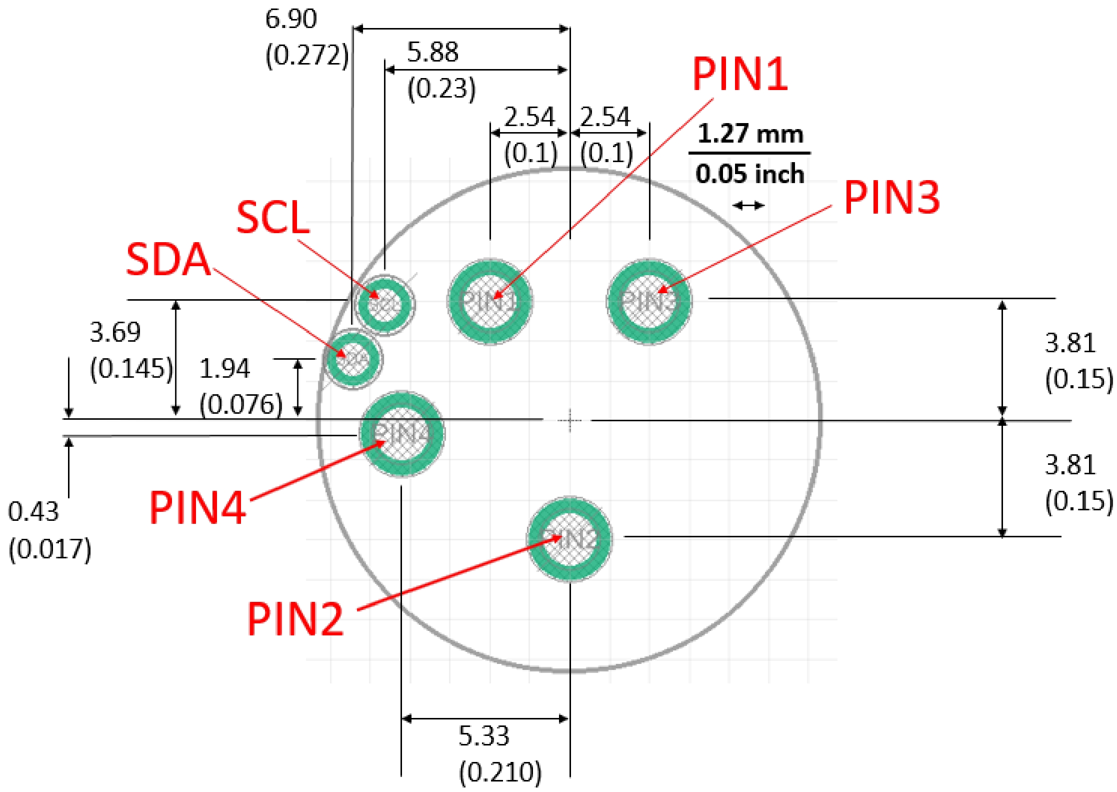

Figure 13: Footprint (dimensions shown in millimeter and inch). The SCL and SDA sockets accepts pins of 0.38 to 0.5 mm diameter.

Recommended plug-in sockets/PCB pins	Drill hole	Pin dameter
450-3326-01-03-00 (Cambion Electronics LTD)	2.6 mm	
5928-0-00-15-00-00-03-0 (Mill-Max)	0.61 mm	0.5 mm

12. RECOMMENDATIONS FOR ELECTRICAL CIRCUITS

To use the 4-20mA transmitter output at pins 2 and 4 in a 4-20 mA circuit properly, the +12 V supply voltage, applied at pin 1 with respective to pin 3, must be galvanically decoupled. There are different options to achieve this requirement. If the +12 V power supply provides floating plus and minus poles, the positive output is wired directly to pin 1 and the negative output is connected with pin 3. Only in this case, the 4-20 mA transmitter circuit can be set up according to figure 14 (right part). If the +12 V power supply has a grounded output (usually it is the negative pole) and if there no galvanic decoupling exists in the 4-20 mA circuit or the decoupling state is unknown, the use of an DC-DC converter (isolation amplifier with gain 1) is mandatory to isolate pin 1 and pin 3 of the sensor from ground as indicated in figure 14. Note, that the polarity of pins 2 and 4 with respect to the 24 V voltage in the current transmitter circuit is not critical, as they are internally wired to a diode bridge.

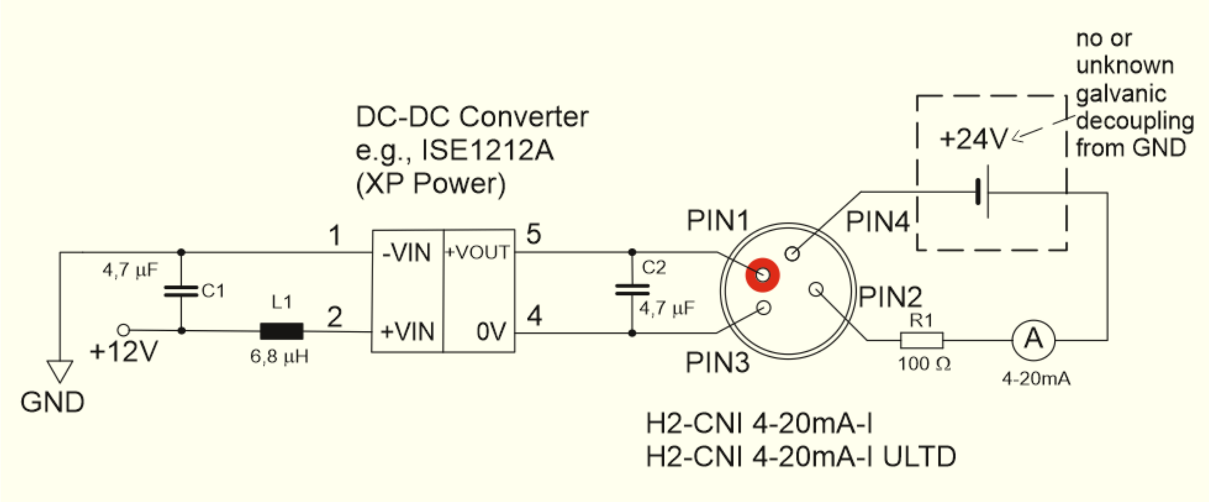

Figure 14: Recommended circuit with DC-DC converter to isolate the supply voltage from ground (GND)

13.ORDERING INFORMATION

Hydrogen sensor H2-meTCD 4-20mA

14.PACKAGING/SHIPPING INFORMATION

This sensor is shipped individually in an ESD/EMI shielded and water vapor-proofed bag according to IPC/JDEC J-STAD-033.

15.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.

16.WARNINGS

⚠ **Warnings:** The sensor H2-meTCD 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.

17.NOTES

18.WORLDWIDE SALES AND CUSTOMER SUPPORT

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