MICRONAS

Hardware
Documentation

Data Sheet

HAL® 385x, HAL 387x

Programmable 2D Position Sensors with Arbitrary Output Function

3D HAL® by Micronas

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Contents

Programmable 2D Position Sensors with Arbitrary Output Function

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

1. Introduction

The HAL 38xy is a new sensor family using the Micronas 3D HAL technology. This new family has several members. HAL 385x provides a linear, ratiometric analog output signal with integrated wire-brake detection working with pull-up or pull-down resistor. HAL 387x features a configurable PWM output with up to 12 bit resolution with frequencies between 0.25 kHz and 2 kHz.

Conventional planar Hall technology is only sensitive to the magnetic field orthogonal to the chip surface. In addition to the orthogonal magnetic field, HAL 38xy is also sensitive for magnetic fields applied in parallel to the chip surface. This is possible by integrating vertical Hall plates into the standard CMOS process.

The sensor cell can measure three magnetic field components BX, BY, and BZ. This enables a new set of potential applications, like wide distance or through-shaft angular measurements. The table below describes the different family members.

Type	Output Format	Detectable Field Component
HAL 3855	Analog	B_Y and B_Z
HAL 3856	Analog	B_X and B_Z
HAL 3875	PWM	B_Y and B_Z
HAL 3876	PWM	B_X and B_Z

On-chip signal processing calculates the angle out of two of the magnetic field components and converts this value to an output signal. Due to the measurement method, the sensor exhibits excellent drift performance over the specified temperature range resulting in a new class of accuracy for angular or linear measurements.

Additionally to the built-in signal processing, the sensor features an arbitrary programmable linear characteristic for linearization of the output signal (with up to 32 setpoints).

Major characteristics like gain and offset of X/Y- and Z-channel, reference position, phase shift between X/Y- and Z-signal, hysteresis, low-pass filter frequency, output slope, and offset and clamping levels can be adjusted to the magnetic circuitry by programming the non-volatile memory.

The sensor contains advanced on-board diagnostic features that enhance fail-safe detection. In addition to standard checks, such as overvoltage and undervoltage detection and wire break, internal blocks such as ROM and signal path are monitored during normal operation. For devices with a PWM output, the error modes are indicated by a change of PWM frequency and duty-cycle.

The devices are designed for automotive applications and operate with junction temperature from –40 °C up to 170 °C.

The sensors are available in a very small four-pin leaded transistor package TO92UP, as well as in a SOIC8 package.

1.1. Major Applications

Due to the sensor’s versatile programming characteristics and its high accuracy, the HAL 38xy is the optimal system solution for applications such as:

- Linear movement measurement,
  - EGR valve position
  - Clutch pedal position
- Through-shaft rotary position measurement, like
  - Gear selector
  - Throttle valve position, etc.

1.2. Features

- Angular and position measurement extremely robust against temperature and stress influence
- 12 bit ratiometric linear output for HAL 385x
- 0.25 kHz to 2 kHz (up to 12 bit) PWM output for HAL 387x
- Programmable arbitrary output characteristic with up to 32 setpoints
- 8 kHz sampling frequency
- Operates from 4.5 V up to 5.5 V supply voltage
- Operates from –40 °C up to 170 °C junction temperature
- Programming via the sensors output pin
- Programmable characteristics in a non-volatile memory (EEPROM) with redundancy and lock function
- Programmable 1^{st}-order low-pass filter
- Programmable hysteresis
- Programmable output slope and offset
- X/Y- and Z-channel gain and offset of signal path programmable
- Phase shift between X/Y- and Z-channel programmable
- Programmable output clamping for error band definition
- Programmable reference position
- Programmable magnetic range detection
- 32 bit identification number for customer
- 32 bit identification number with Micronas production information (like X,Y position; wafer number; lot number)
- On-Board diagnostics of different functional blocks of the sensor
- Short-circuit protected push-pull output
- Over- and reverse voltage protection at V_{SUP}
- Under- and overvoltage detection of V_{SUP}
- Wire-break detection with pull-up or pull-down resistor
- EMC and ESD robust design

2. Ordering Information

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

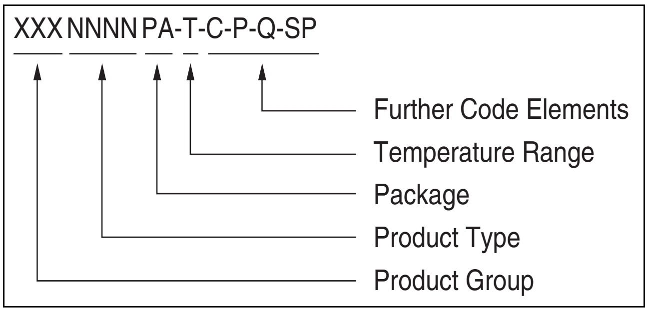


Fig. 2–1: Ordering Code Principle

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

2.1. Device-Specific Ordering Code

The HAL 385x, HAL 387x is available in the following package and temperature variants.

Table 2–1: Available packages

Package Code (PA)	Package Type
DJ	**SOIC8-1**
UP	**TO92UP-1**

Table 2–2: Available temperature ranges

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

The relationship between ambient temperature (T_A) and junction temperature (T_J) is explained in Section 5.1. on page 26.

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

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

Available Ordering Codes	Package Marking
HAL3855DJ-A-[C-P-Q-SP]	**3855A**
HAL3855UP-A-[C-P-Q-SP]	**3855A**
HAL3856DJ-A-[C-P-Q-SP]	**3856A**
HAL3856UP-A-[C-P-Q-SP]	**3856A**
HAL3875DJ-A-[C-P-Q-SP]	**3875A**
HAL3875UP-A-[C-P-Q-SP]	**3875A**
HAL3876DJ-A-[C-P-Q-SP]	**3876A**
HAL3876UP-A-[C-P-Q-SP]	**3876A**

3. Functional Description

3.1. General Function

HAL 385x and HAL 387x are 2D position sensors based on Micronas' 3D HAL technology. The sensors include two vertical and one horizontal Hall plate with spinning current offset compensation for the detection of X or Y and Z magnetic field components, a signal processor for calculation and signal conditioning of the two magnetic field components, protection devices, and a ratiometric linear or PWM output.

The spinning current offset compensation minimizes the errors due to supply voltage and temperature variations as well as external package stress.

The sensors can be used for angle measurements in a range between 0° and 360° (end of shaft and through shaft setup) as well as for robust position detection (linear movement or position). The in-system calibration can be utilized by system designer to optimize performance for a specific system. The calibration information is stored in a on chip EEPROM.

The HAL38xy is programmable by modulation of the output voltage. No additional programming pin is needed.

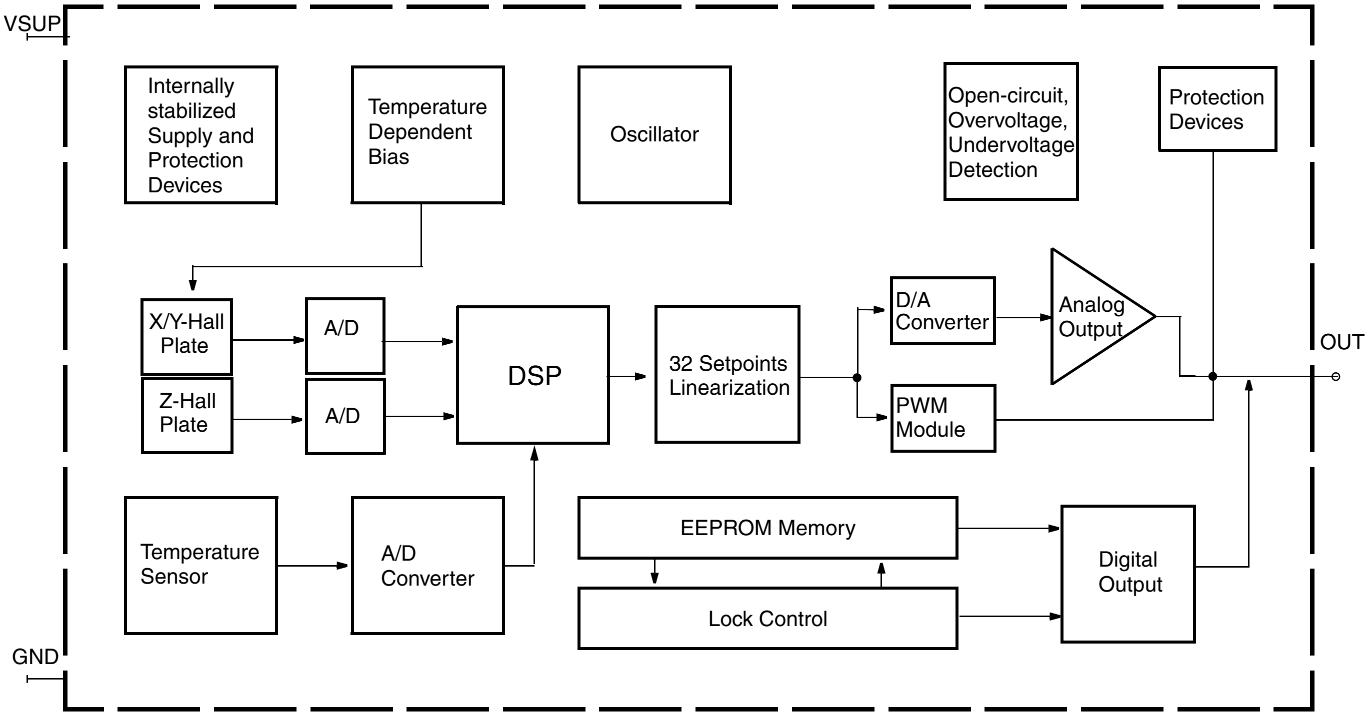


Fig. 3–1: HAL38xy block diagram

3.2. Signal Path and Register Definition

3.2.1. Signal Path

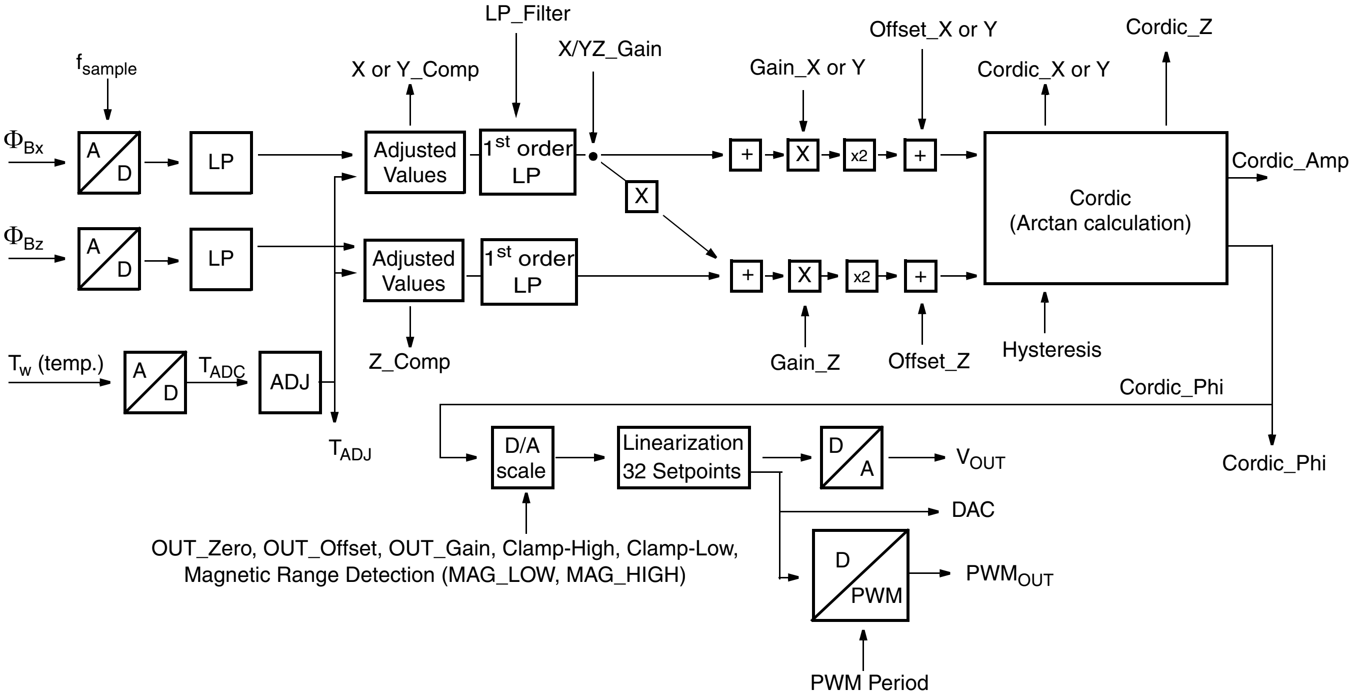


Fig. 3–2: Signal path of HAL38xy

3.2.2. Register Definition

The DSP is the major part of this sensor and performs the signal conditioning. The parameters for the DSP are stored in the EEPROM registers. The details are shown in Fig. 3.2.

Terminology:

GAIN:	name of the register or register value
Gain:	name of the parameter

The sensors signal path contains two kinds of registers. Registers that are readout only (RAM) and programmable registers EEPROM. The RAM registers contain measurement data at certain steps of the signal path and the EEPROM registers have influence on the sensors signal processing.

3.2.2.1. RAM register

TADJ

The TADJ register contains the digital value of the sensor junction temperature. It has a length of 16 bit and is binary coded. From the 16 bit only the range between 0 … 32767 is used for the temperature information. Typically the temperature sensor is calibrated in the way that at −40°C the register value is 100 LSB and at 160°C it is 12000 LSB.

X or Y_COMP and Z_COMP

X or Y_COMP and Z_COMP register contain the temperature compensated magnetic field information of the X/Y- and Z-channel. Both registers have a length of 16 bit each and are two's-complement coded. Therefore, the register values can vary between −32768 … 32767.

CORDIC_X or Y and CORDIC_Z

CORDIC_X/Y and CORDIC_Z register contain the compensated magnetic field information of the X/Y- and Z-channel used for the angle calculation based on CORDIC algorithm. These registers include already customer phase-shift, gain and offset correction. Both registers have a length of 16 bit each and are two's-complement coded. Therefore, the register values can vary between –32768 … 32767.

CORDIC_PHI

The CORDIC_PHI register contains the digital value of the position calculated by the CORDIC algorithm. It has a length of 16 bit and is binary. From the 16 bit only the range between 0 … 32767 is used for the position information.

DAC

The DAC register contains the digital equivalent of the output voltage or PWM output duty-cycle. It has a lenght of 16 bit and is binary. From the 16 bit only the range between 0 … 32767 is used for the position information.

CORDIC_AMP

The CORDIC_AMP register contains the digital value of the magnetic field amplitude calculated by the CORDIC algorithm. From mathematical point of view the amplitude can be calculated based on X- and Z-channel amplitude.

$$\text{Amplitude} = \sqrt{X^2 + Z^2}$$

The CORDIC algorithm adds a factor of roughly 1.6 to the equation for the magnetic amplitude. So the equation for the amplitude is defined as follows:

$$\text{CORDIC\_AMP} \cong 1.6 \times \sqrt{X^2 + Z^2}$$

DIAGNOSIS

The DIAGNOSIS register enables the customer to identify certain failures detected by the sensor. HAL 385x, HAL 387x perform certain self tests during power-up of the sensor and also during normal operation. The result of these self tests is stored in the DIAGNOSIS register. DIAGNOSIS register is a 16 bit register.

Bit no.	Function	Description
15:6	None	Reserved
5	Statemachine Self Test	This bit is set to 1 in case that the statemachine (DSP doing the internal signal processing like ArcTan calculation, temperature compensation, etc.) self test fails. (continuously running)
4	EEPROM Self Test	This bit is set to 1 in case that the EEPROM self test fails. (Performed during power-up only)
3	ROM Check	This bit is set to 1 in case that ROM parity check fails. (continuously running)
2	Reserved	
1	MAGHI	This bit is set to 1 in case that the magnetic field is exceeding the MAG-HI register value (magnetic field to high)
0	MAGLO	This bit is set to 1 in case that the magnetic field isbelow the MAG-LOW register value (magnetic field to low)

Details on the sensor self tests can be found in Section 3.5. on page 14.

PROG_DIAGNOSIS

The PROG_DIAGNOSIS register enables the customer to identify errors occuring during programming and writing of the EEPROM or NVRAM memory. The customer must check either the status of this register after each write or program command or alternatively the first and second acknowledge. Please check the Programming Guide for HAL 385x, HAL 387x for further details.

The PROG_DIAGNOSIS register is a 16 bit register. The following table shows the different bits indicating certain errors possibilities.

Bit no.	Function	Description
15:11	None	Reserved
10	Charge Pump Error	This bit is set to 1 in case that the internal programming voltage was to low
9	Voltage Error during Program/ Erase	This bit is set to 1 in case that the internal supply voltage was to low during program or erase
8	NVRAM Error	This bit is set to 1 in case that the programming of the NVRAM failed
7:0	Programming	These bits are used for programming the memory

3.2.2.2. EEPROM registers

X/YZ_GAIN

X/YZ_GAIN can be used to compensate a phase-shift between X/Y- and Z-channel. The register has a length of 16 bit. It is possible to make a phase shift correction of ±75°. The step size and therefore the smallest possible correction is 0.002°. The register is two's-complement coded and ranges from –32768 to 32767. The register value is sin function based. X/YZ_GAIN is calculated as follows:

$$\text{X/YZ\_GAIN} = \sin(\text{Phase-shift}) \times 32767$$

Neutral value for this register is zero (no Phase-shift correction).

Note: In case the phase-shift correction is used, then it is necessary to adapt the settings of Gain_Z too. For details see definition of GAIN_Z.

GAIN_X/Y and GAIN_Z

Gain_X/Y and Gain_Z can be used to compensate amplitude mismatches between X/Y- and Z-channel. Micronas delivers pre calibrated sensors with no gain mismatch between X/Y- and Z-channel. Nevertheless it is possible that due to the magnetic circuit a mismatch between X/Y- and Z-channel gain occurs. This can be compensated with Gain_X/Y and Gain_Z.
Both register have a length of 16 bit and are two's-complement coded. Therefore, they can have values between –32768 and 32767 (–1 … 1). For neutral settings both register values have to be set to 0.5 (register value 16384).

In case that the phase-shift correction is used it is necessary to change also the gain of channel Z (see also X/YZ_GAIN). If phase-shift correction is used the corresponding register has to be set to

$$\text{GAIN\_Z} = \frac{0.5}{\cos(\text{Phase-shift})} \times 32767$$

Example:

A phase-shift error of 11° between X/Y- and Z-channel should be compensated. X/YZ_GAIN is then set to 6252

$$\text{X/YZ\_GAIN} = \sin(11°) \times 32767 = 6252.24$$

Then Gain_X/Y must be 0.5 (GAIN_X/Y = 16384) and GAIN_Z must be set to 16690.

$$\text{GAIN\_Z} = \frac{0.5}{\cos(\text{Phase-shift})} \times 32767 = 16690.14$$

Note: In case Gain_X/Y or Gain_Z exceed the range of –1 … 1 (–32768 … 32767), then it is possible to reduce the gain of the opposite channel for compensation.

OFFSET_X/Y and OFFSET_Z

Offset_X/Y and Offset_Z can be used to compensate offset mismatches between X/Y- and Z-channel. Micronas delivers pre calibrated sensors. Nevertheless it is possible that due to the magnetic circuit a mismatch between X/Y- and Z-channel offset occurs. This can be compensated with Offset_X/Y and Offset_Z.
Both registers have a length of 16 bit and are two's-complement coded. Therefore, they can have values between –32768 and 32767. For neutral settings both register values have to be set to 0 (register value 0).

OUT_ZERO

OUT_Zero defines the reference position for the cordic phi output. It can be set to any value of the output range. It is the starting point/reference for the 32 setpoints. OUT_ZERO has a register length of 16 bit and it is two's-complement coded.

$$\mathrm{OUT\_ZERO} = 65536 - 2 \times \mathrm{CORDIC\_PHI}$$

Note: Before reading CORDIC_PHI it is necessary to set OUT_ZERO to 0.

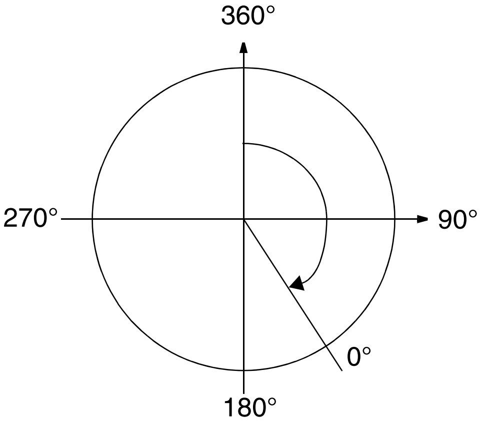


Fig. 3–3: Example definition of zero degree point

OUT_GAIN

OUT_Gain defines the gain of the analog or PWM output signal. The register has a length of 16 bit and is two's-complement coded. OUT_Gain = 1 is neutral setting and leads to a change of the output voltage from 0% to 100% for an angle change from 0° to 360° (if OUT_OFFSET is set to 0).
OUT_Gain can be changed between –64 and 64. The register value is defined by the following equation:

$$\mathrm{OUT\_GAIN} = 16384 \times \sqrt[5]{\frac{\mathrm{OUT\_Gain}}{2}}$$

OUT_OFFSET

OUT_Offset defines the offset of the analog or PWM output signal. The register has a length of 16 bit and is two's complement coded. OUT_OFFSET = 0 is neutral setting and leads to a change of the output voltage from 0% to 200% of V_{SUP} for an angle change from 0° to 360° (If OUT_GAIN is set to 1).
OUT_Offset can be changed between –200% and 200% of V_{SUP}. OUT_OFFSET = 0 leads to a voltage offset of 0% of V_{SUP} and OUT_OFFSET = 32768 leads to a voltage offset of –200% of V_{SUP}.

CLAMP-LOW

CLAMP-LOW defines the minimum output level. The register has a length of 8 bit. Clamp-Low can vary between 0% and 50%. The register value can be calculated by the following equation:

$$\mathrm{CLAMP\text{-}LOW} = 256 - \frac{\mathrm{Clamp\text{-}Low}}{100\%} \times 128$$

Note: In case calculation of CLAMP-LOW gives 256, then CLAMP-LOW has to be set to 0.

CLAMP-HIGH

CLAMP-HIGH defines the maximum output level. The register has a length of 8 bit. Clamp-High can vary between 50% and 100%. The register value is defined by the following equation:

$$\mathrm{CLAMP\text{-}HIGH} = \frac{100\% - \mathrm{Clamp\text{-}High}}{100\%} \times 127$$

Magnetic Range Check

The magnetic range check uses the magnitude output and compares it with an upper and lower limit threshold defined by the registers MAG-LOW and MAG-HIGH. If either low or high limit is exceeded it will be indicate with an overflow on the sensors output (output high clamping).

MAG-LOW

MAG-LOW defines the low level for the magnetic field range check function. This register has a length of 8 bit and is a two's complement number.

The overflow bit is set if:

$$\mathrm{CORDIC\_AMP} < \mathrm{ABS}(\mathrm{MAG\_LOW} \times 256)$$

Example:

MAG_LOW = +30 leads to a detection level of 7680 LSB. As soon as CORDIC_AMP is below 7680 it will be detected as a too low magnetic field and will lead to an error message on the sensors output.

MAG-HIGH

MAG-HIGH defines the high level for the magnetic field range check function. This register has a length of 8 bit and is a two's complement number.

The overflow bit is set if:

$$\mathrm{CORDIC\_AMP} > 32767 - \mathrm{MAG\_HIGH} \times 256$$

Example:

MAG_HIGH = 30 leads to a detection level of 25087 lsb. As soon as CORDIC_AMP is above 25087 it will be detected as a too high magnetic field and will lead to an error message on the sensors output.

Note: MAG_HIGH is MSB aligned.

Low Pass Filter

With the LP_Filter register it is possible to select different –3dB frequencies for HAL38xy. The Low-Pass Filter is a 1^{st}-order digital filter and the register is 16 bit organized. Various typical filter frequencies between 4 kHz (no filter) and 10 Hz are available.

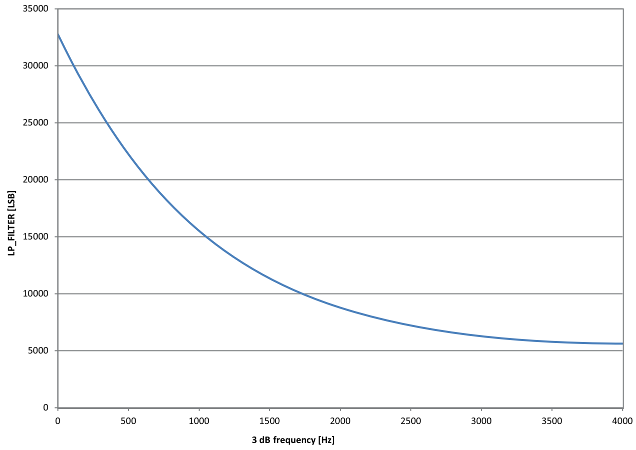


Fig. 3–4: 3dB filter frequency vs. LP_FILTER codes

HYSTERESIS

HYSTERESIS defines the number of digital code used as an hysteresis in the angle calculation. The purpose of this register is to avoid angle variation on the Cordic_Phi register and finally on the output signal due to noise on the Cordic_X and Cordic_Y signals.

The register has a length of 16 bit and is two's complement number.

It is possible to program a hysteresis between 1 LSB and 16383 LSB. The register value itself is calculated with the following equation:

$$\mathrm{HYSTERESIS} = 65536 - 2 \times \mathrm{hysteresis}$$

Example:

A hysteresis of 50 leads to a HYSTERESIS value of 65436.

PWM Frequency

PWM_FREQ defines the frequency of the PWM output signal. This function is only available in HAL 387x. The PWM frequency is selectable by 2 bits. The following four different frequencies can be used:

Table 3–1: Selectable PWM frequencies for HAL 387x

No.	Frequency	Resolution
0	2 kHz	11 bit
1	1 kHz	12 bit
2	500 Hz	12 bit
3	250 Hz	12 bit

3.3. Output Linearization

In certain applications (e.g. through shaft applications or position measurements) it is required to linearize the output characteristic. This is always the case, when the output of the sensor is not a 100% sine wave. The resulting output characteristic “value vs. angle/position” is not a linear curve as in the ideal case. But it can be linearized by applying an inverse nonlinear compensation curve.

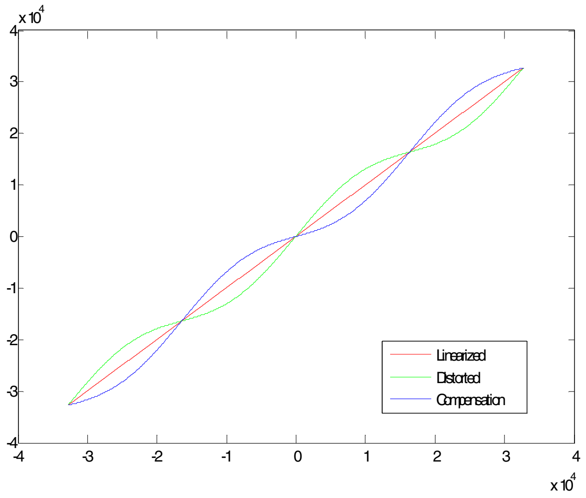


Fig. 3–5: Example for output linearization

For this purpose the compensation curve will be divided into 32 segments with equal distance. Each segment is defined by two setpoints, which are stored in EEPROM. Within the interval, the output is calculated by linear interpolation according to the position within the interval.

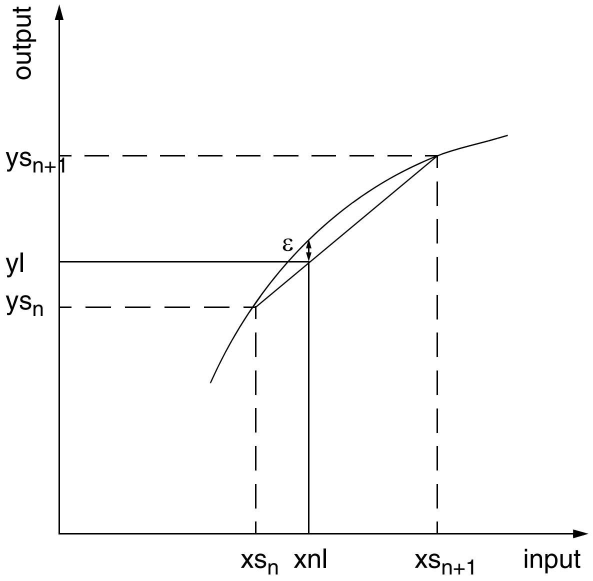


Fig. 3–6: Linearization - Detail

xnl: non linear distorted input value
yl: linearized value
ε: remaining error

The constraint of the linearization is that the input characteristic has to be a monotonic function. In addition to that it is recommended that the input does not have a saddle point or inflection point or regions where the input is nearly constant. This would require a high density of set points.

To do a linearization the following steps are necessary:

- Measure output characteristics over full range
- Find the inverse (Point-wise mirroring the graph on the bisectrix)
- Do a spline fit on the inverse
- Insert digital value of set point position into spline fit function for each set point (0, 1024, 2048, ..., 32768)
- Resulting values can be directly entered into the EEPROM

3.4. NVRAM Register

Customer Setup

The CUST_SETUP register is a 16 bit register. It enables the customer to activate various functions of the sensor like, diagnosis modes, functionality mode, customer lock, etc.

Bit no.	Function	Description
15:6	None	Reserved
5	Functionality Mode	1: Normal
4	Communication Mode (POUT)	Communication via output pin 0: Disabled 1: Enabled
3	Overvoltage Detection	0: Overvoltage detection active 1: Overvoltage detection disabled
2	Diagnosis Latch	Latching of diagnosis bits 0: No latching 1: Latched till next POR (power-on reset)
1	Diagnosis	0: Diagnosis errors force output to error band (V_{SUP}) 1: Diagnosis errors do not force output to error band (V_{SUP})
0	Customer Lock	Bit must be set to 1 to lock the sensor memory

3.5. On-board Diagnostic Features

The HAL38xy features two groups of diagnostic functions. The first group contains basic functions that are always active. The second group can be activated by the customer and contains supervision and self-tests related to the signal path and sensor memory.

Diagnostic features that are always active:

- Wire break detection for supply and ground line
- Undervoltage detection
- Thermal supervision of output stage (overcurrent, short circuit, etc.)

Diagnostic features that can be activated by customer:

- EEPROM programming supervision
- EEPROM self-test at power-on
- ROM parity check
- Continuous state machine self-test
- Magnetic range detection
- Overvoltage detection

In case of HAL 385x, the sensor indicates a failure by switching the output signal to the upper diagnosis level (max. Vout).

HAL 387x indicates a failure by changing the PWM frequency. The different errors are then coded in different duty-cycles.

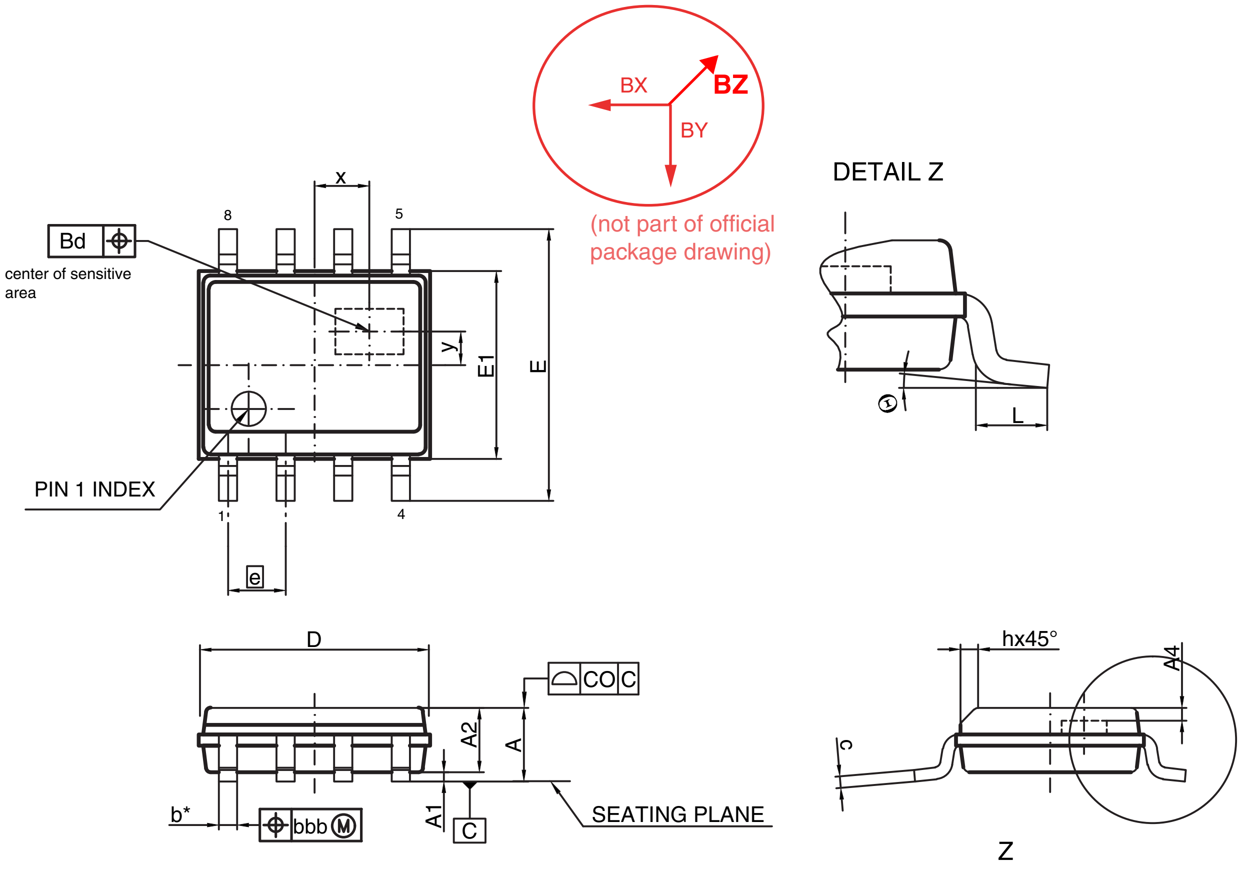
Table 3–2: Failure indication for HAL 387x

Failure Mode	Frequency	Duty-Cycle
EEPROM and state machine self-test	50%	95%
Adder overflow	50%	85%
Magnetic field too low	50%	62.5%
Magnetic field too high	50%	55%
Overvoltage	50%	75%
Undervoltage	50%	100%

Note: In case of an error the sensor changes the selected PWM frequency. Example:
During normal operation the PWM frequency is 1 kHz, in case of an error 500 Hz.

4. Specifications

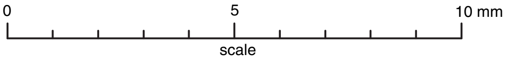
4.1. Outline Dimensions



"D" and "E1" are reference data and do not include mold flash or protrusion.
Mold flash or protrusion shall not exceed 150 µm per side.

* does not include dambar protrusion of 0.1 max. per side

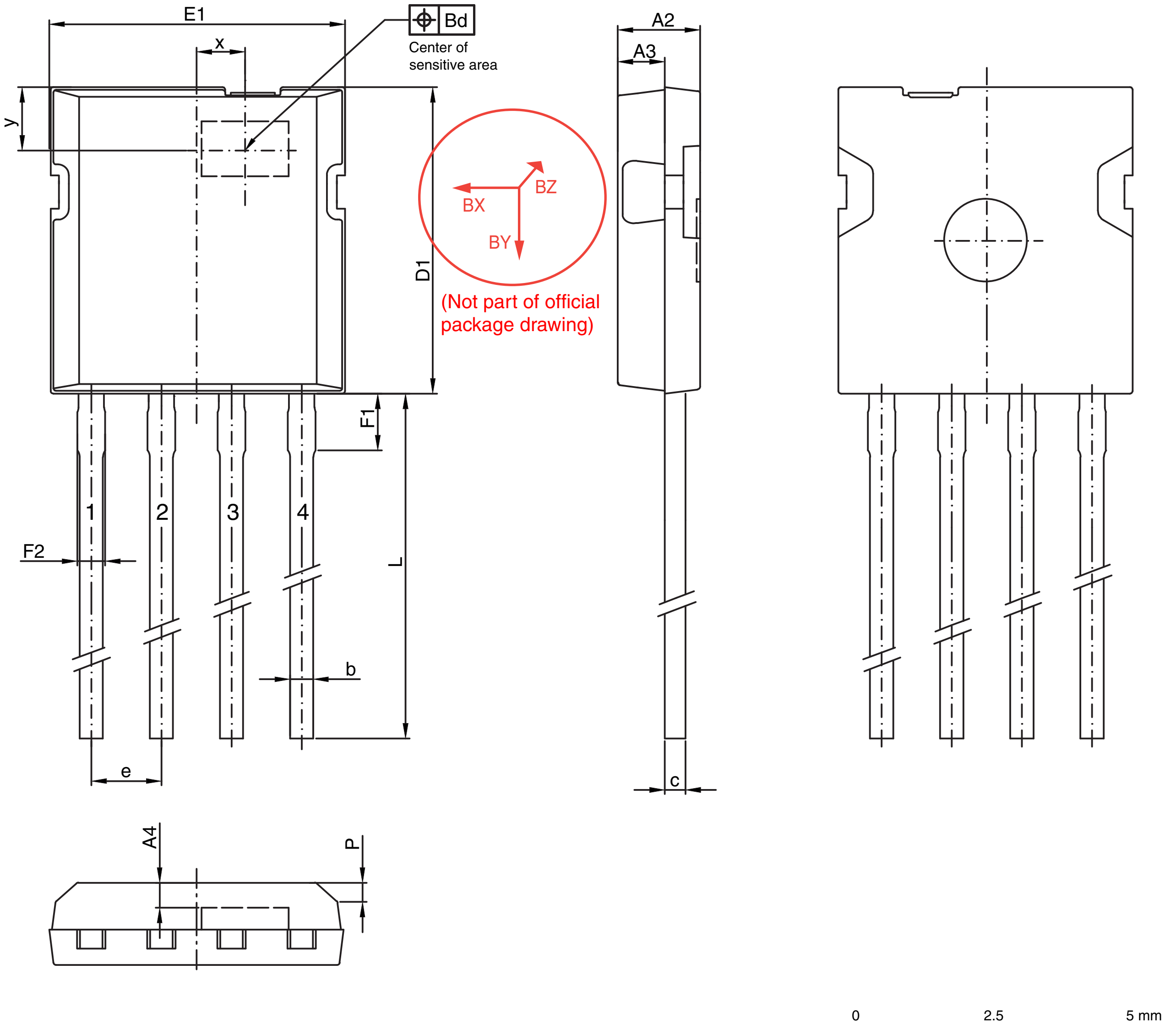
A4, Bd, x,y=these dimensions are different for each sensor type and are specified in the data sheet



UNIT	A	A1	A2	b	bbb	c	CO	D	E	E1	e	h	L	Θ
mm	1.65	0.25 0.1	1.45	0.4	0.25	0.22	0.1	5.0 4.8	6.0	4.0 3.8	1.27	0.3	0.41 min.	8° max.

JEDEC STANDARD			ISSUE DATE YY-MM-DD	DRAWING-NO.	ZG-NO.
ISSUE	ITEM NO.				
F	MS-012		09-07-21	06690.0001.4 Bl. 1	ZG001090_Ver.05

Fig. 4–1:
SOIC8-1: Plastic **S**mall **O**utline **IC** package, 8 leads, gullwing bent, 150 mil
Ordering code: DJ
Weight approximately 0.086 g

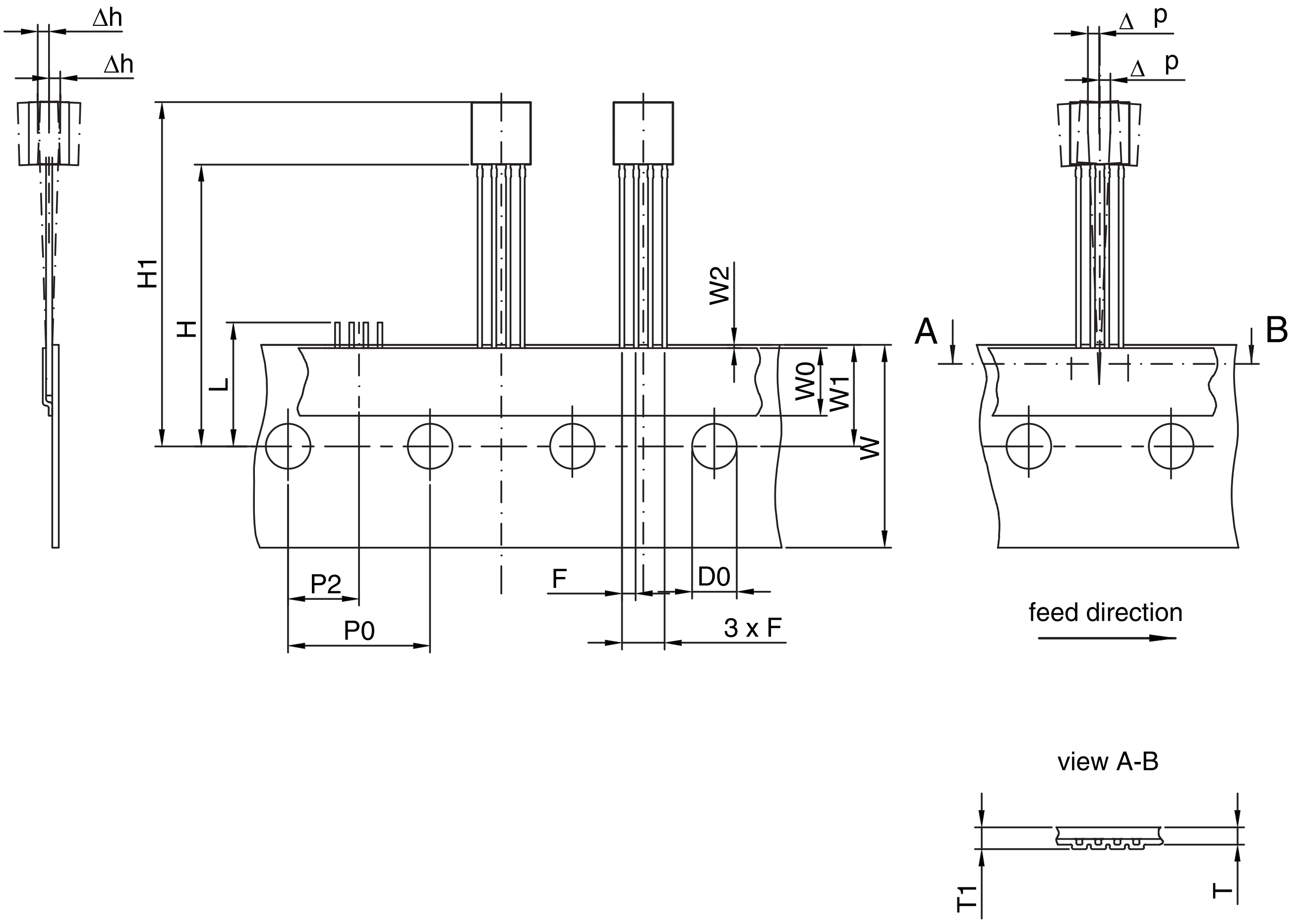


physical dimensions do not include moldflash.
A4, Bd, x, y= these dimensions are different for each sensor type and are specified in the data sheet.
solderability is guaranteed between end of pin and distance F1.
Sn-thickness might be reduced by mechanical handling.
Due to delivery in ammopack, L is defined by the cutting process of the customer.

UNIT	A2	A3	b	c	D1	e	E1	F1	F2	P
mm	1.55 1.45	0.85	0.42	0.36	5.60 5.50	1.27	5.38 5.28	1.20 0.80	0.60 0.42	0.3x45°

JEDEC STANDARD		ANSI	ISSUE DATE YY-MM-DD	DRAWING-NO.	ZG-NO.
ISSUE	ITEM NO.				
-	-	⊕◁	11-07-08	06691.0001.4	ZG001091_001_04

Fig. 4–2:
TO92UP: Plastic Transistor Standard UP package, 4 leads
Weight approximately 0.105 g



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

UNIT	D0	F	H	H1	Δh	L	P0	P2	Δp	T	T1	W	W0	W1	W2
mm	4.0	1.47 1.07	26 24	30.55	±1.0	11.0 max	13.2 12.2	7.05 5.65	±1.0	0.5	0.9	18.0	6.0	9.0	0.3

JEDEC STANDARD		ANSI	ISSUE DATE YY-MM-DD	DRAWING-NO.	ZG-NO.
ISSUE	ITEM NO.				
-	-		10-09-29	06901.4000.1	ZG001095_001_02

Fig. 4–3:
TO92UP: Dimensions ammopack inline, not spread

4.2. Soldering, Welding, Assembly

Please check the Micronas Document "Guidelines for the Assembly of HAL Packages" for further information about solderability, welding, assembly, and second-level packaging. The document is available on the Micronas website or on the service portal.

4.3. Dimensions of Sensitive Area

250 μm x 250 μm

4.4. Package Parameters and Position of Sensitive Areas

	SOIC8-1	TO92UP-1
A4	0.38 mm nominal	0.45 mm nominal
Bd	0.3 mm	0.3 mm
x	0 mm nominal (center of package)	0 mm nominal (center of package)
y	0.13 mm nominal	1.90 mm nominal

4.5. Pin Connections and Short Description

Pin No.		Pin Name	Type	Short Description
TO92UP Package	SOIC8 Package			
1	1	VSUP	SUPPLY	Supply Voltage Pin
2	2	GND	GND	Ground
3	3	TEST	IN	Test
4	4	OUT	I/O	Push-Pull Output and Programming Pin
–	5, 6, 7, 8	NC	NC	not connected

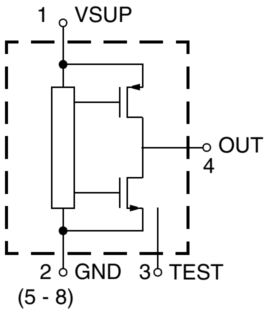


Fig. 4–4: Pin configuration

Note: Pins 3,5,6,7,8 must be connected to GND

4.6. Absolute Maximum Ratings

Stresses beyond those listed in the “Absolute Maximum Ratings” may cause permanent damage to the device. This is a stress rating only. Functional operation of the device at these conditions is not implied. Exposure to absolute maximum rating conditions for extended periods will affect device reliability.

This device contains circuitry to protect the inputs and outputs against damage due to high static voltages or electric fields; however, it is advised that normal precautions be taken to avoid application of any voltage higher than absolute maximum-rated voltages to this high-impedance circuit.

All voltages listed are referenced to ground (GND).

Symbol	Parameter	Pin No.	Min.	Max.	Unit	Condition
V_{SUP}	Supply Voltage	VSUP	–18	18	V	t < 1 hr
V_{OUT}	Output Voltage	OUT	–6	18	V	t < 1 hr
$V_{OUT} – V_{SUP}$	Excess of Output Voltage over Supply Voltage	OUT, VSUP	–	2	V	
I_{OUT}	Continuous Output Current	OUT	–10	10	mA	
T_J	Junction Temperature under bias		–50	190	°C	1)
B_{max}	Magnetic Field	–	–	unlimited	T	
V_{ESD}	ESD Protection	VSUP, OUT, GND, TEST, NC	–4	4	kV	2)

1) For 96 h - Please contact Micronas for other temperature requirements
2) AEC-Q100-002 (100 pF and 1.5 kΩ)

4.6.1. Storage and Shelf Life SOIC8 package

SOIC-8 Package is a Moisture-sensitive Surface Mount Device. The Moisture Sensitivity Level (MSL) is defined according to JEDEC J-STD-020 (Moisture/Reflow Sensitivity Classification for Non hermetic Solid State Surface Mount Devices). The device is packed acc. to IPC/JEDEC J-STD-033: Handling, Packing, Shipping and Use of Moisture/Reflow Sensitive Surface Mount Devices. By using these procedures, safe and damage-free reflow can be achieved.

Please follow the instructions printed on each Moisture Barrier Bag. These instructions contain information about the Moisture Sensitivity Level “MSL”, the maximum reflow temperature “Peak Package Body Temp.” and the time frame “Time for Mounting after opening the MBB”. The dry-bag shelf life capability of sealed dry-bags is minimum 12 months starting from the “Bag seal date” printed on each bag.

If moisture-sensitive components have been exposed to ambient air for longer than the specified time according to their MSL, or the humidity indicator card indicates too much moisture after opening a Moisture Barrier Bag (MBB), the components have to be baked prior to the assembly process. Please refer to IPC/JEDEC J-STD-033 for details. Please be aware that packing materials may not withstand higher baking temperatures.

4.6.2. Storage and Shelf Life TO92UP package

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

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

4.7. Recommended Operating Conditions

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

All voltages listed are referenced to ground (GND).

Symbol	Parameter	Pin No.	Min.	Typ.	Max.	Unit	Condition
V_{SUP}	Supply Voltage	VSUP	4.5 5.7	5 6.0	5.5 6.5	V	Normal Operation During Programming
I_{OUT}	Continuous Output Current	OUT	–1.2	–	1.2	mA	
R_L	Load Resistor	OUT	5 20	10 –	– –	kΩ	HAL385x pull-down resistor pull-up resistor
			1	–	–	kΩ	HAL387x pull-up resistor
C_L	Load Capacitance	OUT	0.33 –	10 1.0	600 10	nF nF	HAL385x HAL387x
N_{PRG}	Number of Memory Programming Cycles[1]	–	–	–	100	cycles	0 °C < T_{amb} < 55 °C
B_{Z_AMP}	Recommended Amplitude of Z-Magnetic Field	–	±30	–	±55	mT	
B_{X/Y_AMP}	Recommended Amplitude of X/Y-Magnetic Field	–	±30	–	±100	mT	
T_J	Junction Temperature [2]		–40 –40 –40	– – –	125 150 170	°C °C °C	for 8000 hrs for 2000 hrs for 1000 hrs Time values are not additive.

[1] In the EEPROM, it is not allowed to program only one single address within a 'bank' in the memory. In case of programming one single address the complete bank has to be programmed.

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

Note: It is also possible to operate the sensor with magnetic fields down to ±5 mT. For magnetic fields below ±30 mT the sensor performance will be reduced.

4.8. Characteristics

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

Symbol	Parameter	Pin No.	Limit Values			Unit	Test Conditions
			Min.	Typ.	Max.		
I_{SUP}	Supply Current over Temperature Range	VSUP	–	10	15	mA	
	Resolution [1]	OUT	– –	12 12	– –	bit bit	for HAL385x ratiometric to VSUP for HAL387x (depends on PWM Period)
$t_{r(O)}$	Response Time of Output [2]	OUT	–	0.5	0.6	ms	C_L = 10 nF, time from ideal step to 90% of final output For HAL387x the response time is defined by the selected PWM period
$t_{\Delta Vs}$	Wake-up time [2]	OUT	–	–	1.7	ms	C_L = 10 nF (see Fig. 4–6 on page 23)
HAL385x (Analog Output)							
DNL	Differential Non-Linearity of D/A converter	OUT	–3	0	3	LSB	
E_R	Ratiometric Error of Output over temperature (Error in V_{OUT}/V_{SUP})	OUT	–0.2	0	0.2	%	Max of [V_{OUT5} – $V_{OUT4.5}$ and $V_{OUT5.5}$ – V_{OUT5}] at V_{OUT} = 10% and 90% V_{SUP}
INL	Non-Linearity of D/A converter	OUT	–0.1	0	0.1	%	% of supply voltage
ΔV_{OFFSET}	D/A converter offset drift over temperature range related to 25 °C [2]	OUT	–0.2	0	0.2	$\%V_{SUP}$	
V_{OUTH}	Output High Voltage [3]	OUT	93	–	–	$\%V_{SUP}$	R_L Pull-up= 20 kΩ R_L Pull-down= 5 kΩ
V_{OUTL}	Output Low Voltage [3]	OUT	–	–	7	$\%V_{SUP}$	R_L Pull-up= 20 kΩ R_L Pull-down= 5 kΩ
ΔV_{OUTCL}	Accuracy of Output Voltage at Clamping Low Voltage over Temperature Range [2]	OUT	–30	0	30	mV	R_L Pull-up= 20 kΩ R_L Pull-down= 5 kΩ
ΔV_{OUTCH}	Accuracy of Output Voltage at Clamping High Voltage over Temperature Range [2]	OUT	–30	0	30	mV	R_L Pull-up= 20 kΩ R_L Pull-down= 5 kΩ V_{SUP} = 5V
OUT_{Noise}	Output Noise RMS [2]	OUT	– –	4.5 1.5	12 4.0	mV mV	Min. magnetic amplitude = ±30 mT Min. magnetic amplitude = ±70 mT with external capacitor on the output f_C = 22 kHz
R_{OUT}	Output Resistance over Recommended Operating Range	OUT	–	1	10	Ω	$V_{OUTLmax} \leq V_{OUT} \leq V_{OUTHmin}$

[1] Guaranteed by Design
[2] Characterized on small sample size, not tested.
[3] 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}

Symbol	Parameter	Pin No.	Limit Values			Unit	Test Conditions
			Min.	Typ.	Max.		
HAL387x (PWM Output)							
V_{OUTH}	Output High Voltage	OUT	–	4.9	–	V	VSUP = 5 V, –1 mA< I_{OUT} < 1 mA
V_{OUTL}	Output Low Voltage	OUT	–	0.1	–	V	VSUP = 5 V, –1 mA < I_{OUT} < 1 mA
OUT_{Noise}	Output Noise RMS [2]	OUT	– –	0.12 0.02	0.24 0.08	% %	Min. magnetic amplitude = ±30 mT Min. magnetic amplitude = ±100 mT with external capacitor on the output Related to 100 % DC
f_{PWM}	PWM Frequency	OUT	1.7 0.85 0.425 0.213	2 1 0.5 0.25	2.3 1.15 0.575 0.288	kHz	Customer programmable
J_{PWM}	RMS PWM Jitter [2]	OUT	–	1	2	LSB_{12}	f_{PWM} = 1 kHz
t_{rise}	Rise Time of Digital Output	OUT	–	0.4	–	µs	R_L Pull-up= 1 kΩ
t_{fall}	Fall Time of Digital Output	OUT	–	0.5	–	µs	R_L Pull-up= 1 kΩ
ROUT_DIG	On Resistance of Digital Pull-Up Driver	OUT	–	100	200	Ω	Includes 25 Ω series pull-up resistor and 50 Ω pull-down
SOIC8 Package							
	Thermal Resistance						
R_{thja}	Junction to Air	–	–	–	142	K/W	Measured with a 1s0p board
		–	–	–	88	K/W	Measured with a 1s1p board
R_{thjc}	Junction to Case	–	–	–	33	K/W	Measured with a 1s0p board
		–	–	–	22	K/W	Measured with a 1s1p board
TO92UP Package							
	Thermal Resistance						
R_{thja}	Junction to Air	–	–	–	198	K/W	Measured with a 1s0p board
		–	–	–	146	K/W	Measured with a 1s1p board
R_{thjc}	Junction to Case	–	–	–	53	K/W	Measured with a 1s0p board
		–	–	–	38	K/W	Measured with a 1s1p board

[2] Characterized on small sample size, not tested.

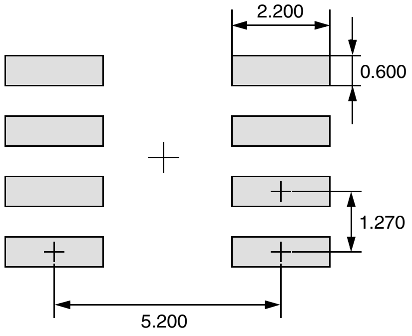


Fig. 4–5: Recommended pad size SOIC8 package

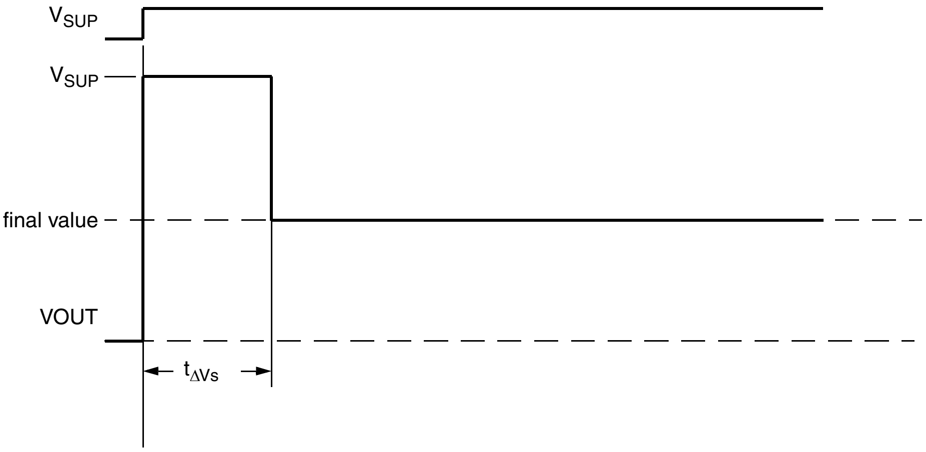


Fig. 4–6: Description of power-on behavior of the sensor

4.9. Magnetic Characteristics

at T_J = –40 °C to +170 °C, V_{SUP} = 4.5 V to 5.5 V, GND = 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_J = 25 °C and V_{SUP} = 5 V.

Symbol	Parameter	Pin No.	Min.	Typ.	Max.	Unit	Test Conditions
ASMm_{XYZ}	Absolute Sensitivity Mismatch on Raw Signals between X or Y and Z Channel 2)	OUT	–10	–	10	%	T_J = 25°C
Sense_{XYZ}	Sensitivity of X or Y and Z Hall Plate1)	OUT	138	150	162	LSB/mT	T_J = 25°C
ΔSense_{XYZ}	Sensitivity Drift of Hall Plates over temperature 1)	–	1.25 0.92 0.4	1.4 1.0 0.5	1.5 1.08 0.6	–	T_J = –40 °C T_J = 25 °C T_J = 170°C
SMm_{XYZ}	Thermal Sensitivity Mismatch Drift on Raw Signals between X or Y and Z Channel 2)	OUT	–3.0	–	3.0	%	over full temperature range related to 25°C
Offset_{XY}	Offset on Raw Signals of X or Y Channel1)	OUT	–50	0	50	LSB_{15}	T_J = 25°C, Can be compensated in customer application (see Section 3.2. on page 8)
Offset_{Z}	Offset on Raw Signals of Z Channel1)	OUT	–25	0	25	LSB_{15}	T_J = 25°C, Can be compensated in customer application (see Section 3.2. on page 8)
ΔOffset_{XY}	Offset Drift on Raw Signals of X or Y Channel1)	OUT	–100	–	100	LSB_{15}	over full temperature range related to 25°C
ΔOffset_{Z}	Offset Drift on Raw Signals Z Channel1)	OUT	–25	–	25	LSB_{15}	over full temperature range related to 25°C
$\text{SMm}_{XYZLife}$	Relative Sensitivity Mismatch Drift on Raw Signals between X or Y and Z Channel over Life Time 2)	OUT	–	1.0	–	%	after 1000 h HTOL
$\Delta\text{Offset}_{XYlife}$	Offset Drift on Raw Signals of X or Y Channel over Life Time 2)	OUT	–	30	–	LSB_{15}	after 1000 h HTOL
$\Delta\text{Offset}_{Zlife}$	Offset Drift on Raw Signals of Z Channel over Life Time 2)	OUT	–	5	–	LSB_{15}	after 1000 h HTOL

1) Characterized on small sample size, not tested. Specification limit is +/– 3 Sigma value.
2) Characterized on small sample size, not tested.

4.10.Open-Circuit Detection (only applicable for HAL385x)

at T_J = –40 °C to +170 °C for, Typical Characteristics for T_J = 25 °C, after programming.

Symbol	Parameter	Pin No.	Min.	Typ.	Max.	Unit	Comment
V_{OUT}	Output voltage at open V_{SUP} line	OUT	0	0	0.15	V	V_{SUP} = 5 V R_L = 20 kΩ to 200 kΩ
V_{OUT}	Output voltage at open GND line	OUT	4.85	4.9	5.0	V	V_{SUP} = 5 V R_L = 10 kΩ to 200 kΩ
			4.8	4.9	5.0	V	V_{SUP} = 5 V 5 kΩ >= R_L < 10 kΩ
R_L: Can be pull-up or pull-down resistor							

4.11.Overvoltage and Undervoltage Detection

at T_J = –40 °C to +170 °C, Typical Characteristics for T_J = 25 °C, after programming and locking the sensor

Symbol	Parameter	Pin No.	Min.	Typ.	Max.	Unit
$V_{SUP,UV}$	Undervoltage detection level	VSUP	3.3	3.7	4.4	V
$V_{SUP,UVhyst}$	Undervoltage detection level hysteresis	VSUP	–	200	–	mV
$V_{SUP,OV}$	Overvoltage detection level	VSUP	5.6	6.2	6.9	V
$V_{SUP,OVhyst}$	Overvoltage detection level hysteresis	VSUP	–	225	–	mV

5. Application Notes

5.1. Ambient Temperature

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

$T_J = T_A + \Delta T$

At static conditions and continuous operation, the following equation applies:

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

The X represents junction to air, 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.

Following example shows the result for junction to air conditions for SOIC8 package.
V_{SUP} = 5.5 V, R_{thja} = 142 K/W and I_{SUP} = 15 mA the temperature difference ΔT = 11.72 K.

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

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

5.2. EMC and ESD

The HAL 38xy is designed for a stabilized 5 V supply. Interferences and disturbances conducted along the 12 V on board system (product standard ISO 7637 part 1) are not relevant for these applications.

For applications with disturbances by capacitive or inductive coupling on the supply line or radiated disturbances, the application circuits shown in Fig. 5–1 and Fig. 5–2 are recommended. Applications with these arrangement pass the EMC tests according to the product standards ISO 7637 part 3 (Electrical transient transmission by capacitive or inductive coupling) and part 4 (Radiated disturbances).

5.3. Application Circuit for HAL385x

For EMC protection, it is recommended to connect one ceramic 47 nF capacitor each between ground and the supply voltage, respectively the output voltage pin.

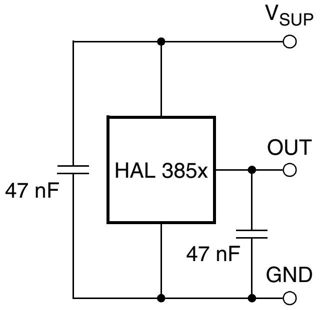


Fig. 5–1: Recommended application circuit for HAL385x

5.4. Application Circuit for HAL387x

For EMC protection, it is recommended to connect one ceramic 47 nF capacitor between ground and the supply voltage and one ceramic 1 nF capacitor between the output pin and ground.

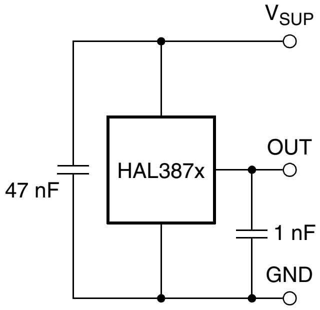


Fig. 5–2: Recommended application circuit for HAL387x

5.5. Measurement of a PWM Output Signal of HAL387x

In case of the PWM output, the magnetic field information is coded in the duty cycle of the PWM signal. The duty cycle is defined as the ratio between the high time “s” and the period “d” of the PWM signal (see Fig. 5–3).

Note: The PWM signal is updated with the rising edge. Hence, for signal evaluation, the trigger-level must be the rising edge of the PWM signal.

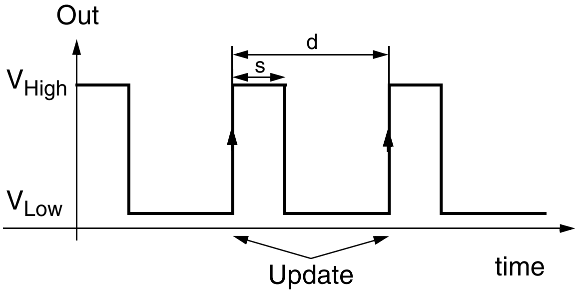


Fig. 5–3: Definition of PWM signal

6. Programming of the Sensor

HAL 38xy features two different customer modes. In **Application Mode** the sensor provides a ratiometric analog output voltage. In **Programming Mode** it is possible to change the register settings of the sensor.

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

6.1. Programming Interface

In Programming Mode HAL 38xy is addressed by modulating a serial telegram on the sensors output pin. Both sensors answer with a modulation of the output voltage.

A logical "0" is coded as no level change within the bit time. A logical "1" is coded as a level change of typically 50% of the bit time. After each bit, a level change occurs (see Fig. 6–1).

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

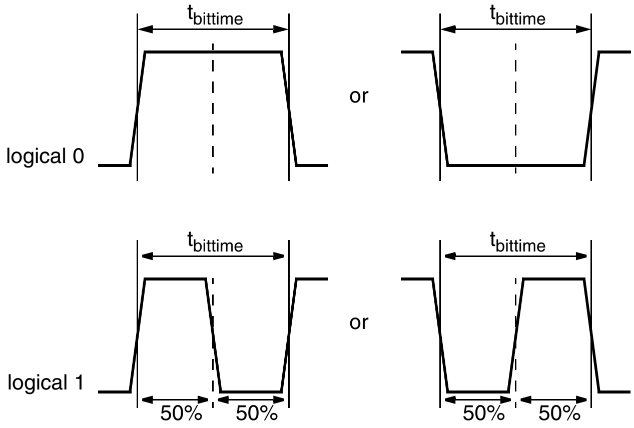


Fig. 6–1: Definition of logical 0 and 1 bit

A description of the communication protocol and the programming of the sensor is available in a separate document (Application Note Programming HAL 38xy).

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

Symbol	Parameter	Pin No.	Limit Values			Unit	Test Conditions
			Min.	Typ.	Max.		
V_{OUTL}	Voltage for Output Low Level during Programming through Sensor Output Pin	OUT	0 0	–	0.2*V_{SUP} 1	V V	 for V_{SUP} = 5 V
V_{OUTH}	Voltage for Output High Level during Programming through Sensor Output Pin	OUT	0.8*V_{SUP} 4	– –	V_{SUP} 5.0	V V	 for V_{SUP} = 5 V
$V_{SUPProgram}$	V_{SUP} Voltage for EEPROM & NVRAM programming (during Programming)	OUT	5.7	6.0	6.5	V	Supply voltage for bidirectional communication via output pin as well as for 3-wire communication via supply voltage modulation
$t_{bittime}$	Biphase Bit Time	OUT	900	1000	1100	µs	T_J = 25°C
	Slew rate	OUT	–	2	–	V/µs	

6.2. Programming Environment and Tools

For the programming of HAL 38xy during product development and also for production purposes a programming tool including hardware and software is available on request. It is recommended to use the Micronas tool kit (HAL-APB V1.x & Lab View Programming Environment) in order to easy the product development. The details of programming sequences are also available on request.

Note: For production HAL-APB V1.5 or higher must be used.

6.3. Programming Information

For production and qualification tests, it is mandatory to set the LOCK bit to one and the POUT bit to zero after final adjustment and programming of HAL 38xy.

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

In order to ensure correct detection of programming errors, the following detailed guidance has to be followed:

- EEPROM: It is mandatory to check the acknowledge (first and second) of the sensor after each write and store sequence to verify that the programming of the EEPROM was successful. To ease debugging of the production line it is recommended to read/check the status of the PROG_DIAGNOSIS register in case of a missing second acknowledge.
- NVRAM: It is mandatory to read/check the status of the PROG_DIAGNOSIS register after programming to verify that the programming of the NVRAM was successful.

In case of programming errors it is possible to reprogram the EEPROM or NVRAM registers as long as the max. number of programming cycles is not exceeded.

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

In case of HAL 387x DAC register values have a direct impact on the programming sequence of the device due to the architecture of the sensor's programming logic. DAC values below 5% and above 25% full-scale potentially increase linearly the number of programming error messages (PUMP error) or respectively missing second acknowledges.

It is recommended to ensure DAC register values between 5% and 25% of Full-Scale. Please contact Micronas in case that DAC register values beyond these limits cannot be avoided during programming of the device.

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

Note: Please check also the "HAL385x, HAL387x Programming Guide". It contains additional information and instructions about the programming of the devices.

7. Data Sheet History

1. Preliminary Data Sheet: “HAL 385x, HAL 387x Programmable 2D Position Sensors with Arbitrary Output Function”, July 3, 2012, PD000209_001EN.
   First release of the preliminary data sheet.
2. Preliminary Data Sheet: “HAL 385x, HAL 387x Programmable 2D Position Sensors with Arbitrary Output Function”, March 21, 2013, PD000209_002EN.
   Second release of the preliminary data sheet.
   Major changes:
   - new package added TO92UP-1
   - K temperature range removed
   - smaller pull-up resistor for HAL 387x
   - maximum BZ-Field amplitude reduced
3. Data Sheet: “HAL 385x, HAL 387x Programmable 2D Position Sensors with Arbitrary Output Function”, Dec. 16, 2014, DSH000167_001EN. First release of the data sheet.
   Major changes:
   - Additional guidance for programming of the sensors
   - Distribution of magnetic parameters changed to +/- 3 sigma
   - Update of application circuit for HAL387x
   - Update of package drawings

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