


# Thermal Conductivity Hydrogen Sensor with I2C Bus for Industrial Applications

## 1. FEATURES

- Accurate detection of hydrogen levels in nitrogen up to 100% vol-%
- 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 +85 °C
- Linear output up to 100 % vol-%

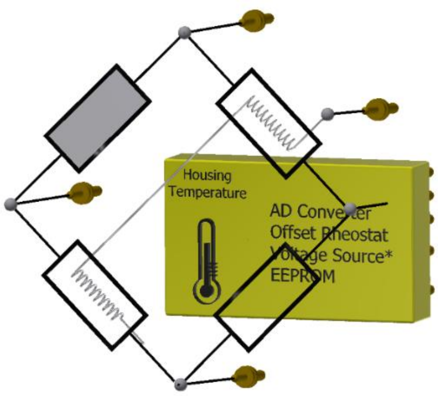
## 2. APPLICATION

- Hydrogen meters

## 3. DESCRIPTION

H2-TCD I2C-I is a hydrogen sensor for applications without oxygen and is based on a thermal conductivity operation principle. The sensor contains on-board electronics, including the voltage sources for the heated transducers and the Wheatstone bridge. In addition, a programmable gain amplifier, a 16-bit $\Delta\Sigma$ analog-to-digital converter, a rheostat, an 1 K bit EEPROM, and a digital temperature sensor are key component of the sensor. 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. | |
|---|---|---|
| June 2, 2024 | 1.0 | Initial Version |
| June 18, 2024 | 1.1 | Updated Table 5 |
| July 15, 2024 | 1.2 | Updated Chapter 8, Initial Warm-up |

# 6. PIN CONFIGURATION AND FUNCTION

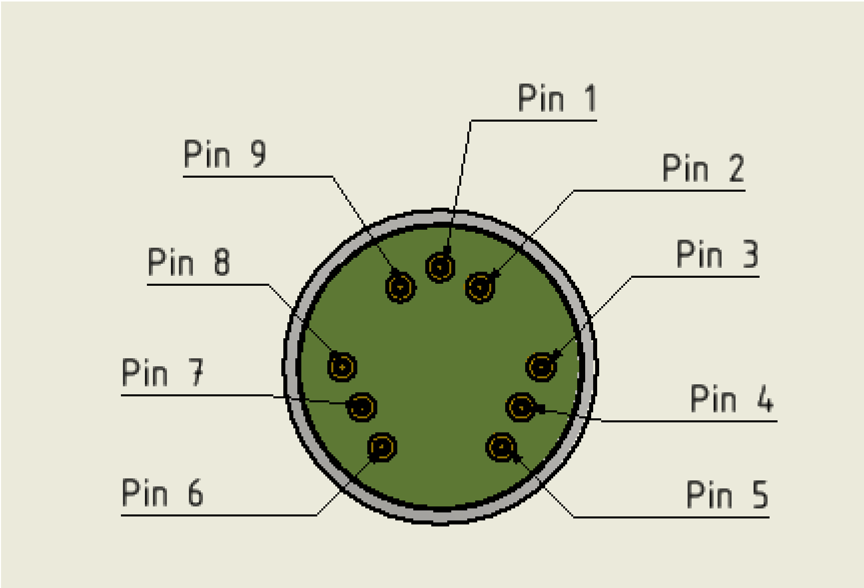


*Figure 1: Bottom view of sensor*

*Table 1*

| PIN NO. | SIGNAL NAME | DESCRIPTION |
|---|---|---|
| 1 | INN | Midpoint of the 2nd branch of the Wheastone bridge (can remain unconnected) |
| 2 | VHEAT | Heater voltage. Leave unconnected. |
| **3** | **SCL** | **SCL line of I2C bus.*** |
| 4 | VBRIDGE | Bridge excitation voltage. Leave unconnected. |
| 5 | INP | Midpoint of the 1st branch of the Wheastone bridge (can remain unconnected) |
| 6 | B | Rheostat. Leave unconnected. |
| **7** | **AGND** | **Ground of the heaters, Wheatstone bridge and I2C bus.*** |
| **8** | **SDA** | **SDA line of $I^2C$ bus.*** |
| **9** | **VPOW** | **Supply voltage of internal electronics. *** |
| ***Required connections (bold)** | | |

# 7. SPECIFICATIONS

## 7.1. ABSOLUTE MAXIMUM RATINGS

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

| *Table 2* | |
|---|---|
| Supply voltage VPOW | +6 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 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

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

| *Table 3* | | | | |
|---|---|---|---|---|
| | MIN | NOM | MAX | UNIT |
| Supply voltage at pin 9 | +5.5 | +6 | +6.5 | 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@ 6V* |
| 20 °C | 150 mA |

## 7.7. ENVIRONMENTAL

| *Table 6* | |
|---|---|
| Ambient temperature range during operation | -40 to +85 °C |
| Operation humidity | 0 to 100 % r.h. |

## 7.8. SENSOR PARAMETERS

| *Table 7* | |
|---|---|
| Digital output | $I^2C$ bus |
| Response time | ≈ 30 s |
| Cross sensitivity for humidity | negligible |

# 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 nitrogen (100 vol-%) and hydrogen (100 vol-%).

## 8.1. INITIAL WARM-UP

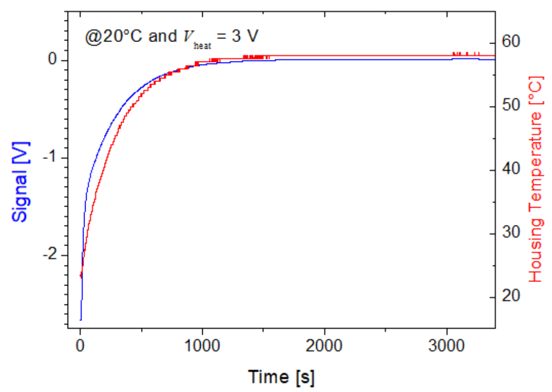


*Figure 2. Typical signal characteristics of the sensor (blue curve) after powering-up with a heating voltage of 3 V at time zero. The red curves shows the housing temperature, as determined with the internal temperature sensor. The signal approaches the zero level after full thermal equilibration and the sensor´s housing temperature is constant.*

The initial warm-up phase of the sensor signal can be significantly shortened if the temperature of the sensor´s housing, determined with the internal digital temperature sensor, is used in an “auto correction” mode (Figure 3). This mode takes into account that the deviation of the sensor signal in the balanced Wheatstone configuration (see Theory of Operation) from zero is mainly determined by the deviation of the actual temperature of the sensor elements from their equilibrium values during the warm-up phase in which the sensor´s housing slowly approaches its final steady-state temperature. The deviation is a linear function of the sensor housing´s temperature.  An example is given in the latest “Manual of Evaluation Kit TCD-Controller for H2-TCD I2C Hydrogen Sensors”.

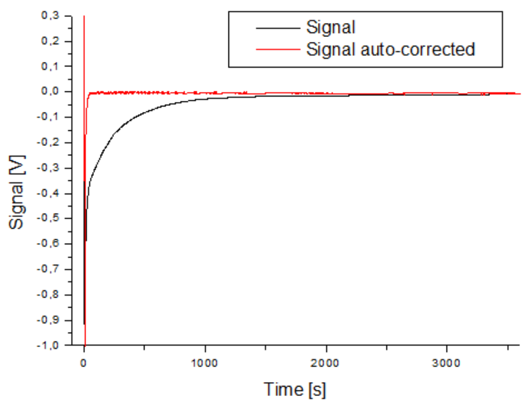


*Figure 3. Typical auto corrected signal of the sensor (red curve) versus the uncorrected signal after powering-up with a heating voltage of 3 V at time zero. Here, the sensor´s gain is set to 4 V/V.*

## 8.2. CALIBRATION CURVE

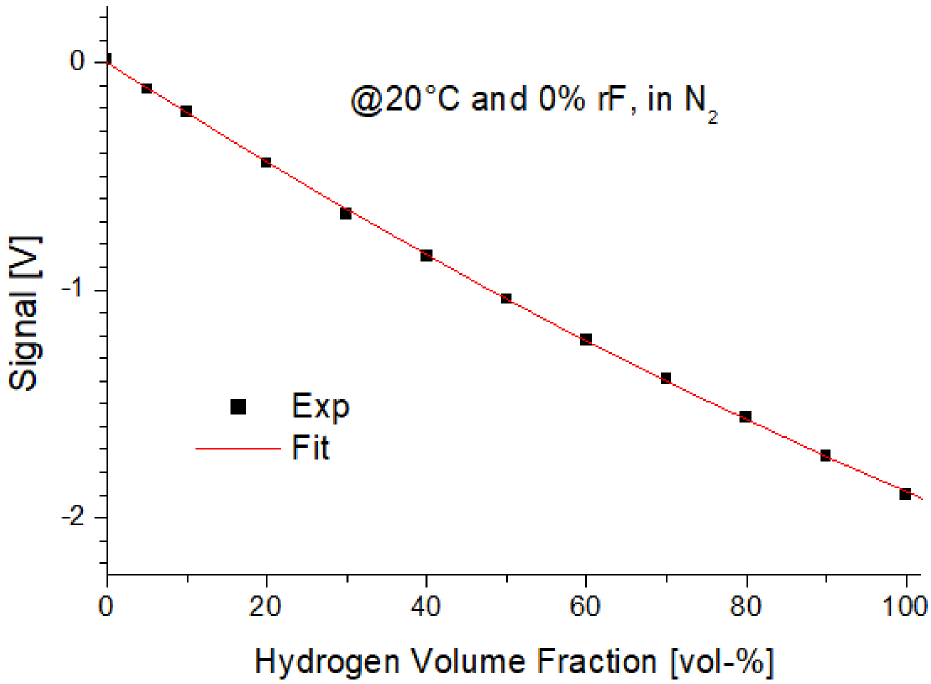


*Figure 4. Typical values of the signal (at a gain of 4 V/V ) as a function of hydrogen volume fraction in nitrogen. Conditions: 3 V heating voltage, 20 °C ambient temperature, 50 sccm/min volume flow.*

## 8.3. TEMPERATURE-DEPENDENCE

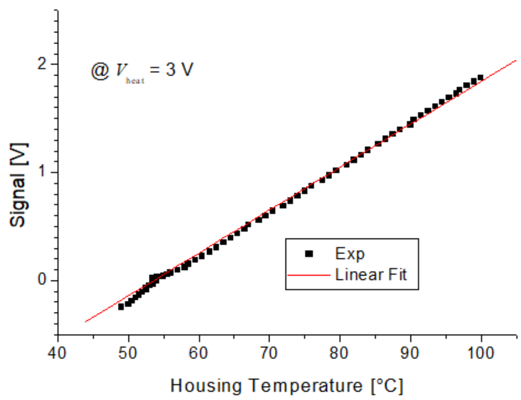


*Figure 5. Temperature dependence of the signal (at a gain of 4 V/V and a heating voltage of 3 V) as a function of the sensor´s housing temperature.*

The signal of the TCD depends on the temperature in a linear relationship (figure 4). Note, that the sensor´s housing is approximately 50°C at a heating voltage of 3 V and 20°C ambient temperature in a calm atmosphere without air flow.

Since the 16-bit ΔΣ analog-to-digital converter (ADC) measures signals in a voltage span from -2.5 to +2.5 V, hydrogen can be determined without changing the programmable gain amplifier´s (PGA) gain for ambient temperatures above room temperature. If the TCD is operated at temperatures below 20 °C or in gas streams, the above shown relationship is still valid and the shift of the signal below 0 V must be compensated either by decreasing the gain or by setting an appropriate offset to avoid a saturation of the ADC at larger hydrogen volume fractions. The relationship between signal and housing temperature can be used to correct for ambient temperature induced changes of the signal. This can be achieved, e.g., by post-signal treatment in the user´s software.

## 8.4. EFFECT OF RELATIVE HUMIDITY ON THE BASE LINE

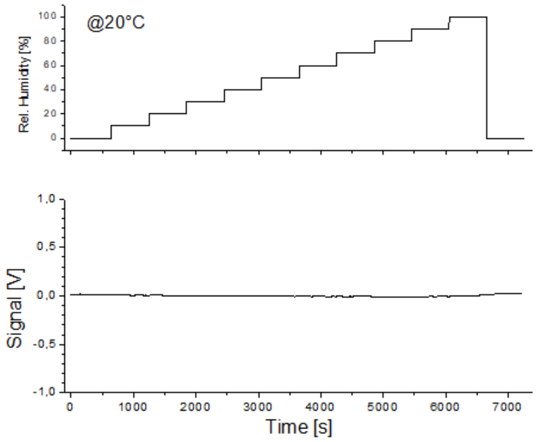


*Figure 6. Sensor signal (gain 8 V/V) as a function of time at different levels of relative humidity from dry air to 100 % at 20 °C (3 V heating voltage, total flow = 50 sscm/min).*

## 8.5. RESPONSE TIME

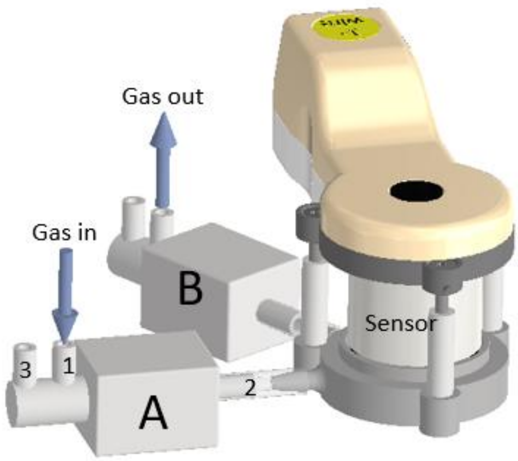


*Figure 7. Special setup to determine the response and decay time of the sensor. Here, the evaluation kit TCD-Controller 3.1 is used to operate the sensor. A flow of 50 vol-% $H_2$ in nitrogen with 50 sccm/min flows into the system at the “gas in” through port 1 of valve A. The valve can be switched 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.*

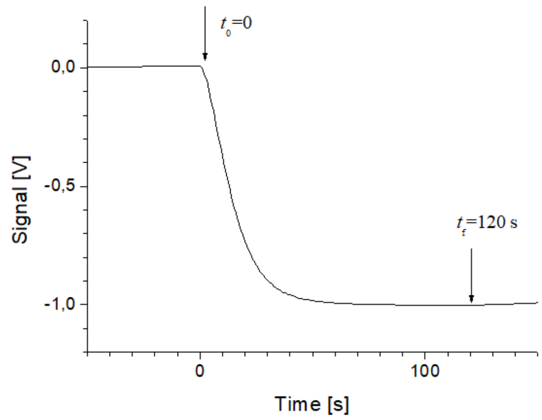


*Figure 8. Sensor signal (gain 4 V/V) as a function of time after applying 50 vol-% $H_2$ in nitrogen at 20 °C (3 V heating voltage) at $t_0$ = 0. The sensor signal reaches a steady-state signal with a $t_{90}$ response time of 30 s. After re-directing the test gas to the port "Out 1" at $t_f$ = 120 s, the signal remains since the hydrogen/nitrogen mixture is confined in the test chamber and hydrogen is not consumed by the sensor.*

# 9. THEORY OF OPERATION

The hydrogen sensor H2-TDC I2C-I comprises two indirectly heated temperature-sensitive transducers that are part of a Wheatstone bridge configuration (Figure 9), complemented by a constant resistor $R_4$, and a combination of $R_1$ and $R_2$ with variable overall resistance.

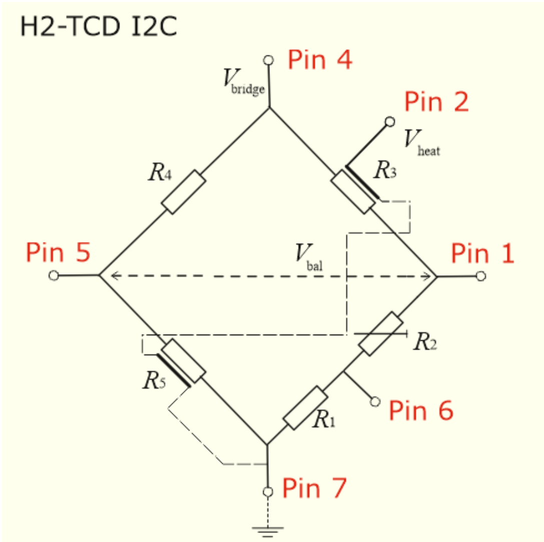


*Figure 9. Wheatstone bridge configuration of H2-TCD I2C-I (schematic) with heated Pt transducers $R_3$ and $R_5$. The dashed lines between the heaters of $R_3$ and $R_5$ as well as between $R_5$ and pin 7 represent internal connections.*

Both transducers are heated simultaneously and equally by passing a current from the voltage source $V_{\text{heat}}$, internally applied to pin 2 with respect to pin 7 . The constant Wheatstone bridge voltage $V_{\text{bridge}}$ is produced by a band-gap voltage reference. The out-of-balance voltage $V_{\text{bal}}$ between pin 5 and pin 1 can be nulled by means of the variable resistor $R_2$ that is composed of a digital nonvolatile 256-step rheostat. For the given values of the resistors $R_4$ and $R_1$, used in the TCD sensor, the balance voltage can be calculated as a function of the transducers temperatures as shown in figure 10.

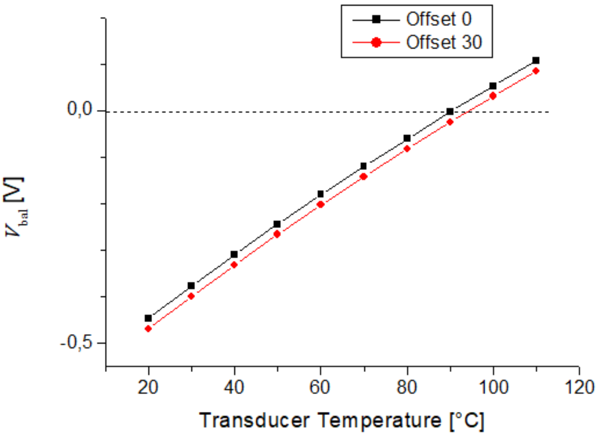


*Figure 10. Balance voltage $V_{\mathrm{bal}}$ as a function of the temperature of the transducers $R_3$ and $R_5$.*

The dotted line with $V_{\mathrm{bal}}$ = 0 suggests an appropriate choice of the transducer temperature of approx. 90 °C which is achieved with a heating voltage of 3 V.

The voltage $V_{\mathrm{bal}}$ is measured with a 16-bit $\Delta\Sigma$ analog-to-digital converter and represents the signal of the TCD hydrogen sensor (figure 11). Exposure to hydrogen in an inert atmosphere (e.g. nitrogen) results in an increase of the heat conductance that causes equal temperature decreases and resistance increases of the transducers $R_3$ and $R_5$. Hence, a variation of the out-of-balance voltage $V_{\mathrm{bal}}$ occurs which is measured and digitalized with the analog-to-digital converter. The converter contains a programmable gain amplifier (PGA) with gains from 1 to 256 in 8 steps. Its reference voltage is set to a precise voltage of $V_{\mathrm{bridge}}/2$ to ensure that positive and negative values of $V_{\mathrm{bal}}$ can be measured. Typical gains of the amplification of $V_{\mathrm{bal}}$ should be in the range of 1 to 8, depending on the desired hydrogen sensitivity and detection range.

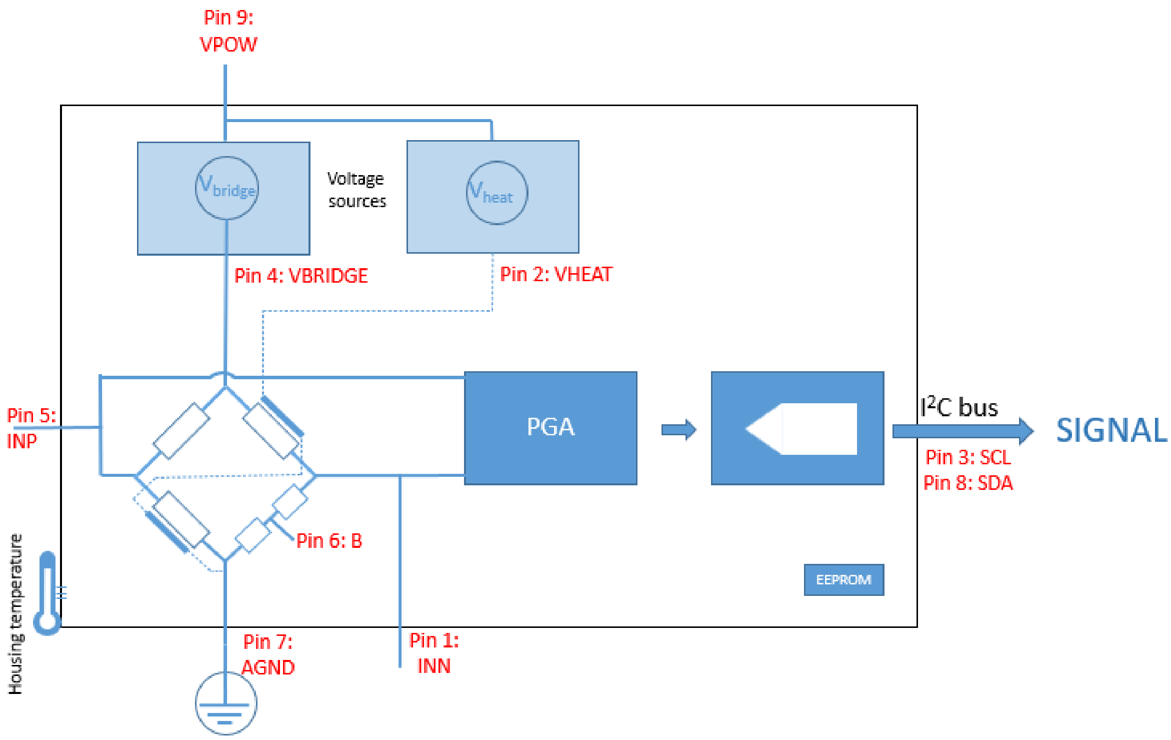


*Figure 11. Components of the circuitry of H2-TCD I2C-I hydrogen sensors. Pin 9 must be connected to an external supply voltage. The constant bridge voltage VBRIDGE and the variable heating voltage VHEAT are generated internally from this supply voltage. The SCL and SDA lines require external pull-up resistors (e.g. 4.7 kΩ).*

# 10.APPLICATION AND IMPLEMENTATION

For most applications, H2-TCD I2C-I can be operated with just a few external components. A single voltage source with maximum 6 V must be connected to pin 9 with respect to ground at pin 7. The supply voltage of the EEPROM, digital temperature sensor, offset rheostat, PGA, and ADC is generated by means of an internal linear voltage regulator from the supply voltage. In addition, this voltage drive the internal precision voltage source for the Wheastone bridge excitation as well as the heating voltage. The latter can be controlled by an digital-to-analog converter through the $I^2C$ bus.

## 10.1. $I^2C$ BUS

Two pull-up resistors are required to ensure that the SCL and SDA lines of the $I^2C$ bus are at high potential.

The following 7bit addresses are used in the H2-TCD I2C-I sensors:

*Table 8: 7bit Addresses*

| Binary code | Hexadecimal code | IC |
|---|---|---|
| 1001000 | x48 | 9- to 12-bit selectable, ±1.0°C accurate digital temperature sensor |
| 1010000 | x50 | 1K bit serial electrically erasable PROM |
| 0100110 | x26 | 16-Bit ΔΣ ADC with Easy Drive® technology and on-chip programmable gain as analog-to-digital converter with PGA |
| 1001110 | x4E | Nonvolatile 256-position digital potentiometer used as rheostat for offset adjustment |
| 1100000 | X60 | 12-Bit digital-to-analog converter with EEPROM used for the programmable voltage source $V_{\mathrm{heat}}$ |

All command and data information is transferred with the Most-Significant Bit (MSB) first.

## 10.2. EEPROM

The EEPROM is organized as a single block of 128 x 8-bit memory. The following table indicates the information, kept under the different word addresses. The word addresses 0x00 to 0x03, 0x05 and 0x06 keep basic information about the sensor, including a CRC value calculated from the entries and stored in 0x04. This information must not be altered.

*Table 9. Contents of the EEPROM*

| Word address | Data byte | Remarks |
|---|---|---|
| 0x00 | Device code | Data must not be changed |
| 0x01 | Serial number (upper byte) | |
| 0x02 | Serial number (middle byte) | |
| 0x03 | Serial number (lower byte) | |
| 0x04 | CRC value | |
| 0x05 | Fabrication date/month | See (a) |
| 0x06 | Fabrication month/year | |
| 0x07...0x02F | Fabrication-related data | Encrypted data. Not intended for users |
| 0x30 | Excitation | Default settings for evaluation kit |
| 0x31 | Gain preamplifier | |
| 0x32 | Gain | |
| 0x33 | Offset A (upper byte) | |
| 0x34 | Offset A (lower byte) | |
| 0x35 | Offset B U(upper byte) | |
| 0x36 | Offset B (lower byte) | |
| 0x37…0x4D | Control data for other evaluation kits not useful for H2-CNI I2C FWB sensors | Encrypted data. Not intended for users |
| 0x4E…0x52 | Resistances and thermal coefficients of sensor and reference elements | Encrypted data. Not intended for users |
| 0x53…0x56 | | Encrypted data. Not intended for users |
| 0x57…06E | | Not intended for users |
| 0x6F | | Not used |
| 0x70 | Calibration offset (upper byte) | See equation (b) for decoding |
| 0x71 | Calibration offset (lower byte) | |
| 0x72 | Calibration gain (upper byte) | See equation (c) for decoding |
| 0x73 | Calibration gain (lower byte) | |
| 0x74 | | Not used |
| 0x75 | Setting of the rheostat in the Wheatstone bridge for midpoint | See equation (d) for decoding |
| 0x76…0x7F | | Not used |

Read operations allow the master to access any memory location. Sequential reads are also possible. Any read operation is initiated by the bust master with the Start signal (S), followed by the address AD = 1010000, and the $R/\overline{W}$ bit, which is a logic low. The EEPROM will acknowledge (ACK) this byte during the ninth clock pulse.

The next byte transmitted by the master is the word address and will be written into the address pointer of the EEPROM. After receiving another acknowledge signal from the EEPROM the master must transmit a Start signal (repeated Start, Sr), followed by the address AD= 1010000 and the $R/\overline{W}$ bit set to one. The EEPROM issues an acknowledge and the eight-bit data word. For a single read operation, the master does not acknowledge the transfer but generates a Stop signal (P) which terminates the read operation.

| S | AD,0 | ACK | Word Address (n) | ACK | Sr | AD,1 | ACK | Data word n | P |
|---|---|---|---|---|---|---|---|---|---|

The sequential read of data bytes are initiated in the same way but the master transmits an acknowledge after the first data word is send by the EEPROM. This directs the EEPROM to transmit the next sequentially addressed data byte.

| S | AD,0 | ACK | Word Address (n) | ACK | Sr | AD,1 | ACK |
|---|---|---|---|---|---|---|---|

| Data word n | ACK | Data word n+1 | ACK | Data word n+2 | … | Data word n+X | P |
|---|---|---|---|---|---|---|---|

Use the following decoding procedure to get the required information from the word addresses:

a) Fabrication time from data bytes in 0x05 and 0x06

| Data byte in 0x06 | | | | | | | | Data byte in 0x05 | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| MSB | | | | | | | LSB | MSB | | | | | | | LSB |
| | | | | | | | | | | | | | | | |
| + 2000 = Fabrication year | | | | | | | Fabrication month | | | | Fabrication date | | | | |

b) Calibration offset from data bytes in 0x70 and 0x71

| Data byte in 0x70 | | | | | | | | Data byte in 0x71 | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| MSB | | | | | | | LSB | MSB | | | | | | | LSB |
| MSB | | | | | | | | | | | | | | | LSB |
| 16 bit word | | | | | | | | | | | | | | | |

$$Offset = -0.15\text{ V} + \frac{\text{16 bit word}}{65535} \times 0.30\text{ V}$$

c) Calibration slope from data bytes in 0x72 and 0x73

| Data byte in 0x72 | | | | | | | | Data byte in 0x73 | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| MSB | | | | | | | LSB | MSB | | | | | | | LSB |
| MSB | | | | | | | | | | | | | | | LSB |
| 16 bit word | | | | | | | | | | | | | | | |

$$Slope = \frac{\text{16 bit word}}{1{,}000{,}000}\ \text{V/vol-\% } H_2$$

d) Offset rheostat´s setting for midpoint in 0x75 and 0x76

| Data byte in 0x75 | | | | | | | |
|---|---|---|---|---|---|---|---|
| MSB | | | | | | | LSB |
| 8 bit word | | | | | | | |

Offset = 8 bit word

To write a single byte into a memory location, the master issues a Start signal, followed by the, address code AD=1010000, and the R/$\overline{\mathrm{W}}$ bit, which is a logic low. The device will acknowledge this byte during the ninth clock pulse. The next byte transmitted by the master is the word address and will be written into the address pointer of the EEPROM. After receiving another acknowledge bit from the EEPROM the master device will transmit the data bye to be written into the addressed memory location. The EEPROM acknowledges again and the master generates a Stop condition. This initiates the internal write cycle, and during this time the EEPROM will not generate acknowledge signals.

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| S | AD,0 | ACK | Word Address (n) | ACK | Data word n | ACK | P |

Write operations should be limited to the free memory locations 0x75…0x7F or if the calibration offset and slope must be adapted to sensing conditions different from those used during the initial calibration of the sensor.

## 10.3. ADJUSTABLE PRECISON VOLTAGE SOURCE

The H2-TCD I2C-I sensors contain an adjustable voltage source to generate the heating voltage. The source is driven by the supply voltage VPOW at pin 9 (see Table 3). After powering of the sensor, the initial voltage $V_{\mathrm{heat}}$ must be set to an appropriate value, e.g. 3 V.

The voltage source is initiated by the following write operation to the digital-to-analog converter, driving an adjustable low dropout regulator, with the Start signal, followed by the address AD=1100000 and the R/$\overline{\mathrm{W}}$ bit, which is a logic low. The variable resistor acknowledges and the master sends an instruction byte 01000000. After receiving the next acknowledge condition the master transmits the data byte. After the next ACK the master terminates the write operation with the Stop signal.

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| S | AD,0 | ACK | Instruction byte | ACK | Data byte | ACK | P |

The data byte is calculated from

$$\text{Data byte} \approx 4095 \times \frac{V_{Heat}}{5\mathrm{V}}$$

Values should be rounded appropriately. Note, that data bytes above 1001 1001 1001 should not be used to prevent the heating voltage from exceeding 3 V.

After the initial write operation with the instruction byte 01000000, the following write operations are performed with an instruction byte 00000000 and a data byte for the chosen heating voltage as given by the formula.

The read mode is initiated by the master by sending the Start signal, followed by the address AD=0101100 and the R/$\overline{W}$ bit, which is a logic high. The data byte follows immediately after the acknowledgment. After receiving the 8 bits of the data byte, the master responses by leaving the SDA line high (no acknowledge bit, NACK) during the ninth SCL clock pulse and then terminates with a Stop signal.

| | | | | | |
|---|---|---|---|---|---|
| S | AD,1 | ACK | Data byte | NACK | P |

## 10.4. ADJUSTING THE BALANCE VOLTAGE

The Wheatstone bridge contains a nonvolatile 256-step variable resistor, used as rheostat, to allow precise zeroing of the balance voltage $V_{bal}$.

The corresponding wiper position is stored in the rheostat and automatically adjusted after powering-up. Due to the special configuration of the Wheatstone bridge, the change of the balance voltage depends nonlinearly on the rheostat wiper setting. Precise zeroing of the Wheatstone bridge is possible with rheostat settings at or in the vicinity of the ideal midpoint setting. The midpoint value is stored under 0x75 address in the EEPROM of the sensor.

## 10.5. READING THE BALANCE VOLTAGE

Both, the basic and advanced versions of the H2-CNI I2C-I FWB sensor contain a 16-bit plus sign no latency ΔΣ analog-to-digital converter which includes an on-chip programmable gain from 1 to 256 in 8 steps and reject line frequencies (50Hz, 60Hz or simultaneous 50Hz/60Hz). The converter powers up in a default mode with a gain of one, is automatically calibrated, and the digital filter simultaneously rejects 50Hz and 60Hz line frequency noise.

A gain of 4 V/V is recommended for applications in a wide range of hydrogen volume fractions (0 to 100 vol-%). The gains are written by the following sequence, initiated by the Start signal (S) of the master and terminated by the Stop signal (P). The 7 bit address of the converter is AD = 0100110.

| | | | | | |
|---|---|---|---|---|---|
| S | AD,0 | ACK | Configuration byte | ACK | P |

The following table configuration bytes are used to set the gain and consequently the input voltage span of the converter. These spans are resolved with a 16 bit resolution, and hence the smallest resolvable voltages increases with increasing gain. Since the balance voltage of the Wheatstone bridge decreases from zero to negative values in the presence of hydrogen, an appropriate gain should be set to prevent the converter from being overloaded.

| *Table 10. Gain, configuration byte, input voltage span, and resolvable voltages* | | | |
|---|---|---|---|
| Gain | Configuration byte | Input voltage span | Resolvable voltages |
| 1 (default) | 00000110 | ±2.5 V | 76 µV |
| 4 | 00100110 | ±0.625 V | 19 µV |
| 8 | 01000110 | ±0.3125 V | 4.77 µV |
| 16 | 01100110 | ±0.156 V | 2.38 µV |
| 32 | 10000110 | ±78 mV | 1.19 µV |
| 64 | 10100110 | ±39 mV | 0.596 µV |
| 128 | 11000110 | ±19.5 mV | 0.298 µV |
| 256 | 11100110 | ±9.77 mV | 0.149 µV |

To initiate a conversion and to receive the balance voltage, the master must perform the following Read operation:

| S | AD,1 | ACK | Data byte 1 | ACK | Data byte 2 | ACK | Data byte 3 | NACK | P |
|---|---|---|---|---|---|---|---|---|---|

After the complete Read operation of 3 bytes, the output register of the converter is emptied, a new conversion is initiated, and a following Read request in the same input/output phase will be NACKed. The converter´s output data stream is 24 bits long:

| Bit 23 SIG | Bit 22 MSB | Bit 21 | Bit 20 | … | Bit 6 LSB | Bit 5 PG2 | Bit 4 PG1 | Bit 3 PG0 | Bit 2 x | Bit 1 IM | Bit 0 SPD |
|---|---|---|---|---|---|---|---|---|---|---|---|

The first bit is the conversion result sign bit (SIG) and the second bit is the most significant bit. These two bits can be used to indicate over range conditions. If both bits are high, the differential input voltage is above + full-scale voltage and the following 16 bits are set to low to indicate an overrange condition. If both bits are low, the input voltage is below – full-scale voltage and the following 16 bits are set to high to indicate an underrange condition. The adjusted gain can be derived from the bits 5, 4, and 3 according to the following table.

| *Table 11. Gain of the converter from PG2, PG1 and PG0* | | | |
|---|---|---|---|
| PG2 | PG1 | PG0 | Gain |
| low | low | low | 1 |
| low | low | high | 4 |
| low | high | low | 8 |
| low | high | high | 16 |
| high | low | low | 32 |
| high | low | high | 64 |
| high | high | low | 128 |
| high | high | high | 256 |

Bit 2 is reserved, bit 1 (IM) refers to the internal temperature sensor (not used here), and bit 0 (SPD) indicates the output rate (not used here).

The following table and the formulae in the flow diagram in figure 12 can be used to get the voltage from the converter´s output.

*Table 12. Converter Output Format for SPD=0*

| $V_{\mathrm{bal}}$ | Bit 23 SGN | Bit 22 MSB | Bit 21 | Bit 20 | Bit 19 | … | Bit 6 |
|---|---|---|---|---|---|---|---|
| $V_{\mathrm{bal}} \geq FS$ | 1 | 1 | 0 | 0 | 0 | | 0 |
| $V_{\mathrm{bal}} = FS - 1LSB$ | 1 | 0 | 1 | 1 | 1 | | 1 |
| $V_{\mathrm{bal}} = 0.5 \cdot FS$ | 1 | 0 | 1 | 0 | 0 | | 0 |
| $V_{\mathrm{bal}} = 0.5 \cdot FS - 1LSB$ | 1 | 0 | 0 | 1 | 1 | | 1 |
| $V_{\mathrm{bal}} = 0$ | 1 | 0 | 0 | 0 | 0 | | 0 |
| $V_{\mathrm{bal}} = -1LSB$ | 0 | 1 | 1 | 1 | 1 | | 1 |
| $V_{\mathrm{bal}} = -FS$ | 0 | 1 | 0 | 0 | 0 | | 0 |
| $V_{\mathrm{bal}} < -FS$ | 0 | 0 | 1 | 1 | 1 | | 1 |
| Full-scale voltage $FS = 2.5 \frac{\mathrm{V}}{Gain}$, *LSB* = least significant bit | | | | | | | |

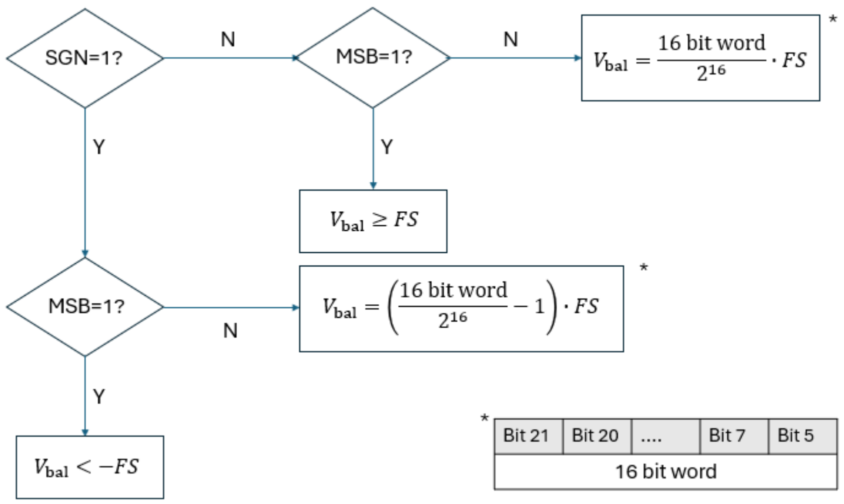


*Figure 12. Flow diagram.*

## 10.6. READING THE HOUSING TEMPERATURE

The temperature sensor is configured by the following write operation, initiated by the master with the Start signal, followed by the address AD=1001000 and the R/$\overline{\mathrm{W}}$ bit, which is a logic low. The temperature sensor acknowledges and the master sends the data byte 00000001 to set the pointer to the configuration register of the sensor.

After receiving the next acknowledge condition the master terminates the write operation with the Stop signal.

In the next Write operation the master transmits the data byte 01100000 for selecting a 12 bit resolution of the temperature. The register of the temperature sensor must subsequently set back to the temperature register issuing a Write operation with the data byte 00000000.

| S | AD,0 | ACK | Data byte | ACK | P |
|---|---|---|---|---|---|

The Read operation is initiated by the master by sending the address, followed by the R/$\overline{W}$ bit, which is a logic high. The temperature will send two data bytes according to the following sequence.

| S | AD,1 | ACK | Data byte 1 | ACK | Data byte 2 | ACK | P |
|---|---|---|---|---|---|---|---|

| Bit 15 SIG | Bit 14 MSB | Bit 13 | … | Bit 5 | Bit 4 LSB | Bit 3 0 | Bit 2 0 | Bit 1 0 | Bit 0 0 |
|---|---|---|---|---|---|---|---|---|---|

*Table 13. Temperature Sensor Output Format*

| Temperature | Bit 15 SGN | Bit 14 MSB | Bit 13 | Bit 12 | Bit 11 | Bit 10 | Bit 9 | Bit 8 | Bit 7 | Bit 6 | Bit 5 | Bit 4 | Bit 3 | Bit 2 | Bit 1 | Bit 0 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| +125 °C | 0 | 1 | 1 | 1 | 1 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| +100 °C | 0 | 1 | 1 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| +75 °C | 0 | 1 | 0 | 0 | 1 | 0 | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| +50.5 °C | 0 | 0 | 1 | 1 | 0 | 0 | 1 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| +25.25 °C | 0 | 0 | 0 | 1 | 1 | 0 | 0 | 1 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 |
| +10.125 °C | 0 | 0 | 0 | 0 | 1 | 0 | 1 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 |
| +0.0625 °C | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 |
| 0 °C | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| -0.0625 °C | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 0 | 0 | 0 | 0 | 0 |
| -10.125 °C | 1 | 1 | 1 | 1 | 0 | 1 | 0 | 1 | 1 | 1 | 1 | 0 | 0 | 0 | 0 | 0 |
| -25.25 °C | 1 | 1 | 1 | 0 | 0 | 1 | 1 | 1 | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 0 |
| -50.5 °C | 1 | 1 | 0 | 0 | 1 | 1 | 1 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| -55 °C | 1 | 1 | 0 | 0 | 1 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |

The following block scheme reveals a LabVIEW® based solution to determine the temperature from data byte 1 and 2. The 'theoretical' resolution of the temperature sensor is 0.0625 °C within the maximum temperature regime between -55 °C and +125 °C. Note, that the TCD hydrogen sensor only allows an industrial regime from -40 °C to +85 °C.

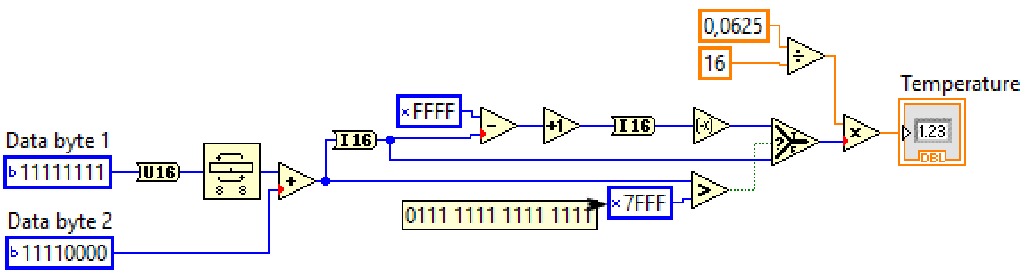


*Figure 13. LabVIEW® code to get the temperature from the two data bytes.*

# 11.FOOTPRINT AND RECOMMENDED PLUG-IN SOCKETS

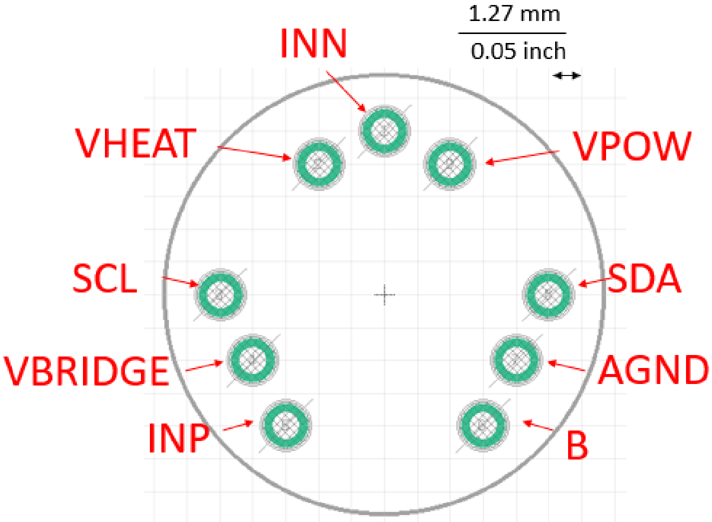


*Figure 14. Footprint*

| *Table 14* | |
|---|---|
| Recommended plug-in sockets | 450-3704-01-03-00 (Cambion) |
| Drill hole: | 1.6 mm |

# 12.ORDERING INFORMATION

Hydrogen sensor H2- TCD I2C-I

# 13.PACKAGING/SHIPPING INFORMATION

This sensor is shipped individually in an antistatic bag.

# 14. WARNINGS

⚠ **Warnings:** The sensor H2-TCD I2C-I 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 (TCD-Controller 3.1 with SBPS-LDO 3.12 and additional accessories) is available to support customers in the performance evaluation of our H2-TCD I2C-I 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

ALDERS electronic GmbH

Arnoldstraße 19 , 47906 Kempen (Germany)

sales@alders.de

+49 2152 8955-230