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# Data Sheet

## HAL<sup>®</sup> 82x

High-Precision Programmable  
Linear Hall-Effect Sensor Family

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**Contents**

<b>Page</b>	<b>Section</b>	<b>Title</b>
<b>4</b>	<b>1.</b>	<b>Introduction</b>
4	1.1.	Major Applications
4	1.2.	Features
5	1.3.	Marking Code
5	1.4.	Operating Junction Temperature Range ( $T_J$ )
5	1.5.	Hall Sensor Package Codes
5	1.6.	Solderability and Welding
5	1.7.	Pin Connections and Short Descriptions
<b>6</b>	<b>2.</b>	<b>Functional Description</b>
6	2.1.	General Function
8	2.2.	Digital Signal Processing and EEPROM
11	2.3.	Calibration Procedure
11	2.3.1.	General Procedure
<b>13</b>	<b>3.</b>	<b>Specifications</b>
13	3.1.	Outline Dimensions
17	3.2.	Dimensions of Sensitive Area
17	3.3.	Positions of Sensitive Areas
17	3.4.	Absolute Maximum Ratings
18	3.4.1.	Storage and Shelf Life
18	3.5.	Recommended Operating Conditions
19	3.6.	Characteristics
20	3.6.1.	Definition of Sensitivity Error ES
21	3.7.	Open-Circuit Detection
22	3.8.	Power-On Operation
22	3.9.	Overvoltage and Undervoltage Detection
22	3.10.	Magnetic Characteristics
<b>23</b>	<b>4.</b>	<b>Application Notes</b>
23	4.1.	Application Circuit
23	4.2.	Use of two HAL82x in Parallel
23	4.3.	Temperature Compensation
24	4.4.	Ambient Temperature
24	4.5.	EMC and ESD
<b>25</b>	<b>5.</b>	<b>Programming of the Sensor</b>
25	5.1.	Definition of Programming Pulses
25	5.2.	Definition of the Telegram
27	5.3.	Telegram Codes
28	5.4.	Number Formats
28	5.5.	Register Information
31	5.5.1.	Programming Information
<b>32</b>	<b>6.</b>	<b>Data Sheet History</b>

## High-Precision Programmable Linear Hall-Effect Sensor Family

**Release Note: Revision bars indicate significant changes to the previous edition.**

### 1. Introduction

The HAL82x is a new member of the Micronas family of programmable linear Hall sensors. As an extension to the HAL 8x5, it offers an improved temperature performance, enhanced wiring failure detection and a 14-bit multiplexed analog data output. It is possible to program different sensors which are in parallel to the same supply voltage individually.

The HAL82x is an universal magnetic field sensor with a linear output based on the Hall effect. The IC can be used for angle or distance measurements if combined with a rotating or moving magnet. The major characteristics like magnetic field range, sensitivity, output quiescent voltage (output voltage at  $B = 0$  mT), and output voltage range are programmable in a non-volatile memory. The sensor has a ratiometric output characteristic, which means that the output voltage is proportional to the magnetic flux and the supply voltage.

The HAL82x features a temperature-compensated Hall plate with chopped offset compensation, an A/D converter, digital signal processing, a D/A converter with output driver, an EEPROM memory with redundancy and lock function for the calibration data, an EEPROM for customer serial number, a serial interface for programming the EEPROM, and protection devices at all pins. The internal digital signal processing is of great benefit because analog offsets, temperature shifts, and mechanical stress do not degrade the sensor accuracy.

The HAL82x is programmable by modulating the supply voltage. No additional programming pin is needed. The easy programmability allows a 2-point calibration by adjusting the output voltage directly to the input signal (like mechanical angle, distance, or current). Individual adjustment of each sensor during the customer's manufacturing process is possible. With this calibration procedure, the tolerances of the sensor, the magnet, and the mechanical positioning can be compensated in the final assembly. This offers a low-cost alternative for all applications that presently need mechanical adjustment or laser trimming for calibrating the system.

In addition, the temperature compensation of the Hall IC can be fit to common magnetic materials by programming first and second order temperature coefficients of the Hall sensor sensitivity. This enables operation over the full temperature range with high accuracy.

The calculation of the individual sensor characteristics and the programming of the EEPROM memory can easily be done with a PC and the application kit from Micronas.

The sensor is designed for hostile industrial and automotive applications and operates with typically 5 V supply voltage in the ambient temperature range from  $-40$  °C up to  $150$  °C. The HAL82x is available in the very small leaded packages TO92UT-1 and TO92UT-2.

### 1.1. Major Applications

Due to the sensor's versatile programming characteristics and low temperature drifts, the HAL82x is the optimal system solution for applications such as:

- contactless potentiometers,
- angle sensors (like throttle position, paddle position and EGR applications),
- distance measurements,
- magnetic field and current measurement.

### 1.2. Features

- high-precision linear Hall effect sensor with ratiometric output and digital signal processing
- Low output voltage drifts over temperature
- 12-bit analog output and 14-bit multiplex analog output
- multiple programmable magnetic characteristics in a non-volatile memory (EEPROM) with redundancy and lock function
- open-circuit (ground and supply line break detection) with  $5$  k $\Omega$  pull-up and pull-down resistor, over-voltage and undervoltage detection
- for programming an individual sensor within several sensors in parallel to the same supply voltage, a selection can be done via the output pin
- temperature characteristics are programmable for matching common magnetic materials
- programmable clamping function
- programming through a modulation of the supply voltage
- operates from  $-40$  °C up to  $150$  °C ambient temperature
- operates from  $4.5$  V up to  $5.5$  V supply voltage in specification and functions up to  $8.5$  V
- operates with static magnetic fields and dynamic magnetic fields up to  $1$  kHz

- overvoltage and reverse-voltage protection at all pins
- magnetic characteristics extremely robust against mechanical stress
- short-circuit protected push-pull output
- EMC and ESD optimized design

**1.3. Marking Code**

The HAL82x has a marking on the package surface (branded side). This marking includes the name of the sensor and the temperature range.

Type	Temperature Range	
	A	K
HAL824	824A	824K
HAL825	825A	825K

**1.4. Operating Junction Temperature Range (T<sub>J</sub>)**

The Hall sensors from Micronas are specified to the chip temperature (junction temperature T<sub>J</sub>).

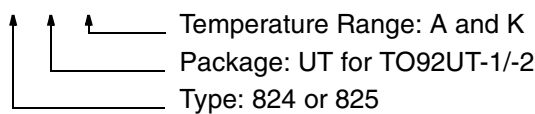
**A:** T<sub>J</sub> = -40 °C to +170 °C

**K:** T<sub>J</sub> = -40 °C to +140 °C

The relationship between ambient temperature (T<sub>A</sub>) and junction temperature is explained in Section 4.4. on page 24.

**1.5. Hall Sensor Package Codes**

HALXXXPA-T



Example: **HAL825UT-K**

- Type: 825
- Package: TO92UT
- Temperature Range: T<sub>J</sub> = -40 °C to +140 °C

Hall sensors are available in a wide variety of packaging versions and quantities. For more detailed information, please refer to the brochure: “Hall Sensors: Ordering Codes, Packaging, Handling”.

**1.6. Solderability and Welding**

**Solderability**

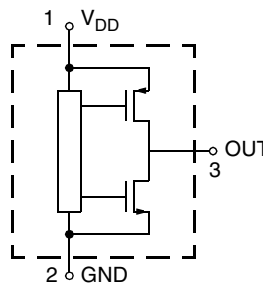
During soldering reflow processing and manual reworking, a component body temperature of 260 °C should not be exceeded.

**Welding**

Device terminals should be compatible with laser and resistance welding. Please note that the success of the welding process is subject to different welding parameters which will vary according to the welding technique used. A very close control of the welding parameters is absolutely necessary in order to reach satisfying results. Micronas, therefore, does not give any implied or express warranty as to the ability to weld the component.

**1.7. Pin Connections and Short Descriptions**

Pin No.	Pin Name	Type	Short Description
1	V <sub>DD</sub>	IN	Supply Voltage and Programming Pin
2	GND		Ground
3	OUT	OUT	Push Pull Output and Selection Pin



**Fig. 1-1: Pin configuration**

**2. Functional Description**

**2.1. General Function**

The HAL82x is a monolithic integrated circuit which provides an output voltage proportional to the magnetic flux through the Hall plate and proportional to the supply voltage (ratiometric behavior).

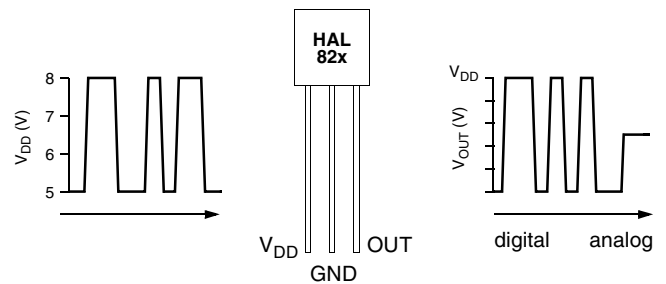
The external magnetic field component perpendicular to the branded side of the package generates a Hall voltage. The Hall IC is sensitive to magnetic north and south polarity. This voltage is converted to a digital value, processed in the Digital Signal Processing Unit (DSP) according to the settings of the EEPROM registers, converted to an analog voltage with ratiometric behavior, and stabilized by a push-pull output transistor stage. The function and the parameters for the DSP are explained in Section 2.2. on page 8.

The setting of the LOCK register disables the programming of the EEPROM memory for all time. This register cannot be reset.

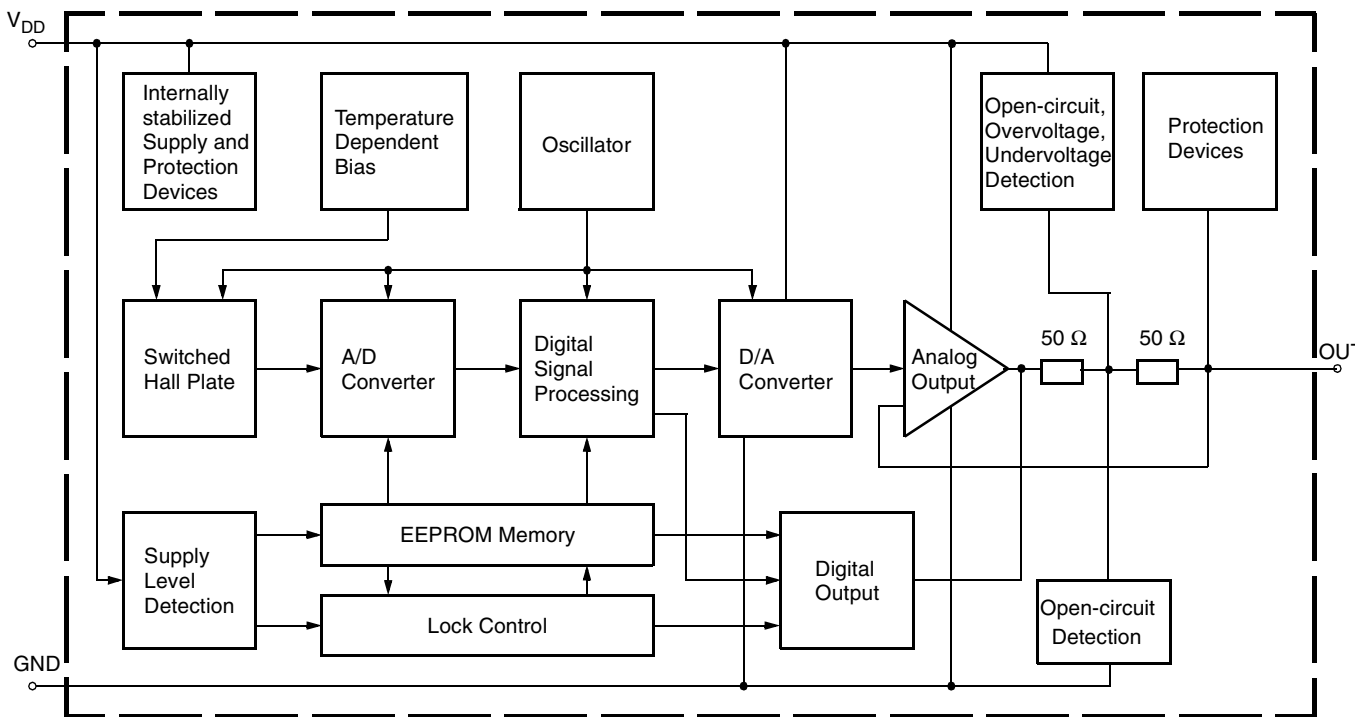
As long as the LOCK register is not set, the output characteristic can be adjusted by programming the EEPROM registers. The IC is addressed by modulating the supply voltage (see Fig. 2-1). In the supply voltage range from 4.5 V up to 5.5 V, the sensor generates an analog output voltage. After detecting a command, the sensor reads or writes the memory and answers with a digital signal on the output pin. The

analog output is switched off during the communication. Several sensors in parallel to the same supply and ground line can be programmed individually. The selection of each sensor is done via its output pin.

The open-circuit detection provides a defined output voltage if the  $V_{DD}$  or GND line is broken. Internal temperature compensation circuitry and the chopped off-set compensation enables operation over the full temperature range with minimal changes in accuracy and high offset stability. The circuitry also rejects offset shifts due to mechanical stress from the package. The non-volatile memory consists of redundant and non-redundant EEPROM cells. The non-redundant EEPROM cells are only used to store production information inside the sensor. In addition, the sensor IC is equipped with devices for overvoltage and reverse-voltage protection at all pins.



**Fig. 2-1:** Programming with  $V_{DD}$  modulation



**Fig. 2-2:** HAL82x block diagram

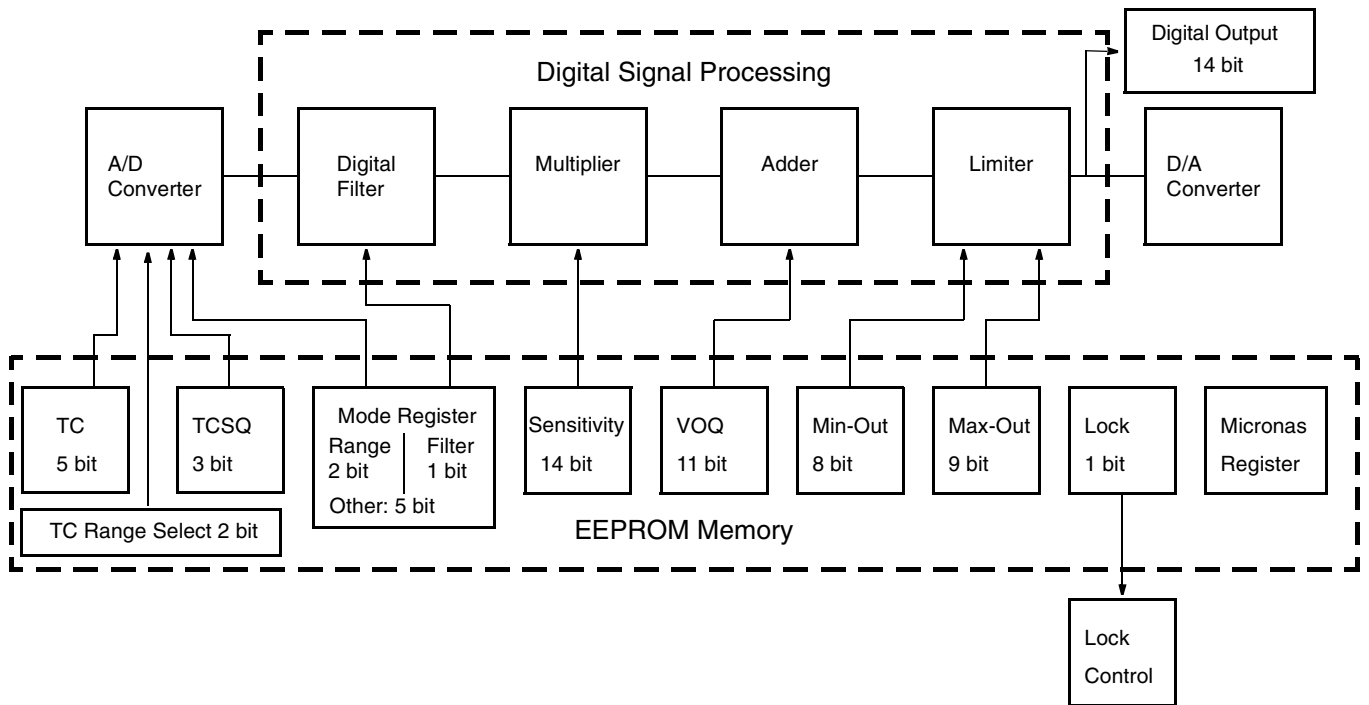


Fig. 2-3: Details of EEPROM and Digital Signal Processing



**2.2. Digital Signal Processing and EEPROM**

The DSP is the main part of this sensor and performs the signal conditioning. The parameters for the DSP are stored in the EEPROM registers. The details are shown in Fig. 2–3.

**Terminology:**

SENSITIVITY: name of the register or register value

Sensitivity: name of the parameter

The EEPROM registers consist of four groups:

Group 1 contains the registers for the adaption of the sensor to the magnetic system: MODE for selecting the magnetic field range and filter frequency, TC, TCSQ and TC-Range for the temperature characteristics of the magnetic sensitivity.

Group 2 contains the registers for defining the output characteristics: SENSITIVITY, VOQ, CLAMP-LOW, and CLAMP-HIGH. The output characteristic of the sensor is defined by these 4 parameters.

- The parameter  $V_{OQ}$  (Output Quiescent Voltage) corresponds to the output voltage at  $B = 0$  mT.
- The parameter Sensitivity defines the magnetic sensitivity:

$$Sensitivity = \frac{\Delta V_{OUT}}{\Delta B}$$

- The output voltage can be calculated as:

$$V_{OUT} \sim Sensitivity \times B + V_{OQ}$$

The output voltage range can be clamped by setting the registers CLAMP-LOW and CLAMP-HIGH in order to enable failure detection (such as short-circuits to  $V_{DD}$  or GND and open connections).

Group 3 contains the general purpose register GP. The GP Register can be used to store customer information, like a serial number after manufacturing. Micronas will use this GP REGISTER to store informations like, Lot number, wafer number, x and y position of the die on the wafer, etc. This information can be readout by the customer and stored in it's on data base or it can stay in the sensor as is.

Group 4 contains the Micronas registers and LOCK for the locking of all registers. The Micronas registers are programmed and locked during production. These registers are used for oscillator frequency trimming, A/D

converter offset compensation, and several other special settings.

An external magnetic field generates a Hall voltage on the Hall plate. The ADC converts the amplified positive or negative Hall voltage (operates with magnetic north and south poles at the branded side of the package) to a digital value. The digital signal is filtered in the internal low-pass filter and manipulated according to the settings stored in the EEPROM. The digital value after signal processing is readable in the D/A-READOUT register. Depending on the programmable magnetic range of the Hall IC, the operating range of the A/D converter is from  $-30$  mT... $+30$  mT up to  $-100$  mT... $+100$  mT.

During further processing, the digital signal is multiplied with the sensitivity factor, added to the quiescent output voltage and limited according to the clamping voltage. The result is converted to an analog signal and stabilized by a push-pull output transistor stage.

The D/A-READOUT at any given magnetic field depends on the programmed magnetic field range, the low-pass filter, TC values and CLAMP-LOW and CLAMP-HIGH. The D/A-READOUT range is min. 0 and max. 16383.

**Note:** During application design, it should be taken into consideration that the maximum and minimum D/A-READOUT should not saturate in the operational range of the specific application.

**Range**

The RANGE bits are bit 2 and 3 of the MODE register; they define the magnetic field range of the A/D converter.

Magnetic Field Range	RANGE
$-30$ mT... $30$ mT	0
$-60$ mT... $60$ mT	1
$-80$ mT... $80$ mT	2
$-100$ mT... $100$ mT	3

**Filter**

The FILTER bit is bit number 4 of the MODE register; it defines the -3 dB frequency of the digital low pass filter.

-3 dB Frequency	FILTER
500 Hz	0
1 kHz	1

**Bit Time**

The BITTIME bit is bit number 5 of the MODE register; It defines the protocol bit time for the communication between the sensor and the programmer board.

Bit Time	BITTIME
1:64 (Typ. 1.75 ms)	1
1:128 (Typ. 3.5 ms)	0

**Output Format**

The OUTPUTMODE bits are the bits number 6 to 7 of the MODE register; They define the different output modes.

Output Format	OUTPUTMODE
Analog Output (12 bit)	0
Internal Burn-In Mode	2
Multiplex Analog Output (external trigger)	-

In Analog Output mode, the sensor provides an ratio-metric 12-bit analog output voltage between 0 V and 5 V.

In Multiplex Analog Output mode, the sensor transmits the LSN and MSN of the output value separately. This enables the sensor to transmit a 14-bit signal. In external trigger mode the ECU can switch the output of the sensor between LSN and MSN by changing current flow direction through sensor output. In case the output is pulled up by a 10 kΩ resistor the sensor sends the MSN. If the output is pulled down the sensor will send the LSN. Maximum refresh rate is about 500 Hz (2 ms). Three pins are sufficient.

**Note:** Please contact Micronas for further information about Multiplex Analog Output Mode.

In Burn-In Mode, the signal path of the sensors DSP is stimulated internally without applied magnetic field. In this mode, the sensor provides a “saw tooth” shape output signal. Shape and frequency of the saw tooth signal depends on the programming of the sensor. This mode can be used for Burn-In test in the customers production line.

**TC Register**

The temperature dependence of the magnetic sensitivity can be adapted to different magnetic materials in order to compensate for the change of the magnetic strength with temperature. The adaption is done by programming the TC (Temperature Coefficient) and the TCSQ registers (Quadratic Temperature Coefficient). Thereby, the slope and the curvature of the temperature dependence of the magnetic sensitivity can be matched to the magnet and the sensor assembly. As a result, the output voltage characteristic can be fixed over the full temperature range. The sensor can compensate for linear temperature coefficients ranging from about -3100 ppm/K up to 1000 ppm/K and quadratic coefficients from about -7 ppm/K<sup>2</sup> to 2 ppm/K<sup>2</sup>. The full TC range is separated in the following four ranges:

TC-Range [ppm/k]	GROUP
-3100 to -1800	0
-1750 to -550	2
-500 to +450 (default value)	1
+450 to +1000	3

TC (5 bit) and TCSQ (3 bit) have to be selected individually within each of the four ranges. For example: 0 ppm/k requires TC-Range = 1, TC = 15 and TCSQ = 1.

**Sensitivity**

The SENSITIVITY register contains the parameter for the multiplier in the DSP. The Sensitivity is programmable between -4 and 4. For  $V_{DD} = 5\text{ V}$ , the register can be changed in steps of 0.00049.

For all calculations, the digital value from the magnetic field of the D/A converter is used. This digital information is readable from the D/A-READOUT register.

$$\text{SENSITIVITY} = \frac{\Delta V_{out} \times 16384}{2 \cdot \Delta \text{DA-Readout} \cdot V_{DD}}$$

**VOQ**

The VOQ register contains the parameter for the adder in the DSP.  $V_{OQ}$  is the output voltage without external magnetic field ( $B = 0\text{ mT}$ ) and programmable from  $-V_{DD}$  up to  $V_{DD}$ . For  $V_{DD} = 5\text{ V}$ , the register can be changed in steps of 4.9 mV.

**Note:** If  $V_{OQ}$  is programmed to a negative voltage, the maximum output voltage is limited to:

$$V_{OUTmax} = V_{OQ} + V_{DD}$$

**Clamping Voltage**

The output voltage range can be clamped in order to detect failures like shorts to  $V_{DD}$  or GND or an open circuit.

The CLAMP-LOW register contains the parameter for the lower limit. The lower clamping voltage is programmable between 0 V and  $V_{DD}/2$ . For  $V_{DD} = 5\text{ V}$ , the register can be changed in steps of 9.77 mV.

The CLAMP-HIGH register contains the parameter for the upper limit. The upper clamping voltage is programmable between 0 V and  $V_{DD}$ . For  $V_{DD} = 5\text{ V}$ , in steps of 9.77 mV.

**GP Register**

This register can be used to store some information, like production date or customer serial number. Micronas will store production Lot number, wafer number and x,y coordinates in three blocks of this registers. The total register contains of four blocks with a length of 13 bit each. The customer can read out this information and store it in his own production data base for reference or he can change them and store own production information.

**Note:** To enable programming of the GP register bit 0 of the MODE register has to be set to 1. This register is not a guarantee for trace-ability.

**LOCKR**

By setting the first bit of this 2-bit register, all registers will be locked, and the sensor will no longer respond to any supply voltage modulation. This bit is active after the first power-off and power-on sequence after setting the LOCK bit.

**Warning: This register cannot be reset!**

**D/A-READOUT**

This 14-bit register delivers the actual digital value of the applied magnetic field after the signal processing. This register can be read out and is the basis for the calibration procedure of the sensor in the system environment.

**Note:** The MSB and LSB are reversed compared with all the other registers. Please reverse this register after readout.

**2.3. Calibration Procedure**

**2.3.1. General Procedure**

For calibration in the system environment, the application kit from Micronas is recommended. It contains the hardware for the generation of the serial telegram for programming (Programmer Board Version 5.1) and the corresponding software (PC824 and PC825) for the input of the register values.

For the individual calibration of each sensor in the customer application, a two point adjustment is recommended. The calibration shall be done as follows:

**Step 1: Input of the registers which need not be adjusted individually**

The magnetic circuit, the magnetic material with its temperature characteristics, the filter frequency, the output mode and the GP Register value are given for this application. Therefore, the values of the following registers should be identical for all sensors of the customer application.

- FILTER  
(according to the maximum signal frequency)
- RANGE  
(according to the maximum magnetic field at the sensor position)
- OUTPUTMODE
- TC, TCSQ and TC-RANGE  
(depends on the material of the magnet and the other temperature dependencies of the application)
- GP  
(if the customer wants to store own production information. It is not necessary to change this register)

As the clamping voltages are given. They have an influence on the D/A-Readout value and have to be set therefore after the adjustment process.

Write the appropriate settings into the HAL82x registers.

**Step 2: Initialize DSP**

As the D/A-READOUT register value depends on the settings of SENSITIVITY, VOQ and CLAMP-LOW/HIGH, these registers have to be initialized with defined values, first:

- $VOQ_{INITIAL} = 2.5 \text{ V}$
- $Sensitivity_{INITIAL} = 0.5$
- Clamp-Low = 0 V
- Clamp-High = 4.999 V

**Step 3: Define Calibration Points**

The calibration points 1 and 2 can be set inside the specified range. The corresponding values for  $V_{OUT1}$  and  $V_{OUT2}$  result from the application requirements.

$$Lowclampingvoltage \leq V_{OUT1,2} \leq Highclampingvoltage$$

For highest accuracy of the sensor, calibration points near the minimum and maximum input signal are recommended. The difference of the output voltage between calibration point 1 and calibration point 2 should be more than 3.5 V.

**Step 4: Calculation of  $V_{OQ}$  and Sensitivity**

Set the system to calibration point 1 and read the register D/A-READOUT. The result is the value D/A-READOUT1.

Now, set the system to calibration point 2, read the register D/A-READOUT again, and get the value D/A-READOUT2.

With these values and the target values  $V_{OUT1}$  and  $V_{OUT2}$ , for the calibration points 1 and 2, respectively, the values for Sensitivity and  $V_{OQ}$  are calculated as:

$$Sensitivity = \frac{1}{2} \times \frac{(V_{out2} - V_{out1})}{(D/A-Readout2 - D/A-Readout1)} \times \frac{16384}{5}$$

$$V_{OQ} = \frac{1}{16} \times \left[ \frac{V_{out2} \times 16384}{5} - [(D/A-Readout2 - 8192) \times Sensitivity \times 2] \right] \times \frac{5}{1024}$$

This calculation has to be done individually for each sensor.

Next, write the calculated values for Sensitivity and  $V_{OQ}$  into the IC for adjusting the sensor. At that time it is also possible to store the application specific values for Clamp-Low and Clamp-High into the sensors EEPROM.

The sensor is now calibrated for the customer application. However, the programming can be changed again and again if necessary.

---

**Note:** For a recalibration, the calibration procedure has to be started at the beginning (step 1). A new initialization is necessary, as the initial values from step 1 are overwritten in step 4.

---

#### **Step 5: Locking the Sensor**

The last step is activating the LOCK function by programming the LOCK bit. Please note that the LOCK function becomes effective after power-down and power-up of the Hall IC. The sensor is now locked and does not respond to any programming or reading commands.

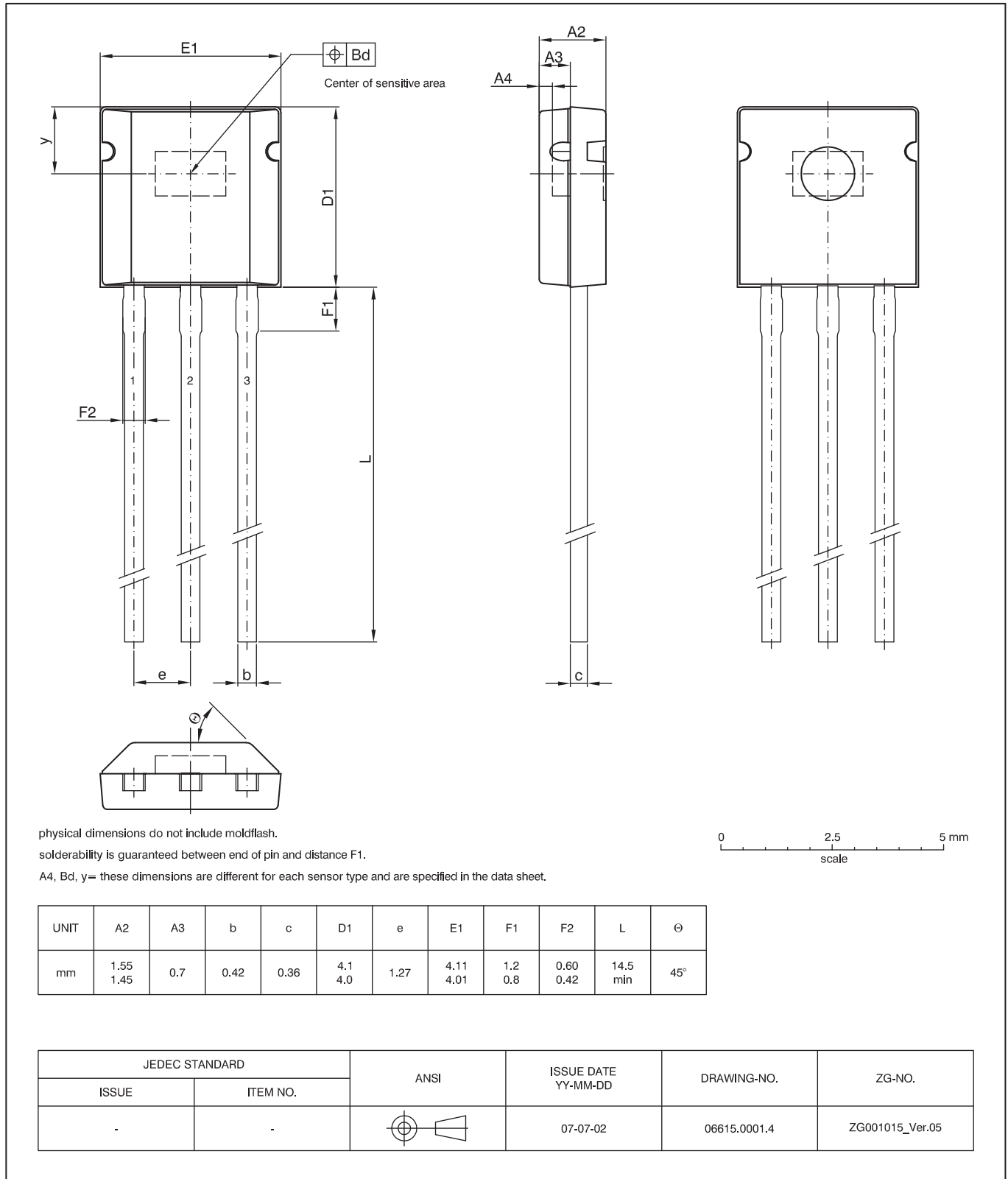
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**Warning: This register can not be reset!**

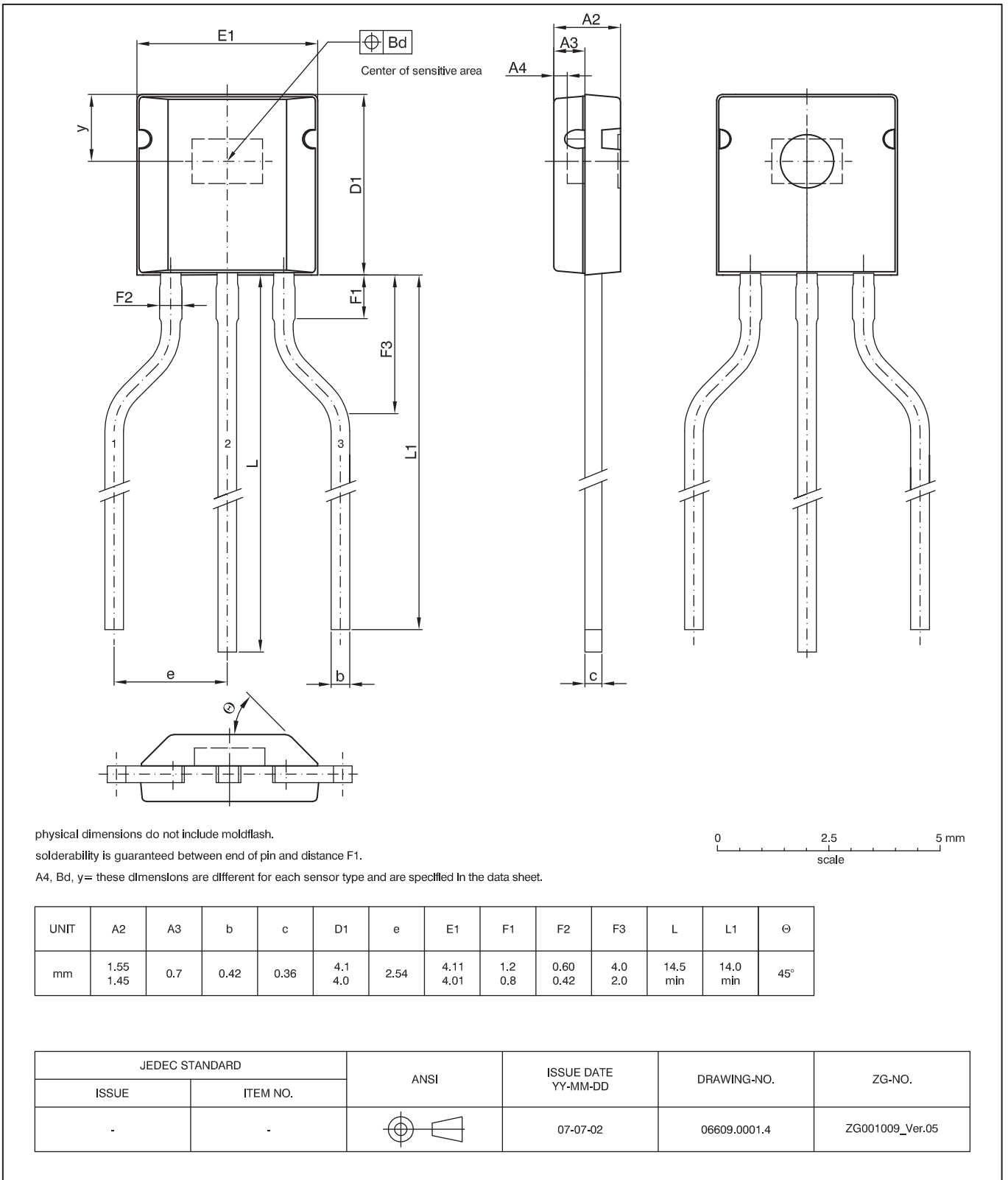
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3. Specifications

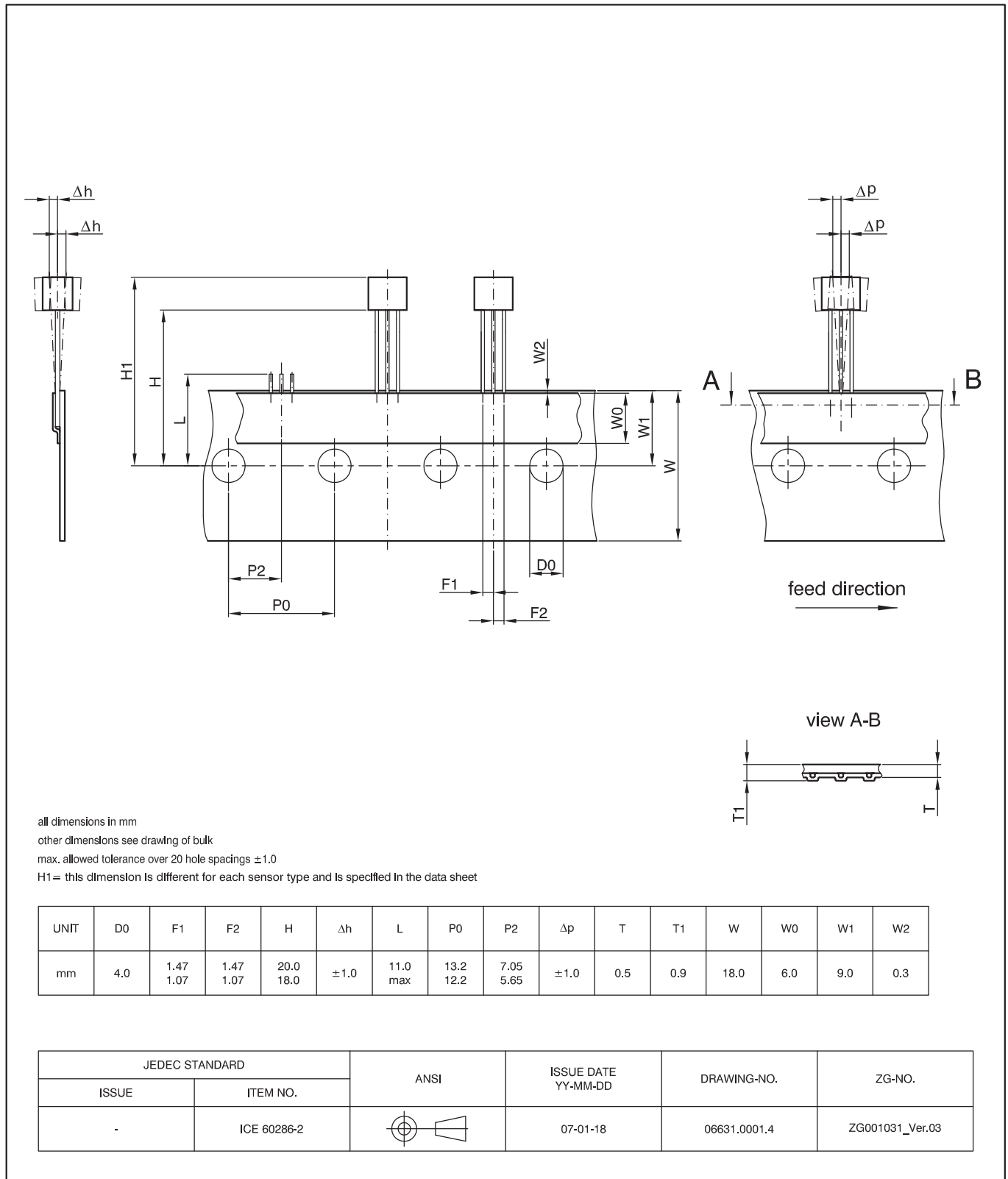
3.1. Outline Dimensions



**Fig. 3-1:**  
**TO92UT-2:** Plastic Transistor Standard UT package, 3 leads, not spread  
 Weight approximately 0.12 g

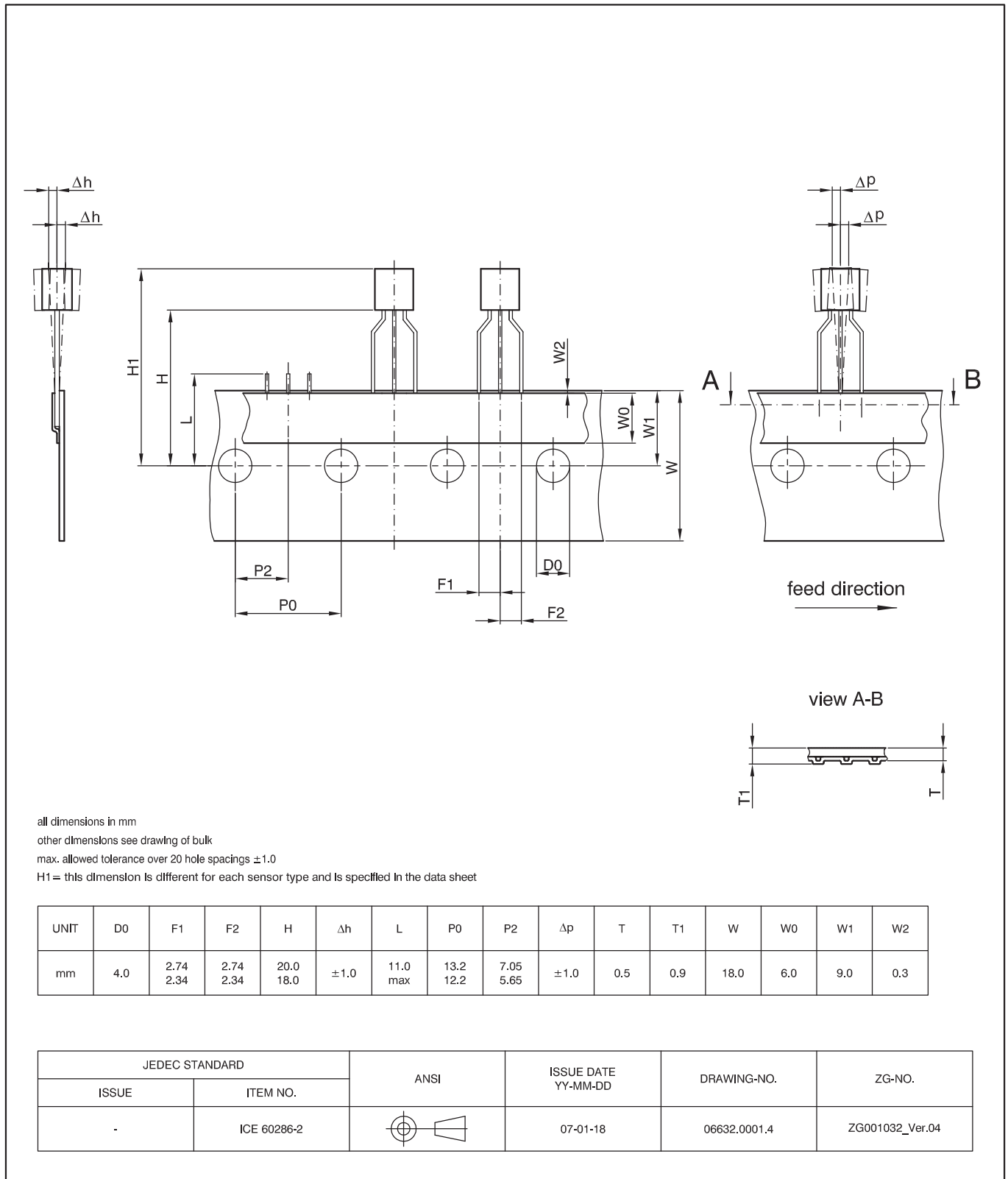


**Fig. 3-2:**  
**TO92UT-1:** Plastic Transistor Standard UT package, 3 leads, spread  
Weight approximately 0.12 g



**Fig. 3-3:**  
**TO92UT-2: Dimensions ammpack inline, not spread**





**Fig. 3-4:**  
**TO92UT-1: Dimensions ammopack inline, spread**

### 3.2. Dimensions of Sensitive Area

0.25 mm x 0.25 mm

### 3.3. Positions of Sensitive Areas

TO92UT-1/-2	
y	1.5 mm nominal
A4	0.3 mm nominal
Bd	0.3 mm

### 3.4. Absolute Maximum Ratings

Stresses beyond those listed in the “Absolute Maximum Ratings” may cause permanent damage to the device. This is a stress rating only. Functional operation of the device at these conditions is not implied. Exposure to absolute maximum rating conditions for extended periods will affect device reliability.

This device contains circuitry to protect the inputs and outputs against damage due to high static voltages or electric fields; however, it is advised that normal precautions be taken to avoid application of any voltage higher than absolute maximum-rated voltages to this circuit.

All voltages listed are referenced to ground (GND).

Symbol	Parameter	Pin No.	Min.	Max.	Unit
$V_{DD}$	Supply Voltage	1	-8.5	8.5	V
$V_{DD}$	Supply Voltage	1	-14.4 <sup>1) 2)</sup>	14.4 <sup>1) 2)</sup>	V
$-I_{DD}$	Reverse Supply Current	1	-	50 <sup>1)</sup>	mA
$V_{OUT}$	Output Voltage	3	-5 <sup>5)</sup> -5 <sup>5)</sup>	8.5 <sup>3)</sup> 14.4 <sup>3) 2)</sup>	V
$V_{OUT} - V_{DD}$	Excess of Output Voltage over Supply Voltage	3,1	-	2	V
$I_{OUT}$	Continuous Output Current	3	-10	10	mA
$t_{Sh}$	Output Short Circuit Duration	3	-	10	min
$T_J$	Junction Temperature Range		-40 -40	170 <sup>4)</sup> 150	°C °C
$N_{PROG}$	Number of Programming Cycles		-	100	
1) as long as $T_{Jmax}$ is not exceeded 2) $t < 10$ min ( $V_{DDmin} = -15$ V for $t < 1$ min, $V_{DDmax} = 16$ V for $t < 1$ min) 3) as long as $T_{Jmax}$ is not exceeded, output is not protected to external 14 V-line (or to -14 V) 4) $t < 1000$ h 5) internal protection resistor = 50 $\Omega$					

### 3.4.1. Storage and Shelf Life

The permissible storage time (shelf life) of the sensors is unlimited, provided the sensors are stored at a maximum of 30 °C and a maximum of 85% relative humidity. At these conditions, no Dry Pack is required.

Solderability is guaranteed for one year from the date code on the package.

### 3.5. Recommended Operating Conditions

Functional operation of the device beyond those indicated in the “Recommended Operating Conditions/Characteristics” is not implied and may result in unpredictable behavior, reduce reliability and lifetime of the device.

All voltages listed are referenced to ground (GND).

Symbol	Parameter	Pin No.	Min.	Typ.	Max.	Unit
V <sub>DD</sub>	Supply Voltage	1	4.5	5	5.5	V
I <sub>OUT</sub>	Continuous Output Current	3	-1	-	1	mA
R <sub>L</sub>	Load Resistor	3	5.0	10	-	kΩ
C <sub>L</sub>	Load Capacitance	3	0.33	10	1000	nF
R <sub>L</sub> : Can be pull-up or pull-down resistor						

**3.6. Characteristics**

at  $T_J = -40\text{ °C}$  to  $+170\text{ °C}$ ,  $V_{DD} = 4.5\text{ V}$  to  $5.5\text{ V}$ ,  $GND = 0\text{ V}$  after programming and locking, at Recommended Operation Conditions if not otherwise specified in the column “Conditions”.  
 Typical Characteristics for  $T_J = 25\text{ °C}$  and  $V_{DD} = 5\text{ V}$ .

Symbol	Parameter	Pin No.	Min.	Typ.	Max.	Unit	Conditions
$I_{DD}$	Supply Current over Temperature Range	1	–	7	10	mA	
$V_{DDZ}$	Overshoot Protection at Supply	1	–	17.5	20	V	$I_{DD} = 25\text{ mA}$ , $T_J = 25\text{ °C}$ , $t = 20\text{ ms}$
$V_{OZ}$	Overshoot Protection at Output	3	–	17	19.5	V	$I_O = 10\text{ mA}$ , $T_J = 25\text{ °C}$ , $t = 20\text{ ms}$
	Resolution	3	–	12	–	bit	ratiometric to $V_{DD}$ <sup>1)</sup>
DNL	Differential Non-Linearity of D/A Converter	3	–0.9	0	0.9	LSB	For HAL824: Only at $25\text{ °C}$ ambient temperature
			–2.0	0	2.0	LSB	For HAL825: Only at $25\text{ °C}$ ambient temperature
INL	Non-Linearity of Output Voltage over Temperature	3	–0.5	0	0.5	%	% of supply voltage <sup>2)</sup> For $V_{out} = 0.35\text{ V} \dots 4.65\text{ V}$ ; $V_{DD} = 5\text{ V}$
$E_R$	Ratiometric Error of Output over Temperature (Error in $V_{OUT} / V_{DD}$ )	3	–0.5	0	0.5	%	$ V_{OUT1} - V_{OUT2}  > 2\text{ V}$ during calibration procedure
Voffset	Offset Drift over Temperature Range $ V_{OUT}(B = 0\text{ mT})_{25\text{ °C}} - V_{OUT}(B = 0\text{ mT})_{max} $	3	0	0.1	0.2	% $V_{DD}$	For HAL824: $V_{DD} = 5\text{ V}$ ; 60 mT range, 3 db frequency = 500 Hz, TC = 15, TCSQ= 1, TC-Range = 1, $-0.6 < \text{sensitivity} < 0.6$
			0	0.15	0.25	% $V_{DD}$	For HAL825: $V_{DD} = 5\text{ V}$ ; 60 mT range, 3 db frequency = 500 Hz, TC = 15, TCSQ= 1, TC-Range = 1, $-0.6 < \text{sensitivity} < 0.6$
ES	Error in Magnetic Sensitivity over Temperature Range	3	–1	0	1	%	For HAL824: $V_{DD} = 5\text{ V}$ ; 60 mT range, 3 db frequency = 500 Hz, TC & TCSQ selection for 0 ppm/k (see Section 3.6.1. on page 20)
			–2	0	2	%	For HAL824 & HAL825: $V_{DD} = 5\text{ V}$ ; 60 mT range, 3 db frequency = 500 Hz, TC & TCSQ selection for linearized temperature coefficients in TC-Range = 1 (see Section 3.6.1. on page 20)
$\Delta V_{OUTCL}$	Accuracy of Output Voltage at Clamping Low Voltage over Temperature Range	3	–45	0	45	mV	$R_L = 5\text{ k}\Omega$ , $V_{DD} = 5\text{ V}$
$\Delta V_{OUTCH}$	Accuracy of Output Voltage at Clamping High Voltage over Temperature Range	3	–45	0	45	mV	$R_L = 5\text{ k}\Omega$ , $V_{DD} = 5\text{ V}$
$V_{OUTH}$	Upper Limit of Signal Band <sup>3)</sup>	3	4.65	4.8	–	V	$V_{DD} = 5\text{ V}$ , $-1\text{ mA} \leq I_{OUT} \leq 1\text{ mA}$
$V_{OUTL}$	Lower Limit of Signal Band <sup>3)</sup>	3	–	0.2	0.35	V	$V_{DD} = 5\text{ V}$ , $-1\text{ mA} \leq I_{OUT} \leq 1\text{ mA}$
$f_{ADC}$	Internal ADC Frequency over Temperature Range	–	–	128	–	kHz	

1) Output DAC full scale = 5 V ratiometric, Output DAC offset = 0 V, Output DAC LSB =  $V_{DD}/4096$   
 2) if more than 50% of the selected magnetic field range is used and the temperature compensation is suitable  
 3) Signal Band Area with full accuracy is located between  $V_{OUTL}$  and  $V_{OUTH}$ . The sensor accuracy is reduced below  $V_{OUTL}$  and above  $V_{OUTH}$

Symbol	Parameter	Pin No.	Min.	Typ.	Max.	Unit	Conditions
t <sub>r(O)</sub>	Step Response Time of Output	3	–	3 2	5 4	ms ms	3 dB Filter frequency = 500 Hz 3 dB Filter frequency = 1 kHz C <sub>L</sub> = 10 nF, time from 10% to 90% of final output voltage for a step like signal B <sub>step</sub> from 0 mT to B <sub>max</sub>
t <sub>d(O)</sub>	Delay Time of Output	3	–	0.1	0.5	ms	C <sub>L</sub> = 10 nF
t <sub>POD</sub>	Power-Up Time (Time to Reach Stabilized Output Voltage)	–	1.5	1.7	1.9	ms	C <sub>L</sub> = 10 nF, 90% of V <sub>OUT</sub>
BW	Small Signal Bandwidth (–3 dB)	3	–	1	–	kHz	B <sub>AC</sub> < 10 mT; 3 dB Filter frequency = 1 kHz
V <sub>OUTn</sub>	Noise Output Voltage <sub>pp</sub>	3	–	6	15	mV	magnetic range = 60 mT <sup>4)</sup> 3 dB Filter frequency = 500 Hz Sensitivity ≤ 0.7; C = 4.7 nF (V <sub>DD</sub> & V <sub>OUT</sub> to GND)
R <sub>OUT</sub>	Output Resistance over Recommended Operating Range	3	–	1	10	Ω	V <sub>OUTLmax</sub> ≤ V <sub>OUT</sub> ≤ V <sub>OUTHmin</sub>
<b>TO92UT Packages</b>							
R <sub>thja</sub>	Thermal Resistance Junction to Air	–	–	–	235	K/W	Measured with a 1s0p board
R <sub>thjc</sub>	Junction to Case	–	–	–	61	K/W	Measured with a 1s0p board
R <sub>thjs</sub>	Junction to Solder Point	–	–	–	128	K/W	Measured with a 1s1p board
4) peak-to-peak value exceeded: 5%							

**3.6.1. Definition of Sensitivity Error ES**

ES is the maximum of the absolute value of 1 minus the quotient of the normalized measured value<sup>1)</sup> over the normalized ideal linear<sup>2)</sup> value:

$$ES = \max \left( \text{abs} \left( \frac{\text{meas}}{\text{ideal}} - 1 \right) \right) \Big|_{[T_{\min}, T_{\max}]}$$

In the below example, the maximum error occurs at -10 °C:

$$ES = \frac{1.001}{0.992} - 1 = 0.9\%$$

1) normalized to achieve a least-square-fit straight-line that has a value of 1 at 25 °C

2) normalized to achieve a value of 1 at 25 °C

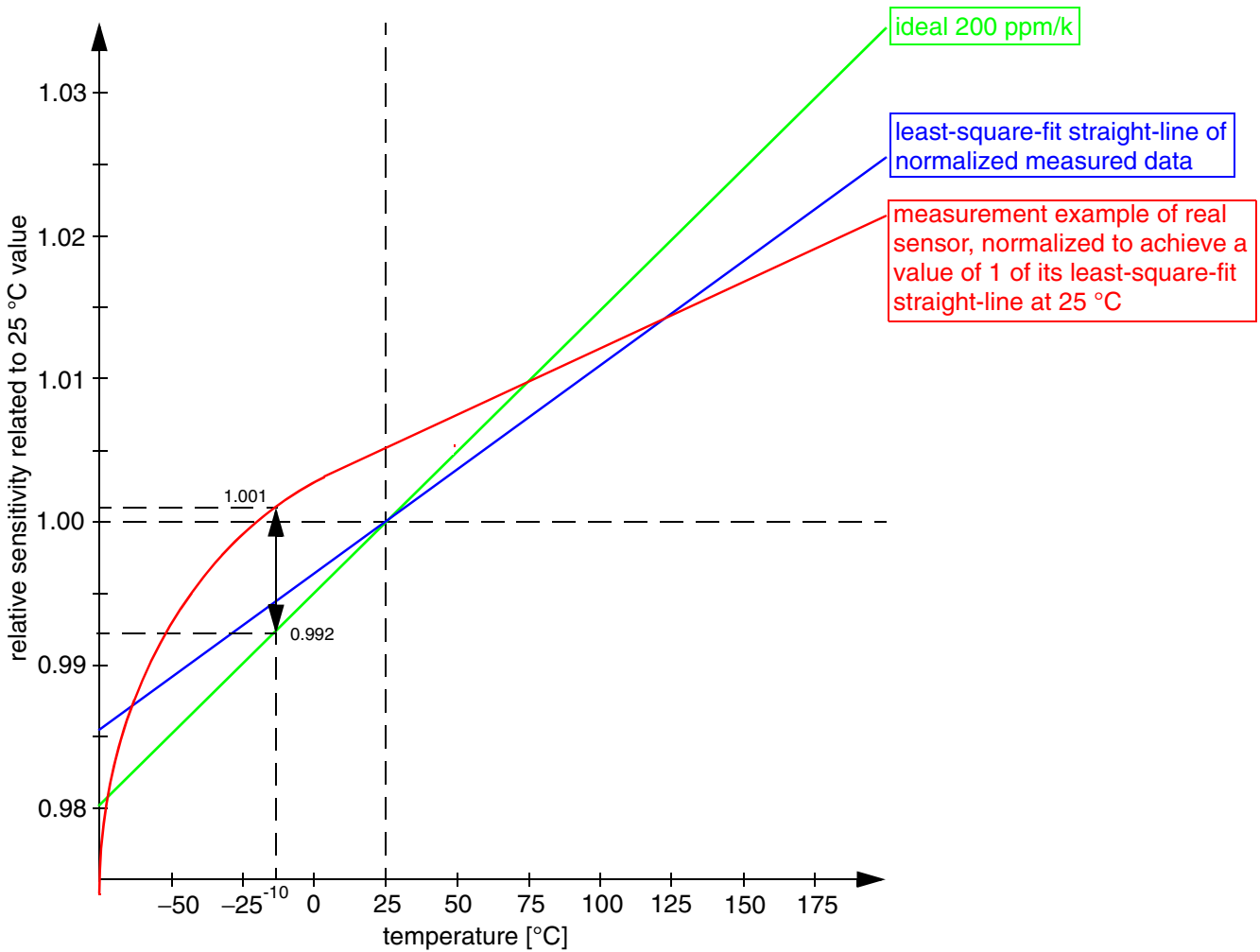


Fig. 3-5: ES definition example

3.7. Open-Circuit Detection

at  $T_J = -40\text{ °C}$  to  $+170\text{ °C}$ , Typical Characteristics for  $T_J = 25\text{ °C}$ , after locking the sensor

Symbol	Parameter	Pin No.	Min.	Typ.	Max.	Unit	Comment
$V_{OUT}$	Output Voltage at Open $V_{DD}$ Line	3	0	0	0.15	V	$V_{DD} = 5\text{ V}$ $R_L = 10\text{ k}\Omega$ to $200\text{ k}\Omega$
			0	0	0.2	V	$V_{DD} = 5\text{ V}$ $R_L = 5\text{ k}\Omega$ to $10\text{ k}\Omega$
$V_{OUT}$	Output Voltage at Open GND Line	3	4.85	4.9	5.0	V	$V_{DD} = 5\text{ V}$ $10\text{ k}\Omega \geq R_L \leq 200\text{ k}\Omega$
			4.8	4.9	5.0	V	$V_{DD} = 5\text{ V}$ $5\text{ k}\Omega \geq R_L < 10\text{ k}\Omega$

$R_L$ : Can be pull-up or pull-down resistor

### 3.8. Power-On Operation

at  $T_J = -40\text{ °C}$  to  $+170\text{ °C}$ , after programming and locking. Typical Characteristics for  $T_J = 25\text{ °C}$ .

Symbol	Parameter	Min.	Typ.	Max.	Unit
POR <sub>UP</sub>	Power-On Reset Voltage (UP)	–	3.4	–	V
POR <sub>DOWN</sub>	Power-On Reset Voltage (DOWN)	–	3.0	–	V

### 3.9. Overvoltage and Undervoltage Detection

at  $T_J = -40\text{ °C}$  to  $+170\text{ °C}$ , Typical Characteristics for  $T_J = 25\text{ °C}$ , after programming and locking

Symbol	Parameter	Pin No.	Min.	Typ.	Max.	Unit	Test Conditions
V <sub>DD,UV</sub>	Undervoltage Detection Level	1	–	4.2	4.3	V	1)
V <sub>DD,OV</sub>	Overvoltage Detection Level	1	8.5	8.9	10.0	V	1)

1) If the supply voltage drops below V<sub>DD,UV</sub> or rises above V<sub>DD,OV</sub>, the output voltage is switched to V<sub>DD</sub> ( $\geq 97\%$  of V<sub>DD</sub> at R<sub>L</sub> = 10 k $\Omega$  to GND). The CLAMP-LOW register has to be set to a voltage  $\geq 200\text{ mV}$ .

**Note: The over- and undervoltage detection is activated only after locking the sensor!**

### 3.10. Magnetic Characteristics

at  $T_J = -40\text{ °C}$  to  $+170\text{ °C}$ , V<sub>DD</sub> = 4.5 V to 5.5 V, GND = 0 V after programming and locking, at Recommended Operation Conditions if not otherwise specified in the column "Conditions". Typical Characteristics for  $T_J = 25\text{ °C}$  and V<sub>DD</sub> = 5 V.

Symbol	Parameter	Pin No.	Min.	Typ.	Max.	Unit	Test Conditions
B <sub>Offset</sub>	Magnetic Offset	3	–0.5	0	0.5	mT	B = 0 mT, I <sub>OUT</sub> = 0 mA, T <sub>J</sub> = 25 °C, unadjusted sensor
$\Delta B_{\text{Offset}}/\Delta T$	Magnetic Offset Change due to T <sub>J</sub>		–10	0	10	$\mu\text{T/K}$	B = 0 mT, I <sub>OUT</sub> = 0 mA

4. Application Notes

4.1. Application Circuit

For EMC protection, it is recommended to connect one ceramic 4.7 nF capacitor each between ground and the supply voltage, respectively the output voltage pin. In addition, the input of the controller unit should be pulled-down with a 10 kΩ resistor and a ceramic 4.7 nF capacitor.

Please note that during programming, the sensor will be supplied repeatedly with the programming voltage of 12.5 V for 100 ms. All components connected to the V<sub>DD</sub> line at this time must be able to resist this voltage.

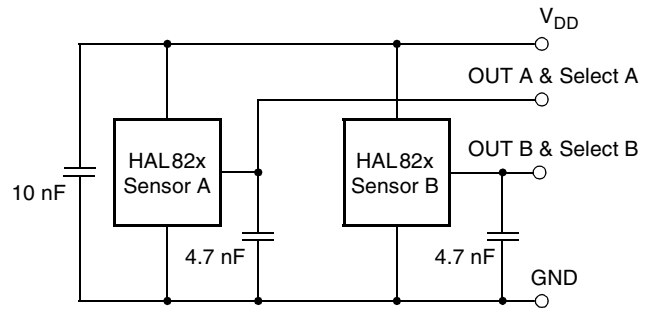


Fig. 4-2: Parallel operation of two HAL82x

4.3. Temperature Compensation

The relationship between the temperature coefficient of the magnet and the corresponding TC, TCSQ and TC-Range codes for linear compensation is given in the following table. In addition to the linear change of the magnetic field with temperature, the curvature can be adjusted as well. For this purpose, other TC, TCSQ and TC-Range combinations are required which are not shown in the table. Please contact Micronas for more detailed information on this higher order temperature compensation.

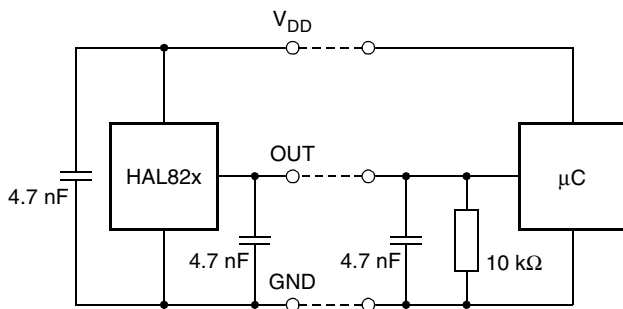


Fig. 4-1: Recommended application circuit

4.2. Use of two HAL82x in Parallel

Two different HAL82x sensors which are operated in parallel to the same supply and ground line can be programmed individually. In order to select the IC which should be programmed, both Hall ICs are inactivated by the “Deactivate” command on the common supply line. Then, the appropriate IC is activated by an “Activate” pulse on its output. Only the activated sensor will react to all following read, write, and program commands. If the second IC has to be programmed, the “Deactivate” command is sent again, and the second IC can be selected.

**Note:** The multi-programming of two sensors works only if the outputs of the two sensors are pulled to GND with a 10 kΩ pull-down resistor.

Temperature Coefficient of Magnet (ppm/K)	TC-Range	TC	TCSQ
1075	3	31	7
1000	3	28	1
900	3	24	0
750	3	16	2
675	3	12	2
575	3	8	2
450	3	4	2
400	1	31	0
250	1	24	1
150	1	20	1
50	1	16	2
0	1	15	1
-100	1	12	0
-200	1	8	1
-300	1	4	4
-400	1	0	7



Temperature Coefficient of Magnet (ppm/K)	TC-Range	TC	TCSQ
-500	1	0	0
-600	2	31	2
-700	2	28	1
-800	2	24	3
-900	2	20	6
-1000	2	16	7
-1100	2	16	2
-1200	2	12	5
-1300	2	12	0
-1400	2	8	3
-1500	2	4	7
-1600	2	4	1
-1700	2	0	6
-1800	0	31	6
-1900	0	28	7
-2000	0	28	2
-2100	0	24	6
-2200	0	24	1
-2400	0	20	0
-2500	0	16	5
-2600	0	14	5
-2800	0	12	1
-2900	0	8	6
-3000	0	8	3
-3100	0	4	7
-3300	0	4	1
-3500	0	0	4

**Note:** The above table shows only some approximate values. Micronas recommends to use the TC-Calc software to find optimal settings for temperature coefficients. Please contact Micronas for more detailed information.

#### 4.4. Ambient Temperature

Due to the internal power dissipation, the temperature on the silicon chip (junction temperature  $T_J$ ) is higher than the temperature outside the package (ambient temperature  $T_A$ ).

$$T_J = T_A + \Delta T$$

At static conditions and continuous operation, the following equation applies:

$$\Delta T = I_{DD} \times V_{DD} \times R_{th,J}$$

For typical values, use the typical parameters. For worst case calculation, use the max. parameters for  $I_{DD}$  and  $R_{th}$ , and the max. value for  $V_{DD}$  from the application.

For  $V_{DD} = 5.5 \text{ V}$ ,  $R_{th} = 235 \text{ K/W}$ , and  $I_{DD} = 10 \text{ mA}$ , the temperature difference  $\Delta T = 12.93 \text{ K}$ .

For all sensors, the junction temperature  $T_J$  is specified. The maximum ambient temperature  $T_{Amax}$  can be calculated as:

$$T_{Amax} = T_{Lmax} - \Delta T$$

#### 4.5. EMC and ESD

The HAL82x is designed for a stabilized 5 V supply. Interferences and disturbances conducted along the 12 V on board system (product standard ISO 7637 part 1) are not relevant for these applications.

For applications with disturbances by capacitive or inductive coupling on the supply line or radiated disturbances, the application circuit shown in Fig. 4-1 is recommended. Applications with this arrangement should pass the EMC tests according to the product standards ISO 7637 part 3 (Electrical transient transmission by capacitive or inductive coupling).

Please contact Micronas for the detailed investigation reports with the EMC and ESD results.

**5. Programming of the Sensor**

**5.1. Definition of Programming Pulses**

The sensor is addressed by modulating a serial telegram on the supply voltage. The sensor answers with a serial telegram on the output pin.

The bits in the serial telegram have a different bit time for the  $V_{DD}$ -line and the output. The bit time for the  $V_{DD}$ -line is defined through the length of the Sync Bit at the beginning of each telegram. The bit time for the output is defined through the Acknowledge Bit.

A logical “0” is coded as no voltage change within the bit time. A logical “1” is coded as a voltage change between 50% and 80% of the bit time. After each bit, a voltage change occurs.

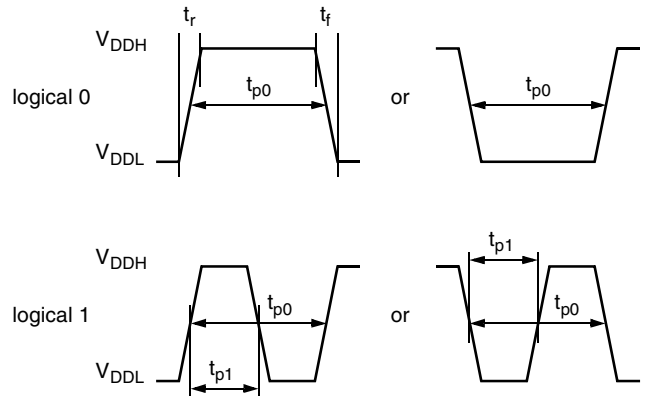
**5.2. Definition of the Telegram**

Each telegram starts with the Sync Bit (logical 0), 3 bits for the Command (COM), the Command Parity Bit (CP), 4 bits for the Address (ADR), and the Address Parity Bit (AP).

There are 4 kinds of telegrams:

- Write a register (see Fig. 5–2)  
After the AP Bit, follow 14 Data Bits (DAT) and the Data Parity Bit (DP). If the telegram is valid and the command has been processed, the sensor answers with an Acknowledge Bit (logical 0) on the output.

- Read a register (see Fig. 5–3)  
After evaluating this command, the sensor answers with the Acknowledge Bit, 14 Data Bits, and the Data Parity Bit on the output.
- Programming the EEPROM cells (see Fig. 5–4)  
After evaluating this command, the sensor answers with the Acknowledge Bit. After the delay time  $t_w$ , the supply voltage rises up to the programming voltage.
- Activate a sensor (see Fig. 5–5)  
If more than one sensor is connected to the supply line, selection can be done by first deactivating all sensors. The output of all sensors will be pulled to ground by the internal 10 kΩ resistors. With an Activate pulse on the appropriate output pin, an individual sensor can be selected. All following commands will only be accepted from the activated sensor.



**Fig. 5–1:** Definition of logical 0 and 1 bit

**Table 5–1:** Telegram parameters

Symbol	Parameter	Pin	Min.	Typ.	Max.	Unit	Remarks
$V_{DDL}$	Supply Voltage for Low Level during Programming	1	5	5.6	6	V	
$V_{DDH}$	Supply Voltage for High Level during Programming	1	6.8	8.0	8.5	V	
$t_r$	Rise Time	1	–	–	0.05	ms	
$t_f$	Fall Time	1	–	–	0.05	ms	
$t_{p0}$	Bit Time on $V_{DD}$	1	1.7	1.75	1.8	ms	$t_{p0}$ is defined through the Sync Bit
$t_{pOUT}$	Bit Time on Output Pin	3	2	3	4	ms	$t_{pOUT}$ is defined through the Acknowledge Bit
$t_{p1}$	Voltage Change for Logical 1	1, 3	50	65	80	%	% of $t_{p0}$ or $t_{pOUT}$
$V_{DDPROG}$	Supply Voltage for Programming the EEPROM	1	12.4	12.5	12.6	V	
$t_{PROG}$	Programming Time for EEPROM	1	95	100	105	ms	
$t_{rp}$	Rise Time of Programming Voltage	1	0.2	0.5	1	ms	