Data Sheet

HAL® 371x, HAL 372x, HAL 373x

Robust Programmable
2D Position Sensor Family
with Arbitrary Output Function

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

1. Introduction

The HAL 37xy family comprises the second generation of sensors using the proprietary Micronas 3D HAL$^®$ technology. This new family has several members. HAL 372x provides a linear, ratiometric analog output signal with integrated wire-break detection working with pull-up or pull-down resistors. Compared to HAL 372x, the HAL 371x is splitting the 360° measurement range either into four repetitive 90° (MOD 90°) or three 120° (MOD 120°) segments. HAL 373x features digital output formats like PWM and SENT (according to SAE-J2716 release 2010). The digital output format is customer programmable. The PWM output is configurable with frequencies between 0.2 kHz and 2 kHz with up to 12 bit resolution.

Conventional planar Hall technology is only sensitive to the magnetic field orthogonal to the chip surface. In addition to the orthogonal magnetic field, HAL 37xy 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 B_X, B_Y, and B_Z. This enables a new set of applications for position detection, like wide distance, angle or through-shaft angular measurements. The Table 1–1 below describes the different family members.

Table 1–1: HAL 37xy family overview

Type	Output Format	Detectable Field Component
HAL 3711	PWM/Modulo	B_X and B_Y
HAL 3715	Analog/Modulo	B_X and B_Y
HAL 3725	Analog	B_X and B_Y
HAL 3726	Analog	B_Y and B_Z
HAL 3727	Analog	B_X and B_Z
HAL 3735	PWM & SENT	B_X and B_Y
HAL 3736	PWM & SENT	B_Y and B_Z
HAL 3737	PWM & SENT	B_X and B_Z

On-chip signal processing calculates the angle from 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 33 setpoints).

Major characteristics like gain and temperature dependent 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 sensors contain 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 selected PWM output, the error modes are indicated by a changing PWM frequency and duty-cycle. For SENT output a dedicated error code will be transmitted.

The devices are designed for automotive and industrial applications and operate in a junction temperature range from −40 °C up to 170 °C.

The sensors are available in a 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 37xy is the optimal system solution for applications such as:

– Linear movement measurement,
  • EGR valve position
  • Clutch pedal position
  • Cylinder and valve position sensing
– Rotary position measurement, like
  • Gear selector
  • Throttle valve position, etc.
  • Chassis position sensors (ride-height control) with HAL 371x
– Joystick
– Non-contact potentiometer

1.2. Features

– Angular and position measurement extremely robust against temperature and stress influence

– 12 bit ratiometric linear analog output for HAL 3715/HAL 372x

– Modulo 90°/120° for HAL 371x

– 0.2 kHz to 2 kHz PWM (up to 12 bit)
 or 12 bit SENT output for HAL 3711/HAL 373x

– Programmable arbitrary output characteristic with up to 33 setpoints

– 8 kHz sampling frequency

– Operates from 4.5 V up to 5.5 V supply voltage

– Operates from −40 °C up to 150 °C ambient temperature

– Programming via the sensor's output pin

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

– Programmable first-order low-pass filter

– Programmable hysteresis on X/Y- or Z-channel

– Programmable output gain and offset

– X/Y- and Z-channel gain of signal path programmable

– Second-order temperature-dependent offset of signal path programmable for X/Y- or Z-channel

– Phase shift between X/Y- and Z-channel programmable

– Programmable offset before angle calculation block

– Programmable output clamping for error band definition

– Programmable reference position

– Programmable magnetic detection range

– 32 bit identification number for customer

– 32 bit identification number with TDK-Micronas production information (like X,Y position on production wafer)

– 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:

```
XXX NNNN PA-T-C-P-Q-SP
 ↑    ↑   ↑  ↑   ↑
 │    │   │  │   └──────── Further Code Elements
 │    │   │  └──────────── Temperature Range
 │    │   └─────────────── Package
 │    └─────────────────── Product Type
 └──────────────────────── Product Group
```
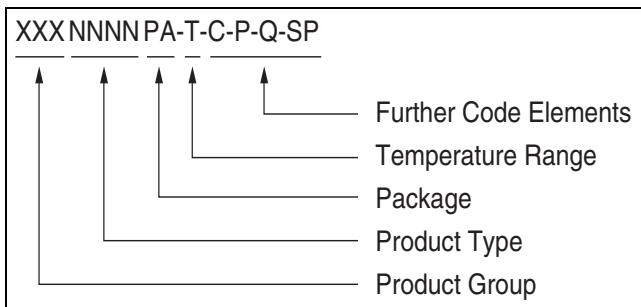
Fig. 2–1: Ordering Code Principle

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

2.1. Device-Specific Ordering Codes

The HAL 37xy 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 40.

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

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

Available Ordering Codes	Package Marking
HAL3711DJ-A-[C-P-Q-SP]	3711A
HAL3711UP-A-[C-P-Q-SP]	3711A
HAL3715DJ-A-[C-P-Q-SP]	3715A
HAL3715UP-A-[C-P-Q-SP]	3715A
HAL3725DJ-A-[C-P-Q-SP]	3725A
HAL3725UP -A-[C-P-Q-SP]	3725A
HAL3726DJ-A-[C-P-Q-SP]	3726A
HAL3726UP-A-[C-P-Q-SP]	3726A
HAL3727DJ-A-[C-P-Q-SP]	3727A
HAL3727UP-A-[C-P-Q-SP]	3727A
HAL3735DJ-A-[C-P-Q-SP]	3735A
HAL3735UP -A-[C-P-Q-SP]	3735A
HAL3736DJ-A-[C-P-Q-SP]	3736A
HAL3736UP-A-[C-P-Q-SP]	3736A
HAL3737DJ-A-[C-P-Q-SP]	3737A
HAL3737UP-A-[C-P-Q-SP]	3737A

HAL 371x, HAL 372x, HAL 373x

3. Functional Description

3.1. General Function

HAL 371x, HAL 372x and HAL 373x are 2D position sensors based on the Micronas 3D HAL® technology. The sensors include two vertical and one horizontal Hall plate with spinning current offset compensation for the detection of X, Y or Z magnetic field components, a signal processor for calculation and signal conditioning of two magnetic field components, protection devices, and a ratiometric linear analog, PWM or SENT output.

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

The signal path of HAL 37xy consists of two channels (CH1 and CH2). Depending on the product variant two out of the three magnetic field components are connected to Channel 1 and Channel 2.

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 the system designer to optimize performance for a specific system. The calibration information is stored in an on-chip EEPROM.

The HAL 37xy is programmable by modulation of the output voltage. No additional programming pin is needed.
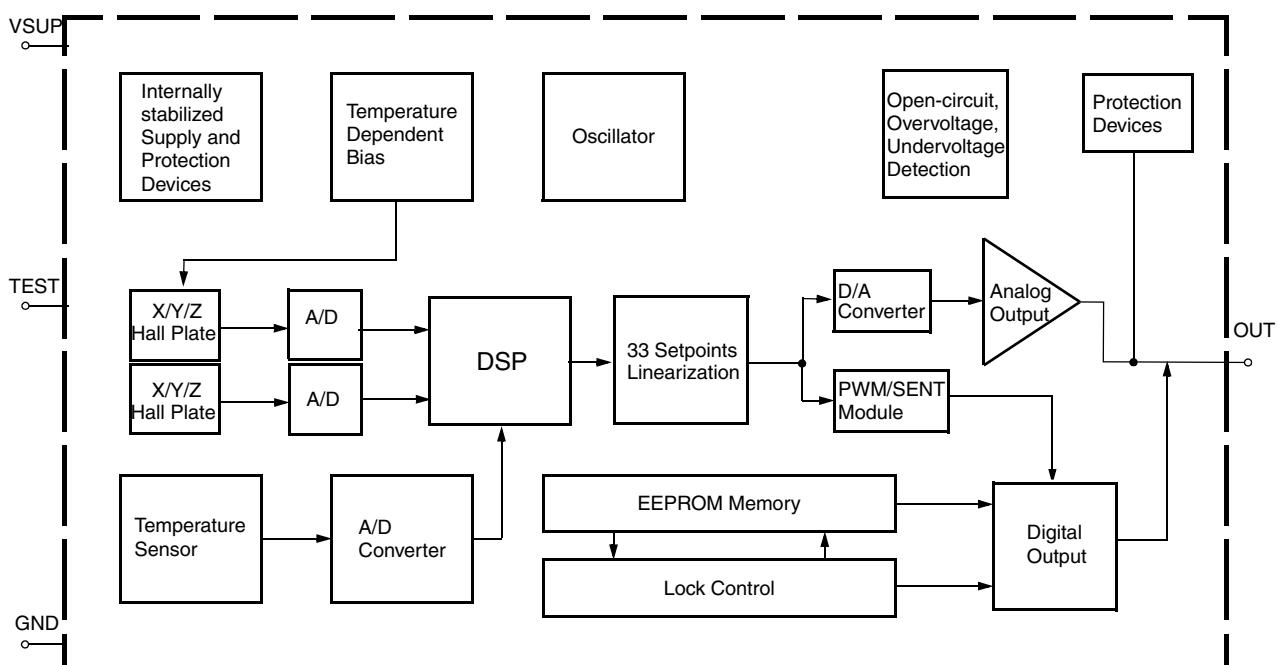
Fig. 3–1: HAL 37xy block diagram

3.2. Signal Path and Register Definition

3.2.1. Signal Path
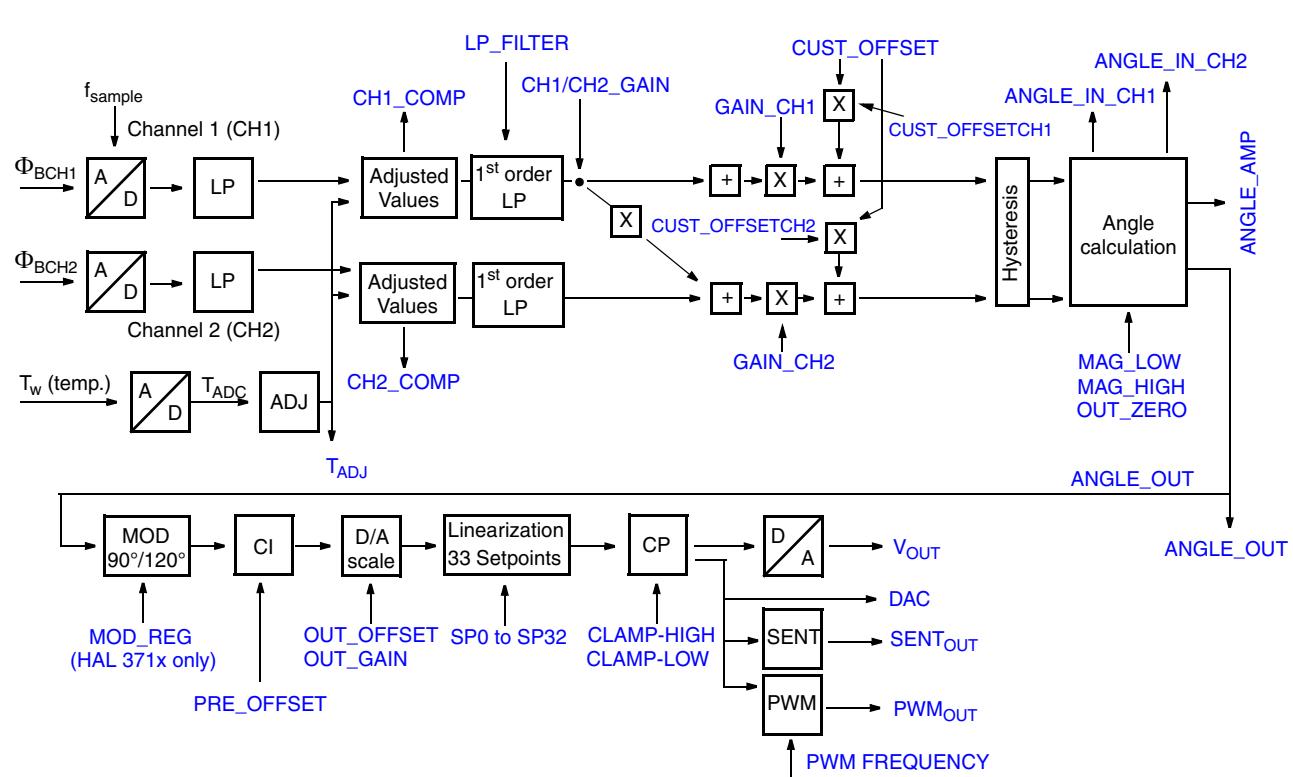
Fig. 3–2: Signal path of HAL 37xy

3.2.2. Register Definition

The DSP part of this sensor performs the signal conditioning. The parameters for the DSP are stored in the EEPROM/NVRAM register. Details of the signal path are shown in Fig. 3.2.

Terminology:

GAIN: name of the register or register value

Gain: name of the parameter

Blue color: register names

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

3.2.2.1. RAM Registers

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.

CH1_COMP and CH2_COMP

CH1_COMP and CH2_COMP register contain the temperature compensated magnetic field information of channel 1 and channel 2. Both registers have a length of 16 bit each and are two's-complement coded. Therefore, the register values can vary between −32768 … 32767.

ANGLE_IN_CH1 and ANGLE_IN_CH2

ANGLE_IN_CH1 and ANGLE_IN_CH2 register contain the customer compensated magnetic field information of channel 1 and channel 2 used for the angle calculation. These registers include already customer phase-shift, gain and offset correction as well as an hysteresis. Both registers have a length of 16 bit each and are two's-complement coded. Therefore, the register values can vary between −32768 … 32767.

ANGLE_OUT

The ANGLE_OUT register contains the digital value of the position calculated by the angle calculation 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. Position can either be an angular position (angle) or a virtual angle calculated out of two magnetic field directions in case of linear position measurements.

DAC

The DAC register contains the digital equivalent of the output voltage, PWM output duty-cycle or the SENT data. 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. Position can either be an angular position (angle) or a virtual angle calculated out of two magnetic field directions in case of linear position measurements.

ANGLE_AMP

The ANGLE_AMP register contains the digital value of the magnetic field amplitude calculated by the angle calculation algorithm. From mathematical point of view the amplitude can be calculated from the signals in channel 1 and channel 2 (X/Y/Z-components).

Example:

$$\text{Amplitude} = \sqrt{CH1^2 + CH2^2}$$

The angle calculation 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:

$$\text{ANGLE\_AMP} \cong 1{,}6 \times \sqrt{CH1^2 + CH2^2}$$

DIAGNOSIS

The DIAGNOSIS register identifies certain failures detected by the sensor. HAL 37xy performs 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.

Table 3–1: Bit definition of the DIAGNOSIS register

Bit no.	Function	Description
15:10	None	Reserved
9	DAC Output High Clamping	This bit is set to 1 in case that the high clamping value of the DAC is reached.
8	DAC Output Low Clamping	This bit is set to 1 in case that the low clamping value of the DAC is reached.
7	Channel 1 Clipping	These bits are set to 1 in case that the A/D converter in channel 1 and/or 2 detects an under- or overflow
6	Channel 2 Clipping	
5	DSP Self Test	The DSP is doing the internal signal processing like angle calculation, temperature compensation, etc. This bit is set to 1 in case that the DSP 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 or continuously running). Bit for diagnosis latching must be set to 1.
3	ROM Check	This bit is set to 1 in case that ROM parity check fails. (continuously running).
2	None	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 is below the MAG-LOW register value (magnetic field to low)

Details on the sensor self tests can be found in Section 3.5. on page 23.

PROG_DIAGNOSIS

The PROG_DIAGNOSIS register allows the customer to identify errors occurring during programming and writing of the EEPROM or NVRAM. The customer must check the first and second acknowledge. It is mandatory to activate the Diagnosis Latch bit during end of line testing. Additionally, CLAMP-LOW must be set to 100% in case of HAL 3711 and HAL 373x. Otherwise programming errors will not be indicated by the second acknowledge. To enable debugging of the production line it is recommended to read back the PROG_DIAGNOSIS register and the DIAGNOSIS register in case of a missing second acknowledge. Please check the "HAL 37xy, HAR 37xy User Manual" for further details.

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

Table 3–2: Bit definition of the PROG_DIAGNOSIS register

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 too low
9	Voltage Error during Program/Erase	This bit is set to 1 in case that the internal supply voltage was too low during program or erase
8	NVRAM Error	This bit is set to 1 in case that the programming of the NVRAM failed
5:0	Programming	These bits are used for programming the memory

3.2.2.2. EEPROM Registers

Note   For production and qualification tests it is mandatory to set the LOCK bit after final adjustment and programming.

Note   Please refer to the "HAL 37xy, HAR 37xy User Manual" for further details on register settings/calculation and programming of the device.

Micronas IDs

The MIC_ID1 and MIC_ID2 registers are both 16 bit organized. They are read-only and contain TDK-Micronas production information, like X/Y position on the wafer, wafer number, etc.

Customer IDs

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

CH1/CH2_GAIN

CH1/CH2_GAIN can be used to compensate a phase-shift between channel 1 and channel 2. The register has a length of 16 bit. It is possible to make a phase shift correction of $\pm75°$. 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.

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_CH2 too. For details see definition of GAIN_CH2.

GAIN_CH1 and GAIN_CH2

GAIN_CH1 and GAIN_CH2 can be used to compensate amplitude mismatches between channel 1 and channel 2. TDK-Micronas delivers pre calibrated sensors with compensated gain mismatch between channel 1 and channel 2. Nevertheless it is possible that due to the magnetic circuit a mismatch between channel 1 and channel 2 gain occurs. This can be compensated with GAIN_CH1 and GAIN_CH2.

Both registers have a length of 16 bit and are two's-complement coded. Therefore, they can have values between -32768 and 32767 ($-2 \ldots 2$). For neutral settings both register values have to be set to 1 (register value 16384).

In case that the phase-shift correction is used it is necessary to change also the gain of channel 2 (see also CH1/CH2_GAIN). If phase-shift correction is used the corresponding register has to be set to

$$\text{GAIN\_CH2} = \frac{16384}{\cos(\text{Phase-shift})}$$

Note	In case GAIN_CH1 or GAIN_CH2 exceed the range of $-2 \ldots 2$ ($-32768 \ldots 32767$), then it is possible to reduce the gain of the opposite channel for compensation.

CUST_OFFSET

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

The customer offset can also have a temperature coefficient to follow the temperature coefficient of a magnet. The customer offset consists of a polynomial of second-order represented by the three registers CUST_OFFSET1...3.

The customer offset can be added to channel 1 and/or channel 2 by the selection coefficients CUST_OFFSETCH1 and CUST_OFFSETCH2. Additionally these two registers can be used to scale the temperature dependent offset between 0% and 100%.

All five registers have a length of 16 bit each and are two's-complement coded. Therefore, they can have values between −32768 and 32767.

HYSTERESIS

HYSTERESIS defines the number of digital codes used as an hysteresis on channel 1 and channel 2 before the angle calculation. The purpose of this register is to avoid angle variation on the ANGLE_OUT register and finally on the output signal due to the noise on the ANGLE_IN_CH1 and ANGLE_IN_CH2 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 must be stored as a negative value.

The hysteresis function is deactivated by setting the register value to zero.

OUT_ZERO

OUT_Zero defines the reference position for the angle output. It can be set to any value of the output range. It is the starting point/reference for the 33 setpoints. OUT_ZERO has a register length of 16 bit and it is two's-complement coded.

Note	Before reading ANGLE_OUT it is necessary to set OUT_ZERO to 0.
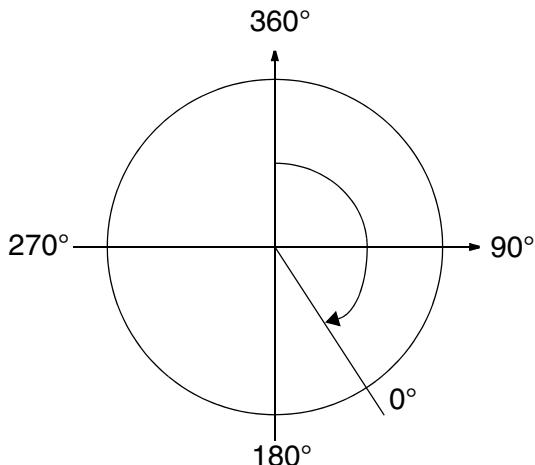
Fig. 3–3: Example definition of zero degree point

Secondly this angle can be used to shift the PI discontinuity point of the angle calculation to the maximum distance from the required angular range in order to avoid the 360°-wrapping of the output due to noise.

PRE_OFFSET

The PRE_OFFSET register allows to shift the angular range to avoid an overflow of the internal 16 bit calculation/signal path.
The PRE_OFFSET register has a length of 16 bit and is two's-complement coded.

OUT_GAIN

OUT_GAIN defines the gain of the 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 signal 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.

OUT_OFFSET

OUT_OFFSET defines the offset of the 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 signal from 0% to 200% of full scale 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 full scale. OUT_OFFSET = 0 leads to a voltage offset of 0% of full scale and OUT_OFFSET = 32768 leads to a offset of -200% of V_{SUP}.

Clamping Levels (CLAMP-LOW & CLAMP-HIGH)

The clamping levels CLAMP_LOW and CLAMP_HIGH define the maximum and minimum output voltage of the analog output. The clamping levels can be used to define the diagnosis band for the sensor output. Both registers have a bit length of 16 bit and are two's-complemented coded. Both clamping levels can have values between 0% and 100% of full scale.

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 then the sensor will indicate it 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 16 bit and is two's complement number.

MAG-HIGH

MAG-HIGH defines the high level for the magnetic field range check function. This register has a length of 16 bit and is two's complement number.

Low-Pass Filter

With the LP_Filter register it is possible to select different −3 dB frequencies for HAL 37xy. The low-pass filter is a 1st-order digital filter and the register is 16 bit organized. Various typical filter frequencies between 4 kHz (no filter) and 10 Hz are available.
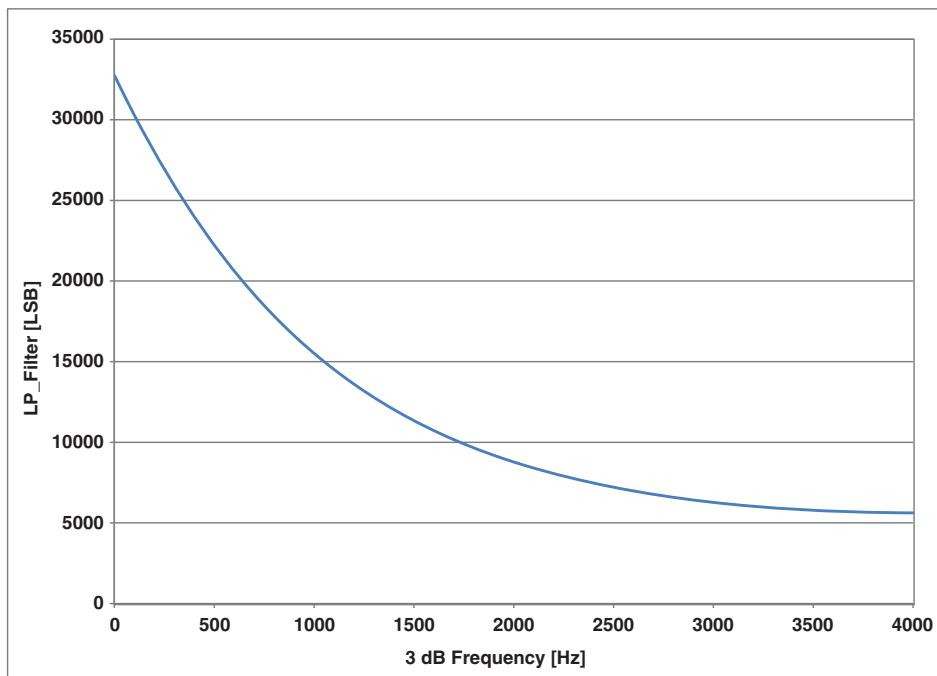
Fig. 3–4: 3dB filter frequency vs. LP_FILTER codes

Modulo Select

The MODULO_Select register is only available in HAL 371x. With this register, the customer can switch between Modulo 90° and 120° output.

HAL 371x is splitting the 360° measurement range either into four repetitive 90° (MOD 90°) or three 120° (MOD 120°) segments.

3.3. Output Linearization

In certain applications (e.g. through shaft applications or position measurements) it is required to linearize the output characteristic. 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.
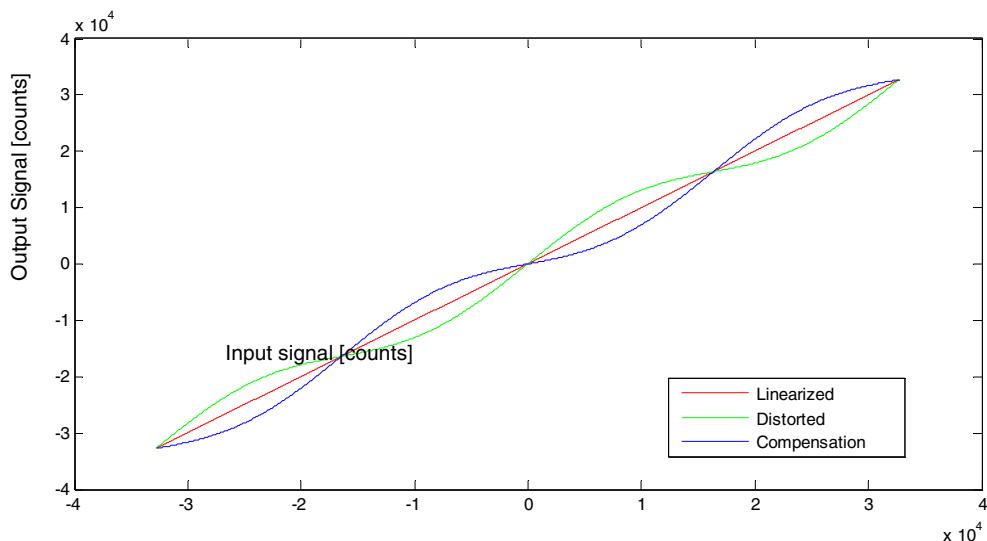
Fig. 3–5: Example for output linearization

For this purpose the compensation curve will be divided into 33 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.

xnl: non linear distorted input value
yl: linearized value
ε: remaining error
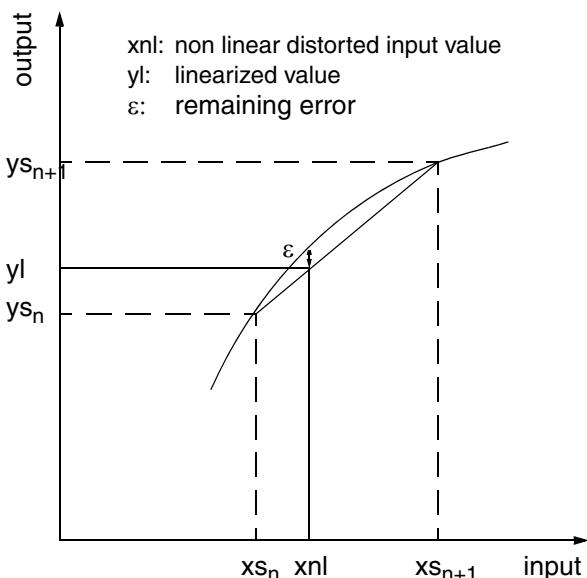
Fig. 3–6: Linearization - detail

The constraint of the linearization is that the input characteristic has to be a monotonic function. In addition, it is recommended that the input does not have a saddle point or inflection point, i.e. 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 that enables the customer to activate various functions of the sensor like diagnosis modes, functionality mode, customer lock, communication protocol speed, etc.

Table 3–3: Customer Setup Register

Bit no.	Function	Description
15	None	Reserved
14	EEPROM Self-Test	EEPROM Self-Test Mode 0: Running during Power-Up 1: Continuously
13	Communication speed	Communication protocol bit time speed 0: typ. 1 ms 1: typ. 0.25 ms
12	DIGMOD	Output format for HAL 3711/HAL 373x devices 0: PWM output 1: SENT output
11:10	PWMFREQ	Defines the frequency of the PWM output for HAL 3711/HAL 373x devices only 0: 1 kHz 1: 500 Hz 2: 200 Hz 3: 2 kHz (11 bit)
9:8	Output Short Detection	0: Disabled 1: High & low side over current detect. Error Band = High: OUT = V_{SUP} Error Band = Low: OUT = GND 2: High & low side over current detect. Error Band = High: OUT = GND Error Band = Low: OUT = V_{SUP} 3: Low side over current detection OUT = Tristate in error case
7	Error Band	Error band selection for locked devices (Customer Lock bit set). 0: High error band (V_{SUP}) 1: Low error band (GND) The sensor will always go to high error band as long as it is not locked (Customer Lock bit not set).
6	Burn-In Mode	0: Disabled 1: Enabled
5	Functionality Mode	0: Extended 1: Normal (see Section 4.8. on page 33)
4	Communication Mode (POUT)	Communication via output pin 0: Disabled 1: Enabled

Table 3–3: Customer Setup Register, continued

Bit no.	Function	Description
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

The Output Short Detection feature is implemented to detect a short circuit between two sensor outputs. The customer can define how the sensor should signalize a detected short circuit (see table above). The time interval in which the sensor is checking for an output short and the detectable short circuit current are defined in Section 4.8. on page 33.

This feature should only be used in case that two sensors are used in one module. In case that the Output Short Detection is not active both sensors will try to drive their output voltage and the resulting voltage will be within the valid signal band.

Note   The Output Short Detection feature is only active after setting the Customer Lock bit and a power-on reset.

3.5. On-board Diagnostic Features

The HAL 37xy 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.)

– EEPROM self-test at power-on

Diagnostic features that can be activated by customer:

– Continuous EEPROM self-test

– ROM parity check

– Output signal clamping

– A/D converter clipping

– Continuous DSP self-test

– Magnetic range detection

– Overvoltage detection

In case of HAL 3715 and HAL 372x, the sensor indicates a fault immediately by switching the output signal to the selected error band in case that the diagnostic mode is activated by the customer. The customer can select if the output goes to the upper or lower error band by setting bit number 7 in the CUST_SETUP register (Table on page 21). An output short drives the output to VSUP, GND or tristate depending of the customer settings as described in Table 3–3 on page 21. Further details can be found in Section 4.8. on page 33.

The sensor switches the output to tristate if an overtemperature is detected by the thermal supervision. The sensor switches the output to ground in case of a V_{SUP} wire break and to VSUP in case of a GND wire break.

HAL 3711 and HAL 373x indicate a failure by changing the PWM frequency. The different errors are then coded in different duty-cycles.

HAL 371x, HAL 372x, HAL 373x

Table 3–4: Failure indication for HAL 373x

Failure Mode	Frequency	Duty-Cycle
EEPROM, ROM and DSP self-test	50%	95%
Magnetic field too low	50%	62.5%
Magnetic field too high	50%	55%
Overvoltage	50%	75%
Undervoltage	No PWM	n.a.
A/D converter clipping	50%	70%

In case of undervoltage, the PWM signal will be constantly 'high' or 'low' depending on the setting of bit number 7 in the CUST_SETUP register. Default setting is 'high' level.

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.

3.6. SENT Output

The SENT (Single-Edge Nibble Transmission) interface of HAL 373x is implemented according to SAE J2716 release 2010-01.

Fig. 3–7 shows the general SENT protocol format. Every transmission starts with a low pulse. The signal is transmitted by the sensor as a series of pulses, whereby the data content is evaluated by time interval between falling edges.

The SENT telegram consists of a synchronization/calibration period, a status & communication nibble, three data nibbles, and a CRC nibble and a pause period. See Section 4.8. on page 33 for the timing parameters of a telegram.

All timing values in a SENT protocol are referenced to the clock tick time t_{tick}.

After reset the output is recessive high. The transmission starts with a low pulse of the synchronization phase (Fig. 3–7). Every low pulse has the same length specified by the parameter t_{nlow}. The synchronization period has always the same length of clock cycles. The clock variation is included in the parameter t_{sync}. The following status and data nibbles always start with a low pulse with t_{nlow}. The nibble high time of the status t_{stat}, the data $t_{d3,2,1}$ and the CRC t_{crc} depends on the transmitted value. Therefore, the message time of a SENT message depends on the tick time and the value which is transmitted by the message.

In order to synchronize the SENT messages to the measurement sampling rate an additional pause period is added, which is transmitted after the checksum nibble.

The time to transmit one message is calculated by:

$t_{message} = t_{sync} + t_{stat} + t_{d3} + t_{d2} + t_{d1} + t_{crc}$

The checksum nibble is a 4 bit CRC of the data nibbles only. The status & communication nibble is not included in the CRC calculation. The CRC is calculated using polynomial $x^4 + x^3 + x^2 + 1$ with seed value of 5. See SAE J2716 for further CRC implementation details.

As recommended by the SAE J2716 an additional zero nibble in addition to the 3 data nibbles for the CRC calculation has been implemented. This is a safety measure against common errors in the last data nibble and the checksum.

In HAL 373x the transmitted data nibbles are generated based on the DAC register value. Special data codes have been implemented for error indication via the SENT interface. The angular or linear position information is coded in the signal range from 2 ... 4087 LSB in the 12 bit range. Table 3–5 gives an overview on the data nibble content.

HAL 373x is not using the status nibble for additional information transmission.

Table 3–5: Data Nibble Content SENT

12-bit value	Definition
4092 to 4095	Reserved
4091	Device Error: Device is failing in one of the self tests (EEPROM, ROM, DSP, Overvoltage)
4090	Signal Path Error: MAG-HIGH or -LOW are exceeded, adder overflow or clipping of channel 1 or 2
4089	Reserved
4088	Clamp-High: Upper signal range violation
2 to 4087	Angular or Position information
1	Clamp-Low: Lower signal range violation
0	During Initialization - Power Up

The SENT protocol starts after the initialization time of the sensor to ensure valid data after power-up.
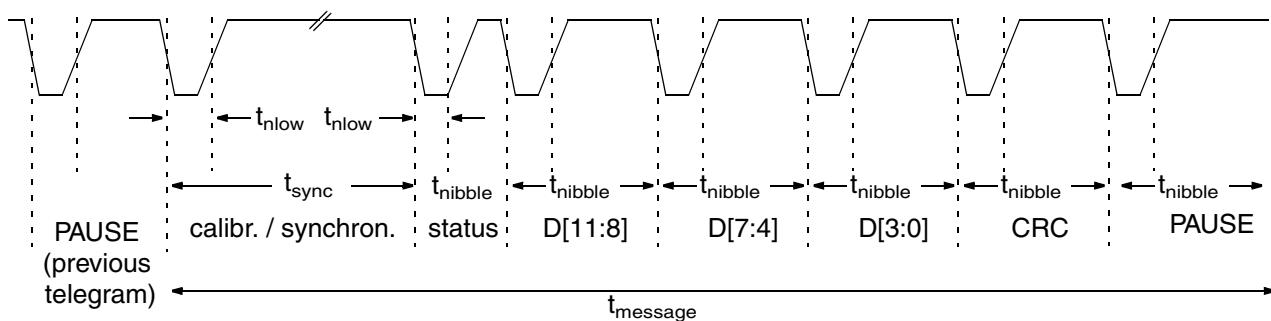
Fig. 3–7: SENT protocol format with 3 data nibbles and pause period

4. Specifications

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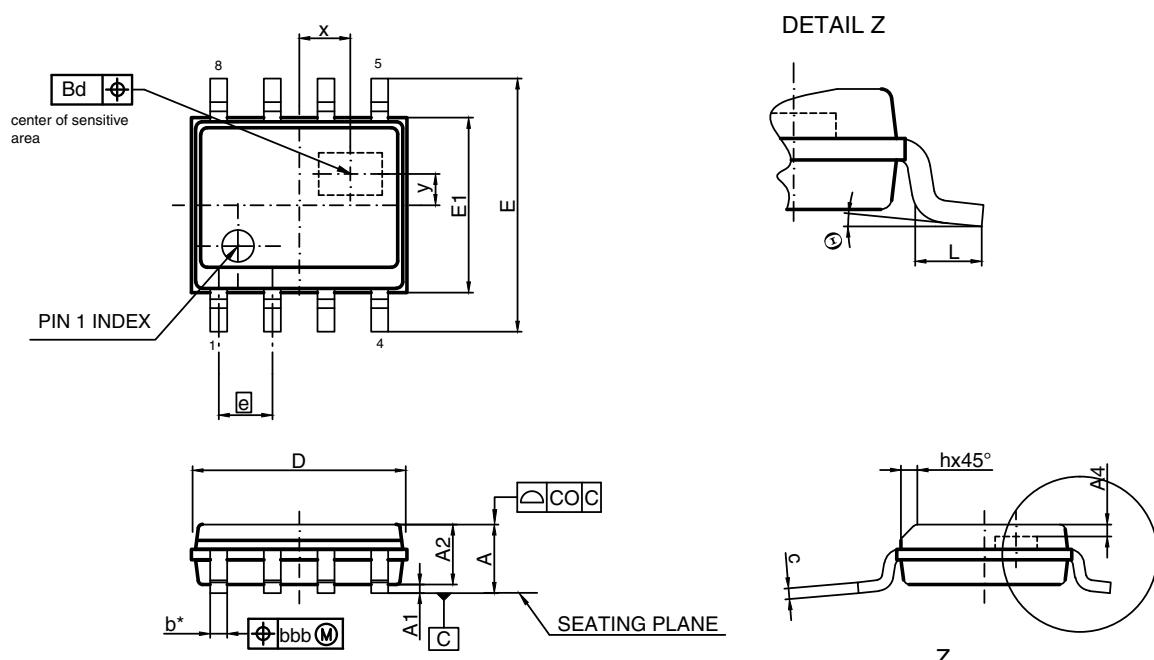
"D" and "E1" are reference data and do not include mold flash or protrusion.
Mold flash or protrusion shall not exceed 150 μm per side.

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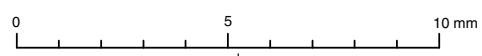
UNIT	A	A1	A2	b	bbb	c	CO	D	E	E1	e	h	L	Θ
mm	1.65	0.25 0.1	1.45	0.4	0.25	0.22	0.1	5.0 4.8	6.0	4.0 3.8	1.27	0.3	0.41 min.	8° max.

| 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 0.076 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 0.22 g

4.2. Soldering, Welding, Assembly

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

4.3. Sensitive Area

4.3.1. Physical Dimension

275 μm x 275 μm

### 4.3.2. Definition of Magnetic Field Vectors
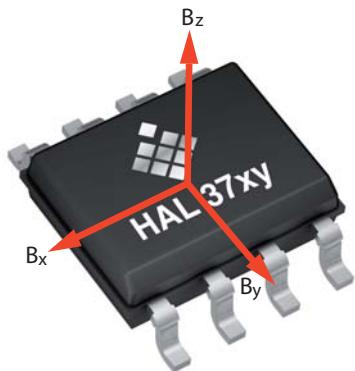
**Fig. 4–3:** Definition of magnetic field vectors for SOIC-8 package

FRONT VIEW
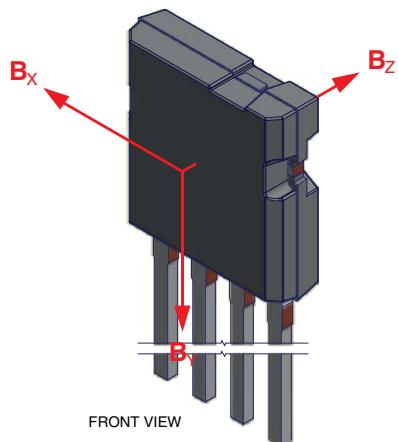
Fig. 4–4: Definition of magnetic field vectors for TO92-UP package

HAL 371x, HAL 372x, HAL 373x

4.3.3. Package Parameters and Position

	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 mm nominal (center of package)	1.90 mm nominal

4.4. 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	GND	connect to GND
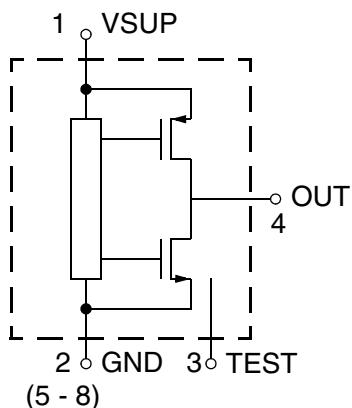
Fig. 4–5: Pin configuration

Note	It is recommended to connect the TEST pin with the GND pin.

4.5. Absolute Maximum Ratings

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

This device contains circuitry to protect the inputs and outputs against damage due to high static voltages or electric fields; however, it is advised that normal precautions 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	−20	20	V	t < 1 hr[3]
V_{OUT}	Output Voltage	VSUP	−6	20	V	t < 1 hr[3]
$V_{OUT} - V_{SUP}$	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][3]
T_A	Ambient Temperature	–	−40	160	°C	[4]
$T_{storage}$	Transportation/Short Term Storage Temperature	–	−55	150	°C	Device only without packing material
B_{max}	Magnetic Field	–	–	-	T	
V_{ESD}	ESD Protection	VSUP, OUT, TEST, GND, NC	−4	4	kV	[2][3]

[1] For 96 h - Please contact TDK-Micronas for other temperature requirements
[2] AEC-Q100-002 (100 pF and 1.5 kΩ)
[3] No cumulated stress
[4] Consider current consumption, mounting condition (e.g. overmold, potting) and mounting situation for T_A in relation to T_J

4.6. Storage and Shelf Life

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

4.7. Recommended Operating Conditions

Functional operation of the device beyond those indicated in the "Recommended Operating Conditions/Characteristics" is not implied and may result in unpredictable behavior, 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 5.5	mA mA	HAL 3715 and HAL 372x HAL 3711 and HAL 373x
R_L	Load Resistor	OUT	5	10	−	kΩ	HAL 3715 and HAL 372x pull-up & pull-down resistor
			1	−	−	kΩ	HAL 3711 and HAL 373x pull-up resistor
C_L	Load Capacitance	OUT	0.33 −	47	330 1	nF nF	HAL 3715 and HAL 372x HAL 3711 and HAL 373x
N_{PRG}	Number of Memory Programming Cycles[1]	-	-	-	100	cycles	0 °C < T_{amb} < 55 °C
B_{AMP}	Recommended Magnetic Field Amplitude	-	±20	-	±100	mT	
T_J	Junction Temperature [2]		−40	−	170	°C	for 1000 hrs
T_A	Ambient Temperature [3]		−40	−	150	°C	

[1] The EEPROM is organized in three banks. Each bank contains up to 32 addresses. It is not allowed to program only one single address within one of the three banks. 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 TDK-Micronas for life time calculations.

[3] Consider current consumption, mounting condition (e.g. overmold, potting) and mounting situation for T_A in relation to T_J

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

HAL 371x, HAL 372x, HAL 373x

4.8. Characteristics

at $T_A = -40$ °C to 150 °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	–	8	13	mA	
	Resolution [1]	OUT	–	12	–	bit	for HAL 3715/HAL 372x ratio-metric to VSUP
			–	12	–	bit	for HAL 3711/HAL 373x (depends on PWM Period)
$t_{Startup}$	Start-up Time[2]	OUT	–	–	1.7	ms	$C_L = 10$ nF (see Fig. 4–6 on page 36), LP-FILTER = OFF
Overvoltage and Undervoltage Detection							
$V_{SUP,UV}$	Undervoltage Detection Level	VSUP	3.3	3.9	4.3	V	Functionality Mode: Normal CUST_SETUP register bit 5
			3.1	3.7	4.1	V	Functionality Mode: Extended CUST_SETUP register bit 5
$V_{SUP,UVhyst}$	Undervoltage Detection Level Hysteresis[2]	VSUP	–	200	–	mV	
$V_{SUP,OV}$	Overvoltage Detection Level	VSUP	5.6	6.2	6.9	V	Functionality Mode: Normal
			8.5	9.5	10.4	V	Functionality Mode: Extended CUST_SETUP register bit 5
$V_{SUP,OVhyst}$	Overvoltage Detection Level Hysteresis[2]	VSUP	–	225	–	mV	
Output Voltage in Case of Error Detection							
$V_{SUP,DIAG}$	Supply Voltage required to get defined Output Voltage Level[2]	VSUP	–	2.3	–	V	Output behavior see Fig. 4–7
$V_{Error,Low}$	Output Voltage Range of Lower Error Band[2]	OUT	0	–	4	%V_{SUP}	$V_{SUP} > V_{SUP,DIAG}$ Analog Output $5\ k\Omega \le R_L \le 200\ k\Omega$
$V_{Error,High}$	Output Voltage Range of Upper Error Band[2]	OUT	96	–	100	%V_{SUP}	$V_{SUP} > V_{SUP,DIAG}$ Analog Output $5\ k\Omega \le R_L \le 200\ k\Omega$

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

HAL 371x, HAL 372x, HAL 373x

Symbol	Parameter	Pin No.	Limit Values			Unit	Test Conditions
			Min.	Typ.	Max.		
Output Short Detection Parameter							
t_{OCD}	Over Current Detection Time[2]	OUT	–	128	–	µs	
$t_{Timeout}$	Time Period without Over Current Detection[2]	OUT	–	256	–	ms	
I_{OVC}	Detectable Output Short Current[2]	OUT	–	10	–	mA	
HAL 3715 and HAL 372x (Analog Output)							
t_{OSD}	Overall Signal Delay[1]	OUT	–	0.312	0.343	ms	Overall signal delay from magnetic field input to sensor output. Based on 8 kHz sample frequency
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	–0.12	0	0.12	%	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}	$R_{L\ Pull-up/-down}$ = 5 kΩ
V_{OUTL}	Output Low Voltage [3]	OUT	–	–	7	%V_{SUP}	$R_{L\ Pull-up/-down}$ = 5 kΩ
ΔV_{OUTCL}	Accuracy of Output Voltage at Clamping Low Voltage over Temperature Range [2]	OUT	–30	0	30	mV	$R_{L\ Pull-up/-down}$ = 5 kΩ V_{SUP} = 5V
ΔV_{OUTCH}	Accuracy of Output Voltage at Clamping High Voltage over Temperature Range [2]	OUT	–30	0	30	mV	
OUT_{Noise}	Output Noise RMS [2)5)]	OUT	–	2	5.2	mV	Output range 10% to 90%
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}

[5] 4 kHz digital low-pass filter (LP-Filter = off): ±20 mT min. magnetic field amplitude; f_{BW} = 22.5 kHz

Symbol	Parameter	Pin No.	Limit Values			Unit	Test Conditions
			Min.	Typ.	Max.		
Open-Circuit Detection							
V_{OUT}	Output voltage at open V_{SUP} line	OUT	0	0	0.15	V	$V_{SUP} = 5$ V $R_L{}^{4)} = 10$ kΩ to 200 kΩ
			0	0	0.2	V	$V_{SUP} = 5$ V 5 kΩ ≥ $R_L{}^{4)}$ < 10 kΩ
V_{OUT}	Output voltage at open GND line	OUT	4.85	4.9	5.0	V	$V_{SUP} = 5$ V $R_L{}^{4)} = 10$ kΩ to 200 kΩ
			4.8	4.9	5.0	V	$V_{SUP} = 5$ V 5 kΩ ≥ $R_L{}^{4)}$ < 10 kΩ
HAL 3711 and HAL 373x (Digital Output)							
V_{OUTH}	Output High Voltage	OUT	4.8	4.9	–	V	$V_{SUP} = 5$ V $R_{L\ Pull-up/-down} = 5$ kΩ
V_{OUTL}	Output Low Voltage	OUT	–	0.1	0.2	V	$V_{SUP} = 5$ V $R_{L\ Pull-up/-down} = 5$ kΩ
			–	0.4	0.65	V	[2] $V_{SUP} = 5$ V $R_{L\ Pull-up} = 1$ kΩ
t_{rise}	Rise Time of Digital Output[2]	OUT	–	0.2	0.4	µs	$V_{SUP} = 5$ V, $R_{L\ Pull-up} = 1$ kΩ, $C_L = 1$ nF
t_{fall}	Fall Time of Digital Output[2]	OUT	–	0.25	0.4	µs	$V_{SUP} = 5$ V, $R_{L\ Pull-up} = 1$ kΩ, $C_L = 1$ nF
ROUT_DIG	On Resistance of Digital Pull-Up Driver	OUT	–	100	200	Ω	
PWM Output							
$t_{startup}$	Start-up Time	OUT	–	1.3	1.7	ms	
t_{OSD}	Overall Signal Delay[1]	OUT	–	0.312	0.343	ms	Overall signal delay from magnetic field input to sensor output. Transmission time of selected PWM frequency to be added. Based on 8 kHz sample frequency.
OUT_{Noise}	Output Noise RMS [2)5)]	OUT	–	0.05	0.13	%	Output range 100% DC
f_{PWM}	PWM Frequency	OUT	1800 900 450 180	2000 1000 500 200	2200 1100 550 220	Hz	Customer programmable
J_{PWM}	RMS PWM Jitter [2]	OUT	–	1	2	LSB_{12}	$f_{PWM} = 1$ kHz

[1] Guaranteed by Design
[2] Characterized on small sample size, not tested.
[4] RL can be pull-up or pull-down resistor
[5] 4 kHz digital low-pass filter (LP-Filter = off): ±20 mT min. magnetic field amplitude; $f_{BW} = 22.5$ kHz

HAL 371x, HAL 372x, HAL 373x

Symbol	Parameter	Pin No.	Limit Values			Unit	Test Conditions
			Min.	Typ.	Max.		
SENT Output							
$t_{startup}$	Start-up Time	OUT	–	1.3	1.7	ms	
t_{tick}	Clock Tick Time	OUT	–	2.75	–	µs	
t_{nlow}	Nibble Low Time	OUT	–	5	–	t_{tick}	
t_{sync}	Calibration / Synchronization Period	OUT	–	56	–	t_{tick}	
t_{nibble}	Status & Communication Nibble, Data Nibbles and CRC Nibble Period	OUT	12	–	27	t_{tick}	t_{nibble} = 12 + [status|data|CRC]
$t_{message}$	Message Time	OUT	116	–	176	t_{tick}	
t_{pause}	Pause Period Time	OUT	12	-	70	t_{tick}	
SOIC8 Package							
R_{thja}	Thermal Resistance Junction to Air[1]	–	–	–	115	K/W	Determined with a 1S1P board
			–	–	110	K/W	Determined with a 2S2P board
R_{thjc}	Thermal Resistance Junction to Case[1]	–	–	–	33	K/W	Determined with a 1S1P board
TO92UP Package							
R_{thja}	Thermal Resistance Junction to Air[1]	–	–	–	198	K/W	Determined with a 1S0P board
			–	–	146	K/W	Determined with a1S1P board
R_{thjc}	Thermal Resistance Junction to Case[1]	–	–	–	53	K/W	Determined with a 1S0P board
			–	–	38	K/W	Determined with a1S1P board

[1] (Self-heating calculation see Section 5.1. on page 40)
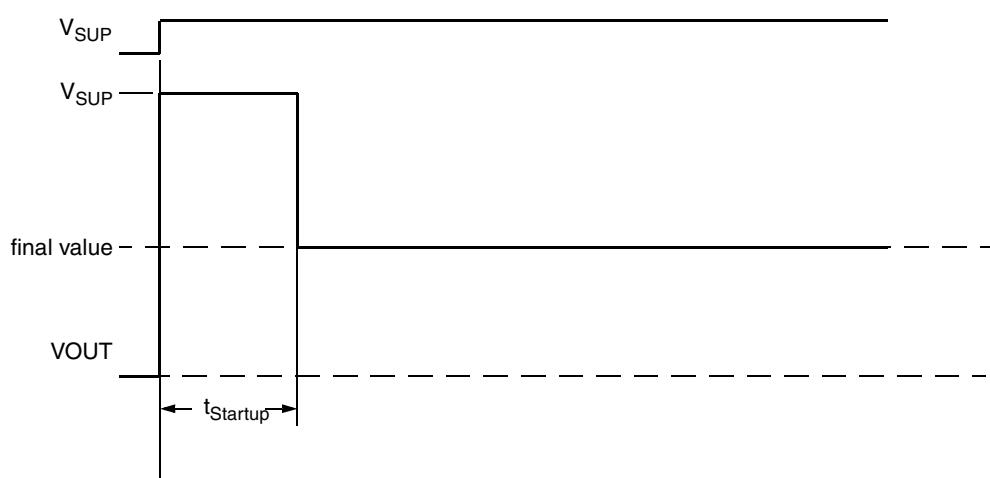

**Fig. 4–6:** POR timing
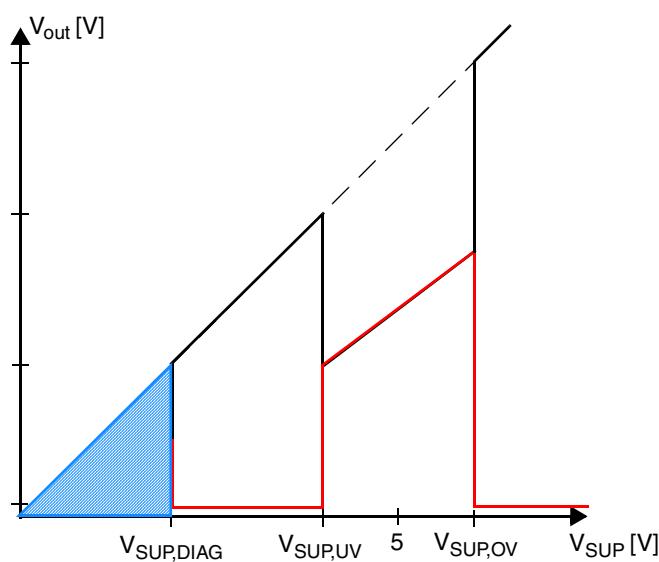
Fig. 4–7: Behavior of HAL 3715 and HAL 372x for different V_{SUP}
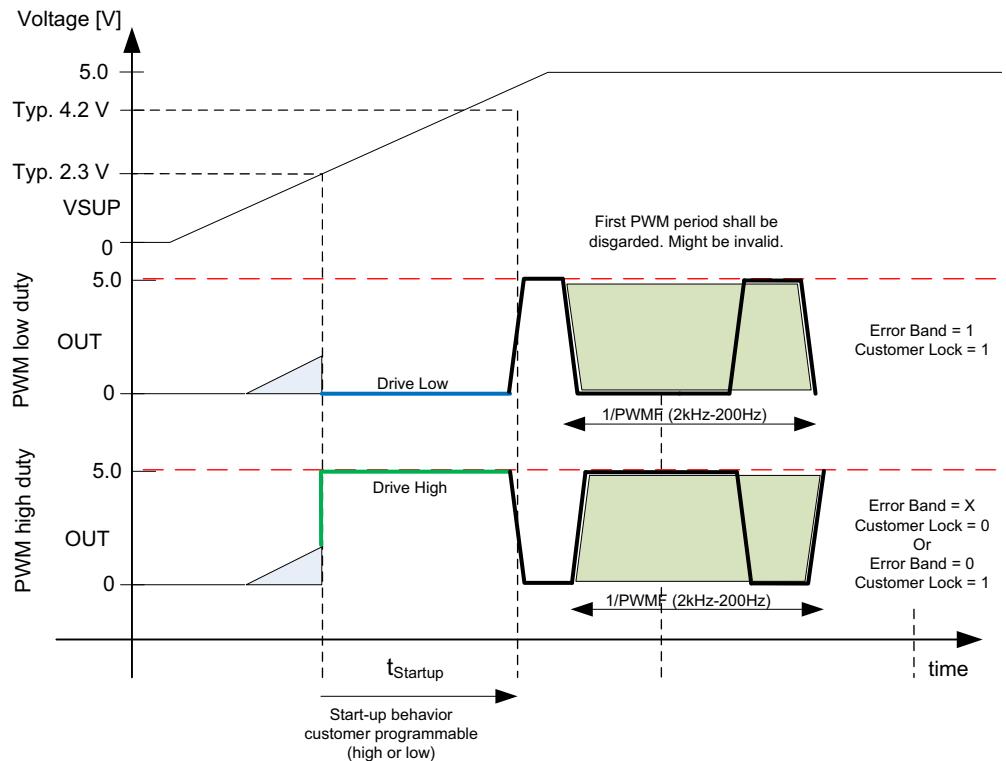

Fig. 4–8: Start-up behavior of HAL 3711 and HAL 373x with PWM output

4.9. Magnetic Characteristics

at $T_A = -40\ °C$ to $150\ °C$, $V_{SUP} = 4.5\ V$ 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
Θ_{RANGE}	Detectable angle range	OUT	0	–	360	°	
Θ_{res}	Angle resolution	OUT	–	–	0.09	°	(360°/4096)
$E_{\Theta linxy}$	XY angle linearity error (on output of CORDIC filter)	OUT	–0.5	–	0.5	°	Min. $B_{AMP} = \pm30$ mT, $T_A = 25\ °C$[1][2]
$E_{\Theta linxy}$	X/Y angle linearity error over temperature (on output of CORDIC filter)	OUT	–1.2	–	1.2	°	Min. $B_{AMP} = \pm30$ mT[1][2]
			–1.7	–	1.7		Min. $B_{AMP} = \pm20$ mT[1][2]
$ASMm_{X/Y\_Z}$	Absolute sensitivity mismatch on raw signals between X/Y and Z channel	OUT	–3 –10	–	3 +10	% %	for SOIC8 package for TO92UP package $T_A = 25\ °C$[1]
$Sense_{XYZ}$	Sensitivity of X/Y and Z Hall Plate	OUT	118	128	138	LSB/mT	$T_A = 25\ °C$[1]
SMm_{X/Y_Z}	Thermal sensitivity mismatch drift of calibrated signals between X/Y and Z channel	OUT	–2.5	–	2.5	%	over full temperature range related to 25 °C[1]
SMm_{XY}	Thermal sensitivity mismatch drift of calibrated signals between X and Y channel	OUT	–2	–	2	%	over full temperature range related to 25 °C[1]
$Offset_{XY}$	Offset of calibrated signals of X or Y channel	OUT	–20	–	20	LSB_{15}	$T_A = 25\ °C$[1] Can be compensated in customer application
$Offset_Z$	Offset of calibrated signal of Z channel	OUT	–12	–	12	LSB_{15}	$T_A = 25\ °C$[1] Can be compensated in customer application
$\Delta Offset_{XY}$	Offset drift of calibrated signals of X or Y channel	OUT	–70	–	70	LSB_{15}	over full temperature range related to 25 °C[1]
$\Delta Offset_Z$	Offset drift of calibrated signals of Z channel	OUT	–10	–	10	LSB_{15}	over full temperature range related to 25 °C[1]
$\Delta SMm_{XYZlife}$	Relative sensitivity mismatch drift of calibrated signals between X or Y channel and Z channel over life time	OUT	–	1.0	–	%	after 1000 h HTOL[1]
$\Delta Offset_{XYlife}$	Offset drift of calibrated signals of X or Y channel	OUT	–	30	–	LSB_{15}	after 1000 h HTOL[1]
$\Delta Offset_{Zlife}$	Offset drift of calibrated signal of Z channel	OUT	–	5	–	LSB_{15}	after 1000 h HTOL[1]

[1] Characterized on sample base, 3-sigma values, not tested for each device
[2] Calculated angular error based on characterization and not on single error summation
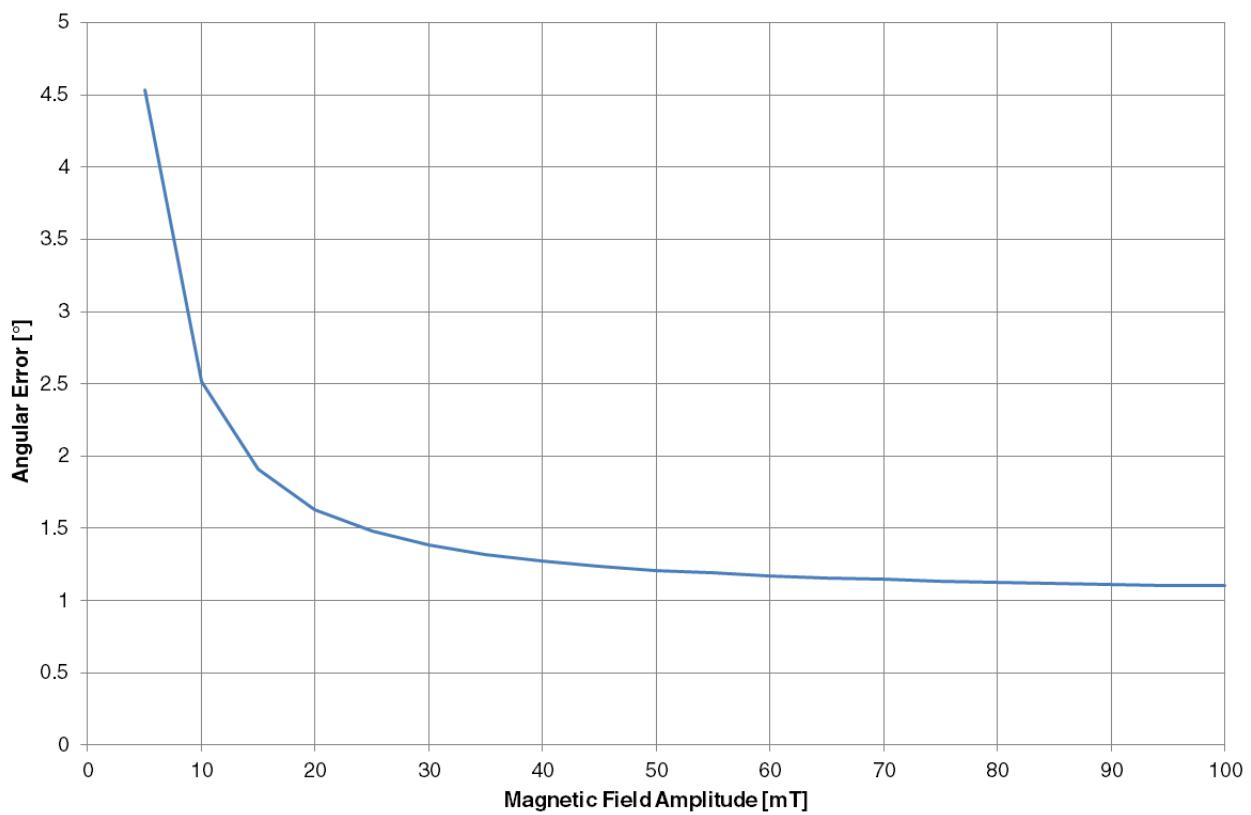
Fig. 4–9: Angular error versus magnetic field amplitude over full temperature range for devices using X and Y magnetic field component (for digital output)

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).

$$T_J = T_A + \Delta T$$

The maximum ambient temperature is a function of power dissipation, maximum allowable die temperature and junction to ambient thermal resistance (R_{thja}). With a maximum of 5.5 V operating supply voltage the power dissipation P is 0.0825 W per die. The junction to ambient thermal resistance R_{thja} is specified in Section 4.8. on page 33.

The difference between junction and ambient air temperature is expressed by the following equation:

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

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

The X represents junction to air or case point.

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 those values.

5.2. EMC and ESD

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

5.3. Application Circuit for HAL 3715 and HAL 372x

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.
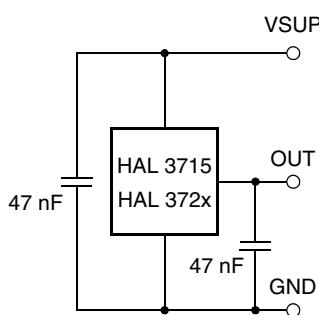

Fig. 5–1: Recommended application circuit for HAL 3715 and HAL 372x

Note	It is recommended to connect the TEST pin with the GND pin.

5.4. Application Circuit for HAL 3711 and HAL 373x

PWM Output

In case of PWM output mode, 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 for EMC protection.
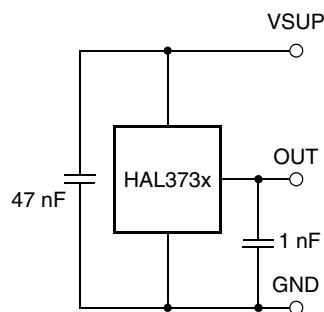

Fig. 5–2: Recommended application circuit for HAL 3711 and HAL 373x in PWM mode

SENT Output

In case of SENT output mode, it is recommended to connect one ceramic 47 nF capacitor between ground and the supply voltage and a filter structure at the output pin for EMC protection as well for having a SENT standard compliant output slew rate.

Following two setups have been tested:

– C01 = 180 pF, C02 = 2.2 nF, R01 = 120 Ω
– C01 = 180 pF, C02 = 3.3 nF, R01 = 180 Ω
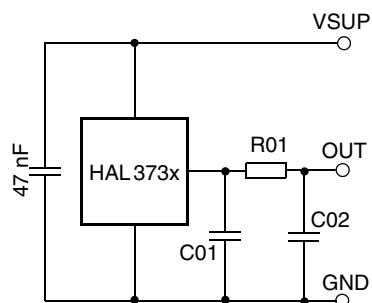
Fig. 5–3: Recommended application circuit for HAL 373x

Note   It is recommended to connect the TEST pin with the GND pin.

5.5. Measurement of a PWM Output Signal of HAL 3711 & HAL 373x

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. 5–4).

| 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.
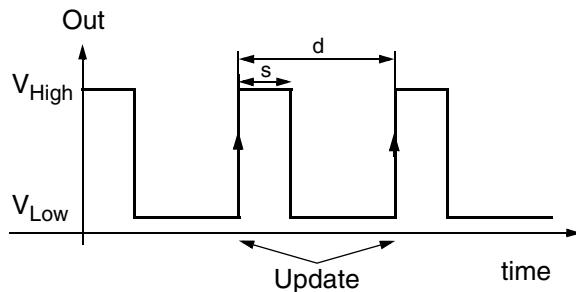
Fig. 5–4: Definition of PWM signal

5.6. Recommended Pad Size SOIC8 Package
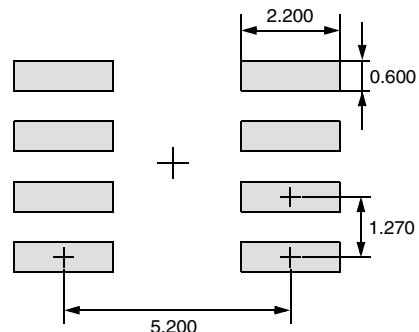
Dimensions in mm

6. Programming of the Sensor

HAL 37xy features two different customer modes. In **Application Mode** the sensors provide a ratiometric analog output voltage or a digital output signal (PWM or SENT). 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 at the sensor output pin.

6.1. Programming Interface

In Programming Mode HAL 37xy 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.
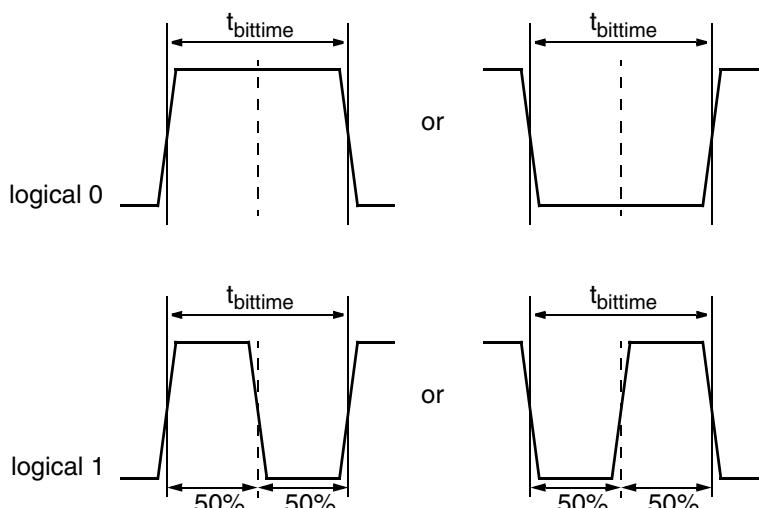

Fig. 6–1: Definition of logical 0 and 1 bit

A description of the communication protocol and the programming of the sensor is available in a separate document (HAL/HAR 37xy Programming Guide).

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)	VSUP	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
$t_{bittime}$	Protocol Bit Time	OUT	900 225	1000 250	1100 275	µs µs	Cust. programmable, T_J = 25 °C Bit 13 of Customer Setup = 0 Bit 13 of Customer Setup = 1
	Slew rate	OUT	–	2	–	V/µs	

6.2. Programming Environment and Tools

For the programming of HAL 37xy during product development a programming tool including hardware and software is available on request. It is recommended to use the Micronas tool kit (USB kit and Lab View Programming Environment) in order to facilitate the product development. The details of programming sequences are also available on request.

6.3. Programming Information

For production and qualification tests, it is mandatory to set the LOCK bit to one and the POUT bit to zero after final adjustment and programming of HAL 37xy.

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 LOCK bit after locking.

It is also mandatory to check the acknowledge (first and second) of the sensor after each write and store sequence to verify if the programming of the sensor was successful. Additionally it is mandatory to set the Diagnosis Latch bit to ensure that programming errors are indicated by the second acknowledge. Additionally, CLAMP-LOW must be set to 100% in case of HAL 3711 and HAL 373x. This bit must be set back to zero to avoid unintended error indication during normal operation of the device. To enable debugging of the production line, it is recommended to read back the PROG_DIAGNOSIS register and the DIAGNOSIS register in case of a missing second acknowledge. Please check HAL/HAR 37xy Programming Guide for further details.

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

Note	Please check also the "HAL 37xy, HAR 37xy User Manual" and relevant documentation for the USB-Kit. It contains additional information and instructions about the programming of the devices.

7. Document History

1. Advance Information: "HAL 372x, HAL 373x" Robust Programmable 2D Position Sensor Family with Arbitrary Output Function", Oct. 10, 2013, AI000171_001EN. First release of the advance information.

2. Advance Information: "HAL 3715, HAL 372x, HAL 373x Robust Programmable 2D Position Sensor Family with Arbitrary Output Function", June 26, 2014, AI000171_002EN. Second release of the advance information.

   Major changes:
   – HAL 3715 added to the document
   – Update of customer NVRAM table
   – Adaptation of parameter Y for SOIC-8 package
   – Adaptation of parameter L for TO92-UP package drawing
   – Recommended application circuit for SENT output mode added
   – Update of SENT interface timing

3. Preliminary Data Sheet: "HAL 3715, HAL 372x, HAL 373x Robust Programmable 2D Position Sensor Family with Arbitrary Output Function", Feb. 2, 2015, PDI000217_001EN. First release of the preliminary data sheet.

   Major changes:
   – SOIC8 package drawing updated
   – Magnetic characteristics table completed
   – Electrical characteristics table completed

4. Data Sheet: "HAL 371x, HAL 372x, HAL 373x Robust Programmable 2D Position Sensor Family with Arbitrary Output Function", Oct. 27, 2017, DS000192_001EN. First release of the data sheet.

   Major changes:
   – Update of signal path diagram
   – Recommendation added to connect TEST pin with GND pin
   – Typing error in electrical characteristics table for parameter f_{PWM} corrected
   – Max. load capacitance for analog output reduced to 330 nF
   – Product shelf life recommendations modified
   – Ambient temperature specification added
   – HAL 3711 device added
   – Additional information about programming of the device added
   – Change of some characteristics (like noise, signal path delay,...)
   – Chart added showing the start-up behavior of HAL 3711 and HAL 373x
   – Chart with showing start-up behavior of HAL 3715 and HAL 372x updated
   – Removal of specification for sensitivity drift of vertical and horizontal Hall-Plates
   – Ammopack drawing removed. This is part of the document "Sensors and Controllers: Ordering Codes, Packaging, Handling".