Hardware
Documentation

Data Sheet

HAL® 1890

Programmable Linear Hall-Effect Sensor with SENT Interface

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Contents

Contents, continued

Programmable Linear Hall-Effect Sensor with SENT Interface

1. Introduction

The HAL 1890 is a programmable Hall-effect sensor with SENT (Single-Edge Nibble Transmission) output. The signal value is proportional to the magnetic flux density applied to the sensor surface. The sensor is sensitive to the magnetic-field strength and can be used to measure current or to detect mechanical movement, such as a small stroke or angle. This robust sensor can be used in harsh electrical and mechanical environments.

Major characteristics like magnetic-field range, sensitivity, offset (signal voltage at zero magnetic field) and the temperature coefficients are programmable in a non-volatile memory. Several output signal clamping levels can be programmed. Diagnostic features are implemented to indicate various fault conditions like undervoltage, under-/overflow or overtemperature.

The HAL 1890 is programmable by modulating the supply voltage with a serial telegram on the sensor's supply pin or output pin. No additional programming pin is needed. Several sensors on the same supply line can be programmed individually via the output pin. This programmability allows a 2-point calibration by adjusting the output signal directly to the input signal, such as mechanical angle, distance, or current.

Individual adjustment of each sensor during the customer's manufacturing process is possible. With this calibration procedure, the tolerance of the sensor, the magnet and the mechanical positioning can be compensated in the final assembly.

The spinning-current offset compensation leads to stable magnetic characteristics over supply voltage and temperature. Furthermore, the first-order and second-order temperature coefficients of the sensor sensitivity can be used to compensate the temperature drift of all common magnetic materials. This enables operation over the full temperature range with high accuracy.

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

The sensor is designed for industrial and automotive applications, is AEC-Q100 qualified, and operates in the junction temperature range from –40 °C up to 170 °C. The HAL 1890 is available in the very small leaded packages TO92UA-1 and TO92UA-2.

1.1. Major Applications

Thanks to the sensor’s robust and cost-effective design, the HAL 1890 is a potential system solution for applications such as:

– Small-angle or linear position measurements

– Gear position detection in transmission application

– Current sensing for battery management

– Rotary selector

1.2. Features

– SENT output according to SAE J2716 Rev. 4
– Support of H.2 format with 3 data nibbles = 12-bit Hall value
– Support of H.4 format with 6 data nibbles = 12-bit Hall value and 12-bit secure information
– Enhanced serial message format with 12-bit data and 8-bit message ID

– Digital signal processing

– Continuous measurement ranges from ±20 mT to ±160 mT

– Selectable clamping levels with selectable diagnosis

– Comprehensive diagnostic feature set

– Lock function and built-in redundancy for EEPROM memory

– Programmable temperature characteristics for matching all common magnetic materials

– Programming via output pin or supply voltage modulation

– On-chip temperature compensation

– Active offset compensation

– Operates from –40 °C up to 170 °C junction temperature

– Operates from 4.5 V up to 5.5 V supply voltage in specification

– Operates with static and dynamic magnetic fields up to 5 kHz

– Selectable sampling frequency (8 kSps or 16 kSps)

– Overvoltage and reverse-voltage protection at VSUP pin

– Magnetic characteristics extremely robust against mechanical stress

– Short-circuit protected open-drain output

– EMC and ESD optimized design

– AEC-Q100 qualified

2. Ordering Information

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

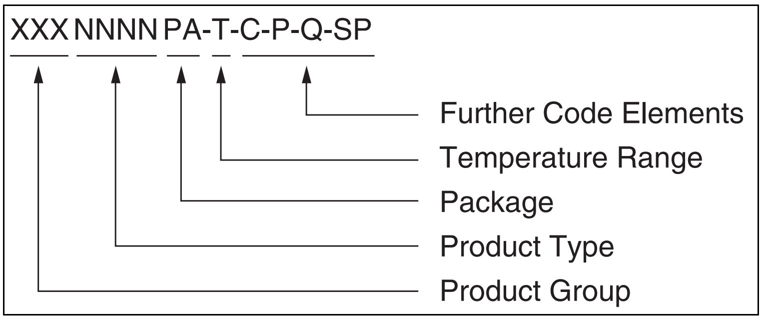


Fig. 2–1: Ordering code principle

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

2.1. Device-Specific Ordering Codes

HAL 1890 is available in the following package and temperature variants.

Table 2–1: Available packages

Package Code (PA)	Package Type
UA	TO92UA

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 5.1. on page 38.

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

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

Available Ordering Codes	Package Marking
HAL 1890UA-A-[C-P-Q-SP]	1890A

3. Functional Description

3.1. General Function

The HAL 1890 is a monolithic integrated circuit (IC) which provides an output signal proportional to the magnetic flux through the Hall plate via the SENT protocol.

The Hall IC is sensitive to magnetic north and south polarity. The Hall voltage is converted to a digital value, processed in the Digital Signal Processing unit (DSP) according to the settings of the EEPROM registers, and coded on the output according to the SENT protocol.

Selectable clamping levels for the output signal as well as diagnostic features are available. The function and the parameter for the DSP are explained in Section 3.2. on page 9. Internal temperature compensation circuitry and spinning-current offset compensation enable operation over the full temperature range with minimal degradation in accuracy and offset. The circuitry also rejects offset shifts due to mechanical stress from the package. In addition, the sensor IC is equipped with devices for overvoltage and reverse polarity protection at supply pin.

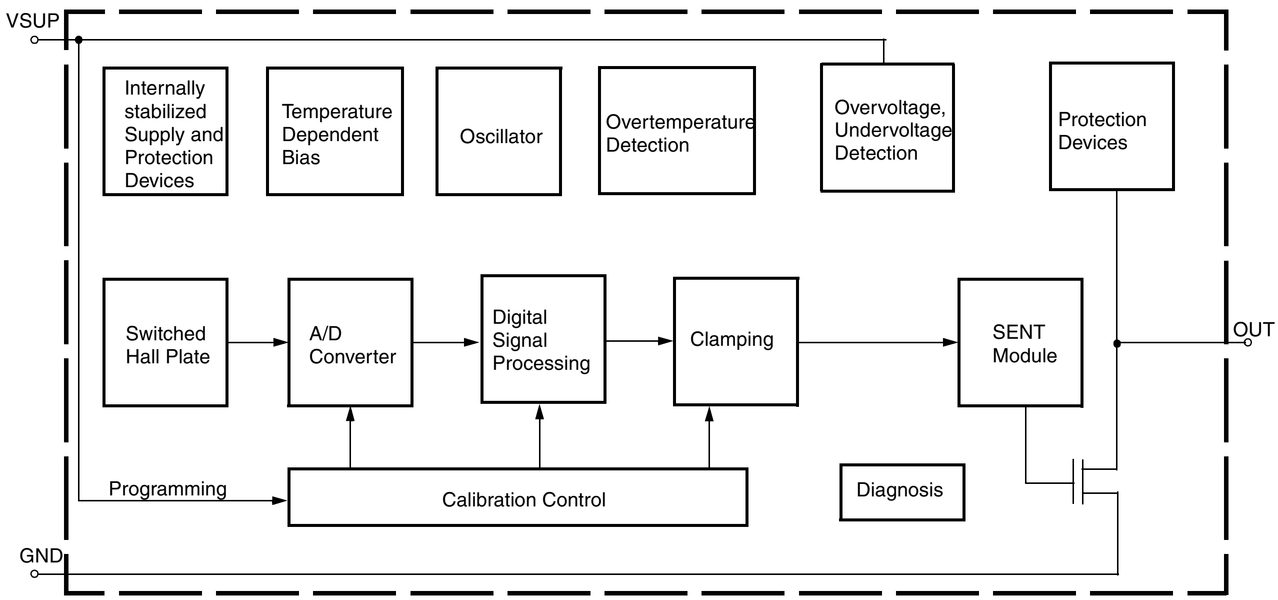


Fig. 3–1: HAL 1890 block diagram

The IC can be programmed via supply or output pin voltage modulation. After detecting a command, the sensor reads or writes the memory and answers with a digital signal on the output pin. As long as the LOCK register is not set, the output characteristic can be adjusted by programming the EEPROM registers. The LOCK register disables the programming of the EEPROM memory. This register cannot be reset.

Furthermore, HAL 1890 features an internal error detection. The following error modes can be detected: over-/underflow in adder or multiplier, over-/underflow in A/D converter (ADC) and overtemperature.

3.2. Digital Signal Processing and EEPROM

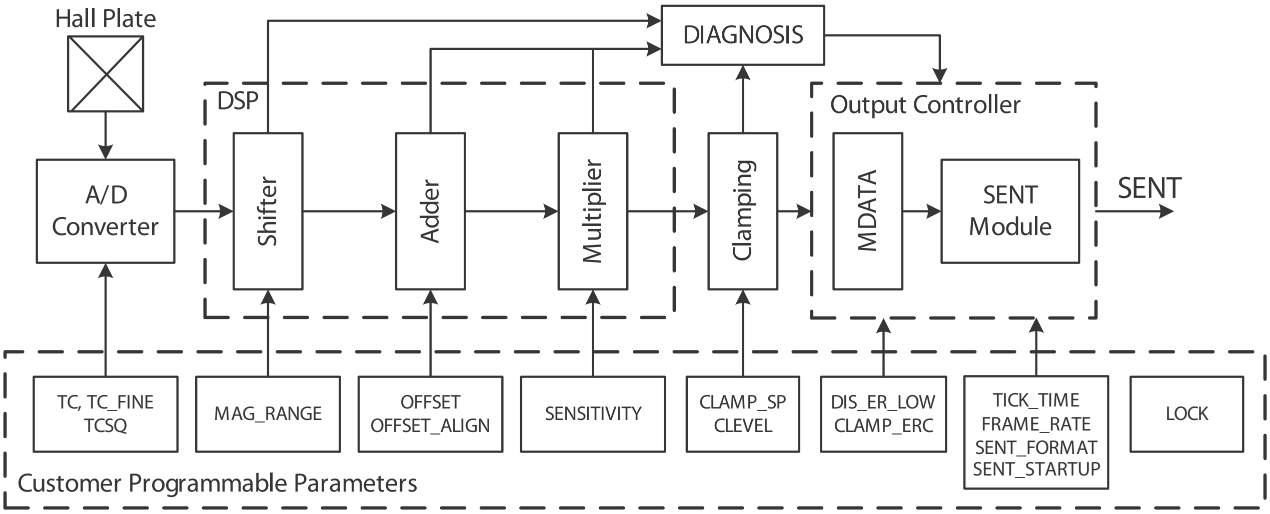


Fig. 3–2: Details of Programming Parameter and Digital Signal Processing

Table 3–1: Cross reference table for EEPROM register and sensor parameter

EEPROM Register	Parameter	Data Bits	Function
Customer Setup 1	DSDOUBLE	1	Sampling frequency selection
	CLEVEL	2	Output clamping values selection
	EN_ERC_HI	1	Set signal path’s overflow and underflow behavior
	TC_FINE	1	Fine adjustment of linear temperature coefficient
	TICK_TIME	2	SENT tick time
	FRAME_RATE	2	SENT frame repetition rate
	SENT_FORMAT	1	SENT format selection (H.2 or H.4)
	SENT_STARTUP	1	SENT start-up behavior
Customer Setup 2	LOCK	1	Customer lock
	CLAMP_SP	1	Activates unbalanced clamping levels
	CLAMP_ERC	1	Activates Error Flag on SENT output
	OFFSET_ ALIGN	1	Magnetic offset alignment bit (MSB or LSB aligned)
	TCSQ	5	Quadratic temperature coefficient
	TC	5	Linear temperature coefficient
	MAG_RANGE	3	Available magnetic ranges
Output Scaling	SENSITIVITY	8	Magnetic sensitivity
	OFFSET	8	Magnetic offset
Micronas ID1	MIC_ID_1	16	Micronas production information (read only)
Micronas ID2	MIC_ID_2	16	Micronas production information (read only)

Note For more information on the registers and the memory map of the HAL 1890, please refer to the application note “**HAL 1870/1880/1890 User Manual**”.

The DSP is a key function of this sensor and performs the signal conditioning. The parameters for the DSP are stored in the EEPROM registers. Details are shown in Fig. 3–2 on page 9.

The measurement data can be readout from the digital output register MDATA.

3.2.1. Digital Output Register

MDATA register

This 16-bit register delivers the actual digital value of the applied magnetic field after the signal processing. This register can only be read out, and it is the basis for the calibration procedure of the sensor in the customer application. Only 12 bits of the register contain valid data. The MDATA range is 1 to 4088, limited by clamping settings.

The area in the EEPROM accessible to the customer consists of registers with a size of 16 bits each.

For SENSITIVITY >0 the MDATA value will increase for negative magnetic fields (i.e. when a north pole is applied perpendicular to the branded side of the package).

Note During application design, it shall be taken into consideration that the MDATA value should not saturate in the full operational range of the specific application.

3.2.2. Output Scaling Register

The Output Scaling register contains the bits for magnetic sensitivity (SENSITIVITY) and magnetic offset (OFFSET).

SENSITIVITY

The SENSITIVITY bits define the parameter for the multiplier in the DSP and is programmable between [–2...2] in steps of 0.0156. SENSITIVITY = 1 (at Offset = 0) corresponds to full-scale (FS) of the output signal if the A/D converter value has reached the full-scale value. The SENSITIVITY register has a resolution of 8 bits.

OFFSET

The OFFSET bits define the parameter for the adder in the DSP.

The customer can decide if the offset is MSB or LSB aligned. The MSB or LSB alignment is enabled by an additional offset alignment bit (OFFSET_ALIGN). In case this bit is set to 1, the offset is programmable from –25%FS up to 25%FS.
If the OFFSET_ALIGN bit is set to zero, then the offset covers only 1/8 of the full-scale (–6.25%FS up to 6.25%FS) but with a finer step size. The customer can adjust the offset symmetrically around 50% of V_{SUP}. The OFFSET register can be set with 8-bit resolution.

3.2.3. Micronas ID Number Registers

Micronas ID Number registers contain 16 bits each. TDK-Micronas uses the registers to store production information like wafer position, wafer number and production lot number. These two registers can be read by the customer.

3.2.4. Customer Setup 1 Register

The Customer Setup 1 register contains the bits to select the sampling frequency, to enable/disable the High Error Band for error indication, to define the output signal clamping levels and to adjust the SENT signal parameters (tick time, frame rate, format selection, start-up behavior).

TICK_TIME:

The 2-bit TICK_TIME allows to select the tick time between four different values: 1.5 µs, 2 µs, 2.5 µs, and 3 µs.

FRAME_RATE

The 2-bit FRAME_RATE allows to select the SENT frame repetition rate between 250 Hz, 500 Hz, 1 kHz, and 2 kHz.

SENT_FORMAT

The bit SENT_FORMAT allows to select between H.2 and H.4 SENT format.

SENT_STARTUP

The bit SENT_STARTUP determines the output start-up behavior of HAL 1890 during $t_{startup}$.

DSDOUBLE

The bit DSDOUBLE allows to double the sampling frequency. The permitted values are 8 kSps and 16 kSps, corresponding to a bandwidth of 2.5 kHz and 5 kHz.

CLEVEL

The 2-bit CLEVEL together with CLAMP_SP select the clamping levels, i.e. the maximum and minimum SENT output codes. The following choices are available {CLAMP_SP:CLEVEL}:

Table 3–2: Clamping level definition

CLAMP_SP	CLEVEL	Clamping Level (%FS)		SENT Low Clamp	SENT Upper Clamp
		low	high	MDATA(11:0)	MDATA(11:0)
0	00	0 (clamping disabled)	100 (clamping disabled)	1	4088
0	01	5	95	205	3891
0	10	10	90	410	3686
0	11	15	85	614	3482
1	00	5	90	205	3686
1	01	10	95	410	3891
1	10	20	90	819	3686
1	11	10	80	410	3277

Clamping is normally not considered as an error. However, the user is able to activate the clamping error code by setting the CLAMP_ERC bit of the Customer Setup 1 register. In that case the output will be forced to an error state as soon as the output signal reaches the programmed clamping levels. The resulting clamping behavior therefore depends on the selection of the clamping levels, the setting of the CLAMP_ERC bit, and the setting of the EN_ERC_HI bit (Error Code Selection). All possible clamping variations are shown in Fig. 3–3.

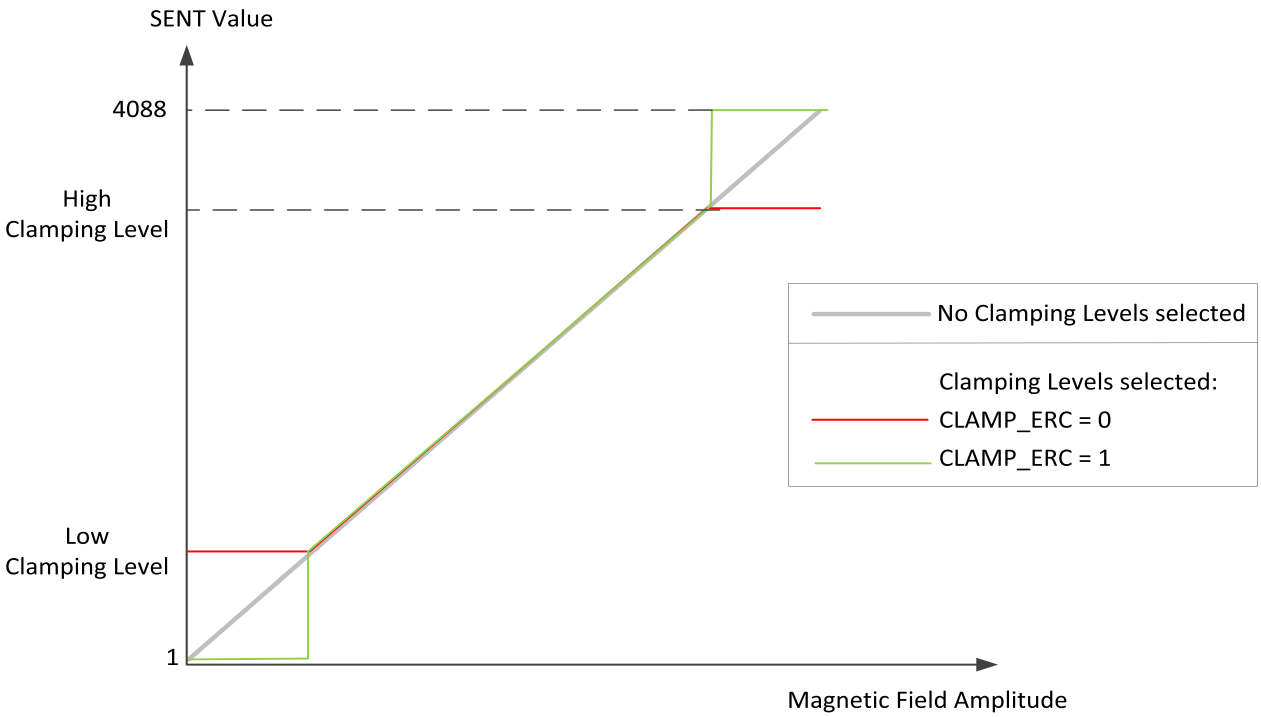


Fig. 3–3: HAL 1890 clamping behavior

3.2.5. Customer Setup 2 Register

Customer Setup 2 register contains the bits for magnetic range (MAG_RANGE), linear and quadratic temperature coefficients (TC and TCSQ), magnetic offset alignment (OFFSET_ALIGN), unbalanced clamping levels (CLAMP_SP) and the customer lock bit.

MAG_RANGE

The MAG_RANGE bits are used to set the magnetic measurement range. The following eight measurement ranges are available:

Table 3–3: MAG_RANGE bit definition

Magnetic-Field Range	Bit Setting
–20 mT...20 mT	0
–40 mT...40 mT	1
–60 mT...60 mT	2
–80 mT...80 mT	3
–100 mT...100 mT	4
–120 mT...120 mT	5
–140 mT...140 mT	6
–160 mT...160 mT	7

TC and TCSQ

The temperature dependence of the magnetic sensitivity can be adapted to different magnetic materials in order to compensate for the change of the magnetic sensitivity with temperature. The adaption is done by programming the TC (linear temperature coefficient) and the TCSQ registers (quadratic temperature coefficient). Thereby, the slope and the curvature of the temperature dependence of the magnetic sensitivity can be matched to the magnet and the sensor assembly. As a result, the output signal characteristic can be fixed over the full temperature range. The sensor can compensate for linear temperature coefficients ranging from about –3100 ppm/K up to 2550 ppm/K and quadratic coefficients from about –7 ppm/K^2 to 15 ppm/K^2 (typical range). Min. and max. values for the quadratic temperature coefficient depend on the linear temperature coefficient. Please refer to Section 5.4. on page 40 for the recommended settings for different linear temperature coefficients.

Magnetic Offset Alignment Bit (OFFSET_ALIGN)

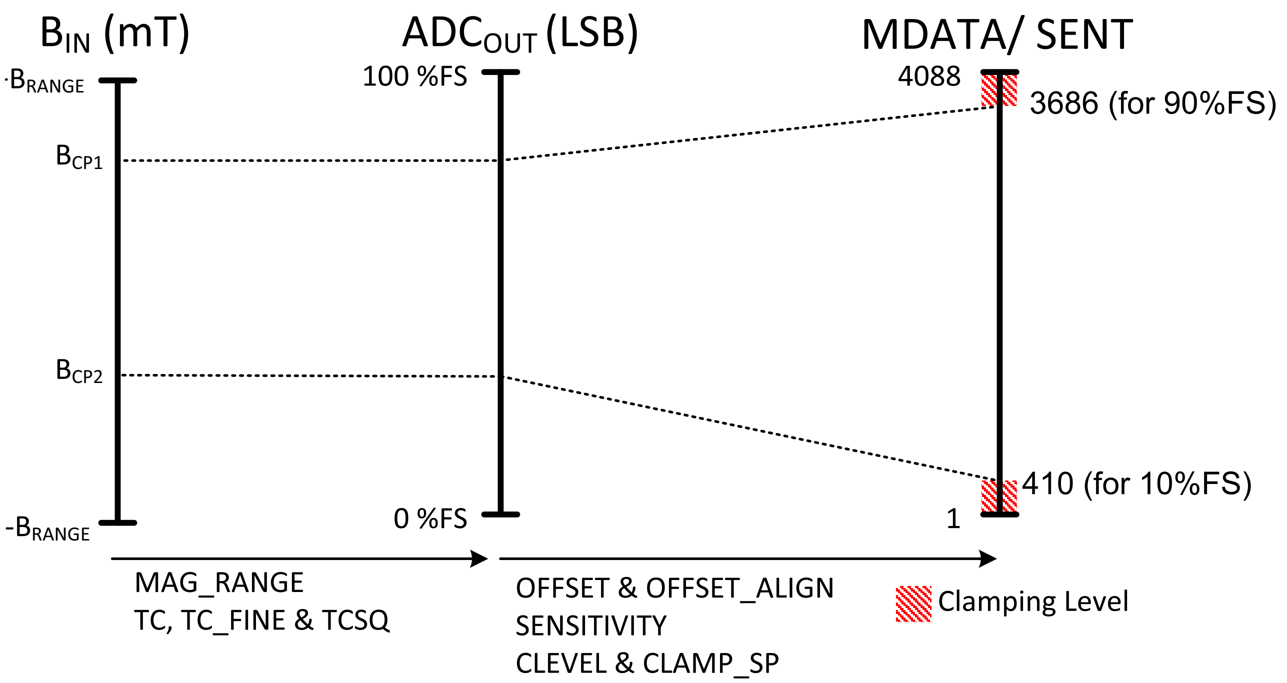
Please refer to Section 3.2.2. on page 10 (OFFSET).

LOCK

By setting this 1-bit register, all registers will be locked, and the EEPROM content can not be changed anymore. The LOCK bit is active after the first power-off and power-on sequence after setting the LOCK bit.

Warning **This register cannot be reset!**

3.2.6. Signal Path



B_{IN} : Magnetic Field Input
B_{RANGE} : Magnetic Range
$B_{CP1/2}$: Magnetic Field at Calibration Point 1/2
ADC_{OUT}: Output of Analog/Digital-Converter
%FS : Percentage of Full Scale

Fig. 3–4: Signal path of HAL 1890 (CLAMP_ERC=0, FRAME_RATE=0.5 kHz, MDATA=12 bits)

Fig. 3–4 shows the signal path and signal processing of HAL 1890. The measurement output value MDATA is calculated with the output value of the ADC by the following equation and corresponds to the SENT output value.

$$MDATA \approx SENSITIVITY \times (ADC_{OUT} + OFFSET)$$

The register values OFFSET and SENSITIVITY are two's complement encoded 8-bit values (see Section 3.2.5. on page 14).

3.3. On-Board Diagnostic Features

The HAL 1890 features following diagnostic functions:

– Thermal supervision of the output stage (overcurrent, short circuit, etc.)
The sensor switches the output to tristate if overtemperature is detected by the thermal supervision.

– Undervoltage detection with internal reset
The occurrence of an undervoltage is indicated immediately by switching the output to tristate.

– Magnetic signal amplitude out of range (overflow or underflow in ADC)

– Over-/underflow in adder or multiplier
These faults are visible at the output as long as present. The occurrence of these faults forces the output to the value of 1or 4088, depending on the source of the error, and the sign of the sensitivity (see Table 3–4).

Table 3–4: Error Code source and settings combinations for HAL 1890

Settings	Source					
Sign of Sensitivity	A/D-Converter		Adder		Multiplier	
	Underflow	Overflow	Underflow	Overflow	Underflow	Overflow
+	1	4088	1	4088	1	4088
–	4088	1	4088	1		

3.3.1. Output/Magnetic-Field Polarity

Applying a south-pole magnetic field perpendicular to the branded side of the package will increase the output value for SENSITIVITY <0 from the quiescent (offset) value. A north-pole magnetic field will decrease the output value.
The output will be inverted for a SENSITIVITY setting >0.

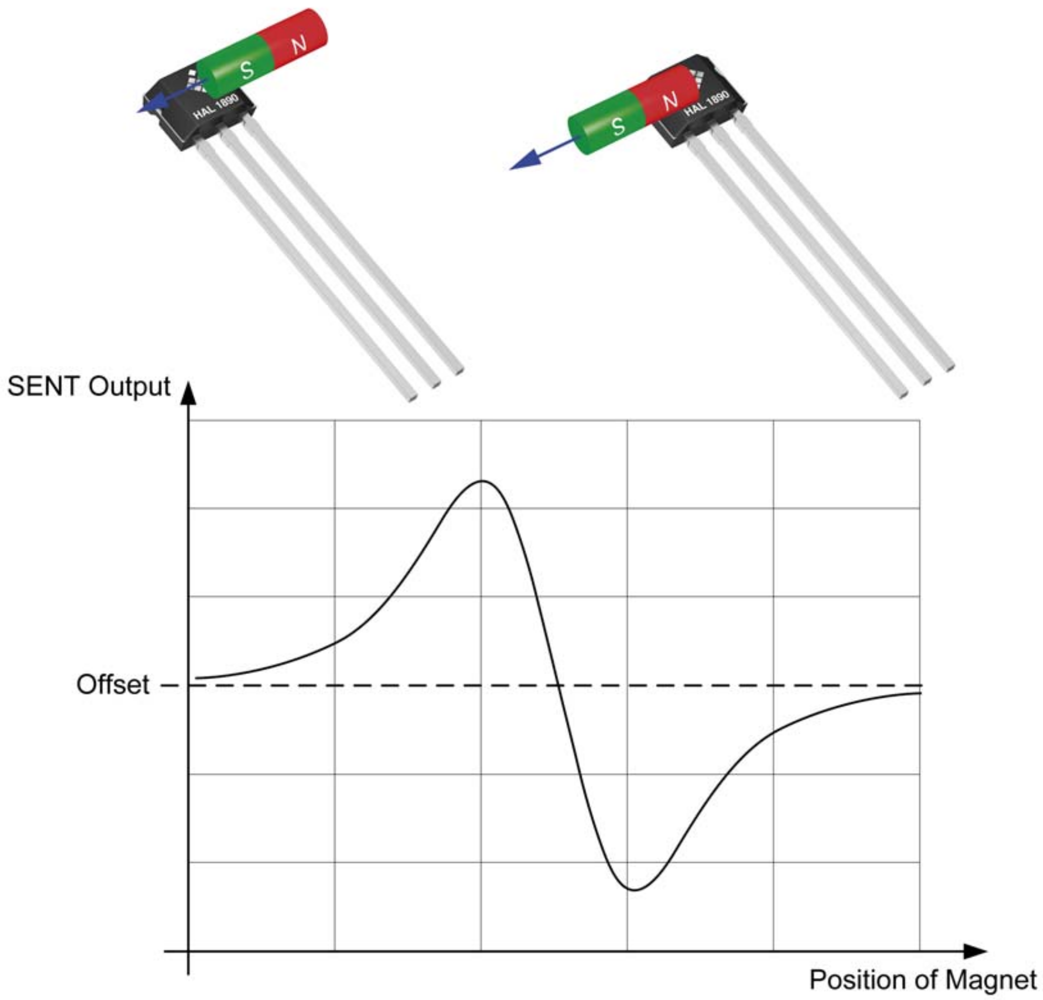


Fig. 3–5: SENT output depending on magnet polarity and position

3.4. Sensor Calibration

3.4.1. General Procedure for Development or Evaluation Purposes

For calibration of the sensor in the customer application, the development tool kit from TDK-Micronas is recommended. It contains the hardware for the generation of the serial telegram during programming and the corresponding software to program the various registers.

For the individual calibration of each sensor in the final customer application, a two-point adjustment is recommended. Please refer to “**HAL 1870/1880/1890 User Manual**” for further details on calibration procedure.

3.4.2. Locking the Sensor

For qualification and production purpose the device has to be locked in order to guarantee its functionality.

The last programming step activates the memory lock function by setting the LOCK bit. Please note that the memory lock function becomes effective after power-down and power-up of the Hall IC. The sensors EEPROM is then locked and its content can not be changed nor read anymore.

Warning **This register cannot be reset!**

3.5. SENT Output Protocol

The SENT output mode is a unidirectional communication protocol from the sensor to a receiver module, e.g. an electronic control unit (ECU). It occurs independently of any action of the receiver module. It does not require any synchronization signal from the receiver module and does not include a coordination signal from the controller/receiving devices.

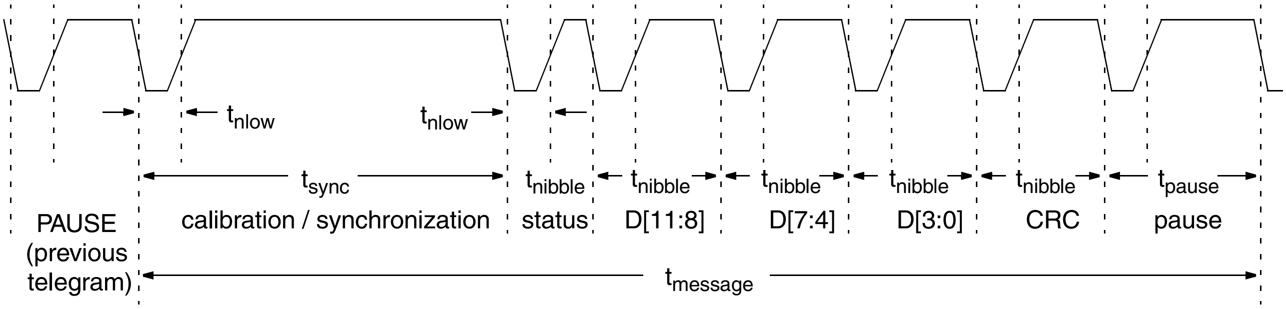


Fig. 3–6: SENT protocol format with 3 data nibbles and pause pulse with constant frame length

The SENT message supported by the HAL 1890 consists of a synchronization / calibration pulse, a status & communication nibble, three or six data nibbles, a CRC nibble, and a pause pulse. Fig. 3–6 shows an example of the general SENT protocol format for a 3 data nibble frame.

The SENT encodes data nibbles (4 bits) by one pulse per nibble. The pulse length is measured between two falling edges and reflects the nibble value. The minimum nibble pulse length is 12 clock ticks (representing the nibble value 0x0) and the maximum nibble pulse length is 27 clock ticks (12 +15 ticks, representing 0xF).

The SENT messages are synchronous with the delivery of new Hall samples. Maximum one SENT message is transmitted per Hall sample. Thus, the propagation delay is very low and the message time is nearly constant.

HAL 1890 is compliant with the SAEJ2716 rev.4 standard.

The sensor transmits SENT frames with 3 data nibbles containing the 12-bit Hall value (Format H.2), or with 6 data nibbles containing the 12-bit Hall value and secure information (Format H.4).

They are formatted according to Table 3–5 and Table 3–6.

The mode without pause pulse is not featured.

Table 3–5: Nibble description for H.2 format: 3 data nibble frame format with one fast channel

#	Pulse	Parameter	Number of Clock Ticks		Description
			min.	max.	
1	Synchronization/ Calibration	t_{sync}	56		It is mandatory to measure the synchronization / calibration period for calibration of the clock tick time t_{tick} at the ECU.
2	4-bit Status & Communication Nibble	t_{nibble}	12[1)]	27[1)]	Bit 0: status bit Bit 1: Not used Bit 2, 3: Enhanced Slow Channel information
3	4-bit Data Nibble MSN 1				Hall value [11:8]
4	4-bit Data Nibble MidN 1				Hall value [7:4]
5	4-bit Data Nibble LSN 1				Hall value [3:0]
6	4-bit CRC Nibble				Enhanced CRC according to SAEJ2716
7	Pause Pulse	t_{pause}			Duration depends on mode, sampling frequency, tick time and message duration

1) (12+N) t_{tick} represents number “N” (12 = “x0” ... 27 =”0xF”)

Table 3–6: Nibble description for H4 format: 6 data nibble frame format with secure information

#	Pulse	Parameter	Number of Clock Ticks		Description
			min.	max.	
1	Synchronization/ Calibration	t_{sync}	56		It is mandatory to measure the synchronization / calibration period for calibration of the clock tick time t_{tick} at the ECU.

#	Pulse	Parameter	Number of Clock Ticks		Description
			min.	max.	
2	4-bit Status & Communication Nibble	t_{nibble}	12[1)]	27[1)]	Bit 0: Status bit Bit 1: Not used Bit 2, 3: Enhanced serial message data
3	4-bit Data Nibble MSN 1				Hall value [11:8]
4	4-bit Data Nibble MidN 1				Hall value [7:4]
5	4-bit Data Nibble LSN 1				Hall value [3:0]
6	4-bit Data Nibble MSN 2				Rolling counter MSN
7	4-bit Data Nibble MidN 2				Rolling counter LSN
8	4-bit Data Nibble LSN 2				Inverted copy of nibble MSN 1
9	4-bit CRC Nibble				Enhanced CRC according to SAEJ2716
10	Pause Pulse	t_{pause}			Duration depends on mode, sampling frequency, tick time and message duration

1) (12+N) t_{tick} represents number “N” (12 = “x0” ... 27 =”0xF”)

3.5.1. Error Diagnostic Reporting on Fast Channel

The Status bit 0 is set to one in case of “sensor error indication” or “sensor functionality and processing error indication”.

In addition, the diagnostic can be reported through the 12-bit payload of slow channel. The regular angular or linear position information is coded in the signal range from 2 to 4087 in the 12-bit range. Values out of this range represent abnormal conditions. Table 3–7 shows the values that will be sent in case of an internal error or during the SENT interface initialization.

Table 3–7: Error codes transmitted on the fast channel 1

Error Code	Definition	Status bit value
4088	Data Clamping: High (too small magnetic range or wrong settings producing overflows in signal path): ADC Overflow Signal path overflow (Adder, Multiplier)	 0 1
1	Data clamping: Low (too high magnetic range or wrong settings producing underflows in signal path): ADC Underflow Signal path underflow (Adder, Multiplier)	 0 1
0	Initialization	0

3.5.2. Pause Pulse

The pause pulse is present at the end of each frame. The length of the pause pulse is automatically adjusted by the chip internal SENT block in order to achieve a constant frame length independent from the message content.

The length depends on the frame content, the SENT frame rate, as well as on the tick time.

3.5.3. CRC Implementation

HAL 1890 supports the recommended CRC implementation defined in SAEJ2716 rev. 4.

3.5.4. Slow Channel

HAL 1890 transmits the slow message according to the Enhanced Serial Message format as specified in the SENT standard SAEJ2716.

The configuration bit is always 0, representing 12-bit data and 8-bit message ID.

3.5.4.1. Serial Message Sequence

The device is always transmitting the serial message sequence shown in Table 3–8.

Table 3–8: Serial Message Sequence

#	8-bit ID	Item	12-bit Data	Comment
1	0x01	Error Codes	0x800 - 0xFFF	
2	0x03	Sensor Type	H.2: 0x051 H.4: 0x055	Linear position
3	0x29	Micronas SN1	8-bit MSB MIC_ID1	MSB Micronas Serial Number register 1.
4	0x2A	Micronas SN2	8-bit LSB MIC_ID1	LSB Micronas Serial Number register 1.
5	0x01	Error Codes	0x800 - 0xFFF	
6	0x2B	Micronas SN3	8-bit MSB MIC_ID2	MSB Micronas Serial Number register 2.
7	0x2C	Micronas SN4	8-bit LSB MIC_ID2	LSB Micronas Serial Number register 2.
8	0x05	Micronas Manufacturer code	0x007	Micronas manufacturer code
9	0x01	Error Codes	0x800 - 0xFFF	
10	0x06	Protocol Standard Revision	0x004	SAEJ2716 revision 4
11	0x80	Range and Sensitivity		Magnetic range and sensitivity
12	0x81	Offset		Magnetic offset alignment and offset data
13	0x01	Error Codes	0x800 - 0xFFF	
14	0x82	Temperature Coefficient		
15	0x83	Speed		sampling frequency, SENT message frequency, oscillator’s trimming frequency and slew rate (open drain strength) informations

3.5.4.2. Serial Message Error Codes

Diagnostic status codes are transmitted via the serial message. The 8-bit message ID for the diagnostic status code is 0x01. HAL 1890 features the error codes described in Table 3–9.

Table 3–9: Serial Message Error Codes

Bit position	**Error Type**
0	Clamp High
1	Clamp Low
2	Multiplier Overflow
3	Multiplier Underflow
4	Adder Overflow
5	Adder Underflow
6	ADC Overflow
7	ADC Underflow
8	V_{SUP} Overvoltage[1)]

[1)] Status bit = 1 in fast channel

3.5.5. Start-Up Behavior

The start-up behavior of the HAL 1890 is programmable. The customer is able to choose whether the SENT protocol shall start during the power-on delay with sending 0 messages or only when valid data is available. The two scenarios are shown in Fig. 3–7.

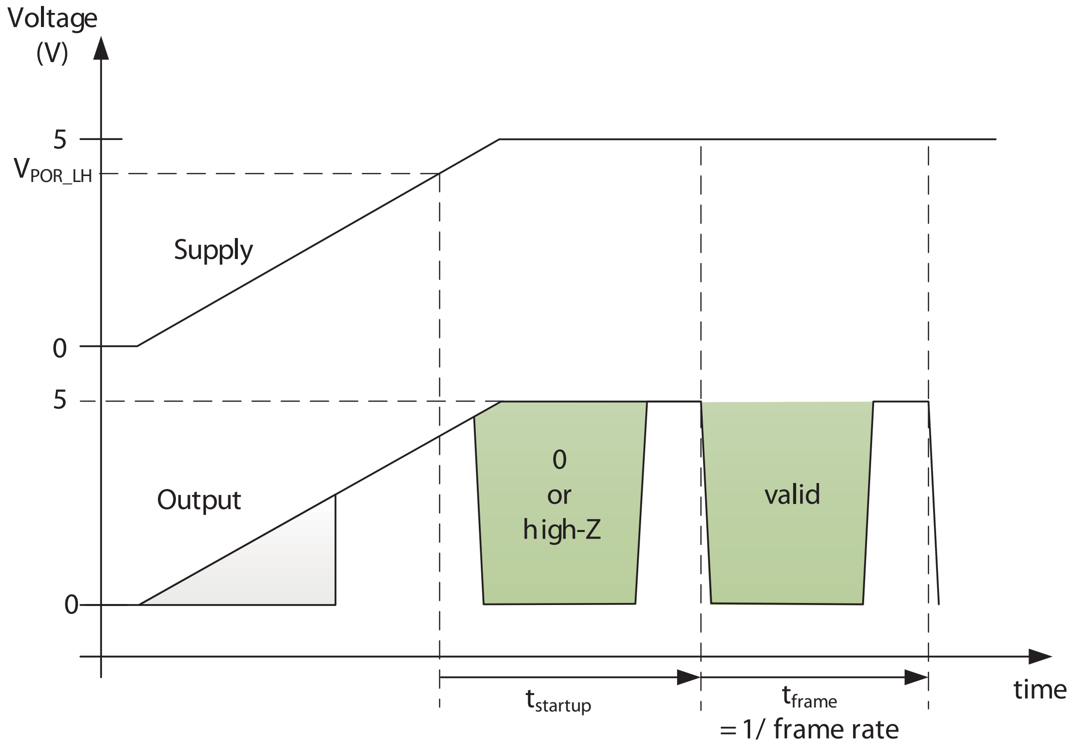


Fig. 3–7: HAL 1890 Start-up behavior

3.5.6. Message Timing

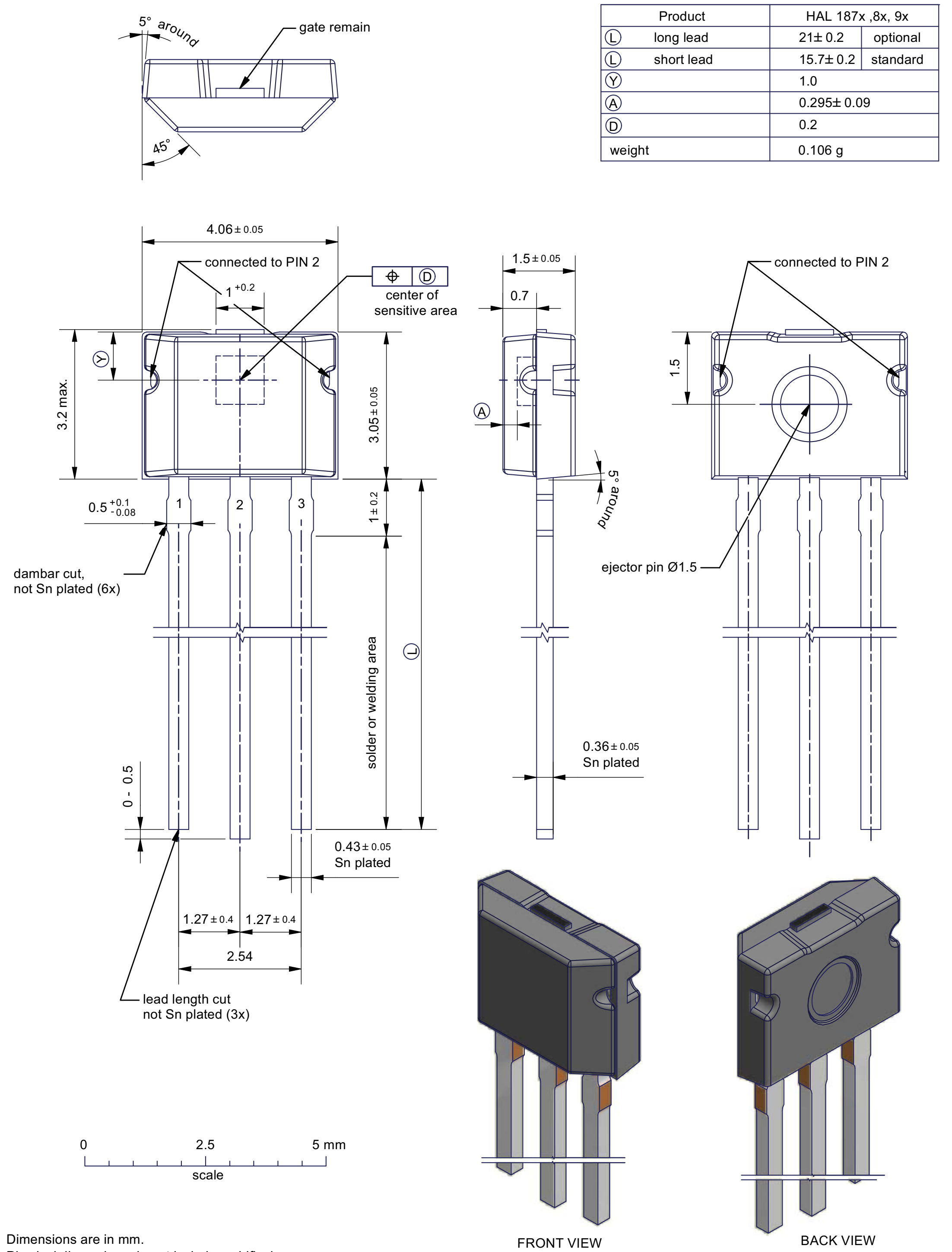
The message time of a SENT frame is selectable. The repetition rate for SENT frames is customer programmable and can be selected between 0.25 kHz, 0.5 kHz, 1 kHz, and 2 kHz.

The tick time is customer programmable and can be selected between 1.5 µs and 3 µs in steps of 0.5 µs (see TICK_TIME in Customer Setup 1 of Table 3–1 on page 9).

4. Specifications

4.1. Outline Dimensions

Product		HAL 187x ,8x, 9x	
Ⓛ	long lead	21± 0.2	optional
Ⓛ	short lead	15.7± 0.2	standard
Ⓨ		1.0	
Ⓐ		0.295± 0.09	
Ⓓ		0.2	
weight		0.106 g	

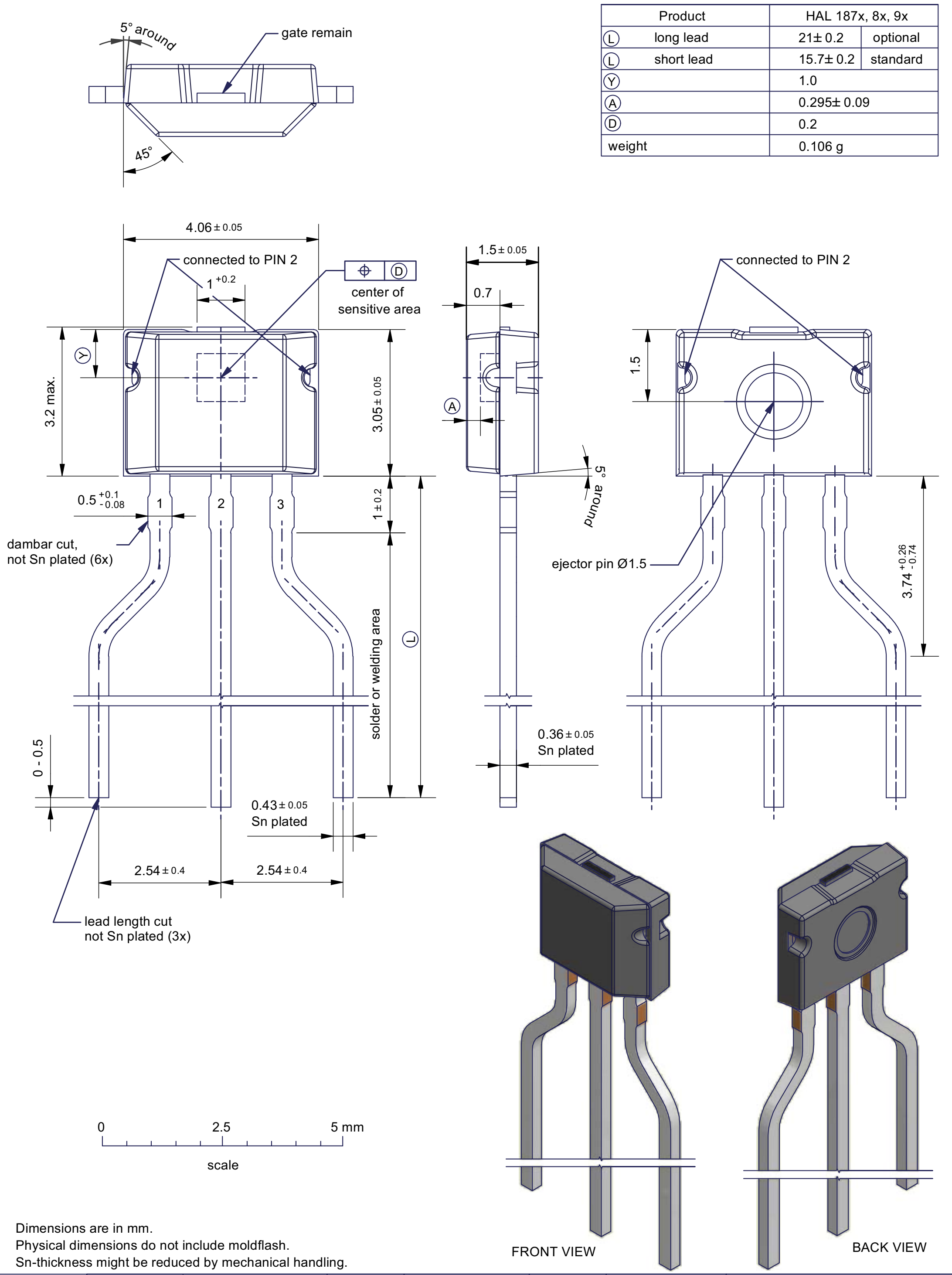


Dimensions are in mm.
Physical dimensions do not include moldflash.
Sn-thickness might be reduced by mechanical handling.

PACKAGE	ISSUE DATE (YY-MM-DD)	JEDEC STANDARD		ANSI	REVISION DATE (YY-MM-DD)	REV.NO.	DRAWING-NO.	SPECIFICATION	
		ITEM NO.	ISSUE					TYPE	NO.
TO92UA-2	18-09-24				20-04-07	2	CUAI00031033.1	ZG	2101_Ver.02

Fig. 4–1:
TO92UA-2 Plastic Transistor Standard UA package, 3 leads, non-spread

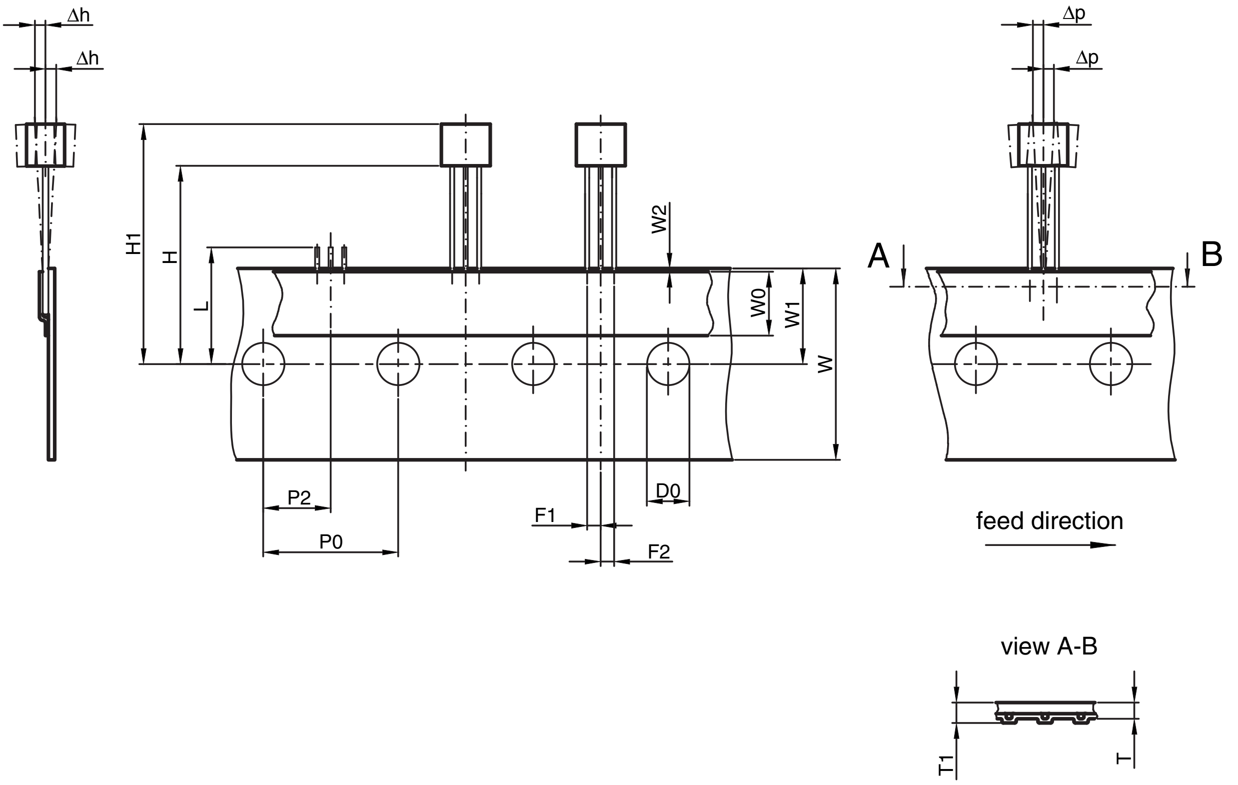
Product	HAL 187x, 8x, 9x	
Ⓛ long lead	21± 0.2	optional
Ⓛ short lead	15.7± 0.2	standard
Ⓨ	1.0	
Ⓐ	0.295± 0.09	
Ⓓ	0.2	
weight	0.106 g	



Dimensions are in mm.
Physical dimensions do not include moldflash.
Sn-thickness might be reduced by mechanical handling.

PACKAGE	ISSUE DATE (YY-MM-DD)	JEDEC STANDARD ITEM NO.	JEDEC STANDARD ISSUE	ANSI	REVISION DATE (YY-MM-DD)	REV.NO.	DRAWING-NO.	SPECIFICATION TYPE	SPECIFICATION NO.
TO92UA-1	18-09-24				20-04-07	2	CUAS00031034.1	ZG	2102_Ver.02

Fig. 4–2:
TO92UA-1 Plastic Transistor Standard UA package, 3 leads, spread



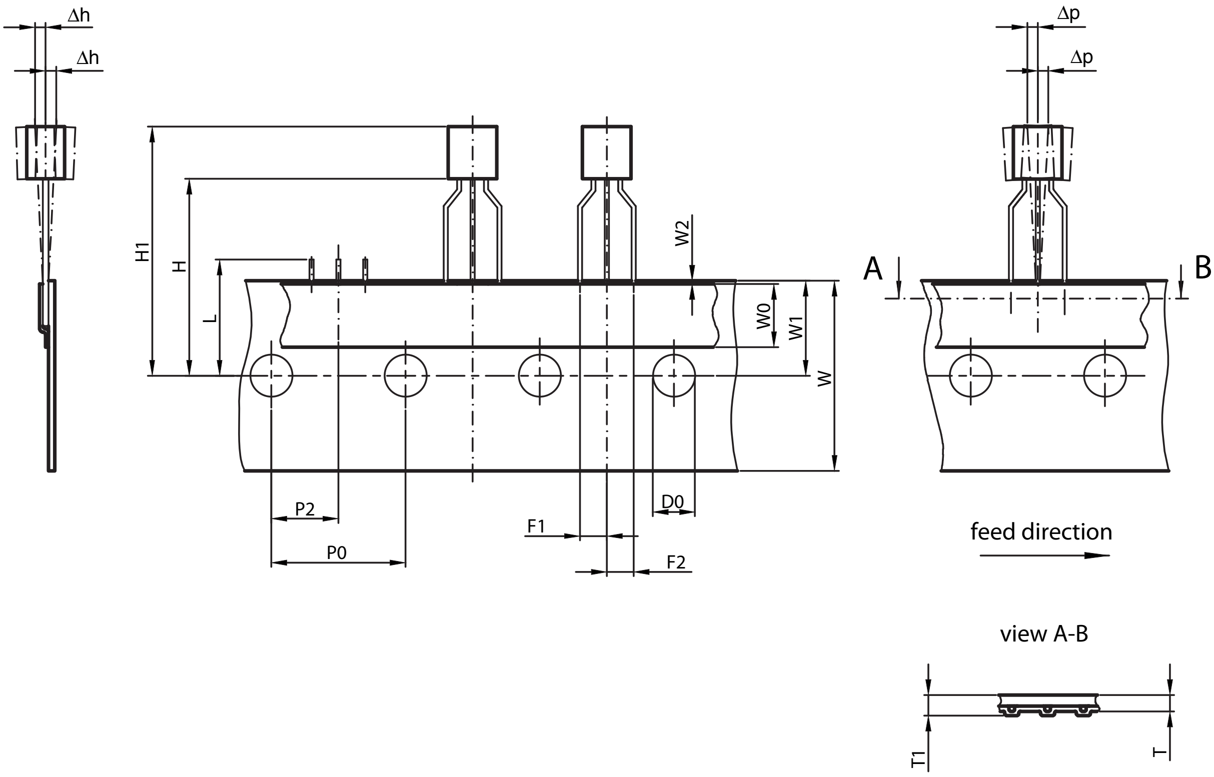
all dimensions in mm
other dimensions see drawing of bulk
max. allowed tolerance over 20 hole spacings ±1.0

	H	H1	
		TO92UA	TO92UT
Short leads	18 - 20	21 - 23.1	22 - 24.1
Long leads	24 - 26	27 - 29.1	28 - 30.1

UNIT	D0	F1	F2	Δh	L	P0	P2	Δp	T	T1	W	W0	W1	W2
mm	4.0	1.47 1.07	1.47 1.07	±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

STANDARD		ANSI	ISSUE DATE YY-MM-DD	DRAWING-NO.	ZG-NO.
ISSUE	ITEM NO.				
-	IEC 60286-2		16-07-18	06631.0001.4	ZG001031_Ver.05

Fig. 4–3:
TO92UA: 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

	H	H1	
		TO92UA	TO92UT
Short leads	18 - 20	21 - 23.1	22 - 24.1
Long leads	24 - 26	27 - 29.1	28 - 30.1

UNIT	D0	F1	F2	Δh	L	P0	P2	Δp	T	T1	W	W0	W1	W2
mm	4.0	2.74 2.34	2.74 2.34	±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		16-07-18	06632.0001.4	ZG001032_Ver.06

Fig. 4–4:
TO92UA: 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 TDK-Micronas website (https://www.micronas.com/en/service-center/downloads) or on the service portal (https://service.micronas.com).

4.3. Pin Connections and Short Descriptions

Pin No.	Pin Name	Short Description
1	VSUP	Supply Voltage
2	GND	Ground
3	OUT	Open-Drain Output

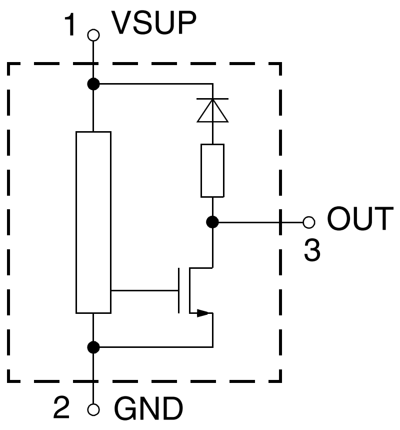


Fig. 4–5: Pin configuration

4.4. Dimensions of Sensitive Area

Hall plate area = 0.2 mm × 0.1 mm

See Fig. 4–1 on page 26 for more information on the Hall plate position.

4.5. 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 must be taken to avoid application of any voltage higher than absolute maximum-rated voltages to this circuit.

All voltages listed are referenced to ground (GND).

Symbol	Parameter	Pin No.	Min.	Max.	Unit	Notes
V_{SUP}	Supply Voltage	1	–8.5 –14.4 –15	8.5 14.4 16	V	t < 96 h[1)] t < 10 min[1)2)] t < 1 min[1)2)]
V_{OUT}	Output Voltage	3	–0.5 –0.5 –0.5	8.5 14.4 16	V	t < 96 h[1)] t < 10 min[1)] t < 1 min[1)]
$V_{OUT}-V_{SUP}$	Excess of Output Voltage over Supply Voltage	1, 3	–	0.5	V	
I_{OUT}	Continuous Output Current	3	–10	10	mA	
t_{sh}	Output Short Circuit Duration	3	–	10	min	
T_J	Junction Temperature under Bias		–40	190	°C	[3)]
$T_{STORAGE}$	Transportation/Short-Term Storage Temperature		–55	150	°C	Device only without packing material
V_{ESD}	ESD Protection at VSUP[4)]	1	–4.0	4.0	kV	
	ESD Protection at OUT[4)]	3	–8.0	8.0	kV	

[1)] No cumulated stress
[2)] As long as T_{Jmax} is not exceeded
[3)] For 96 h - Please contact TDK-Micronas for other temperature requirements
[4)] AEC-Q100-002 (100 pF and 1.5 kΩ)

4.6. 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 provides recommendations linked to moisture sensitivity level and long-term storage.
It is available on the TDK-Micronas website (https://www.micronas.com/en/service-center/downloads) or on the service portal (https://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 of the device and may reduce reliability and lifetime.

All voltages listed are referenced to ground (GND).

Symbol	Parameter	Pin No.	Min.	Typ.	Max.	Unit	Notes
V_{SUP}	Supply Voltage	1	4.5 5.7	5 6	5.5 8.0	V	Normal operation During programming
I_{OUT}	Continuous Output Current	3	0	–	5	mA	
R_L	Load Resistor	3	1.0	1	–	kΩ	
C_L	Load Capacitance	3	0.33	–	47	nF	
N_{PRG}	Number of EEPROM Programming Cycles	–	–	–	100	–	0 °C < T_{amb} < 55 °C
T_J	Junction Operating Temperature[1)]	–	–40 –40 –40	– – –	125 150 170	°C	for 8000 h[2)] for 2000 h[2)] for 1000 h[2)]

[1)] Depends on the temperature profile of the application. Please contact TDK-Micronas for life time calculations.
[2)] Time values are not cumulative.

4.8. Characteristics

at T_J = –40 °C to 170 °C, V_{SUP} = 4.5 V to 5.5 V, GND = 0 V, after programming the sensor and locking the EEPROM, at Recommended Operation Conditions if not otherwise specified in the column “Notes”. Typical characteristics for T_J = 25 °C and V_{SUP} = 5 V.

Symbol	Parameter	Pin No.	Min.	Typ.	Max.	Unit	Conditions
I_{SUP}	Supply Current over Temperature Range	1	5	6.75	8.5	mA	
$t_{startup}$	Power-Up Time time until a valid SENT frame is available	3	30	65	300	µs	Time where MDATA is available and first SENT frame starts with reliable value
SENT Output Pin							
$t_{startup}$	Start-Up Time	3	0.5	–	4.6	ms	Depends on selected sampling frequency and SENT frame rate, (for definition see Fig. 3–6 on page 22)
t_{delay_sm}	New Hall Sample to Message Start Delay	3	–	1	–	µs	2 system clocks, ±10%
$\Delta T_{OSC}/T_{OSC}$	Clock Accuracy	3	–10	0	10	%	
t_{tick}	Clock Tick Time	3	0.5	–	3.0	µs	Selectable (see Section 3.2.4. on page 11)
t_{nlow}	Sensor Pulse Low Time	3	–	5	–	t_{tick}	
Signal							
–	Resolution	3	–	12	–	Bit	
f_s	Sampling Frequency	– –	– –	8 16	– –	kSps kSps	DSDOUBLE = 0 DSDOUBLE = 1
INL	Non-Linearity of Output Voltage over Temperature[2]	3	–1.0	0	1.0	%	of Supply Voltage (Linear regression) T_J = 25 °C
BW	Small Signal Bandwidth (–3 dB)[2]	3	2.25 4.5	2.5 5	– –	kHz kHz	B_{AC} <10 mT, f_s = 8 kHz f_s = 16 kHz

1) Guaranteed by design
2) Characterized on small sample size, not tested

Symbol	Parameter	Pin No.	Min.	Typ.	Max.	Unit	Conditions	
$CLAMP_L$	Clamp Low[1]					%FS	CLAMP_SP	CLEVEL
		3	–	0	–		0	00
			–	5	–		0	01
			–	10	–		0	10
			–	15	–		0	10
			–	5	–		1	00
			–	10	–		1	01
			–	20	–		1	10
			–	10	–		1	11
$CLAMP_H$	Clamp High[1]					%FS	CLAMP_SP	CLEVEL
		3	–	100	–		0	00
			–	95	–		0	01
			–	90	–		0	10
			–	85	–		0	10
			–	90	–		1	00
			–	95	–		1	01
			–	90	–		1	10
			–	80	–		1	11
TO92UA Package								
	Thermal Resistance						Determined with a 1s0p board	
R_{thja}	Junction to Air	–	–	–	250	K/W		
R_{thjc}	Junction to Case	–	–	–	70	K/W		

1) Guaranteed by design
2) Characterized on small sample size, not tested

4.9. Power-On Reset / Undervoltage Detection

at T_J = –40 °C to 170 °C, GND=0 V, typical characteristics for T_J = 25 °C, after programming and locking.

Symbol	Parameter	Pin	Min.	Typ.	Max.	Unit	Test Conditions
V_{POR_LH}	Undervoltage Detection Level (Power-On Reset, Rising Supply)[1)]	1	4.15	4.3	4.45	V	
V_{POR_HL}	Undervoltage Detection Level (Power-On Reset, Falling Supply)[1)]	1	3.9	4.05	4.25	V	
V_{POR_HYS}	Undervoltage/POR Detection Level Hysteresis[1)]	1	150	225	300	mV	

[1)] Characterized on small sample size, not tested

4.10. Magnetic Characteristics

at Recommended Operating Conditions if not otherwise specified in the column 'Notes', T_J = –40 °C to 170 °C, V_{SUP} = 4.5 V to 5.5 V, after programming the sensor and locking the EEPROM. Typical Characteristics for T_A = 25 °C and V_{SUP} = 5 V.

Symbol	Parameter	Pin No.	Values			Unit	Notes
			Min.	Typ.	Max.		
$RANGE_{ABS}$	Absolute Magnetic Range of A/D Converter over temperature	–	80	100	120	%	% of nominal RANGE Nominal RANGE programmable from 20 mT up to 160 mT
RANGE	Magnetic-field range	–	±20	±80	±160	mT	TO92UA-1/-2
SENS	Sensitivity	3	±0.2		±2.2	%FS /mT	Depending on magnetic-field range [1] and SENSIVITY register content
$\Delta Sens_{trim}$	Trim Step for Absolute Sensitivity	3	0.006		0.02	%FS /mT	At min. sensitivity At max. sensitivity
$\Delta Offset_{trim}$	Offset Trim	3	±0.05 ±0.2		±6.25 ±25	%FS	OALN = 0 OALN = 1
ES	Sensitivity Error over Temperature Range[1]	3	–6	0	6	%	Part to part variation for certain combinations of TC and TCSQ (see Section 4.10.1.)
B_{OFFSET}	Magnetic Offset	3	–2	0	2	mT	B = 0 mT, T_A = 25 °C
ΔB_{OFFSET}	Magnetic Offset Drift over temperature range[1] $B_{OFFSET}(T) – B_{OFFSET}$ (25 °C)	3	–600	0	600	µT	B = 0 mT, RANGE = ±40 mT, Sens = 100 mV/mT
$B_{Hysteresis}$	Magnetic Hysteresis[1]	3	–20	0	20	µT	Range = ±40 mT

[1] Characterized on small sample size, not tested

4.10.1. 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 value[2)] minus 1:

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

In the example shown in Fig. 4–6 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

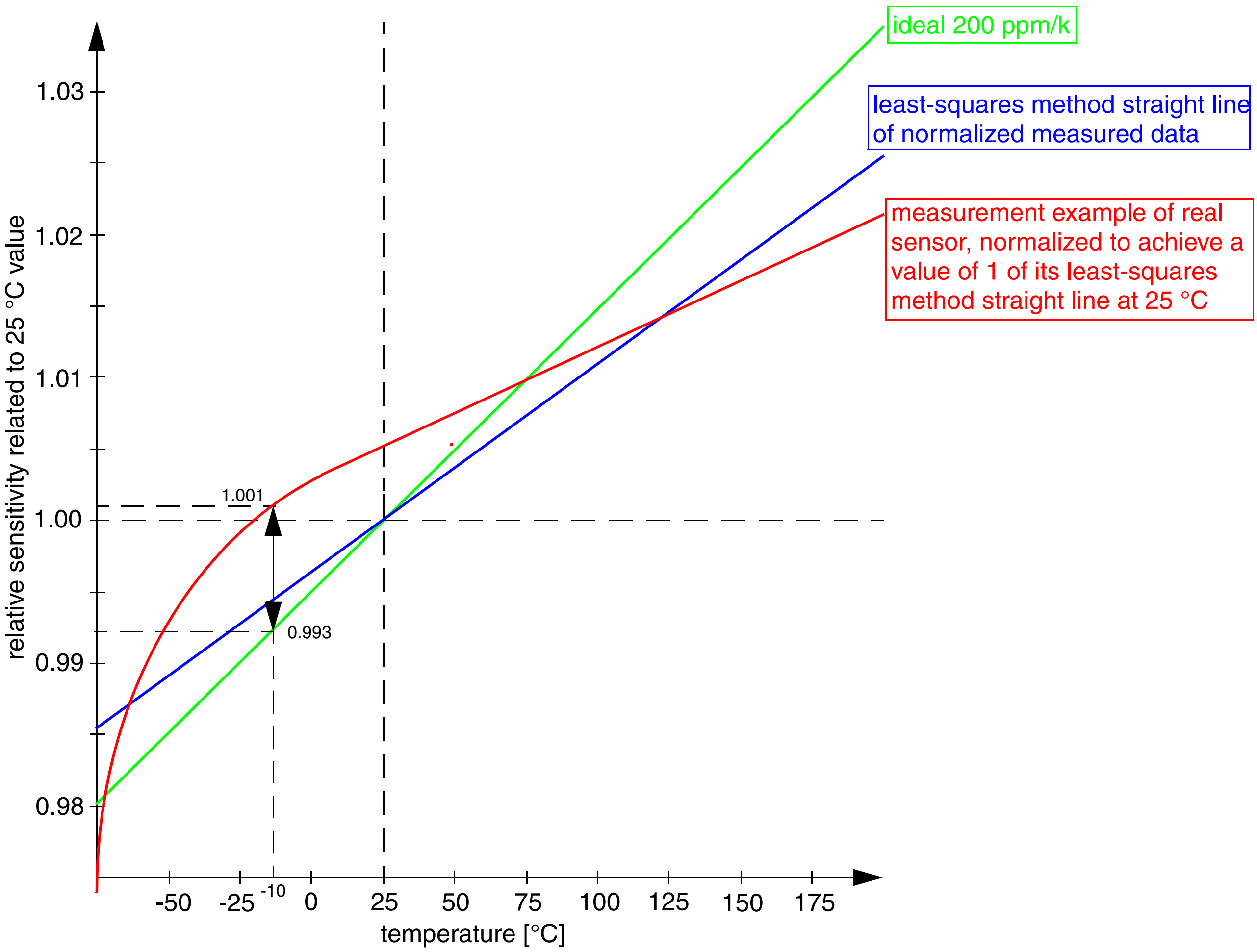


Fig. 4–6: Definition of Sensitivity Error ES

5. Application Notes

5.1. 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:

$\Delta T = I_{SUP} * V_{SUP} * R_{thjX}$

The X represents junction to air or to case.

In order to estimate the temperature difference ΔT between the junction and the respective reference (e.g. air, case, or solder point) use the max. parameters for I_{SUP}, R_{thX}, and the max. value for V_{SUP} from the application.

The following example shows the result for junction to air conditions. $V_{SUP} = 5.5$ V, $R_{thja} = 250$ K/W and $I_{SUP} = 10$ mA the temperature difference $\Delta T = 13.75$ K.

The junction temperature T_J is specified. The maximum ambient temperature T_{Amax} can be estimated as:

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

Note The calculated self-heating of the devices is only valid for the Rth test boards. Depending on the application setup the final results in an application environment might deviate from these values.

5.2. EMC

HAL 1890 is designed for a stabilized 5 V supply. Interferences and disturbances conducted along the 12 V onboard system (product standard ISO 7637 part 1) are not relevant for these applications.

For applications with disturbances by capacitive or inductive coupling on the supply line or radiated disturbances, the application circuit shown in Fig. 5–1 on page 39 is recommended. Applications with this arrangement should pass the EMC tests according to the product standards ISO 7637 part 3 (electrical transient transmission by capacitive or inductive coupling).

5.3. Application Circuit

It is recommended to connect a 100 nF ceramic capacitor between ground and the supply voltage and a filter structure at the output pin for EMC protection as well for having a SENT standard compliant output slew rate.

The following two setups have been tested:

– C01 = 180 pF, C02 = 2.2 nF, R01 = 120 Ω

– C01 = 180 pF, C02 = 3.3 nF, R01 = 180 Ω

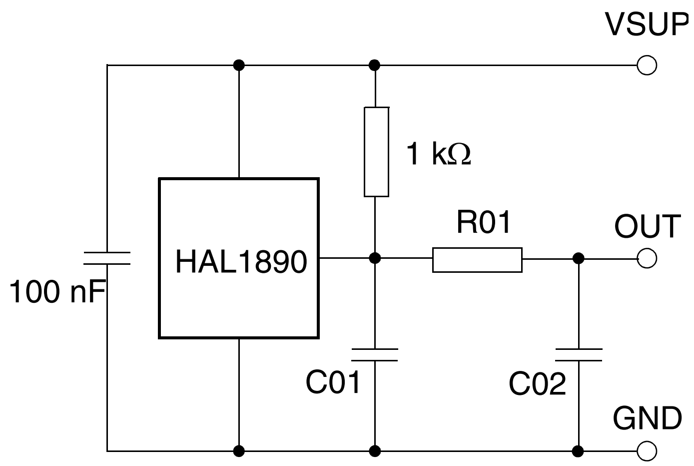


Fig. 5–1: Recommended application circuit

5.4. Temperature Compensation

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

Temperature Coefficient of Magnet System (ppm/K)	TC	TCSQ
2100	5	–9
1800	7	–8
1500	10	–8
1200	13	–6
900	16	–5
500	20	–5
150	23	–4
0	25	–4
–300	28	–3
–500	29	–3
–750	32	–2
–1000	34	–2
–1500	39	–2
–2100	45	0
–2700	51	1

Note For development or evaluation purposes TDK-Micronas recommends to use the HAL 1870/1880/1890 Programming Environment to find optimal settings for temperature coefficients. Please contact TDK-Micronas for more detailed information.

6. Programming of the Sensor

HAL 1890 features two different operating modes. In **Application Mode** the sensor provides a SENT signal/output. 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.** As long as the sensor is not locked it can be switched to the **Programming Mode** by voltage pulse on the sensor OUT pin.

6.1. Programming Interface

In **Programming Mode** the sensor is addressed by modulating a serial telegram on the sensor's output pin or on the sensor's supply voltage. The sensor answers with a modulation of the output voltage.

A logical "0" 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 Fig. 6–1).

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

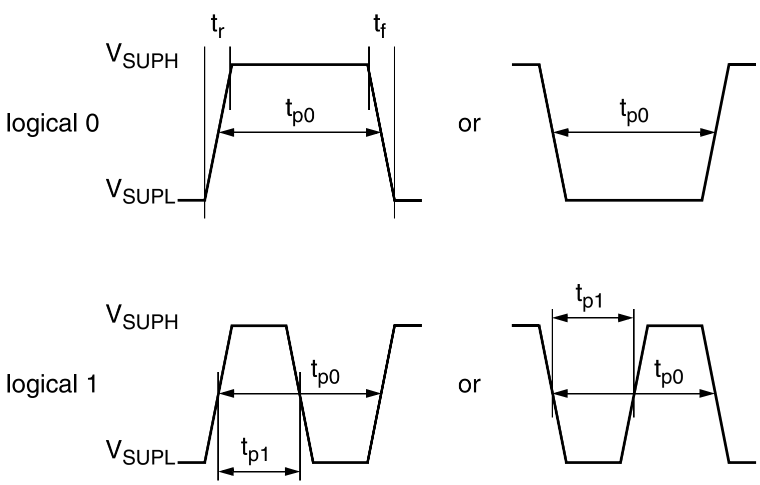


Fig. 6–1: Definition of logical 0 and 1 bit

A description of the communication protocol and the programming of the sensor is available in a separate document (Application Note "HAL 1870/1880/1890 Programming Guide").

Table 6–1: Telegram parameters for host (All voltages are referenced to GND.)

Symbol	Parameter	Pin No.	Limit Values			Unit
			Min.	Typ.	Max.	
V_{SUPL}	Supply Voltage for Low level during programming through sensor VSUP pin	1	5	–	6	V
V_{SUPH}	Supply Voltage for High level during programming through sensor VSUP pin	1	8	–	9	V
$V_{SUPProgram}$	Supply Voltage for EEPROM programming	1	5.7	6	6.5	V
t_{p0}	Bit time if command send to the sensor	1, 3	–	1024	–	µs
t_{p1}	BiPhase half bit time	1, 3	–	0.5	–	t_{p0}
t_{pOUT}	Bit time for sensor answer	3	–	1024	–	µs

6.2. Programming Environment and Tools

For the programming of HAL 1890 during product development a programming tool including hardware and software is available on request. It is recommended to use the TDK MSP V1.x Magnetic Sensor Programmer or TDK-Micronas' tool kit (HAL USB-Kit and LabView^{TM} programming environment) in order to ease the product development. The details of programming sequences can be found in the "HAL 1870/1880/1890 User Manual" and in the "HAL 1870/1880/1890 Programming Guide".

6.3. Programming Information

For production and qualification tests, it is mandatory to set the LOCK bit after final adjustment and programming of HAL 1890. The lock function is active after the next power-up of the sensor.

The success of the lock process shall be checked by reading the status of the LOCK bit after locking and by a negative communication test after power-on reset.

HAL 1890 features a diagnostic register to check the success and quality of the programming process. Detailed information about programming the sensor can be found in the "HAL 1870/1880/1890 User Manual" and in the "HAL 1870/1880/1890 Programming Guide".

EMI (Electromagnetic Interference) may disturb the programming pulses. Please take precautions against EMI.

7. Document History

1. Data Sheet: "HAL 1890 Programmable Linear Hall-Effect Sensor with SENT Interface", April 15, 2021, DSH000202_001EN. First release of the data sheet.

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