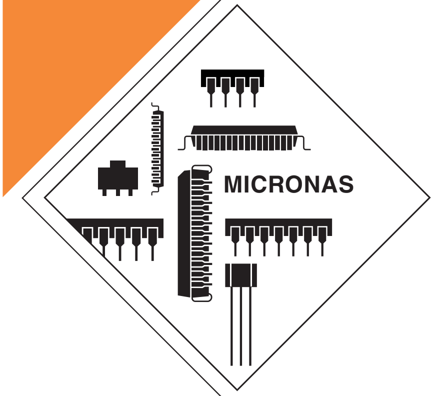


DATA SHEET

HAL1000 Programmable Hall Switch

Edition March 4, 2004
6251-528-1DS

MICRONAS

Contents

Programmable Hall Switch

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

1. Introduction

The HAL 1000 is a programmable Hall switch. The major sensor characteristics, the two switching points B_{ON} and B_{OFF}, are programmable for the application. The sensor can be programmed to be unipolar or latching, sensitive to the magnetic north pole or sensitive to the south pole, with normal or with an electrically inverted output signal. Several examples are shown in Fig. 2–4 through Fig. 2–7.

The HAL 1000 is based on the HAL 8xx family and features a temperature-compensated Hall plate with choppered offset compensation, an A/D converter, digital signal processing, a push-pull output stage, an EEPROM memory with redundancy and lock function for the calibration data, a serial interface for programming the EEPROM, and protection devices at all pins. Internal digital signal processing is of great benefit because analog offsets, temperature shifts, and mechanical stress effects do not degrade the sensor accuracy.

The HAL 1000 is programmable by modulating the supply voltage. No additional programming pin is needed. Programming is simplified through the use of a 2-point calibration. Calibration is accomplished by adjusting the sensor output directly to the input signal. 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 for the final assembly. This offers a low-cost alternative for all applications that presently require mechanical adjustment or other system calibration.

In addition, the temperature compensation of the Hall IC can be tailored to all 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 constant switching points.

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 and produced in sub-micron CMOS technology for use in hostile industrial and automotive applications with nominal supply voltage of 5 V in the ambient temperature range from –40 °C up to 150 °C.

The HAL 1000 is available in the leaded packages TO92UT-1 and TO92UT-2.

1.1. Major Applications

Due to the sensor's versatile programming characteristics, the HAL 1000 is the optimal system solution for applications which require very precise contactless switching:

- end point detection
- level switch (e.g. liquid level)
- electronic fuse (current measurement)

WARNING:
DO NOT USE THESE SENSORS IN LIFE-SUPPORTING SYSTEMS, AVIATION, AND AEROSPACE APPLICATIONS.

1.2. Features

- high-precision Hall switch with programmable switching points and switching behavior
- switching points programmable from –150 mT up to 150 mT in steps of 0.5% of the magnetic field range
- multiple programmable magnetic characteristics in a non-volatile memory (EEPROM) with redundancy and lock function
- temperature characteristics are programmable for matching all common magnetic materials
- 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 2 kHz
- magnetic characteristics extremely robust against mechanical stress effects
- overvoltage and reverse-voltage protection at all pins
- short-circuit protected push-pull output
- EMC and ESD optimized design

1.3. Marking Code

The HAL1000 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
HAL1000	1000A	1000K

1.3.1. Special Marking of Prototype Parts

Prototype parts are coded with an underscore beneath the temperature range letter on each IC. They may be used for lab experiments and design-ins but are not intended to be used for qualification tests or as production parts.

1.4. Operating Junction Temperature Range (T_J)

The Hall sensors from Micronas are specified to the chip temperature (junction temperature T_J).

A: T_J = –40 °C to +170 °C

K: T_J = –40 °C to +140 °C

The relationship between ambient temperature (T_A) and junction temperature is explained in Section 4.3. on page 22.

1.5. Hall Sensor Package Codes

HALxxxxPA-T
Temperature Range: A or K
Package: UT for TO92UT
Type: 1000

Example: **HAL1000UT-K**

→ Type: 1000
→ Package: TO92UT
→ Temperature Range: T_J = –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

All packages according to IEC68-2-58

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

1.7. Pin Connections and Short Descriptions

Pin No.	Pin Name	Type	Short Description
1	V_{DD}	IN	Supply Voltage and Programming Pin
2	GND		Ground
3	OUT	OUT	Push-Pull Output and Selection Pin

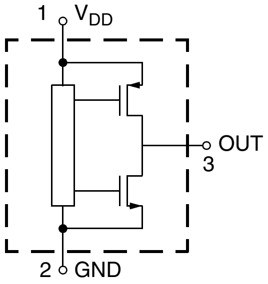


Fig. 1–1: Pin configuration

2. Functional Description

2.1. General Function

The HAL1000 is a monolithic integrated circuit which provides a digital output signal. The sensor is based on the HAL 8xx design. All blocks before the comparator are identical to the HAL 810 and the signal processing is very similar.

The Hall plate is sensitive to magnetic north and south polarity. The external magnetic field component perpendicular to the branded side of the package generates a Hall voltage. This voltage is converted to a digital value and processed in the Digital Signal Processing Unit (DSP) according to the settings of the EEPROM registers. The function and the parameters for the DSP are explained in Section 2.2. on page 6.

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 digital output is switched off during the communication.

Internal temperature compensation circuitry and the choppered offset compensation enables operation over the full temperature range with minimal changes of the switching points. The circuitry also rejects offset shifts due to mechanical stress from the package. The non-volatile memory consists of redundant EEPROM cells. In addition, the HAL1000 is equipped with devices for overvoltage and reverse-voltage protection at all pins.

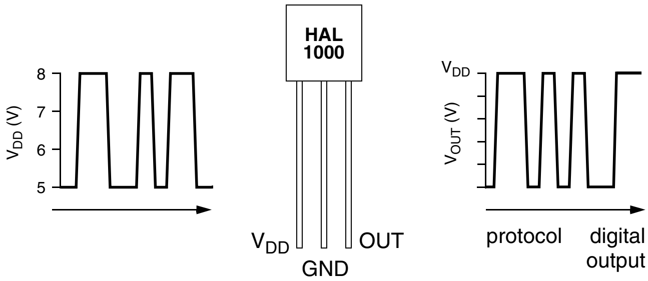


Fig. 2–1: Programming with V_{DD} modulation

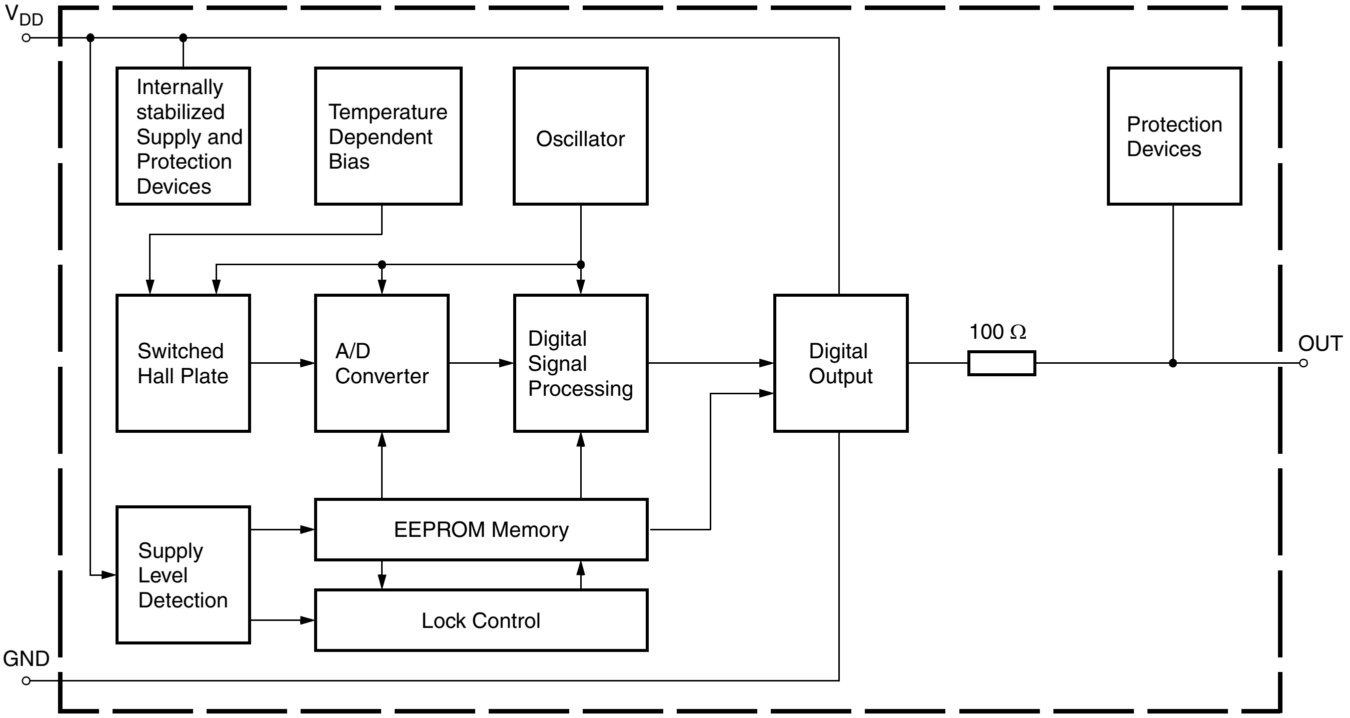


Fig. 2–2: HAL1000 block diagram

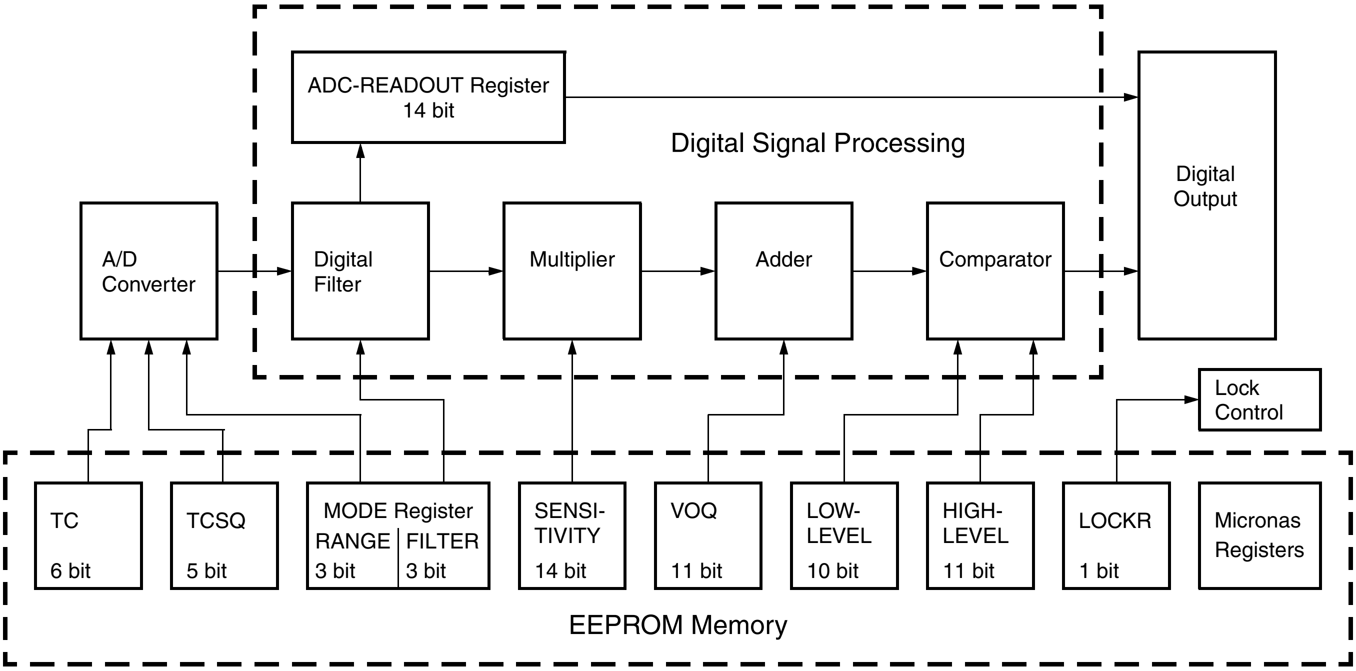


Fig. 2–3: Details of EEPROM and Digital Signal Processing

2.2. Digital Signal Processing and EEPROM

The DSP is the main part of the sensor and performs the signal processing. 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

EEPROM Registers:

The EEPROM registers include three 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 and TCSQ for the temperature characteristics of the magnetic sensitivity and thereby for the switching points.

Group 2 contains the registers for defining the switching points: SENSITIVITY, VOQ, LOW-LEVEL, and HIGH-LEVEL.

The comparator compares the processed signal voltage with the reference values Low-Level and High-Level.

The output switches on (low) if the signal voltage is higher than the High-Level, and switches off (high) if the signal falls below the Low-Level. Several examples of different switching characteristics are shown in Fig. 2–4 to Fig. 2–7.

– The parameter V_{OQ} (Output Quiescent Voltage) corresponds to the signal voltage at B = 0 mT.

– The parameter Sensitivity defines the magnetic sensitivity:

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

– The signal voltage can be calculated as:

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

Therefore, the switching points are programmed by setting the SENSITIVITY, VOQ, LOW-LEVEL, and HIGH-LEVEL registers. The available Micronas software calculates the best parameter set respecting the ranges of each register.

Group 3 contains the Micronas registers and LOCK for the locking of all registers. The Micronas registers are programmed and locked during production and are read-only for the customer. These registers are used for oscillator frequency trimming, A/D converter offset compensation, and several other special settings.

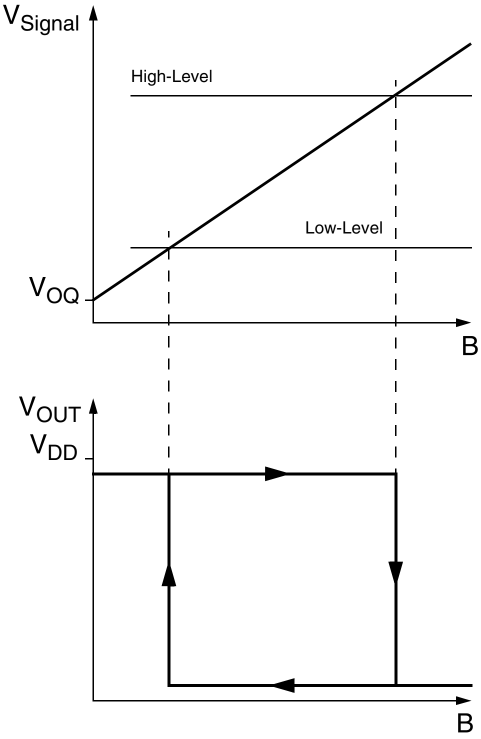


Fig. 2–4: HAL 1000 with unipolar behavior

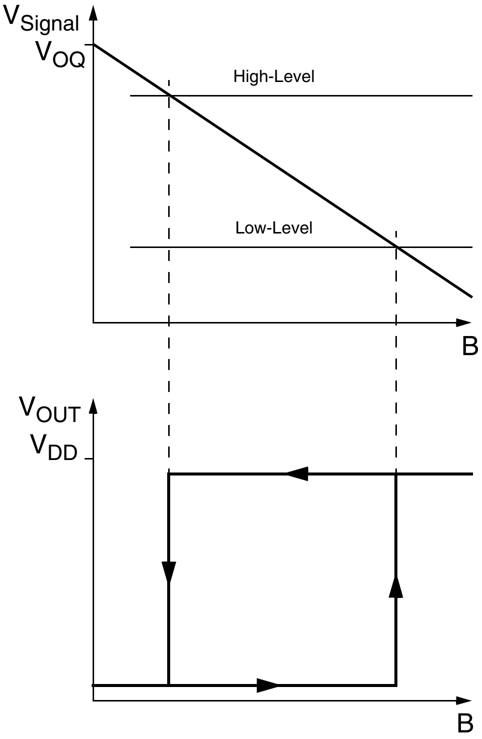


Fig. 2–6: HAL 1000 with unipolar inverted behavior

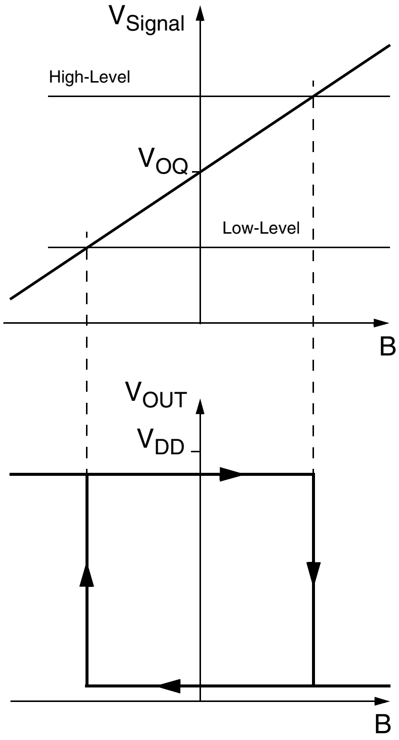


Fig. 2–5: HAL 1000 with latching behavior

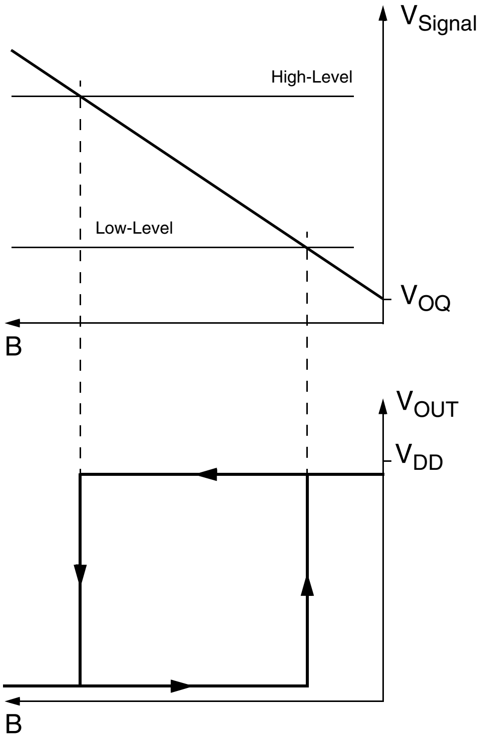


Fig. 2–7: HAL 1000 with unipolar behavior sensitive to the other magnetic polarity

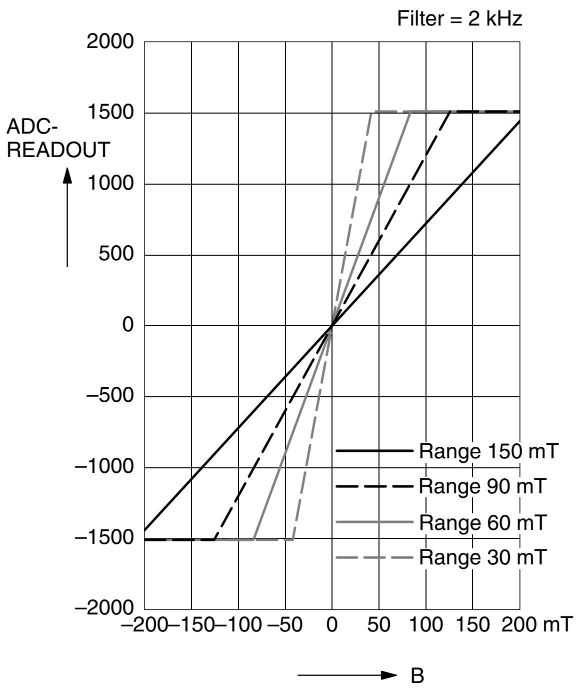


Fig. 2–8: Typical ADC-READOUT versus magnetic field for filter = 2 kHz

An external magnetic field generates a Hall voltage at the Hall plate. The ADC converts this amplified Hall voltage (operates with magnetic north and south poles at the branded side of the package) to a digital value. Positive values correspond to a magnetic north pole on the branded side of the package. The digital signal is filtered in the internal low-pass filter and is then readable in the ADC-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 –150 mT ... +150 mT.

The ADC-READOUT at any given magnetic field depends on the programmed magnetic field range and also on the filter frequency. Fig. 2–8 shows the typical ADC-READOUT values for the different magnetic field ranges with the filter frequency set to 2 kHz.

The relationship between the minimum and maximum ADC-READOUT values and the filter frequency setting can be seen in the following table.

Filter Frequency	ADC-READOUT RANGE
80 Hz	–3968...3967
160 Hz	–1985...1985
500 Hz	–5292...5290
1 kHz	–2646...2645
2 kHz	–1512...1511

Note: The maximum and minimum ADC-READOUT must not be exceeded during calibration of the sensor and operation near the switching points.

Range

The RANGE bits are the three lowest bits of the MODE register; they define the magnetic field range of the A/D converter.

Magnetic Field Range	RANGE
–30 mT...30 mT	0
–40 mT...40 mT	4
–60 mT...60 mT	5
–75 mT...75 mT	1
–80 mT...80 mT	6
–90 mT...90 mT	2
–100 mT...100 mT	7
–150 mT...150 mT	3

Filter

The FILTER bits are the three highest bits of the MODE register; they define the –3 dB frequency of the digital low pass filter.

–3 dB Frequency	FILTER
80 Hz	0
160 Hz	1
500 Hz	2
1 kHz	3
2 kHz	4

TC and TCSQ

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 switching points can be stabilized over the full temperature range. The sensor can compensate for linear temperature coefficients ranging from about −3100 ppm/K up to 400 ppm/K and quadratic coefficients from about −5 ppm/K² to 5 ppm/K². Please refer to Section 4.2. on page 21 for the recommended settings for different linear temperature coefficients.

Sensitivity

The SENSITIVITY register contains the parameter for the multiplier in the DSP. Sensitivity is programmable between −4 and 4 in steps of 0.00049. Sensitivity = 1 corresponds to an increase of the signal voltage by V_{DD} if the ADC-READOUT increases by 2048.

VOQ

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

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

$$V_{Signal\ max} = V_{OQ} + V_{DD}$$

Reference Levels

The LOW-LEVEL and HIGH-LEVEL registers contain the reference values of the comparator.

The Low-Level is programmable between 0 V and $V_{DD}/2$. The register can be changed in steps of 2.44 mV. The High-Level is programmable between 0 V and V_{DD} in steps of 2.44 mV.

The four parameters Sensitivity, V_{OQ}, Low-Level, and High-Level define the switching points B_{ON} and B_{OFF}. For calibration in the system environment, a 2-point adjustment procedure (see Section 2.3.) is recommended. The suitable parameter set for each sensor can be calculated individually by this procedure.

LOCKR

By setting this 1-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: The LOCKR register cannot be reset!

ADC-READOUT

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

2.3. General Calibration 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 and the corresponding software for the input or calculating of the register values.

In this section, the programming of the sensor using this tool is explained. Please refer to Section 5. on page 23 for information about programming without this tool.

For the individual calibration of each sensor in the customer‘s application, a two-point adjustment is recommended (see Fig. 2–9 for an example). When using the application kit, the calibration can be done in three steps:

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

The magnetic circuit, the magnetic material with its temperature characteristics, and the filter frequency, are given for this application.

Therefore, the values of the following registers should be identical for all sensors in the application.

- FILTER
  (according to the maximum signal frequency)
  The 500 Hz range is recommended for highest accuracy.
- RANGE
  (according to the maximum magnetic field at the sensor position)
- TC and TCSQ
  (depends on the material of the magnet and the other temperature dependencies of the application)

Write the appropriate settings into the HAL 1000 registers.

Step 2: Calculation of the Sensor Parameters

Fig. 2–9 shows the typical characteristics for a contactless switch. There is a mechanical range where the sensor must be switched high and where the sensor must be switched low.

Set the system to the calibration point where the sensor output must be high, and press the key “Readout B_{OFF}”. The result is the corresponding ADC-READOUT value.

Note: The magnetic south pole on the branded side generates negative ADC-READOUT values, the north polarity positive values.

Then, set the system to the calibration point where the sensor output must be low, press the key “Readout B_{ON}” and get the second ADC-READOUT value.

Now, adjust the hysteresis to the desired value. The hysteresis is the difference between the switching points and suppresses oscillation of the output signal. With 100% hysteresis, the sensor will switch low and high exactly at the calibration points. A lower value will adjust the switching points closer together. Fig. 2–9 shows an example with 80% hysteresis.

By pressing the key “calibrate and store”, the software will calculate the corresponding parameters for Sensitivity, VOQ, Low-Level, High-Level and store these values in the EEPROM.

This calibration must be done individually for each sensor.

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

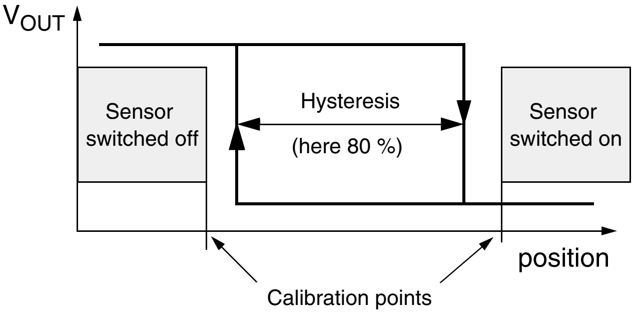


Fig. 2–9: Characteristics of a position switch

Step 3: Locking the Sensor

The last step is activating the LOCK function with the “lock” key. The sensor is now locked and does not respond to any programming or reading commands.

Warning: The LOCKR register cannot be reset!

2.4. Example: Calibration of a Position Switch

The following description explains the calibration procedure using a position switch as an example.

- The mechanical switching points are given.
- temperature coefficient of the magnet: –500 ppm/K

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

The register values for the following registers are given for all sensors in the application:

- FILTER
  Select the filter frequency: 500 Hz
- RANGE
  Select the magnetic field range: 30 mT
- TC
  For this magnetic material: 6
- TCSQ
  For this magnetic material: 14

Enter these values in the software, and use the "write and store" command to store these values permanently in the registers.

Step 2: Calculation of the Sensor Parameters

Set the system to the calibration point where the sensor output must be high, and press "Readout B_{OFF}".

Set the system to the calibration point where the sensor output must be low, and press "Readout B_{ON}"

Now, adjust the hysteresis to 80%, and press the key "calibrate and store".

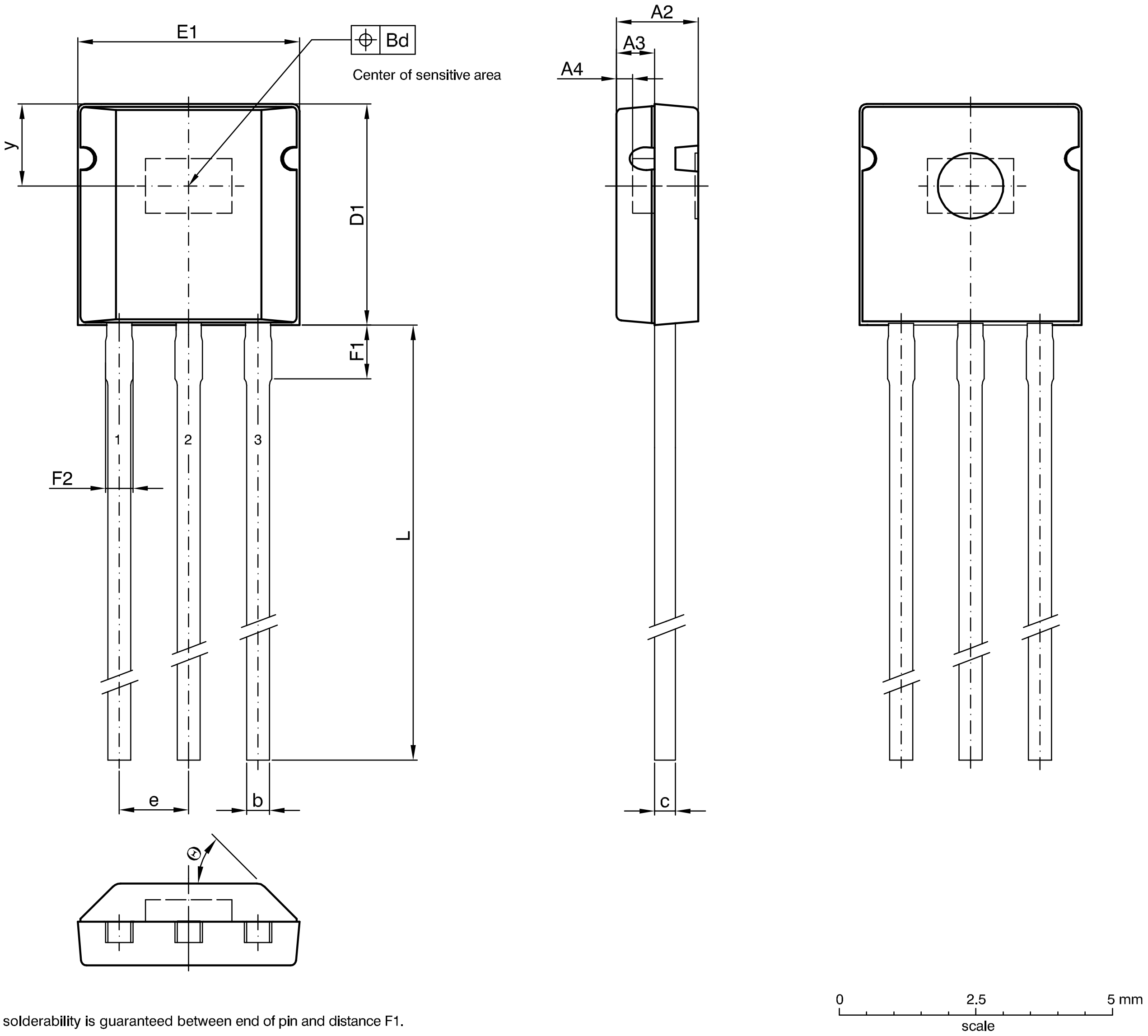
Step 3: Locking the Sensor

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

Warning: The LOCKR register cannot be reset!

3. Specifications

3.1. Outline Dimensions



solderability is guaranteed between end of pin and distance F1.

Bd, y= these dimensions are different for each sensor type and are specified in the data sheet.

UNIT	A2	A3	A4	b	c	D1	e	E1	F1	F2	L	Θ
mm	1.55 1.45	0.7	0.3	0.42	0.36	4.1 4.0	1.27	4.11 4.01	1.2 0.8	0.60 0.42	14.5 min	45°

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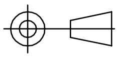
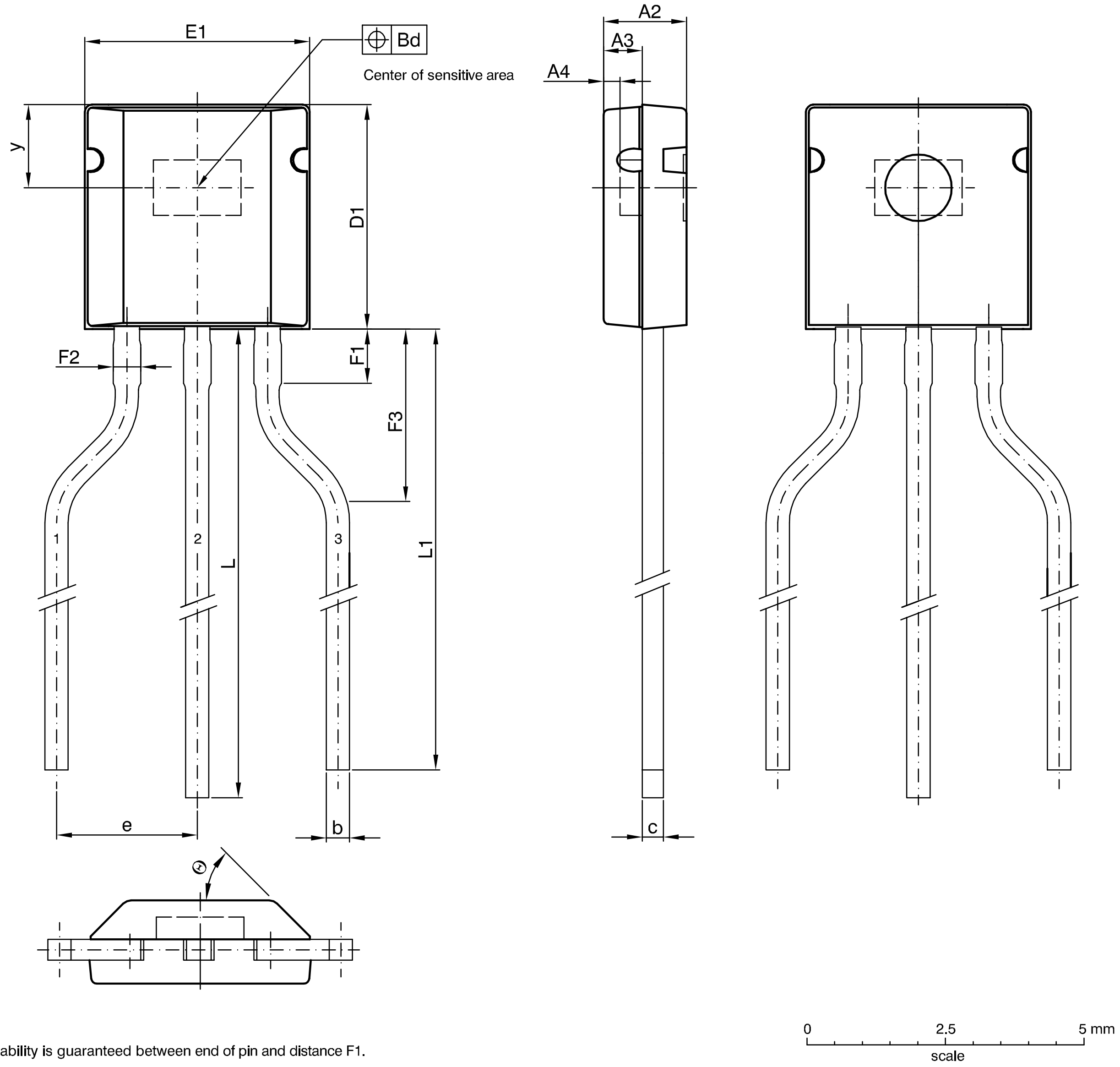
-	-		03-11-18	06615.0001.4	SPZG001015_001_03

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



solderability is guaranteed between end of pin and distance F1.

Bd, y= these dimensions are different for each sensor type and are specified in the data sheet.

UNIT	A2	A3	A4	b	c	D1	e	E1	F1	F2	F3	L	L1	Θ
mm	1.55 1.45	0.7	0.3	0.42	0.36	4.1 4.0	2.54	4.11 4.01	1.2 0.8	0.60 0.42	4.0 2.0	14.5 min	14.0 min	45°

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ISSUE	ITEM NO.				
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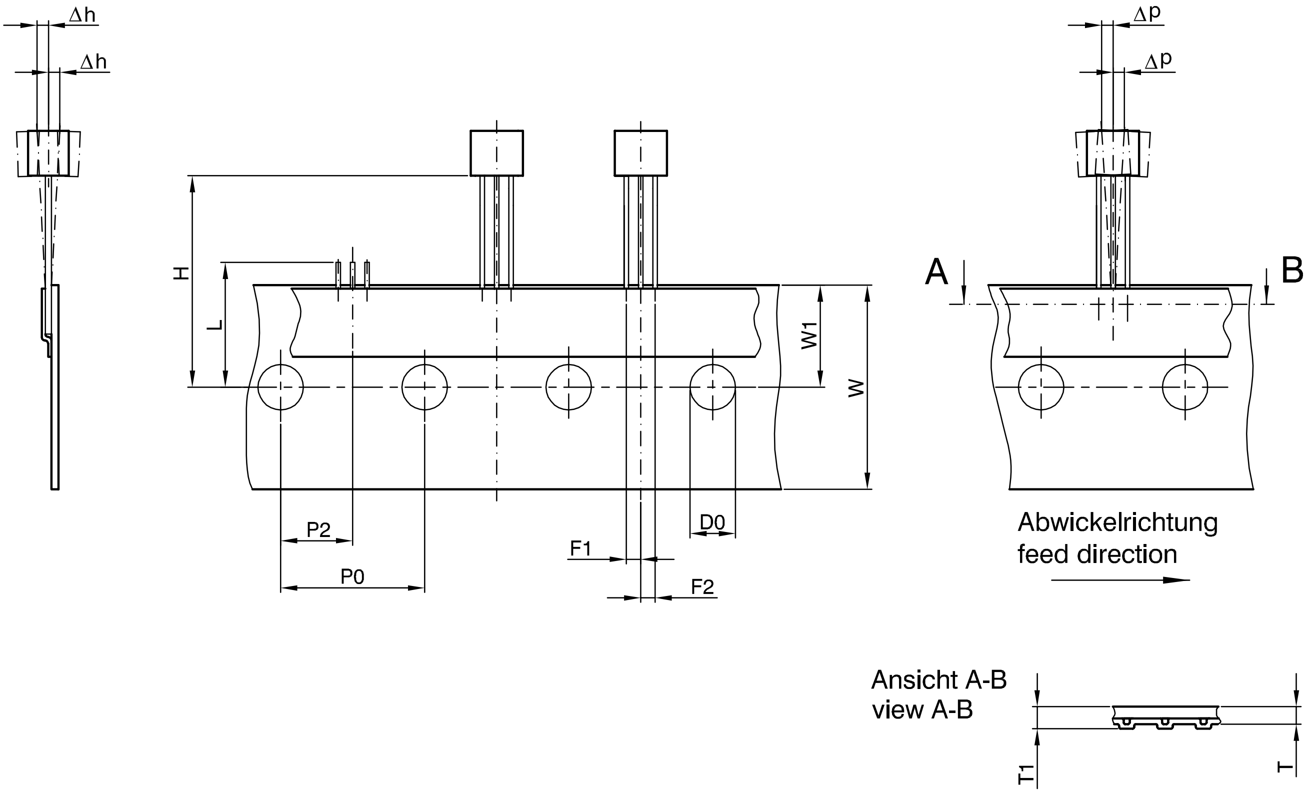
Fig. 3–2:
TO92UT-1: Plastic Transistor Standard UT package, 3 leads, spread
Weight approximately 0.12 g



alle Maße in mm / all dimensions in mm

max. zul. Abweichung über 20 Lochabstände ±1.0 / max. allowed tolerance over 20 hole spacings ±1.0

UNIT	D0	F1	F2	H	Δh	L	P0	P2	Δp	T	T1	W	W1
mm	4.0	1.47 1.07	1.47 1.07	20.0 18.0	±1.0	11.0 max	13.2 12.2	7.05 5.65	±1.0	0.5	0.9	18.0	9.0

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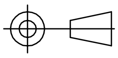
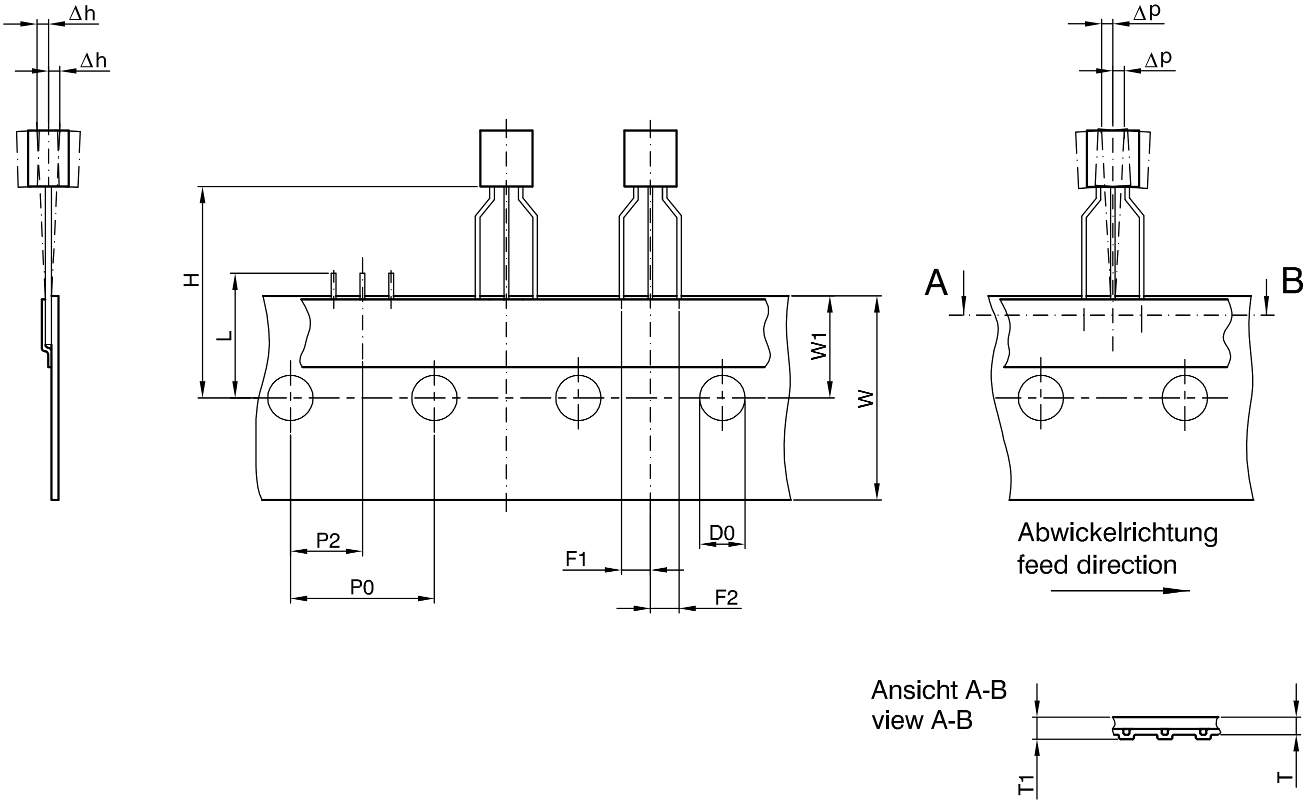
-	ICE 60286-2		03-09-12	06631.0001.4	SPZG001031_001_02

Fig. 3–3:
TO92UT-2: Dimensions ammopack inline, not spread



alle Maße in mm / all dimensions in mm

max. zul. Abweichung über 20 Lochabstände ±1.0 / max. allowed tolerance over 20 hole spacings ±1.0

UNIT	D0	F1	F2	H	Δh	L	P0	P2	Δp	T	T1	W	W1
mm	4.0	2.74 2.34	2.74 2.34	20.0 18.0	±1.0	11.0 max	13.2 12.2	7.05 5.65	±1.0	0.5	0.9	18.0	9.0

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ISSUE	ITEM NO.				
-	ICE 60286-2		03-09-12	06632.0001.4	SPZG001032_001_02

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

3.2. Dimensions of Sensitive Area

0.25 mm x 0.25 mm

3.3. Position of Sensitive Area

TO92UT-1/-2
y = 1.5 mm ± 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 high-impedance circuit.

All voltages listed are referenced to ground.

Symbol	Parameter	Pin No.	Limit Values		Unit
			Min.	Max.	
V_{DD}	Supply Voltage	1	–8.5	8.5	V
V_{DD}	Supply Voltage	1	–14.4[1][2]	14.4[1][2]	V
V_{OUT}	Output Voltage	3	–5[6] –5[6]	8.5[3] 14.4[3][2]	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[5] 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 < 2 ms
[5] t < 1000 h
[6] internal protection resistor = 100 Ω

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. Solderability has been tested after storing the devices for 16 hours at 155 °C. The wettability was more than 95%.

3.5. Recommended Operating Conditions

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

All voltages listed are referenced to ground.

Symbol	**Parameter**	**Pin No.**	**Limit Values**			**Unit**
			Min.	**Typ.**	**Max.**	
V_{DD}	Supply Voltage	1	4.5	5	5.5	V
I_{OUT}	Continuous Output Current	3	–1	–	1	mA
R_L	Load Resistor	3	4.7	–	–	kΩ
C_L	Load Capacitance	3	0.33	10	1000	nF

3.6. Characteristics

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

Symbol	Parameter	Pin No.	Limit Values			Unit	Test Conditions
			Min.	Typ.	Max.		
I_{DD}	Supply Current over Temperature Range	1		7	10	mA	
V_{DDZ}	Overvoltage Protection at Supply	1		17.5	20	V	I_{DD} = 25 mA, T_J = 25 °C, t = 20 ms
V_{OZ}	Overvoltage Protection at Output	3		17	19.5	V	I_O = 10 mA, T_J = 25 °C, t = 20 ms
V_{OUTH}	Output High Voltage	3	4.65	4.8		V	V_{DD} = 5 V, $-1\ \text{mA} \leq I_{OUT} \leq 1\text{mA}$
V_{OUTL}	Output Low Voltage	3		0.2	0.35	V	V_{DD} = 5 V, $-1\ \text{mA} \leq I_{OUT} \leq 1\text{mA}$
f_{ADC}	Internal ADC Frequency	–	120	128	140	kHz	T_J = 25 °C
f_{ADC}	Internal ADC Frequency over Temperature Range	–	110	128	150	kHz	V_{DD} = 4.5 V to 8.5 V
$t_{r(O)}$	Response Time of Output	3	–	5 4 2 1	10 8 4 2	ms ms ms ms	3 dB Filter frequency = 80 Hz 3 dB Filter frequency = 160 Hz 3 dB Filter frequency = 500 Hz 3 dB Filter frequency = 2 kHz C_L = 10 nF, time from 10% to 90% of final output voltage for a steplike signal B_{step} from 0 mT to B_{max}
$t_{d(O)}$	Delay Time of Output	3		0.1	0.5	ms	C_L = 10 nF
t_{POD}	Power-Up Time (Time to reach stabilized Output Voltage)			6 5 3 2	11 9 5 3	ms ms ms ms	3 dB Filter frequency = 80 Hz 3 dB Filter frequency = 160 Hz 3 dB Filter frequency = 500 Hz 3 dB Filter frequency = 2 kHz C_L = 10 nF, 90% of V_{OUT}
BW	Small Signal Bandwidth (–3 dB)	3	–	2	–	kHz	B_{AC} < 10 mT; 3 dB Filter frequency = 2 kHz
R_{thJA} TO92UT-1 TO92UT-2	Thermal Resistance Junction to Soldering Point	–	–	150	200	K/W	

3.7. Magnetic Characteristics

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

Symbol	Parameter	Pin No.	Limit Values			Unit	Test Conditions
			Min.	Typ.	Max.		
B_{Offset}	Magnetic Offset	3	–1	0	1	mT	B = 0 mT, I_{OUT} = 0 mA, T_J = 25 °C
$\Delta B_{Offset}/\Delta T$	Magnetic Offset Change due to T_J		–15	0	15	µT/K	B = 0 mT, I_{OUT} = 0 mA

3.8. Typical Characteristics

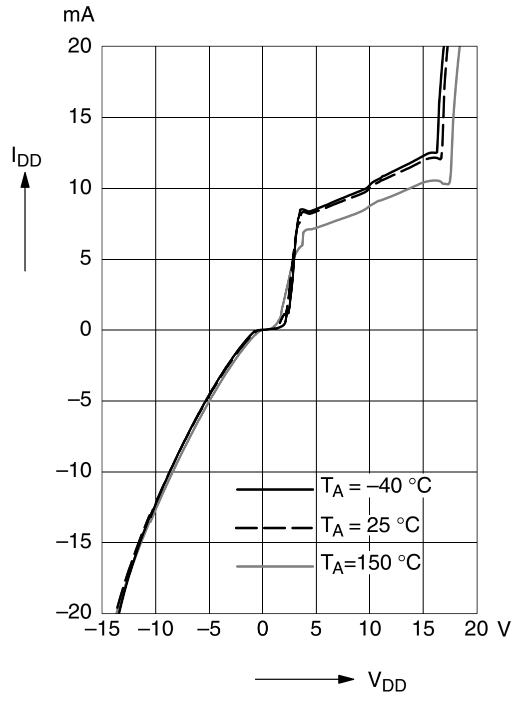

Fig. 3–5: Typical current consumption versus supply voltage

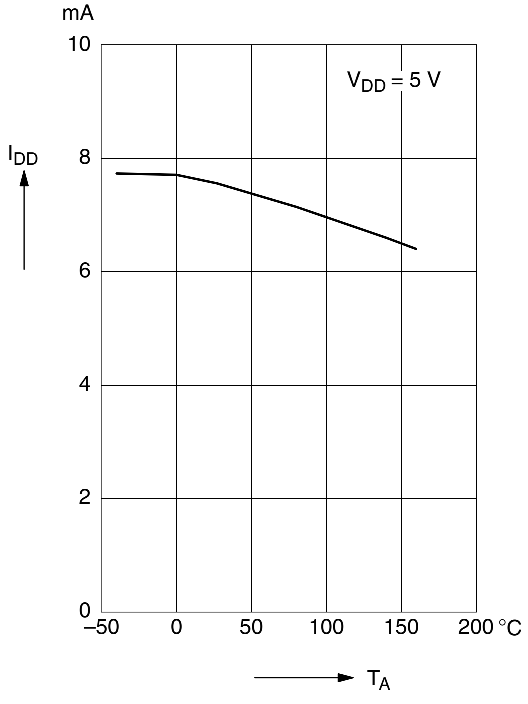

Fig. 3–6: Typical current consumption versus ambient temperature

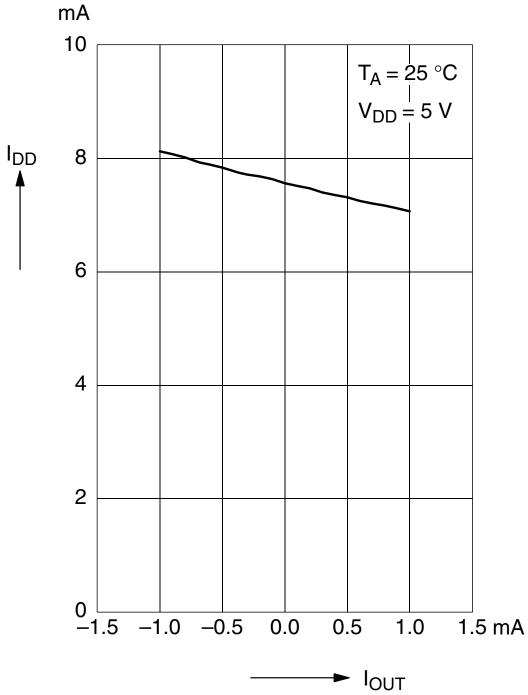

Fig. 3–7: Typical current consumption versus output current

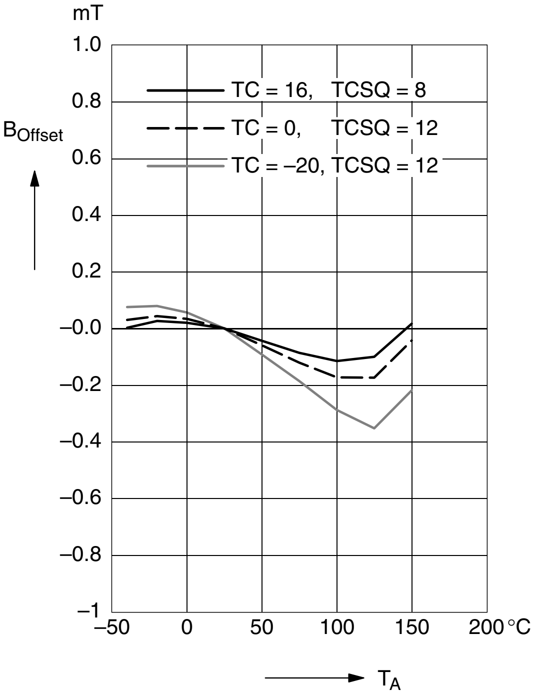

Fig. 3–9: Typical magnetic offset versus ambient temperature

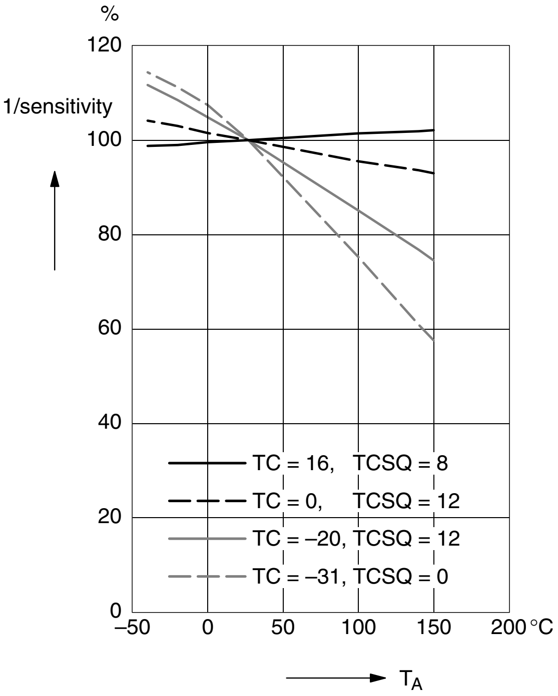

Fig. 3–8: Typical 1/sensitivity versus ambient temperature

4. Application Notes

4.1. Application Circuit

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

WARNING:
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_{DD} LINE AT THIS TIME MUST BE ABLE TO RESIST THIS VOLTAGE.

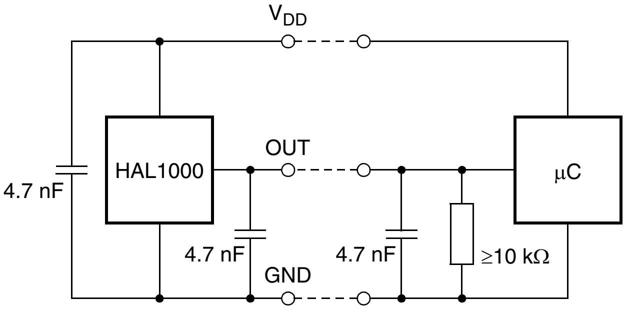

Fig. 4–1: Recommended application circuit

4.2. Temperature Compensation

The relationship between the temperature coefficient of the magnet and the corresponding TC and TCSQ 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 and TCSQ combinations are required which are not shown in the table. Please contact Micronas for more detailed information on this higher order temperature compensation.

The HAL 8xx and HAL 1000 contain the same temperature compensation circuits. If an optimal setting for the HAL 8xx is already available, the same settings may be used for the HAL 1000.

Temperature Coefficient of Magnet (ppm/K)	TC	TCSQ
400	31	6
300	28	7
200	24	8
100	21	9
0	18	10
–50	17	10
–90	16	11
–130	15	11
–170	14	11
–200	13	12
–240	12	12
–280	11	12
–320	10	13
–360	9	13
–410	8	13
–450	7	13
–500	6	14
–550	5	14
–600	4	14
–650	3	14
–700	2	15
–750	1	15
–810	0	15
–860	–1	16
–910	–2	16
–960	–3	16
–1020	–4	17
–1070	–5	17
–1120	–6	17
–1180	–7	18
–1250	–8	18
–1320	–9	19
–1380	–10	19
–1430	–11	20

Temperature Coefficient of Magnet (ppm/K)	TC	TCSQ
–1500	–12	20
–1570	–13	20
–1640	–14	21
–1710	–15	21
–1780	–16	22
–1870	–17	22
–1950	–18	23
–2030	–19	23
–2100	–20	24
–2180	–21	24
–2270	–22	25
–2420	–24	26
–2500	–25	27
–2600	–26	27
–2700	–27	28
–2800	–28	28
–2900	–29	29
–3000	–30	30
–3100	–31	31

4.3. 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:

$\Delta T = I_{DD} * V_{DD} * R_{thJA}$

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 V, R_{th} = 200 K/W and I_{DD} = 10 mA the temperature difference ΔT = 11 K.

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

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

4.4. EMC and ESD

The HAL 1000 is designed for a stabilized 5 V supply. EMC testing related to “Road vehicles – Electrical disturbances from conduction and coupling – Part 2: Electrical transient conduction along supply lines only.” (product standard ISO 7637-2) is 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.

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 which is available 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 processing this command, the sensor answers with the Acknowledge Bit. After the delay time t_w, the supply voltage rises up to the programming voltage.

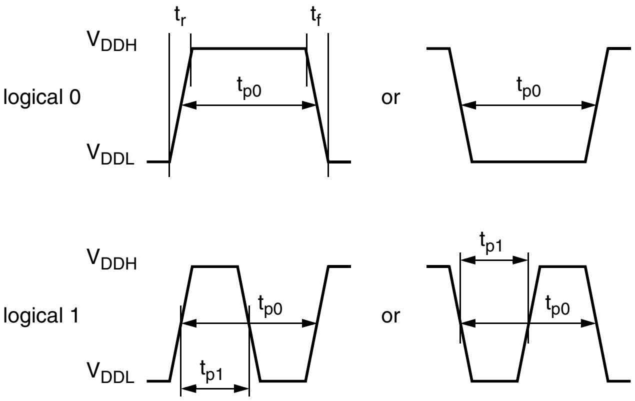

Fig. 5–1: Definition of logical 0 and 1 bit

Table 5–1: Telegram parameters

Symbol	Parameter	Pin No.	Limit Values			Unit	Remarks
			Min.	Typ.	Max.		
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	
t_{fp}	Fall time of programming voltage	1	0		1	ms	
t_w	Delay time of programming voltage after Acknowledge	1	0.5	0.7	1	ms	

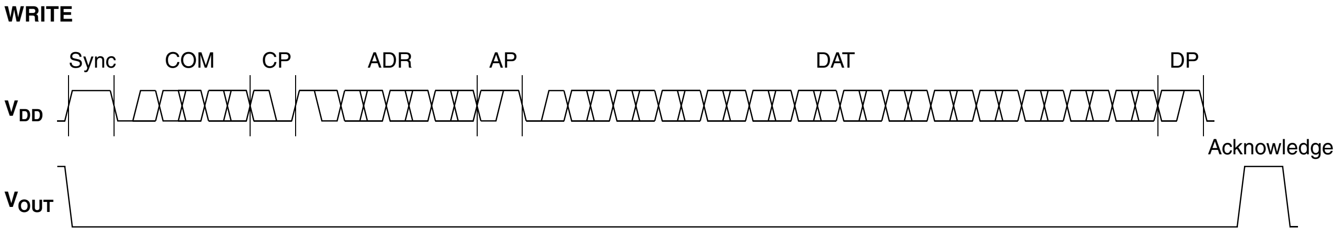

Fig. 5–2: Telegram for coding a Write command

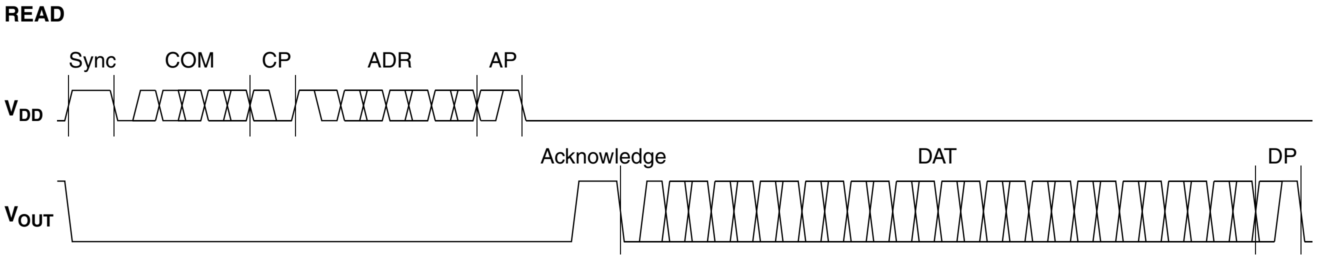

Fig. 5–3: Telegram for coding a Read command

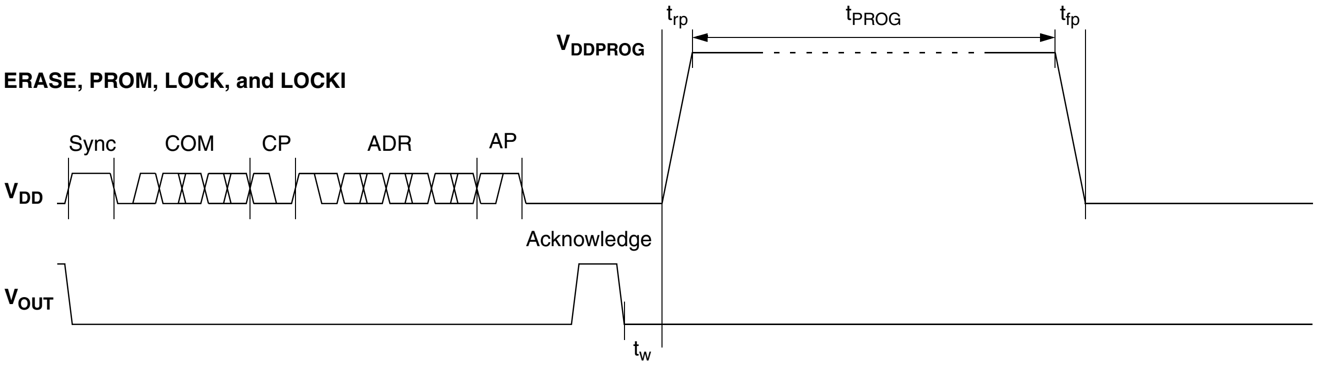

Fig. 5–4: Telegram for coding the EEPROM programming

5.3. Telegram Codes

Sync Bit

Each telegram starts with the Sync Bit. This logical “0” pulse defines the exact timing for t_{p0}.

Command Bits (COM)

The Command code contains 3 bits and is a binary number. Table 5–2 shows the available commands and the corresponding codes for the HAL 1000.

Command Parity Bit (CP)

This parity bit is “1” if the number of zeros within the 3 Command Bits is uneven. The parity bit is “0”, if the number of zeros is even.

Address Bits (ADR)

The Address code contains 4 bits and is a binary number. Table 5–3 shows the available addresses for the HAL 1000 registers.

Address Parity Bit (AP)

This parity bit is “1” if the number of zeros within the 4 Address bits is uneven. The parity bit is “0” if the number of zeros is even.

Data Bits (DAT)

The 14 Data Bits contain the register information.

The registers use different number formats for the Data Bits. These formats are explained in Section 5.4.

In the Write command, the last bits are valid. If, for example, the TC register (6 bits) is written, only the last 6 bits are valid.

In the Read command, the first bits are valid. If, for example, the TC register (6 bits) is read, only the first 6 bits are valid.

Data Parity Bit (DP)

This parity bit is “1” if the number of zeros within the binary number is even. The parity bit is “0” if the number of zeros is uneven.

Acknowledge

After each telegram, the output answers with the Acknowledge signal. This logical “0” pulse defines the exact timing for t_{pOUT}.

Table 5–2: Available commands

Command	Code	Explanation
READ	2	read a register
WRITE	3	write a register
PROM	4	program all nonvolatile registers (except the lock bits)
ERASE	5	erase all nonvolatile registers (except the lock bits)
LOCK	7	lock the whole device and switch permanently to the analog-mode
Please note: The Micronas LOCK bit has already been set during production and cannot be reset.		

5.4. Number Formats

Binary number:

The most significant bit is given as first, the least significant bit as last digit.

Example: `101001` represents 41 decimal.

Signed binary number:

The first digit represents the sign of the following binary number (1 for negative, 0 for positive sign).

Example: `0101001` represents +41 decimal
`1101001` represents –41 decimal

Two-complementary number:

The first digit of positive numbers is “0”, the rest of the number is a binary number. Negative numbers start with “1”. In order to calculate the absolute value of the number, calculate the complement of the remaining digits and add “1”.

Example: `0101001` represents +41 decimal
`1010111` represents –41 decimal

Table 5–3: Available register addresses

Register	Code	Data Bits	Format	Customer	Remark
LOW-LEVEL	1	10	binary	read/write/program	off switching level
HIGH-LEVEL	2	11	binary	read/write/program	on switching level
VOQ	3	11	two compl. binary	read/write/program	
SENSITIVITY	4	14	signed binary	read/write/program	
MODE	5	6	binary	read/write/program	Range and filter settings
LOCKR	6	1	binary	lock	Lock Bit
ADC-READOUT	7	14	two compl. binary	read	
TC	11	6	signed binary	read/write/program	
TCSQ	12	5	binary	read/write/program	

5.5. Register Information

LOW-LEVEL

- The register range is from 0 up to 1023.
- The register value is calculated by:

$$LOW\text{-}LEVEL = \frac{Low\text{-}Level\ Voltage}{V_{DD}} * 2048$$

HIGH-LEVEL

- The register range is from 0 up to 2047.
- The register value is calculated by:

$$HIGH\text{-}LEVEL = \frac{High\text{-}Level\ Voltage}{V_{DD}} * 2048$$

VOQ

- The register range is from –1024 up to 1023.
- The register value is calculated by:

$$VOQ = \frac{V_{OQ}}{V_{DD}} * 1024$$

SENSITIVITY

- The register range is from –8192 up to 8191.
- The register value is calculated by:

$$SENSITIVITY = \text{Sensitivity} * 2048$$

TC and TCSQ

- The TC register range is from –31 up to 31.
- The TCSQ register range is from 0 up to 31.

Please refer Section 4.2. on page 21 for the recommended values.

MODE

- The register range is from 0 up to 63 and contains the settings for FILTER and RANGE:

$$MODE = FILTER * 8 + RANGE$$

Please refer to Section 2.2. on page 6 for the available FILTER and RANGE values.

ADC-READOUT

- This register is read only.
- The register range is from –8192 up to 8191.

5.6. Programming Information

If the content of any register (except the lock registers) has to be changed, the desired value must first be written into the corresponding RAM register. Before reading out the RAM register again, the register value must be permanently stored in the EEPROM.

Permanently storing a value in the EEPROM is done by first sending an ERASE command followed by sending a PROM command. The address within the ERASE and PROM commands is not important. ERASE and PROM act on all registers in parallel.

If all HAL 1000 registers have to be changed, all writing commands can be sent one after the other, followed by sending one ERASE and PROM command at the end.

Note: For production and qualification tests, it is recommended to set the LOCK bit after final adjustment and programming of the sensor. The LOCK function is active after the next power-up of the sensor. We recommend sending an additional ERASE command directly after sending the LOCK command.

Note: Electrostatic Discharges (ESD) may disturb the programming pulses. Please take precautions against ESD.

6. Data Sheet History

1. Advance Information: “HAL 1000 Programmable Hall Switch, May 31, 2000, 6251-528-1AI. First release of the advance information.
2. Data Sheet: “HAL 1000 Programmable Hall Switch”, March 4, 2004, 6251-528-1DS. First release of the data sheet. Major changes:

– new package diagram for TO92UT-1

– package diagram for TO92UT-2 added

– ammopack diagrams for TO92UT-1/-2 added

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