MICRONAS

Hardware Documentation

Advance Information

HAL® 302x

Fast Stray-Field Robust Motor Position Sensor Family with Analog Output

Edition July 14, 2023
AI000244_002EN

Copyright, Warranty, and Limitation of Liability

TDK-Micronas Trademarks

– HAL

– HAC

Third-Party Trademarks

Contents

Fast Stray-Field Robust Motor Position Sensor Family with Analog Output

Release Note:Revision bars indicate significant changes to the Advance Information rev. 1.

1. Introduction

HAL 302x is a fast angular position sensor family addressing the need for stray-field robust motor position sensing as well as the ISO 26262 compliance. This new sensor family features differential or single-ended sine and cosine analog outputs with passive wire-break detection working with pull-up or pull-down resistors. The rotation angle of a magnet can be calculated by an external A/D-converter and a microcontroller/ECU.

This new family has two members. Both members measure, based on Hall-effect technology, vertical magnetic-field components (B_Z). HAL 3020 uses an array of three horizontal Hall plates. HAL 3021 uses an array of six horizontal Hall plates. Speciality of HAL 3021 is that the device offers a higher robustness against static and dynamic mechanical tolerances. The Table 1–1 describes the different family members.

Table 1–1: HAL 302x family overview

Type	Hall Plate Configuration	Device Specific Features
HAL 3020	Z1, Z3, Z5	– Lower current consumption
HAL 3021	Z1, Z2, Z3, Z4, Z5, Z6	– Higher robustness against static and dynamic mechanical tolerances – Higher signal-to-noise ratio – Lower inherent angular error drifts – Support of closer air gaps and smaller target magnets

Both devices are able to suppress external magnetic stray-fields by design by an array of Hall plates. Only a simple two-pole magnet in an end-of-shaft configuration is required to measure the absolute angular position. The magnet can be placed above or below the sensor.

The measuring principle of the Hall plate array minimizes the errors due to supply voltage and temperature variations.

Major characteristics like sine and cosine gain, offset, (absolute) 0-angle, orthogonality and bandwidth can be adjusted using the integrated signal path by programming the non-volatile memory of HAL 302x.

This product is defined as Safety Element out of Context (SEooC) ASIL C ready according to ISO 26262:2018. HAL 302x contains on-board diagnostic features, such as overvoltage and undervoltage detection as well as wire-break monitoring during normal operation.

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

The sensor is available in the SOIC8 SMD package.

1.1. Major Applications

Thanks to the sensor's analog signal path and its stray-field robustness, the HAL 302x is a potential solution for the following application examples:

– Rotary position measurement for commutation of:
  - brushless DC motors (BLDC)
  - permanent magnet synchronous motors (PMSM)
  - AC induction motors (ACIM)
– Clutch and transmission actuators
– Starter/generator systems
– Electromechanical brake booster
– Electric pumps
– Electric valves

1.2. Features

– High-speed 360° contactless angle measurement extremely robust against temperature and stress influence
– EMC robust differential or single-ended sine/cosine analog output signals
– Ratiometric analog outputs related to the supply voltage
– Compensation of magnetic stray-fields according to ISO 11452-8:2015
– SEooC ASIL C ready according to ISO 26262:2018 to support Functional Safety applications (The device can be integrated in automotive safety related systems up to ASIL D)
– Various integrated diagnostic mechanisms ensure correct operation and enable simplified external safety supervision
– Operates from 3.0 V up to 5.5 V supply voltage
– Fast response time and high output bandwidth for applications up to at least 30,000 rpm
– Operates from –40 °C up to 170 °C junction temperature (max. ambient temperature: 160 °C)
– Programming via the sensor's output pin. No additional programming pin required
– Configurable signal processing parameter, like output gain, offset, (absolute) 0-angle, orthogonality and magnetic signal bandwidth
– Overvoltage and reverse-voltage protection

2. Ordering Information

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

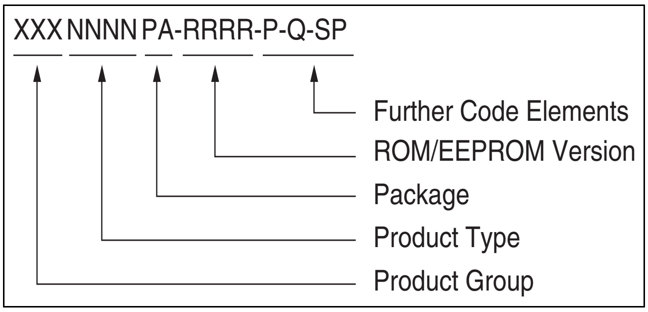


Fig. 2–1: Ordering Code Principle

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

2.1. Device-Specific Ordering Code

The HAL 302x is available in the following package variant.

Table 2–1: Available package

Package Code (PA)	Package Type
DJ	SOIC8

The HAL 302x can be provided with different operating voltage and output behavior configurations.

Table 2–2: Legend: Possible supply voltage and output behavior configurations

Option Code	Configurations
	xxxx – TDK-Micronas Factory Calibration
xxAx:	Non-calibrated sensor
xxBx:	Pre-calibrated sensor
	xxxx – Operating Supply Voltage and Output Behavior
xxxA:	V_{SUP} = 3.0 V to 3.6 V, non-ratiometric to V_{SUP}
xxxB:	V_{SUP} = 4.5 V to 5.5 V, non-ratiometric to V_{SUP}
xxxC:	V_{SUP} = 3.0 V to 5.5 V, ratiometric to V_{SUP}
–	**xxxx – Not used**
Example	xxAA: V_{SUP} = 3.0 V to 3.6 V, non-ratiometric to V_{SUP}, Non-calibrated sensor

Any combination of the option code (see Table 2–2) can be available upon request. The combination of the option codes result in a device-specific ROM/EEPROM Version number (RRRR). Please contact TDK-Micronas for more details.

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

Table 2–3: Ordering information

Product	**Package**	**Option Code**	**ROM/EEPROM Version** [-RRRR]	**Further Code** [-P-Q-SP]	**Comments**
HAL 3020	DJ = SOIC8	xxBC	Please contact TDK-Micronas for more details	See TDK-Micronas Ordering Information	Any combination of the option code can be provided (see Table 2–2) pending on yearly volume.
HAL 3021	DJ = SOIC8	xxBC			

Table 2–4: Available ordering code and corresponding package marking

Ordering Code	**Package Marking**	**Description**
HAL3020DJ-[RRRR-P-Q-SP]		Line 1: Product Type / ROM/EEPROM Version Line 2: Lot number Line 3: Date code / Special Procedure SB (optional)
HAL3021DJ-[RRRR-P-Q-SP]		

3. Functional Description

3.1. General Function

HAL 302x is a fast angular position sensor family based on Hall-effect technology. The HAL 3020 includes three horizontal Hall plates arranged on a circle in an angle distance of 120°. The HAL 3021 expands the Hall plate array to six plates with an angle distance of 60°. The array of Hall plates has a diameter C of 1.91 mm (nominal).

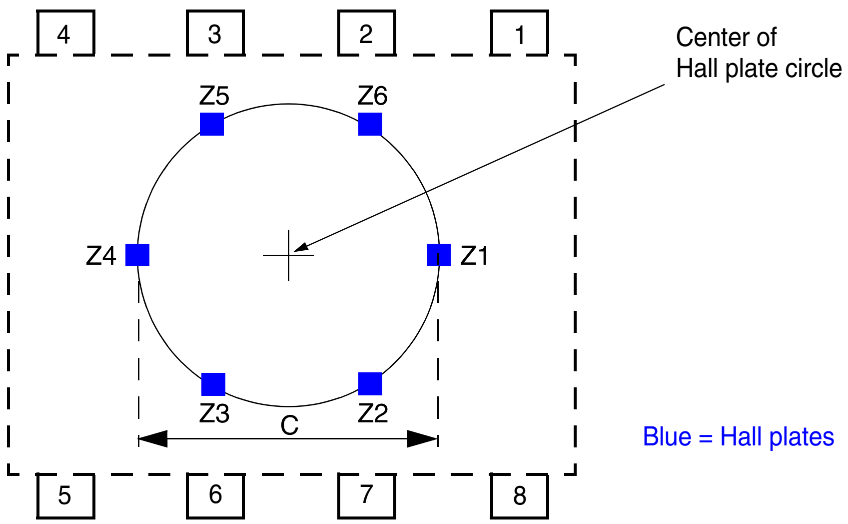


Fig. 3–1: Hall plate position definition for HAL 302x

Each of the Hall plates provides a voltage signal dependent on the angle position of the rotating magnet. An internal transformation is using each signal of the Hall plates to cancel the common z-field component (stray-field) while amplifying the differential z-field (magnetic field). The absolute angular information is output with an absolute sinusoidal position signal.

Using internal programming parameters, the HAL 302x can compensate for the main sensor non-idealities, like offset error, amplitude mismatch and orthogonality error. In addition, it is possible to define the angular reference position (0-angle) for the sine and cosine output signals. This allows the compensation of mechanical twist between magnet and sensor at module level.

The HAL 302x provides differential or single-ended analog sine and cosine output signals. These signals allow the user to calculate the angle with high resolution by an external A/D-converter and a microcontroller/ECU.

Stray-field compensation according to ISO 11452-8 definition is done device inherent. Therefore, neither shielding nor a stronger target magnet is required to achieve a stray-field robust measurement.

The sensor can be used in an end-of-shaft configuration for high-speed angular measurements in a range between 0° and 360°.

The HAL 302x is programmable by modulation of the output voltage (OUT3 pin). No additional programming pin is needed and fast end-of-line programming is enabled.

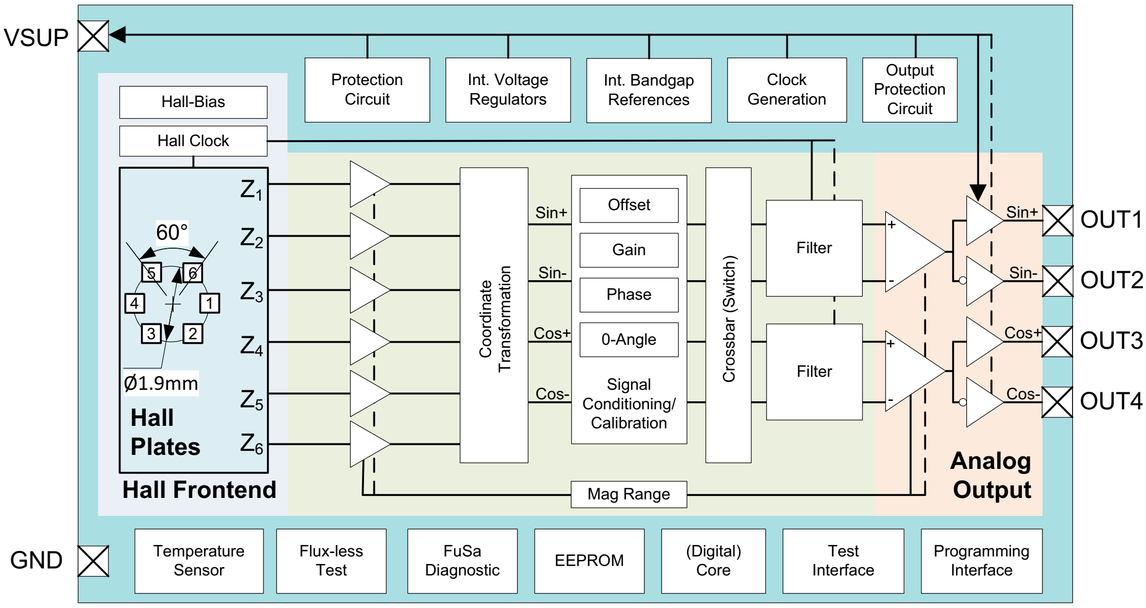


Fig. 3–2: HAL 3021 block diagram

3.2. Signal Path

The sensor signal path includes programmable register (EEPROM register) with individually configurable bits within those EEPROM registers. These enable to store configuration data and have influence on the sensor's signal processing. Details of the overall signal path are shown in Fig. 3–3.

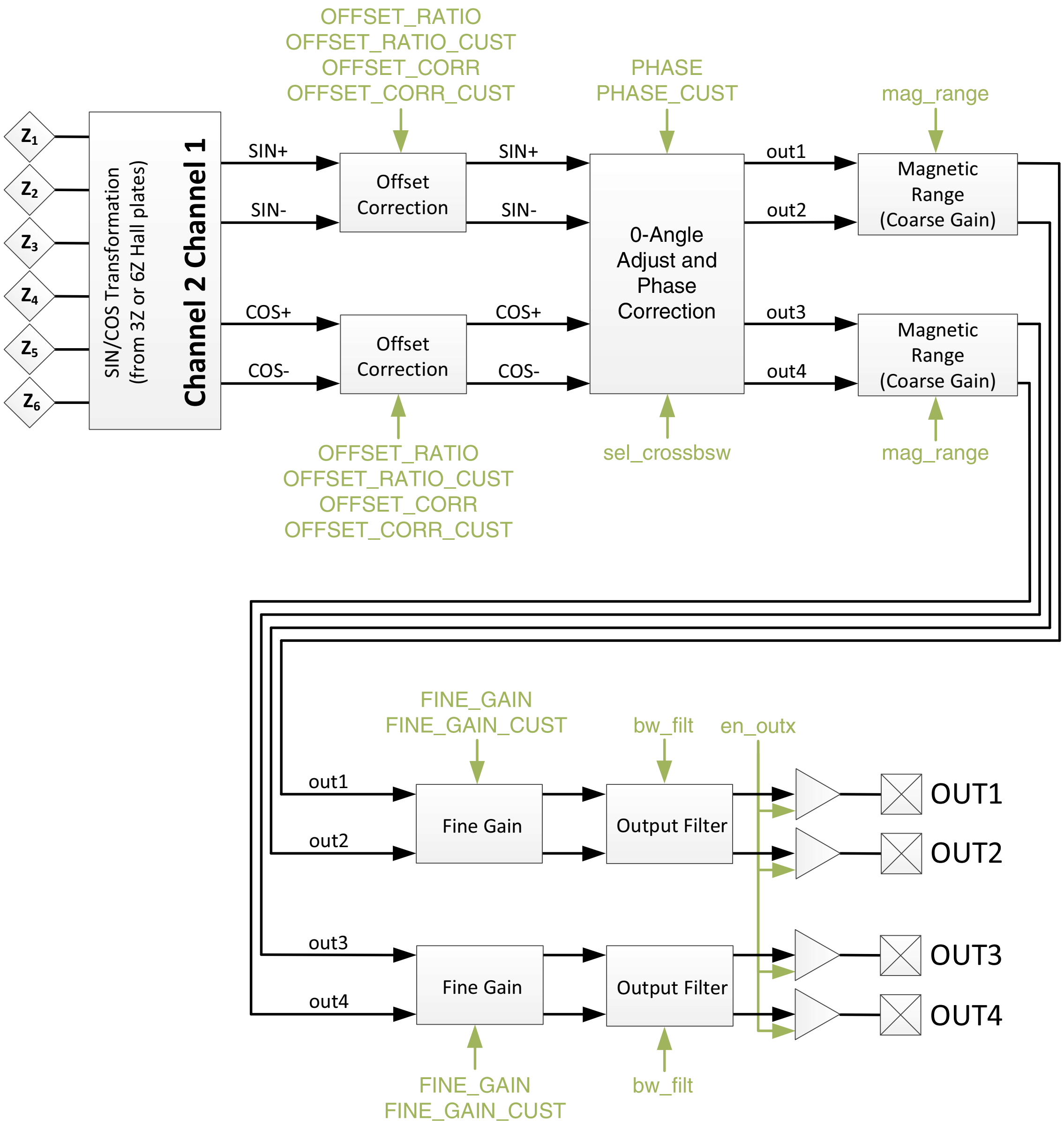


Fig. 3–3: Signal path of HAL 302x

3.3. Register Definition

Note Further details about the programming of the device and detailed register setting description as well as memory table can be found in the document: HAL/HAC 302x User Manual.

3.3.1. RAM Registers

Micronas IDs

The MIC_ID1 and MIC_ID2 register 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.

3.3.2. EEPROM Registers

Customer IDs

The CUST_ID1 and CUST_ID2 register are both 16-bit organized. These two register can be used to store customer production information, like serial number, project information, etc.

TDK-Micronas pre-calibration and customer calibration (en_ctrim)

TDK-Micronas delivers pre-calibrated sensors. The registers OFFSET_RATIO, OFFSET_CORR, PHASE and FINE_GAIN can be used by TDK-Micronas to compensate for the main sensor non-idealities. In case en_ctrim = 0, TDK-Micronas trimming parameters are applied to the signal path.

Customers can use their own trimming parameters: OFFSET_RATIO_CUST, OFFSET_CORR_CUST, PHASE_CUST, and FINE_GAIN_CUST to additionally adapt for potential system related errors. The customer trimmings are applied to the signal path by setting en_ctrim = 1.

OFFSET_RATIO/OFFSET_RATIO_CUST and OFFSET_CORR/OFFSET_CORR_CUST

The customer offset OFFSET_RATIO_CUST can be used to compensate a ratiometric offset in sine and cosine signal channels. The customer offset can be added to sine and/or cosine signal channels by the selection of the coefficients offset_ratio_ch1_cust and offset_ratio_ch2_cust. The offsets are shifted differentially. This means that the signals on signal path channel 1 (e.g. SIN+ and SIN-), depending on sel_crossbsw as well as the signals on signal path channel 2 (e.g. COS+ and COS-) are shifted in pairs.

The register has a length of 16 bits and is split into

– offset_ratio_ch1_cust (OFFSET_RATIO_CUST[4:0]),

– offset_ratio_sign_ch1_cust (OFFSET_RATIO_CUST[5]),

– offset_ratio_ch2_cust (OFFSET_RATIO_CUST[12:8]),

– and offset_ratio_sign_ch2_cust (OFFSET_RATIO_CUST[13]).

Offset_ratio_ch1_cust and offset_ratio_ch2_cust are stored unsigned (0...31) with a step size of 20 µT per LSB. For positive values, offset_ratio_sign_ch1_cust respectively offset_ratio_sign_ch2_cust has to be set to 0, whereas offset_ratio_sign_ch1_cust = 1 and/or offset_ratio_sign_ch2_cust = 1 correspond to negative values.

The default values are:

– offset_ratio_ch1_cust/offset_ratio_ch2_cust = 0,

– offset_ratio_sign_ch1_cust/offset_ratio_sign_ch2_cust = 0.

In addition, the customer offset OFFSET_CORR_CUST can be added to sine and/or cosine signal channels by the selection of the coefficients offset_corr_ch1_cust and offset_corr_ch2_cust. The offsets are shifted differentially. This means that the signals on signal path channel 1 (e.g. SIN+ and SIN-), depending on sel_crossbsw as well as the signals on signal path channel 2 (e.g. COS+ and COS-) are shifted in pairs.

The register has a length of 16 bits and is split into offset_corr_ch1_cust (OFFSET_CORR_CUST[6:0]), offset_corr_sign_ch1_cust (OFFSET_CORR_CUST[7]), offset_corr_ch2_cust (OFFSET_CORR_CUST[14:8] and offset_corr_sign_ch2_cust (OFFSET_CORR_CUST[15]). Offset_corr_ch1_cust and offset_corr_ch2_cust are stored unsigned (0...127) with a step size of 0.105% FS per LSB. For positive values, offset_corr_sign_ch1_cust respectively offset_corr_sign_ch2_cust has to be set to 0, whereas offset_corr_sign_ch1_cust = 1 and/or offset_corr_sign_ch2_cust correspond to negative values.

The default values are:

– offset_corr_ch1_cust/offset_corr_ch2_cust = 0,

– offset_corr_sign_ch1_cust/offset_corr_sign_ch2_cust = 0.

Note The offset correction OFFSET_CORR_CUST can be enabled by setting offset_corr_en = 1 and disabled by offset_corr_en = 0.
OFFSET_CORR_CUST is disabled as default.

PHASE_CUST

PHASE_CUST can be used to compensate a phase shift non-ideality between sine and cosine channel (orthogonality error) and to define the reference position (0-angle) for the sine and cosine output signals.

The programming of a positive/negative phase shift will determine a counterclockwise/clockwise rotation of cosine/sine of the geometrical reference for the magnetic field direction.

The register has a length of 16 bits and is split into:

– phase_ch1_cust (PHASE_CUST[6:0]),

– phase_sign_ch1_cust (PHASE_CUST[7]),

– phase_ch2_cust (PHASE_CUST[14:8]),

– and phase_sign_ch2_cust (PHASE_CUST[15]).

The neutral value for the register is zero (no phase-shift correction). It is possible to make a position correction of ±14°. The step size and therefore the smallest possible correction is 0.11°.

Magnetic Range (mag_range)

The Magnetic Range (Coarse Gain) block is responsible for setting the coarse gain for both channels relative to the magnitude of the applied external magnetic field (magnet). This customer-programmable magnetic field range is set by mag_range (MAG_CROSS_IHALL_BW[15:11]).
It is possible to program a range from min. 5 mT (MAG_CROSS_IHALL_BW[15:11] = 29) up to max. 250 mT (MAG_CROSS_IHALL_BW[15:11] = 0). The available ranges can be found in Table 3–3 on page 17.

Note During application design, it must be taken into consideration that the external magnetic field never exceeds the mag_range in the operational range of the specific application. In case of a potential exceeding, the mag_range setting should be set to a higher range.

FINE_GAIN_CUST

FINE_GAIN_CUST defines the customer trimming factor for each channel's gain separately. It is possible to program a trimming factor between 1.25 and 1.5 (compensating the amplitude mismatch between the channels after the Magnetic Range block). The overall gain of the sensor is defined by the selected magnetic field range (coarse adjustment) multiplied by the trimming factor (fine adjustment). This enables the user to consistently adjust the magnetic range in small steps to adjust for different mechanical requirements and magnetic fields.

The register has a length of 16 bits and is split into: fine_gain_ch1_cust (FINE_GAIN_CUST[5:0]) and fine_gain_ch2_cust (FINE_GAIN_CUST[13:8]). Fine_gain_ch1_cust and fine_gain_ch2_cust are stored in LSB (0...63 respectively gain factor 1.25...1.5) as follows:

$$\text{Gain Factor} = \frac{15}{\left(12 - \left(2 \times \frac{\text{fine\_gain\_chx\_cust[LSB]}}{63}\right)\right)}$$

Customer Configuration Registers

CONFIG, OUT_DRV_CONFIG, MAG_CROSS_IHALL_BW and REGULATOR registers are 16-bit registers that enable the customers to activate various functions of the sensor. The following tables describe in detail the available combinations and resulting functions.

Table 3–1: CONFIG Register

Bit no.	Function	Description
15	customer_lock	Customer lock: 0: Unlocked 1: Locked
14:13	oc_bip_mode	Overcurrent pattern to enter Biphase mode: 00: complex overcurrent pattern on OUT3 pin (2048 µs low -> 1536 µs high -> 1024 µs low -> 512 µs high) 01: simple overcurrent pattern on OUT3 pin (2048 µs low -> 2048 µs high) 1x: Biphase mode detection disabled (only active if customer_lock set after start-up) 10: Biphase mode detection disabled (customer_lock inactive: overcurrent and complex pattern are enabled; customer_lock active: overcurrent and complex pattern are disabled and no Biphase via overcurrent) 11: Biphase mode detection disabled (customer_lock inactive: overcurrent and simple pattern are enabled; customer_lock active: overcurrent and simple pattern are disabled and no Biphase via overcurrent) **Note**: For more details please refer to the HAL/HAC 302x Programming Guide
12:11	err_band	Error band selection (for all OUTx): 00: High-Z error band 01: Active low error band 10: Active high error band 11: High-Z error band **Note:** Some diagnostic errors result in an High-Z error band, regardless of the selection. For details see Section 4–1 on page 19.

Table 3–1: CONFIG Register, continued

Bit no.	Function	Description
10	en_ctrim	Trimming parameters copied to signal path shadow registers: 0: copy TDK-Micronas trimming to signal path shadow registers 1: copy customer trimming to signal path shadow registers
9	dis_overvolt	V_{SUP} overvoltage indication (error band): 0: enabled 1: disabled
8	dis_undervolt	V_{SUP} undervoltage indication (error band): 0: enabled 1: disabled
7:6	fluxless_tangle	Fluxless self-test angle/step time*: 00: 64 µs 01: 32 µs 10: 16 µs 11: Reserved *steps: 16x high-Z (only if fluxless_mode = 01); 16x angle; 16x error band
5:4	fluxless_mode	Fluxless self-test modes: 00: fluxless self-test disabled at start-up 01: fluxless self-test start-up trigger enabled 10: start-up always with fluxless self-test (executed once) 11: fluxless self-test endless loop
3	en_out4	Analog output 4 at OUT4 pin: 0: analog output 4 off/high-Z 1: analog output 4 connected to OUT4 pin
2	en_out3	Analog output 3 at OUT3 pin: 0: analog output 3 off/high-Z 1: analog output 3 connected to OUT3 pin
1	en_out2	Analog output 2 at OUT2 pin: 0: analog output 2 off/high-Z 1: analog output 2 connected to OUT2 pin
0	en_out1	Analog output 1 at OUT1 pin: 0: analog output 1 off/high-Z 1: analog output 1 connected to OUT1 pin

Table 3–2: OUT_DRV_CONFIG Register

Bit no.	Function	Description
15:14	initact_lvl_out4	Initial active level of output 4 at start-up (must match with external resistor): 00: random (OUT4 application without external pull-up or pull-down is not allowed) 01: low 10: high 11: random (OUT4 application without external pull-up or pull-down is not allowed)
13:12	initact_lvl_out3	Initial active level of output 3 at start-up (must match with external resistor): 00: random (OUT3 application without external pull-up or pull-down is not allowed) 01: low 10: high 11: random (OUT3 application without external pull-up or pull-down is not allowed)
11:10	initact_lvl_out2	Initial active level of output 2 at start-up (must match with external resistor): 00: random (OUT2 application without external pull-up or pull-down is not allowed) 01: low 10: high 11: random (OUT2 application without external pull-up or pull-down is not allowed)
9:8	initact_lvl_out1	Initial active level of output 1 at start-up (must match with external resistor): 00: random (OUT1 application without external pull-up or pull-down is not allowed) 01: low 10: high 11: random (OUT1 application without external pull-up or pull-down is not allowed)
7	fusa_thold	FuSa safe state minimum hold time: 0: 128-160 µs 1: 4096-5120 µs
6:5	fusa_tfilt	Analog FuSa filter time: 00: 1.5-2 µs 01: 96-128 µs 10: 192-256 µs 11: 384-512 µs **Note:** Overcurrent detection time (t_{OCD}) stays unchanged.
4	en_curlim	OUTx pins current limitation: 0: passive, no overcurrent pattern detection 1: according to low side/high side limit settings (curlim_ls, curlim_hs)
3:2	curlim_hs	High side current limit of OUTx pins: 00: 30 mA 01: 20 mA 10: 15 mA 11: 10 mA
1:0	curlim_ls	Low side current limit of OUTx pins: 00: 30 mA 01: 20 mA 10: 15 mA 11: 10 mA

Table 3–3: MAG_CROSS_IHALL_BW Register

<table>
<tr><th>Bit no.</th><th>Function</th><th colspan="5">Description</th></tr>
<tr><td rowspan="3">15:11</td><td rowspan="3">mag_range</td><td colspan="5">Max. magnetic field range selection:</td></tr>
<tr><td>00000: ±250 mT
00001: ±218 mT
00010: ±200 mT
00011: ±171 mT
00100: ±150 mT
00101: ±133 mT</td><td>00110: ±114 mT
00111: ±100 mT
01000: ±85.7 mT
01001: ±75 mT
01010: ±64.8 mT
01011: ±57.2 mT</td><td>01100: ±50 mT
01101: ±42.9 mT
01110: ±37.5 mT
01111: ±32.4 mT
10000: ±28.6 mT
10001: ±25 mT</td><td>10010: ±21.4 mT
10011: ±18.75 mT
10100: ±16.2 mT
10101: ±14.3 mT
10110: ±12.5 mT
10111: ±10.8 mT</td><td>11000: ±9.4 mT
11001: ±8.1 mT
11010: ±7.1 mT
11011: ±6.25 mT
11100: ±5.6 mT
11101: ±5 mT
1111x: Reserved</td></tr>
<tr><td colspan="5">Note: Default value of mag_range is 01001: ±75 mT. The overall gain of the sensor is defined by the 5 bit mag_range (coarse gain) in combination with the register FINE_GAIN_CUST.</td></tr>
<tr><td rowspan="3">10:8</td><td rowspan="3">sel_crossbsw</td><td colspan="5">Crossbar switch selection:</td></tr>
<tr><td>
000:
001:
010:
011:
100:
101:
110:
111:</td><td>OUT1
+SIN
+SIN
–SIN
–SIN
+COS
–COS
+COS
–COS</td><td>OUT2
–SIN
–SIN
+SIN
+SIN
–COS
+COS
–COS
+COS</td><td>OUT3
+COS
–COS
+COS
–COS
+SIN
+SIN
–SIN
–SIN</td><td>OUT4
–COS
+COS
–COS
+COS
–SIN
–SIN
+SIN
+SIN</td></tr>
<tr><td colspan="5">Note: Limited configuration possibilities are available in case of single-ended outputs used, because OUT3 is used as the programming pin.</td></tr>
<tr><td>7</td><td>offset_corr_en</td><td colspan="5">Signal channel 1 and 2 offset correction enable:
0: disabled
1: enabled</td></tr>
<tr><td>6:2</td><td>-</td><td colspan="5">Reserved (must be set to 0b01100).</td></tr>
<tr><td>1:0</td><td>bw_filt</td><td colspan="5">Amplifier bandwidth for channel 1 and channel 2:
00: Maximum bandwidth
01: High bandwidth
10: Medium bandwidth (default)
11: Low bandwidth
Note: The selected magnetic signal bandwidth has impact on the response time and angular noise (RMS) of the sensor.</td></tr>
</table>

Table 3–4: REGULATOR Register

Bit no.	Function	Description
15:2	-	Reserved
1:0	xvdd_suvi_band	Select supply voltage supervision level: 00: default supervision band 01: symmetric 3.3V supply supervision band for ratiometric mode 10: symmetric 5V supply supervision band for ratiometric mode 11: must not be used

4. Functional Safety

4.1. Functional Safety Manual and Functional Safety Report

The Functional Safety Manual for HAL 302x contains the necessary information to support the customers to realize a safety compliant application by integrating HAL 302x, as an ASIL C ready component, in their system. The Functional Safety Manual will be provided upon request.

The Functional Safety Report describes the assumed Safety Goal, the corresponding Failure Modes as well as the Base Failure Rate for die and package according to ISO 26262-11:2018. It can be provided based on a TDK-Micronas mission profile as well as customer mission profiles.

4.2. Integrated Diagnostic Mechanisms

HAL 302x performs self-tests during start-up and normal operation, which increase the robustness of the device functionality. The sensor switches all outputs to high-impedance (High-Z) when the device detects a wire break for VSUP or GND line, a memory error or an overtemperature. The output signals can be pulled to the error band by using external pull-up or pull-down resistors. The output behavior is configurable for the other error types by setting the err_band bit (CONFIG[12:11]). For further details about integrated diagnostic mechanisms and safe state options see Table 4–1 on page 19.

Table 4–1: Diagnostic Functions and Safe States

Diagnosis	Safe State Options	
	High-Z	Active Error Band
Wire break detection for supply and ground line	•	–
Undervoltage detection (external supply voltage too low)	•	–
Overvoltage detection (external supply voltage too high)	•	•
Hall plate supervision	•	•
Bandgap supervision	•	•
Configuration register monitoring	•	–
EEPROM protection	•	–
Clock supervision	•	•
Hall plate spinning supervision	•	•
Overtemperature supervision	•	–
0-angle adjustment monitoring	•	•
Crossbar monitoring	•	•

In order to integrate HAL 302x as an ASIL C ready component, the external microcontroller/ECU on system level has to check integrity of the HAL 302x by means of sine and cosine analog output signal plausibility evaluation. Further details are available in the Functional Safety Manual.

Fluxless Self-Test

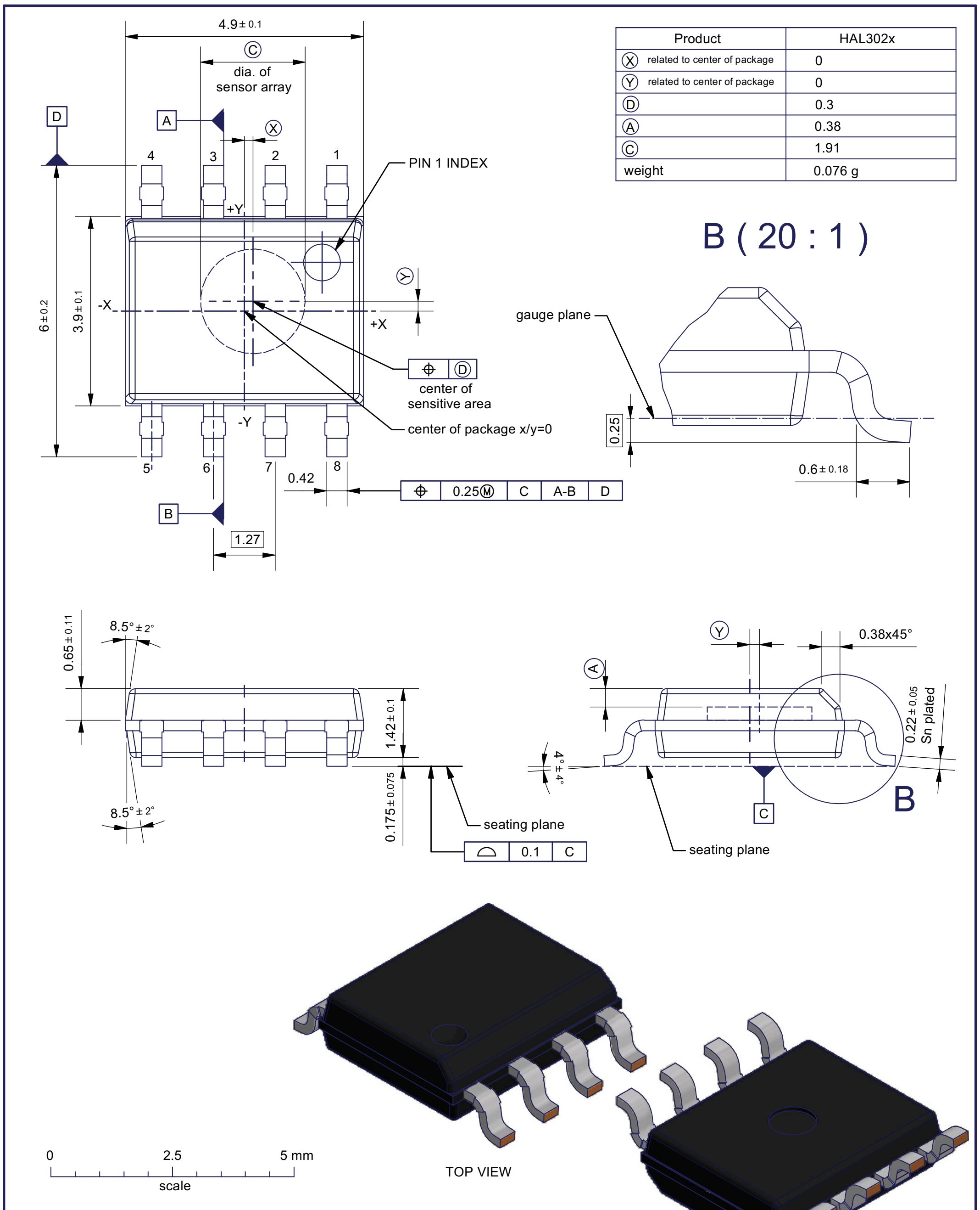
The fluxless self-test allows the customers to execute a functional test and check of the signal path without applying a magnetic field. Electrical stimulation is used instead to provoke a predefined magnetic state or pattern at the IC’s output. In an application setup the test can be used to check correct wiring between sensor and ECU as well.

The fluxless self-test itself is available after power-up of the device. The CONFIG[7:6] bits (= fluxless_tangle) and CONFIG[5:4] bits (= fluxless_mode) can be used to configure the fluxless self-test.

The steps are 16 times High-Z and 16 times angle information followed by 16 times error band. After fluxless self-test completion, the evaluation of test results takes place on microcontroller/ECU side. The sensor always returns to normal operation regardless of the test result.

5. Specifications

Outline Dimension

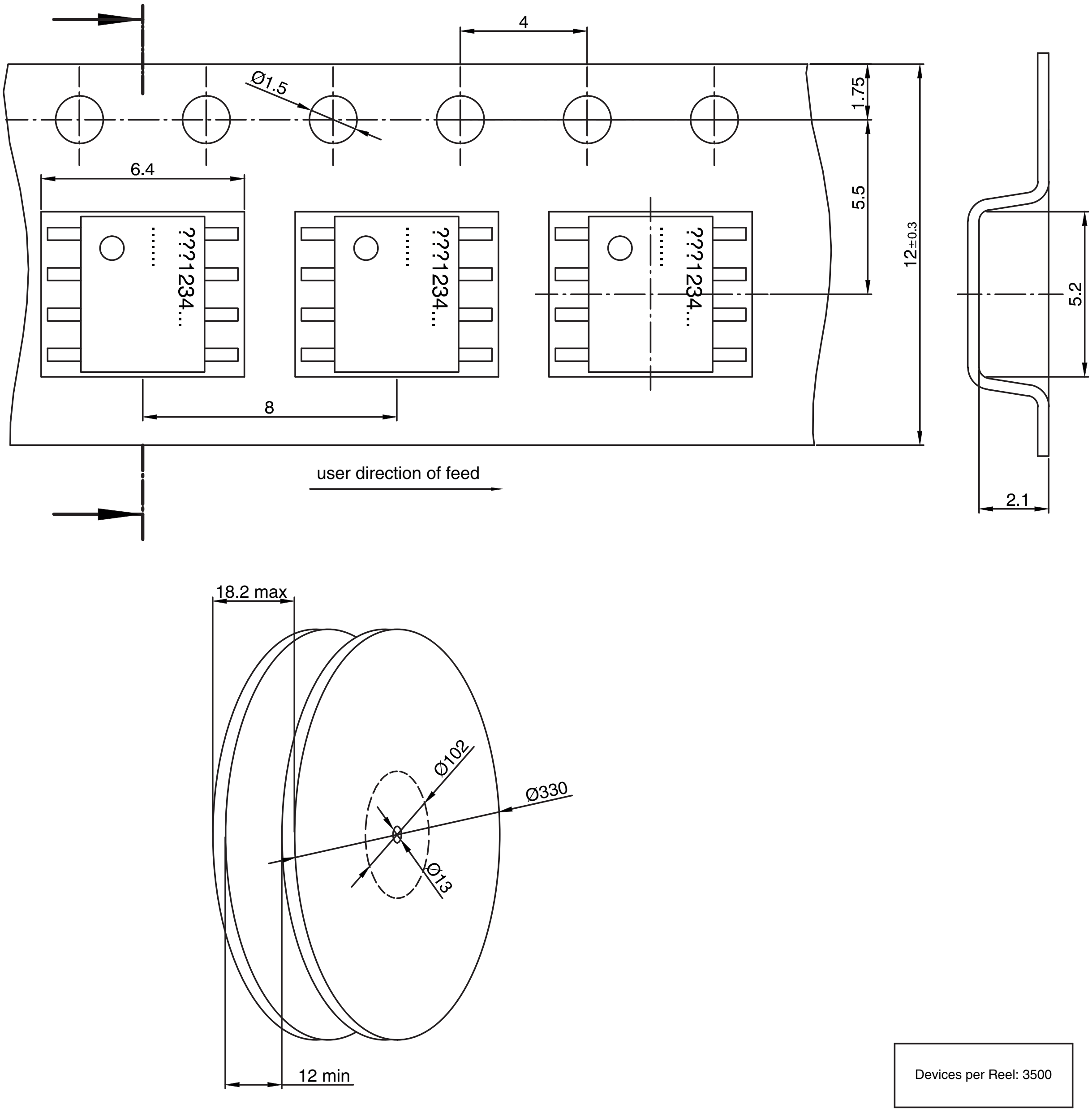


Product	HAL302x
Ⓧ related to center of package	0
Ⓨ related to center of package	0
Ⓓ	0.3
Ⓐ	0.38
Ⓒ	1.91
weight	0.076 g

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	19-11-28	MS-012	F		21-12-02	3	CSOIC0083007.1	ZG	2107_Ver.03

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



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. 5–2: SOIC8-1: Tape and Reel Finishing, all dimensions in mm

5.1. 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 (https://service.micronas.com).

5.2. Storage and Shelf Life Package

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

5.3. Size and Position of Sensitive Areas

Diameter of Hall plate circle: C = 1.91 mm

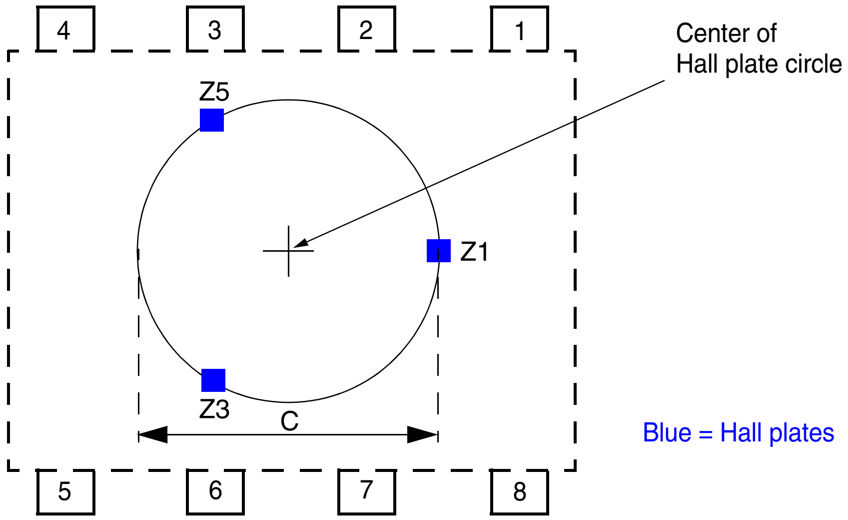


Fig. 5–3: Hall plate configuration HAL 3020

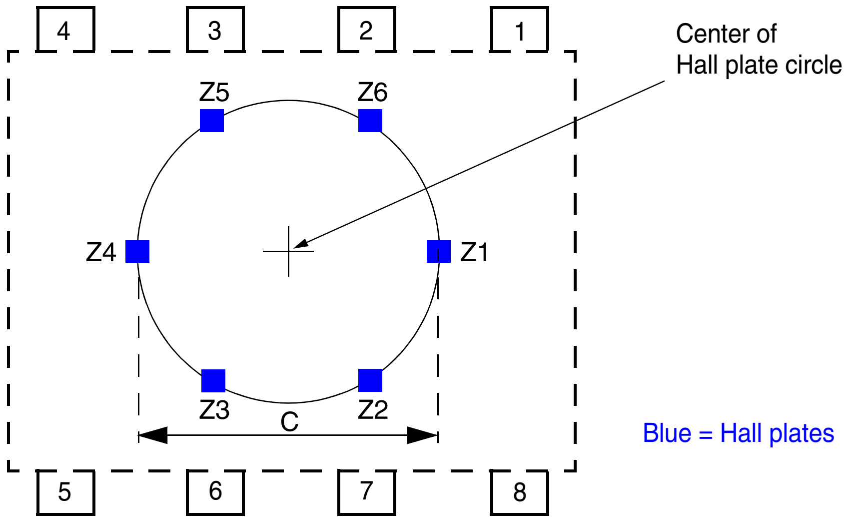


Fig. 5–4: Hall plate configuration HAL 3021

5.4. Definition of Magnetic-Field Vectors

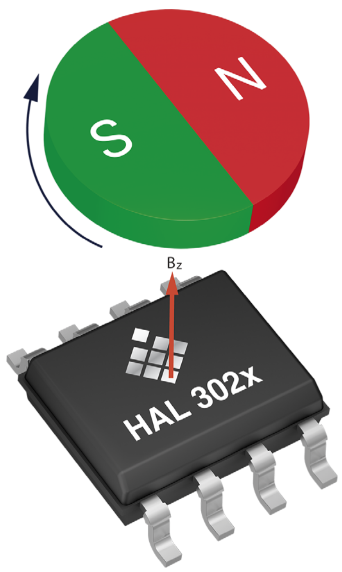


Fig. 5–5: Definition of magnetic-field vectors and angular detection for HAL 302x

The two-pole diametral magnet needs to be turned clockwise to get a positive slope of the angle calculated by arctan (SIN/COS).

The clockwise or counterclockwise rotation direction can be modified by changing the SIN/COS assignment to COS/SIN with an angle correction of 90°.

5.5. Pin Connections and Short Description

Table 5–1: Pin connection SOIC8

Pin No.	Pin Name	Type	Short Description
SOIC8 Package			
1	VSUP	IN	Supply voltage
2	GND	GND	Ground
3	OUT4	OUT	Analog output (–COS) (customer configurable)
4	OUT3	I/O	Analog output (+COS) (customer configurable) and programming pin
5	NC	GND	Connect to GND (low impedance)
6	NC	GND	Connect to GND (low impedance)
7	OUT2	OUT	Analog output (–SIN) (customer configurable)
8	OUT1	I/O	Analog output (+SIN) (customer configurable)

Note The crossbar switch can swap the output pin to signal assignment. The position of the programming pin is not influenced by the crossbar switch.

Note Pins 2, 5, and 6 must be connected to GND. Not used output drivers should be switched-off and the corresponding pins must stay open.

5.6. Characteristic Definitions

Table 5–2: Characteristic Definitions

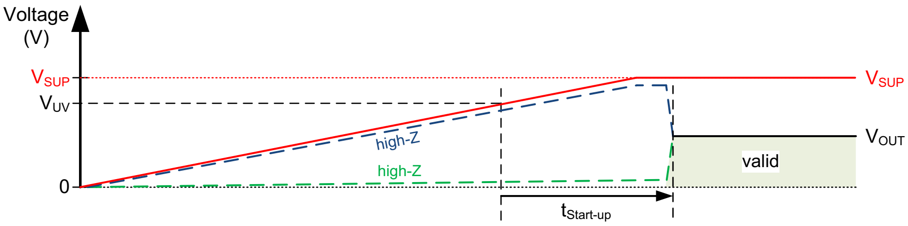
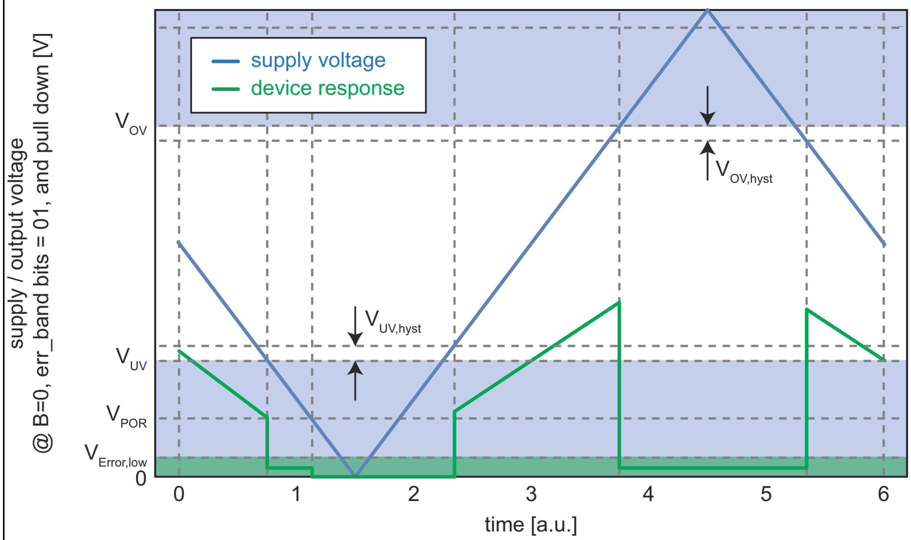
Parameter	Symbol	Definition
Start-up Time	$t_{Start\text{-}up}$	The start-up time is defined as the time span between V_{SUP} exceeding the undervoltage threshold level for rising supply edges and a valid signal at the output pins during start-up.  **Fig. 5–6:** Start-up time
Overvoltage and Undervoltage Detection		
Undervoltage Detection Level	V_{UV}	The undervoltage detection level indicates the threshold level the supply voltage needs to fall below to provoke a safe state. The overvoltage detection level indicates the threshold level the supply voltage needs to exceed to provoke a safe state:  **Fig. 5–7:** Overvoltage and undervoltage detection
Overvoltage Detection Level	V_{OV}	

Table 5–2: Characteristic Definitions, continued

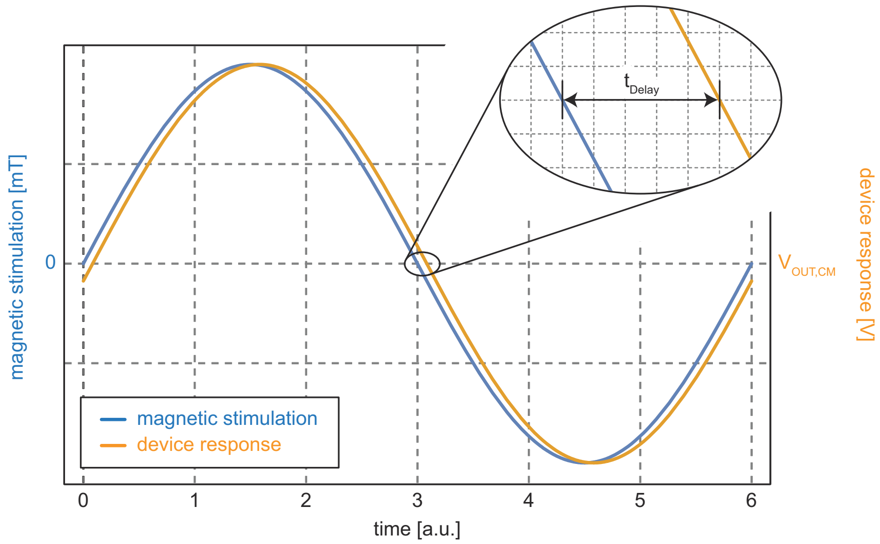
Parameter	Symbol	Definition
SIN/COS Output Parameter		
SIN/COS Delay Time	t_{Delay}	The delay time indicates the phase shift between a sinusoidal magnetic stimulation and the corresponding response of the device.  **Fig. 5–8:** SIN, COS delay time
Jitter of Delay Time	$t_{Delay,jitter}$	The jitter of the delay time indicates the instability / RMS fluctuation of the delay time.

Table 5–2: Characteristic Definitions, continued

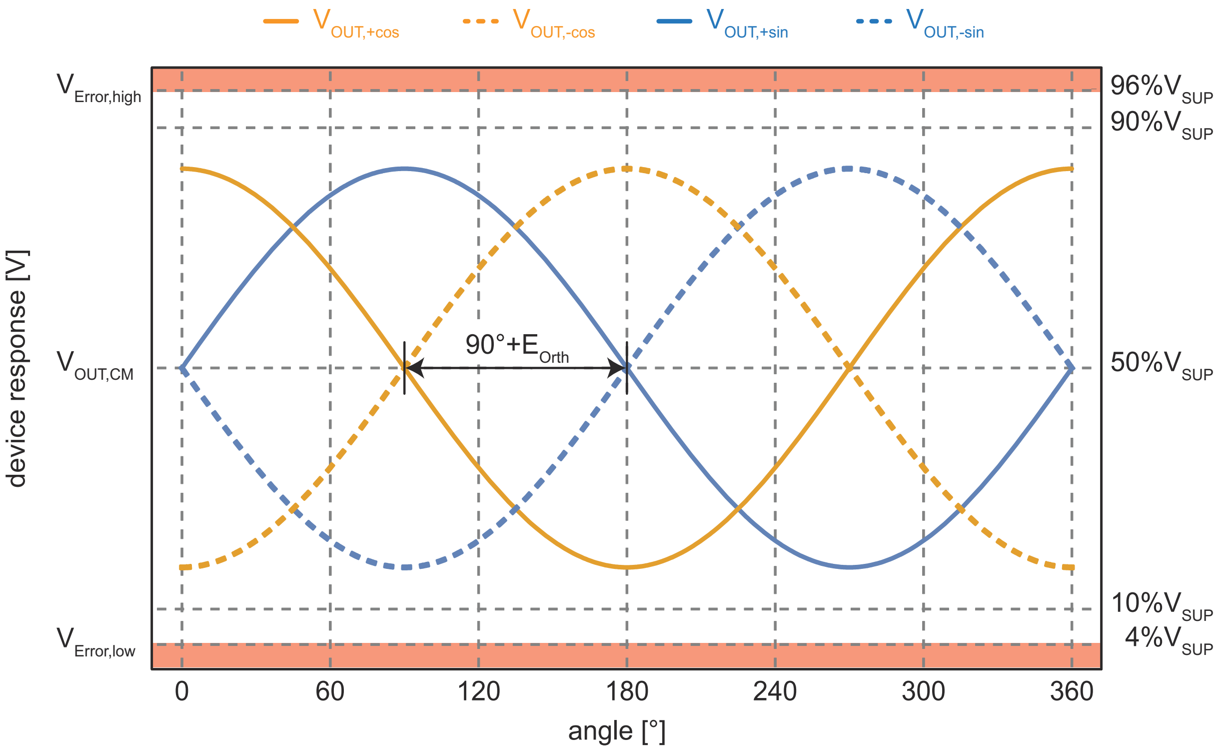
Parameter	Symbol	Definition
Fig. 5–9 shows the ideal sine and cosine output curves of the HAL 302x. HAL 302x can be used in single-ended or differential output mode. The differential output voltages can be externally calculated from the ±SIN and ±COS output voltages with the following equations: $\Delta V_{SIN} = V_{OUT,+SIN} - V_{OUT,-SIN}$ $\Delta V_{COS} = V_{OUT,+COS} - V_{OUT,-COS}$ The typical application circuits can be found in Section 6.3. on page 37.  **Fig. 5–9:** Ideal output of the sensor		
Output Voltage per V_{SUP}	V_{OUT}	The output voltage per V_{SUP} indicates the range of valid output voltages, percental w.r.t. V_{SUP}, that can be provided by the device as long as the magnetic stimulation complies with the selected magnetic-field range (mag_range).
Output Sensitivity at RT	$V_{OUT,gain}$	The output sensitivity at RT quantifies the output voltage amplitude and maybe also show the amplitude in the graph per magnetic stimulation at room temperature, depending on the supply voltage and the selected field range.
Output Common Mode Voltage at RT	$V_{OUT,CM}$	The output common mode voltage at RT indicates the zero magnetic field output voltage at room temperature, percental w.r.t. V_{SUP}.
Output Noise RMS	$V_{OUT,noise}$	The output noise indicates the root mean square (RMS) output voltage noise considering frequencies up to the device-specific cut-off frequency.
SIN/COS Amplitude Mismatch at RT	k	The SIN/COS amplitude mismatch at RT indicates the percental discrepancy of the SIN and COS amplitudes at room temperature

Table 5–2: Characteristic Definitions, continued

Parameter	Symbol	Definition
SIN/COS Orthogonality Error at RT	E_{Orth}	The SIN/COS orthogonality error at RT indicates the deviation from an ideal 90° phase shift between the SIN and COS signals as shown in Fig. 5–9.
Output Voltage Range of Lower Error Band	$V_{Error,low}$	The output voltage range of lower error band indicates the output voltage, percental w.r.t. V_{SUP}, actively driven by the device in safe state if the err_band bits are set to 01.
Output Voltage Range of Upper Error Band	$V_{Error,high}$	The output voltage range of upper error band indicates the output voltage, percental w.r.t. V_{SUP}, actively driven by the device in safe state if the err_band bits are set to 10.
Output Voltage Range of Lower/ Upper Error Band in High-Z mode	$V_{Error,high-Z}$	The output voltage range of lower error band in high-z mode indicates the output voltages, percental w.r.t.V_{SUP}, occurring in safe state using a pull-down load resistor if the err_band bits are set to 00 or 11.
		The output voltage range of upper error band in high-z mode indicates the output voltages, percental w.r.t. V_{SUP}, occurring in safe state using a pull-up load resistor if the err_band bits are set to 00 or 11.
Output Leakage Current in High-Z Mode	$I_{Leak,high-Z}$	The output leakage current in high-z mode indicates the current flowing across the load resistor in high-z safe state.
Overcurrent Detection Time	t_{OCD}	The overcurrent detection time indicates the time span between the first occurrence of an overcurrent and the switch to a safe state.
Overcurrent Detection Level	I_{OCD}	The overcurrent detection level indicates the current required to extract from / inject into the outputs to provoke a safe state or to enter Biphase Mode (Listen Mode).
Output Current Limitation Level	$I_{OUT,limit}$	The output current limitation level indicates the clamp level to which the output current is limited to protect the output, e.g. in the event of short circuits.

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.

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 high-impedance circuit.

All voltages listed are referenced to ground (GND).

Symbol	Parameter	Pin Name	Min.	Max.	Unit	Condition
V_{SUP}	Supply Voltage	VSUP	–18	18	V	t < 96 h
V_{OUT}	Output Voltage	OUTx	–6	18	V	t < 1 h
I_{OUT}	Continuous Output Current	OUTx	–10	10	mA	
I_{IN}	Input Current (Latch-up Immunity)	All pins	–100	100	mA	AEC-Q100-004
B_{Max}	Magnetic Field	–	–1	1	T	
T_J	Junction Temperature	–	–40	190	°C	t < 96 h
T_A	Ambient Temperature	–	–40	160	°C	4)
$T_{Storage}$	Transportation/Short-Term Storage Temperature	–	–55	150	°C	Device only without packing material
V_{ESD}	ESD Protection	VSUP, OUTx, NC, GND	–4	4	kV	1)
		VSUP	–8	8	kV	2)3)
		OUTx	–8	8	kV	2)3)

No cumulative stress for all parameter.
1) AEC-Q100-002 (100 pF and 1.5 kΩ)
2) Unpowered gun test (150 pF/330 Ω) according to ISO 10605-2008
3) With additional protection on the PCB (100 nF on VSUP, 47 nF on OUTx)
4) Determined according to JEDEC JESD-51. 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.

5.8. Recommended Operating Conditions

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

All voltages listed are referenced to ground (GND).

Symbol	Parameter	Pin Name	Min.	Typ.	Max.	Unit	Condition
V_{SUP}	Supply Voltage	VSUP	3.0	5.0	5.5	V	
I_{OUT}	Continuous Output Current	OUTx	–1.2	–	1.2	mA	V_{SUP} = 5.5 V $R_{L\ Pull\text{-}up/\text{-}down} \geq$ 4.7 kΩ
R_L	Load Resistor	OUTx	4.7	4.7	10	kΩ	
C_L	Load Capacitance	OUTx	–	4.7	47	nF	
C_{SUP}	Supply Decoupling Capacitance	VSUP	–	100	–	nF	
N_{PRG}	Number of Memory Programming Cycles	–	–	–	100	cycles	0°C < T_A < 55°C
B_{AMP}	Recommended Magnetic Field Amplitude with respect to mag_range setting	–	–	–	100	%	The appropriate customer application specific mag_range setting can be selected between 5 mT and 250 mT out of 30 possible steps (see Table 3–3 on page 17).
T_J	Junction Temperature	–	–40	–	170	°C	[1] for 1000 h
T_A	Ambient Temperature	–	–40	25	150	°C	[2]

[1] Depends on the temperature profile of the application. Please contact TDK-Micronas for life time calculations.
[2] Determined according to JEDEC JESD-51. Consider current consumption, mounting condition (e.g. overmold, potting) and mounting situation for T_A and in relation to T_J

5.9. Characteristics

At T_A = –40 °C to +150 °C, GND = 0 V, after programming and locking of the sensor, at Recommended Operation Conditions if not otherwise specified in the column “Conditions”. SIN/COS output parameter performance is only valid for default crossbar switch setting. Typical Characteristics correspond to typical Recommended Operation Conditions.

Symbol	Parameter	Pin Name	Limit Values Min.	Typ.	Max.	Unit	Conditions
$I_{SUP,5V}$	Supply Current at typical supply voltage	VSUP	–	9.5	11	mA	HAL 3020, excluding external load on OUTx, V_{SUP} = 5 V
			–	12	13	mA	HAL 3021, excluding external load on OUTx, V_{SUP} = 5 V
$I_{SUP,\Delta V}$	Supply Current dependency on supply voltage	VSUP	0.3	0.4	0.5	mA/V	[1] HAL 3020, excluding external load on OUTx
			0.4	0.6	0.7	mA/V	[1] HAL 3021, excluding external load on OUTx
$t_{Start-up}$	Start-up Time	OUTx	–	–	0.25	ms	[2]
Θ_{Speed}	Rotation Speed	–	–	–	>30000	rpm	[1] Rotation speed not limited by sensor IC design. No theoretical limitation
Power-On Operation							
V_{POR}	Power On Reset Voltage	VSUP	1.5	1.75	2	V	Decreasing supply voltage ramp
Overvoltage and Undervoltage Detection							
V_{UV}	Undervoltage Detection Level	VSUP					Decreasing supply voltage ramp
			2.4	2.65	2.9	V	xvdd_suvi_band = 00 & 01
			tbd	4.1	tbd	V	xvdd_suvi_band = 10 (for 5V application)
$V_{UV,hyst}$	Undervoltage Detection Level Hysteresis	VSUP	140	180	220	mV	Increasing supply voltage ramp
V_{OV}	Overvoltage Detection Level	VSUP					Increasing supply voltage ramp
			5.95	6.2	6.45	V	xvdd_suvi_band = 00 & 10
			tbd	4.2	tbd	V	xvdd_suvi_band = 01 (for 3.3V application)
$V_{OV,hyst}$	Overvoltage Detection Level Hysteresis	VSUP	180	250	320	mV	Decreasing supply voltage ramp

[1] Characterized on small sample size, not tested.
[2] For definition see Section 5.6. on page 26.

Symbol	Parameter	Pin Name	Limit Values			Unit	Conditions
			Min.	Typ.	Max.		
SIN/COS Output Parameter[4]							
t_{Delay}	SIN/COS Delay Time	OUTx	tbd	tbd	5	µs	[2] bw_filt bit = 00 (maximum)
			tbd	tbd	8	µs	[2] bw_filt bit = 01 (high)
			tbd	tbd	12	µs	[2] bw_filt bit = 10 (medium)
			tbd	tbd	20	µs	[2] bw_filt bit = 11 (low)
$t_{Delay,jitter}$	Jitter of Delay Time (RMS)	OUTx	–	–	2	ns	[2][3]
V_{OUT}	Output Voltage per V_{SUP}	OUTx	10	–	90	%V_{SUP}	[1][2]
$V_{OUT,gain}$	Output Sensitivity at RT	OUTx	30	35	40	%V_{SUP} /mag_ range	[1][2] T_A = 25 °C. Example: $V_{OUT,gain}$ = 0.0233 V/mT at V_{SUP} = 5 V and mag_range = 75 mT
$\Delta V_{OUT,gain}$	Output Sensitivity Drift	OUTx	–6	–	2	%	[1] Over temperature related to T_A = 25 °C. See Fig. 5–10 on page 35 for the typical output sensitivity drift characteristics at V_{SUP} = 3.3 V and 5.0 V
$V_{OUT,CM}$	Output Common Mode Voltage at RT	OUTx	49.75	50	50.25	%V_{SUP}	[1][2][5] T_A = 25 °C, B_{AMP} = 0 mT
$\Delta V_{OUT,CM}$	Output Common Mode Voltage Drift	OUTx					[1][5] Over temperature related to T_A = 25 °C, B_{AMP} = 0 mT
			–0.25	–	0.25	%V_{SUP}	HAL 3020
			–0.20	–	0.20	%V_{SUP}	HAL 3021
$V_{OUT,noise}$	Output Noise (RMS)	OUTx					[1][5] bw_filt bit = 00 (maximum)
			–	0.85	1.55	mV	HAL 3020
			–	0.75	1.35	mV	HAL 3021
							[1][5] bw_filt bit = 01 (high)
			–	0.7	1.3	mV	HAL 3020
			–	0.6	1.1	mV	HAL 3021
							[1][5] bw_filt bit = 10 (medium)
			–	0.55	1.05	mV	HAL 3020
			–	0.45	0.85	mV	HAL 3021
							[1][5] bw_filt bit = 11 (low)
			–	0.4	0.8	mV	HAL 3020
			–	0.3	0.6	mV	HAL 3021
k	SIN/COS Amplitude Mismatch at RT	OUTx/y	–0.9	–	0.9	%	[1][2] T_A = 25 °C

[1] Characterized on small sample size, not tested.
[2] For definition see Section 5.6. on page 26.
[3] Guaranteed by design.
[4] All min./max. values indicate 3-sigma values as long as not otherwise specified.
[5] mag_range bit = 01001 (75 mT).

Symbol	Parameter	Pin Name	Limit Values			Unit	Conditions
			Min.	Typ.	Max.		
Δk	SIN/COS Amplitude Mismatch Drift	OUTx/y					1) Over temperature related to T_A = 25 °C
			–1.5	–	1.5	%	HAL 3020
			–0.8	–	0.8	%	HAL 3021
E_{Orth}	SIN/COS Orthogonality Error at RT	OUTx/y	–0.4	–	0.4	°	1)2) T_A = 25 °C
ΔE_{Orth}	SIN/COS Orthogonality Error Drift	OUTx/y				°	1) Over temperature related to T_A = 25 °C
			–0.7	–	0.7		HAL 3020
			–0.4	–	0.4		HAL 3021
Output Behavior in Case of Error Detection							
$V_{Error,low}$	Output Voltage Range of Lower Error Band	OUTx	0	–	4	$\%V_{SUP}$	2) err_band bit = 01 (Actively driven by the device)
$V_{Error,high}$	Output Voltage Range of Upper Error Band	OUTx	96	–	100	$\%V_{SUP}$	2) err_band bit = 10 (Actively driven by the device)
$V_{Error,high-Z}$	Output Voltage Range of Lower Error Band in High-Z Mode	OUTx	0	–	4	$\%V_{SUP}$	2)6) err_band bit = 00 & 11, R_L = Pull-down
	Output Voltage Range of Upper Error Band in High-Z Mode	OUTx	96	–	100	$\%V_{SUP}$	2)6) err_band bit = 00 & 11, R_L = Pull-up
$I_{Leak,high-Z}$	Output Leakage Current in High-Z Mode	OUTx	0	–	22	µA	2)
Overcurrent Detection Parameter							
t_{OCD}	Overcurrent Detection Time	OUTx	–	128	–	µs	2)3)
I_{OCD}	Overcurrent Detection Level	OUTx	tbd	7.5	tbd	mA	1)2)
$I_{OUT,limit}$	Output Current Limitation Level	OUTx	tbd	10	tbd	mA	1)2) curlim_xs bit = 11
			tbd	15	tbd	mA	1)2) curlim_xs bit = 10
			tbd	20	tbd	mA	1)2) curlim_xs bit = 01
			tbd	30	tbd	mA	1)2) curlim_xs bit = 00
SOIC8 Package							
R_{ThJA}	Thermal Resistance Junction to Air	–	–	–	142	K/W	7) Determined with a 1S0P board
			–	–	96	K/W	7) Determined with a 2S2P board
R_{ThJC}	Thermal Resistance Junction to Case	–	–	–	38	K/W	7) Determined with a 1S0P board & 2S2P board

1) Characterized on small sample size, not tested.
2) For definition see Section 5.6. on page 26.
3) Guaranteed by Design.
6) The external circuitry defines the output behavior in case of error detection (see Section 4.2. on page 19). This error indication also holds in case the device detects a wire break of supply or ground line.
7) According to JEDEC JESD-51. Self-heating calculation see Section 6.1. on page 37.

5.9.1. Output Sensitivity Drift Characteristic

In Section 5.9. the output sensitivity drift of HAL 302x is specified over temperature related to T_A = 25°C.

Fig. 5–10 on page 35 lists the typical output sensitivity drift characteristics for V_{SUP} = 3.3 V and 5.0 V. Fig. 5–10 is made from characterization data of a small sample size and is indicative.

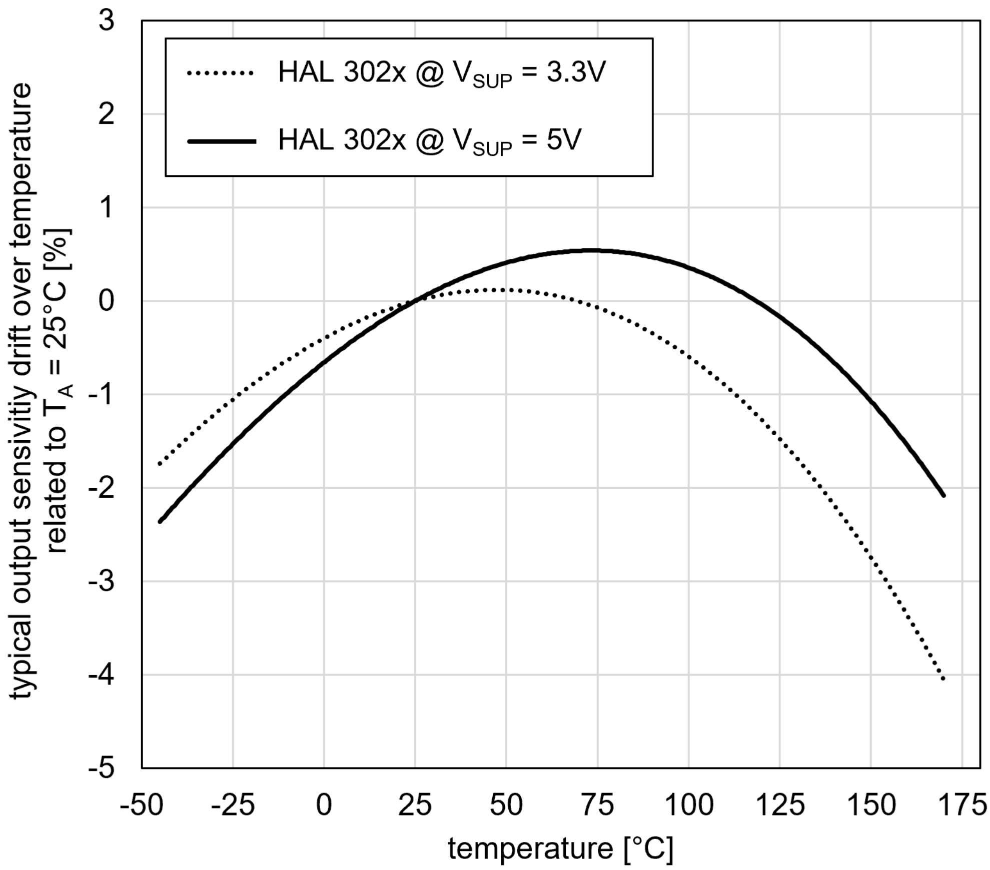


Fig. 5–10: Output sensitivity drift of HAL 302x

5.10. Angle Sensing Performance

At T_A = –40 °C to +150 °C, GND = 0 V, after programming and locking of the sensor, at Recommended Operation Conditions if not otherwise specified in the column “Conditions”. SIN/COS output parameter performance are only valid for default crossbar switch setting. Angle information is calculated from SIN/COS signals using arctan. Typical Characteristics correspond to typical Recommended Operation Conditions.

Symbol	Parameter	Pin Name	Min.	Typ.	Max.	Unit	Conditions
Θ_{Range}	Detectable Angle Range	OUTx/y	0	–	360	°	1)
$E_{\Theta,RT}$	Angular Error at RT	OUTx/y	–	–	0.7	°	4) T_A = 25 °C
$\Delta E_{\Theta,temp}$	Angular Error Drift over Temperature	OUTx/y					Over temperature related to T_A = 25 °C
			–	–	0.8	°	HAL 3020
			–	–	0.6	°	HAL 3021
$\Delta E_{\Theta,life}$	Angular Error Drift over Lifetime	OUTx/y					After 1008h HTOL related to 0h
			–	tbd	tbd	°	HAL 3020
			–	tbd	tbd	°	HAL 3021
$\Delta E_{\Theta,SF}$	Angular Error Drift due to Stray-Field	OUTx/y					2) Related to the absence of a stray field
			–	–	0.15	°	HAL 3020
			–	–	0.07	°	HAL 3021
$E_{\Theta,noise}$	Angular Noise (RMS)	OUTx/y	–	0.04	0.07	°	3) HAL 3020
			–	0.03	0.05	°	3) HAL 3021
$E_{\Theta,dynamic}$	Angular Error with External Dynamic Compensation over Temperature and Lifetime	OUTx/y					5)6) With dynamic offset and gain compensation, but static orthogonality compensation
			–	–	tbd	°	HAL 3020
			–	–	tbd	°	HAL 3021
		OUTx/y	–	–	0.1	°	6) With dynamic offset, gain and orthogonality compensation

All values are modeled based using characterization data at B_{AMP} = 35 mT, mag_range bit = 01001 (75 mT) and V_{SUP} = 5V on small sample size (not tested). All min./max. values indicate 3-sigma values as long as not otherwise specified.

1) Guaranteed by Design.
2) According to ISO 11452-8:2015, at 25°C, with stray-field strength of 4 kA/m from X, Y, and Z direction.
3) bw_filt bit = 11 (low). Derived from $V_{OUT,noise}$.
4) Can be further improved by proper end-of-line calibration in the microcontroller/ECU.
5) Static compensation = ideal one-time end-of-line compensation (25°C and 0h).
6) Dynamic compensation = ideal permanent external compensation under all operating temperatures and lifetime.

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 0.055 W for HAL 3020 and 0.065 W for HAL 3021. The junction to ambient thermal resistance R_{ThJA} is specified in Section 5.9.

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

$\Delta T = P * R_{ThJX}$

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 results.

6.3. Application Circuit

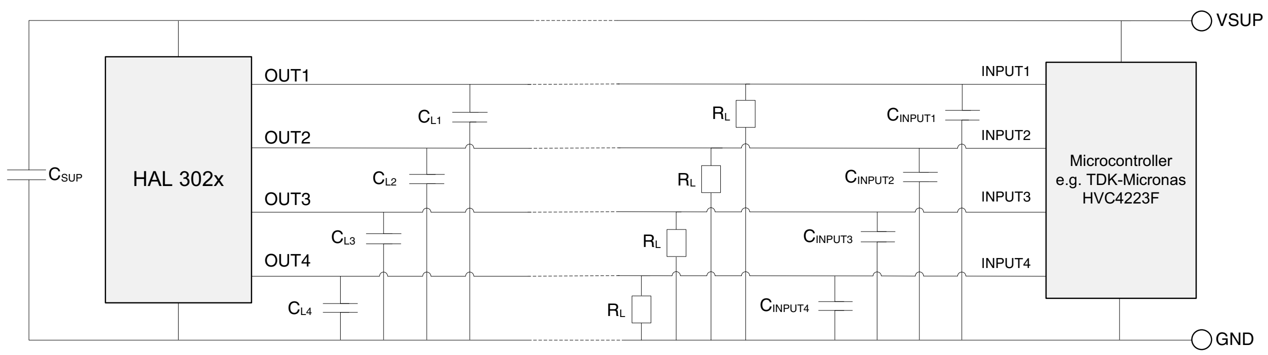


Fig. 6–1: Recommended application circuit for HAL 302x (differential output, pull-down)

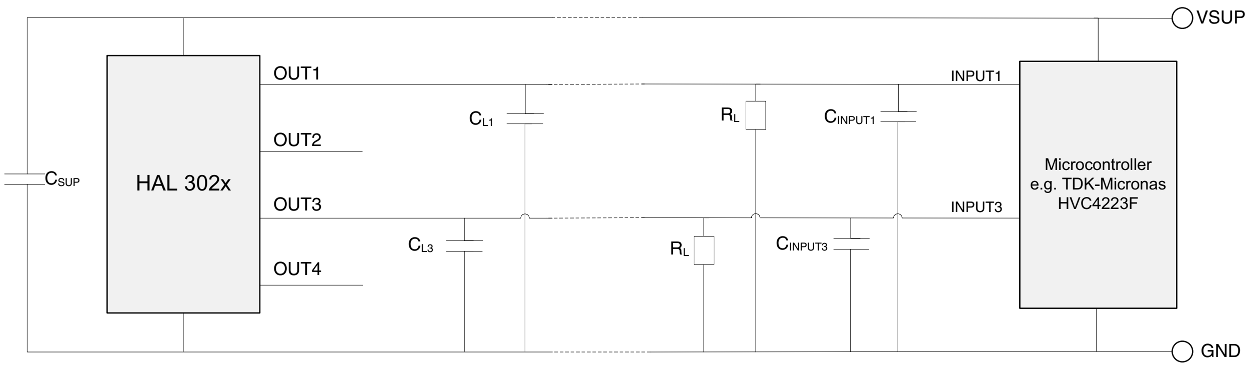


Fig. 6–2: Recommended application circuit for HAL 302x (single-ended output, pull-down)

Table 6–1: Recommended components

Name	Recommended Value
C_{SUP}	100 nF
C_{Lx}+ C_{INPUTx}	4.7 nF (47 nF for increased ESD/EMC protection)
R_L	10 kΩ

6.4. Recommended Pad Size SOIC8 Package

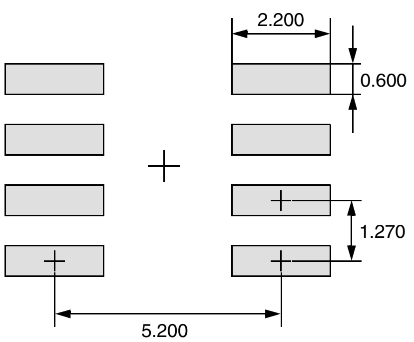


Fig. 6–3: Pad size recommendation for SOIC8 package (all dimensions in mm)

7. Programming of the Sensor

HAL 302x features two different customer modes. In **Application Mode** the sensor provides ratiometric sine and cosine analog outputs. In **Biphase Mode (Listen Mode)** it is possible to read and change the register settings of the sensor through the output pin (OUT3).

After power-up the sensor is always operating in the **Application Mode.** It is switched to the **Biphase Mode** by a BiPhase-M protocol via output voltage modulation. Therefore the programming device needs to provide a long sync pulse at the output pin (OUT3).

7.1. Programming Interface

In Biphase Mode HAL 302x 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 of 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 from and to the sensor.

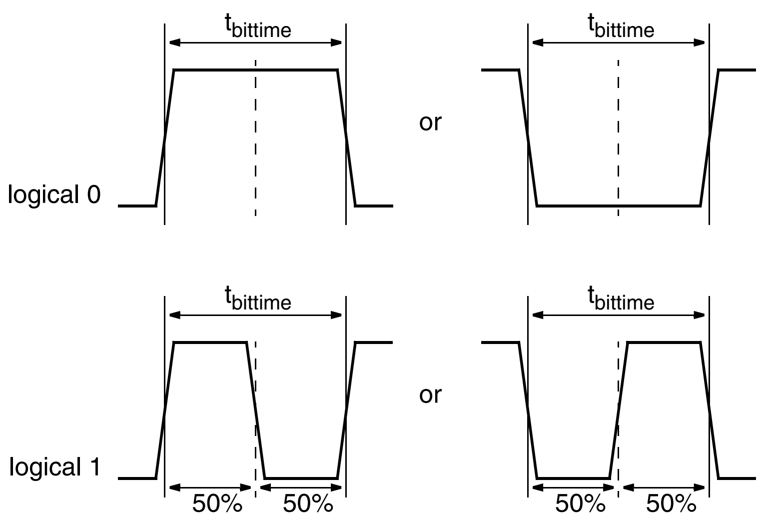


Fig. 7–1: Definition of logical 0 and 1 bit

A description of the communication protocol and the programming of the sensor is available in a separate document (HAL/HAC 302x Programming Guide).

7.2. Programming Environment and Tools

For the programming of HAL 302x 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 LabView Programming Environment) in order to facilitate the product development. The details of programming sequences are content of the HAL/HAC 302x Programming Guide.

7.3. Programming Information

For production and qualification tests, it is mandatory to set the customer_lock bit to one after final adjustment and programming of HAL 302x.

Before locking the device, it is recommended to read back all register values to ensure that the intended data is correctly stored in the sensor's memory. Alternatively, it is also possible to cross-check the sensor output signal with the intended output behavior.

The success of the LOCK process shall be checked by reading the status of the customer_lock bit after locking.

Even after locking the device it is still possible to read the memory content.

It is also mandatory to check the acknowledge of the sensor after each write and store sequence to verify if the programming of the sensor was successful.

Electrostatic Discharges (ESD) may disturb the programming pulses. Please take precautions against ESD.

Note A description of the communication protocol and the programming of the sensor is available in a separate document HAL/HAC 302x Programming Guide.

8. Document History

1. Advance Information: “HAL 302x Fast Stray-Field Robust Motor Position Sensor Family with Analog Output”, Aug. 8, 2022;, AI000244_001EN. First release of the advance information.

2. Advance Information: “HAL 302x Fast Stray-Field Robust Motor Position Sensor Family with Analog Output”, July 14, 2023, AI000244_002EN. Second release of the advance information.

   Major changes:
   - Fig. 3-2: HAL 3021 block diagram detailed
   - OFFSET_CORR/OFFSET_CORR_CUST register added
   - Additional fluxless self-test modes added
   - Additional functions added to OUT_DRV_CONFIG Register (fusa_thold, fusa_tfilt)
   - Additional output current limitation settings added
   - REGULATOR register added
   - Pin No. 5 & 6 are NC (were Test pins before)
   - Sub chapter 5.6: Characteristic Definitions added
   - Sub chapter 5.9: Characteristics updated
   - Sub chapter 5.9.1: Figure added: “Output Sensitivity Drift Characteristic”
   - Recommended application circuit updated
   - Non-calibrated variant (option code: xxAx) and non-ratiometric variant (option code: xxxA) removed from chapter 5.

TDK-Micronas GmbH
Hans-Bunte-Strasse 19 · D-79108 Freiburg · P.O. Box 840 · D-79008 Freiburg, Germany
Tel. +49-761-517-0 · www.micronas.tdk.com