MICRONAS

Hardware
Documentation

Advance Information

HAL® 283x

Linear Hall-Effect Sensor Family with SENT Interface

Edition Sept. 6, 2010
AI000143-002EN

Contents

Linear Hall-Effect Sensor Family with SENT Interface

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

1. Introduction

The HAL 283x are members of the Micronas family of programmable linear Hall-effect sensors. The subfamily HAL 283x consists of the four members described in the following table:

Table 1–1: Family Overview

Type	Resolution	Pause Pulse	SENT version
HAL 2830	12 bit	No	SAE-J2716 release 2010-01
HAL 2831	16 bit	No	SAE-J2716 release 2010-01
HAL 2832	12 bit	Yes	SAE-J2716 release 2010-01
HAL 2833	16 bit	Yes	SAE-J2716 release 2010-01

The HAL 283x features a temperature-compensated Hall plate with spinning current offset compensation, an A/D converter, digital signal processing, an EEPROM memory with redundancy and lock function for the calibration data, 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 digital signals.

The easy programmability allows a 2-point calibration by adjusting the output signal 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.

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. It is also possible to compensate offset drifts over temperature generated by the customer application with a first order temperature coefficient of the sensors offset. This enables operation over the full temperature range with high accuracy.

For programming purpose, the sensor features a programming interface with a Biphase-M protocol on the DIO pin (output).

In the application mode, the sensor provides a continuous SENT data stream.

1.1. Major Applications

– Contactless potentiometers
– Angular measurements (e.g. valve, throttle, pedal position)
– Linear movement (e.g. seat track position)
– Linear force or torque measurements
– Current sensing (e.g. battery management)

1.2. Features

– High precision linear Hall-effect sensor
– Spinning current offset compensation
– 20 bit digital signal processing
– Output resolution up to 16 bit
– ESD protection (±8 kV HBM) at all pins and reverse protection at V_{SUP} pin
– Various sensor parameter are programmable (like offset, sensitivity, temperature coefficients, etc.)
– NV memory with redundancy and lock function
– Programmable temperature compensation for sensitivity (2nd order) and offset (1st order)
– Typical magnetic ranges from ±20 mT up to ±160 mT in 20 mT steps
– Sample period programmable from 0.5 ms to 33 ms. Second-order low-pass filter for sample period down to 2 ms
– Onboard diagnostics (overvoltage, output current, overtemperature, signal path overflow)
– Power-On self-test covering memory and full signal path from Hall plates to SENT output
– Biphase-M interface (programming mode)
– SENT clock tick time programmable between 2 µs and 17.75 µs
– Low tick time programmable between 3 and 6.75 clock ticks
– Sample accurate transmission of magnetic field information
– Transmission of temperature and device information by serial data messages in the status nibble
– Open-drain output with slew-rate control (load independent)
– Programming and operation of multiple sensors at the same supply line

1.3. Marking Code

The HAL 283x have 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
HAL 2830	2830A	2830K
HAL 2831	2831A	2831K
HAL 2832	2832A	2832K
HAL 2833	2833A	2833K

1.4. Operating Junction Temperature Range (T_J)

The Hall sensors from Micronas are specified to the chip temperature (junction temperature range 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 6.1. on page 29

1.5. Hall Sensor Package Codes

HALXXXXPA-T

Temperature Range: A or K

Package: UT for TO92UT -1/-2

Type: 2832

Example: **HAL 2832UT-K**

→ Type: 2832
→ Package: TO92UT-1/-2
→ 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 and Welding

Solderability

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

Welding

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

1.7. Pin Connections and Short Descriptions

Pin No.	Pin Name	Type	Short Description
1	VSUP		Supply Voltage
2	GND		Ground
3	DIO	IN/ OUT	Digital IO SENT Output

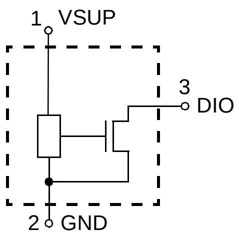


Fig. 1–1: Pin configuration

2. Functional Description

2.1. General Function

The HAL 283x is a monolithic integrated circuit, which provides an output signal 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.

The function and the parameters for the DSP are explained in Section 2.2. on page 7.

Internal temperature compensation circuitry and the spinning current 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 HAL 283x provides two operation modes, the application mode and the programming mode.

Application Mode

The output signal is provided as continuous SENT data stream.

Programming Mode

For the programming of the sensor parameters, a Biphase-M protocol is used.

The HAL 283x provides non-volatile memory which is divided in different blocks. The first block is used for the configuration of the digital signal processing, the second one is used by the various customer settings. The non-volatile memory employs inherent redundancy.

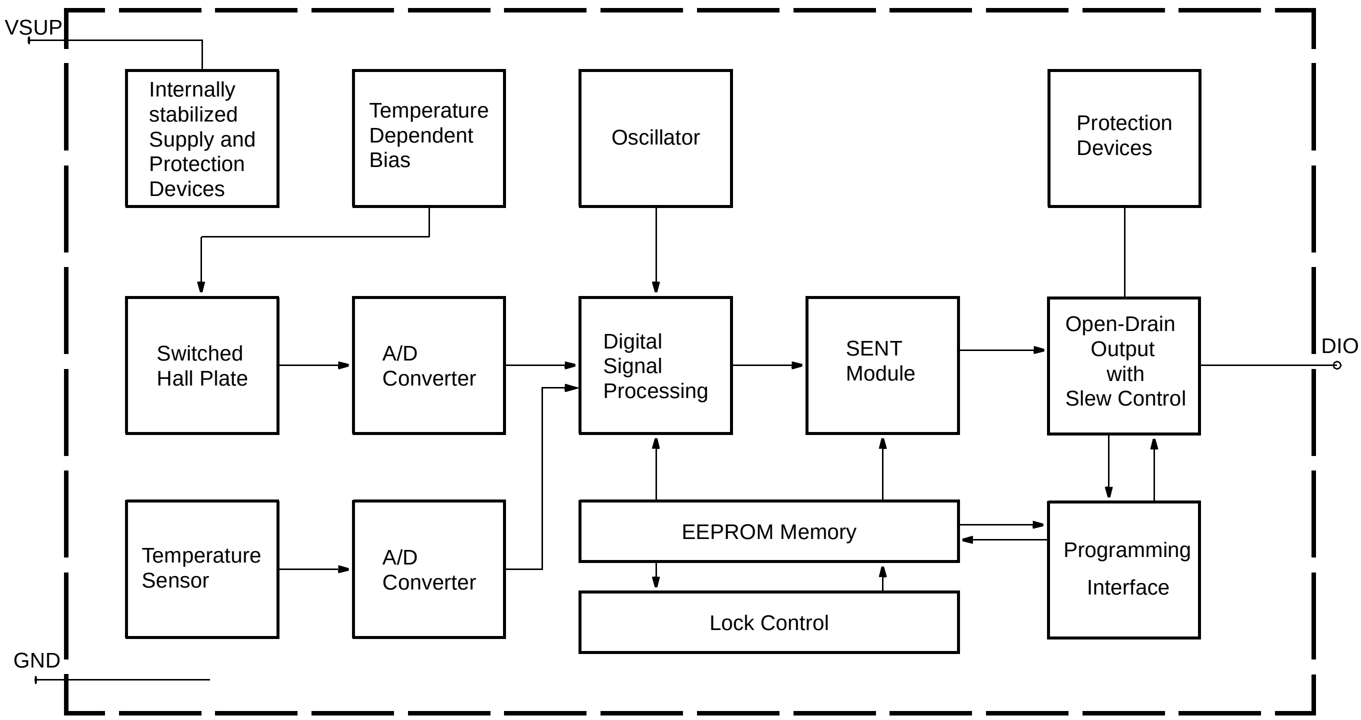


Fig. 2–1: HAL 283x block diagram

2.2. Digital Signal Processing

All parameters and the values y, y_{TCI} are normalized to the interval (–1, 1) which represents the full-scale magnetic range as programmed in the RANGE register.

Example for 40 mT Range

–1 equals –40 mT
+1 equals + 40 mT

For the definition of the register values, please refer to Section 2.2.2. on page 9.

The digital signal processing (DSP) is the major part of the sensor and performs the signal conditioning. The parameters of the DSP are stored in the DSP CONFIG area of the EEPROM.

The device provides a digital temperature compensation. It consists of the internal temperature compensation, the customer temperature compensation, as well as an offset and sensitivity adjustment. The internal temperature compensation (factory compensation) eliminates the temperature drift of the Hall sensor itself. The customer temperature compensation is calculated after the internal temperature drift has been compensated. Thus, the customer has not to take care about the sensor's internal temperature drift.

The output value y is calculated out of the factory-compensated Hall value y_{TCI} as:

$$y = [y_{TCI} + d(TVAL)] \cdot c(TVAL)$$

Parameter d is representing the offset and c is the coefficient for sensitivity.

The signal path contains a digital low-pass filter up to second order with a programmable sampling frequency from 32 Hz up to 2 kHz (see Table 2–2 on page 11).

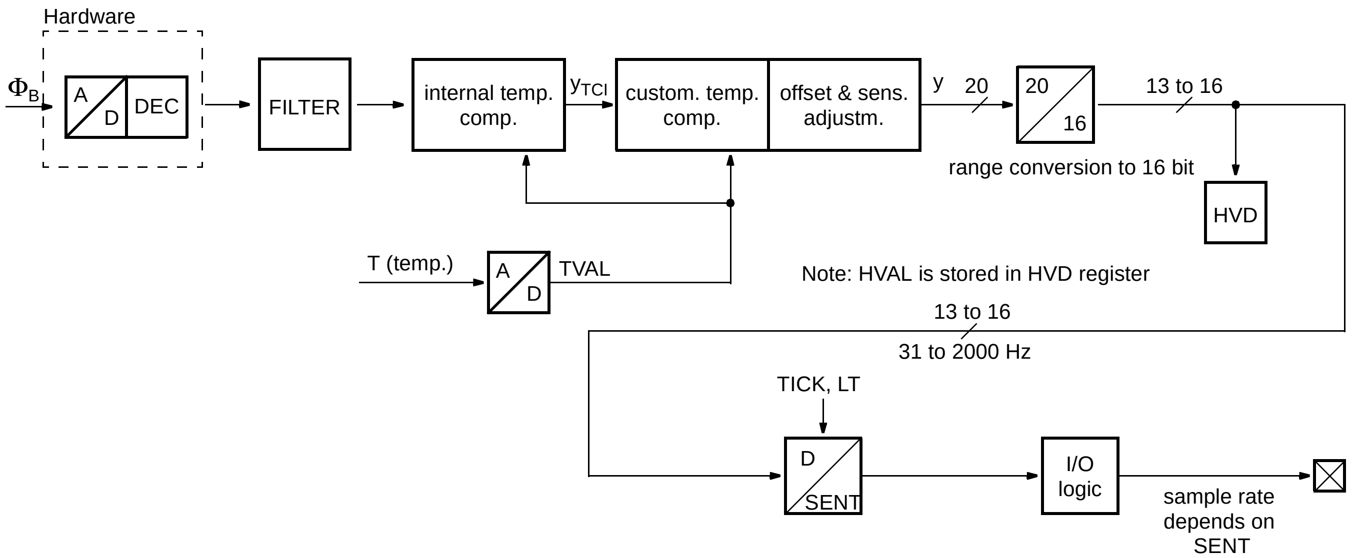


Fig. 2–2: Block diagram of digital signal path including digital filter

The temperature-compensated Hall value is saved in the HVD register.

The SENT interface transmits continuously Hall samples. The HVD value is transmitted at the the beginning of a new SENT message.

After power-up, the registers HVD and TVD are set to the negative overflow value until valid data are available.

2.2.1. Temperature Compensation

Terminology:

D0: name of the register or register value

d_0: name of the parameter

The customer programmable parameters “c” (sensitivity) and d (offset) are polynomials of the temperature. The temperature is represented by the adjusted readout value TVAL of a built-in temperature sensor.

The update rate of the temperature value TVAL is less than 100 ms.

The sensitivity polynomial c(TVAL) is of second order in temperature:

$$c(TVAL) = c_0 + c_1 \cdot TVAL + c_2 \cdot TVAL^2$$

For the definition of the polynomial coefficients, please refer to Section 2.2.2. on page 9.

The offset polynomial d(TVAL) is linear in temperature:

$$d(TVAL) = d_0 + d_1 \cdot TVAL$$

For the definition of the polynomial coefficients, please refer to Section 2.2.2. on page 9.

For the calibration procedure of the sensor in the system environment, the two values HVAL and TVAL are provided. These values are stored in volatile registers.

HVAL

The number HVAL represents the digital output value y which is proportional to the applied magnetic field.

HVAL is 16-bit two’s complement binary ranging from –32768 to +32767.

Note: The number of valid bits varies between 13 and 16 bit. The resolution depends on the selected sample and filter frequency.

It is stored in the HVD register (see Section 5.2. on page 27).

$$y = \frac{HVAL}{32768}$$

In case of internal overflows, the output will clamp to the maximum or minimum HVAL value.
Please take care that during calibration, the output signal range does not reach the maximum/minimum value.

TVAL

The number TVAL provides the adjusted value of the built-in temperature sensor.

TVAL is a 16-bit two’s complement binary ranging from –32768 to 32767.

It is stored in the TVD register (see Section 5.2. on page 27).

Note: The actual resolution of the temperature sensor is 12 bit. The 16-bit representation avoids rounding errors in the computation.

The relation between TVAL and the junction temperature T_J is

$$T_J = \alpha_0 + TVAL \cdot \alpha_1$$

Table 2–1: Relation between T_J and T_{ADJ} (typical values)

Coefficient	Value	Unit
α_0	71.65	°C
α_1	1 / 231.56	°C

2.2.2. DSP Configuration Registers

This section describes the function of the DSP configuration registers. For details on the EEPROM please refer to Section 5.5. on page 29.

Magnetic Range: RANGE

The RANGE register defines the magnetic range of the A/D converter. The RANGE register has to be set according to the applied magnetic field range.

It can be varied between:
Typical ±20 mT and ±160 mT in steps of ±20 mT.

For details, see Section 5.5. on page 29.

Note: The A/D values are not temperature compensated. Please take care that the A/D is not saturating over the used temperature range.

Filter Settings: FS and resolution of HVD

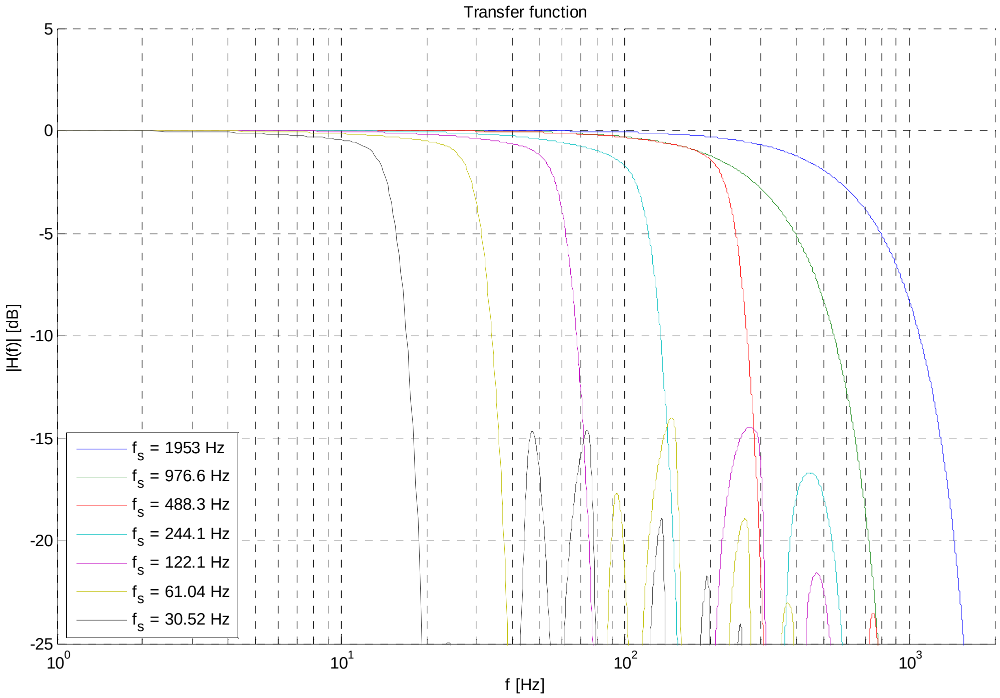
The FS register defines the sampling frequency of the built in digital low-pass filter. HAL 2831/HAL 2833 transmit 16 data bits for sampling frequencies below 500 Hz. Side effect is that the SENT protocol is extended by a fourth data nibble.

Fig. 2–3 shows the sensor's transfer function. The transfer functions for all recommended settings of FS have been combined in this graph. The upper graph of **Fig. 2–3** shows the magnitude at the pass band and stop band. The lower graph is a zoom-in of the magnitude at the pass band.

The sensors have a linear phase behavior for sample frequencies of 1 or 2 kHz and a constant group delay. For the remaining sample frequencies, the phase is nearly linear at the pass band and the group delay is nearly constant.

All filter combinations have a very constant gain at the pass band and a high attenuation at the stop band. The low pass filter is of first order for 1 or 2 kHz filter frequency. At the remaining sample frequencies, the low pass filter is of second order. Thus, the slope at the cut-off frequency is bigger.

The graphs do include the transfer function of the Hall ADC (ADC and decimation filter) and the digital filter.



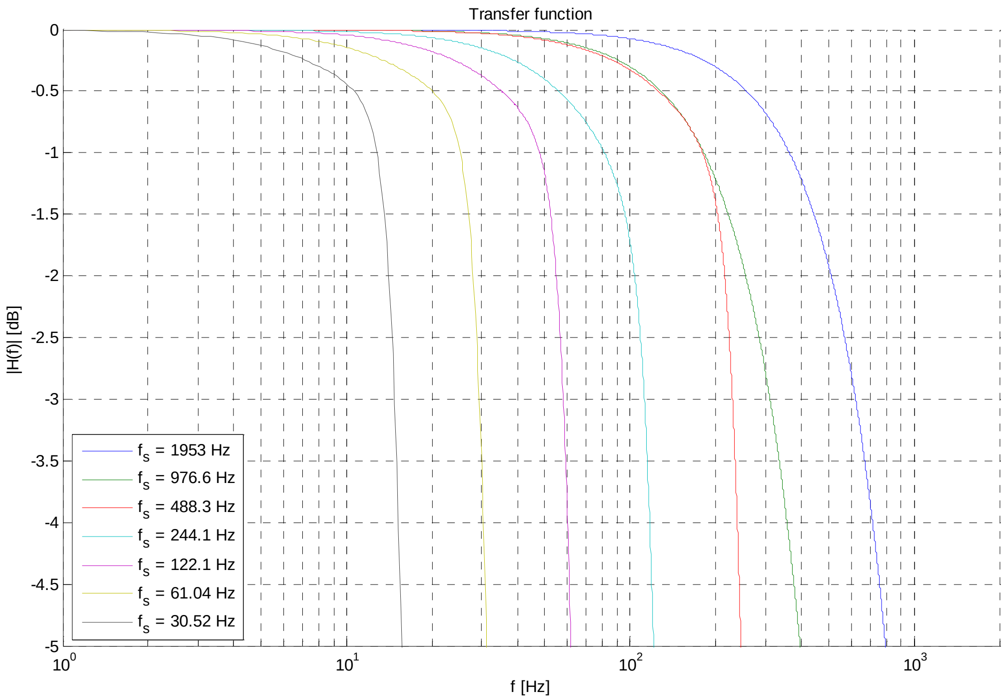


Fig. 2–3: Transfer function, magnitude

Table 2–2: Available sample frequencies and low pass filter.

Sample Frequency		FS	Resolution of HVD		Recommend clock tick time			
			Sensor type		No pause pulse		Pause pulse	
typ.			HAL 2831/3	HAL 2830/2	HAL 2831	HAL 2830	HAL 2833	HAL 2832
[Hz]	[ms]	[Hex]	[LSB]	[LSB]	[μs]			
2000	0.5	0x00	13	13 2)	2.25	2.00 and 2.50	2.00	2.00, 2.25
1000	1	0x01	15	15 2)	2.00 to 4.50	2.00 to 5.25	2.00 to 4.25	2.00 to 5.00
500	2	0x03	16	16 2)	2.00 to 9.25	2.00 to 10.75	2.50 1) to 8.75	2.50 1) to 10.00
250	4	0x07			2.00 to 17.75	2.00 to 17.75	4.75 1) to 17.75	4.75 1) to 17.75
125	8	0x0B					9.25 1) to 17.75	9.5 1) to 17.75
62	16	0x0F					n.a. 1)	n.a. 1)
31	32	0x13						

1) Limited by the maximum pause pulse length specified in SAE-J2716.
2) A resolution of 12-bit is guaranteed only.

Magnetic Offset D

The D (offset) registers contain the parameter for the adder in the DSP. The added value is a first order polynomial of the temperature.

D0 Register

Table 2–3: Temperature independent coefficient

Parameter	Range	Resolution
d_0	–0.5508 ... 0.5497	10 bit
D0	–512 ... 511	

D0 is encoded as two’s complement binary.

$$d_0 = \frac{0,5508}{512} \cdot D0$$

D1 Register

Table 2–4: Linear temperature coefficient

Parameter	Range	Resolution
d_1	-3.076×10^{-6} ... 3.028×10^{-6}	7 bit
D1	–64 ... 63	

D1 is encoded as two’s complement binary.

$$d_1 = \frac{0,1008}{64} \cdot D1 \cdot 3,0518 \cdot 10^{-5}$$

Magnetic Sensitivity C

The C (sensitivity) registers contain the parameter for the multiplier in the DSP. The multiplication factor is a second order polynomial of the temperature.

C0 Register

Table 2–5: Temperature independent coefficient

Parameter	Range	Resolution
c_0	–2.0810 ... 2.2696	12 bit
C0	–2048 ... 2047	

C0 is encoded as two's complement binary:

$$c_0 = \frac{2{,}1758}{2048} \cdot (C0 + 89{,}261)$$

C1 Register

Table 2–6: Linear temperature coefficient

Parameter	Range	Resolution
c_1	$-7.955 \times 10^{-6} \ldots 1.951 \times 10^{-5}$	9 bit
C1	–256 ... 255	

C1 is encoded as two's complement binary.

$$c_1 = \frac{0{,}4509}{256} \cdot (C1 + 108{,}0) \cdot 3{,}0518 \cdot 10^{-5}$$

C2 Register

Table 2–7: Quadratic temperature coefficient

Parameter	Range	Resolution
c_2	$-1.87 \times 10^{-10} \ldots 1.86 \times 10^{-10}$	8 bit
C2	–128 ... 127	

C2 is encoded as two's complement binary.

$$c_2 = \frac{0{,}2008}{128} \cdot C2 \cdot 9{,}3132 \cdot 10^{-10}$$

2.3. Power-on Self Test (POST)

The HAL 283x features a built-in power-on self test to support in system start-up tests to enhanced the system failure detection possibilities.

The power-on self test comprises the following sensor blocks:

– RAM
– ROM
– EEPROM
– Full signal path included (Hall-Plates, ADC, low pass filter, temperature compensation and the SENT output)

The power-on self test can be activated by setting certain bits in the sensor's EEPROM. Also the test complexity is customer selectable. The following table shows the available test combinations.

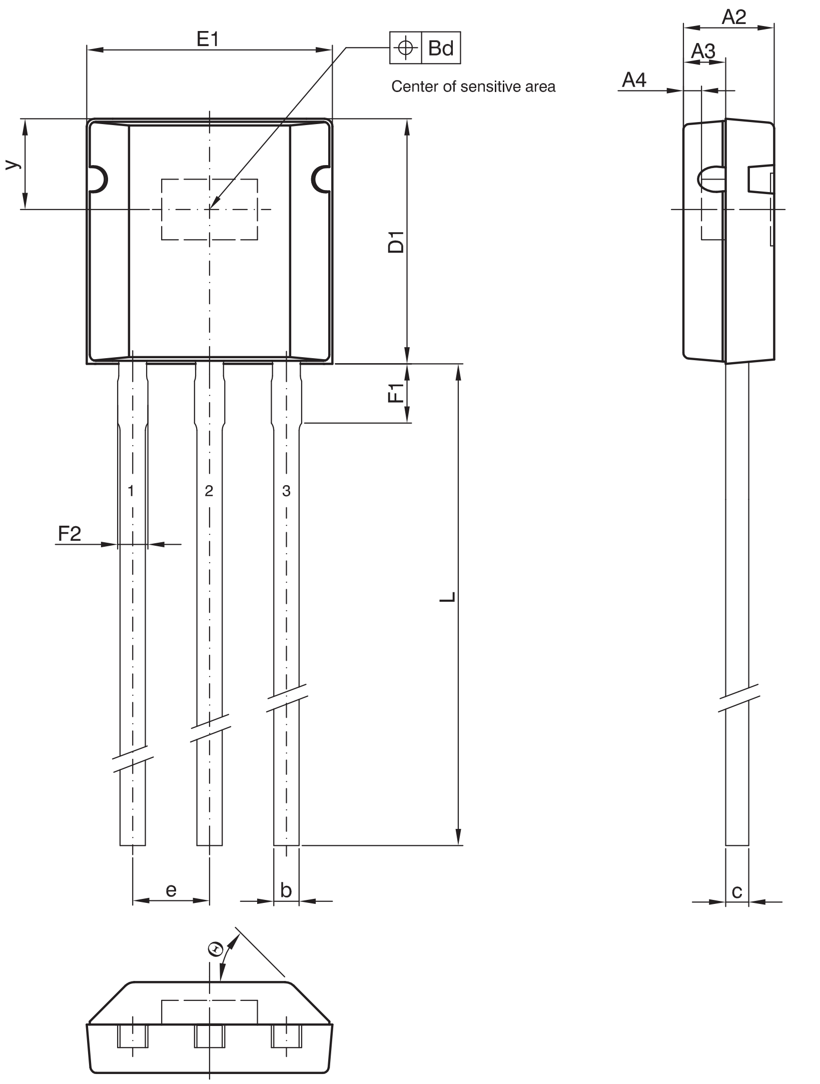
Table 2–8: Power-On Self Test Modes

EEPROM.POST			Mode / Function
[2]	[1]	[0]	
x	x	0	POST disabled.
x	0	1	Memory test only enabled (RAM, ROM, EEPROM).
x	1	1	Memory test and signal path stimulation enabled.
0	x	1	POST errors will be reported at the register PTE only. Hall values will be transmitted after POST fails.
1	x	1	POST errors will be reported at the status register PTE and do force HVAL to –32768. No Hall values will be transmitted after POST fails.

Note: Please contact Micronas for further information about power-on self test.

3. Specifications

3.1. Outline Dimensions

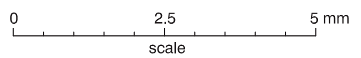


physical dimensions do not include moldflash.

solderability is guaranteed between end of pin and distance F1.

A4, Bd, y= these dimensions are different for each sensor type and are specified in the data sheet.

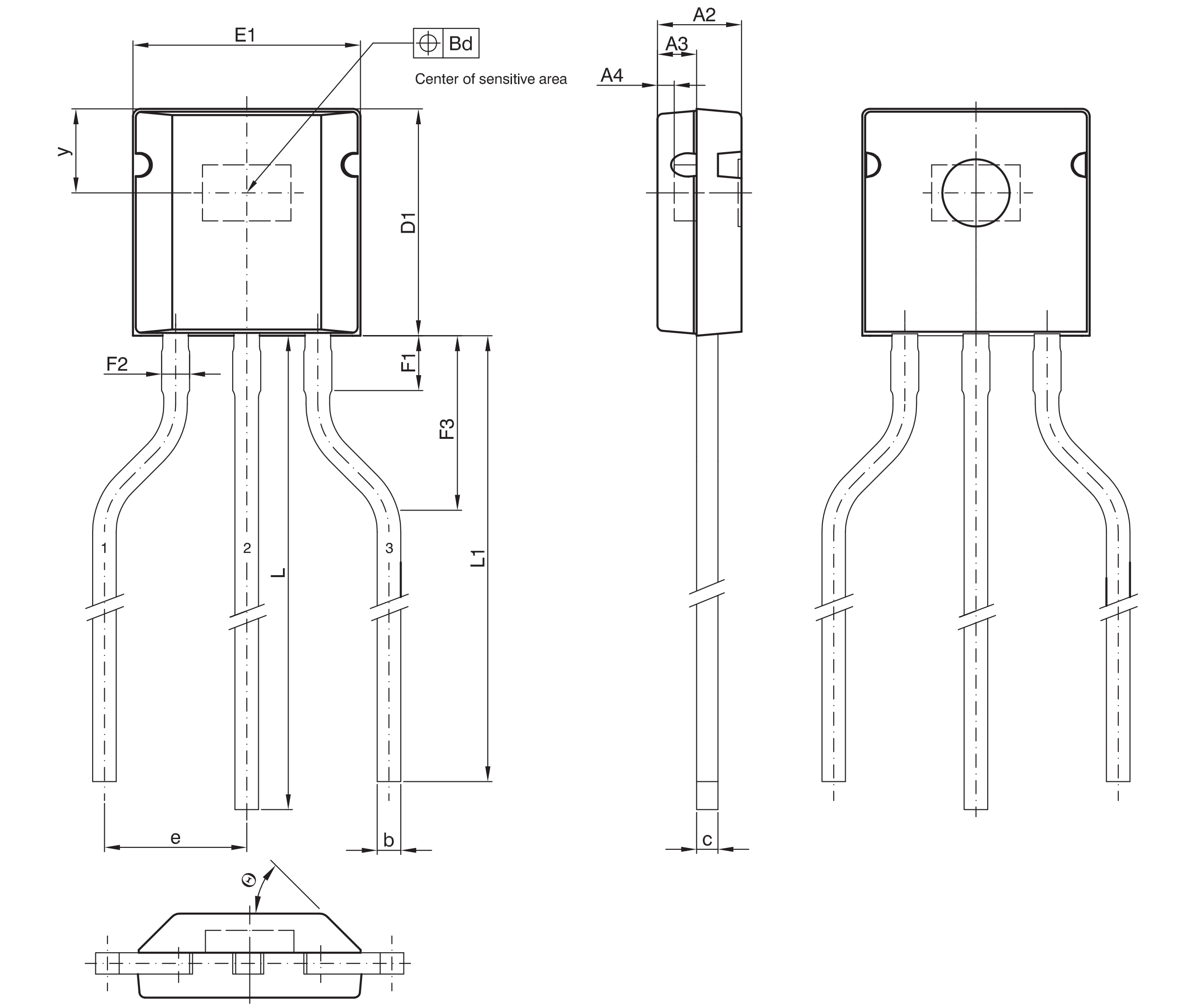
min/max of D1 are specified in the datasheet.



UNIT	A2	A3	b	c	D1	e	E1	F1	F2	L	Θ
mm	1.55 1.45	0.7	0.42	0.36	4.05	1.27	4.11 4.01	1.2 0.8	0.60 0.42	14.5 min	45°

JEDEC STANDARD		ANSI	ISSUE DATE YY-MM-DD	DRAWING-NO.	ZG-NO.
ISSUE	ITEM NO.				
-	-		10-04-29	06615.0001.4	ZG001015_Ver.06

Fig. 3–1:
TO92UT-2 Plastic Transistor Standard UT package, 3 leads
Weight approximately 0.105 g



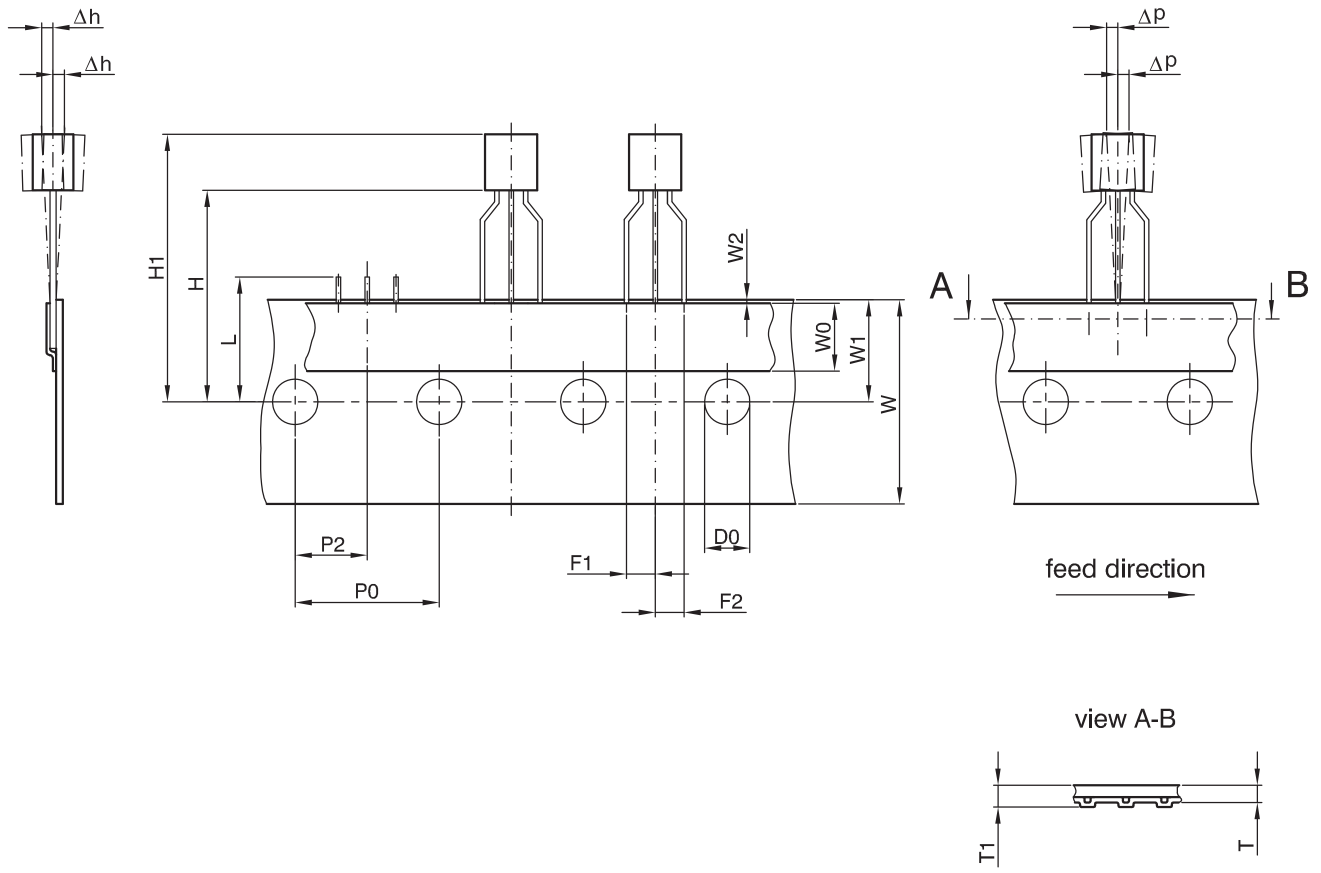
physical dimensions do not include moldflash.
solderability is guaranteed between end of pin and distance F1.
A4, Bd, y= these dimensions are different for each sensor type and are specified in the data sheet.
min/max of D1 are specified in the datasheet.

0 2.5 5 mm
scale

UNIT	A2	A3	b	c	D1	e	E1	F1	F2	F3	L	L1	Θ
mm	1.55 1.45	0.7	0.42	0.36	4.05	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.	ZG-NO.
ISSUE	ITEM NO.				
-	-		10-04-29	06609.0001.4	ZG001009_Ver.06

Fig. 3–1:
TO92UT-1 Plastic Transistor Standard UT package, 3 leads, spread
Weight approximately 0.105 g

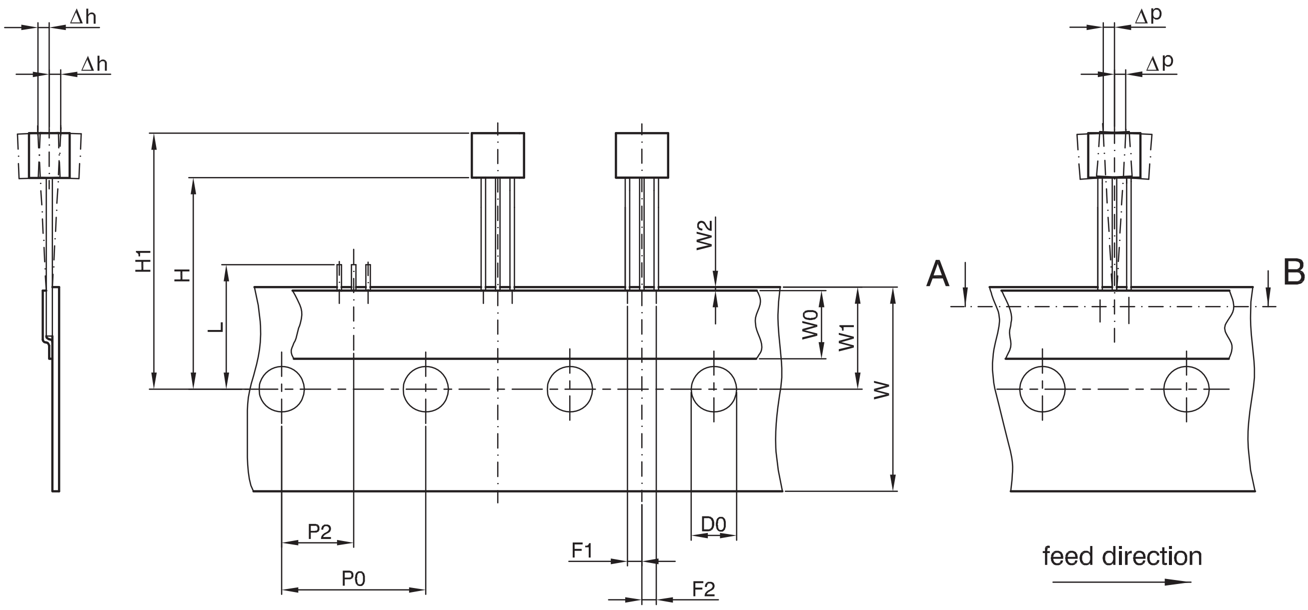


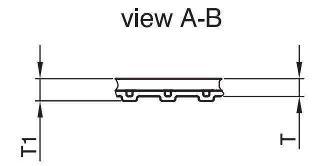
all dimensions in mm
other dimensions see drawing of bulk
max. allowed tolerance over 20 hole spacings ±1.0
H1 = this dimension is different for each sensor type and is specified in the data sheet

UNIT	D0	F1	F2	H	Δh	L	P0	P2	Δp	T	T1	W	W0	W1	W2
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	6.0	9.0	0.3

JEDEC STANDARD		ANSI	ISSUE DATE YY-MM-DD	DRAWING-NO.	ZG-NO.
ISSUE	ITEM NO.				
-	ICE 60286-2		07-01-18	06632.0001.4	ZG001032_Ver.04

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





all dimensions in mm
other dimensions see drawing of bulk
max. allowed tolerance over 20 hole spacings ±1.0
H1 = this dimension is different for each sensor type and is specified in the data sheet

UNIT	D0	F1	F2	H	Δh	L	P0	P2	Δp	T	T1	W	W0	W1	W2
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	6.0	9.0	0.3

JEDEC STANDARD		ANSI	ISSUE DATE YY-MM-DD	DRAWING-NO.	ZG-NO.
ISSUE	ITEM NO.				
-	ICE 60286-2		07-01-18	06631.0001.4	ZG001031_Ver.03

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

3.2. Dimensions of Sensitive Area

0.213 mm x 0.213 mm

3.3. Positions of Sensitive Area

	TO92UT-1/2
A4	0.4 mm
Bd	0.3 mm
D1	min. 4.0 mm, max. 4.1 mm
y	1.5 mm nominal
H1	min. 22.0 mm, max. 24.1 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 (GND).

Symbol	Parameter	Pin Name	Min.	Max.	Unit	Condition
T_J	Junction Operating Temperature	–	–40	190[1]	°C	not additive
V_{SUP}	Supply Voltage	VSUP	–18	26.5 40	V V	t < 5 min. t < five times 400 ms not additive
V_{DIO}	IO Voltage	DIO	–0.3	26.5	V	t < 5 min.
B_{max}	Magnetic field	–	–	unlimited	T	
V_{ESD}	ESD Protection[2]	VSUP, DIO	–8.0	8.0	kV	

[1] for 96 h - Please contact Micronas for other temperature requirements.
[2] JESD22-A-114 (100 pF and 1.5 kΩ)

3.4.1. Storage, Moisture Sensitivity Class, and Shelf Life

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

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

3.5. Recommended Operating Conditions

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

All voltages listed are referenced to ground (GND).

Symbol	Parameter	Pin Name	Min.	Max.	Unit	Remarks
V_{SUP}	Supply Voltage	VSUP	4.5	18	V	
V_{DIO}	Output Voltage	DIO	0	18	V	
I_{DIO}	Continuous Output Current	DIO	–	20	mA	for V_{DIO} = 0.8 V
$V_{Pull\text{-}Up}$	Pull-Up Voltage	–	3.0	18	V	In typical applications $V_{Pull\text{-}UP,max}$ = 5.5 V
$R_{Pull\text{-}Up}$	Pull-Up Resistor	DIO	(see Section 6.3. on page 29)			
C_L	Load Capacitance	DIO	180	(see Section 6.3. on page 29)	pF	
N_{PRG}	Number of EEPROM Programming Cycles	–	–	100	cycles	0 °C <T_{amb} <55 °C
T_J	Junction Operating Temperature[1]	–	–40 –40 –40	125 150 170	°C	for 8000 h (not additive) for 2000 h (not additive) for 1000 h (not additive)

[1] Depends on the temperature profile of the application. Please contact Micronas for life time calculations.

3.6. Electrical Characteristics

at T_J = –40 °C to +170 °C, V_{SUP} = 4.5 V to 18 V, after programming the sensor and locking the DSP CONFIG EEPROM,
at Recommended Operating Conditions if not otherwise specified in the column “Conditions”.
Typical Characteristics for T_A = 25 °C and V_{SUP} = 5 V.
For all other temperature ranges this table is also valid, but only in the junction temperature range defined by the temperature grade (Example: For K-Type this table is limited to T_J = –40 °C to +140 °C).

Symbol	Parameter	Pin Name	Min.	Typ.	Max.	Unit	Conditions
I_{SUP}	Supply Current	VSUP	–	12	19	mA	
I_{DIOH}	Output Leakage Current	DIO	–	–	20	µA	
Digital I/O (DIO) Pin							
V_{OL}	Output Low Voltage	DIO	– – –	– – –	0.8 0.2 0.09	V	I_{OL} = 20 mA I_{OL} = 5 mA I_{OL} = 2.2 mA
	Output Resolution	DIO	–	–	16	bit	Depending on programming of the sensor and on the sensor type
$\Delta V/\Delta t_{fall}$	Falling Edge Slew Rate	DIO	1.4 0.7	2 1	2.6 1.3	V/µs	SLEW = 2 SLEW = 3

Symbol	Parameter	Pin Name	Min.	Typ.	Max.	Unit	Conditions
$\Delta V / \Delta t_{rise\_max}$	Max. Rising Edge Slew Rate	DIO	1.4 0.7	2 1	2.6 1.3	V/µs	SLEW = 2 SLEW = 3
t_{POD}	Power-Up Time (time to reach valid hall data at SENT output)	DIO	–	8	tbd	ms	Condition: sample frequency = 2 kHz and POST = 0 For sample frequencies below 2 kHz, the power-up time will increase due of the sample rate of the signal processing.
$t_{startSENT}$	Power-Up Time of the SENT Interface	DIO	–	tbd	tbd	ms	
V_{SUPon}	Power-On Reset Level	VSUP	–	–	4.45	V	

3.7. Magnetic Characteristics

at T_J = –40 °C to +170 °C, V_{SUP} = 4.5 V to 18 V, after programming the sensor and locking the DSP CONFIG EEPROM,
at Recommended Operating Conditions if not otherwise specified in the column “Conditions”.
Typical Characteristics for T_A = 25 °C and V_{DD} = 5 V.
For all other temperature ranges this table is also valid, but only in the junction temperature range defined by the temperature grade (Example: For K-Type this table is limited to T_J = –40 °C to +140 °C).

Symbol	Parameter	Pin Name	Min.	Typ.	Max.	Unit	Conditions
$RANGE_{ABS}$	Absolute Magnetic Range of A/D Converter over Temperature	–	60	100	110	%	% of nominal RANGE Nominal RANGE programmable from +/- 20 mT up to +/- 160 mT
INL	Non-Linearity	DIO	–0.25	0	0.25	%	% of full-scale
ES	Sensitivity Error over Temperature Range	DIO	–3	0	3	%	(see Section 3.8.1.)
$HVAL_{noise}$	Output Noise (rms)	DIO	–	0.05	0.1	mT	B = 0 mT, ±100 mT range, T_J = 25 °C, fs = 2 kHz HAL 2830/HAL 2832
B_{OFFSET}	Magnetic Offset	DIO	–0.4	0	0.4	mT	B = 0 mT, T_A = 25 °C RANGE 80 mT
ΔB_{OFFSET}	Magnetic Offset Drift over Temperature Range $B_{OFFSET}(T) - B_{OFFSET}(25\ °C)$	DIO	–5	0	5	µT/°C	B = 0 mT RANGE 80 mT

3.8. Thermal Characteristics

at Recommended Operating Conditions if not otherwise specified in the column “Conditions”, T_J = –40 °C to +170 °C, V_{SUP} = 4.5 V to 18 V.

Symbol	Parameter	Pin Name	Min.	Typ.	Max.	Unit	Conditions
TO92UT Package							
	Thermal Resistance	–					
R_{thja}	Junction to Ambient		–	–	235	K/W	measured on 1s0p board
R_{thjc}	Junction to Case		–	–	61	K/W	measured on 1s0p board
R_{thjs}	Junction to Solder Point		–	–	128	K/W	measured on 1s0p board

3.8.1. Definition of Sensitivity Error ES

ES is the maximum of the absolute value of 1 minus the quotient of the normalized measured value[1)] over the normalized ideal linear[2)] value:

$$ES = \max\left(\mathrm{abs}\left(\frac{meas}{ideal} - 1\right)\right)\Big|_{[Tmin,\ Tmax]}$$

In the example shown in Fig. 3–3 on page 21, the maximum error occurs at –10 °C:

$$ES = \frac{1{,}001}{0{,}993} - 1 = 0.8\%$$

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

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

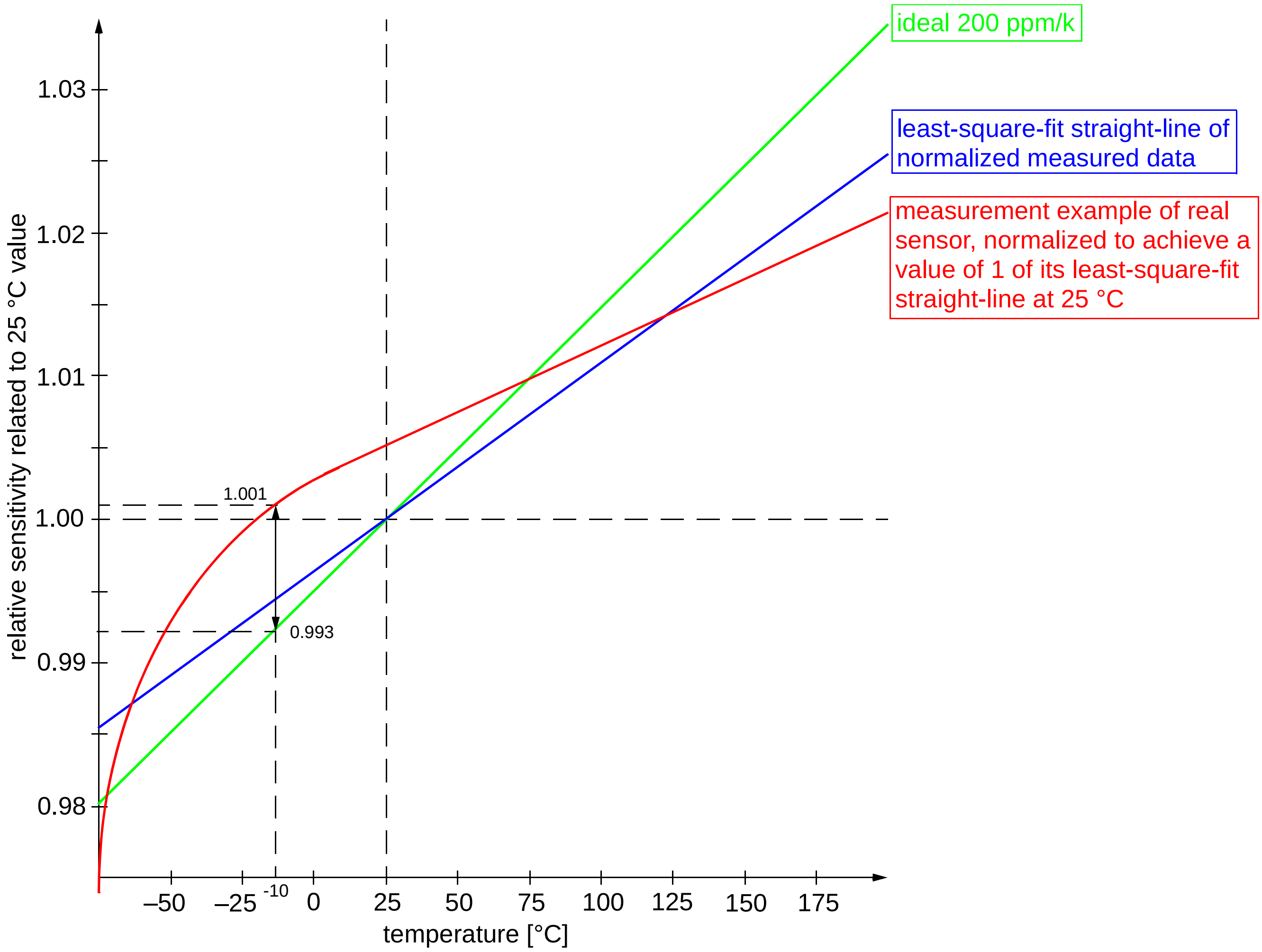


Fig. 3–3: Definition of sensitivity error (ES)

4. The SENT Module

The SENT interface is used for transmitting Hall values from the sensor to an ECU. Additional information is transmitted by serial data messages in the status nibble. HAL 2830/HAL 2831 feature a SENT output without pause pulse and HAL 2832/HAL 2833 provides SENT messages with pause pulse. All sensors of the family HAL 283x supports the related SAE standards.

Fig. 4–1, Fig. 4–2, Fig. 4–3 and Table 4–1 describe the SENT timing in detail.

A SENT message consists of a synchronization / calibration pulse, a status and communication nibble, three or four data nibbles, a CRC nibble, and an optional pause pulse (only for HAL 2832/HAL 2833). Fig. 4–1, Fig. 4–2, and Fig. 4–3 are valid for SENT messages with three data nibbles. The timing of a SENT message with four data nibbles is similar. The fourth data nibble is inserted between the third data nibble and the CRC nibble. It has the same characteristics as the remaining data nibbles. See Table 4–4 for the description of the pulses/nibbles of a message. The number of data nibbles depends on the sensor type.

After reset, the output is high. The transmission of SENT messages starts immediately after initialization. Due to the fact that the first valid Hall value will be typically calculated after the transmission has been started, the sensor transmits the initial value of HVD.HVAL first.

In case of an overcurrent at the DIO output, the output transistor will be switched off (high impedance).

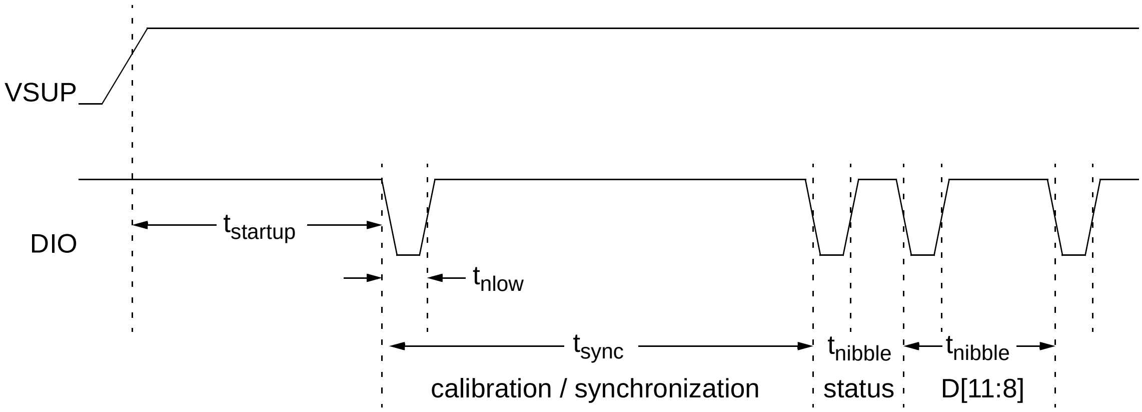


Fig. 4–1: SENT interface startup timing of HAL 283x

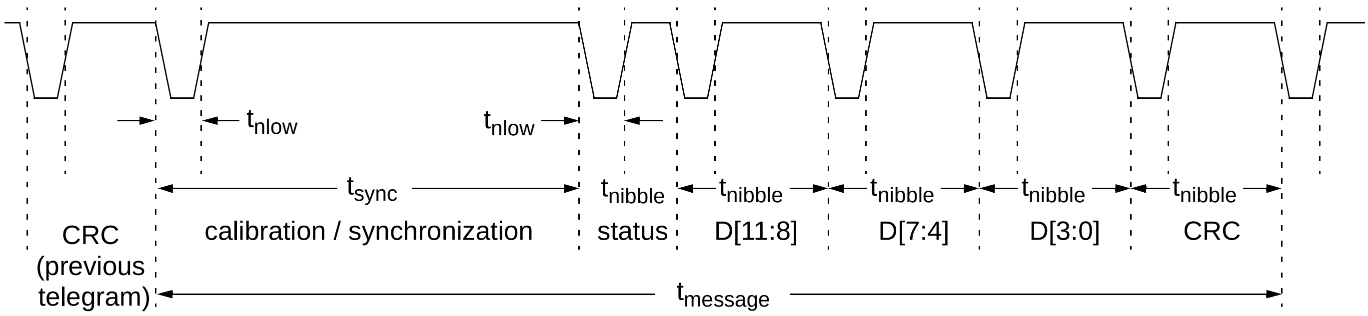


Fig. 4–2: SENT interface timing in case of HAL 2830/HAL 2831

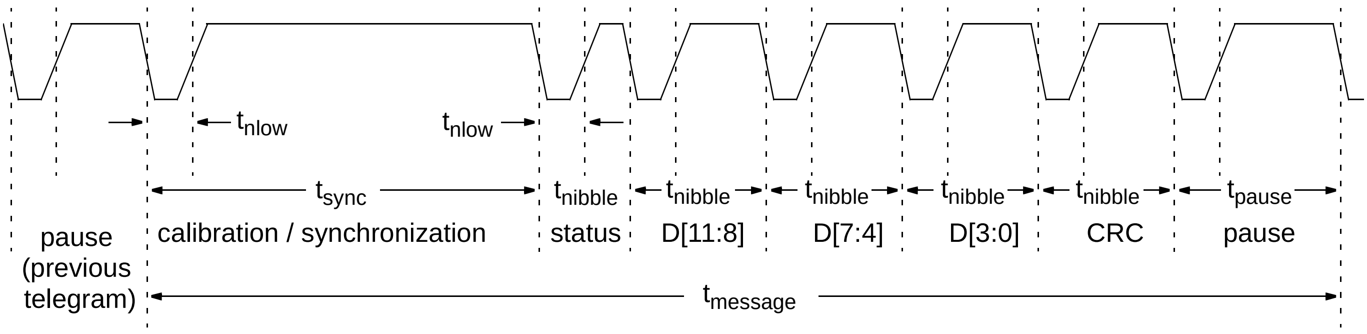


Fig. 4–3: SENT interface timing in case of HAL 2832/HAL 2833

Table 4–1: SENT interface timing

Symbol	Parameter	Min.	Typ.	Max.	Unit	Condition / Remark
t_{tick}	Clock Tick Time	2.00[1)2)]	–	17.75 [1)2)]	µs	
t_{nlow}	Nibble Low Time[5)]		3)		µs	
		3.00		6.75	t_{tick}	Due to truncation errors, the max. low time may be slightly smaller at some clock tick times.
$\Delta V/\Delta t_{fall}$	Falling edge slew rate	(see Section 3.6. on page 18) Not reverse voltage protected I/O logic, Typical slew rate = 1 V/µs				
$\Delta V/\Delta t_{rise}$	Rising edge slew rate	(see Section 3.6. on page 18) Not reverse voltage protected I/O logic, Typical slew rate = 2 V/µs				
t_{sync}	Calibration / Synchronization Pulse Period		56		t_{tick}	
t_{nibble}	Nibble Pulse Period	12		27	t_{tick}	t_{nibble} = 12 + data
t_{pause}	Pause Pulse Period	12 [4)]		768 [4)]	t_{tick}	Only available for HAL 2832/ HAL 2833
$t_{message}$	Message Time		(see Table on page 26)			
t_{delay_sm}	New Hall Sample to Message Start Delay			1	$t_{message}$	SENT message without pause pulse (HAL2830/ HAL 2831)
				tbd	µs	SENT message with pause pulse (HAL 2832/ HAL 2833)

[1)] Clock tolerance of +/- 10 % is not included
[2)] $t_{tick} = (8 + \text{TICK}) \times 0.25$ µs, TICK = 0 to 63 [0.227 µs to 0.278 µs]
[3)] $t_{nlow} = \text{trunc}((8 + \text{TICK}) \times (12 + \text{LT}) / 4) \times 0.25$, TICK = 0 to 63, LT = 0 to 15 [0.227 µs to 0.278 µs]
[4)] Specified value of SAE-J2716 2010-01. It is necessary to select an appropriate sample rate and clock tick time to guarantee the limit.
[5)] Internal timing only. The timing at the output pin depends on the selected Tick Time due to the different recommended slew rates. Internal low time and external low time are nearly identical for Tick Times t_{tick} = 2 µs to 2.5 µs. Tick Times t_{tick} > 2.5 µs generate an offset between internal and external Nibble Low Time. The offset can be calculated as follows:
Offset ~ $(V_{Pull\text{-}Up} - V_{OL})/\Delta V/\Delta t_{rise} - (V_{Pull\text{-}Up} - V_{OL})/\Delta V/\Delta t_{fall}$

In case of HAL 2830/HAL 2831 the message time of a SENT message depends on the configured tick time and the transmitted data value. The SENT messages are transmitted asynchronously to the Hall samples. See Table 4–2 for recommended tick times. In case that slower tick times will be chosen, Hall samples may be lost and aliasing may occur. When using the recommended tick times, samples may be transmitted twice in series due to the fact that the mean message time is shorter than the Hall sample time. A RDBL (read double) flag has been implemented for marking messages which does not contain a new Hall sample. The RDBL flag is located in the register SPS and is transmitted by the status and communication nibble.

This is not necessary for HAL 2832/HAL 2833 with pause pulse. For these devices the SENT messages are synchronous with the delivery of new Hall samples. One SENT message is transmitted per Hall sample. Thus, the propagation delay is very low and the message time is nearly constant. See Table 4–2 for recommended tick times. The usage of tick times slower than recommended may lead to corrupted SENT messages. The usage of tick times faster than recommended may lead to a pause pulse which exceeds the limit specified in SAE-J2716 2010-01.

Additional information is transmitted by serial data messages (short format). Serial messages are transmitted by bit 2 and 3 of the status nibble. See SAE-J2716 for more information about the short serial data message format. See Table 4–5 for the used IDs and the data content of the IDs. The IDs are continuously transmitted from the lowest ID to highest ID.

The SENT clock tick time can be configured by the EEPROM bit field TICK. See Table 4–1 and Table 4–2. The low time can be configured by the EEPROM bit field LT. See Table 4–1 and Table 4–2. The adjusted slew rate depends on the SENT clock tick time. See Table 4–1.

Table 4–2: Recommended settings for Low Tick Time

TICK	**t_{tick}**	**Slew Rate**	**Min. Recommended Low Time**			**Max. Recommended Low Time**			**Remark**
	typ.	**typ.**	**LT**	**t_{nlow}**		**LT**	**t_{nlow}**		
[LSB]	**[µs]**	**[V/µs]**	**[LSB]**	**[t_{tick}]**	**[µs] 1)**	**[LSB]**	**[t_{tick}]**	**[µs] 1)**	
0	2.00	2	0	3.00	6.00	15	6.75	13.50	
1	2.25				6.75		6.67	15.00	
2	2.50				7.50		6.70	16.75	
3	2.75	1	2	3.45	9.50	11	5.73	15.75	
4	3.00		1	3.25	9.75	13	6.25	18.75	
5	3.25		0	3.00	9.75	14	6.46	21.00	
6	3.50				10.50	15	6.71	23.50	
8	4.00				12.00		6.75	27.00	
12	5.00				15.00		6.75	33.75	
63	17.75				53.25		6.75	119.75	

1) Clock tolerance of ±10 % is not included

Table 4–3: Recommended settings for SAE-J2716 compliance

TICK	t_{tick}	Slew Rate	Min. Recommended Low Time			Max. Recommended Low Time			Remark
	typ.	typ.	LT	t_{nlow}		LT	t_{nlow}		
[LSB]	[µs]	[V/µs]	[LSB]	[t_{tick}]	[µs] 1)	[LSB]	[t_{tick}]	[µs] 1)	
3	2.75	1	4	4.00	11.00	11	5.73	15.75	
4	3.00				12.00	13	6.25	18.75	
5	3.25				13.00	14	6.46	21.00	
6	3.50				14.00	15	6.71	23.50	
8	4.00				16.00		6.75	27.00	
12	5.00				20.00		6.75	33.75	
63	17.75				71.00		6.75	119.75	

1) Clock tolerance of ±10 % is not included

Table 4–4: Nibble / pulse description

#	Pulse	Number of Clock Ticks		Description
		min.	max.	
1	Synchronization/ Calibration	56		It is recommended to measure the synchronization / calibration period for calibration of the clock tick time t_{tick} at the ECU.
2	Status & Communication Nibble	12	27	Bit 0: SPS.RDBL (Hall sample has been already transmitted) Bit 1: MDS.PTO (Power on test is operating) Bit 2: Serial message data bit (See SAE-J2716) Bit 3: Serial message start (See SAE-J2716)
3	Data Nibble 1			HVD[15:12]
4	Data Nibble 2			HVD[11:8]
5	Data Nibble 3			HVD[7:4]
- / 6	Data Nibble 4 (optional)			HVD[3:0] Only in case of HAL 2831/HAL 2833
6 / 7	CRC Nibble			Checksum of data nibble 1 to data nibble 4. See SAE-J2716 2008-02 or SAE-J2716 2010-01 for more information.
- / 7 / 8	Pause Pulse (optional)	12 1)	768 1)	Only for HAL 2832/HAL 2833

1) Recommended value. See Table 4–1 for more information

Table 4–5: Serial message content

ID	Content	Remark
0	SN[7:0]	Serial Number, byte 1
1	SN[15:8]	Serial Number, byte 2
2	SN[23:16]	Serial Number, byte 3
3	SN[31:24]	Serial Number, byte 4
4	TVD[7:0]	Temperature value data register. High byte must be captured when low byte is read for transmission.
5	TVD[15:8]	
6	SPE	Signal path status register
7	DS	Device status register
8	PTE	Power-on test error register
9	SYSCLK[7:0]	System clock, byte 1
10	SYSCLK[15:8]	System clock, byte 2

Table 4–6: Message length

TICK	t_{tick}	SENT Message Sensor Type			
		HAL 2830/2		HAL 2831/3	
		Message Length in t_{tick} and µs (brackets) [3]			
[LSB]	[µs]	min.	max.	min.	max.
0	2.00	116 (232 µs)	191 (382 µs)	128 (256 µs)	218 (436 µs)
1	2.25	116 (261 µs)	191 (430 µs)	128 (288 µs)	218 (491 µs)
2	2.50	116 (290 µs)	191 (478 µs)	128 (320 µs)	218 (545 µs)
3	2.75	116 (319 µs)	191 (525 µs)	128 (352 µs)	218 (560 µs)
4	3.00	116 (348 µs)	191 (573 µs)	128 (384 µs)	218 (654 µs)
8	4.00	116 (464 µs)	191 (764 µs)	128 (512 µs)	218 (872 µs)
12	5.00	116 (580 µs)	191 (955 µs)	128 (640 µs)	218 (1090 µs)
63	17.75	116 (2059 µs)	191 (3390 µs)	128 (2272 µs)	218 (3870 µs)

[1] Recommended min. message time. $t_{message}$ = max. $t_{message}$ of no pause pulse + 12 ticks
[2] Recommended max. message time. $t_{message}$ = min. $t_{message}$ of no pause pulse + 256 * 3 ticks
[3] Clock tolerance of ±10 % is not included

5. Programming of the Sensor

HAL 283x features two different customer modes. In **Application Mode** the sensor provides a continuos PWM signal transmitting temperature-compensated magnetic field values. In **Programming Mode** it is possible to change the register settings of the sensor.

After power-up the sensor is always operating in the **Application Mode**. It is switched to the **Programming Mode** by a defined sequence on the sensor output pin.

5.1. Programming Interface

In Programming Mode the sensor is addressed by modulating a serial telegram (BiPhase-M) with constant bit time on the output pin. The sensor answers with a modulation of the output voltage.

A logical “0” of the serial telegram is coded as no level change within the bit time. A logical “1” is coded as a level change of typically 50% of the bit time. After each bit, a level change occurs (see Table 5–1).

The serial telegram is used to transmit the EEPROM content, error codes and digital values of the magnetic field or temperature from and to the sensor.

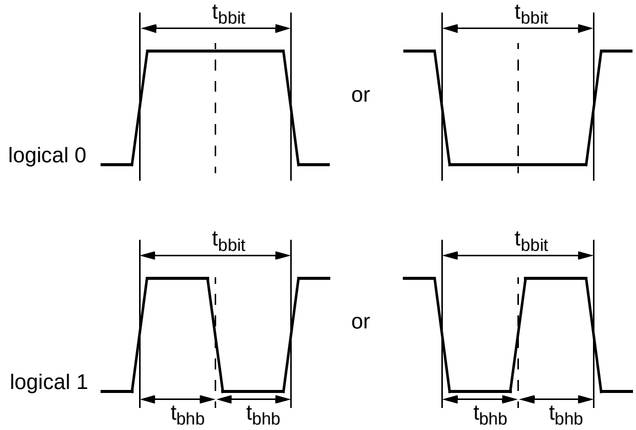


Fig. 5–1: Definition of logical 0 and 1 bit

A description of the communication protocol and the programming of the sensor is available in a separate document (Application Note Programming HAL 283x).

Table 5–1: Biphase-M frame characteristics of the host

Symbol	Parameter	Min.	Typ.	Max.	Unit	Remark
$t_{bbit\ (host)}$	Biphase Bit Time	970	1024	1075	µs	
$t_{bhb\ (host)}$	Biphase Half Bit Time	0.45	0.5	0.55	$t_{bbit\ (host)}$	
$t_{bifsp\ (host)}$	Biphase Interframe Space	3	–	–	$t_{bbit\ (host)}$	
V_{OUTL}	Voltage for Low Level	tbd	tbd	tbd	V	
V_{OUTH}	Voltage for High Level	tbd	tbd	tbd	V	
V_{DDPRG}	Supply Voltage During Programming	5.5	–	18	V	

Table 5–2: Biphase-M frame characteristics of the sensor

Symbol	Parameter	Min.	Typ.	Max.	Unit	Remark
$t_{bbit\ (sensor)}$	Biphase Bit Time	820	1024	1225	µs	
$t_{bhb\ (sensor)}$	Biphase Half Bit Time	–	0.5	–	$t_{bbit\ (sensor)}$	
t_{bresp}	Biphase Response Time	1	–	5	$t_{bbit\ (sensor)}$	
	Slew Rate		2		V/µs	

5.2. Programming Environment and Tools

For the programming of HAL 283x during product development and also for production purposes a programming tool including hardware and software is available on request. It is recommended to use the Micronas tool kit in order to ease the product development. The details of programming sequences are also available on request.

5.3. Programming Information

For production and qualification tests, it is mandatory to set the LOCK bit after final adjustment and programming of HAL 283x. The LOCK function is active after the next power-up of the sensor.

The success of the LOCK procedure should be checked by reading the status of the LOCK bit after locking and/or by a check of the sensors output signal.

Electrostatic Discharge (ESD) may disturb the programming pulses. Please take precautions against ESD and check the sensors error flags.

6. Application Notes

6.1. 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:

$$\Delta T = I_{SUP} \times V_{SUP} \times R_{thJX} + I_{DIO} \times V_{DIO} \times R_{thJX}$$

For typical values, use the typical parameters. For worst case calculation, use the max. parameters for I_{SUP} and R_{th}, and the max. value for V_{SUP} from the application. The choice of the relevant R_{thJX}-parameter (R_{thja}, R_{thjc}, or R_{thjs}) depends on the way the device is (thermally) coupled to its application environment.

For the HAL 283x, the junction temperature T_J is specified. The maximum ambient temperature T_{Amax} can be calculated as:

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

6.2. EMC and ESD

For applications that cause disturbances on the supply line or radiated disturbances, a series resistor and a capacitor are recommended. The series resistor and the capacitor should be placed as closely as possible to the Hall sensor.

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

6.3. Application Circuit

Micronas recommends the following two application circuits for the HAL 283x.

The external circuit mentioned in Fig. 6–1 is recommended when $V_{BAT} \geq V_{Pull\text{-}up}$. It is typically used when the supply pin is directly connected with the battery voltage and the DIO pin operates on a regulated power supply.

Fig. 6–2 shows the recommended circuit according to the SAE-J2716 2010-01. It can be used when $V_{BAT} = V_{Pull\text{-}up} < 7$ V. The Pull-up resistor $R_{Pull\text{-}up1}$ must be placed close to the sensor to be compliant with the SENT specification. For saving external components, the resistors $R_{Pull\text{-}up1}$ and $R_{Pull\text{-}up2}$ could be combined to $R_{Pull\text{-}up}$ and placed close to the ECU. This might be possible for some applications only and will not be compliant with the SENT specification.

The electrical characteristics mentioned in Section 3. (e.g. V_{SUP}) has to be considered at the system setup. They may reduce the operation range.

Values of external components:

C_{VSUP} = 47 nF
C_{DIO} = 180 pF

The maximum allowed load capacitor and the minimum resistance can be calculated with the following equation:

$C_L = C_{DIO} + C_{wire} + C_{INPUT}$
$R_L = R_{Pull\text{-}up}$

$R_L \geq (V_{Pull\text{-}up\ (max.)} - V_{DIOL\ (max.)}) / (I_{DIO} - (C_L \times (\Delta V/\Delta t_{fall})$
$C_L \leq 0.4 \times V_{Pull\text{-}up\ (min.)} / (R_L \times (\Delta V/\Delta t_{rise}))$
$R_{Pull\text{-}up} = R_{Pull\text{-}up1} \mid\mid R_{Pull\text{-}up2}$

$R_{Pull\text{-}up}$: Pull-up resistor between DIO and $V_{Pull\text{-}up}$
C_{VSUP} : Capacitance between the VSUP pin and GND
C_{DIO} : EMC protection capacitance on the DIO pin
C_{wire} : Capacity of the wire
C_{INPUT} : Input capacitance of the ECU

$V_{Pull\text{-}up\ (max.)}$: Max. applied Pull-up voltage, must be lower than the value specified in section 3.5.
$V_{Pull\text{-}up\ (min.)}$: Min. applied Pull-up voltage, must be higher than the value specified in section 3.5.
$V_{DIOL\ (max.)}$: Max. DIO low voltage, it is recommended to use the value specified in section 3.6.
I_{DIO} : DIO current at $V_{DIOL\ (max.)}$
$\Delta V/\Delta t_{rise}$: Selected rising edge slew rate, the max. value specified in section 3.6. has to be used
$\Delta V/\Delta t_{fall}$: Selected falling edge slew rate, the max. value specified in section 3.6. has to be used

Example for Calculating R_L and C_L (max.)

The application operates at following conditions:
falling slew rate = 1 V/µs (typ.)
rising slew rate = 0.5 V/µs (typ.)
$V_{Pull\text{-}up}$ = 5.5 V (max.)
C_L = 400 pF

Calculation:

$R_L \geq$ (5.5 V – 0.8 V) / (20 mA – 400 pF × 1.3 V/µs) = 241 Ohm **R_L = 1000 Ohm**

Check C_L:
C_L = 400 pF ≤ 0.4 × 4.5 V / (1000 Ohm×0.65 V/µs) = 2.77 nF
The used C_L is below the limit.

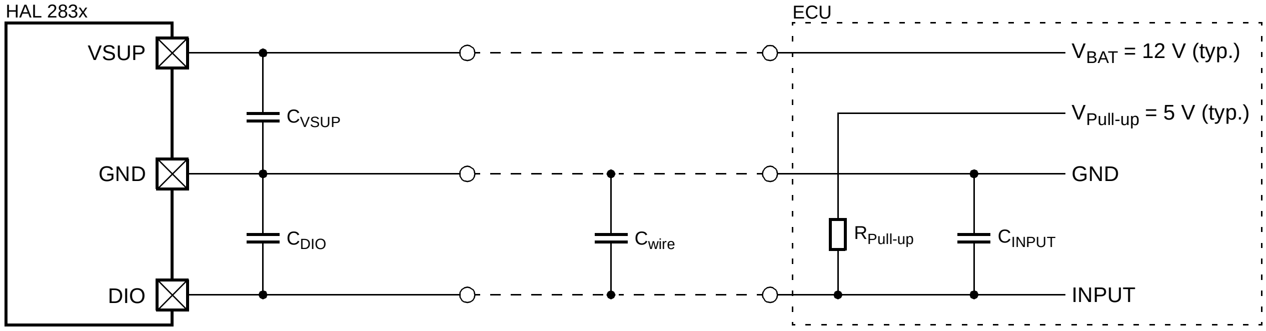


Fig. 6–1: Recommended external circuit for $V_{BAT} \geq V_{Pull\text{-}up}$

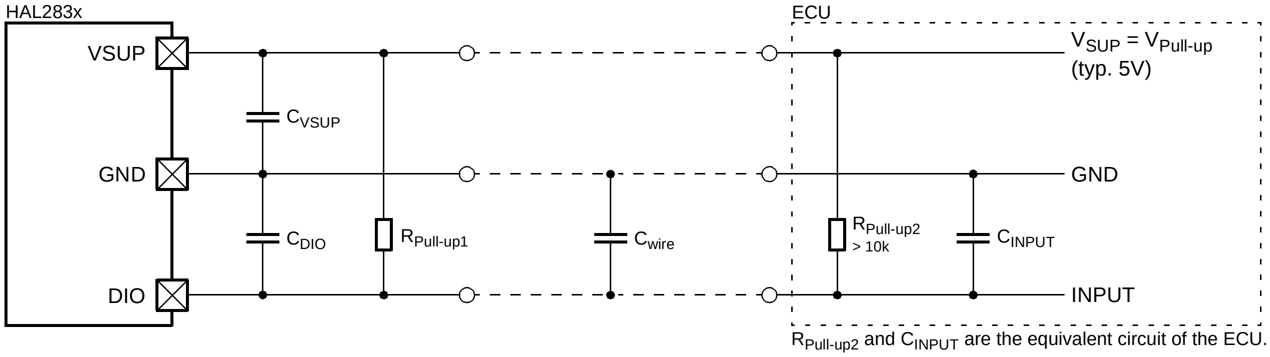


Fig. 6–2: Recommended external circuit for $V_{BAT} = V_{Pull\text{-}up} < 7$ V

Note: The external components needed to protect against EMC and ESD may differ from the application circuit shown and have to be determined according to the needs of the application specific environment.

intentionally left vacant

7. Data Sheet History

1. Advance Information: “HAL 2830 Linear Hall-Effect Sensor Family with SENT Interface”, Oct. 9, 2008, AI000143-001EN. First release of the advance information.
   Originally created for HW version HAPB-2-F & 2-G.

2. Advance Information: “HAL 283x Linear Hall-Effect Sensor Family with SENT Interface”, Sept. 6, 2010, AI000143-002EN. Second release of the advance information.

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