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Hardware
Documentation

Data Sheet

HAL® 2850

Linear Hall-Effect Sensor with PWM Output

vario|HAL® by Micronas

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Contents

Page	Section	Title
4	**1.**	**Introduction**
4	1.1.	Features
4	1.2.	Major Applications
5	**2.**	**Ordering Information**
5	2.1.	Device-Specific Ordering Codes
6	**3.**	**Functional Description**
6	3.1.	General Function
7	3.2.	Digital Signal Processing
8	3.2.1.	Temperature Compensation
9	3.2.2.	DSP Configuration Registers
10	3.3.	Power-on Self Test (POST)
10	3.3.1.	Description of POST Implementation
11	3.3.2.	RAM Test
11	3.3.3.	ROM Test
11	3.3.4.	EEPROM Test
11	3.4.	Sensor Behavior in Case of External Errors
11	3.5.	Detection of Signal Path Errors
12	**4.**	**Specifications**
12	4.1.	Outline Dimensions
16	4.2.	Soldering, Welding and Assembly
16	4.3.	Pin Connections and Short Descriptions
16	4.4.	Dimensions of Sensitive Area
16	4.5.	Positions of Sensitive Area
17	4.6.	Absolute Maximum Ratings
17	4.6.1.	Storage and Shelf Life
18	4.7.	Recommended Operating Conditions
18	4.8.	Characteristics
20	4.9.	Magnetic Characteristics
21	4.9.1.	Definition of Sensitivity Error ES
22	**5.**	**The PWM Module**
24	5.1.	Programmable PWM Parameter
27	**6.**	**Programming of the Sensor**
27	6.1.	Programming Interface
28	6.2.	Programming Environment and Tools
28	6.3.	Programming Information
29	**7.**	**Application Note**
29	7.1.	Ambient Temperature
29	7.2.	EMC and ESD
29	7.3.	Output Description
29	7.3.1.	How to Measure PWM Output Signal
30	7.4.	Application Circuit
32	**8.**	**Data Sheet History**

Linear Hall-Effect Sensor with PWM Output

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

1. Introduction

The HAL 2850 is a high-precision programmable linear Hall-effect sensor.

The HAL 2850 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 sensor offset. This enables operation over the full temperature range with high accuracy.

For programming purposes, 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 PWM signal.

The sensor is designed for hostile industrial and automotive applications (T_J = –40 °C up to 170 °C). The HAL 2850 is available in the very small leaded RoHs package TO92-UT and is AECQ100 qualified.

1.1. Features

- PWM frequency programmable from 31.25 Hz up to 2 kHz
- PWM resolution between 11 bit and 16 bit depending on the PWM frequency
- The magnetic measurement range over temperature is adjustable from ±24 mT up to ±96 mT
- Sample accurate transmission for certain periods (Each PWM period transmits a new Hall sample)
- Open-drain output with slew rate control (load independent)
- On-board diagnostics (overvoltage, output current, overtemperature, signal path overflow)
- Power-on self-test covering all memories
- 20 bit digital signal processing
- Various sensor parameter are programmable (like offset, sensitivity, temperature coefficients, etc.)
- Non-volatile memory with redundancy and lock function
- Programmable temperature compensation for sensitivity (2^{nd} order) and offset (1^{st} order)
- Biphase-M interface (programming mode)
- Digital readout of temperature and magnetic field information in calibration mode
- Programming and operation of multiple sensors at the same supply line
- High immunity against mechanical stress, ESD, and EMC
- Reverse voltage and ESD protection at V_{SUP} pin
- ESD protection at DIO pin
- Qualified according to AECQ-100

1.2. Major Applications

- Contactless potentiometers
- Angular measurements
  (e.g.; torque force, pedal position, suspension level, headlight adjustment; or valve position)
- Linear position
- Current sensing for motor control, battery management

2. Ordering Information

A Micronas device is available in a variety of delivery forms. They are distinguished by a specific ordering code:

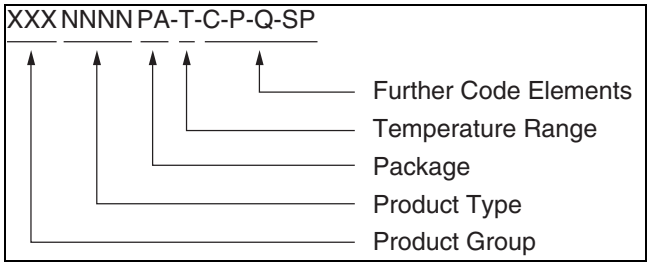


Fig. 2–1: Ordering Code Principle

For a detailed information, please refer to the brochure: “Micronas Sensors and Controllers: Ordering Codes, Packaging, Handling”.

2.1. Device-Specific Ordering Codes

HAL2850 is available in the following package and temperature variants.

Table 2–1: Available package

Package Code (PA)	Package Type
UT	TO92UT

Table 2–2: Available temperature ranges

Temperature Code (T)	Temperature Range
A	T_J = –40 °C to +170 °C

The relationship between ambient temperature (T_A) and junction temperature (T_J) is explained in Section 5.4. on page 29.

For available variants for Configuration (C), Packaging (P), Quantity (Q), and Special Procedure (SP) please contact Micronas.

Table 2–3: Available ordering codes and corresponding package marking

Available Ordering Codes	Package Marking
HAL2850UT-A-[C-P-Q-SP]	2850

3. Functional Description

3.1. General Function

The HAL 2850 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 3.2. 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 2850 provides two operation modes, the application mode and the programming mode.

Application Mode

The output signal is provided as continuous PWM signal.

Programming Mode

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

The HAL 2850 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 to configure the PWM module. The non-volatile memory employs inherent redundancy.

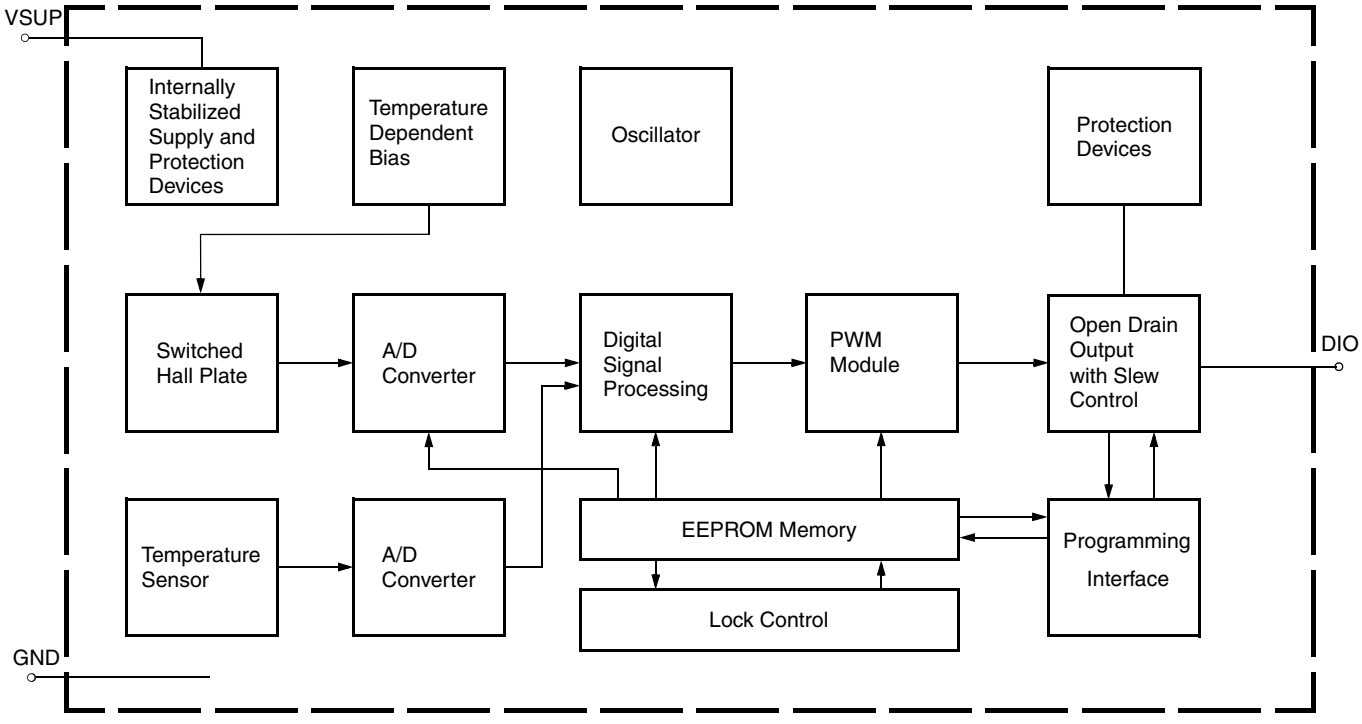


Fig. 3–1: HAL 2850 block diagram

3.2. 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 3.2.2. 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 current Hall value y is stored in the data register HVD immediately after it has been temperature compensated.

A new PWM period transmits the recent temperature-compensated Hall sample. A new Hall sample is transmitted by the next PWM period and samples will neither be lost nor doubly transmitted. Sample accurate transmission is available for native PWM periods (0.512 ms, 1.024 ms, 2.048 ms, 4.096 ms, 8.192 ms, 16.384 ms and 32.768 ms period).

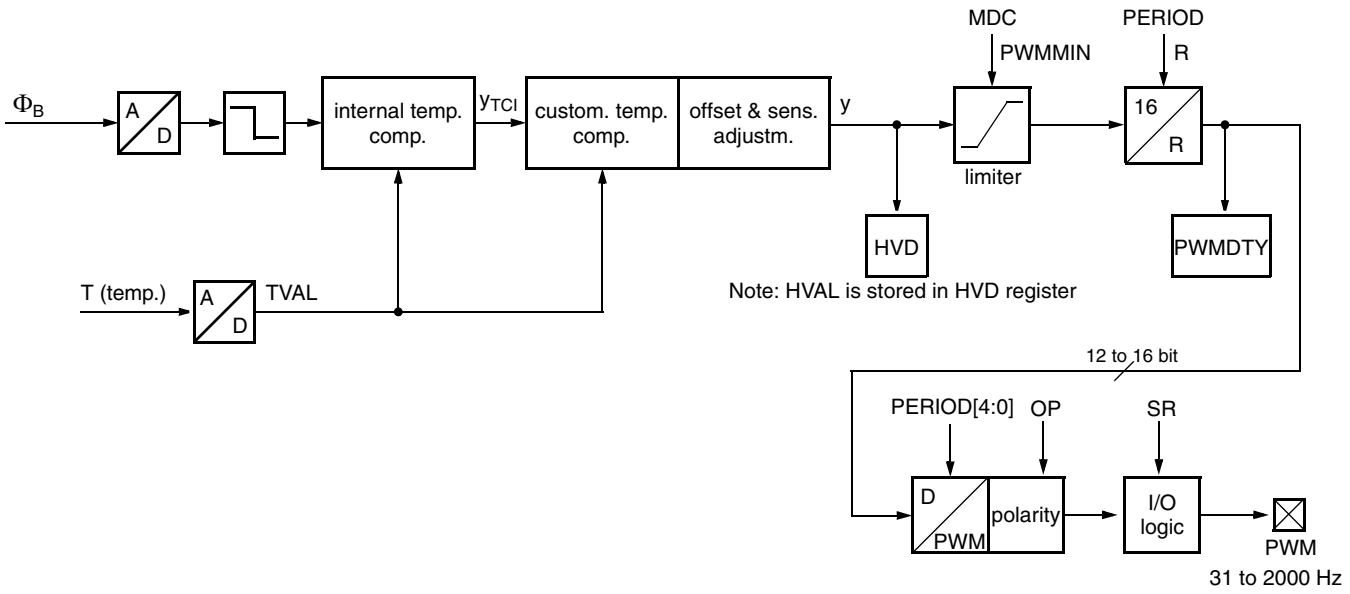


Fig. 3–2: Block diagram of digital signal path

3.2.1. 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 3.2.2. on page 9.

The Offset polynomial d(T_{ADJ}) is linear in temperature:

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

For the definition of the polynomial coefficients, please refer to Section 3.2.2. on page 9.

For the calibration procedure of the sensor in the system environment, the two values HVAL and TADJ 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 a 16-bit two’s complement binary ranging from −32768 to +32767.

It is stored in the HVD register.

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

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.

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 3–1: Relation between T_J and T_{ADJ} (typical values)

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

3.2.2. DSP Configuration Registers

This section describes the function of the DSP configuration registers. For details on the EEPROM please refer to Application Note Programming of HAL 2850.

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.

EEPROM. RANGE	Nominal Range
0	reserved
1	40 mT
2	60 mT
3	80 mT
4	100 mT
5	120 mT
6	140 mT
7	160 mT

For calculation of magnetic measurement range over temperature see Section 4.9. on page 20 parameter $RANGE_{abs}$. The minimum value has to be used in order to guarantee no clipping over temperature.

Magnetic Offset D

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

D0 Register

Table 3–2: 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 3–3: 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 parameters for the multiplier in the DSP. The multiplication factor is a second order polynomial of the temperature.

C0 Register

Table 3–4: 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 3–5: Linear temperature coefficient

Parameter	Range	Resolution
c_1	-7.955×10^{-6}... 1.951×10^{-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 3–6: Quadratic temperature coefficient

Parameter	Range	Resolution
c_2	-1.87×10^{-10}... 1.86×10^{-10}	8 bit
C2	–128 ... 127	

C2 is encoded as two's complement binary.

$$c_2 = \frac{0.2008}{128} \cdot C2 \cdot 9.3132 \cdot 10^{-10}$$

3.3. Power-on Self Test (POST)

The HAL 2850 features a built-in power-on self test to support in system start-up test to enhanced the system failure detection possibilities.

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

– RAM

– ROM

– EEPROM

The power-on self test can be activated by setting certain bits in the sensors EEPROM.

Table 3–7: Power-On Self Test Modes

EEPROM. POST		Mode / Function
[1]	[0]	
0	0	POST disabled.
0	1	Memory test enabled (RAM, ROM, EEPROM).

3.3.1. Description of POST Implementation

HAL 2850 starts the internal POST as soon as the external supply voltage reaches the minimum supply voltage (V_{SUPon}). The sensor output is disabled during the POST. It is enabled after the POST has been finished (after $t_{startup}$).

A failed POST is immediately setting the PWM output to the minimum duty cycle.

3.3.2. RAM Test

The RAM test consists of an address test and an RAM cell test. The address test checks if each byte of the RAM can be singly accessed. The RAM cell test checks if the RAM cells are capable of holding both 0 and 1.

3.3.3. ROM Test

The ROM test consists of a checksum algorithm. The checksum is calculated by a byte by byte summation of the entire ROM. The 8-bit checksum value is stored in the ROM.

The checksum is calculated at the ROM test using the entire ROM and is then compared with the stored checksum. An error will be indicated in case that there is a difference between stored and calculated checksum.

3.3.4. EEPROM Test

The EEPROM test is similar to the ROM test. The only difference is that the checksum is calculated for the EEPROM memory and that the 8-bit checksum is stored in one register of the EEPROM.

3.4. Sensor Behavior in Case of External Errors

HAL 2850 shows the following behavior in case of external errors:

- Short of output against V_{SUP}: The sensor output is switched off (high impedance) when an over current occurs in the DIO output. It is re enabled before or while the next low pulse of the PWM signal is transmitted.Therefore the ECU must discard the first rising edge after a disturbance has occurred. The ECU has to identify destroyed PWM periods by evaluating the period time
- Break of V_{SUP} or GND line: A sensor with open-drain output and digital interface does not need a wire-break detection logic. The wire-break function is covered by the pull-up resistor on the receiver. Assuming a pull-up resistor in the receiver 100% duty-cycle (output always high) indicates a GND or V_{SUP} line break. This error can be detected one period after its occurrence
- Under or over voltage: The sensor output is switched off (high impedance) after under or over voltage has been detected by the sensor
- Over temperature detection: The sensor output is switched off (high impedance) after a too high temperature has been detected by the sensor (typ.180°C). It is switched on again after the chip temperature has reached a normal level. A build in hysteresis avoids oscillation of the output (typ. 25°C)

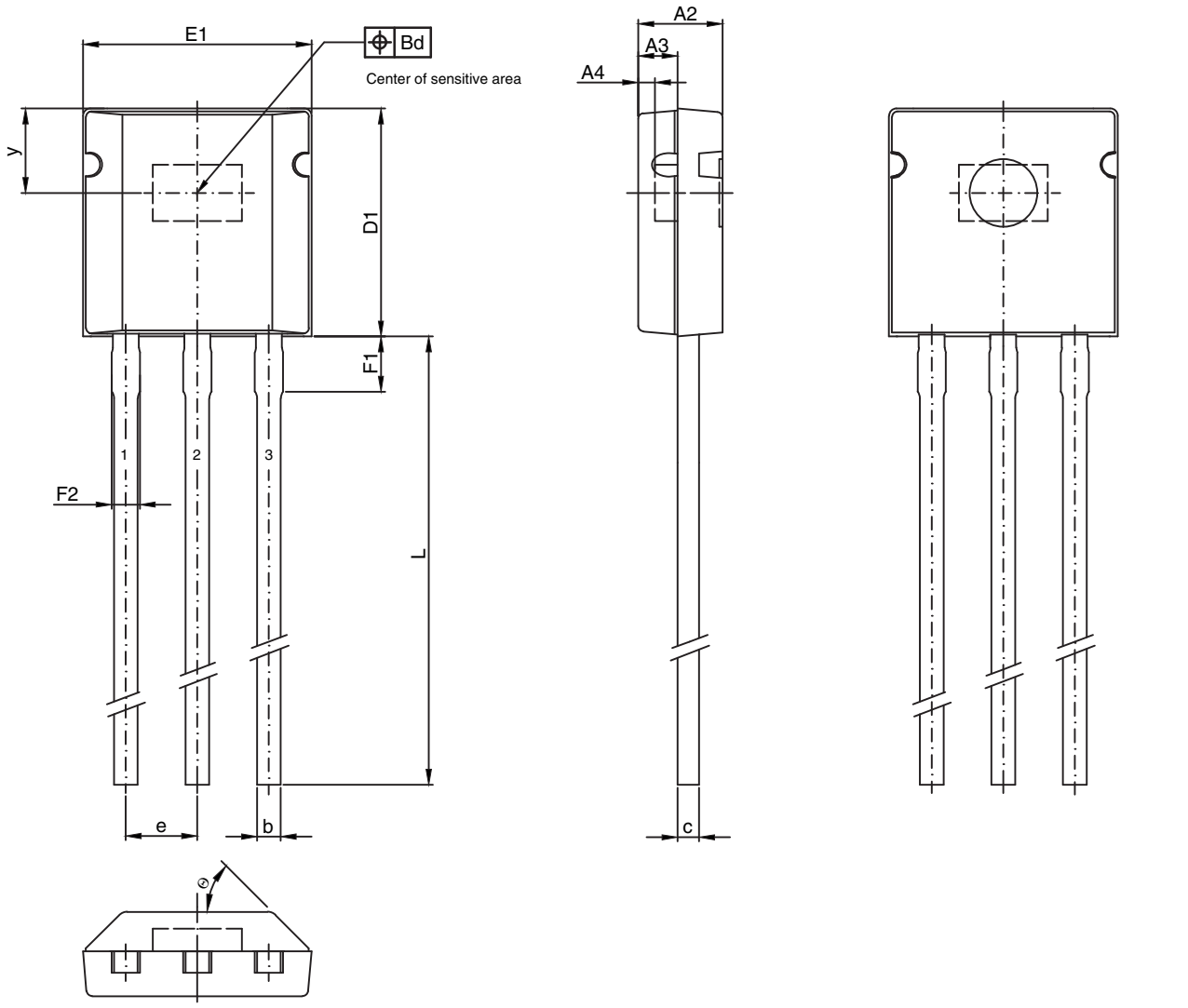
3.5. Detection of Signal Path Errors

HAL 2850 can detect the following overflows within the signal path:

- A positive overflow of the A/D converter, a positive overflow within the calculation of the low pass filter or the temperature compensation will set the PWM output to maximum duty cycle
- A negative overflow of the A/D converter, a negative overflow within the calculation of the low pass filter or the temperature compensation will set the PWM output to minimum duty cycle
- A positive or negative overflow of the A/D converter of the temperature sensor or a positive/negative overflow within the calculation of the calibrated temperature value sets the PWM output to minimum-duty-cycle

4. Specifications

4.1. Outline Dimensions



physical dimensions do not include moldflash.

solderability is guaranteed between end of pin and distance F1.

Sn-thickness might be reduced by mechanical handling.

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	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°

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ISSUE	ITEM NO.				
-	-		15-01-09	06615.0001.4 Bl. 1	ZG001015_Ver.08

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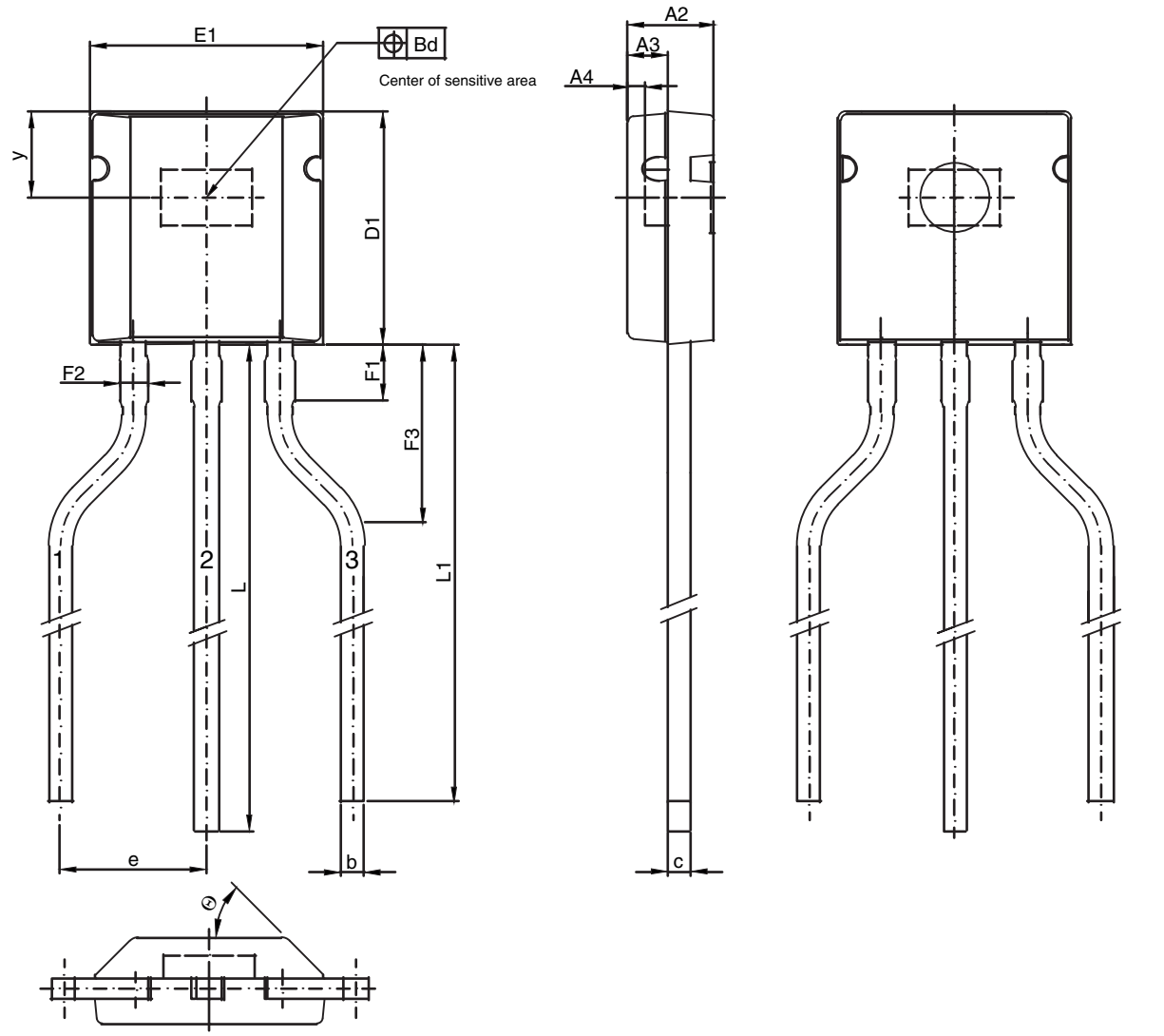
Fig. 4–1:
TO92UT-2 Plastic Transistor Standard UT package, 3 pins
Weight approximately 0.12 g



physical dimensions do not include moldflash.

solderability is guaranteed between end of pin and distance F1.

Sn-thickness might be reduced by mechanical handling.

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°

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-	-		10-04-29	06609.0001.4	ZG001009_Ver.07

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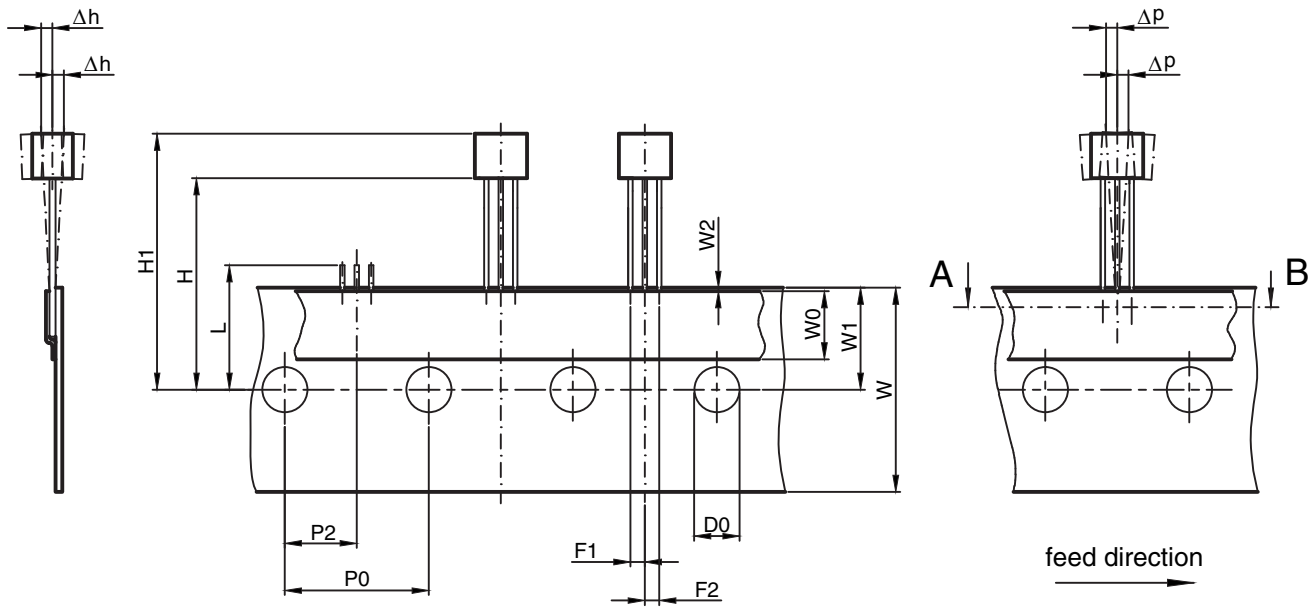
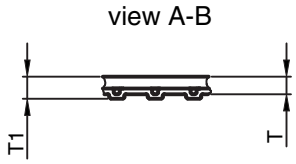
Fig. 4–2:
TO92UT-1 Plastic Transistor Standard UT package, 3 leads, spread
Weight approximately 0.12 g





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	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

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ISSUE	ITEM NO.				
-	IEC 60286-2		15-01-09	06631.0001.4 Bl. 1	ZG001031_Ver.04

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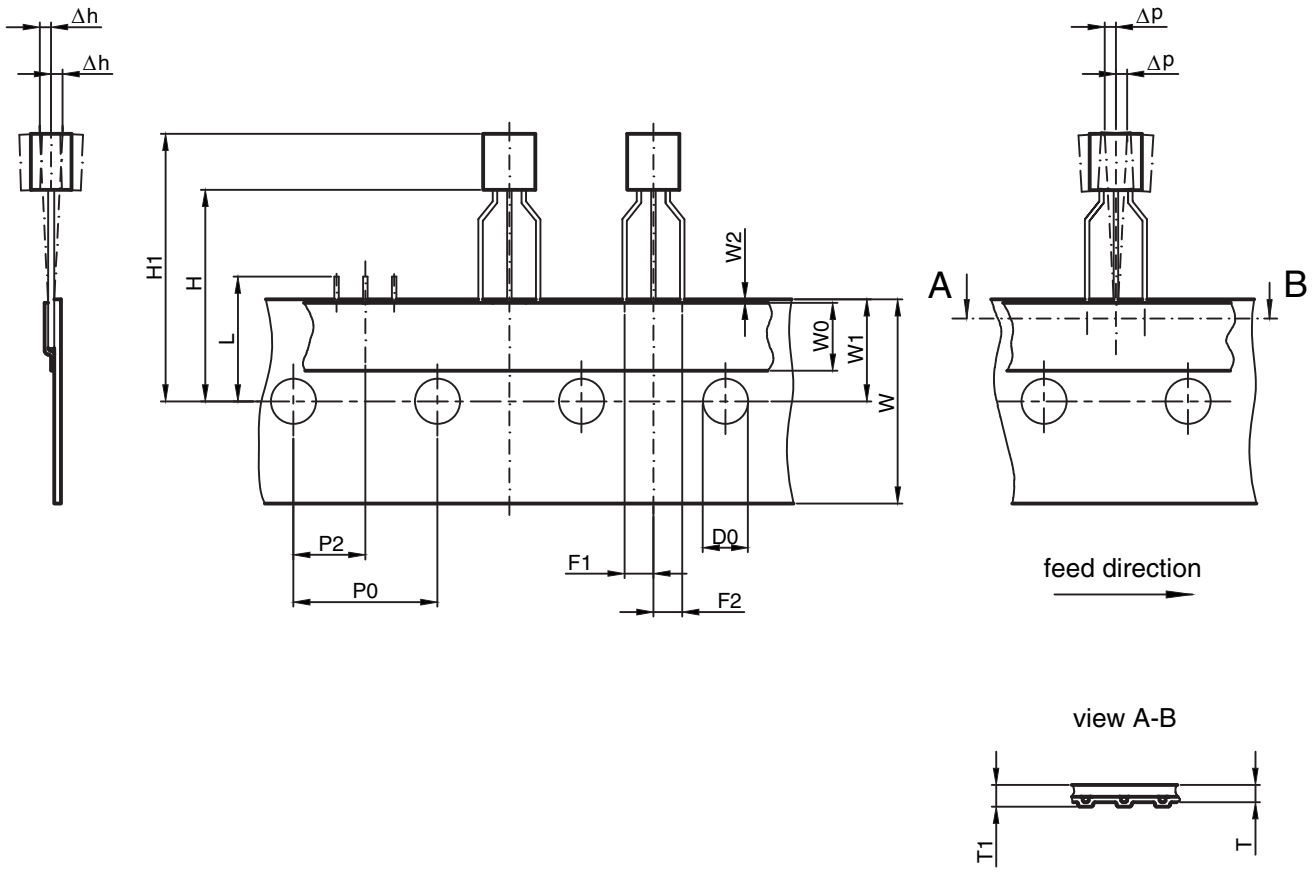
Fig. 4–3:
TO92UA/UT: Dimensions ammopack inline, not spread, standard lead length



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

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ISSUE	ITEM NO.				
-	ICE 60286-2		15-01-09	06632.0001.4 Bl. 1	ZG001032_Ver.05

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Fig. 4–4:
TO92UA/UT: Dimensions ammopack inline, spread, standard lead length

4.2. Soldering, Welding and Assembly

Information related to solderability, welding, assembly, and second-level packaging is included in the document “Guidelines for the Assembly of Micronas Packages”.
It is available on the Micronas website (http://www.micronas.com/en/service-center/downloads) or on the service portal (http://service.micronas.com).

4.3. 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 PWM Output

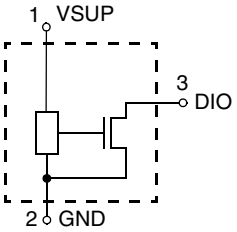

Fig. 4–5: Pin configuration

4.4. Dimensions of Sensitive Area

0.213 mm x 0.213 mm

4.5. Positions of Sensitive Area

	TO92UT-1/-2
A4	0.4 mm
Bd	0.3 mm
D1	4.05 ±0.05 mm
H1	min. 22.0 mm, max. 24.1 mm
y	1.55 mm nominal

4.6. 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	Comment
T_J	Junction Operating Temperature	–	–40	190[1)]	°C	not additive
V_{SUP}	Supply Voltage	VSUP	–18	26.5 [2)] 40 [3)]	V V	not additive not additive
V_{DIO}	IO Voltage	DIO	–0.5	26.5 [2)]	V	not additive
B_{max}	Magnetic field	–	–	unlimited	T	
V_{ESD}	ESD Protection	VSUP, DIO	–8.0[4)]	8.0[4)]	kV	

[1)] for 96h. Please contact Micronas for other temperature requirements
[2)] t < 5 min.
[3)] t < 5 x 500 ms
[4)] AEC-Q100-002 (100 pF and 1.5 kΩ)

4.6.1. Storage and Shelf Life

Information related to storage conditions of Micronas sensors is included in the document “Guidelines for the Assembly of Micronas Packages”. It gives recommendations linked to moisture sensitivity level and long-term storage.
It is available on the Micronas website (http://www.micronas.com/en/service-center/downloads) or on the service portal (http://service.micronas.com).

4.7. 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	17	V	
V_{DIO}	Output Voltage	DIO	0	18	V	
I_{OUT}	Continuous Output Current	DIO	–	20	mA	for V_{DIO} = 0.6 V
$V_{Pull\text{-}Up}$	Pull-Up Voltage	DIO	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 7.4. on page 30)			
[1] Depends on the temperature profile of the application. Please contact Micronas for life time calculations.						
C_L	Load Capacitance	DIO	180	(see Section 7.4. on page 30)	pF	
N_{PRG}	Number of EEPROM Programming Cycles	–	–	100	cycles	0 °C < Tamb < 55 °C
T_J	Junction Operating Temperature[1]	–	–40 –40 –40	125 150 170	°C °C °C	for 8000h (not additive) for 2000h (not additive) < 1000h (not additive)
[1] Depends on the temperature profile of the application. Please contact Micronas for life time calculations.						

4.8. Characteristics

at T_J = 40 °C to +170 °C (for temperature type A), V_{SUP} = 4.5 V to 17 V, GND = 0 V,
at Recommended Operation Conditions if not otherwise specified in the column Conditions.
Typical Characteristics for T_J = 25 °C and V_{SUP} = 5 V..

Symbol	Parameter	Pin Name	Min.	Typ.	Max.	Unit	Conditions
I_{SUP}	Supply Current	VSUP	–	12	19	mA	
I_{DIOH}	Output Leakage Current	DIO	–	–	10	µA	
Digital I/O (DIO) Pin							
V_{OL}	Output Low Voltage	DIO	–	– – –	0.6 0.2 0.09	V	I_{OL} = 20 mA I_{OL} = 5 mA I_{OL} = 2.2 mA
T_{PERIOD}	PWM Period	DIO	0.5	–	32	ms	Customer programmable (see Table on page 24)
$DUTY_{Range}$	Available Duty-Cycle Range	DIO	0.78	–	99.22	%	Min. and max. values depend on MDC register setting.
	Output Resolution	DIO	–	–	16	bit	Depending on selected PWM period and slew rate

Symbol	Parameter	Pin Name	Min.	Typ.	Max.	Unit	Conditions
$\Delta V/\Delta t_{fall}$	Falling Edge Slew Rate	DIO	1.4	2	2.6	V/µs	SLEW = 2 Measured between 70% and 30%, $V_{Pull\text{-}Up}$ = 5 V, $R_{Pull\text{-}UP}$ = 1 kΩ, C_L = 470 nF
			4.9	7	10.4		SLEW = 1 Measured between 70% and 30%, $V_{Pull\text{-}Up}$ = 5 V, $R_{Pull\text{-}UP}$ = 510 Ω, C_L = 220 pF
			25	–	–		SLEW = 0 Measured between 30% and 70%, $V_{Pull\text{-}Up}$ = 5 V, $R_{Pull\text{-}UP}$ = 510 Ω, C_L = 220 pF
$\Delta V/\Delta t_{rise_max}$	Max. Rising Edge Slew Rate	DIO	1.4	2	2.6	V/µs	SLEW = 2 Measured between 30% and 70%, $V_{Pull\text{-}Up}$ = 5 V, $R_{Pull\text{-}UP}$ = 1 kΩ, C_L = 470 nF
			3.8	7	10.4		SLEW = 1 Measured between 30% and 70%, $V_{Pull\text{-}Up}$ = 5 V, $R_{Pull\text{-}UP}$=510 Ω, C_L=220 pF
			25	–	–		SLEW = 0 Measured between 30% and 70%, $V_{Pull\text{-}Up}$ = 5 V, $R_{Pull\text{-}UP}$=510 Ω, C_L=220 pF
$t_{startup}$	Power-Up Time (time to reach stabilized output duty cycle)	DIO	Depends on customer programming. Please see (see Table 5–1 on page 23)			ms	
f_{OSC16}	Internal Frequency of 16 MHz Oscillator	–	–	16	–	MHz	
V_{SUPon}	Power-On Reset Level	VSUP	3.7	4.15	4.45	V	
$V_{SUPonHyst}$	Power-On Reset Level Hysteresis	VSUP	–	0.1	–	V	
V_{SUPOV}	Supply Over Voltage Reset Level	VSUP	17	19.5	21	V	
$V_{SUPOVHyst}$	Supply Over Voltage Reset Level Hysteresis	VSUP	–	0.4	–	V	
Out_{noise}	Output noise (rms)	DIO	–	1	2	LSB_{12}	B = 0 mT, ±100 mT range, 0.5 ms PWM period, T_J = 25 °C
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 1s1p board

4.9. Magnetic Characteristics

at T_J = 40 °C to +170 °C, V_{SUP} = 4.5 V to 17 V, GND = 0 V,
at Recommended Operation Conditions if not otherwise specified in the column Conditions.
Typical Characteristics for T_J = 25 °C and V_{SUP} = 5 V.

Symbol	Parameter	Pin Name	Min.	Typ.	Max.	Unit	Conditions
$RANGE_{ABS}$	Absolute Magnetic Range of A/D Converter	–	60	100	110	%	% of nominal RANGE Nominal RANGE programmable from ±40 mT up to ±160 mT
INL	Full Scale Non-Linearity	DIO	–0.25	0	0.25		% of full-scale RANGE = 1 (±40 mT)
			–0.15	0	0.15		% of full-scale RANGE ≥ 2 (≥ ±60 mT)
ES	Sensitivity Error over Junction Temperature Range	DIO	–1	0	1	%	at T_J=–40 °C to 120 °C (see Section 4.9.1.)
ES	Sensitivity Error over Junction Temperature Range	DIO	–1.5	0	1.5	%	at T_J=120 °C to 170 °C (see Section 4.9.1.)
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

4.9.1. Definition of Sensitivity Error ES

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

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

In the example shown in Fig. 4–6 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-squares method straight line that has a value of 1 at 25 °C

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

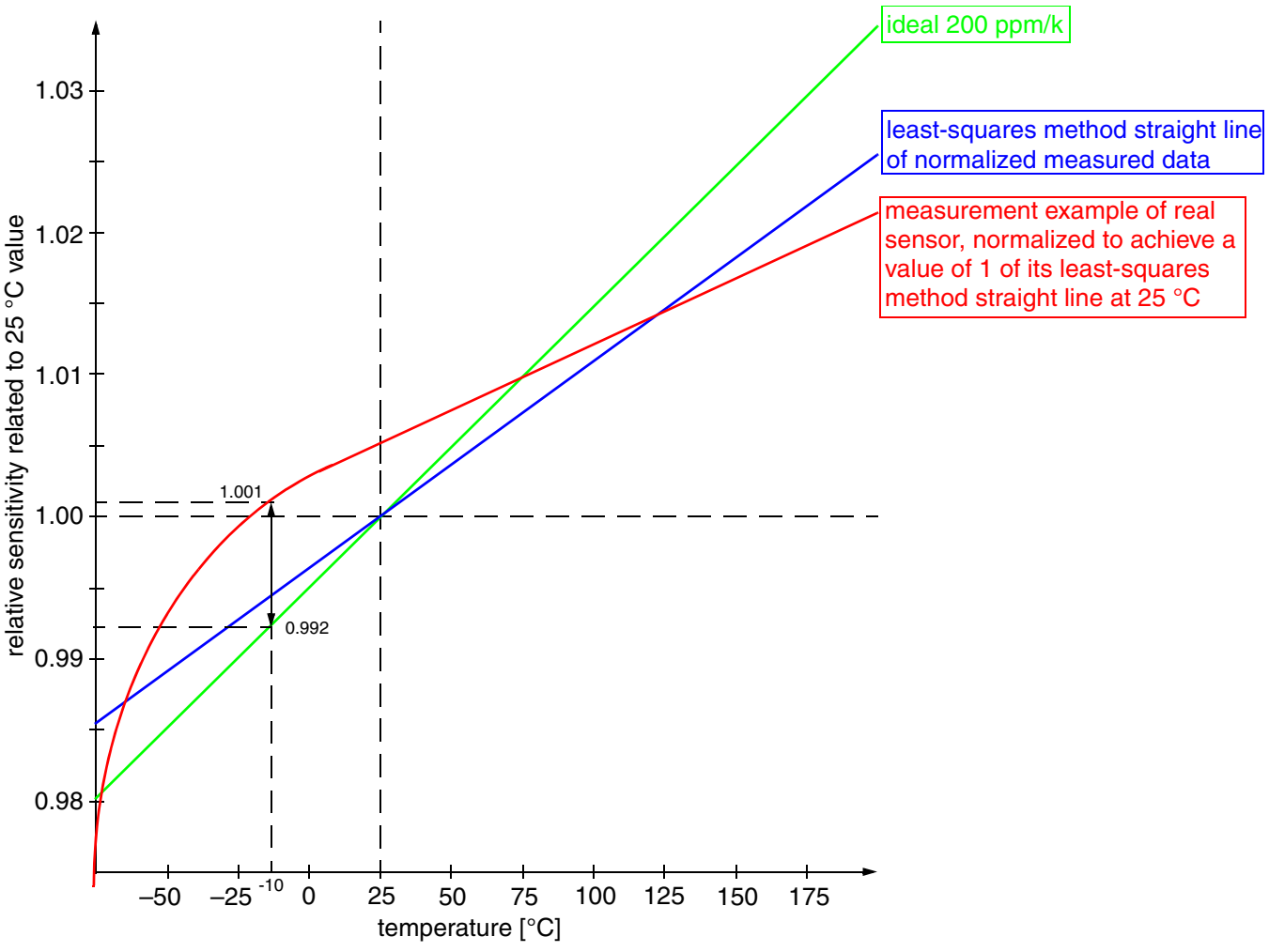

Fig. 4–6: Definition of sensitivity error (ES)

5. The PWM Module

The HAL 2850 transmits the magnetic field information by sending a PWM signal.

A pulse width modulated (PWM) signal consists of successive square wave pulses. The information is coded in the ratio between high time "t_{high}" and low time "t_{low}".

$$duty\ cycle = \frac{t_{high}}{t_{period}}$$

Table 5–1 describes the PWM interface timing.

After reset, the output is recessive high. The transmission starts after the first valid Hall value has been calculated. In case of an overcurrent in the DIO output, the transmit transistor is switched off (high impedance). The transistor is re-enabled before transmitting a new pulse.

The first PWM period after a reset or an overcurrent condition cannot be captured due to no edge at the beginning of the transmission.

The PWM signal can be configured by the EEPROM bits PERIOD, PERIOD_ADJ (Trimming of native PWM periods), MDC (minimum/maximum duty cycle), SR (slew rate) and OP (output polarity) (see Section 5.1. on page 24).

The native PWM periods can be set by the EEPROM bit field PERIOD. Native PWM periods are 0.512 ms, 1.024 ms,…, 16.384 ms and 32.768 ms (see Table on page 24).

The EEPROM field PERIOD_ADJ can be used to trim the PWM period in small steps. This feature enables variable PWM periods in between the natural periods (see Table on page 24).

The output polarity can be configured by the flag OP in the EEPROM. According to the OP value, a PWM period starts either with a high pulse (OP = 0) or with a low pulse (OP = 1). Please note that if OP is set to 1, the output is recessive high until the output has been enabled (t_{OE} has been elapsed). After the output has been enabled, it remains low until the transition within the first period (see Fig. 5–2).

The slew rate can be configured by the bits SR in the EEPROM. See Table 5–1 for selectable slew rates.

Note: Please consider at which edge a new period starts. When OP is set to zero, a new period starts with the rising edge and the period must be captured by triggering the rising edge.

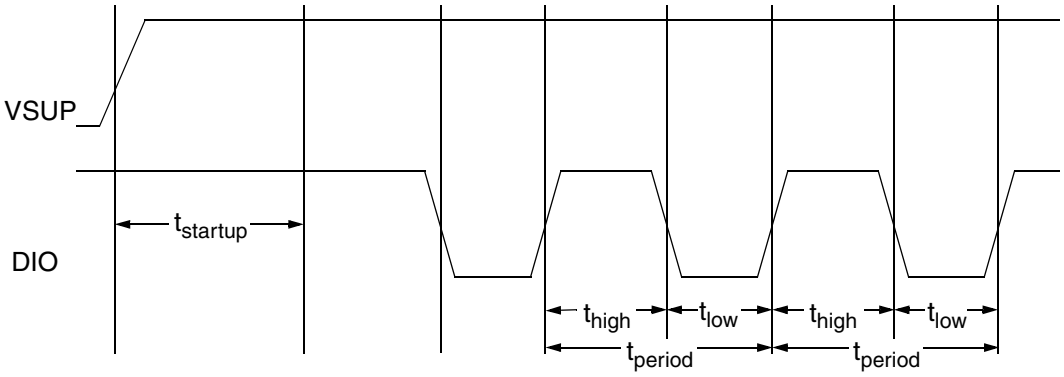

Fig. 5–1: PWM interface startup timing

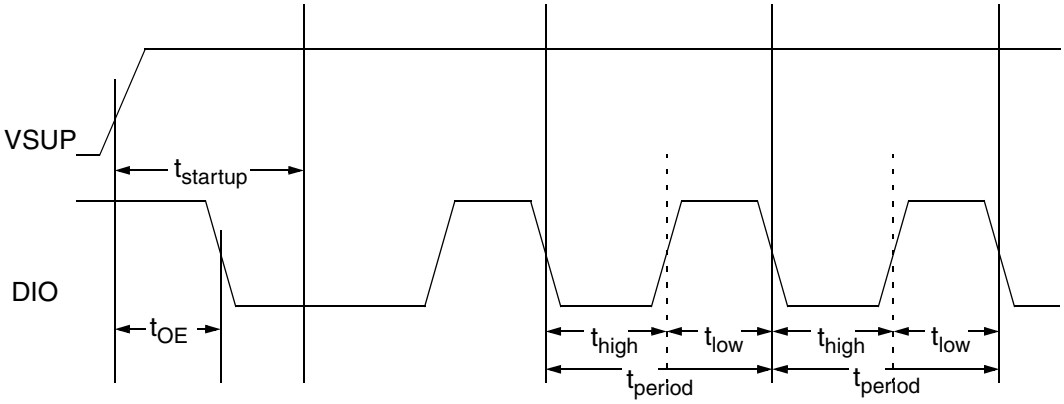

Fig. 5–2: PWM interface startup timing for inverted output

Table 5–1: PWM interface timing

Symbol	Parameter	Min.	Typ.	Max.	Unit	Remark
$t_{startup}$	Startup Time[1)]	–	–	8 9 10 10 20 40 80	ms ms ms ms ms ms ms	Period = 0.5 ms Period = 1 ms Period = 2 ms Period = 4 ms Period = 8 ms Period = 16 ms Period = 32 ms
t_{OE}	Output Enable Time	60	–	150[2)]	µs	
PWM_{Jitter}	PWM Period Sample to Sample Jitter (RMS)	–	30	60	ns	Period = 0.5 ms
$DUTY_{Jitter}$	PWM Duty Cycle Sample to Sample Jitter (RMS)	–	63	125	ns	Period = 0.5, ±100 mT RANGE, B = 0 mT, including noise
t_{period}	PWM Period	see Fig. 5–1 and Fig. 5–2				PWM period is customer programmable
DUTY	PWM High Duty Cycle	t_{high} / t_{period}			%	

[1)] Values are valid for deactivated power-on self test. 10 ms must be added when power-on self test is active.

[2)] 10 ms must be added when power-on self test is active.

5.1. Programmable PWM Parameter

PWM Periods

Table 5–2: Supported native PWM periods

PWM Period	Sample Frequency	PERIOD Bit No.		
	Typ.	[4:2]	[1]	[0]
[ms]	[Hz]			
0.512	1953	0	0	0
1.024	977	0	0	1
2.048	488	0	1	1
4.096	244	1	1	1
8.192	122	2	1	1
16.384	61	3	1	1
32.768	31	4	1	1

Table 5–3: Supported intermediate PWM period

EEPROM.PERIOD	Period steps	max. Period, PERIOD_ADJ = 0				min. Period, PERIOD_ADJ = 255			
		PWM period	resolution	C_0 for full magnetic range, MDC=0	magnetic range for C_0 = 1, MDC=0	PWM period	resolution	C_0 for full magnetic range, MDC=0	magnetic range for C_0 = 1, MDC=0
[LSB]	[µs]	[ms]	[LSB]		[%]	[ms]	[LSB]		[%]
0	1	0.512	12	0.9375	93.75	0.257	11	0.4395	43.95
1	2	1.024	13	0.9688	96.88	0.514	12	0.4707	47.07
3	4	2.048	14	0.9844	98.44	1.028	13	0.4863	48.63
7	8	4.096	15	0.9922	99.22	2.056	14	0.4941	49.41
11	16	8.192	16	0.9961	99.61	4.112	15	0.4980	49.80
15	32	16.384	16	0.9961	99.61	8.224	15	0.4980	49.80
19	64	32.768	16	0.9961	99.61	16.448	15	0.4980	49.80

Note: When the period is trimmed with the PERIOD_ADJ register, then either the measurable magnetic range is reduced or the resolution is reduced.
The PWM period is faster than the sample rate when PERIOD_ADJ is greater than 0. Aliasing may occur due to double transmitted samples.

Minimum Duty Cycle

The minimum and maximum duty cycle is symmetrical to 50% duty cycle. The MDC register acts on the minimum and maximum duty cycle. The minimum and maximum duty cycle depend on the output slew rates and the PWM period (see Table 5–4).

The minimum/maximum duty cycle can be calculated with the following equations:

$PWMPER16 = 2^{16} - (PERIOD_ADJ \times 2^{7})$
$PWMMIN = (1 + MDC) \times 2^{9}$

$PWMMAX = PWMPER16 - PWMMIN$
$PWMPERIOD = trunc(PWMPER16 / 2^{(16-R)})$

Definition:

R:	PWM resolution in LSB (see Table)
PWMMIN:	minimum high time in LSB
PWMMAX:	maximum low time in LSB
PWMPERIOD:	PWM period in LSB
PWMPER16:	PWM period in LSB for 16 bit resolution
MDC:	EEPROM value for adjusting min./max. duty cycle
PERIOD_ADJ:	EEPROM value for adjusting the period

The measured high duty cycle (DUTY) may differ from the internal high duty cycle ($DUTY_i$) due of internal delays within the output logic, a difference between the rising and falling slope time, the threshold voltage of the external receiver; and other effects.

Setting the clamping levels reduces the measurable magnetic range (C0 = 1). The full magnetic range can be used in case the slope coefficient C0 is used for compressing the range of HVAL.

Two options are available:

1. Use full magnetic range with a reduced resolution or
2. full resolution with a reduced magnetic range.

The full magnetic range can be addressed by using the equations below.

$C0 = C_{target}/C_{measured}$

C_{target}: Target output sensitivity
$C_{measured}$: Measured output sensitivity for default settings

Example: C_{target} = 40% / 60 mT
$C_{measured}$ = 30% / 60 mT
C0 = 0.667%/mT / 0.5%/mT = 1.334

Table 5–4: PWM period (PERIOD), slew rate (SR) and minimum duty cycle (MDC)

Period	Slew Rate	$V_{PULL-UP}$	PWMmin @ R		min. Duty Cycle		Rec. Limit	
typ.	typ.	max.	min. (MDC=0)	max. (MDC=31)	min.	max.	min. duty cycle	MDC
[µs]	[V/µs]	[V]	[LSB]	[LSB]	[%]	[%]	[%]	[LSB]
512	infinite (> 25)	18	32	1024	0.78	25	0.78 [1)]	0
	8	7					3.13	3
	2	7					3.13	3
1024	infinite (> 25)	18	64	2048			0.78 [1)]	0
	8	7					1.56	1
	2	7					1.56	1
2048	infinite (> 25)	18	128	4096			0.78	0
	8	7						
	2	7						
4096	infinite (> 25)	18	256	8192			0.78	0
	8	7						
	2	7						
8192	infinite (> 25)	18	512	16384			0.78	0
	8	7						
	2	7						
16384	infinite (> 25)	18	512	16384			0.78	0
	8	7						
	2	7						
32768	infinite (> 25)	18	512	16384			0.78	0
	8	7						
	2	7						

[1)] An overcurrent may not be detected.

6. Programming of the Sensor

HAL 2850 features two different customer modes. In **Application Mode** the sensor is providing 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.

6.1. 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 6–1).

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.

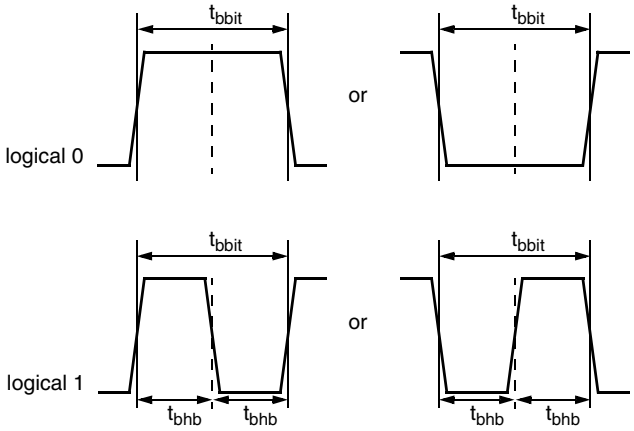

Fig. 6–1: Definition of logical 0 and 1 bit

A description of the communication protocol and the programming of the sensor is available in a separate document (Application Note Programming HAL 2850).

Table 6–1: 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_{rxth_lh}	Receiver low-to-high threshold voltage	1.2	–	1.5	V	
V_{rxth_hh}	Receiver high-to-low threshold voltage	1.1	–	1.4	V	
V_{SUPPRG}	Supply Voltage During Programming	5.6	–	6.5	V	

Table 6–2: 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	

6.2. Programming Environment and Tools

For the programming of HAL 2850 during product development 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.

6.3. Programming Information

For production and qualification tests, it is mandatory to set the LOCK bit after final adjustment and programming of HAL 2850. The LOCK function is active after the next power-up of the sensor.

The success of the LOCK process should be checked by reading the status of the LOCK bit after locking and/or by an analog 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.

7. Application Note

7.1. 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 2850 the junction temperature T_J is specified. The maximum ambient temperature T_{Amax} can be calculated as:

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

7.2. 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.

7.3. Output Description

7.3.1. How to Measure PWM Output Signal

The HAL 2850 codes the magnetic field information in the duty cycle of a PWM signal. The duty cycle is defined as the ratio between the high time "t_{high}" and the period "t_{period}" of the PWM signal (see Fig. 7–1).

Note: Please consider at which edge a new period starts. When OP is set to zero, a new period starts with the rising edge and the period must be captured by triggering the rising edge.

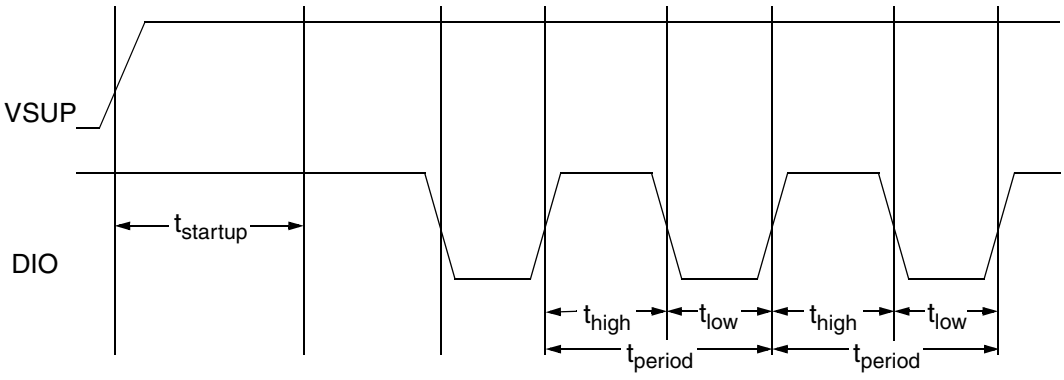

Fig. 7–1: Definition of PWM signal

7.4. Application Circuit

Micronas recommends the following two application circuits for the HAL 2850.

The first circuit is recommended when the sensor is powered with 5 V supply (see Fig. 7–2).

The second circuit should be used for applications connected directly to the car's battery with a pull-up to a 5 V line (see Fig. 7–3 on page 31).

To avoid noise on the controller input pin, it is recommended to use only these two circuits.

Values of external components

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

The maximum load capacitor and minimum resistor is given by the following equation:

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

$R_{L\ (min.)} = (V_{pull\text{-}up\ (max.)} - V_{DIOL\ (max.)}) / (I_{DIO} - (C_L \times (\Delta V/\Delta t_{fall})$
$C_{L\ (max.)} = 0.4 \times V_{pull\text{-}up\ (min.)} / (R_L \times (\Delta V/\Delta t_{rise}))$

$R_{pull\text{-}up}$: Pull-up resistor between DIO and $V_{pull\text{-}up}$
C_{VSUP}: Capacitance between the V_{SUP} 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 4.7. on page 18
$V_{DIOL\ (max.)}$: max. DIO low voltage, it is recommended to use the value specified in Section 4.8. on page 18
I_{DIO}: DIO current at $V_{DIOL\ (max.)}$
$\Delta V/\Delta t_{rise}$: selected rising edge slew rate, the max. value specified in Section 4.8. must be used
$\Delta V/\Delta t_{fall}$: selected falling edge slew rate, the max. value specified in Section 4.8. must be used

Example for Calculating R_L and C_L (max.)

The application operates at following conditions:
slew rate = 8 V/µs (typ.)
$V_{pull\text{-}up}$ = 5.5 V (max.)
C_L = 400 pF

Calculation:
$R_{L\ (min.)}$ = (5.5 V – 0.8 V) / (20 mA – 400 pF x 10.4 V/µs) = 297 Ω. => **R_L = 330 Ω**

$C_{L\ (max.)}$ = 400 pF <= 0.4 × 4.5 V / (330 Ω × 10.4 V/µs) = 524 pF
=> The used C_L is below the limit.

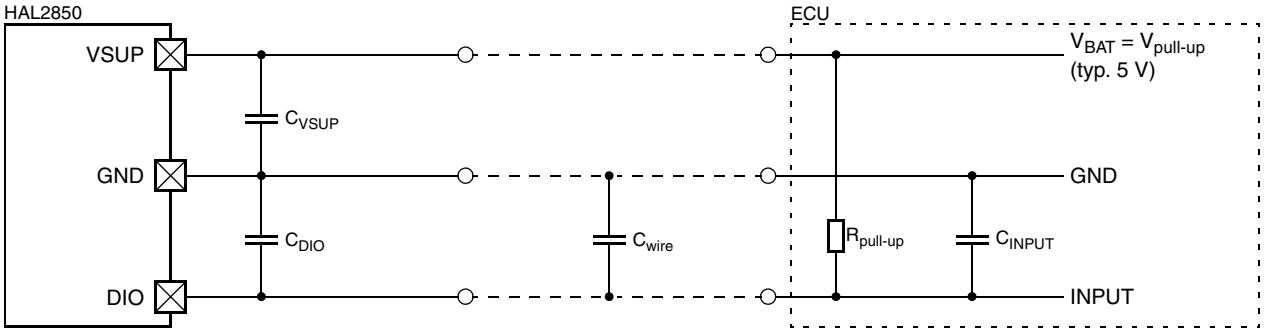

Fig. 7–2: Application circuit for 5 V supply

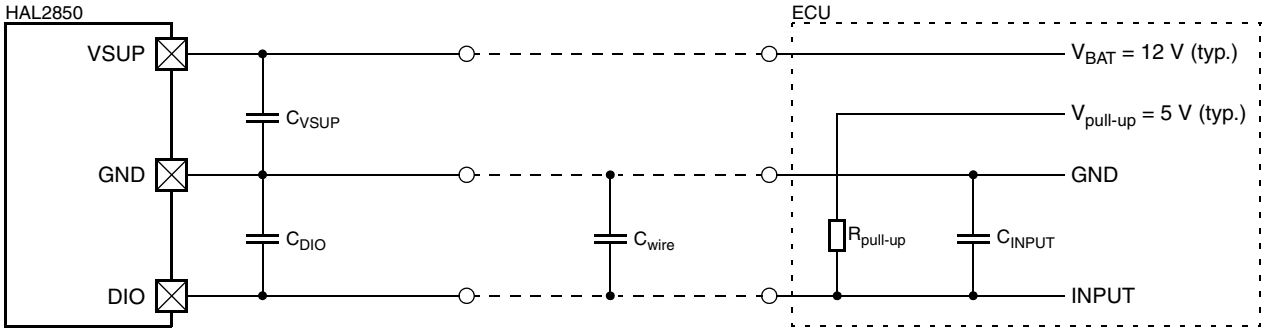

Fig. 7–3: Application circuit for battery and 5 V pull-up voltage

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.

8. Data Sheet History

1. Advance Information: “HAL 2850 Linear Hall-Effect Sensor with PWM Output”, Dec. 5, 2008, AI000144_001EN. First release of the advance information.
2. Advance Information: “HAL 2850 Linear Hall-Effect Sensor with PWM Output”, March 24, 2010, AI000144_002EN. Second release of the advance information.
   Major changes:
   - Electrical characteristics
   - Signal path width
3. Advance Information: “HAL 2850 Linear Hall-Effect Sensor with PWM Output”, July 9, 2010, AI000144_003EN. Third release of the advance information.
   Major changes:
   - Electrical and Magnetic Characteristics
4. Data Sheet: “HAL 2850 Linear Hall-Effect Sensor with PWM Output”, August 9, 2011, DSH000160_001EN. First release of the data sheet.
   Major changes:
   - Power-on Self Test (POST) details
   - Error detection and behavior
   - TO92UT package drawings
   - Electrical and magnetic characteristics
5. Data Sheet: “HAL 2850 Linear Hall-Effect Sensor with PWM Output”, July 25, 2013, DSH000160_002EN. Second release of the data sheet. Major changes:
   - Temperature type K removed
   - Package drawings updated
   - Magnetic Characteristics over Temperature updated
   - Power-on Self Test Coverage updated
6. Data Sheet: “HAL 2850 Linear Hall-Effect Sensor with PWM Output”, Feb. 16, 2016, DSH000160_003EN. Third release of the data sheet. Major changes:
   - Package drawings updated
   - Magnetic Characteristics:
     “Sensitivity Error over Junction Temperature Range” (ES) values updated
   - Programming Interface:
     “Receiver low-to-high/high-to-low threshold voltage (V_{rxth_lh} / V_{rxth_hh})” values changed

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