MICRONAS

Data Sheet

HAL / HAR 3927

Robust Programmable 2D Position Sensor with Analog and SENT Output Interface

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HAL/HAR 3927

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Release Note: Revision bars indicate significant changes to the previous document

Robust Programmable 2D Position Sensor with Analog and SENT Output Interface

1. Introduction

HAL/HAR 3927 are members of TDK-Micronas 2D position sensors based on TDK-Micronas' 3D HAL technology addressing the need for ISO 26262 compliant development. The device is a high-resolution position sensor for highly accurate position measurements. HAR 3927 provides full redundancy due to two independent dies stacked in a single package, each electrically connected to the pins of one package side. HAR 3927 is the dual-die version of HAL 3927.

The stacked-die architecture ensures that both dies occupy the same magnetic-field position, thus generating synchronous measurement outputs.

HAL/HAR 3927 feature a linear, ratiometric analog output signal with integrated wire-break detection working with pull-up or pull-down resistors as well as an SAE J2716 compliant SENT output according to rev. 4.

The HAL/HAR 3927 are based on the Hall technology and is able to measure horizontal and vertical magnetic-field components B_X, B_Y and B_Z.

Based on the signals of two magnetic-field components out of B_X, B_Y or B_Z, the device can measure 360° angular range and linear movements.

On-chip signal processing calculates one angle out of two orthogonal magnetic-field components and converts this value into an output signal. Additionally to the built-in signal processing, the sensor features an arbitrary programmable characteristic, e.g. for linearization of the output signal via up to 33 setpoints (17 variable or 33 fixed).

Major characteristics like gain and offset, reference position, etc. can be adjusted to the magnetic circuitry by programming the non-volatile memory.

This product is defined as SEooC (Safety Element out of Context) ASIL B ready according to ISO 26262. It can be integrated in automotive safety-related systems up to ASIL-D.

The device is designed for automotive and industrial applications. It operates in the ambient temperature range from −40 °C...150 °C.

The sensor is available in the eight-pin SOIC8 SMD package.

1.1. Major Applications

Thanks to the sensor's versatile programming characteristics and its high accuracy, the HAL/HAR 3927 is a potential solution for the following application examples:

– Linear movement measurements in dual-clutch transmissions, engine stroke sensors, clutch pedal, as well as cylinder and valve position measurements

– Rotary position measurement in gear selectors, rotary selectors with push function, rear-axis steering, electronic throttle control, accelerator pedal, etc.

1.2. Main Features

– Accurate angular measurement up to 360° and linear position detection

– SEooC ASIL B ready according to ISO 26262 to support Functional Safety applications

– Operates from 4.5 V up to 5.5 V supply voltage

– 12-bit ratiometric linear analog output

– Up to 8 kSps sampling frequency

– Operates from −40 °C up to 170 °C junction temperature
  (Max. Ambient Temperature: $T_{A,absmax}$ = 160 °C)

– Programming via the sensor's output pin. No additional programming pin required

– Various configurable signal processing parameters, like output gain and offset, reference position, temperature-dependent offset, etc.

– Programmable arbitrary output characteristic with 17 variable or 33 equidistant distributed setpoints

– Programmable characteristics in a non-volatile memory (EEPROM) with redundancy and lock function

– Read access on non-volatile memory after customer lock

– On-Board diagnostics of different functional blocks of the sensor

– Short-circuit protected push-pull output

– Overvoltage and reverse-voltage protection

– Under- and overvoltage detection of V_{SUP}

– Integrated wire-break detection with pull-up or pull-down resistor

– SENT according to SAE J2716 rev. 4

  • Support of four different frame formats
  • H.1 format: Two 12-bit Fast Channels
    (supporting A.1 Dual Throttle Position Sensors)
  • H.2 format: One 12-bit Fast Channel
  • H.4 format: Secure sensor with 12-bit Fast Channel 1 and secure sensor information on Fast Channel 2
  • Enhanced 8-bit ID serial message format including temperature information
  • Programmable tick time between 1.5 µs and 12 µs
  • Low time of 3, 4, 5 and 6 ticks
  • Transmission of OEM ID's via Slow Channel

2. Ordering Information

A Micronas device is available in a variety of delivery forms. They are distinguished by a specific ordering code:
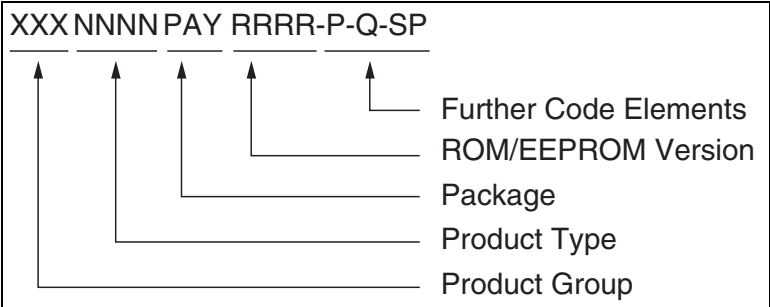
Fig. 2–1: Ordering code principle

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

2.1. Device-Specific Ordering Codes

The HAL/HAR 3927 is available in the following package.

Table 2–1: Available packages

Package Code (PA)	Package Type
DJ	SOIC8

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

Table 2–2: Ordering Information

Product	Package	Configuration-ID	Further Code [-P-Q-SP]
HAL3927	DJ = SOIC8	4300	See TDK-Micronas Ordering Information
HAR3927	DJ = SOIC8	4301	See TDK-Micronas Ordering Information

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

Ordering Code	Package Marking	Description
HAL3927DJ-4300[-P-Q-SP]	39274300 Lot number YWWD SB	Line 1: Product Type / Configuration-ID Line 2: Lot number Line 3: Date code / Special Procedure SB (optional)
HAR3927DJ-4301[-P-Q-SP]	R39274301 Lot number YWWD SB	Line 1: Product Type / Configuration-ID Line 2: Lot number Line 3: Date code / Special Procedure SB (optional)

3. Functional Description

3.1. General Function

HAL/HAR 3927 are 2D position sensors based on TDK-Micronas' 3D HAL technology. Each die includes two vertical and one horizontal Hall-plate for the detection of X, Y, or Z magnetic-field components, a signal processor for calculation and signal conditioning of two magnetic-field components, protection devices, and a ratiometric analog or SENT output.

The Hall-plate signals are measured by two A/D converters, filtered and temperature compensated. Offset compensation by spinning current minimizes the errors due to supply voltage and temperature variations as well as external package stress. A linearization block can be used optionally to reduce the overall system non-linearity error, due to mechanical misalignment, magnet imperfections, etc.

Overall, the in-system calibration can be utilized by the system designer to optimize performance for a specific system. The calibration information is stored in an on-chip memory.

The calculated position information is provided as a ratiometric analog output voltage proportional to the position or via SENT frames according to SAE J2716 rev.4.

HAL/HAR 3927 are programmable by modulation of the output voltage. No additional programming pin is needed and fast end-of-line programming is enabled.
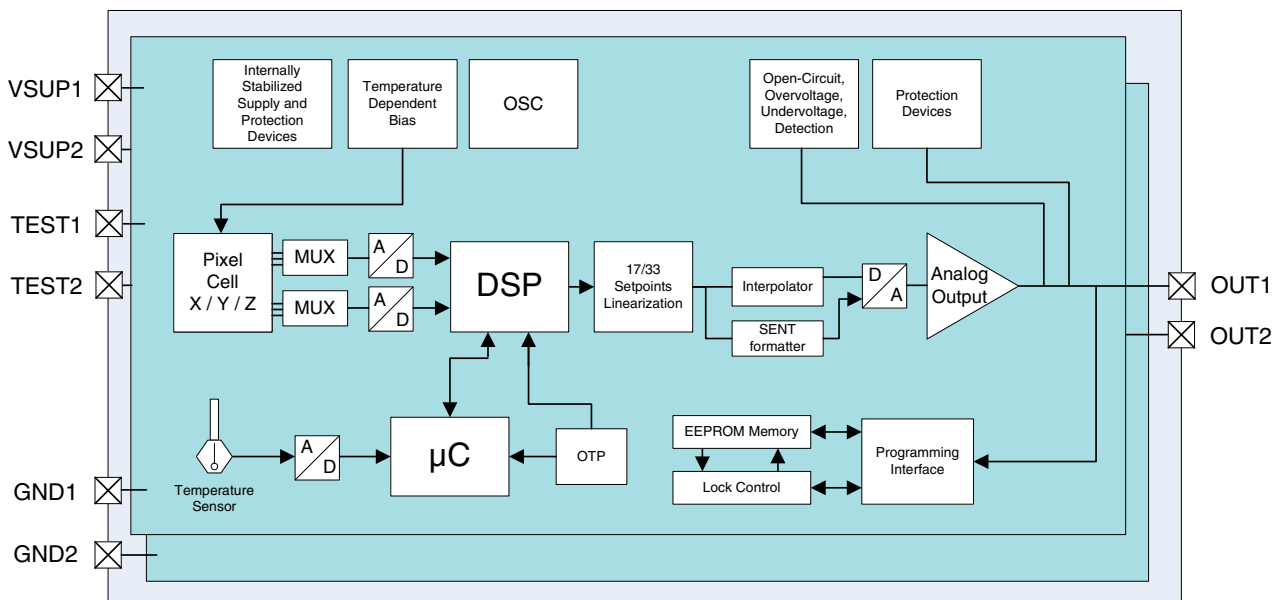
Fig. 3–1: Example block diagram for HAR 3927

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3.2. Signal Path

The DSP part of this sensor performs the signal conditioning. The parameters for the DSP are stored in the memory registers. Details of the overall signal path are shown in Fig. 3–2.
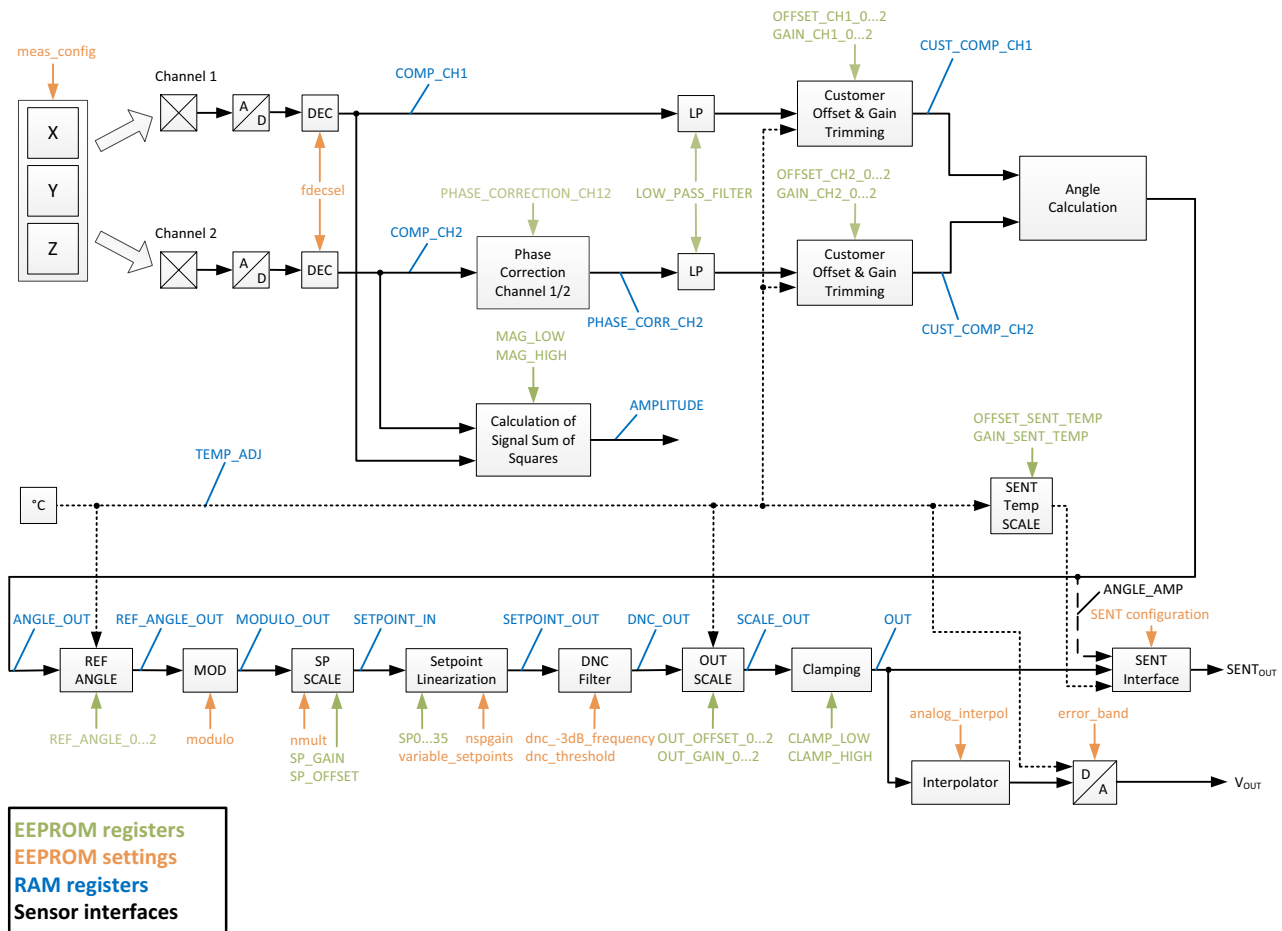
Fig. 3–2: Signal path of HAL/HAR 3927

The sensor signal path contains two kinds of registers. Registers that are read-only and programmable registers (non-volatile memory). The read-only (RAM) registers contain measurement data at certain steps of the signal path and the non-volatile memory registers (EEPROM) change the sensor's signal processing. EEPROM settings are individually configurable bits within an EEPROM register.

3.3. Register Definition

3.3.1. RAM Registers

TEMP_ADJ

The TEMP_ADJ register already contains the TDK-Micronas compensated digital value of the sensor's junction temperature.

COMP_CH1 and COMP_CH2

COMP_CH1 and COMP_CH2 registers contain the temperature-compensated magnetic-field information of channel 1 and channel 2.

AMPLITUDE

The AMPLITUDE register contains the sum of squares of the magnetic-field amplitude of the two signals calculated with the following equation. This information is used for the magnet loss detection:

$$\text{AMPLITUDE} = \frac{\text{COMP\_CH1}^2}{32768} + \frac{\text{COMP\_CH2}^2}{32768}$$

CUST_COMP_CH1 and CUST_COMP_CH2

CUST_COMP_CH1 and CUST_COMP_CH2 register contain the customer-compensated magnetic-field information of channel 1 and channel 2 used for the angle calculation. These registers contain already the customer phase-shift, gain and offset corrected data.

PHASE_CORR_CH2

PHASE_CORR_CH2 register contains the customer compensated magnetic-field information of channel 2 after customer phase-shift error correction using the PHASE_CORRECTION_CH12 register.

ANGLE_OUT

The ANGLE_OUT register contains the digital value of the position calculated by the angle calculation algorithm.

REF_ANGLE_OUT

The REF_ANGLE_OUT register contains the digital value of the angle information after setting the reference angle defining the zero angle position.

MODULO_OUT

The MODULO_OUT register contains the digital value of the angle information after applying the modulo calculation algorithm.

SETPOINT_IN

The SETPOINT_IN register contains the digital value of the angle information after the setpoint scaling block and are the values used for the input of the setpoint linearization block.

SETPOINT_OUT

The SETPOINT_OUT register contains the digital value of the angle information after the setpoint linearization block.

DNC_OUT

The DNC_OUT register contains the digital value of the angle information after the DNC filter.

SCALE_OUT

The SCALE_OUT register contains already the position information after the customer output scaling using the OUT_GAIN and OUT_OFFSET registers.

OUT

The OUT register contains the digital value of the angle information after all signal processing steps and depends on all customer configuration settings.

DIAGNOSIS

The DIAGNOSIS_0 and DIAGNOSIS_1 registers report certain failures detected by the sensor. HAL/HAR 3927 performs self-tests during power-up as well as continued system integrity tests during normal operation. The result of those tests is reported via the DIAGNOSIS_X registers.

Micronas IDs

The MIC_ID1 and MIC_ID2 registers are both 16-bit organized. They are read-only and contain TDK-Micronas production information, like X,Y position on the wafer, wafer number, etc. This register content will be send via the SENT interface if the serial message channel has been activated.

3.3.2. EEPROM Registers

Customer IDs

The customer ID registers (CUSTOMER_ID0 to CUSTOMER_ID9) consist of ten 16-bit words and can be used to store customer production information, like serial number, project information, OEM codes, etc. The customer IDs will be part of the SENT Slow Channel in case that the SENT output is activated and transmission via Slow Channel is selected as well.

Magnetic Range Check

The magnetic range check uses the AMPLITUDE register value and compares it with an upper and lower limit threshold defined by the customer programmable registers MAG_LOW and MAG_HIGH. If either low or high limit is exceeded, the sensor will indicate an error.

Mag-Low Limit

MAG_LOW defines the low level for the magnetic-field range check function.

Mag-High Limit

MAG_HIGH defines the high level for the magnetic-field range check function.

Phase Correction

PHASE_CORRECTION_CH12 can be used to compensate a phase-shift of channel 2 in relation to channel 1.

Neutral value for the register is zero (no phase-shift correction).

Low-Pass Filter

With the LOW_PASS_FILTER register it is possible to select different −3 dB cutoff frequencies for HAL/HAR 3927. The default value is zero (low-pass filter disabled). The filter frequency is valid for both channels.

Gain for Channel 1 and 2

GAIN_CH1_0...2 and GAIN_CH2_0...2 can be used to compensate amplitude mismatches between channel 1 and channel 2. TDK-Micronas delivers pre calibrated sensors with compensated gain mismatch. Nevertheless, it is possible that due to the magnetic circuit a mismatch between the channels occurs.

In addition a temperature-dependent gain can be added for both channels. GAIN_CHx_0...2 supports a polynomial of 2nd order. This means that a constant, linear and quadratic gain factor can be programmed.

Customer Offset

OFFSET_CH1_0...2 and OFFSET_CH2_0...2 can be used to compensate a remaining offset in channel 1 and channel 2. TDK-Micronas delivers pre calibrated sensors. Nevertheless it is possible that due to the magnetic circuit an offset in channel 1 and 2 occurs. This can be compensated with OFFSET_CHx_0...2.

The customer offset can have a temperature coefficient to follow the temperature coefficient of a magnet. The customer offset consists of a polynomial of second order. This means that a constant, linear and quadratic offset factor can be programmed.

Reference Angle Position

The output signal zero position defines the reference position for the angle output and therefore it is possible to shift the discontinuity in the output characteristics out of the measurement range with these parameters. It can be set to any value of the angular range.

REF_ANGLE_0...2 defines a polynomial of second order with REF_ANGLE_0 (constant part), REF_ANGLE_1 (linear part) and REF_ANGLE_2 (quadratic part).
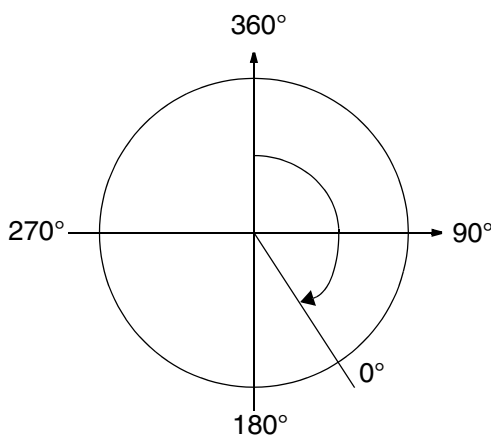
Fig. 3–3: Example definition of zero degree point

Setpoint Gain

SP_GAIN and nmult define the gain of the input signal for the linearization block. They are used to scale the position information to the input range of the linearization block.

Setpoint Offset

SP_OFFSET defines the offset of the input signals for the linearization block. They are used to scale the position information to the input range of the linearization block.

Setpoint Linearization

The setpoint linearization block enables the linearization of the sensor's output characteristic for the customer's application. For fixed setpoints it consists of 33 setpoints (SP0, SP1, ..., SP32). Each setpoint is defined by its fixed X position and its programmable Y value. The setpoint X positions (SP(n)_X) are equally distributed between $-32768... 32767$ LSB.

The setpoint registers have a length of 16 bits and are two's complement coded. Therefore the setpoint Y values (SP(n)_Y) can vary between $-32768...32767$ LSB.

Alternatively 17 variable setpoints can be used. In this case the 17 setpoint X positions and 19 setpoint Y values (the first corresponds to position -32768 and the last to 32767) are freely programmable.

The SETUP_DATAPATH[1:0] bits (= variable_setpoints) offer the selection between 33 fixed and 17 variable setpoints and if the setpoint Y values are stored absolutely or differentially to their setpoint X positions.

The setpoint register values are initially set to 0 (neutral) by default. The setpoint linearization block works in a way that the incoming signal (SETPOINT_IN value) is interpolated linearly between two adjacent setpoints (SP(n) and SP(n+1)). The resulting SETPOINT_OUT register value represents the angular information after the setpoint scaling.

nspgain

The SETUP_DATAPATH[5:2] bits (= nspgain) set the gain exponent for the internal setpoint slope calculation, which is used for variable setpoints only.

DNC Filter Register (dnc_−3dB_frequency & dnc_threshold)

The DNC (Dynamic Noise Cancellation) filter decreases the output noise significantly by adding a low-pass filter with a very low cut-off frequency for signals below a certain signal change threshold (dnc_threshold, DNC[15:8]).

The attenuation factor dnc_−3 dB_frequency of this IIR filter can be selected by the bits DNC[7:0] of the DNC register. Both parameters have a length of 8 bits.

For dnc_threshold only values from 0 to 255 are allowed. For the dnc_−3 dB_frequency only cut-off frequencies up to 50% of the sample frequency ($0.5 \times$ fdecsel) are allowed. To disable the DNC filter both registers must be set to 0.

Clamping Levels (CLAMP_LOW & CLAMP_HIGH)

The clamping levels CLAMP_LOW and CLAMP_HIGH define the maximum and minimum output values. The two registers have a bit length of 16 bit. Both clamping levels can have values between 0% FS and 100% FS.

Output Gain

OUT_GAIN_0...2 defines the final gain scaling for the desired output signal. It can also be used to invert the output signal. The register has a length of 16 bit. OUT_GAIN_0...2 supports a polynomial of 2nd order. This means that a constant, linear and quadratic gain factor can be programmed.

Output Offset

OUT_OFFSET_0...2 defines the final offset scaling for the desired output signal. The register has a length of 16 bit. OUT_OFFSET_0...2 supports a polynomial of 2nd order. Hence, a constant, linear and quadratic offset factor can be programmed.

Interpolator (analog_interpol)

HAL/HAR 3927 features a programmable interpolator before the D/A converter. The interpolator provides a linear interpolation between two successive 8 kHz samples, resulting in an increased update rate at the input of the DAC.

The benefit of this block are reduced amplitude steps by a factor of 32, resulting in a smoother DAC analog output and reduced out-of-band noise.

Please note, that the interpolator does not change the overall signal bandwidth.

The interpolator can be switched on and off.

SENT Temperature Scaling

If SENT H.1 Format of secondary output (second fast channel SENT) is selected, the registers OFFSET_SENT_TEMP and GAIN_SENT_TEMP can be used for offset and gain scaling of the digital value of the sensor's junction temperature.

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Customer Configuration Registers

SETUP_FRONTEND, SETUP_DATAPATH, SETUP_OUTPUT and SETUP_SUPERVISION registers are 16-bit registers that enable the customer to activate various functions of the sensor. The table below describes in detail the available combinations and resulting functions.

Table 3–1: SETUP_FRONTEND

Bit No.	Function	Description
15:9	–	Reserved
8	customer_burnin	Customer burn-in mode 0: disabled 1: activated
7:6	fdecsel	Decimation frequency: 00: 2 kSps 01: 4 kSps 10: 8 kSps 11: reserved
5:2	–	Reserved
1:0	meas_config	Measurement configuration 00: CH1: X CH2: Y 01: CH1: X CH2: Z 10: CH1: Y CH2: Z 11: reserved

Table 3–2: SETUP_DATAPATH

Bit No.	Function	Description
15	fusa_en	Functional Safety support 0: Limited FuSa support 1: Full FuSa support **Note:** If fusa_en = 0 (SETUP_DATAPATH[15] = 0) not all Functional Safety diagnostic mechanisms are active. In this configuration, HAR 3927 is not defined as SEooC ASIL B ready according to ISO 26262. Further details can be found in Section 4. on page 32.
14:13	-	Reserved
12:11	modulo	Modulo operation: 00: No Modulo 01: Modulo 90° 10: Modulo 120° 11: Modulo 180°
10:8	nmult	Gain exponent for SETPOINT_IN channel 1 $SP\_Gain = SP\_GAIN \times 2^{nmult}$
7:6	–	Reserved
5:2	nspgain	Gain exponent for internal setpoint slope calculation (only for variable setpoints) $Slope = SPGn \times 2^{nspgain+1}$
1:0	variable_setpoints	Fixed/variable setpoints: 00: fixed setpoints, absolutely stored SP_Y values 01: fixed setpoints, differentially stored SP_Y values 10: variable setpoints, absolutely stored SP_Y values 11: variable setpoints, differentially stored SP_Y values

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Table 3–3: SETUP_OUTPUT

Bit No.	Function	Description	
15:14	primary_output	Primary output protocol selection: 00: Analog 01: SENT 10: reserved 11: reserved	
Analog Output (SETUP_OUTPUT[15:14] = 00)			
13:1	–	Reserved	
0	analog_interpol	Analog output interpolator: 0: off 1: on	
SENT Output (SETUP_OUTPUT[15:14] = 01)			
13	–	Reserved	
12	secondary_output	0: ANGLE_AMP 1: TEMP_SENT	
11:8	sent_slew_rate	Slew rate control: 0xxx: slew rate control disabled 1000: Fall: 5V/1.0µs, Rise: 5V/1.0µs 1001: Fall: 5V/1.0µs, Rise: 5V/1.5µs 1010: Fall: 5V/1.2µs, Rise: 5V/1.2µs 1011: Fall: 5V/1.2µs, Rise: 5V/2.7µs 1100: Fall: 5V/1.6µs, Rise: 5V/1.6µs 1101: Fall: 5V/1.6µs, Rise: 5V/5.2µs 1110: Fall: 5V/2.7µs, Rise: 5V/2.7µs 1111: Fall: 5V/2.7µs, Rise: 5V/10.3µs Measured from/to 1.1V to/from 3.8 V with C_L =4.7 nF, V_{SUP} = 5V	
7	sent_synchronicity	Synchronicity mode: 0: SENT Continuous 1: SENT with Pause Pulse	
6:4	sent_tick_time	SENT tick time selection (typ. value): 000: reserved 001: 1.50 µs 010: 2.00 µs 011: 2.50 µs 100: 2.75 µs 101: 3.00 µs 110: 6.00 µs 111: 12.0 µs **Note:** Not all combinations of tick time and repetition rate are possible.	
3:0	sent_repetition_rate	SENT data rate 0000: reserved 0001: reserved 0010: 2.66 kHz 0011: 2 kHz 0100: 1.6 kHz 0101: 1 kHz 0110: 0.8 kHz 0111: 0.5 kHz	SENT message length (PPC) 1000: 225 ticks 1001: 239 ticks 1010: 250 ticks 1011: 269 ticks 1100: 294 ticks 1101: 366 ticks 1110: 375 ticks 1111: 450 ticks

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Table 3–4: SETUP_SUPERVISION

Bit No.	Function	Description
15	customer_lock	Customer lock 0: unlocked 1: locked
14:13	overcurrent_ configuration	Overcurrent configuration customer_lock = 0 (SETUP_SUPERVISION[15] = 0) xx: entering Listen Mode via OUT Pin always enabled customer lock = 1 (SETUP_SUPERVISION[15] = 1) 00: entering Listen Mode via OUT Pin enabled 01: entering Listen Mode via OUT Pin disabled. In case of an overcurrent event, output goes to tristate and returns to Application Mode after approx. 80 ms 10: entering Listen Mode via OUT Pin disabled. Output continues driving also in case of overcurrent. 11: reserved
12	–	Reserved
11:10	short_current_limit	Short current limitation levels (only valid for Analog, in SENT mapped to 00) 00: 19.0 mA 01: 22.0 mA 10: 25.5 mA 11: 28.5 mA
9:8	overcurrent_level	Overcurrent (OC) detection levels (only valid for Analog, in SENT mapped to 00) 00: on: 4.75 mA, off: 3.75 mA 01: on: 8.5 mA, off: 7.5 mA 10: on: 12.5 mA, off: 11.5 mA 11: on: 16.5 mA, off: 15.5 mA
7	dis_temp_sup	Temperature supervision 0: enabled 1: disabled **Note:** If dis_temp_sup = 1 (SETUP_SUPERVISION[7] = 1) is selected, the temperature range supervision as well as the plausibility check of the redundant temperature sensor are disabled. In this case, HAL/HAR 3927 is not defined as SEooC ASIL B ready according to ISO 26262. Further details can be found in Section 4. on page 32.
6	–	Must be set to 1
5:4	ov_level	Overvoltage threshold 00: 9.3 V 01: 5.7 V 10: reserved 11: reserved
3:2	uv_level	Undervoltage threshold 00: 3.8 V 01: 4.1 V 10: 4.25 V 11: reserved
1	–	Must be set to 0
0	error_band	Error band mode 0: low level on error 1: high level on error

3.4. SENT Output Protocol

The HAL/HAR 3927 complies with the SAE J2716 standard rev.4 and supports the following three frame formats:

– H.1 Format: Two 12-bit Fast Channels

- A.1 Dual Throttle Position Sensors: 3 nibble position information and 3 nibble negated position information (1-position)
- A.7 Position Sensors: 3 nibble position information and 3 nibble temperature information or magnetic-field amplitude

– H.2 Format: One 12-bit Fast Channel (3 nibble position information)

– H.4 Format: Secure Single Sensors with 12-bit Fast Channel (3 nibble position information) and 12-bit Secure Sensor Information

All frame formats are customer selectable via bits (Table 3–3 on page 19 and Table 3–5).

Beside the supported frame formats, a lot of other SENT interface parameter can be configured by the customer, like tick time, pause pulse, start-up behavior, transmission of error codes, serial message channel content, etc. All configurable parameter are defined in Table 3–3, Table 3–5 and Table 3–14.

In SENT output mode, the unidirectional communication from the sensor to a receiver module (e.g. an Electronic Control Unit) 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.

Table 3–5: SETUP_PROTOCOL

Bit No.	Function	Description
15:14	sent_channel_format	SENT fast channel data format: 00: H.2, CH1 primary channel 01: H.4, CH1 primary channel, CH2 secure counter 10: H.1 - A1, CH1 primary channel, CH2 inverse primary channel 11: H.1 - A.7, CH1 primary channel, CH2 secondary channel
13:12	sent_low_time	SENT low time: 00: 3 ticks 01: 4 ticks 10: 5 ticks 11: 6 ticks
11	sent_crc_type	CRC type: 0: CRC acc. SAE J2716 rev. 2010 1: legacy CRC acc. SAE J2716 rev. 2008
10	sent_status_crc	Include status nibble in CRC 0: disabled (conformal to SENT) 1: enabled
9	sent_wakeup_behaviour	SENT start-up behavior: 0: send 4094 during start-up 1: send 0 during start-up
8	-	Reserved

Table 3–5: SETUP_PROTOCOL, continued

Bit No.	Function	Description
7	-	Reserved
6	sent_error_status	SENT error status bits (see Section 3.4.4. on page 26): 0: always zero 1: according to SENT SAE J2716
5	sent_fast_error_codes	SENT transmission of error codes on fast channel 0: disabled 1: enabled
4	sent_slow_channel_format	Slow serial channel format: 0: No serial message channel 1: 12-bit enhanced serial message format
3:1	sent_slow_channel_content	Selection which blocks have to be send in addition to block 1 in the slow channel: xx1: Block 2 x1x: Block 3 1xx: Block 4+5
0	sent_sdf	SENT SDF mode: 0: Send diagnosis info in front of every block 1: Send diagnosis info in front of every ID

3.4.1. H.1 Format: 6 Data Nibble Frame with Two Fast Channels

In this SENT mode the sensor transmits SENT frames with 6 data nibbles.

Two different application specific protocols are supported:

– A.1 Dual Throttle Position Sensors

– A.7 Position Sensors

In case of A.1 the first 3 data nibbles contain a 12-bit position information and the second 3 data nibbles contain the negated position of the first 3 nibbles (1-position).

In case of A.7 the first 3 data nibbles contain a 12-bit position information and the second 3 data nibbles contain a 12-bit temperature information or 12-bit magnetic-field amplitude information (customer configurable: Table 3–3). They are formatted according to Table 3–6.

Table 3–6: Nibble description for H.1 A.1 format

Pulse		Remarks
#	Description	
1	Synchronization/ Calibration	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	Status [0...1]: According selection in Table 3–5 Status [2...3]: According selection in Table 3–5
3	4-bit Data Nibble MSN 1	Position Value [11:8]
4	4-bit Data Nibble MidN 1	Position Value [7:4]
5	4-bit Data Nibble LSN 1	Position Value [3:0]
6	4-bit Data Nibble LSN 2	Negated Position Value[3:0]
7	4-bit Data Nibble MidN 2	Negated Position Value[7:4]
8	4-bit Data Nibble MSN 2	Negated Position Value[11:8]
9	4-bit CRC Nibble	According selection in Table 3–5
10	Pause Pulse	According selection in Table 3–3

Table 3–7: Nibble description for H.1 A.7 format

Pulse		Remarks
#	Description	
1	Synchronization/ Calibration	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	Status [0...1]: According selection in Table 3–5 Status [2...3]: According selection in Table 3–5
3	4-bit Data Nibble MSN 1	Position Value [11:8]
4	4-bit Data Nibble MidN 1	Position Value [7:4]
5	4-bit Data Nibble LSN 1	Position Value [3:0]
6	4-bit Data Nibble LSN 2	Value [3:0] -> According selection in Table 3–5 on page 21
7	4-bit Data Nibble MidN 2	Value [7:4] -> According selection in Table 3–5 on page 21
8	4-bit Data Nibble MSN 2	Value [11:8] -> According selection in Table 3–5 on page 21
9	4-bit CRC Nibble	According selection in Table 3–5
10	Pause Pulse	According selection in Table 3–3

3.4.2. H.2 Format: 3 Data Nibble Frame with One Fast Channel

Following application-specific protocol is supported:

– A.7 Position Sensors

In this mode, the sensor transmits SENT frames with 3 data nibbles containing 12-bit position information. They are formatted according to Table 3–8.

Table 3–8: Nibble description for 3 data nibble frame format with one Fast Channel

Pulse		Remarks
#	Description	
1	Synchronization/ Calibration	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	Status [0...1]: According selection in Table 3–5 on page 21 Status [2...3]: According selection in Table 3–5 on page 21
3	4-bit Data Nibble MSN 1	Position Value [11:8]
4	4-bit Data Nibble MidN 1	Position Value [7:4]
5	4-bit Data Nibble LSN 1	Position Value [3:0]
6	4-bit CRC Nibble	According selection in Table 3–5 on page 21
7	Pause Pulse	According selection in Table 3–3 on page 19

3.4.3. H.4 Format: Secure Single Sensors with 12-bit Fast Channel

Following application-specific protocol is supported:

– A.7 Position Sensors

In this SENT mode, the sensor transmits SENT frames with 3 data nibbles containing 12-bit position information as well as 3 data nibbles containing 12-bit secure sensor information. The secure sensor information consists of an 8-bit rolling counter and the inverted copy of the MSN of the transmitted position information. They are formatted according to Table 3–9.

Table 3–9: Nibble description for 6 data nibble frame format with secure information

Pulse		Remarks
#	Description	
1	Synchronization/ Calibration	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	Status [0...1]: According selection in Table 3–5 Status [2...3]: According selection in Table 3–5
3	4-bit Data Nibble MSN 1	Position Value [11:8]
4	4-bit Data Nibble MidN 1	Position Value [7:4]
5	4-bit Data Nibble LSN 1	Position 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 Data Nibble MSN 1
9	4-bit CRC Nibble	According selection in Table 3–5
10	Pause Pulse	According selection in Table 3–3

3.4.4. Error Diagnostic Reporting on Fast Channel and Status Bits

The error diagnostic reporting is customer configurable. By setting bits in the SETUP_PROTOCOL register (see Table 3–5 on page 21) different error handling can be activated:

– Always zero: Status bits are always set to zero independent from an error
– Error indication according to SAE J2716 rev. 4: The Status bits are 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 channel 1 and/or channel 2. Table 3–10 shows the values that will be sent in case of an internal error.

Table 3–10: Error codes transmitted on Fast Channel 1 and/or 2

Error	Code		A.1 Mode	
	CH 1	CH 2	CH 1	CH 2
A.1 error code	–	–	4095	4095
Sensor error indication	4091	4091	N/A	N/A
Sensor functionality and processing error indication	4090	4090	–	–
Data Clamping: High	1)	1)	1)	1)
Data Clamping: Low	1)	1)	1)	1)
[1] The output will clamp according to the settings for CLAMP_HIGH and CLAMP_LOW				

A description with the mapping of internal errors with "Sensor error indication" and "Sensor functionality and processing error indication" can be found in Table 3–15 on page 30.

The transmission of error codes on Fast Channel 1 and/or 2 can be deactivated by a customer EEPROM bit (bit[5] of SETUP_PROTOCOL, Table 3–5 on page 21). The sensor will then continue to transmit measurement data. Status error bits will be transmitted according to bits[7:6] in the SETUP_PROTOCOL register.

Note	It is not recommended to deactivate the transmission of the error codes on the Fast Channel 1 and/or 2.

3.4.5. Pause Pulse

The pause pulse is present at the end of every frame as defined by the SAE J2716 standard. HAL/HAR 3927 offers two options:

PPC: The length of the pause pulse is automatically adjusted in order to achieve a constant frame length independent from the message content. The overall length can be defined by the sent_repetition_rate bits (SETUP_OUTPUT bits[3:0]). Two different types of PPC are supported. For the first type the overall frame length is defined in fixed μs steps and for the second type the frame length is adapted to a fixed sample rate (see Table 3–3 on page 19).

Table 3–11: Message length for PPC (ticks related)

SETUP_OUTPUT [3:0]	1000	1001	1010	1011	1100	1101	1110	1111
ticks PPC	225	239	250	269	294	366	375	450

Following PPC message length are supported for the various frame formats:

Table 3–12: Recommended PPC message length

ticks PPC	H.1 A.1 Format: 6 Data Nibble Frame	H.1 A.7 Format: 6 Data Nibble Frame	H.2 A.7 Format: 3 Data Nibble Frame	H.4 A.7: Secure Single Sensor
	PP Length [ticks]	PP Length [ticks]	PP Length [ticks]	PP Length [ticks]
225	–	–	36	–
239	–	–	50	–
250	–	–	61	–
269	44	–	80	–
294	69	24	105	39
366	141	96	177	111
375	150	105	186	120
450	225	180	261	195

Table 3–13: Message repetition rate for PPC (sampling aligned)

SETUP_OUTPUT [3:0]	0000	0001	0010	0011	0100	0101	0110	0111
frequency PPC [kHz]	–	–	2.66	2.00	1.60	1.00	0.80	0.50

NPP: It is also possible that in case of deactivated pause pulse (npp), some samples may be transmitted twice in series due to the fact that the message time can be shorter than the sample time. Status[0] bit will then be set to one in case that a sample is transmitted twice.

3.4.6. CRC Implementation

HAL/HAR 3927 is supporting the recommended CRC implementation defined in SAE J2716 Rev. 4. The Legacy CRC can also be activated by bit[11] in the SETUP_PROTOCOL register (see Table 3–5 on page 21). It is possible to include the status nibble in the CRC calculation. This function can be activated by bit[10] in the SETUP_PROTOCOL register as well.

3.4.7. Slow Channel: Enhanced Serial Message

HAL/HAR 3927 supports a Slow Channel according to the Enhanced Serial Message with 12-bit data and 8-bit message ID. It is also possible to deactivate the Slow Channel by setting bit[4] in the SETUP_PROTOCOL register (see Table 3–5 on page 21).

3.4.8. Slow Channel: Serial Message Sequence

The device can transmit the serial message sequence shown in Table 3–14. The content/ length of the serial message can be tailored by configuration bits in the SETUP_PROTOCOL register (see Table 3–5 on page 21). It is possible to activate up to five blocks. Block 1 will always be transmitted if the serial message channel is activated.

Table 3–14: Serial message sequence

Block	#	8-bit ID	Item	12-bit Data	Comment
1	1	0x01	Error Codes	(see Table 3–15 on page 30)	
	2	0x03	Sensor type	(see Section 3.4.10. on page 30)	Bits 0...11 in CUSTOMER_ID0 register (12 bit) Examples: 0x050 = not specified position sensor 0x055 = position and secure channel 0x060 = angle sensor 0x064 = angle sensor + secure channel, etc.
	3	0x05	Manufacturer Code	0x007	TDK Manufacturer Code
	4	0x06	Protocol Revision	0x004	SAE J2716 rev. 4
	5	0x23	Temperature	1 to 4088 temperature data	Temperature information according SAE J2716
2	6	0x01	Error Codes	(see Table 3–15 on page 30)	
	7	0x29	TDK-Micronas SN	8-bit MSB MIC_ID1	Right aligned
	8	0x2A	TDK-Micronas SN	8-bit LSB MIC_ID1	Right aligned
	9	0x2B	TDK-Micronas SN	8-bit MSB MIC_ID2	Right aligned
	10	0x2C	TDK-Micronas SN	8-bit LSB MIC_ID2	Right aligned

Table 3–14: Serial message sequence, continued

Block	#	8-bit ID	Item	12-bit Data	Comment
3	11	0x01	Error Codes	(see Table 3–15 on page 30)	Customer configurable
	12	0x07	Fast CH1 - X1	Fast channel 1 characteristics	Bits 0...11 in CUSTOMER_ID1 register
	13	0x08	Fast CH1 - X2	Fast channel 2 characteristics	Bits 12...15 in CUSTOMER_ID1 register Bits 0...7 in CUSTOMER_ID2 register
	14	0x09	Fast CH1 - Y1	Fast channel 1 characteristics	Bits 8...15 in CUSTOMER_ID2 register Bits 0...3 in CUSTOMER_ID3 register
	15	0x0A	Fast CH1 - Y2	Fast channel 2 characteristics	Bits 4...15 in CUSTOMER_ID3 register
4	16	0x01	Error Codes	(see Table 3–15 on page 30)	
	17	0x90	OEM Code 1 ID	ASCII character OEM Codes	Bits 0...11 in CUSTOMER_ID4 register
	18	0x91	OEM Code 2 ID	ASCII character OEM Codes	Bits 12...15 in CUSTOMER_ID4 register Bits 0...7 in CUSTOMER_ID5 register
	19	0x92	OEM Code 3 ID	ASCII character OEM Codes	Bits 8...15 in CUSTOMER_ID5 register Bits 0...3 in CUSTOMER_ID6 register
	20	0x93	OEM Code 4 ID	ASCII character OEM Codes	Bits 4...15 in CUSTOMER_ID6 register
5	21	0x01	Error Codes	(see Table 3–15 on page 30)	
	22	0x94	OEM Code 5 ID	ASCII character OEM Codes	Bits 0...11 in CUSTOMER_ID7 register
	23	0x95	OEM Code 6 ID	ASCII character OEM Codes	Bits 12...15 in CUSTOMER_ID7 register Bits 0...7 in CUSTOMER_ID8 register
	24	0x96	OEM Code 7 ID	ASCII character OEM Codes	Bits 8...15 in CUSTOMER_ID8 register Bits 0...3 in CUSTOMER_ID9 register
	25	0x97	OEM Code 8 ID	ASCII character OEM Codes	Bits 4...15 in CUSTOMER_ID9 register

Alternatively, the Error Code can be transmitted as every second Slow Channel message by selecting a bit in the SETUP_PROTOCOL register (see Table 3–5 on page 21)

3.4.9. Slow Channel: Serial Message Error Codes

Diagnostic status codes are transmitted via the serial message. The 8-bit message ID for the diagnostic status code is 01h. HAL/HAR 3927 features the error codes described in Table 3–15.

Table 3–15: Serial message error codes

Bit Position	Error Type	Fast Channel Error Code
0	Memory self-test error or checksum error	4090
1	ADC error or DSP self-test error	4090
2	Voltage regulator error	4090
3	ADC clipping	4091
4	Invalid temperature sensor values	4090
5	Signal path under/ overflow	CLAMP_LOW/CLAMP_HIGH
6	Overvoltage warning	4091
7	Undervoltage warning	4091
8	Reserved	N/A
9	Hall-plate error	4090
10	Magnet field out of range (MAG_HIGH, MAG_LOW)	4091
11	Always set to one	–

3.4.10. Slow Channel: Sensor Types

HAL/HAR 3927 can transmit the sensor type information via the Slow Channel. The sensor type depends on the final customer application and is therefor customer programmable. The 12-bit value for the sensor type can be directly stored in CUSTOMER_ID0 register.

3.4.11. Start-Up Behavior

HAL/HAR 3927 can either transmit frames with value zero until a valid information is available (SAE J2716 conform) or alternatively frames with 4094. The start-up behavior is customer configurable by a bit in the SETUP_PROTOCOL register (see Table 3–5 on page 21).

3.4.12. Message Time for SENT Frames in PP Mode

The SENT frame repetition frequency (sent_repetition_rate in SETUP_OUTPUT[3:0] register) is defined by the position sampling frequency. The selectable SENT frame repetition frequency is limited by the configured tick time, the transmitted data value and the minimum and maximum pause pulse duration.

The tick time is customer programmable and can be selected between 1.5 µs and 12 µs.

The pulse low time can be configured to 3, 4, 5 and 6 ticks.

The delivery of new position values is synchronous with the SENT messages, i.e. one SENT message is transmitted per position sample. Thus, the propagation delay is very low and the message time is nearly constant.

4. Functional Safety

4.1. Functional Safety Manual and Functional Safety Report

The Functional Safety Manual for HAL/HAR 3927 contains the necessary information to support customers to realize a safety compliant application by integrating HAL/HAR 3927, as an ASIL B ready component, in their system. The Functional Safety Manual will be provided upon request.

The Functional Safety Analysis Report describes the assumed Safety Goal, the corresponding Failure Modes as well as the Base Failure Rate for die and package according to IEC TR 62380. It can be provided based on a TDK-Micronas mission profile as well as customer mission profiles.

4.2. Integrated Diagnostic Mechanism

HAL/HAR 3927 performs self-tests during start-up and normal operation. These increase the robustness of the device functionality by either preventing the sensor to provide wrong output signals or by reporting the failure according to SENT. Further details about error reporting in case of SENT.

output see Section 3.4.9. on page 30.The internal diagnostic mechanisms increase the robustness of the device functionality by either preventing the sensor to provide wrong output signals or by reporting the failure according SENT definition. For further details about error reporting in case of SENT output see Section 3.4. on page 21.

Configured to analog output mode, the sensor indicates a fault by switching the output signal to the selected error band.

The sensor switches the output to ground in case of a VSUP wire break and to V_{SUP} in case of a GND wire break.

The result of the internal diagnostics is as well available via the DIAGNOSIS_X registers.

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Table 4–1: DIAGNOSIS_0 register

Bit no.	Description when bit is set to 1
15	DSP self-check routines (redundancy or plausibility checks)
14	DSP and µC check of 16-bit checksum covering the EEPROM parameter
13	DSP checksum for ROM and RAM
12	Chip junction temperature out of range
11	Plausibility check of redundant temperature sensor
10	Hall-plate supply too high
9	Hardware overtemperature supervision: Junction temperature > 180°C
8	Reserved
7	One of the A/D converters delivers a stuck signal
6	Overflow or underflow of decimation filter
5	Magnetic field amplitude is above the MAG_HIGH threshold
4	Magnetic field amplitude is below the MAG_LOW threshold
3	The result of the position calculation exceeds the programmed upper threshold register value (CLAMP_HIGH)
2	The result of the position calculation falls below the programmed lower threshold register value (CLAMP_LOW)
1	Hall-plate current out of range
0	Reserved
Note:	**Bit[13] can not be read via the programming interface as they are triggering immediately a reset of the device. Bit [9] can not be read via the programming interface as the output will not respond.**

Table 4–2: DIAGNOSIS_1 register

Bit no.	Description when bit is set to 1
15, 10	Supply Overvoltage
14	General purpose ADC error
13, 11	Supply Undervoltage
12	Bandgap voltage out of range
9	Internal analog voltage out of range
8	Internal digital voltage out of range
7	µC self-test error
6	µC ROM OP code error
5:0	Reserved
Note:	**Bits[7:6] cannot be read via the programming interface as they are triggering immediately a reset of the device.**

5. Specifications

5.1. Outline Dimensions

Product	HAL 3927
$\text{\textcircled{X}}$ related to center of package	0
$\text{\textcircled{Y}}$ related to center of package	0
$\text{\textcircled{D}}$	0.3
$\text{\textcircled{A}}$	0.38
weight	0.076 g

B (20 : 1)

All 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.
SOIC8-1	21-08-19	MS-012	F		21-08-26	1	CSOIC0083015.1	ZG	2123_Ver.01

Fig. 5–1:
SOIC8-1: Plastic small outline IC package, 8 leads, gullwing bent, 150 mil
Ordering code: DJ

HAL/HAR 3927

Product	HAR3927
X1	0
X2	0
Y1	0
Y2	0
D	0.3
A1	0.65
A2	0.24
weight	0.076 g

4.9 ± 0.1

PIN 1 INDEX

6 ± 0.2
3.9 ± 0.1

+Y
-X
+X
-Y

X2 X1

center of sensitive area
center of package x/y=0

$\oplus$ | D

$\oplus$ | 0.25 (M) | C | A-B | D

1.27   0.42

B (20 : 1)

gauge plane
0.25
0.6 ± 0.18

8.5° ± 2°
0.65 ± 0.11
1.42 ± 0.1
0.175 ± 0.075
8.5° ± 2°

seating plane

$\bigcirc$ | 0.1 | C

Y1
Y2
A2
A1
0.38x45°
0.22 ± 0.05 Sn plated
4° ± 4°
seating plane
B
C

0   2.5   5 mm
scale

TOP VIEW

BOTTOM VIEW

All 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.
SOIC8-1	19-05-16	MS-012	F		21-04-22	3	CSOIC0083005.1	ZG	2105_Ver.03

Fig. 5–2:
SOIC8-1: Plastic small outline IC package, 8 leads, gullwing bent, 150 mil
Ordering code: DJ

HAL/HAR 3927

Ø1.5

4

6.4

8

1.75

5.5

12±0.3

5.2

2.1

???1234...

???1234...

???1234...

user direction of feed

18.2 max

Ø102

Ø330

Ø13

12 min

Devices per Reel: 3500

IEC STANDARD		ANSI	ISSUE DATE YY-MM-DD	DRAWING-NO.	ZG-NO.
ISSUE	ITEM NO.				
4th	60286-3		12-01-31	06836.0001.4	ZG002036_001_01

Fig. 5–3:
SOIC8-1: Dimensions Tape & Reel

5.2. Soldering, Welding, 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.tdk.com/en/service-center/downloads) or on the service portal (http://service.micronas.com).

5.3. 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 avai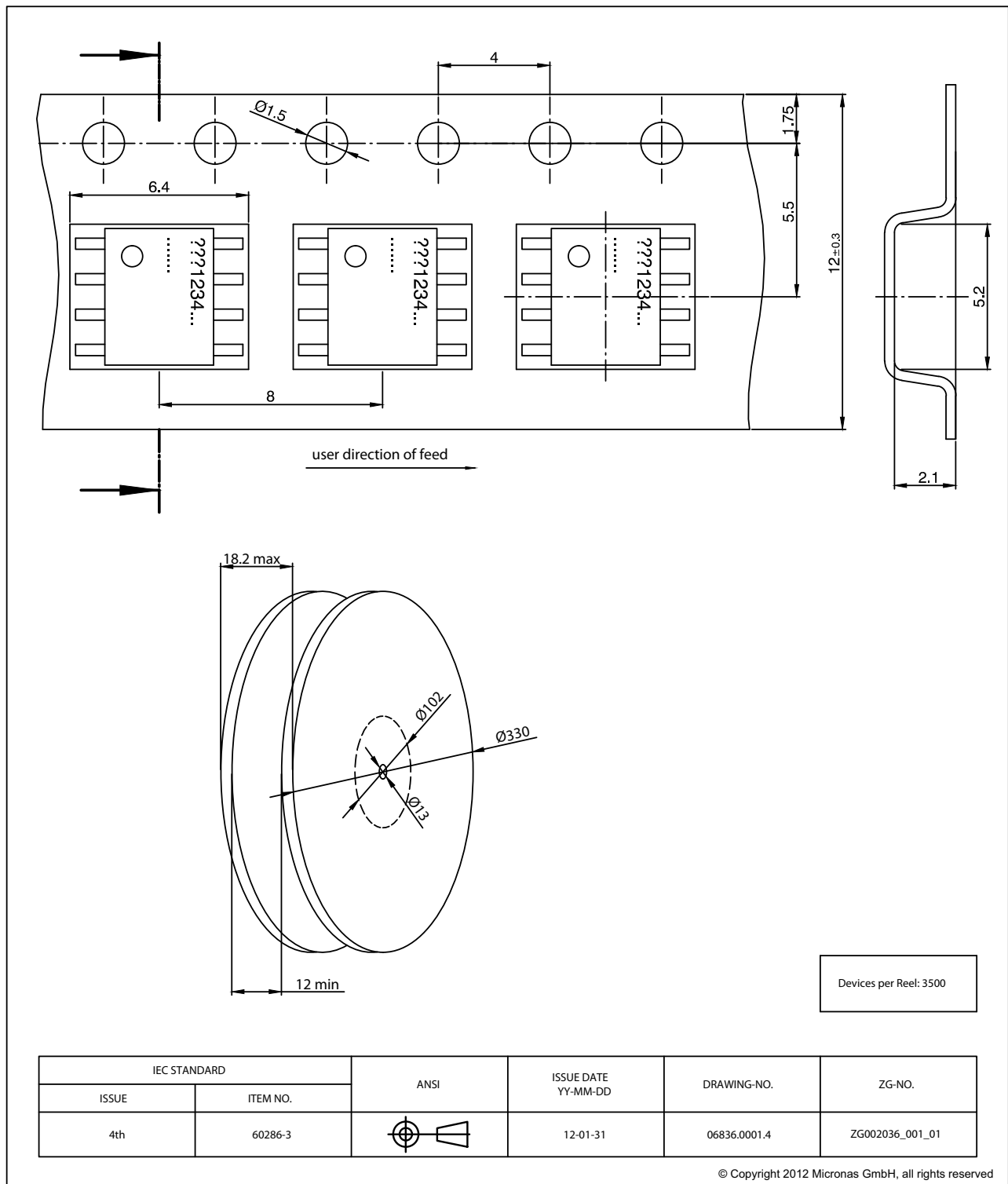lable on the TDK-Micronas website (https://www.micronas.tdk.com/en/service-center/downloads) or on the service portal (http://service.micronas.com).

5.4. Size of Sensitive Area

Hall-plate area = 125 µm x 125 µm (active area of the complete pixel cell).

See Fig. 5–1 on page 34 for more information on the Hall-plate position.

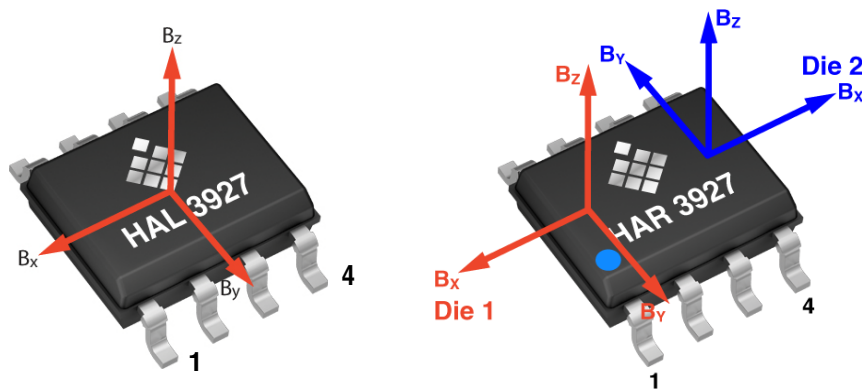## 5.5. Definition of Magnetic-Field Vectors

Fig. 5–4: Definition of magnetic-field vectors for HAL/HAR 3927

Note   Die 2 is 180° rotated in relation to die 1. Therefore the measurement values of X and Y components have opposite signs compared to die 1.

5.6. Pin Connections and Short Description

Table 5–1: Pin connection SOIC8 single die

Pin No.	Pin Name	Type	Short Description
1	VSUP	SUPPLY	Supply Voltage
2	GND	GND	Ground
3	TEST	I/O	Test
4	OUT	I/O	Output and Programming
5, 6, 7, 8	NC	–	Not connected

Table 5–2: Pin connection SOIC8 dual die

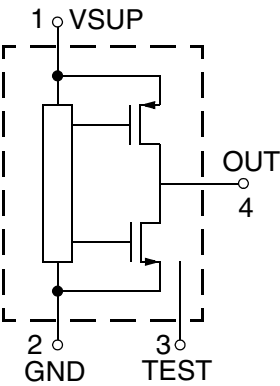| Pin No.	Pin Name	Type	Short Description
Die 1			
1	VSUP1	SUPPLY	Supply Voltage 1
2	GND1	GND	Ground 1
3	TEST1	I/O	Test 1
4	OUT1	I/O	Output and Programming 1
Die 2			
5	VSUP2	SUPPLY	Supply Voltage 2
6	GND2	GND	Ground 2
7	TEST2	I/O	Test 2
8	OUT2	I/O	Output and Programming 2

Fig. 5–5: Pin configuration HAL 3927
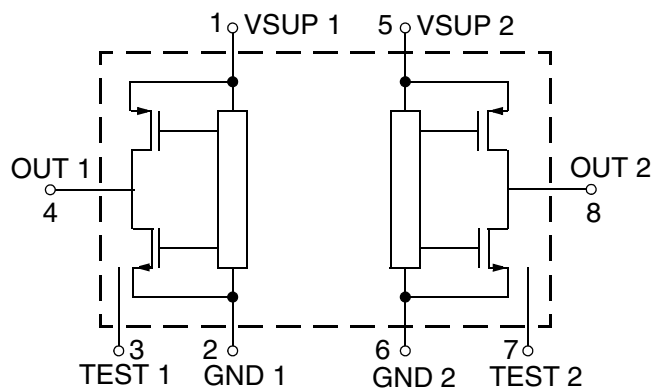
Note   Pin TEST and pin 5-8 must be connected to pin GND.

Fig. 5–6: Pin configuration HAR 3927

Note	Pin TEST1 must be connected to pin GND1 and pin TEST2 must be connected to pin GND2.

5.7. 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.

The 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 high-impedance circuit.

All voltages listed are referenced to ground (GNDx).

Table 5–3: Absolute maximum ratings

Symbol	Parameter	Pin Name	Min.	Max.	Unit	Condition
V_{SUP}	Supply Voltage	VSUPx	−8.5	16	V	t = 96 h
			−18	18	V	t = 1 h
V_{OUT}	Output Voltage	OUTx	−6	16	V	t = 96 h
			−6	18	V	t = 1 h
$V_{OUT}-V_{SUP}$	Excess of Output Voltage over Supply Voltage	OUTx, VSUPx	–	2	V	t = 96 h
			–	7	V	t = 1 h
I_{OUT}	Output Short Current	OUTx	−30	30	mA	[1] t = 96 h; output short to GND or V_{SUP}
B_{max}	Magnetic-Field Amplitude	–	−5	5	T	
T_J	Junction Temperature under Bias	–	−50	190	°C	t = 96 h
T_A	Ambient Temperature	–	−40	160	°C	[2]
$T_{storage}$	Transportation/Short-Term Storage Temperature	–	−55	150	°C	Device only without packing material

No cumulative stress for all parameter.
[1] Maximum resulting current with applied conditions
[2] For 96 h, not additive. Consider current consumption, mounting condition (e.g. overmold, potting) and mounting situation for T_A in relation to T_J. Please contact TDK-Micronas for other temperature requirements

Table 5–3: Absolute maximum ratings, continued

Symbol	Parameter	Pin Name	Min.	Max.	Unit	Condition
V_{ESD}	ESD Protection	VSUPx, GNDx, OUTx, TESTx	−2	2	kV	[3] For all pin combinations (including die 1 to die 2)
		VSUP1, GND1, OUT1, TEST1	−4	4	kV	[3] Die 1 alone or HAL 3927
		VSUP2, GND2, OUT2, TEST2	−4	4	kV	[3] Die 2 alone
[3] AEC-Q100-002-Rev H(100 pF and 1.5 kΩ)						

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5.8. 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, reduced reliability and lifetime of the device.

All voltages listed are referenced to ground (GNDx).

Table 5–4: Recommended operating conditions

Symbol	Parameter	Pin Name	Min.	Typ.	Max.	Unit	Condition
V_{SUP}	Supply Voltage	VSUPx	4.5	5.0	5.5	V	
I_{OUT}	Output Current	OUTx	−2.1	–	2.1	mA	
R_L	Load Resistor	OUTx	2.7	10	–	kΩ	Pull-Up or Pull-Down
C_L	Load Capacitance	OUTx	–	100	400	nF	Analog output BiPhase Bit time = 1 kHz
			–	4.7	15	nF	SENT output. 3 µs tick time
N_{PRG}	Number of Memory Programming Cycles	–	–	–	100	cycles	0°C < T_{amb} < 55°C
B_{AMP}	Recommended Magnetic-Field Amplitude	–	±20	–	±130	mT	
T_J	Junction Temperature [1]	–	−40	–	170	°C	For 1000 h
T_A	Ambient Temperature [2]	–	−40	–	150	°C	

[1] Depends on the temperature profile of the application. Please contact TDK-Micronas for life-time calculations.
[2] Consider current consumption, mounting condition (e.g. overmold, potting) and mounting situation for T_A and in relation to T_J

Note	It is possible to operate the sensor with magnetic fields down to ±5 mT. For magnetic fields below ±20 mT the sensor performance will be reduced.

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5.9. Characteristics

At $T_A = -40°C$ to $150°C$, $V_{SUPx} = 4.5$ V to 5.5 V, GNDx = 0 V, after programming and locking of the sensor, at Recommended Operation Conditions if not otherwise specified in the column "Conditions".
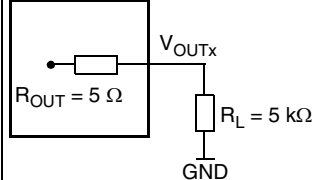Typical Characteristics for $T_A = 25$ °C and $V_{SUPx} = 5$ V.

Table 5–5: Characteristics

Symbol	Parameter	Pin Name	Limit Values			Unit	Conditions
			Min.	Typ.	Max.		
I_{SUP}	Supply Current	VSUPx	–	–	12.5	mA	[2] fusa_en bit = 0 Current consumption of each die.
			–	–	14	mA	[2] fusa_en bit = 1 Current consumption of each die.
f_{osc}	Internal Oscillator Frequency		–	32	–	MHz	
f_{sample}	Sampling Frequency		–	1.953	–	kSps	[1] Configurable
			–	3.906	–		
			–	7.812	–		
OUT_{Res}	Output Resolution	OUTx	–	12	–	bit	[1]
BW	Small Signal Bandwidth (-3 dB)	OUTx	–	2	–	kHz	[1] LP-Filter: OFF, bandwidth of each channel, fdecsel bit = 10 (f_{sample} = 8 kSps)
Overvoltage and Undervoltage Detection							
$V_{SUP,UVdown}$	Undervoltage Detection Level (down)	VSUPx	3.6	3.8	4.0	V	uv_level bit = 00
			3.8	4.1	4.4		[2] uv_level bit = 01
			3.95	4.25	4.55		[2] uv_level bit = 10
$V_{SUP,UVup}$	Undervoltage Detection Level (up)	VSUPx	3.85	4.05	4.25	V	uv_level bit = 00
			4.05	4.35	4.65		[2] uv_level bit = 01
			4.15	4.45	4.75		[2] uv_level bit = 10
$V_{SUP,OVdown}$	Overvoltage Detection Level (down)	VSUPx	8.5	8.9	9.3	V	ov_level bit = 00
			5.15	5.45	5.75		[2] ov_level bit = 01
$V_{SUP,OVup}$	Overvoltage Detection Level (up)	VSUPx	8.9	9.3	9.7	V	ov_level bit = 00
			5.4	5.7	6.0		[2] ov_level bit = 01

[1] Guaranteed by Design.
[2] Characterized on small sample size, not tested.

Table 5–5: Characteristics, continued

Symbol	Parameter	Pin Name	Limit Values			Unit	Conditions
			Min.	Typ.	Max.		
Open-Circuit Detection							
$V_{OUT,VSUP-Break}$	Output Voltage in case of Supply wire break	OUTx	0	–	0.1	V	$V_{SUP} = 5$ V $10\ k\Omega \leq R_L$
			0	–	0.2	V	$V_{SUP} = 5$ V $5\ k\Omega \leq R_L < 10\ k\Omega$
			0	–	0.35	V	$V_{SUP} = 5$ V $3\ k\Omega \leq R_L < 5\ k\Omega$
$V_{OUT,GND-Break}$	Output Voltage in case of GND wire break	OUTx	4.9	–	5.0	V	$V_{SUP} = 5$ V $10\ k\Omega \leq R_L$
			4.8	–	5.0	V	$V_{SUP} = 5$ V $5\ k\Omega \leq R_L < 10\ k\Omega$
			4.65	–	5.0	V	$V_{SUP} = 5$ V $3\ k\Omega \leq R_L < 5\ k\Omega$
Power-On Operation							
POR_{up}	Power on reset voltage (up)	VSUPx	3.6	3.8	4.0	V	
POR_{down}	Power on reset voltage (down)	VSUPx	3.2	3.4	3.6	V	
Analog Output Parameter							
$t_{startup}$	Start-up Time	OUTx					For definition see Fig. 5–7
			–	–	3.0	ms	[2][8] fusa_en bit = 0 fdecsel bit = 10
			–	–	6.5	ms	[2] fusa_en bit = 1 fdecsel bit = 10
$V_{SUP,DIAG}$	Supply Voltage required to get defined Output Voltage Level	VSUPx	–	–	2.49	V	
$V_{Error,Low}$	Output Voltage Range of Lower Error Band	OUTx	0	–	3	%V_{SUP}	$V_{SUP} > V_{SUP,DIAG}$ $10\ k\Omega \leq R_L$
			0	–	4	%V_{SUP}	$V_{SUP} > V_{SUP,DIAG}$ $5\ k\Omega \leq R_L < 10\ k\Omega$
			0	–	7	%V_{SUP}	$V_{SUP} > V_{SUP,DIAG}$ $R_L = 3\ k\Omega$
$V_{Error,High}$	Output Voltage Range of Upper Error Band	OUTx	97	–	100	%V_{SUP}	$V_{SUP} > V_{SUP,DIAG}$ $10\ k\Omega \leq R_L$
			96	–	100	%V_{SUP}	$V_{SUP} > V_{SUP,DIAG}$ $5\ k\Omega \leq R_L < 10\ k\Omega$
			93	–	100	%V_{SUP}	$V_{SUP} > V_{SUP,DIAG}$ $R_L = 3\ k\Omega$
$V_{Error,HighZ,Low}$	Output Voltage Range of Low Error Band if output is in High-Z mode	OUTx	0	–	7	%V_{SUP}	$R_L = 3\ k\Omega$
$V_{Error,HighZ,High}$	Output Voltage Range of High Error Band if output is in High-Z mode	OUTx	93	–	100	%V_{SUP}	$R_L = 3\ k\Omega$

[2] Characterized on small sample size, not tested.
[8] If $dV_{SUP}/dt < 1$ V/ms and uv_level bit = 01 or 10 selected, the startup time is delayed by additional 1.2 ms.

Table 5–5: Characteristics, continued

Symbol	Parameter	Pin Name	Limit Values			Unit	Conditions
			Min.	Typ.	Max.		
DNL	Differential Non-Linearity of D/A converter	OUTx	−0.9	–	0.9	LSB	
DAC_{INL}	Non-Linearity of Output Stage	OUTx	−0.1	–	0.1	$\%V_{SUP}$	For definition see Fig. 5–8
E_R	Ratiometric Error of Output (Error in V_{OUT}/V_{SUP})	OUTx	−0.1	–	0.1	$\%V_{SUP}$	
V_{OUT,DAC_ERR_RT}	Absolute D/A converter error at 25°C	OUTx	−0.18	–	0.18	$\%V_{SUP}$	[2][3] For definition see Fig. 5–8
$\Delta V_{OUT,DAC\_ERR}$	Absolute D/A converter error drift over Temperature related to 25°C	OUTx	−0.08	–	0.08	$\%V_{SUP}$	[2][3]
V_{OUTH}	Output High Voltage	OUTx	93	–	–	$\%V_{SUP}$	[4] $3\ k\Omega \leq R_L$
V_{OUTL}	Output Low Voltage	OUTx	–	–	7	$\%V_{SUP}$	[4] $3\ k\Omega \leq R_L$
$t_{r(O)}$	Rise Time of Output	OUTx	–	0.100	0.125	ms	[2] LP-Filter: OFF For definition see Fig. 5–9
$t_{d(O)}$	Delay Time of Output	OUTx	–	–	$3.5/f_{sample}$		[1] For f_{sample}, please refer to page 43. For definition see Fig. 5–9
OUT_{Noise}	Output Noise RMS	OUTx	–	1.7	3.0	mV	[2][5] Output range $10\%V_{SUP}$ to $90\%V_{SUP}$
$R_{OUT,analog}$	Output Resistance over Recommended Operating Range in Analog Output Mode	OUTx	–	0.15	5	Ω	$V_{OUTLmax} \leq V_{OUT} \leq V_{OUTHmin}$ IC $R_{OUT} = 5\ \Omega$ V_{OUTx} $R_L = 5\ k\Omega$ GND

[1] Guaranteed by Design.
[2] Characterized on small sample size, not tested.
[3] The accuracy of the output voltage at clamp low / clamp high voltage over temperature range can be calculated with the following formula: $\Delta V_{OUTCL,CH} = (V_{OUT,DAC\_ERR\_RT}^2 + \Delta V_{OUT,DAC\_ERR}^2)^{(1/2)}$.
[4] Signal band area with full accuracy is located between V_{OUTL} and V_{OUTH}. The sensors accuracy is reduced below V_{OUTL} and above V_{OUTH}.
[5] 4 kHz digital low-pass filter; ±20 mT min. magnetic-field amplitude; f_{BW} = 22.5 kHz.
[6] Measured from/to 1.1 V to/from 3.8 V with C_L = 4.7 nF, V_{SUP} = 5 V

Table 5–5: Characteristics, continued

Symbol	Parameter	Pin Name	Limit Values			Unit	Conditions
			Min.	Typ.	Max.		
SENT Output Parameter							
V_{OL}	Output Low Voltage	OUTx	–	–	0.5	V	Recommended SENT load and 3 µs tick time
V_{OH}	Output High Voltage	OUTx	4.1	–	–	V	
t_{rise_sym}	Rise Time of Output symmetrical to Fall Time	OUTx	–	1.0	–	µs	[2][6]sent_slew_rate bit = 1000
			–	1.2	–		[2][6]sent_slew_rate bit = 1010
			–	1.6	–		[2][6]sent_slew_rate bit = 1100
			–	2.7	–		[2][6]sent_slew_rate bit = 1110
t_{rise_asym}	Rise Time of Output asymmetrical to Fall Time (recommended for SENT)	OUTx	–	1.5	–	µs	[2][6]sent_slew_rate bit = 1001
			–	2.7	–		[2][6]sent_slew_rate bit = 1011
			–	5.2	–		[2][6]sent_slew_rate bit = 1101
			–	10.3	–		[2][6]sent_slew_rate bit = 1111
t_{fall}	Fall Time of Output	OUTx	–	1.0	–	µs	[2][6]sent_slew_rate bit = 100x
			–	1.2	–		[2][6]sent_slew_rate bit = 101x
			–	1.6	–		[2][6]sent_slew_rate bit = 110x
			–	2.7	–		[2][6]sent_slew_rate bit = 111x
t_{tick}	SENT Tick Time	OUTx	1.41	1.50	1.59	µs	
			1.88	2.00	2.12	µs	
			2.35	2.50	2.65	µs	
			2.58	2.75	2.92	µs	
			2.82	3.00	3.18	µs	
			5.64	6.00	6.36	µs	
			11.28	12.00	12.72	µs	
t_{S_Init}	SENT Start-up Time	OUTx					Initial start-up time until output is ready. For definition see Fig. 5–7.
			–	–	1.5	ms	[2][7] fusa_en bit = 0
			–	–	3.1	ms	[2][7] fusa_en bit = 1
t_{S_high}	SENT drive high	OUTx	–	–	1	ms	For definition see Fig. 5–7
$t_{latency}$	SENT average Latency	OUTx	–	0.75	–	ms	[1] fdecsel bit = 10, t_{S_frame} = 0.5 ms, LP-Filter: OFF, sent_repetition_rate = 2 kHz
t_{wcresp}	SENT Step Response Time (worst case)	OUTx	–	–	1	ms	
$R_{OUT,SENT}$	Output Resistance over Recommended Operating Range in SENT Output Mode	OUTx	–	52	70	Ω	$V_{OUTLmax} \leq V_{OUT} \leq V_{OUTHmin}$

[1] Guaranteed by Design.
[2] Characterized on small sample size, not tested.
[6] Measured from/to 1.1 V to/from 3.8 V with C_L = 4.7 nF, V_{SUP} = 5 V.
[7] If dV_{SUP}/dt < 1 V/ms and uv_level bit = 01 or 10 are selected, the start-up time can be delayed by additional 1.2 ms.

Table 5–5: Characteristics, continued

Symbol	Parameter	Pin Name	Limit Values			Unit	Conditions
			Min.	Typ.	Max.		
SOIC8 Package (HAL 3927)							
R_{thja}	Thermal Resistance Junction to Air	–	–	–	140	K/W	[8] Determined with a 1S0P board
		–	–	–	93	K/W	[8] Determined with a 2S2P board
R_{thjc}	Thermal Resistance Junction to Case	–	–	–	30	K/W	[8] Determined with a 1S0P and 2S2P board
SOIC8 Package (HAR 3927)							
R_{thja}	Thermal Resistance Junction to Air	–	–	–	116	K/W	[8] Determined with a 1s1p board
		–	–	–	111	K/W	[8] Determined with a 2s2p board
R_{thjc}	Thermal Resistance Junction to Case	–	–	–	30	K/W	[8] Determined with a 1s1p board
		–	–	–	30	K/W	[8] Determined with a 2s2p board
R_{ISOL}	Isolation Resistance	GND1, GND2	4	–	–	MΩ	[9] Between two dies (Between GND1 and GND2 pin)

[8] Self-heating calculation see Section 6.1. on page 53.
[9] Galvanic isolation of GNDs not tested

5.10. Notes for Electrical Characteristics

5.10.1. Power-On Operation
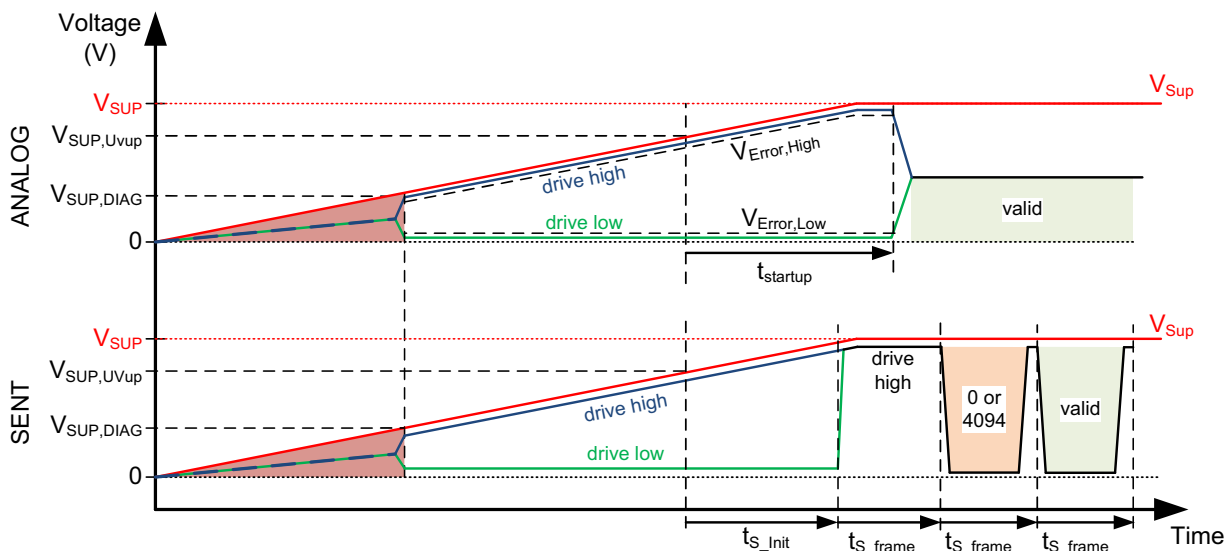
SENT Frame Time depends on customer configuration:
SETUP_OUTPUT[7] = 0: 1/sent_repetition_rate (1/2.66kHz – 0.5 kHz) or tick length
SETUP_OUTPUT[7] = 1: Depends on sent_tick_time and frame format (different for valid data and 0/4094)

Fig. 5–7: Start-up behavior of HAL/HAR 3927

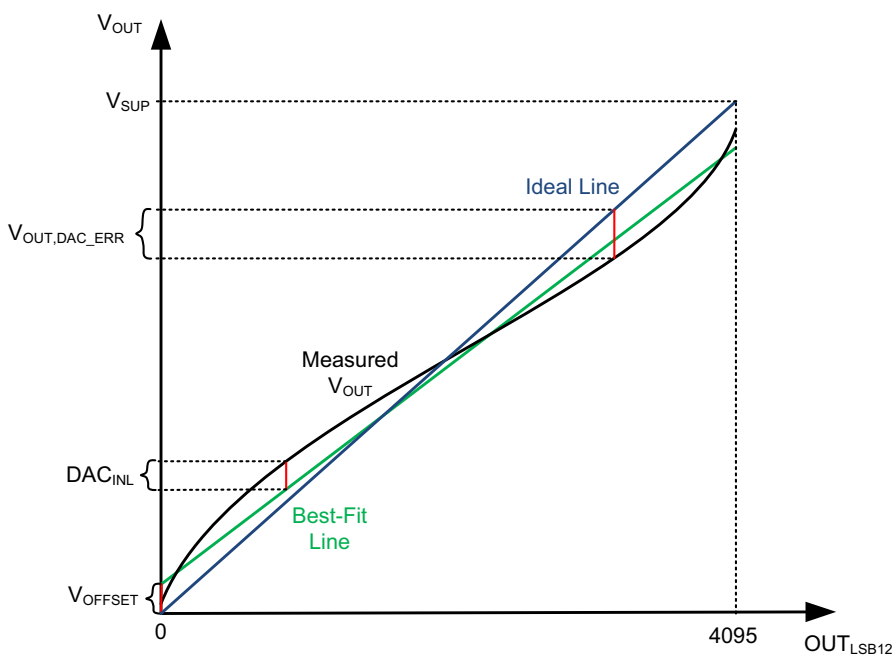### 5.10.2. Definition of Parameter INL and absolute D/A Converter Error

Fig. 5–8: Definition of INL and absolute D/A converter error

5.10.3. Definition of Rise and Delay Time of Output
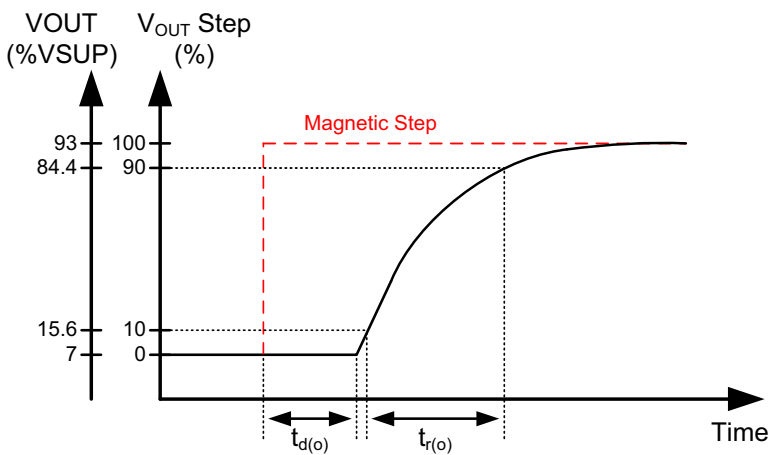
Fig. 5–9: Definition of rise and delay time of output

5.11. Magnetic Characteristics

At T_A = −40 °C to 150 °C, V_{SUPx} = 4.5 V to 5.5 V, GNDx = 0 V, after programming and locking of the sensor, at Recommended Operation Conditions if not otherwise specified in the column "Conditions".
Typical characteristics for T_A = 25 °C and V_{SUPx} = 5 V.

Table 5–6: Magnetic characteristics

Symbol	Parameter	Pin Name	Min.	Typ.	Max.	Unit	Conditions
Θ_{RANGE}	Detectable angle range	OUTx	0	–	360	°	[7]
Θ_{res}	Angle resolution	OUTx	–	–	0.09	°	[7] (360°/4096)
$E_{\Theta linxy\_RT}$	XY angle linearity error (on output of CORDIC)	OUTx	−0.3	–	0.3	°	[1][2][3][5] INL T_A = 25 °C; V_{SUP} = 5 V B_{AMP} = ± 20 mT
$E_{\Theta linxy\_temp}$	XY angle linearity error over temperature related to 25 °C (on output of CORDIC)	OUTx					T_A = −40 ... 150 °C V_{SUP} = 5 V
			−1.0	–	1.0	°	[2][3][5][6] B_{AMP} = ±30 mT
			−1.5	–	1.5	°	[1][2][3][5] B_{AMP} = ±20 mT
$E_{\Theta linxy\_RT\_life}$	XY angle linearity error over life time (on output of CORDIC)	OUTx	–	±1.3	–	°	[2][3][4][5][6] T_A = 25 °C; V_{SUP} = 5 V; B_{AMP} = ± 20 mT
$ASMm_{XY}$	Absolute Sensitivity Mis-match between X and Y Hall-plates	OUTx	−2	–	2	%	[1][8] T_A = 25 °C
$ASMm_{X/Y\_Z}$	Absolute Sensitivity Mis-match between X/Y and Z Hall-plates	OUTx	−4	–	4	%	[1][8] T_A = 25 °C
$Sense_{XYZ}$	Sensitivity of X,Y and Z Hall-plate	OUTx	123	128	133	LSB/ mT	[1] T_A = 25 °C
ΔSMm_{XY}	Thermal Sensitivity Mis-match Drift of calibrated signals between X and Y channel	OUTx	−2	–	2	%	[1][8] Related to T_A = 25 °C
$\Delta SMm_{X/Y\_Z}$	Thermal Sensitivity Mis-match Drift of calibrated signals between X/Y and Z channel	OUTx	−2.5	–	2.5	%	[1][8] Related to T_A = 25 °C
$Offset_{XY}$	Offset of X and Y Hall-plates	OUTx	−20	–	20	LSB_{15}	[1][8] T_A = 25 °C
$Offset_Z$	Offset of Z Hall-plate	OUTx	−12	–	12	LSB_{15}	[1][8] T_A = 25 °C

[1] Characterized on small sample size, 3-sigma values, not tested for each device.
[2] Pure sine/cosine w/o distortion (ideal diametral magnet). Zero angle calibration in the system. The supply voltage V_{SUP} is regarded as constant over temperature.
[3] After proper setpoint linearization done at 25 °C.
[4] After 1008 h HTOL.
[5] Calculated/simulated angular error based on characterization and not on single error summation.
[6] Based on Simulation Model, 3-sigma values (not tested).
[7] Guaranteed by Design.
[8] Can be compensated in customer application.

Table 5–6: Magnetic characteristics, continued

Symbol	Parameter	Pin Name	Min.	Typ.	Max.	Unit	Conditions
ΔOffset_{XY}	Offset Drift of X and Y Hall-plates	OUTx	−45	–	45	LSB_{15}	[1][8] Related to $T_A = 25\ °C$
ΔOffset_{Z}	Offset Drift of Z Hall-plate	OUTx	−45	–	45	LSB_{15}	[1][8] Related to $T_A = 25\ °C$
$E_{\Theta PhaseXY}$	Phase Error between X and Y Hall-plates	OUTx	–	±2	–	°	[1][8]
$E_{\Theta PhaseX/Y\_Z}$	Phase Error between X/Y and Z Hall-plates	OUTx	–	±2	–	°	[1][8]
$\Delta\text{SMm}_{XYZ\_life}$	Relative Sensitivity Mismatch Drift between X, Y and Z Hall-plates over life time	OUTx	–	±3	–	%	[1][4]
$\Delta\text{Offset}_{XY\_life}$	Offset Drift of calibrated signals of X or Y channel over life time	OUTx	–	±40	–	LSB_{15}	[1][4]
$\Delta\text{Offset}_{Z\_life}$	Offset Drift of calibrated signals of Z channel over life time	OUTx	–	±5	–	LSB_{15}	[1][4]

[1] Characterized on small sample size, 3-sigma values, not tested for each device.
[4] After 1008 h HTOL.
[8] Can be compensated in customer application.

5.12. Temperature Sensor

At $T_A = -40\,°C$ to $150\,°C$, $V_{SUPx} = 4.5\,V$ to $5.5\,V$, $GNDx = 0\,V$, after programming and locking of the sensor, at Recommended Operation Conditions if not otherwise specified in the column "Conditions".
Typical characteristics for $T_A = 25\,°C$ and $V_{SUPx} = 5\,V$.

Table 5–7: Temperature sensor conditions at recommended operating conditions

Symbol	Parameter	Pin Name	Min.	Typ.	Max.	Unit	Conditions
$TEMP\_ADJ_{Gain}$	Gain of Temperature Sensor	OUTx	–	89.25	–	$LSB_{15}/°C$	[1] for TEMP_ADJ register
$TEMP\_ADJ_{Offset}$	Temperature Sensor Offset	OUTx	–	3720	–	LSB_{15}	[1] for TEMP_ADJ register
$TEMP\_SENT_{Gain}$	Gain of Temperature Sensor for SENT Output	OUTx	–	8.0	–	$LSB_{12}/°C$	[1] SENT slow and fast channel
$TEMP\_SENT_{Offset}$	Temperature Sensor Offset for SENT Output	OUTx	–	585.5	–	LSB_{12}	[1] SENT slow and fast channel
ΔT_{Lin}	Temperature Sensor Linearity Error	OUTx	–2	–	2	°C	[2] Junction Temperature
ΔT_{Acc}	Temperature Sensor Accuracy	OUTx	–5	–	5	°C	[2] Junction Temperature

[1] Not tested.
[2] Characterized on small sample size, 3-sigma values, not tested for each device.

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6. Application Notes

6.1. Ambient Temperature

Due to the internal power dissipation, the temperature on the silicon chip (junction temperature T_J) is higher than the temperature outside the package (ambient temperature T_A).

$$T_J = T_A + \Delta T$$

The maximum ambient temperature is a function of power dissipation, maximum allowable die temperature and junction to ambient thermal resistance (R_{thja}). With a typical supply voltage of 5.0 V the power dissipation P is 0.063 W per die. The junction to ambient thermal resistance R_{thja} is specified in Section 5.9. on page 43.

The difference between junction and ambient air temperature is expressed by the following equation (at static conditions and continuous operation):

$$\Delta T = P \times R_{thjX}$$

The X represents junction to air, case or solder point.

For worst case calculation, use the max. parameters for I_{SUP} and R_{thjX}, and the max. value for V_{SUP} from the application.

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

6.2. EMC and ESD

Please contact TDK-Micronas for detailed information on EMC and ESD.

6.3. Application Circuits for HAL/HAR 3927
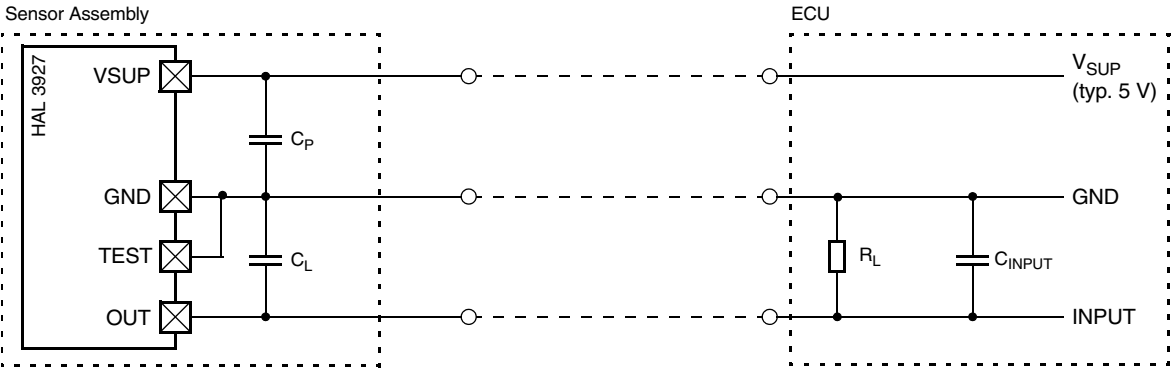
Analog Outputs

Fig. 6–1: Recommended application circuit for HAL 3927 in analog output mode (pull-down)
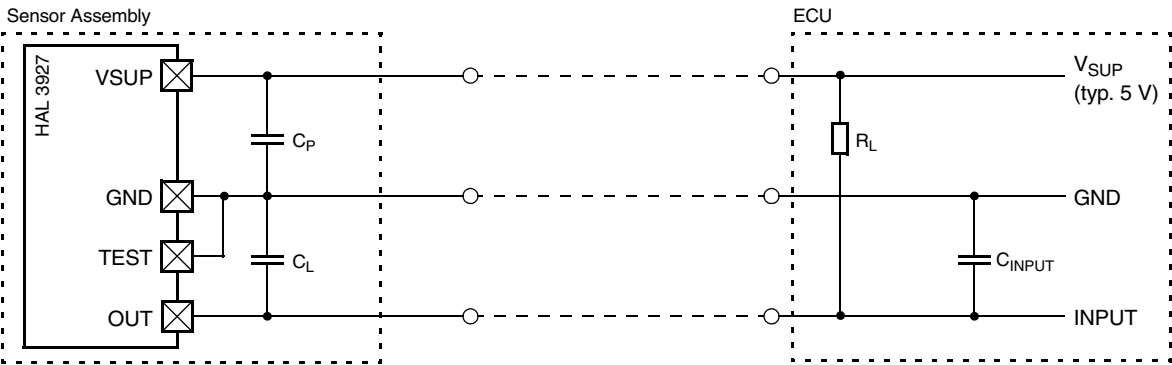

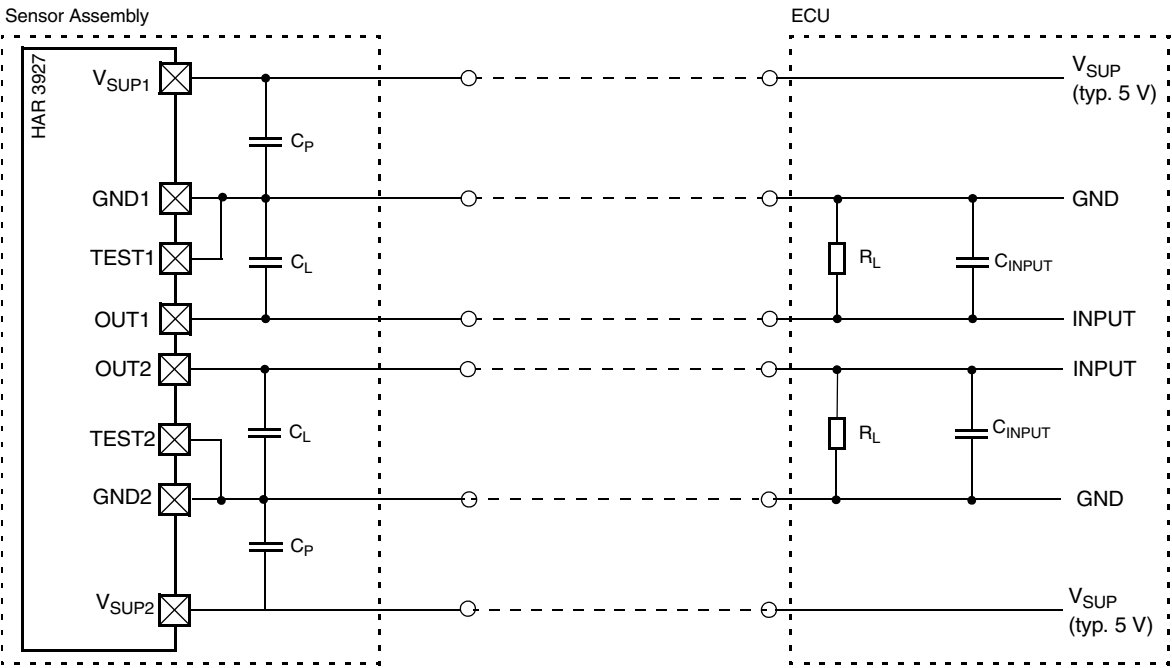**Fig. 6–2:** Recommended application circuit for HAL 3927 in analog output mode (pull-up)

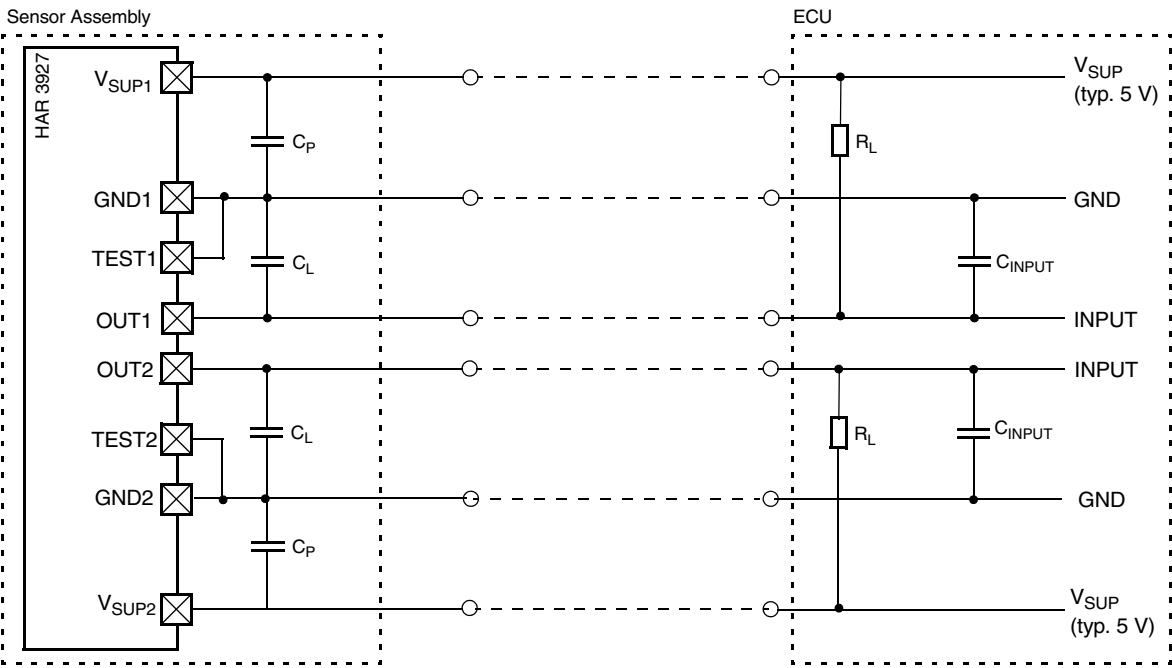**Fig. 6–3:** Recommended application circuit for HAR 3927 in analog output mode (pull-down)

Fig. 6–4: Recommended application circuit for HAR 3927 in analog output mode (pull-up)

Table 6–1: Recommended components in analog output mode

Name	Recommended Value
C_P	100 nF (470 nF for CISPR Class 5)
$C_L + C_{INPUT}$	100 nF
$R_{L\ Pull-down}$	10 kΩ
$R_{L\ Pull-up}$	10 kΩ

SENT Outputs

In case of SAE J2716 SENT output mode, it is recommended to add a filter structure at the output pin for having a SENT standard compliant output slew rate.
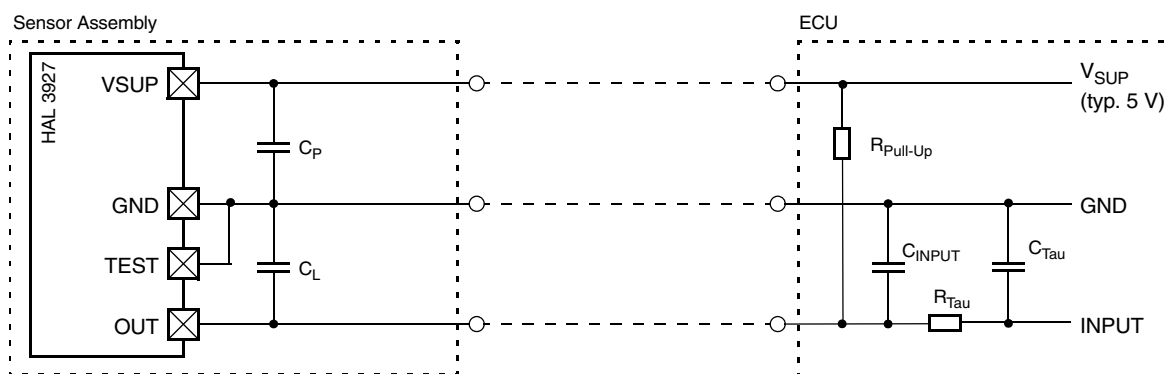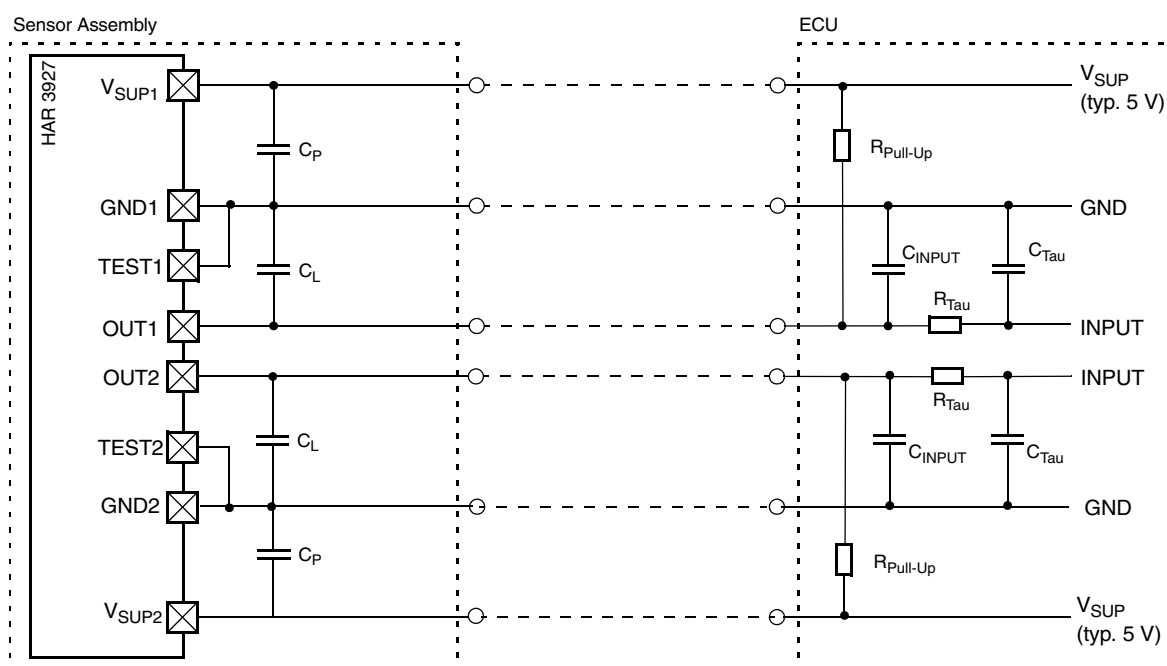

Fig. 6–5: Recommended application circuit for HAL 3927 in SENT mode

Fig. 6–6: Recommended application circuit for HAR 3927 in SENT mode

Table 6–2: Recommended components in SENT mode

Name	SENT Specification	Recommended Value
C_P	N/A	470 nF
C_{INPUT}	< 0.1 nF	68 pF
C_{Tau}	1.54 nF – 2.86 nF	2.2 nF
$R_{Pull-Up}$	10 kΩ – 55 kΩ	10 kΩ
R_{Tau}	448 Ω – 672 Ω	560 Ω
C_L	N/A	4.7 nF

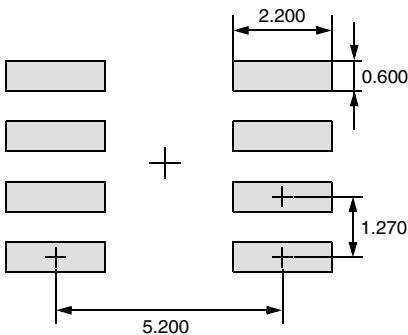## 6.4. Recommended Pad Size SOIC8 Package

Fig. 6–7: Pad size recommendation for SOIC8 package (all dimensions in mm)

HAL/HAR 3927

7. Programming of the Sensor

HAL/HAR 3927 features two different customer modes. In **Application Mode**, the sensors provide an analog output voltage or a digital output signal in accordance with the SENT standard. In **Programming Mode (Listen Mode)** it is possible to change the register settings of the sensor.

After power-up, the sensor is always operating in **Application Mode.** It is switched to **Programming Mode** by a BiPhase-M protocol via output voltage modulation. Therefore the programming device needs to provide a sync pulse at the output pin.

7.1. Programming Interface

In Programming Mode, HAL/HAR 3927 is addressed by modulating a serial telegram on the sensor's output pin. 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 at typically 50% of the bit time. After each bit, a level change occurs (see Fig. 7–1).

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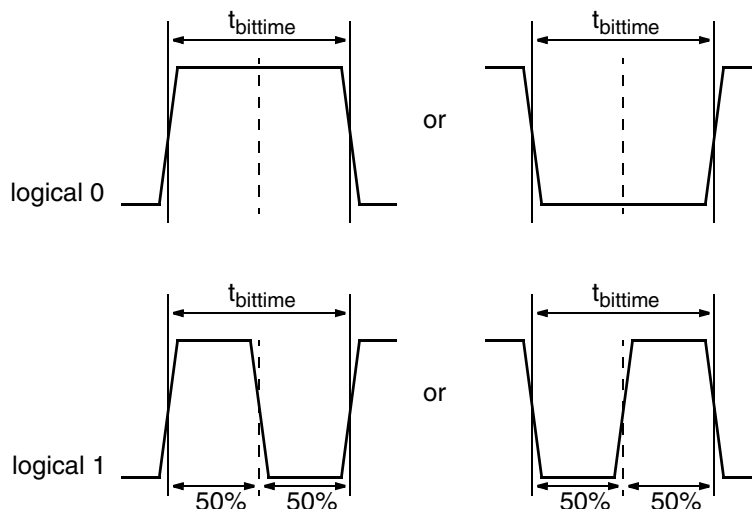

Fig. 7–1: Definition of logical 0 and 1 bit

Table 7–1: Telegram parameters (All voltages are referenced to GNDx.)

Symbol	Parameter	Pin Name	Limit Values			Unit	Conditions
			Min.	Typ.	Max.		
t_{H_bbit}	Host BiPhase bit time	OUTx	0.01	–	1.1	ms	
V_{H_OUTL}	Host OUT Pin Voltage for Low Level during Programming	OUTx	0	–	0.5	V	
V_{H_OUTH}	Host OUT Pin Voltage for High Level during Programming	OUTx	4.5	–	5.0	V	
SR	Host slew rate BiPhase protocol	OUTx	10	–	–	V/µs	[1] For recommended application circuit.
$V_{SUPProgr}$	V_{SUP} Voltage for memory programming	VSUP	4.5	5.0	5.5	V	
[1] Not tested.							

7.2. Programming Environment and Tools

For the programming of HAL/HAR 3927 during product development, a programming tool including hardware and software is available on request. It is recommended to use the TDK-Micronas tool kit (TDK MSP V1.x and Lab View Programming Environment) in order to facilitate the product development. The details of programming sequences are content of the application notes "HAL/HAR 3927 User Manual" and "HAL/HAR 3927 Programming Guide".

7.3. Programming Information

For reliability in service, it is mandatory to set the customer lock bit (SETUP_SUPERVISION[15]) to 1 after final adjustment and final EEPROM programming.

Note – After the customer lock is activated (by writing and power-on-reset), it is not possible to program the sensor anymore.
– Because the lock bit is also included in the customer checksum, the checksum has to be calculated considering the lock bit.

To lock the sensor, the customer checksum has to be calculated and stored as described in application note "HAL/HAR 3927 User Manual". Refer to this section and the following flowchart for more details.
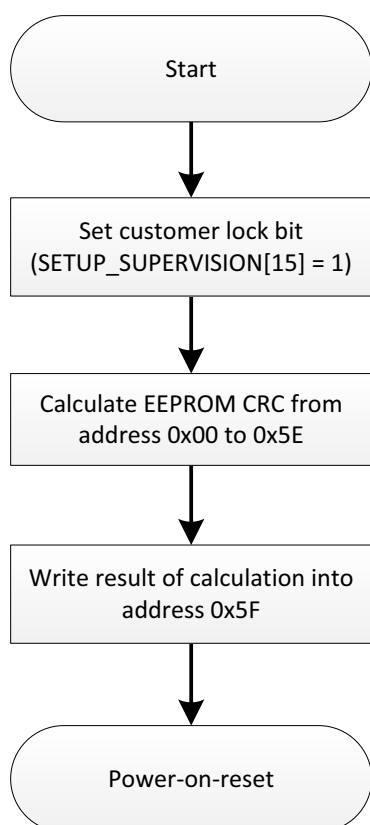
Fig. 7–2: Locking the Sensor

The successful setting of the customer lock bit shall be checked, e.g. by reading back the customer lock bit after programming and downloading it to the shadow RAM, but before a power-on-reset. The lock mechanism becomes only active after the next power-on-reset.

Electro-static discharges (ESD) may disturb the supply voltage during programming. Please take precautions against ESD.

A programming tool including hardware and software can be provided for product evaluation and application development. It is recommended to use the TDK-Micronas tool kit to simplify the product development phase.

The HAL/HAR 3927 allows to read the registers after locking, provided that valid commands with correct CRC are recognized by the sensor and the over-current detection is not disabled (see Table 3–9 in the application note "HAL/HAR3927 User Manual"). The programming command does not have any effect on the memory of locked devices.

Note   A description of the communication protocol and the programming of the sensor is available in a separate document (application note "HAL/HAR 3927 Programming Guide").

8. Document History

1. Advance Information "HAR 3927 Robust Dual-Die Programmable 2D Position Sensor with Analog and SENT Output Interface", May 13, 2020, AI000222_001EN.
   First release of the advance information.

2. Data Sheet "HAR 3927 Robust Dual-Die Programmable 2D Position Sensor with Analog and SENT Output Interface", July 27, 2023, DSH000215_001EN.
   First release of the data sheet.
   Describing ROM-ID release: 4301 (mass production release):

Major changes compared to previous Advance Information:

   – Electrical and magnetic characteristics updated
   – Parameter t_{UV} and t_{OV} removed as it is covered by overall FDTI

3. Data Sheet "HAL/HAR 3927 Robust Programmable 2D Position Sensor with Analog and SENT Output Interface", Oct. 15, 2024, DSH000215_002EN.
   Second release of data sheet.

Major change:

   – HAL 3927 added