Data Sheet

MICRONAS

HAL® 85x

Programmable Linear
Hall-Effect Sensor

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Contents

Programmable Linear Hall Effect Sensor

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

1. Introduction

The HAL85x is a member of the Micronas family of programmable linear Hall sensors. As an extension to the HAL8x5 family, the HAL85x offers an arbitrary output characteristic, as well as a 2-wire output for HAL856 and individual programming of different sensors which are in parallel to the same supply voltage.

The HAL85x is an universal magnetic field sensor based on the Hall effect. The IC is designed and produced in sub-micron CMOS technology and can be used for angle or distance measurements if combined with a rotating or moving magnet. The major characteristics like magnetic field range, output characteristic, output format, sensitivity, shift (offset), PWM period, low and high current, and the temperature coefficients are programmable in a non-volatile memory. The output characteristic can be set with 32 setpoints.

The HAL85x features a temperature-compensated Hall plate with chopped offset compensation, an A/D converter, digital signal processing, 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. The internal digital signal processing is of great benefit because analog offsets, temperature shifts, and mechanical stress do not degrade the sensor accuracy.

The HAL85x 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 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 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 sensors are designed for automotive or industrial applications. They operate in a wide supply voltage range and with ambient temperatures from $-40\ °C$ up to $150\ °C$. The HAL85x is available in the very small leaded package TO92UT-1 and TO92UT-2.

1.1. Major Applications

Due to the sensor's versatile programming characteristics, the HAL85x is the optimal system solution for applications such as:

- contactless potentiometers,
- rotary position measurement (e.g. Pedal sensor),
- fluid level measurement,
- linear position detection, and
- magnetic field detection.

1.2. Features

- High-precision linear Hall effect sensors with different output formats
- Various programmable magnetic characteristics with non-volatile memory
- Programmable output characteristic (32 setpoints with 9-bit resolution)
- Programmable output formats (PWM or serial Biphase-M)
- Programmable PWM Period
- Open-drain output for HAL855
- Programmable output current source for HAL856 (low and high current)
- Digital signal processing
- Temperature characteristics programmable for matching all common magnetic materials
- Programming by modulation of the supply voltage
- Lock function and built-in redundancy for EEPROM memory
- Operates from $-40\ °C$ up to $150\ °C$ ambient temperature (HAL855)
- Operates from 4.5 V up to 18 V supply voltage
- Operates with static magnetic fields and dynamic magnetic fields up to 2 kHz
- Chopped offset compensation
- Over-voltage protection on all pins
- Reverse-voltage protection on V_{DD} pin
- Magnetic characteristics extremely robust against mechanical stress
- Short-circuit protected output
- EMC-optimized design

1.3. Marking Code

The HAL85x 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
HAL855	855A	855K
HAL856	856A	856K

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 4.6. on page 29.

1.5. Hall Sensor Package Codes

HALXXXPA-T

Temperature Range: A and K
Package: UT for TO92UT-1/-2
Type: 855
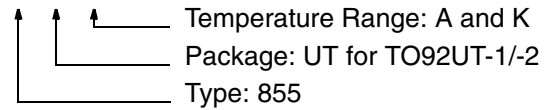
Example: **HAL855UT-K**

→ Type: 855
→ 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: "Micronas Hall Sensors: Ordering Codes, Packaging, Handling".

1.6. 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	Open-drain Output and Selection Pin (ONLY HAL855)
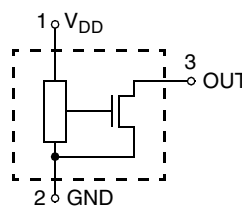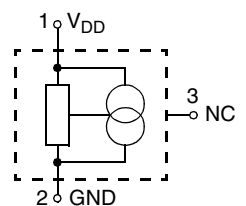
Fig. 1–1: Pin configuration

Note: In case of HAL856, the third sensor pin should be floating or connected to the GND line.

2. Functional Description

2.1. General Function

The HAL85x is a monolithic integrated circuit which provides an output voltage proportional to the magnetic flux through the Hall plate.

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 the different digital output formats (PWM, Split PWM, Biphase-M serial protocol) and provided by an open-drain 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). After detecting a command, the sensor reads or writes the memory and answers with a digital signal on the output pin, or in case of HAL856, with a modulation of the sensor's current consumption. The output is switched off during the communication.

When no command is detected or processed and the supply voltage is within the recommended operating range the PWM output is enabled.

In case of HAL855, it is possible to program several sensors individually if they are in parallel to the same supply and ground line. The selection of each sensor is done via its output pin.

Internal temperature compensation circuitry and the choppered offset 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 EEPROM cells. In addition, the sensor IC is equipped with devices for over voltage and reverse-voltage protection at all pins.
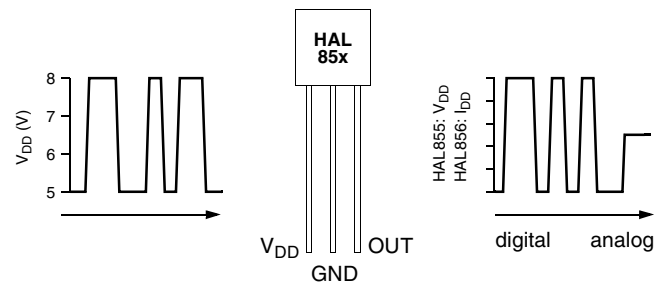
Fig. 2–1: Programming with V_{DD} modulation
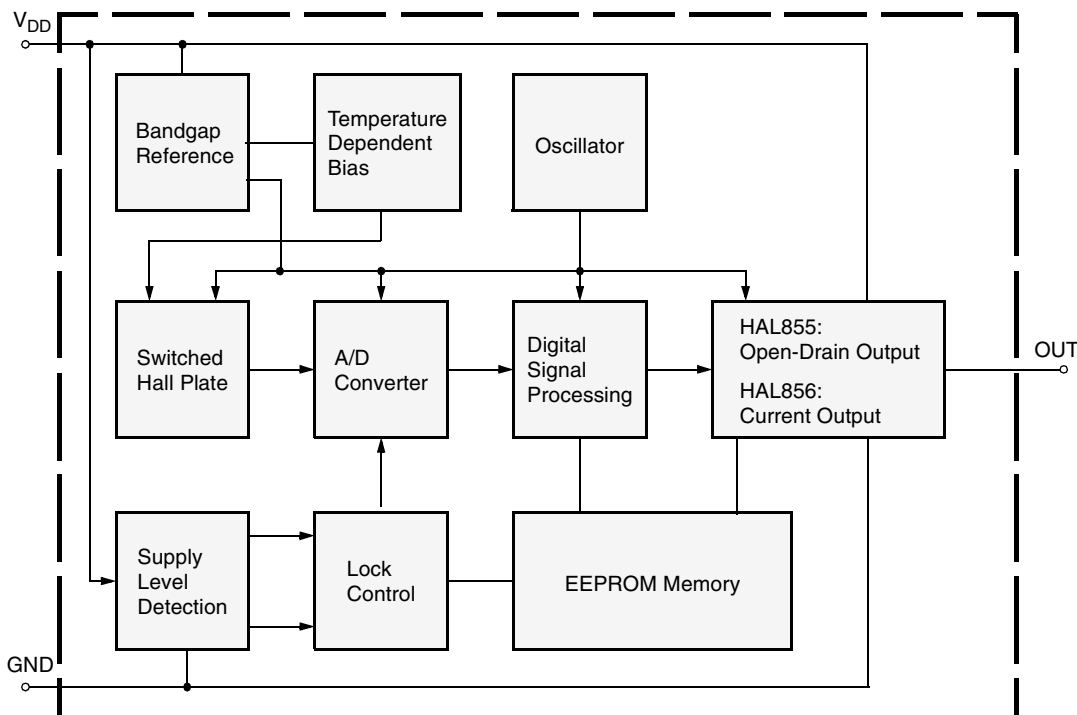
Fig. 2–2: HAL85x block diagram
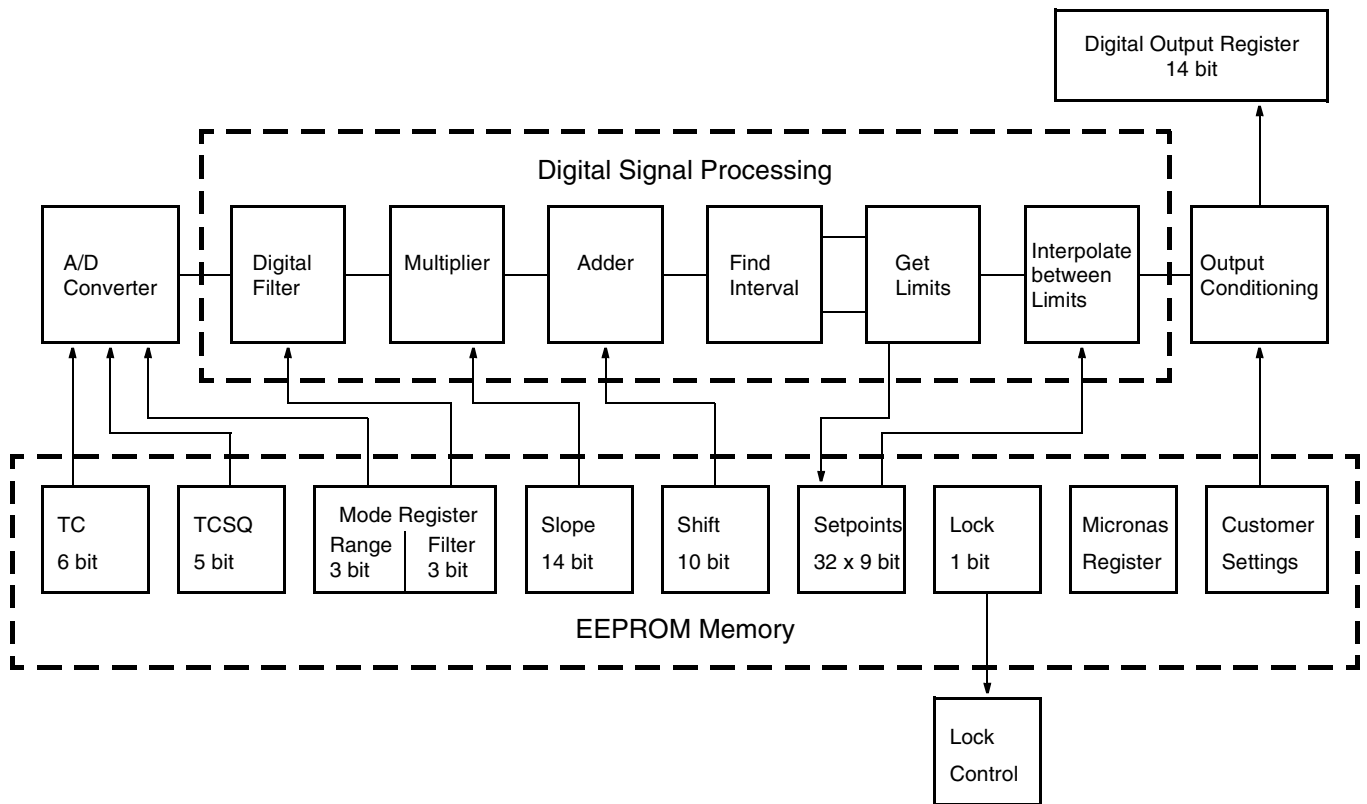
Fig. 2–3: Details of EEPROM and Digital Signal Processing

2.2. Digital Signal Processing and EEPROM

The DSP is the major 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:

SLOPE: name of the register or register value

Slope: name of the parameter

The EEPROM registers consist of 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.

The parameters SLOPE and SHIFT are used for the individual calibration of the sensor in the magnetic cirucit.

– The parameter Shift corresponds to the output signal at B = 0 mT.

– The parameter Slope defines the magnetic sensitivity.

Group 2 contains the registers for defining the output characteristics: OUTPUT FORMAT, OUTPUT PERIOD or OUTPUT BITTIME, SLEW RATE and OUTPUT CHARACTERISTIC. For HAL856 two additional registers are available: LOW CURRENT and HIGH CURRENT.

The shape of the output signal is determined by the Output Characteristic, which, in turn, is defined by the 32 setpoints of the sensor. A value for each of the setpoints must be defined. The setpoints are distributed evenly along the magnetic field axis allowing linear interpolation between the 32 setpoints (see Fig. 2–4).

Group 3 contains the PARTNUMBER, the Micronas registers, and LOCK for the locking of all registers. The PARTNUMBER register is only available in Biphase-M output mode. The sensor transmits a part number via its output for 100 ms after power-up. The Micronas registers are programmed and locked during production and are read-only for the customer. These registers are used for oscillator frequency trimming and several other special settings.

An external magnetic field generates a Hall voltage on the Hall plate. The A/D-converter 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
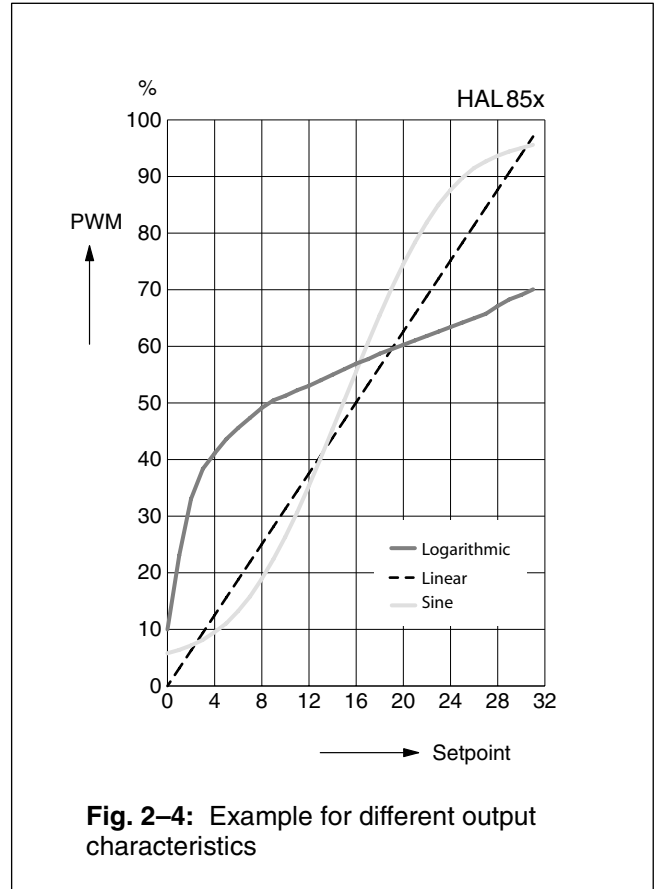
Fig. 2–4: Example for different output characteristics

DIGITAL OUTPUT 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.

During further processing, the digital signal is calculated based on the values of slope, shift, and the defined output characteristic. The result is converted to the different digital output formats (PWM, Split PWM and Biphase-M) and stabilized by a open-drain output transistor stage (or current source in case of HAL856).

The DIGITAL OUTPUT value at any given magnetic field depends on the settings of the magnetic field range, the low-pass filter, TC, TCSQ values and the programmed Output Characteristic. The DIGITAL OUTPUT range is min. 0 to max. 4095.

Note: During application design, it should be taken into consideration that DIGITAL OUTPUT should not saturate in the operational range of the specific application.

MODE

The MODE register consists of four "sub"-registers defining the magnetic and output behavior of the sensor. The RANGE bits are the three lowest bits of the MODE register; they define the magnetic field range of the A/D converter. The next three bits (FILTER) define the −3 dB frequency of the digital low pass filter. The next sub-register is the FORMAT register, and it defines the different output formats as described below. This sub-register also consists of 3 bits. The last three MSBs define the OUTPUT PERIOD of the PWM signal.

RANGE

Table 2–1: RANGE register definition

Magnetic Field Range	BIT SETTING
−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

Table 2–2: FILTER register definition

−3 dB Frequency	BIT SETTING
80 Hz	0
160 Hz	1
500 Hz	2
1 kHz	3
2 kHz	4

OUTPUT FORMAT

The HAL85x provides two different output formats: a PWM and Biphase-M output.

PMW output is a pulse width modulated output. The signal is defined by the ratio of pulse width to pulse period.

The Biphase-M output is a serial protocol. A logical "0" is coded as no output level change within the bit time. A logical "1" is coded as an output level change between 50% and 80% of the bit time. After each bit, an output level change occurs (see Section 3.6.1. on page 24).

Table 2–3: OUTPUT FORMAT register definition

Output Format	BIT SETTING
PWM	2
Biphase-M	4[1]
Biphase-M (test)	5[2]

[1] In case of OUTPUT FORMAT = 4 the continuous Biphase-M output will be active after locking the device. In order to test the Biphase-M output with nonlocked sensors OUTPUT FORMAT = 5 has to be used.
[2] writing OUTPUT FORMAT = 5 will activate the Biphase-M output for test purpose. The test can be deactivated by switching the device off.

OUTPUT PERIOD

The OUTPUT PERIOD register defines the PWM-Period of the output signal.

Table 2–4: OUTPUT PERIOD register definition

PWM Output Period	BIT SETTING
128 ms; 12-bit resolution	0
64 ms; 12-bit resolution	1
32 ms; 12-bit resolution	2
16 ms; 12-bit resolution	3
8 ms; 12-bit resolution	4
4 ms; 11-bit resolution	5
2 ms; 10-bit resolution	6
1 ms; 9-bit resolution	7

OUTPUT BITTIME

The OUTPUT BITTIME register defines the bit time of the Biphase-M output signal. OUTPUT BITTIME is "sub"-register of the SPECIAL CUSTOMER register.

Table 2–5: OUTPUT BITTIME register definition

Biphase-M Output Bit Time	BIT SETTING
40 μs	0
3.2 ms	5

Note: Setting the Biphase-M bit time to 40 μs simultaneously switches the programming telegram to the same bit time. Hence after writing the OUTPUT BITTIME register the timing of the programming device has to be set accordingly.

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 (Linear 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 signal 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 400 ppm/K and quadratic coefficients from about −5 ppm/K^2 to 5 ppm/K^2. Please refer to Section 4.5. on page 28 for the recommended settings for different linear temperature coefficients.

SLOPE

The SLOPE register contains the parameter for the multiplier in the DSP. The Slope is programmable between −4 and 4. The register can be changed in steps of 0.00049. Slope = 1 corresponds to an increase of the output signal by 100% if the digital value at the A/D-converter output increases by 2048.

For all calculations, the digital value after the digital signal processing is used. This digital information is readable from the DIGITAL OUTPUT register.

SHIFT

The SHIFT register contains the parameter for the adder in the DSP. Shift is the output signal without external magnetic field (B = 0 mT) and programmable from −100% up to 100%.

For calibration in the system environment, a 2-point adjustment procedure is recommended. The suitable Slope and Shift values for each sensor can be calculated individually by this procedure.

PARTNUMBER

In case of Biphase-M output, a part number can be defined. This part number will be sent during power-on of the sensor if the PARTNUMBER ENABLE bit is set. The first 100 ms will display the part number. Afterwards, the sensor will send the digital value corresponding to the applied magnetic field.

The PARTNUMBER ENABLE bit is part of the SPECIAL CUSTOMER register.

OUTPUT CHARACTERISTIC

The OUTPUT CHARACTERISTIC register defines the shape of the sensor output signal. It consists of 32 setpoints. Each setpoint can be set to values between 0 and 511 LSB. The output characteristic has to be monotonic increasing (Setpoint0 ≥ Setpoint1 ≥ SetpointN).

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: This register cannot be reset!

DIGITAL OUTPUT

This 12-bit register delivers the actual digital value of the applied magnetic field after the signal processing. This register can only be read out, and it is the basis for the calibration procedure of the sensor in the system environment.

OFFSET CORRECTION

The OFFSET CORRECTION register allows to adjust the digital offset of the built-in A/D-converter. The digital offset can be programmed to $-3/4$, $-1/2$, $-1/4$, 0, $+1/4$, $+1/2$, $+3/4$ of full-scale.

Table 2–6: OFFSET CORRECTION register definition

Offset Correction	BIT SETTING
$-3/4$	28
$-1/2$	29
$-1/4$	30
0	0
1/4	17
1/2	18
3/4	19

SLEW RATE

The SLEW RATE register is a "sub"-register of the CURRENTSOURCE register. The output fall time of the HAL855 depends on the SLEW RATE register setting and the external load circuit.

Note: The output rise time is purely due to the external load and is not controlled by the SLEW RATE register.

Table 2–7: SLEW RATE register definition

Typ. Slew Rate (3.6 kΩ Pull-up, 4.7 nF)	BIT SETTING (HAL855)
0.3 µs	0
0.8 µs	1
1.2 µs	2
1.5 µs	3

2.2.1. Additional Registers for HAL856

CURRENTSOURCE

The CURRENTSOURCE register contains three "sub"-registers: the 3 LSB contain the HIGH CURRENT setting, the next 4 bits the LOW CURRENT setting of the two-wire output (HAL856). The two MSB define the SLEW RATE of the three-wire output (HAL855).

There are six combination of high- and low-current levels.

Table 2–8: HIGH / LOW CURRENT register definition

Typ. Supply Current $I_{DD,Low}$ $I_{DD,High}$	HIGH CUR-RENT	LOW CUR-RENT
6 mA 14 mA	4	12
6 mA 15 mA	2	12
6 mA 16 mA	0	12
7 mA 14 mA	6	4
7 mA 15 mA	4	4
7 mA 16 mA	2	4

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 (PC85x) for the input of the register values.

For the individual calibration of each sensor in the customer application, a two-point adjustment is recommended (see Fig. 2–5 for an example). 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 part number, the output format, the low and high current (in case of HAL856) 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)

– TC and TCSQ
 (depends on the material of the magnet and the other temperature dependencies of the application)

– OUTPUT FORMAT
 (according to the application requirements)

– OUTPUT PERIOD
 (according to the application requirements)

– PARTNUMBER
 (in case Biphase-M output format is used)

– LOW OUTPUT CURRENT
 (in case of HAL856)

– HIGH OUTPUT CURRENT
 (in case of HAL856)

– OFFSET CORRECTION

– SLEW RATE

Write the appropriate settings into the HAL85x registers.

Step 2: Initialize DSP

As the DIGITAL OUTPUT register value depends on the settings of SLOPE, SHIFT and the OUTPUT

CHARACTERISTIC, these registers have to be initialized with defined values, first:

– $Shift_{INITIAL}$ = 50%

– OUTPUT CHARACTERISITC = 'Linear Standard'
 (Setpoint 0 = 0, Setpoint 1 = 16, Setpoint 2 = 32, ..., Setpoint 31 = 496).

– $Slope_{INITIAL}$ depends on the setting of the digital low-pass filter (see Table 2–9).

Table 2–9: Initial Slope values

−3 dB Frequency	$Slope_{INITIAL}$
80	0.2578
160	0.2578
500	0.1938
1000	0.1938
2000	0.3398

Step 3: Define Calibration Points

For highest accuracy of the sensor, calibration points near the minimum and maximum input signal are recommended.

Define nominal values $DOUT1_{NOM}$ and $DOUT2_{NOM}$ of the DIGITAL OUTPUT register at the calibration points 1 and 2, respectively.

Note: The Micronas software PC85x uses default settings $DOUT1_{NOM}$ = 0 and $DOUT2_{NOM}$ = 3968.

Note: The output is clamped to Setpoint 0 and Setpoint 31. In case of 'Linear Standard' Setpoint 0 corresponds to DIGITAL OUTPUT = 0 while Setpoint 31 corresponds to DIGITAL OUTPUT = 3968.

Step 4: Calculation of Shift and Slope

Set the system to calibration point 1 and read the register DIGITAL OUTPUT. The result is the value DOUT1.

Now, set the system to calibration point 2, read the register DIGITAL OUTPUT, and get the value DOUT2.

With these values, the values for Sensitivity and Shift are calculated as:

$$Slope = Slope_{INITIAL} \cdot \frac{(DOUT2_{NOM} - DOUT1_{NOM})}{(DOUT2 - DOUT1)}$$

$$Shift = \frac{100\%}{4096} \cdot \left(DOUT2_{NOM} - \frac{(DOUT2 - 2048) \cdot Slope}{Slope_{INITIAL}} \right)$$

Write the calculated values for Slope, Shift, and the desired output characteristic into the EEPROM. The sensor is now calibrated for the customer application.

As long as the LOCK bit is not set, the calibration procedure can be applied repeatedly.

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 for $Slope_{INITIAL}$, $Shift_{INITAL}$ and Output Characteristic are overwritten in step 5.

Step 5: Locking the Sensor

The last step is activating the LOCK function with the "LOCK" command. 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.

Warning: This register cannot be reset!

2.3.2. Example: Calibration of an Angle Sensor

The following description explains the calibration procedure using an angle sensor with a HAL855 as an example. The required output characteristic is shown in Fig. 2–5.

– the angle range is from −25° to 25°

– temperature coefficient of the magnet: −500 ppm/K
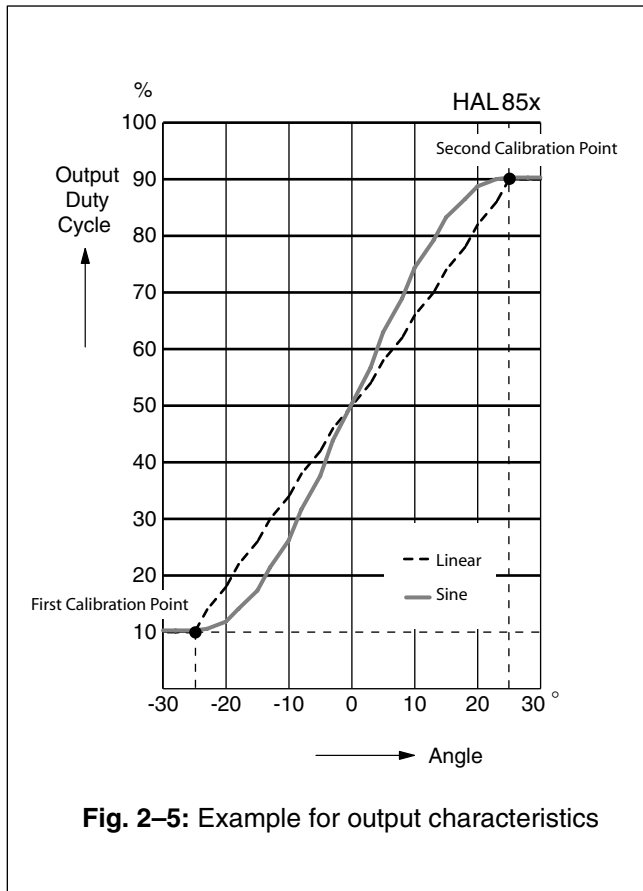
Fig. 2–5: Example for output characteristics

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

The register values for the following registers are given for all applications:

– FILTER
Select the filter frequency: 500 Hz

– RANGE
Select the magnetic field range: 40 mT

– TC
For this magnetic material: 6

– TCSQ
For this magnetic material: 14

– OUTPUT FORMAT
Select the output format: PWM

– OUTPUT PERIOD
Select the output format: 8 ms

– PARTNUMBER
For this example: 1

– OFFSET CORRECTION
For this example: none

– SLEW RATE
For this example: 0 (fastest)

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

Step 2: Initialize DSP

– SHIFT
Select Shift: 50%

– SLOPE
Select Slope: 0.1938 (see Table 2–9 on page 12)

– OUTPUT CHARACTERISTIC
Select output characteristic: 'Linear Standard'

Step 3: Define Calibration Points

The Micronas software PC85x uses default settings $DOUT1_{NOM} = 0$ and $DOUT2_{NOM} = 3968$.

$DOUT1_{NOM}$ corresponds to the angle position −25°, $DOUT2_{NOM}$ to +25°.

Step 4: Calculation of Shift and Slope

There are two ways to calculate the values for Shift and Slope.

Manual Calculation:

1. Set the system to calibration point 1 (angle 1 = 25°)

2. read the register DIGITAL OUTPUT.

For our example, the result is

DIGITAL OUTPUT = DOUT1 = 3291.

3. Set the system to calibration point 2 (angle 2 = −25°)

4. read the register DIGITAL OUTPUT again.

For our example, the result is

DIGITAL OUPTUT = DOUT2 = 985.

With these measurements and the pre-programming of the sensor, the values for Slope and Shift are calculated as:

$$Slope = \frac{3968}{(985 - 3291)} \cdot 0.1938 = -0.3335$$

$$Shift = \frac{100\%}{4096} \cdot \left(3968 - \frac{(985 - 2048) \cdot (-0.3335)}{0.1938} \right) = 52.22\%$$

Write the calculated values for Slope and Shift and a linear output characteristic ranging from 10% to 90% output duty cycle into the EEPROM memory.

Software Calibration:

Use the menu CALIBRATE from the PC software and enter the values for the registers which are not adjusted individually. Set the system to calibration point 1 (angle 1 = 25°), hit the button "Digital Output1", set the system to calibration point 2 (angle 2 = −25°), hit the button "Digital Output2", and hit the button "Calculate". The software will then calculate the appropriate Shift and Slope.

This calculation has to be done individually for each sensor. Now, select an output characteristic from the selection box "Output Characteristics" and then press the button "write and store" for programming the sensor.

Step 5: Locking the Sensor

The last step is activating the LOCK function with the "LOCK" command. 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.

Warning: This 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 mln	45°

JEDEC STANDARD		ANSI	ISSUE DATE YY-MM-DD	DRAWING-NO.	SPZG-NO.
ISSUE	ITEM NO.				
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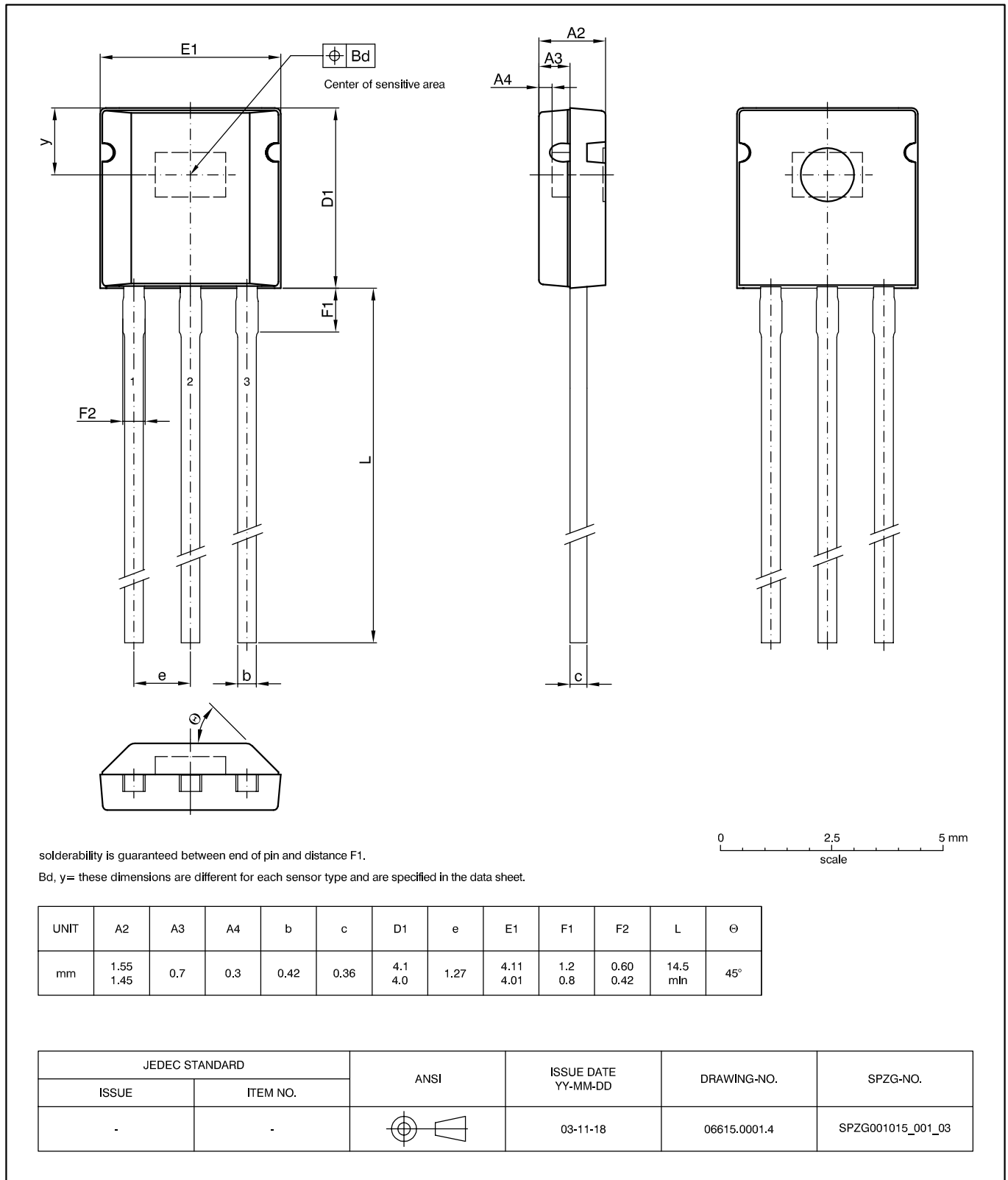
Fig. 3–1:
TO92UT-2: Plastic Transistor Standard UT package, 3 leads
Weight approximately 0.12 g

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°

JEDEC STANDARD		ANSI	ISSUE DATE YY-MM-DD	DRAWING-NO.	SPZG-NO.
ISSUE	ITEM NO.				
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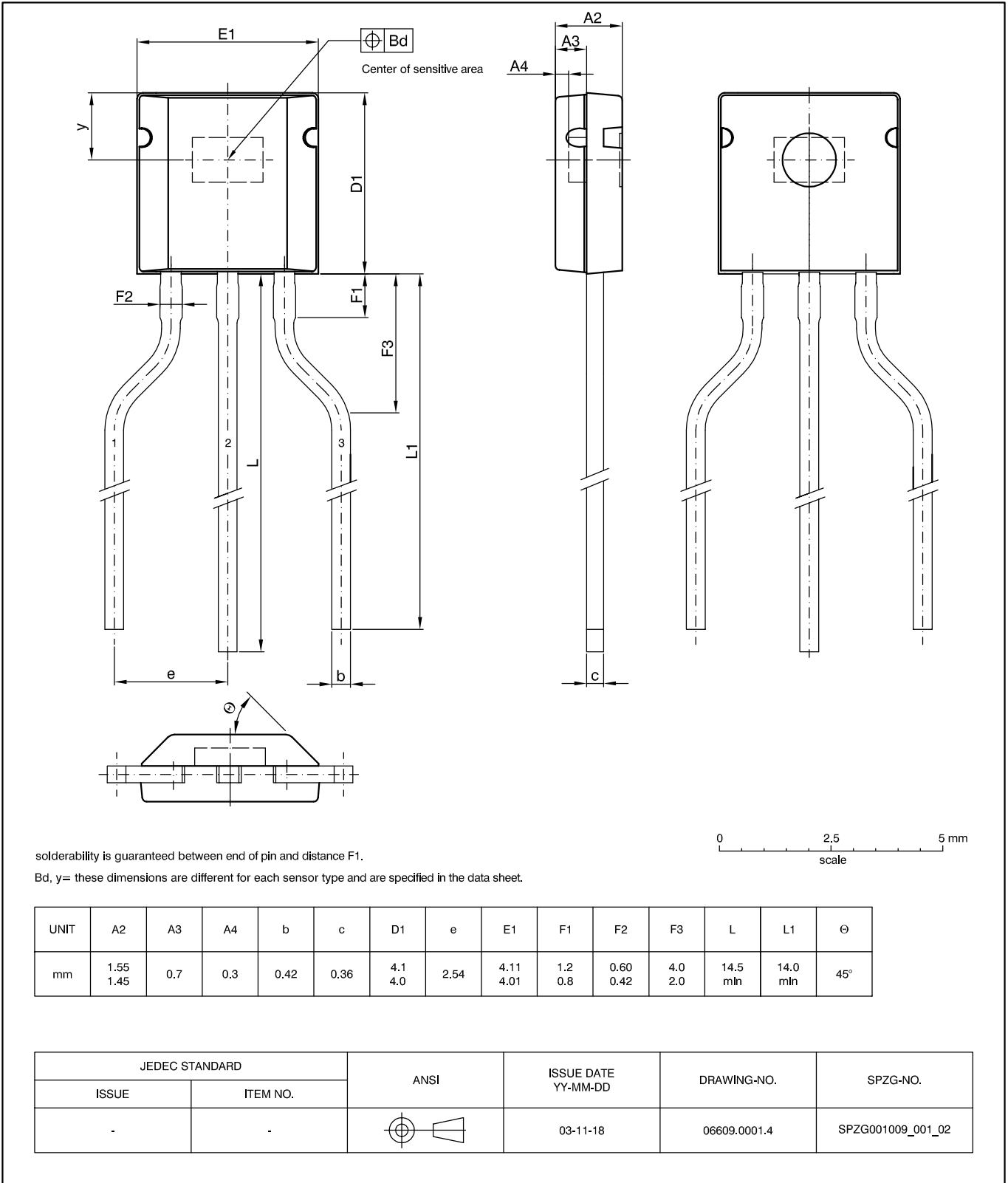
Fig. 3–2:
TO92UT-1: Plastic Transistor Standard UT package, 3 leads, spread
Weight approximately 0.12 g

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

JEDEC STANDARD		ANSI	ISSUE DATE YY-MM-DD	DRAWING-NO.	SPZG-NO.
ISSUE	ITEM NO.				
-	ICE 60286-2	⊕ ◁	03-09-12	06631.0001.4	SPZG001031_001_02
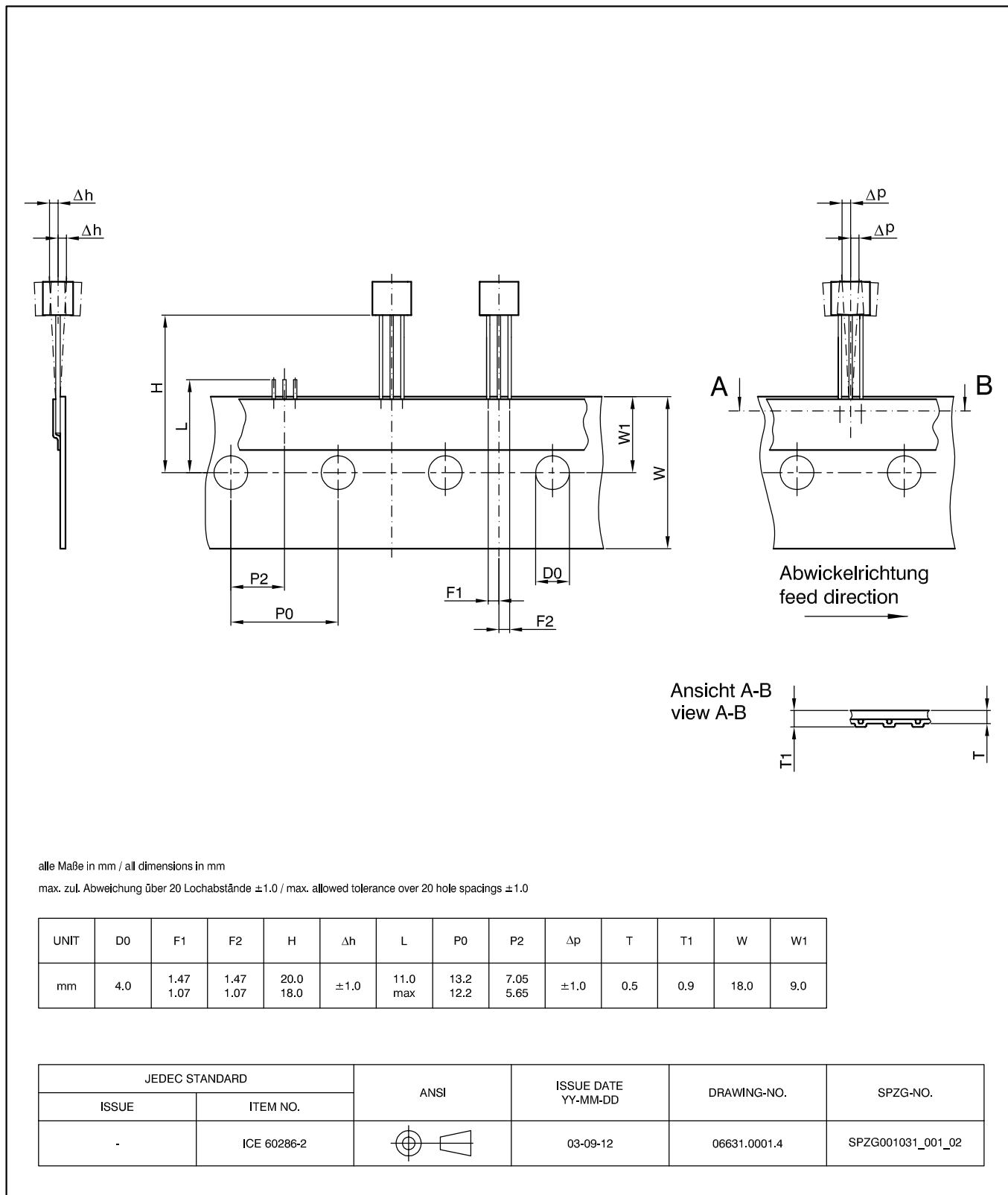
Fig. 3–3:
TO92UT-2: Dimensions ammopack inline, not spread

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

JEDEC STANDARD		ANSI	ISSUE DATE YY-MM-DD	DRAWING-NO.	SPZG-NO.
ISSUE	ITEM NO.				
-	ICE 60286-2	⊕ ◁	03-09-12	06632.0001.4	SPZG001032_001_02
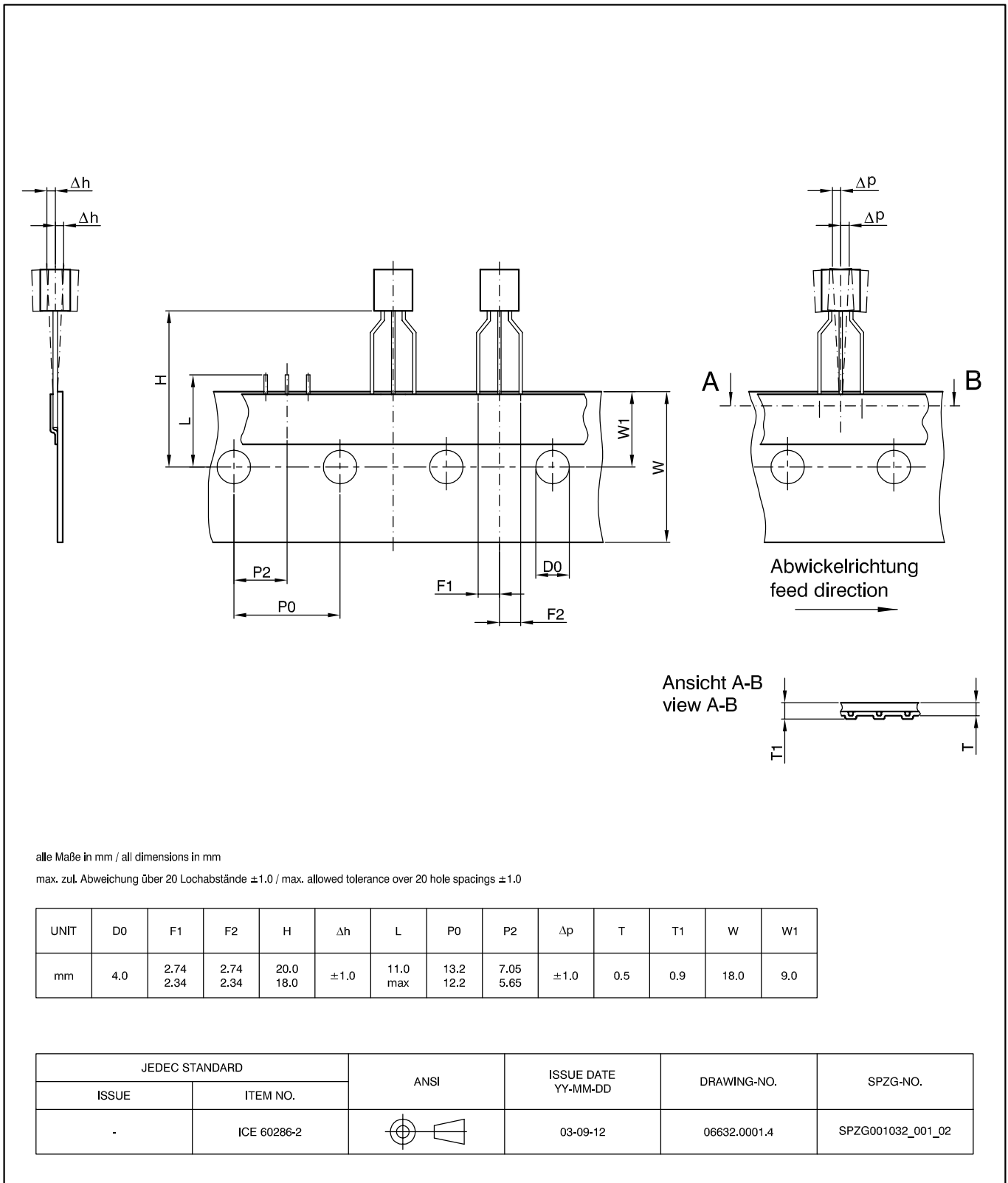
Fig. 3–4:
TO92UT-1: Dimensions ammopack inline, spread

3.2. Dimensions of Sensitive Area

0.25 mm x 0.25 mm

3.3. Position of Sensitive Areas

	TO92UT-1/-2
x	center of the package
y	1.5 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.	Limit Values		Unit
			Min.	Max.	
V_{DD}	Supply Voltage	1	−14.5[1]	18	V
$-I_{DD}$	Reverse Supply Current	1	–	50[2]	mA
I_Z	Current through Protection Device	1 or 3	−50[2]	50[2]	mA
V_{OUT}	Output Voltage	3	−0.3	18	V
I_{OUT}	Continuous Output Current	3	−50[2]	50[2]	mA
T_J	Junction Temperature Range		−40 −40	150 170[3]	°C
N_{PROG}	Number of Programming Cycles		–	100	

[1] t < 1 min.
[2] as long as T_{Jmax} is not exceeded
[3] t < 1000h

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 of the device and may reduce reliability and lifetime.

All voltages listed are referenced to ground (GND).

Symbol	Parameter	Pin No.	Limit Values			Unit	Remarks
			Min.	Typ.	Max.		
V_{DD}	Supply Voltage	1	4.5	–	14	V	
I_{OUT}	Continuous Output Current	3	–	–	20	mA	HAL 855
C_P	Protection Capacitance	1,2	4.7	4.7	1000	nF	
C_L	Load Capacitance	2,3	0.33	4.7	100	nF	

3.6. Characteristics

at $T_J = -40 \, °C$ to $+170 \, °C$, $V_{DD} = 4.5 \, V$ to $14 \, V$, after programming,
at Recommended Operation Conditions if not otherwise specified in the column "Conditions".
Typical Characteristics for $T_J = 25 \, °C$ and $V_{DD} = 5 \, V$.

All voltages listed are referenced to ground (GND).

Symbol	Parameter	Pin No.	Limit Values			Unit	Test Conditions
			Min.	Typ.	Max.		
I_{DD}	Supply Current over Temperature Range	1		7	10	mA	
$I_{DD,Low}$	Low level sink current	1	5	6	8	mA	programmable Parameter
			6	7	9	mA	Only HAL 856
$I_{DD,High}$	High level sink current	1	12	14	17	mA	programmable Parameter
			13	15	18	mA	Only HAL 856
			14	16	19	mA	
I_{OH}	Output Leakage Current over Temperature Range	3	–	–	10	µA	
V_{DDZ}	Over Voltage Protection at Supply	1		22		V	
V_{OZ}	Over Voltage Protection at Output	3		22		V	
	Resolution	2,3			12	bit	1)
INL	Integral non-linearity over temperature range	2,3	−0.5	0	0.5	%	2)
f_{PWM}	PWM output frequency over temperature range	3	840	1000	1080	Hz	PWM period: 1 ms; 9 bit res.
			420	500	540	Hz	PWM period: 2 ms; 10 bit res.
			210	250	270	Hz	PWM period: 4 ms; 11 bit res.
			105	125	135	Hz	PWM period: 8 ms; 12 bit res.
			52	62.5	68	Hz	PWM period: 16 ms; 12 bit res.
			26	31.3	34	Hz	PWM period: 32 ms; 12 bit res.
			13	15.6	17	Hz	PWM period: 64 ms; 12 bit res.
			6.5	7.8	8.5	Hz	PWM period: 128 ms;12 bit res.
t_{p0}	Biphase M output bittime over temperature range	3	0.03	0.04	0.05	ms	Biphase-M bit time: 40 µs
			2	3.2	4	ms	Biphase-M bit time: 3.2 ms
t_{p1}	Biphase-M output timing for logical 1	3	50	65	80	% t_{p0}	
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 internal signal[3]	3	–	5	10	ms	3 dB filter frequency = 80 Hz
				4	8	ms	3 dB filter frequency = 160 Hz
				2	4	ms	3 dB filter frequency = 500 Hz
				1	2	ms	3 dB filter frequency = 2 kHz
$t_{d(O)}$	Delay time of internal signal	3	–	0.1	0.5	ms	
t_{POD}	Power-up time (time to reach stabilized internal signal)[3]			6	11	ms	3 dB filter frequency = 80 Hz
				5	9	ms	3 dB filter frequency = 160 Hz
				3	5	ms	3 dB filter frequency = 500 Hz
				2	3	ms	3 dB filter frequency = 2 kHz

1) if the Hall IC is programmed suitably
2) if more than 50% of the selected magnetic field range are used and the Hall IC is programmed suitably
3) the output signal is updated at the begin of each PWM period or biphase-M period. The update time depends on the output format settings

Symbol	Parameter	Pin No.	Limit Values			Unit	Test Conditions
			Min.	Typ.	Max.		
t_{LVD}	Power-down time (time until output is off)			50	75	µs	
V_{LVD}	Power-down voltage	1	–	3.8	–	V	
V_{POD}	Power-on reset voltage	1	–	4.0	–	V	
BW	Small signal bandwidth (−3 dB)	3	–	2	–	kHz	B_{AC} < 10 mT; 3 dB Filter frequency = 2 kHz
$R_{DS,On}$	'On' resistance R_{DS} of output transistor	3	–	50	100	Ω	
R_{thJA} TO92UT-1, TO92UT-2	Thermal resistance junction to soldering point	–	–	150	200	K/W	

3.6.1. Specification of Biphase-M Output

In case of output format biphase-M a continuous data stream is provided. It consists of:

– 1 SYNC bit defining the bit time t_{p0},

– 14 data bits (DAT)

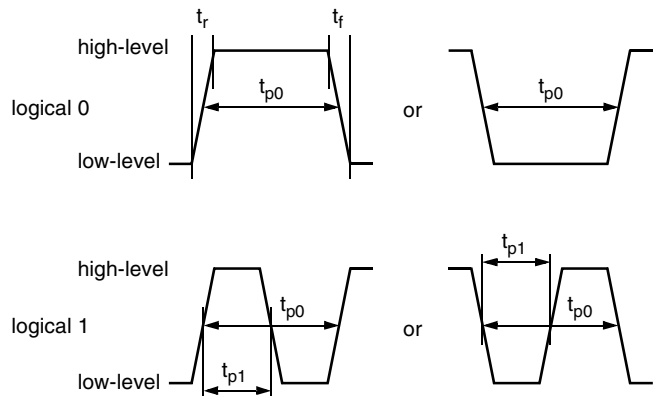– 1 parity bit (DP)

– a gap (signal quiescent) of 8 x t_{p0}

The complete signal period is: $T = 24$ x t_{p0}.

The signal quiescent level and the polarity of the SYNC bit depends on the sensor type (see Fig. 3–5).

Type	SYNC Bit Polarity
HAL855	negative
HAL856	positive

Definition of Biphase-M Pulses

A logical "0" is coded as no output level change within the bit time. A logical "1" is coded as an output level change between 50% and 80% of the bit time. After each bit, an output level change occurs.


Data Bits (DAT)

The 12 MSB of the 14 data bits (DAT) contain the digital output reading.

Data Parity Bit (DP)

This parity bit is "1" if the number of zeros within the 14 data bits is even. The parity bit is "0" if the number of zeros is odd.

Note: For the first 100 ms after power-up the biphase-M data are not valid.
In case the partnumber output is activated the partnumber will be transmitted for the first 100 ms after power-up.
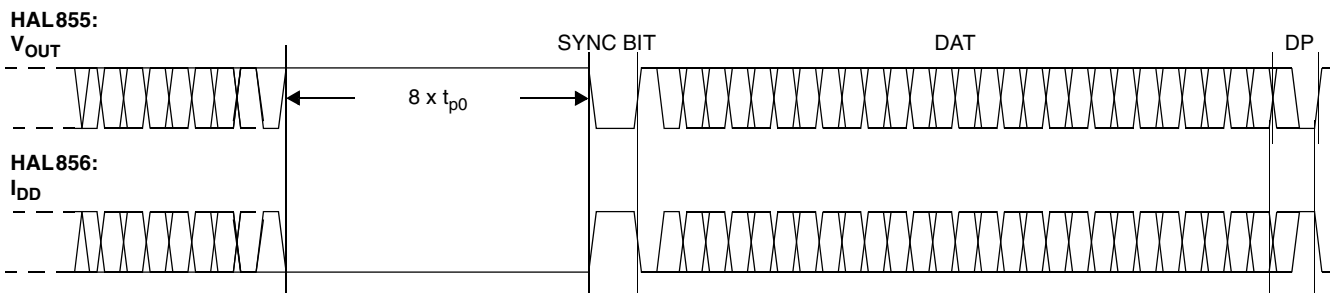
Fig. 3–5: Output format biphase M: continuous data stream.

3.7. Magnetic Characteristics

at T_J = −40 °C to +170 °C, V_{DD} = 4.5 V to 14 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, T_J = 25 °C
$\Delta B_{Offset}/\Delta T$	Magnetic offset change due to T_J		−15	0	15	µT/K	B = 0 mT
$\Delta\alpha$	Error of Linear temperature coefficient of magnetic sensitivity		−400		400	ppm/ K	TC and TCSQ suitable for the application
$NL_{SB(T)}$	Integral non-linearity of temperature dependence of sensitivity		− −	1 2	− −	% %	α < 2000 ppm/K α >= 2000 ppm/K TC and TCSQ suitable for the application
$B_{Hysteresis}$	Magnetic hysteresis		−20	0	20	µT	Range = 30 mT, Filter = 500 Hz

Definition of Sensitivity Errors over Temperature

A ideal Hall-effect device would not be affected by temperature. Its temperature compensation would allow to compensate for a linear temperature coefficient α_{IDEAL} of a permanent magnet.

$$S_{IDEAL} = 1 + \alpha_{IDEAL} \cdot (T - T_0)$$

The temperature dependence of the sensitivity of a real sensor is not ideal linear. Its linear temperature coefficient α is determined by a linear least square fit.

$$S_B = S_0 \cdot (1 + \alpha \cdot (T - T_0) + res(T))$$

S_0 and α are the fit parameters, *res(T)* the residual error.

Micronas specifies two sensitivity errors over temperature:

1. the error of the linear temperature coefficient α:

$$\Delta\alpha = \alpha - \alpha_{IDEAL}$$

2. the maximum residual error over temperature resulting from the least square fit. I.e. the integral non-linearity of the temperature dependence of sensitivity:

$$NL_{SB(T)} = max_T |res(T)|$$

3.8. Diagnosis Functions

The HAL85x features various diagnosis functions, such as under voltage detection and open-circuit detection. A description of the sensor's behavior is shown in the table below (Typical Characteristics for $T_J = 25\ °C$).

Parameter	Limit Values			Unit	Output Behavior
	Min.	Typ.	Max.		
Under voltage detection level $V_{DD, UV}$	1	3.7	–	V	No PWM output signal (output on high-level)
Open V_{DD} line	–	–	–	–	No PWM output signal (output on high-level)
Open GND line	–	–	–	–	No PWM output signal

4. Application Notes

4.1. Application Circuit

Micronas recommends the following application circuit for applications with HAL 856:
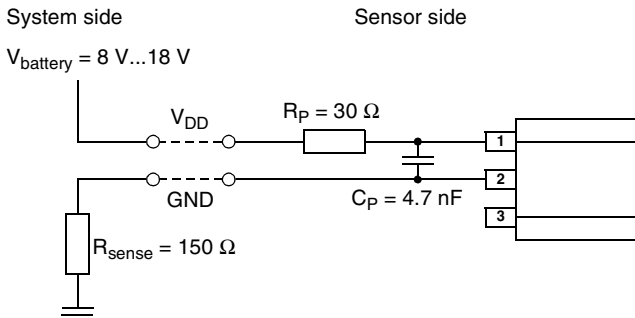

Fig. 4–1: Application circuit HAL856

For EMC protection, it is recommended to connect one ceramic 4.7 nF capacitor between ground and the supply voltage line. It is also recommended to place a 30 Ω protection resistor in the supply voltage line.

Note: In case of HAL856, the third sensor pin should be floating or connected to the GND line.

In addition, Micronas recommends the following two application circuits for HAL855. The first circuit is recommended for applications with a connection to a regulated 5 V supply; the second, should be used for applications connected directly to the car battery and a pull-up to a 5 V line.

For both circuits, it is recommended to connect a ceramic 4.7 nF capacitor between ground and the supply voltage, respectively, the output pin.
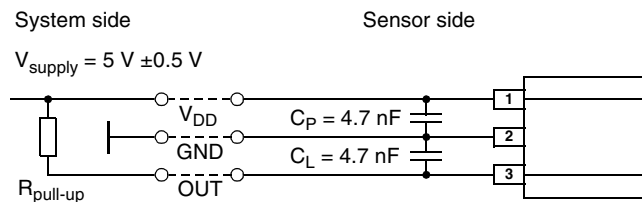

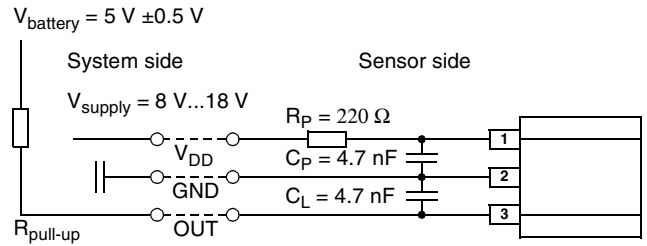**Fig. 4–2:** Application circuit HAL855 for regulated power supply

Fig. 4–3: Application circuit HAL855 for connection with car battery.

4.2. Use of Two HAL 855 in Parallel

Two different HAL855 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 deactivated 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.
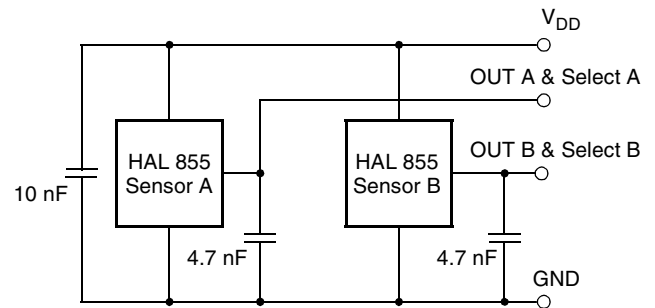

Fig. 4–4: Parallel operation of two HAL855

4.3. Measurement of a PWM Output Signal

In case that the PWM output mode is activated, the magnetic field information is coded in the duty-cycle of the PWM signal. The duty-cycle is defined as the ratio between the high time "s" and the period "d" of the PWM signal (see Fig. 4–5).

Note: The PWM signal is updated with the falling edge. Hence, for signal evaluation, the trigger-level must be the falling edge of the PWM signal.
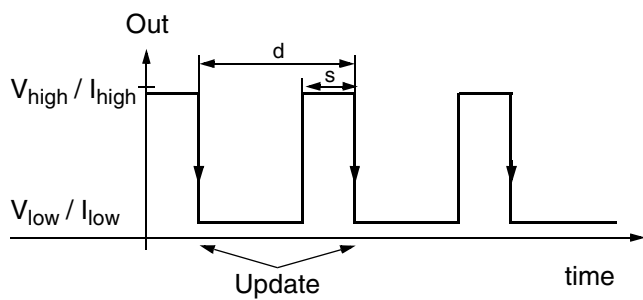
Fig. 4–5: Definition of PWM signal

Note: The PWM shall be evaluated using a digital receiver. Integration of the PWM signal with passive or active filters will reduce the accuracy of the sensor output significantly.

4.4. Measurement of a Biphase-M Output Signal

In order to read the Biphase-M signal Micronas suggests to use a port interrupt which is configured to generate interrupts with both the falling and rising edge of the incoming signal.

With each interrupt a timer shall be read out. The first two edges (SYNC bit) define the bit time t_{p0}. Comparing subsequent timer readouts with t_{p0} successively decodes the biphase-M pattern.

4.5. 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. Micronas also offers a software named TC-Calc to optimize the TC and TCSQ values for each individual

application based on customer measurement results. Please contact Micronas for more detailed information.

The HAL85x and HAL8x5 contain the same temperature compensation circuits. If an optimal setting for the HAL8x5 is already available, the same settings may be used for the HAL85x.

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

Temperature Coefficient of Magnet (ppm/K)	TC	TCSQ
−1180	−7	18
−1250	−8	18
−1320	−9	19
−1380	−10	19
−1430	−11	20
−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

4.6. 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 $\Delta T = 11$ K.

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

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

4.7. EMC and ESD

For applications with disturbances by capacitive or inductive coupling on the supply line or radiated disturbances, the application circuits shown in section 4.1 are recommended. Applications with this arrangement should pass the EMC tests according to the product standards ISO 7637-1...-3.

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

Note: Micronas recommends to supply the three wire device HAL 855 with stabilized 5 V supply. If a HAL 855 is supplied with $V_{BAT} = 8$ V .. 18 V (car battery) a 220 Ω...270 Ω series resistor in the sensors supply line is needed in order to protect against load dump (see Fig. 4–3).

5. Programming of the Sensor

5.1. Definition of Programming Telegram

The sensor is addressed by modulating a serial telegram on the supply voltage. The sensor answers with a serial telegram on the output pin (for HAL855) or a modulation of the current consumption in case of HAL856.

The bits in the serial telegram have a different bit time for the V_{DD}-line and the sensors answer. 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 sensors answer is defined through the Acknowledge Bit.

A logical "0" is coded as no output level change within the bit time. A logical "1" is coded as an output level change between 50% and 80% of the bit time. After each bit, an output level 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.

Note: The sensor can only be programmed with programmer board version 5.1. If you have an older version, please contact Micronas or your supplier.

– 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
  In order to permanently store the written data into the EEPROM cells, an erase and program command have to be sent to the sensor. After the recognition of the erase and program commands, the HAL85x answers with an acknowledge pulse on its output signal. After the acknowledge pulse, a pulse on the V_{DD}-line is created to start the charging of the EEPROM cells. Then, the supply voltage is kept constant during the charging time. To stop the charging, a further command is sent to the HAL85x. This stopping command can be a further programming command or a read command (see Fig. 5–5).

– Lock a sensor (see Fig. 5–6)
  To lock the EEPROM registers, the lock bit has to be programmed. After recognition of the corresponding lock command, the HAL85x provides an acknowledge pulse on the output signal. Similar to the programming of a sensor, a pulse is generated on the supply voltage to start the charging of the lock bit. To stop the charging, a read command is sent to the IC.

Note: It is recommended to lock the sensor before performing any kind of reliability tests or after the last programming of the sensor. The HAL85x has its full performance only after setting the LOCK bit.

Activate a sensor (see Fig. 5–4)
If more than one sensor is connected to the supply line, selection can be done by first deactivating all sensors. 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.

**Note:** The activate and deactivate commands are available only with HAL855.
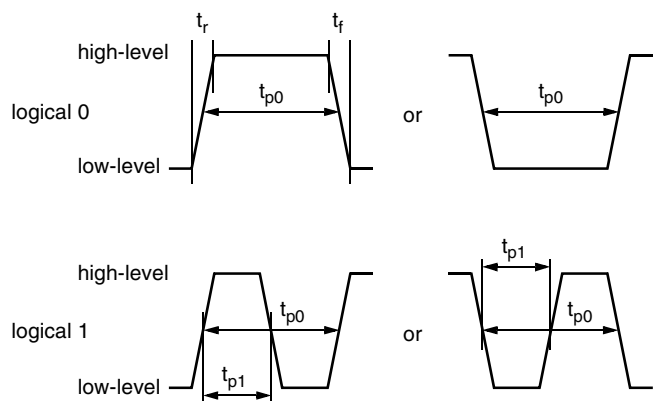
Fig. 5–1: Definition of logical 0 and 1 bit

**Table 5–1:** Telegram parameters (All voltages are referenced to GND.)

| Symbol	Parameter	Pin No.	Limit Values			Unit	Test Conditions
			Min.	Typ.	Max.		
V_{DDL}	Supply Voltage for Low Level during Programming	1	5	5.5	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}
t_{PROG}	Programming Time for EEPROM	1	95	100	105	ms	
$V_{DD,PROG}$	Supply voltage during Programming	1	4.9	5	5.1	V	
t_{rp}	Rise time of charging pulse	1	0.2	0.5	1	ms	
t_{fp}	Fall time of charging pulse	1	0		1	ms	
t_w	Delay time of charging pulse after Acknowledge	1	0.5	0.7	1	ms	
V_{act}	Voltage for an Activate pulse	3	0	0	0.5	V	(HAL855 only)
t_{act}	Duration of an Activate pulse	3	0.05	0.1	–	ms	

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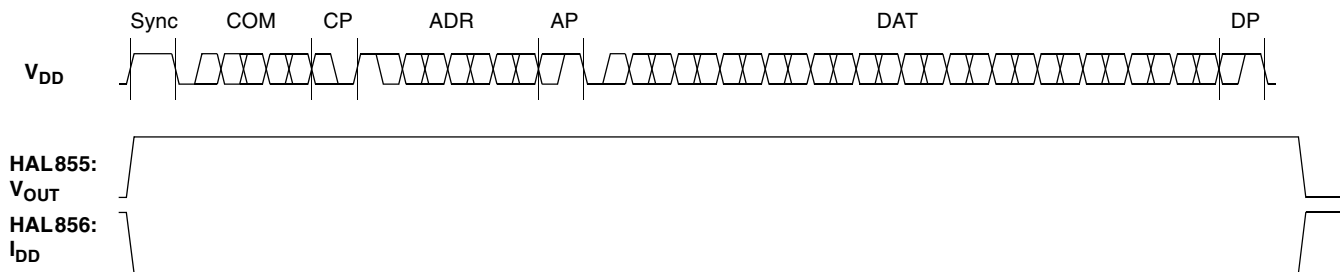
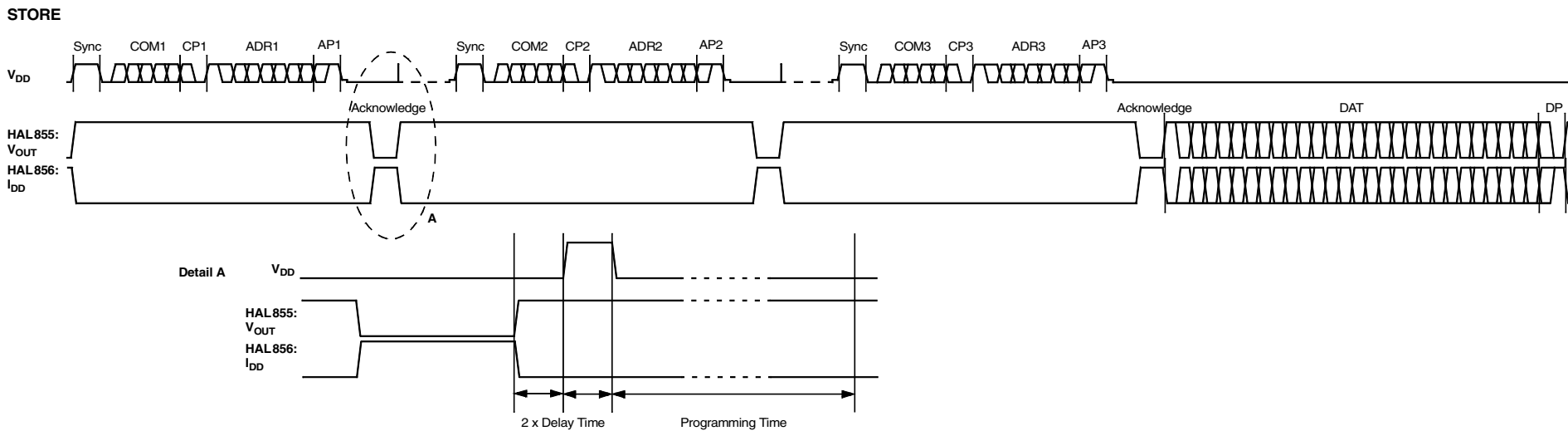**Fig. 5–2:** Telegram for coding a Write command

READ
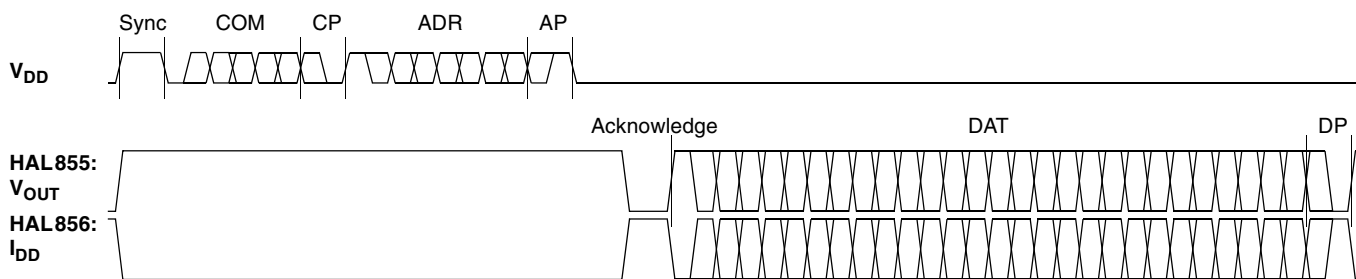
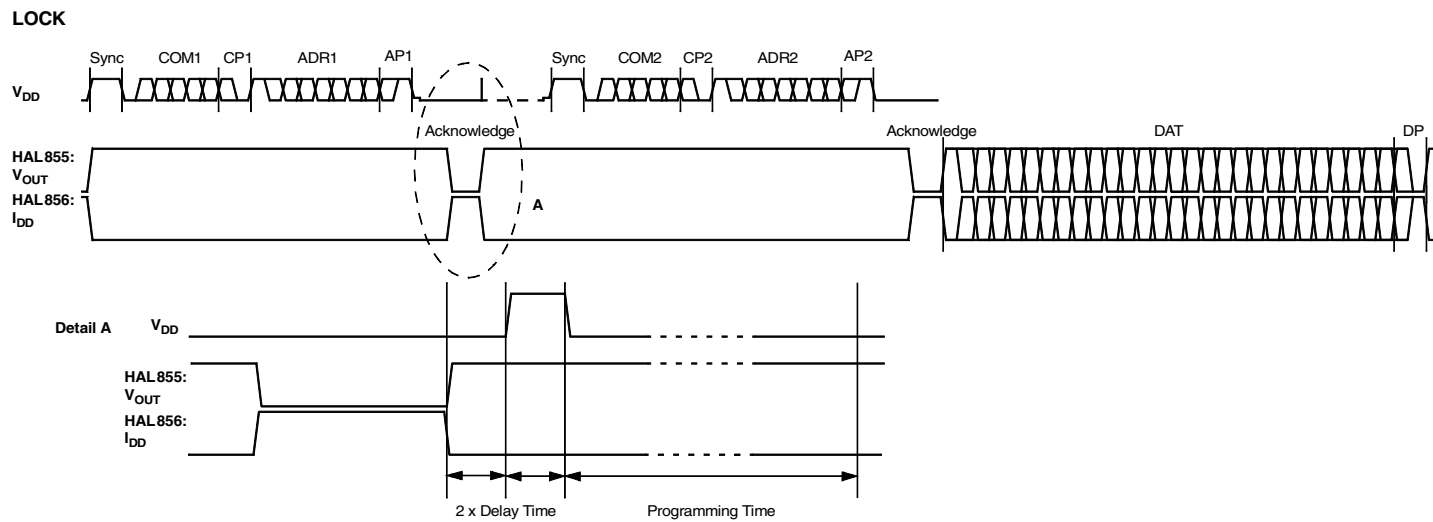**Fig. 5–3:** Telegram for coding a Read command
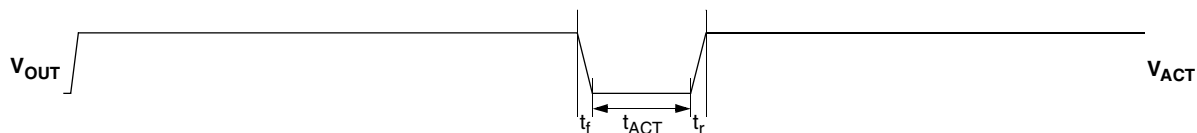
Fig. 5–4: Activate pulse (only for HAL855)

Fig. 5–5: Telegram for programming the EEPROM

Fig. 5–6: Telegram for locking the sensor

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 HAL85x.

Command Parity Bit (CP)

This parity bit is "1" if the number of zeros within the 3 Command Bits is odd. 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 HAL85x registers.

Address Parity Bit (AP)

This parity bit is "1" if the number of zeros within the 4 Address bits is odd. 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 (7 bits) is written, only the last 7 bits are valid.

In the Read command, the first bits are valid. If, for example, the TC register (7 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 odd.

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	0	read a Setup EEPROM register (like TC, TCSQ, Magnetic range, etc.)
READL	6	read a Characteristics EEPROM register (setpoints 0 to 15)
READH	7	read a Characteristics EEPROM register (setpoints 16 to 31)
WRITE	3	write a Setup EEPROM register (like TC, TCSQ, Magnetic range, etc.)
WRITEL	1	write a Characteristics EEPROM register (setpoints 0 to 15)
WRITEH	2	write a Characteristics EEPROM register (setpoints 16 to 31)
PROM	4	program all non-volatile registers
ERASE	5	erase all non-volatile registers
Please note: The LOCK bit is set by using the WRITE command followed by a PROM.		

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 for HAL85x

Register	Code	Data Bits	Format	Customer	Remark
Currentsource	1	10	binary	read/write/program	To define current levels (I_{DD_HIGH} and I_{DD_LOW}) **Only for HAL856** and Slew Rate
Partnumber	2	11	binary	read/write/program	Only with BiPhase-M mode
Shift	3	11	two compl.	read/write/program	
Slope	4	14	signed binary	read/write/program	
Mode	5	14	binary	read/write/program	Range, filter and output format settings
Lock	6	2	binary	write/program	Lock Bit
Digital Readout	7	12	binary	read	Digital value after signal processing
Offset Correction	8	5	two compl. (4 LSBs)	read/write/program	Compensation of system offsets
Specialcust.	9	6	binary	read/write/program	Special customer register To define Biphase-M bittime and Partnumber Enable
TC	11	7	signed binary (6 LSBs)	read/write/program	linear temperature coefficient
TCSQ	12	5	binary	read/write/program	quadratic temperature coefficient
DEACTIVATE	15	11	binary	write	Deactivate the sensor **Only for** HAL855

Table 5–3: Available register addresses for HAL85x, continued

Register	Code	Data Bits	Format	Customer	Remark
Curve Low	0 .. 15	9	binary	write/read/program	Setpoints 1 to 16
Curve High	0 .. 15	9	binary	write/read/program	Setpoints 17 to 32

5.5. Register Information

CURRENTSOURCE

– The register range is from 0 to 1023 and contains the settings for LOW CURRENT, HIGH CURRENT, and SLEW RATE:

$$CURRENTSOURCE = SLEW\ RATE * 256 + LOW\ CURRENT * 8 + HIGH\ CURRENT$$

PARTNUMBER

– The register range is from 0 up to 2047.

SHIFT

– The register range is from −1024 up to 1023.

– The register value is calculated by:

$$SHIFT = \frac{Shift}{100\%} \times 1024$$

SLOPE

– The register range is from −8192 up to 8191.

– The register value is calculated by:

$$SLOPE = Slope \times 2048$$

TC and TCSQ

– The TC register range is from −31 up to 31.

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

Note: The word length TC register is 7 bit. The 6 LSBs represent a signed binary number. The MSB has to be ignored.

MODE

– The register range is from 0 up to 16383 and contains the settings for PERIOD, FORMAT, FILTER, and RANGE:

$$MODE = PERIOD * 512 + FORMAT * 64 + FILTER * 8 + RANGE$$

Please refer to the data sheet for the available PERIOD, FORMAT, FILTER, and RANGE values.

DIGITAL-READOUT

– This register is read only.

– The register range is from 0 up to 4095.

OFFSET CORRECTION

– The register range is from 0 to 31

– The MSB is set to activate the Offset Correction.

SPECIAL CUSTOMER

– The register range is from 0 to 63 and contains the settings for OUTPUT BITTIME and PARTNUMBER ENABLE:

$$SPECIAL\ CUSTOMER = PARTNUMBER\ ENABLE * 16 + OUTPUT\ BITTIME$$

Note: When output format PWM is used the default values for the PARTNUMBER ENABLE bit must not be modified:
HAL856: PARTNUMBER ENABLE = 0
HAL855: PARTNUMBER ENABLE = 1

DEACTIVATE (only for HAL855)

– This register can only be written.

– The register has to be written with 2063 decimal (80F hexadecimal) for the deactivation.

– The sensor can be reset with an Activate pulse on the output pin or by switching off and on the supply voltage.

5.6. Programming Information

If the content of any register is 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 HAL85x registers are to be changed, all writing commands can be sent one after the other, followed by sending one ERASE and PROM command at the end.

During all communication sequences, the customer has to check if the communication with the sensor was successful. This means that the acknowledge and the parity bits sent by the sensor have to be checked by the customer. If the Micronas programmer board is used, the customer has to check the error flags sent from the programmer board.

Note: For production and qualification tests, it is recommended to set the LOCK bit after final adjustment and programming of HAL85x. The LOCK function is active after the next power-up of the sensor.
The success of the Lock Process should be checked by reading at least one sensor register after locking and/or by an analog check of the sensors output signal.
Electrostatic Discharges (ESD) may disturb the programming pulses. Please take precautions against ESD.

6. Data Sheet History

1. Advance Information: "HAL85x Programmable Linear Hall Effect Sensor", March 8, 2004, 6251-604-1AI. First release of the advance information.

2. Data Sheet: "HAL85x Programmable Linear Hall Effect Sensor", Dec. 5, 2005, 6251-604-1DS. First release of the data sheet. Major changes:

   – Section 3.6. Characteristics changed

   – Section 2. Functional Description: new features added

   – Section 2.3. Calibration Procedure: completely revised

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