HAL® 3625, HAL 3675
Programmable Direct-Angle Sensors
Copyright, Warranty, and Limitation of Liability

The information and data contained in this document are believed to be accurate and reliable. The software and proprietary information contained therein may be protected by copyright, patent, trademark and/or other intellectual property rights of Micronas. All rights not expressly granted remain reserved by Micronas.

Micronas assumes no liability for errors and gives no warranty representation or guarantee regarding the suitability of its products for any particular purpose due to these specifications.

By this publication, Micronas does not assume responsibility for patent infringements or other rights of third parties which may result from its use. Commercial conditions, product availability and delivery are exclusively subject to the respective order confirmation.

Any information and data which may be provided in the document can and do vary in different applications, and actual performance may vary over time.

All operating parameters must be validated for each customer application by customers’ technical experts. Any new issue of this document invalidates previous issues. Micronas reserves the right to review this document and to make changes to the document’s content at any time without obligation to notify any person or entity of such revision or changes. For further advice please contact us directly.

Do not use our products in life-supporting systems, military, aviation and aerospace applications! Unless explicitly agreed to otherwise in writing between the parties, Micronas’ products are not designed, intended or authorized for use as components in systems intended for surgical implants into the body, or other applications intended to support or sustain life, or for any other application in which the failure of the product could create a situation where personal injury or death could occur.

No part of this publication may be reproduced, photocopied, stored on a retrieval system or transmitted without the express written consent of Micronas.

Micronas Trademarks
– HAL
– 3D HAL

Third-Party Trademarks

All other brand and product names or company names may be trademarks of their respective companies.

License Note

HAL 3625 and HAL 3675 use licenses of Fraunhofer Institute for Integrated Circuits IIS.
## Contents

<table>
<thead>
<tr>
<th>Page</th>
<th>Section</th>
<th>Title</th>
</tr>
</thead>
<tbody>
<tr>
<td>4</td>
<td>1.</td>
<td>Introduction</td>
</tr>
<tr>
<td>4</td>
<td>1.1.</td>
<td>Major Applications</td>
</tr>
<tr>
<td>5</td>
<td>1.2.</td>
<td>Features</td>
</tr>
<tr>
<td>6</td>
<td>2.</td>
<td>Ordering Information</td>
</tr>
<tr>
<td>6</td>
<td>2.1.</td>
<td>Device-Specific Ordering Codes</td>
</tr>
<tr>
<td>7</td>
<td>3.</td>
<td>Functional Description</td>
</tr>
<tr>
<td>7</td>
<td>3.1.</td>
<td>General Function</td>
</tr>
<tr>
<td>8</td>
<td>3.2.</td>
<td>Signal Path and Register Definition</td>
</tr>
<tr>
<td>8</td>
<td>3.2.1.</td>
<td>Signal Path</td>
</tr>
<tr>
<td>8</td>
<td>3.2.2.</td>
<td>Register Definition</td>
</tr>
<tr>
<td>8</td>
<td>3.2.2.1.</td>
<td>RAM Register</td>
</tr>
<tr>
<td>10</td>
<td>3.2.2.2.</td>
<td>EEPROM Register</td>
</tr>
<tr>
<td>13</td>
<td>3.3.</td>
<td>Output Linearization</td>
</tr>
<tr>
<td>14</td>
<td>3.4.</td>
<td>NVRAM Registers</td>
</tr>
<tr>
<td>15</td>
<td>3.5.</td>
<td>On-board Diagnostic features</td>
</tr>
<tr>
<td>16</td>
<td>4.</td>
<td>Specifications</td>
</tr>
<tr>
<td>16</td>
<td>4.1.</td>
<td>Outline Dimensions</td>
</tr>
<tr>
<td>19</td>
<td>4.2.</td>
<td>Soldering, Welding and Assembly</td>
</tr>
<tr>
<td>19</td>
<td>4.3.</td>
<td>Dimensions of Sensitive Area</td>
</tr>
<tr>
<td>19</td>
<td>4.4.</td>
<td>Package Parameters and Position of Sensitive Areas</td>
</tr>
<tr>
<td>19</td>
<td>4.5.</td>
<td>Pin Connections and Short Description</td>
</tr>
<tr>
<td>20</td>
<td>4.6.</td>
<td>Absolute Maximum Ratings</td>
</tr>
<tr>
<td>20</td>
<td>4.6.1.</td>
<td>Storage and Shelf Life TO92UP Package</td>
</tr>
<tr>
<td>20</td>
<td>4.6.2.</td>
<td>Storage and Shelf Life SOIC8 Package</td>
</tr>
<tr>
<td>21</td>
<td>4.7.</td>
<td>Recommended Operating Conditions</td>
</tr>
<tr>
<td>22</td>
<td>4.8.</td>
<td>Characteristics</td>
</tr>
<tr>
<td>25</td>
<td>4.9.</td>
<td>Magnetic Characteristics</td>
</tr>
<tr>
<td>26</td>
<td>4.10.</td>
<td>Open-Circuit Detection (only applicable for HAL3625)</td>
</tr>
<tr>
<td>26</td>
<td>4.11.</td>
<td>Overvoltage and Undervoltage Detection</td>
</tr>
<tr>
<td>27</td>
<td>5.</td>
<td>Application Notes</td>
</tr>
<tr>
<td>27</td>
<td>5.1.</td>
<td>Ambient Temperature</td>
</tr>
<tr>
<td>27</td>
<td>5.2.</td>
<td>EMC and ESD</td>
</tr>
<tr>
<td>27</td>
<td>5.3.</td>
<td>Application Circuit for HAL3625</td>
</tr>
<tr>
<td>27</td>
<td>5.4.</td>
<td>Application Circuit for HAL3675</td>
</tr>
<tr>
<td>28</td>
<td>5.5.</td>
<td>Measurement of a PWM Output Signal of HAL3675</td>
</tr>
<tr>
<td>29</td>
<td>6.</td>
<td>Programming of the Sensor</td>
</tr>
<tr>
<td>29</td>
<td>6.1.</td>
<td>Programming Interface</td>
</tr>
<tr>
<td>30</td>
<td>6.2.</td>
<td>Programming Environment and Tools</td>
</tr>
<tr>
<td>30</td>
<td>6.3.</td>
<td>Programming Information</td>
</tr>
<tr>
<td>31</td>
<td>7.</td>
<td>Data Sheet History</td>
</tr>
</tbody>
</table>
1. Introduction

The HAL 36xy is a member of a new sensor family using the Micronas 3D HAL technology. This new family has several members. HAL 3625 provides a linear, ratiometric analog output signal with integrated wire-break detection working with pull-up or pull-down resistor. HAL 3675 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 contrast, the HAL 36xy is sensitive for magnetic fields applied in parallel to the chip surface. This is possible by integrating vertical Hall plates into the standard CMOS process.

With the new vertical Hall technology it is possible to directly measure rotation angles over the entire range from 0° to 360° with simple magnetic circuits. The magnetic field of a small magnet (diametrical magnetization) rotating above the sensor can be measured in a non-contacting way.

The sensor measures both magnetic field components BX and BY. The diametrical magnetization of a rotating magnet generates a flux vector. The vertical Hall elements measure the X- and Y-Component of the magnetic field vector, which normally corresponds to a sine and cosine waveform.

The direct angle information is internally calculated and converted into an analog output voltage. The angle information is proportional to the output voltage.

Due to the measurement method, the sensor provides excellent drift performance over temperature delivering a new class of accuracy.

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).

<table>
<thead>
<tr>
<th>Type</th>
<th>Output Format</th>
</tr>
</thead>
<tbody>
<tr>
<td>HAL 3625</td>
<td>Analog</td>
</tr>
<tr>
<td>HAL 3675</td>
<td>PWM</td>
</tr>
</tbody>
</table>

Major characteristics like gain and offset of X- and Y-channel, zero angle position, phase shift between X- and Y-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 the standard checks, such as over and undervoltage and wire-break, internal blocks such as ROM and the signal path are monitored during normal operation. The error modes are indicated by forcing the output voltage into error band. For HAL 3675 the error modes are indicated by a change of PWM frequency and duty-cycle.

The HAL 36xy is designed for automotive applications. The devices operates with junction temperatures ranging 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 36xy is the optimal system solution for applications such as:

- Contactless potentiometers
- Rotary position measurement, like
  - Throttle position
  - EGR value position
  - Accelerator paddle position, etc.
1.2. Features

- Angle measurement is extremely robust against temperature and stress influence
- 12 bit ratiometric linear output proportional to the measurement angle for HAL 3625
- 0.25 kHz to 2 kHz (up to 12 bit) PWM output for HAL 3675
- 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
- On-chip temperature compensation
- Active offset compensation
- Programming via the sensors output pin
- Programmable characteristics in a non-volatile memory (EEPROM) with redundancy and lock function
- Programmable 1st-order low-pass filter
- Programmable hysteresis
- Programmable output slope and offset
- X- and Y-channel gain and offset of signal path programmable
- Phase shift between X- and Y-channel programmable
- Programmable output clamping voltages for error band definition
- Programmable zero angle 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:

XXXNNNN 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 36xy is available in the following package and temperature variants.

Table 2–1: Available packages

<table>
<thead>
<tr>
<th>Package Code (PA)</th>
<th>Package Type</th>
</tr>
</thead>
<tbody>
<tr>
<td>DJ</td>
<td>SOIC8-1</td>
</tr>
<tr>
<td>UP</td>
<td>TO92UP-1</td>
</tr>
</tbody>
</table>

Table 2–2: Available temperature ranges

<table>
<thead>
<tr>
<th>Temperature Code (T)</th>
<th>Temperature Range</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>T_J = -40 °C to +170 °C</td>
</tr>
</tbody>
</table>

The relationship between ambient temperature (T_A) and junction temperature (T_J) is explained in Section 5.1. on page 27.

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

<table>
<thead>
<tr>
<th>Available Ordering Codes</th>
<th>Package Marking</th>
</tr>
</thead>
<tbody>
<tr>
<td>HAL3625DJ-A-[C-P-Q-SP]</td>
<td>3625A</td>
</tr>
<tr>
<td>HAL3625UP-A-[C-P-Q-SP]</td>
<td>3625A</td>
</tr>
<tr>
<td>HAL3675DJ-A-[C-P-Q-SP]</td>
<td>3675A</td>
</tr>
<tr>
<td>HAL3675UP-A-[C-P-Q-SP]</td>
<td>3675A</td>
</tr>
</tbody>
</table>
3. Functional Description

3.1. General Function

The HAL 36xy is a direct angle sensor based on Micronas’ 3D HAL technology. The sensor includes two vertical Hall plates for the detection of X and Y magnetic field components, a signal processor for calculation of the angle information, protection devices and a ratiometric linear output or PWM output.

The output signal is proportional to the angle of a rotating magnet target with respect to the sensor. The spinning current offset compensation minimizes the angle error due to supply voltage and temperature variations as well as external package stress.

The sensor can be used for angle measurements in a range between 0° and 360°. 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 angle measurement is compensated in respect to the flux density variations caused by airgap variations or drifts. Therefore, the sensor enables the development of systems running in harsh electrical and mechanical environments.

The HAL 36xy is programmable by modulation of the output voltage. No additional programming pin is needed.

---

Fig. 3–1: HAL 36xy block diagram
3.2. Signal Path and Register Definition

3.2.1. Signal Path

Fig. 3–2: Signal path of HAL 36xy

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_COMP and Y_COMP

X_COMP and Y_COMP register contain the temperature compensated magnetic field information of the X- and Y-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 and CORDIC_Y

CORDIC_X and CORDIC_Y register contain the compensated magnetic field information of the X- and Y-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 angle 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 angle information.

DAC

The DAC register contains the digital equivalent of the output voltage or PWM output duty-cycle. 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.

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 Y-channel amplitude.

\[
\text{Amplitude} = \sqrt{X^2 + Y^2}
\]

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:

\[
\text{CORDIC_AMP} \equiv 1.6 \times \sqrt{X^2 + Y^2}
\]

DIAGNOSIS

The DIAGNOSIS register enables the customer to identify certain failures detected by the sensor. HAL 36xy performs 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.

<table>
<thead>
<tr>
<th>Bit no.</th>
<th>Function</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>15:6</td>
<td>None</td>
<td>Reserved</td>
</tr>
<tr>
<td>5</td>
<td>Statemachine Self Test</td>
<td>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)</td>
</tr>
<tr>
<td>4</td>
<td>EEPROM Self Test</td>
<td>This bit is set to 1 in case that the EEPROM self test fails. (Performed during power-up only)</td>
</tr>
<tr>
<td>3</td>
<td>ROM Check</td>
<td>This bit is set to 1 in case that ROM parity check fails. (continuously running)</td>
</tr>
<tr>
<td>2</td>
<td>Reserved</td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>MAGHI</td>
<td>This bit is set to 1 in case that the magnetic field is exceeding the MAG-HI register value (magnetic field to high)</td>
</tr>
<tr>
<td>0</td>
<td>MAGLO</td>
<td>This bit is set to 1 in case that the magnetic field is below the MAG-LOW register value (magnetic field to low)</td>
</tr>
</tbody>
</table>

Details on the sensor self-tests can be found in Section 3.5. on page 15.

PROG_DIAGNOSIS

The PROG_DIAGNOSIS register enables the customer to identify errors occurring 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 36xy for further details.

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

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

**XY_GAIN**

XY_GAIN can be used to compensate a phase-shift between X- and Y-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. XY_GAIN is calculated as follows:

\[
XY\_GAIN = \sin(\text{Phase-shift}) \times 32767
\]

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_Y too. For details see definition of GAIN_Y.

**GAIN_X and GAIN_Y**

GAIN_X and GAIN_Y can be used to compensate amplitude mismatches between X- and Y-channel. Micronas delivers pre calibrated sensors with no gain mismatch between X- and Y-channel. Nevertheless it is possible that due to the magnetic circuit a mismatch between X- and Y-channel gain occurs. This can be compensated with Gain_X and Gain_Y. Both registers 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 Y (see also XY_GAIN). If phase-shift correction is used the corresponding register has to be set to

\[
GAIN\_Y = \frac{0.5}{\cos(\text{Phase-shift})} \times 32767
\]

Example:

A phase-shift error of 11° between X- and Y-channel should be compensated. XY_GAIN is then set to 6252.24 Then Gain_X must be 0.5 (GAIN_X = 16384) and GAIN_Y must be set to 16690.

**OFFSET_X and OFFSET_Y**

OFFSET_X and OFFSET_Y can be used to compensate offset mismatches between X- and Y-channel. Micronas delivers pre calibrated sensors. Nevertheless it is possible that due to the magnetic circuit a mismatch between X- and Y-channel offset occurs. This can be compensated with Offset_X and Offset_Y. 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).

**DAC_ZERO**

DAC_Zero defines the zero degree point on the 360° circle. It can be set to any angle point located on the 360° circle. It is also the starting point/reference for the 32 setpoints. DAC_ZERO has a register length of 16 bit and it is two's-complement coded.

\[
DAC\_ZERO = 65536 - 2 \times CORDIC\_PHI
\]

**Note:** Before reading CORDIC_PHI it is necessary to set DAC_ZERO to 0.
DAC_GAIN

DAC_Gain defines the gain of the analog or PWM output. The register has a length of 16 bit and is two's-complement coded. DAC_Gain = 1 is neutral setting and leads to a change of the output voltage from 0% to 100% V_SUP for an angle change from 0° to 360° (if DAC_OFFSET is set to 0).

DAC_Gain can be changed between -64 and 64. The register value is defined by the following equation:

\[
DAC_{GAIN} = 16384 \times \frac{5}{0.5} \times DAC_{Gain}
\]

DAC_OFFSET

DAC_Offset defines the offset of the analog or PWM output. The register has a length of 16 bit and is two's-complementary. DAC_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 DAC_GAIN is set to 1).

DAC_Offset can be changed between -200% and 200% of V_SUP. DAC_OFFSET = 0 leads to a voltage offset of 0% of V_SUP and DAC_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% of V_SUP. The register value is defined by the following equation:

\[
CLAMP-LOW = 256 - \frac{Clamp-Low}{100\%} \times 128
\]

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% of V_SUP. The register value is defined by the following equation:

\[
CLAMP-HIGH = \frac{100\% - \text{Clamp-High}}{100\%} \times 127
\]

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 MAGHIGH. If either low or high limit is exceeded then the sensor will indicate it with an overflow on the sensor's 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:

\[
\text{CORDIC}_\text{AMP} < \text{ABS} (\text{MAG}_\text{LOW} \times 256)
\]

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 sensor's 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:

\[
\text{CORDIC\_AMP} > 32767 - \text{MAG\_HIGH} \times 256
\]

Example:

\[
\text{MAG\_HIGH} = 30 \text{ leads to a detection level of 25087 lsb. As soon as CORDIC\_AMP is above 25087 it will be detected as a too high magnetic field and will lead to an error message on the sensors output.}
\]

\[\text{Note: MAG\_HIGH is MSB aligned.}\]

Low-Pass Filter

With the LP_Filter register it is possible to select different –3 dB frequencies for HAL 36xy. 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.

\[
\text{HYSTERESIS} = 65536 - 2 \times \text{hysteresis}
\]

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>
<thead>
<tr>
<th>No.</th>
<th>Frequency</th>
<th>Resolution</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>2 kHz</td>
<td>11 bit</td>
</tr>
<tr>
<td>1</td>
<td>1 kHz</td>
<td>12 bit</td>
</tr>
<tr>
<td>2</td>
<td>500 Hz</td>
<td>12 bit</td>
</tr>
<tr>
<td>3</td>
<td>250 Hz</td>
<td>12 bit</td>
</tr>
</tbody>
</table>

HYSTERESIS

HYSTERESIS defines the number of digital code uses 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.
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.

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.

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, 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

Fig. 3–5: Example for output linearization

Fig. 3–6: Linearization - Detail

\[ \text{yn} \]: non linear distorted input value
\[ y_l \]: linearized value
\[ \epsilon \]: remaining error
3.4. NVRAM Registers

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.

<table>
<thead>
<tr>
<th>Bit no.</th>
<th>Function</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>15:12</td>
<td>None</td>
<td>Reserved</td>
</tr>
<tr>
<td>11:10</td>
<td>PWMFREQ</td>
<td>For HAL 3675 only</td>
</tr>
<tr>
<td></td>
<td></td>
<td>0: 1 kHz</td>
</tr>
<tr>
<td></td>
<td></td>
<td>1: 500 Hz</td>
</tr>
<tr>
<td></td>
<td></td>
<td>2: 250 Hz</td>
</tr>
<tr>
<td></td>
<td></td>
<td>3: 2 kHz</td>
</tr>
<tr>
<td>9:7</td>
<td>None</td>
<td>Reserved</td>
</tr>
<tr>
<td>6</td>
<td>Customer Burn-in Mode</td>
<td></td>
</tr>
<tr>
<td></td>
<td>0: Disabled</td>
<td></td>
</tr>
<tr>
<td></td>
<td>1: Enabled</td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>Functionality Mode</td>
<td>1: Normal</td>
</tr>
<tr>
<td>4</td>
<td>Communication Mode (POUT)</td>
<td>Communication via output pin</td>
</tr>
<tr>
<td></td>
<td>0: Disabled</td>
<td></td>
</tr>
<tr>
<td></td>
<td>1: Enabled</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>Overvoltage Detection</td>
<td>0: Overvoltage detection active</td>
</tr>
<tr>
<td></td>
<td></td>
<td>1: Overvoltage detection disabled</td>
</tr>
<tr>
<td>2</td>
<td>Diagnosis Latch</td>
<td>Latching of diagnosis bits</td>
</tr>
<tr>
<td></td>
<td></td>
<td>0: No latching</td>
</tr>
<tr>
<td></td>
<td></td>
<td>1: Latched till next POR (power-on reset)</td>
</tr>
<tr>
<td>1</td>
<td>Diagnosis</td>
<td>0: Diagnosis errors force output to error band (V_{SUP})</td>
</tr>
<tr>
<td></td>
<td></td>
<td>1: Diagnosis errors do not force output to error band (V_{SUP})</td>
</tr>
<tr>
<td>0</td>
<td>Customer Lock</td>
<td>Bit must be set to 1 to lock the sensor memory</td>
</tr>
</tbody>
</table>


3.5. On-board Diagnostic features

The HAL 36xy 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 HAL3625, the sensor indicates a failure by switching the output signal to the upper diagnosis level (max. Vout).

HAL 3675 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**

<table>
<thead>
<tr>
<th>Failure Mode</th>
<th>Frequency</th>
<th>Duty-Cycle</th>
</tr>
</thead>
<tbody>
<tr>
<td>EEPROM and state machine self-test</td>
<td>50%</td>
<td>95%</td>
</tr>
<tr>
<td>Adder overflow</td>
<td>50%</td>
<td>85%</td>
</tr>
<tr>
<td>Magnetic field too low</td>
<td>50%</td>
<td>62.5%</td>
</tr>
<tr>
<td>Magnetic field too high</td>
<td>50%</td>
<td>55%</td>
</tr>
<tr>
<td>Overvoltage</td>
<td>50%</td>
<td>75%</td>
</tr>
<tr>
<td>Undervoltage</td>
<td>50%</td>
<td>100%</td>
</tr>
</tbody>
</table>

**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

**Fig. 4–1:** Plastic Small Outline IC package, 8 leads, gullwing bent, 150 mil
Ordering code: DJ
Weight approximately 0.086 g
Fig. 4–2:
**TO92UP-1**: Plastic Transistor Standard UP package, 4 leads

Weight approximately 0.105 g
Fig. 4–3:
TO92UP: Dimensions ammopack inline, not spread

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

<table>
<thead>
<tr>
<th>UNIT</th>
<th>D0</th>
<th>F</th>
<th>H</th>
<th>H1</th>
<th>2h</th>
<th>L</th>
<th>P0</th>
<th>P2</th>
<th>2p</th>
<th>T</th>
<th>T1</th>
<th>W</th>
<th>W0</th>
<th>W1</th>
<th>W2</th>
</tr>
</thead>
<tbody>
<tr>
<td>mm</td>
<td>4.0</td>
<td>1.47</td>
<td>1.07</td>
<td>26</td>
<td>24</td>
<td>30.55</td>
<td>±1.0</td>
<td>11.0</td>
<td>max</td>
<td>13.2</td>
<td>12.0</td>
<td>7.05</td>
<td>±1.0</td>
<td>0.5</td>
<td>0.9</td>
</tr>
</tbody>
</table>

© Copyright 2010 Micronas GmbH, all rights reserved
4.2. Soldering, Welding and 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

<table>
<thead>
<tr>
<th></th>
<th>SOIC8-1</th>
<th>TO92UP-1</th>
</tr>
</thead>
<tbody>
<tr>
<td>A4</td>
<td>0.38 mm nominal</td>
<td>0.45 mm nominal</td>
</tr>
<tr>
<td>Bd</td>
<td>0.3 mm</td>
<td>0.3 mm</td>
</tr>
<tr>
<td>x</td>
<td>0 mm nominal (center of package)</td>
<td>0 mm nominal (center of package)</td>
</tr>
<tr>
<td>y</td>
<td>0.13 mm nominal</td>
<td>1.90 mm nominal</td>
</tr>
</tbody>
</table>

4.5. Pin Connections and Short Description

<table>
<thead>
<tr>
<th>Pin No.</th>
<th>Pin Name</th>
<th>Type</th>
<th>Short Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>VSUP</td>
<td>SUPPLY</td>
<td>Supply Voltage Pin</td>
</tr>
<tr>
<td>2</td>
<td>GND</td>
<td>GND</td>
<td>Ground</td>
</tr>
<tr>
<td>3</td>
<td>TEST</td>
<td>IN</td>
<td>Test</td>
</tr>
<tr>
<td>4</td>
<td>OUT</td>
<td>I/O</td>
<td>Push-Pull Output and Programming Pin</td>
</tr>
<tr>
<td>5,6,7,8</td>
<td>NC</td>
<td>NC</td>
<td>not connected (only available on SOIC8)</td>
</tr>
</tbody>
</table>

**Fig. 4–1: 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).

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

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 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 years from the date code on the package.

4.6.2. Storage and Shelf Life SOIC8 Package

SOIC8 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 Nonhermetic 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.
4.7. 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).

<table>
<thead>
<tr>
<th>Symbol</th>
<th>Parameter</th>
<th>Pin No.</th>
<th>Min.</th>
<th>Typ.</th>
<th>Max.</th>
<th>Unit</th>
<th>Remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td>V_SUP</td>
<td>Supply Voltage</td>
<td>VSUP</td>
<td>4.5</td>
<td>5</td>
<td>5.5</td>
<td>V</td>
<td>Normal operation</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>5.7</td>
<td>6</td>
<td>6.5</td>
<td>V</td>
<td>During Programming</td>
</tr>
<tr>
<td>I_OUT</td>
<td>Continuous Output Current</td>
<td>OUT</td>
<td>–1.2</td>
<td>–</td>
<td>1.2</td>
<td>mA</td>
<td></td>
</tr>
<tr>
<td>R_L</td>
<td>Load Resistor</td>
<td>OUT</td>
<td>5</td>
<td>10</td>
<td>–</td>
<td>kΩ</td>
<td>HAL3625 pull-down resistor</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>20</td>
<td>–</td>
<td>–</td>
<td>kΩ</td>
<td>pull-up resistor</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>1</td>
<td>–</td>
<td>–</td>
<td>kΩ</td>
<td>HAL3675 pull-up resistor</td>
</tr>
<tr>
<td>C_L</td>
<td>Load Capacitance</td>
<td>OUT</td>
<td>0.33</td>
<td>47</td>
<td>600</td>
<td>nF</td>
<td>HAL3625</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>–</td>
<td>1.0</td>
<td>10</td>
<td>nF</td>
<td>HAL3675</td>
</tr>
<tr>
<td>N_PRG</td>
<td>Number of Memory Programming Cycles</td>
<td>–</td>
<td>–</td>
<td>–</td>
<td>100</td>
<td>cycles</td>
<td>0 °C &lt; T_{amb} &lt; 55 °C</td>
</tr>
<tr>
<td>B_AMP</td>
<td>Recommended Amplitude of Magnetic Field</td>
<td>–</td>
<td>–</td>
<td>±30</td>
<td>±100</td>
<td>mT</td>
<td></td>
</tr>
</tbody>
</table>

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.

| T_J    | Junction Temperature 2)           | –      | –40  | –    | 125  | °C   | for 8000 h for 2000 h for 1000 h Time values are not additive |
|        |                                    |        | –40  | –    | 150  |      |                                              |
|        |                                    |        | –40  | –    | 170  |      |                                              |

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. Magnetic fields below ±30 mT will lead to an additional angle error.
4.8. Characteristics

at $T_J = -40 \, ^\circ C$ to $+170 \, ^\circ C$, $V_{SUP} = 4.5 \, V$ 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 $T_J = 25 \, ^\circ C$ and $V_{SUP} = 5 \, V$.

<table>
<thead>
<tr>
<th>Symbol</th>
<th>Parameter</th>
<th>Pin No.</th>
<th>Limit Values</th>
<th>Unit</th>
<th>Test Conditions</th>
</tr>
</thead>
<tbody>
<tr>
<td>$I_{SUP}$</td>
<td>Supply Current over Temperature Range</td>
<td>VSUP</td>
<td>–</td>
<td>10</td>
<td>15 mA</td>
</tr>
<tr>
<td>–</td>
<td>Resolution 1)</td>
<td>OUT</td>
<td>–</td>
<td>12</td>
<td>–</td>
</tr>
<tr>
<td>$t_{(O)}$</td>
<td>Response Time of Output 2)</td>
<td>OUT</td>
<td>–</td>
<td>0.5</td>
<td>0.6 ms</td>
</tr>
<tr>
<td>$t_{WS}$</td>
<td>Wake-up time 2)</td>
<td>OUT</td>
<td>–</td>
<td>1.7</td>
<td>ms</td>
</tr>
</tbody>
</table>

HAL3625 (Analog Output)

<table>
<thead>
<tr>
<th>Symbol</th>
<th>Parameter</th>
<th>Pin No.</th>
<th>Limit Values</th>
<th>Unit</th>
<th>Test Conditions</th>
</tr>
</thead>
<tbody>
<tr>
<td>DNL</td>
<td>Differential Non-Linearity of D/A converter</td>
<td>OUT</td>
<td>–3</td>
<td>0</td>
<td>3 LSB</td>
</tr>
<tr>
<td>$E_R$</td>
<td>Ratiometric Error of Output over temperature (Error in $V_{OUT}/V_{SUP}$)</td>
<td>OUT</td>
<td>–0.2</td>
<td>0</td>
<td>0.2 %</td>
</tr>
<tr>
<td>INL</td>
<td>Non-Linearity of D/A converter</td>
<td>OUT</td>
<td>–0.1</td>
<td>0</td>
<td>0.1 %</td>
</tr>
<tr>
<td>$\Delta V_{OFFSET}$</td>
<td>D/A converter offset drift over temperature range related to 25 °C 2)</td>
<td>OUT</td>
<td>–0.2</td>
<td>0</td>
<td>0.2 %$V_{SUP}$</td>
</tr>
<tr>
<td>$V_{OUTH}$</td>
<td>Output High Voltage 3)</td>
<td>OUT</td>
<td>93</td>
<td>–</td>
<td>–</td>
</tr>
<tr>
<td>$V_{OUTL}$</td>
<td>Output Low Voltage 3)</td>
<td>OUT</td>
<td>–</td>
<td>–</td>
<td>7 %$V_{SUP}$</td>
</tr>
<tr>
<td>$\Delta V_{OUTCL}$</td>
<td>Accuracy of Output Voltage at Clamping Low Voltage over Temperature Range 3)</td>
<td>OUT</td>
<td>–30</td>
<td>0</td>
<td>30 mV</td>
</tr>
<tr>
<td>$\Delta V_{OUTH}$</td>
<td>Accuracy of Output Voltage at Clamping High Voltage over Temperature Range 3)</td>
<td>OUT</td>
<td>–30</td>
<td>0</td>
<td>30 mV</td>
</tr>
<tr>
<td>$OUT_Noise$</td>
<td>Output Noise RMS 2)</td>
<td>OUT</td>
<td>–</td>
<td>4.5</td>
<td>12 mV</td>
</tr>
<tr>
<td>–</td>
<td></td>
<td></td>
<td></td>
<td>1.5</td>
<td>4.0 mV</td>
</tr>
<tr>
<td>$R_{OUT}$</td>
<td>Output Resistance over Recommended Operating Range</td>
<td>OUT</td>
<td>–</td>
<td>1</td>
<td>10 $\Omega$</td>
</tr>
</tbody>
</table>

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 $V_{OUTH}$
HAL3675 (PWM Output)

<table>
<thead>
<tr>
<th>Symbol</th>
<th>Parameter</th>
<th>Pin No.</th>
<th>Limit Values</th>
<th>Unit</th>
<th>Test Conditions</th>
</tr>
</thead>
<tbody>
<tr>
<td>$V_{OUTH}$</td>
<td>Output High Voltage</td>
<td>OUT</td>
<td>–</td>
<td>4.9</td>
<td>– V</td>
</tr>
<tr>
<td>$V_{OUTL}$</td>
<td>Output Low Voltage</td>
<td>OUT</td>
<td>–</td>
<td>0.1</td>
<td>– V</td>
</tr>
<tr>
<td>$V_{OUTN}$</td>
<td>Output Noise RMS $^2$</td>
<td>OUT</td>
<td>–</td>
<td>0.12</td>
<td>0.24 %</td>
</tr>
<tr>
<td>$V_{OUTL}$</td>
<td>Output Low Voltage</td>
<td>OUT</td>
<td>–</td>
<td>0.02</td>
<td>0.08 %</td>
</tr>
<tr>
<td>$f_{PWM}$</td>
<td>PWM Frequency</td>
<td>OUT</td>
<td>1.7</td>
<td>2</td>
<td>2.3 kHz</td>
</tr>
<tr>
<td>$J_{PWM}$</td>
<td>RMS PWM Jitter $^2$</td>
<td>OUT</td>
<td>–</td>
<td>1</td>
<td>2 LSB$_{12}$</td>
</tr>
<tr>
<td>$t_{rise}$</td>
<td>Rise Time of Digital Output</td>
<td>OUT</td>
<td>–</td>
<td>0.4</td>
<td>– µs</td>
</tr>
<tr>
<td>$t_{fall}$</td>
<td>Fall Time of Digital Output</td>
<td>OUT</td>
<td>–</td>
<td>0.5</td>
<td>– µs</td>
</tr>
<tr>
<td>ROUT_DIG</td>
<td>On Resistance of Digital Pull-Up Driver</td>
<td>OUT</td>
<td>–</td>
<td>100</td>
<td>200 Ω</td>
</tr>
</tbody>
</table>

SOIC8 Package

<table>
<thead>
<tr>
<th>Symbol</th>
<th>Parameter</th>
<th>Limit Values</th>
<th>Unit</th>
<th>Test Conditions</th>
</tr>
</thead>
<tbody>
<tr>
<td>$R_{thja}$</td>
<td>Thermal Resistance</td>
<td>–</td>
<td>–</td>
<td>142 K/W</td>
</tr>
<tr>
<td>$R_{thjc}$</td>
<td>Junction to Case</td>
<td>–</td>
<td>–</td>
<td>88 K/W</td>
</tr>
<tr>
<td>$R_{thja}$</td>
<td>Thermal Resistance</td>
<td>–</td>
<td>–</td>
<td>33 K/W</td>
</tr>
<tr>
<td>$R_{thjc}$</td>
<td>Junction to Case</td>
<td>–</td>
<td>–</td>
<td>22 K/W</td>
</tr>
</tbody>
</table>

TO92UP Package

<table>
<thead>
<tr>
<th>Symbol</th>
<th>Parameter</th>
<th>Limit Values</th>
<th>Unit</th>
<th>Test Conditions</th>
</tr>
</thead>
<tbody>
<tr>
<td>$R_{thja}$</td>
<td>Thermal Resistance</td>
<td>–</td>
<td>–</td>
<td>198 K/W</td>
</tr>
<tr>
<td>$R_{thjc}$</td>
<td>Junction to Case</td>
<td>–</td>
<td>–</td>
<td>146 K/W</td>
</tr>
<tr>
<td>$R_{thja}$</td>
<td>Thermal Resistance</td>
<td>–</td>
<td>–</td>
<td>53 K/W</td>
</tr>
<tr>
<td>$R_{thjc}$</td>
<td>Junction to Case</td>
<td>–</td>
<td>–</td>
<td>38 K/W</td>
</tr>
</tbody>
</table>

$^2$ Characterized on small sample size, not tested.

Fig. 4–2: Recommended pad size SOIC8 package (in mm)
**Fig. 4–3:** Description of power-on behavior of the sensor
4.9. Magnetic Characteristics

at $T_J = -40 \, ^\circ C$ to $+170 \, ^\circ C$, $V_{SUP} = 4.5 \, V$ 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 $T_J = 25 \, ^\circ C$ and $V_{SUP} = 5 \, V$.

<table>
<thead>
<tr>
<th>Symbol</th>
<th>Parameter</th>
<th>Pin No.</th>
<th>Min.</th>
<th>Typ.</th>
<th>Max.</th>
<th>Unit</th>
<th>Test Conditions</th>
</tr>
</thead>
<tbody>
<tr>
<td>$\phi_{RANGE}$</td>
<td>Detectable Angle Range$^1$</td>
<td>OUT</td>
<td>0</td>
<td>–</td>
<td>360</td>
<td>°</td>
<td></td>
</tr>
<tr>
<td>$\phi_{res}$</td>
<td>Angle Resolution$^1$</td>
<td>OUT</td>
<td>–</td>
<td>–</td>
<td>0.09</td>
<td>°</td>
<td></td>
</tr>
<tr>
<td>$E_{\mu lin}$</td>
<td>Micro Linearity Error$^1$</td>
<td>OUT</td>
<td>–0.2</td>
<td>–</td>
<td>0.2</td>
<td>°/1° for 120° angle range</td>
<td></td>
</tr>
<tr>
<td>SenseXY</td>
<td>Sensitivity of X and Y Hall Plate$^2$</td>
<td>OUT</td>
<td>138</td>
<td>150</td>
<td>162</td>
<td>LSB/mT</td>
<td>$T_J = 25^\circ C$</td>
</tr>
<tr>
<td>$\Delta$SenseXY</td>
<td>Sensitivity Drift Factor of Hall Plates over Temperature $^2$</td>
<td>–</td>
<td>1.25</td>
<td>0.92</td>
<td>0.4</td>
<td></td>
<td></td>
</tr>
<tr>
<td>$\Delta$OffsetXY</td>
<td>Offset Drift on Raw Signals of X or Y Channel$^1$</td>
<td>OUT</td>
<td>–100</td>
<td>–</td>
<td>100</td>
<td>LSB$_{15}$</td>
<td>$T_J = 25^\circ C$, can be compensated in customer application (see Section 3.2. on page 8)</td>
</tr>
<tr>
<td>$E_{\mu lin}$</td>
<td>Resulting Angle Linearity Error (on output of cordic filter) $^2$</td>
<td>OUT</td>
<td>–1.3</td>
<td>–</td>
<td>1.3</td>
<td>°</td>
<td>Min. magnetic amplitude = ±30 mT $T_J = 25^\circ C$</td>
</tr>
<tr>
<td>$\Delta$E$_{\mu lin}$</td>
<td>Resulting Angle Linearity Error drift over temperature (on output of cordic filter) $^2$</td>
<td>OUT</td>
<td>–1.3</td>
<td>–</td>
<td>1.3</td>
<td>°</td>
<td>Related to $T_J = 25^\circ C$</td>
</tr>
<tr>
<td>$E_{\mu temp}$</td>
<td>Temperature Drift Error $^5$</td>
<td>OUT</td>
<td>–0.9</td>
<td>–</td>
<td>0.3</td>
<td>°</td>
<td>for 360° for 120° The error is given due to the temperature drift of the analog output and is linear scaling with the angular range. For HAL3625 only.</td>
</tr>
<tr>
<td>$E_{\mu hyst}$</td>
<td>Hysteresis Error$^1$</td>
<td>OUT</td>
<td>–</td>
<td>0.03</td>
<td>–</td>
<td>°</td>
<td></td>
</tr>
<tr>
<td>$\Delta$OffsetXYlife</td>
<td>Offset Drift on Raw Signals of X or Y Channel over Lifetime $^5$</td>
<td>OUT</td>
<td>–</td>
<td>30</td>
<td>–</td>
<td>LSB$_{15}$</td>
<td>after 1000 h HTOL</td>
</tr>
</tbody>
</table>

1) Guaranteed by Design
2) Characterized on small sample size, not tested. Specification limit is ±3 Sigma value
3) in homogeneous magnetic field
4) Calculated angular error based on characterization and not on single error summation
5) Characterized on small sample size, not tested.
Fig. 4–4: Angular error vs. magnetic field amplitude (3 sigma values)

Note: \( \text{T}_J = 130^\circ \text{C} \) is worst case condition and the temperature with the highest angular error.

4.10 Open-Circuit Detection (only applicable for HAL3625)
at \( \text{T}_J = -40 \, ^\circ\text{C} \) to \(+170 \, ^\circ\text{C} \), Typical Characteristics for \( \text{T}_J = 25 \, ^\circ\text{C} \), after locking the sensor

<table>
<thead>
<tr>
<th>Symbol</th>
<th>Parameter</th>
<th>Pin No.</th>
<th>Min.</th>
<th>Typ.</th>
<th>Max.</th>
<th>Unit</th>
<th>Comment</th>
</tr>
</thead>
<tbody>
<tr>
<td>( \text{V}_{\text{OUT}} )</td>
<td>Output voltage at open ( \text{V}_{\text{SUP}} ) line</td>
<td>OUT</td>
<td>0</td>
<td>0</td>
<td>0.15</td>
<td>V</td>
<td>( \text{V}_{\text{SUP}} = 5 , \text{V} ) ( R_L = 20 , \text{k}\Omega ) to 200 ( \text{k}\Omega )</td>
</tr>
<tr>
<td>( \text{V}_{\text{OUT}} )</td>
<td>Output voltage at open GND line</td>
<td>OUT</td>
<td>4.85</td>
<td>4.9</td>
<td>5.0</td>
<td>V</td>
<td>( \text{V}_{\text{SUP}} = 5 , \text{V} ) ( R_L = 10 , \text{k}\Omega ) to 200 ( \text{k}\Omega )</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>4.8</td>
<td>4.9</td>
<td>5.0</td>
<td>V</td>
<td>( \text{V}_{\text{SUP}} = 5 , \text{V} ) ( 5 , \text{k}\Omega \geq R_L &lt; 10 , \text{k}\Omega )</td>
</tr>
</tbody>
</table>

\( R_L \): Can be pull-up or pull-down resistor

4.11 Overvoltage and Undervoltage Detection
at \( \text{T}_J = -40 \, ^\circ\text{C} \) to \(+170 \, ^\circ\text{C} \), Typical Characteristics for \( \text{T}_J = 25 \, ^\circ\text{C} \), after programming and locking

<table>
<thead>
<tr>
<th>Symbol</th>
<th>Parameter</th>
<th>Pin No.</th>
<th>Min.</th>
<th>Typ.</th>
<th>Max.</th>
<th>Unit</th>
</tr>
</thead>
<tbody>
<tr>
<td>( \text{V}_{\text{SUP,UV}} )</td>
<td>Undervoltage Detection Level</td>
<td>VSUP</td>
<td>3.3</td>
<td>3.7</td>
<td>4.4</td>
<td>V</td>
</tr>
<tr>
<td>( \text{V}_{\text{SUP,UV\text{hyst}}} )</td>
<td>Undervoltage Detection Level Hysteresis</td>
<td>VSUP</td>
<td>–</td>
<td>200</td>
<td>–</td>
<td>mV</td>
</tr>
<tr>
<td>( \text{V}_{\text{SUP,OV}} )</td>
<td>Overvoltage Detection Level</td>
<td>VSUP</td>
<td>5.6</td>
<td>6.2</td>
<td>6.9</td>
<td>V</td>
</tr>
<tr>
<td>( \text{V}_{\text{SUP,OV\text{hyst}}} )</td>
<td>Overvoltage Detection Level Hysteresis</td>
<td>VSUP</td>
<td>–</td>
<td>225</td>
<td>–</td>
<td>mV</td>
</tr>
</tbody>
</table>
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:

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

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.

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

The junction temperature $T_J$ is specified. The maximum ambient temperature $T_{A\text{max}}$ can be calculated as:

$$T_{A\text{max}} = T_{J\text{max}} - \Delta T$$

5.2. EMC and ESD

The HAL36xy is designed for a stabilized 5 V supply. Interferences and disturbances conducted along the 12 V onboard system (product standard ISO 7637 part 1) are not relevant for these applications.

For applications with disturbances by capacitive or inductive coupling on the supply line or radiated disturbances, the application circuits shown in Fig. 5–1 and Fig. 5–2 are recommended. Applications with these arrangements passed 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 HAL3625

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 HAL3625](image)

5.4. Application Circuit for HAL3675

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 HAL3675](image)
5.5. Measurement of a PWM Output Signal of HAL3675

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](image-url)
6. Programming of the Sensor

HAL 36xy 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 the sensor is addressed by modulating a serial telegram on the sensors output pin. The sensor answers with a modulation of the output voltage.

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

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

<table>
<thead>
<tr>
<th>Symbol</th>
<th>Parameter</th>
<th>Pin No.</th>
<th>Limit Values</th>
<th>Unit</th>
<th>Test Conditions</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Pin No.</td>
<td>Min.</td>
<td>Typ.</td>
<td>Max.</td>
</tr>
<tr>
<td>$V_{OUTL}$</td>
<td>Voltage for Output Low Level during Programming through Sensor Output Pin</td>
<td>OUT</td>
<td>0</td>
<td>–</td>
<td>0.2$V_{SUP}$ 1</td>
</tr>
<tr>
<td>$V_{OUTH}$</td>
<td>Voltage for Output High Level during Programming through Sensor Output Pin</td>
<td>OUT</td>
<td>0.8$V_{SUP}$</td>
<td>–</td>
<td>$V_{SUP}$ 5.0</td>
</tr>
<tr>
<td>$V_{SUP,program}$</td>
<td>Voltage for EEPROM &amp; NVRAM programming (during Programming)</td>
<td>VSUP</td>
<td>5.7</td>
<td>6.0</td>
<td>6.5</td>
</tr>
<tr>
<td>$t_{bit}$</td>
<td>Biphase Bit Time</td>
<td>OUT</td>
<td>900</td>
<td>1000</td>
<td>1100</td>
</tr>
<tr>
<td>Slew rate</td>
<td></td>
<td>OUT</td>
<td>–</td>
<td>2</td>
<td>–</td>
</tr>
</tbody>
</table>
6.2. Programming Environment and Tools

For the programming of HAL 36xy 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 ease 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 36xy. 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 3675 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 “HAL36xy Programming Guide”. It contains additional information and instructions about the programming of the devices.
7. Data Sheet History


   Major Changes:
   • new package added TO92UP
   • K temperature range removed
   • smaller pull-up resistor specified for HAL3675

   Major Changes:
   • Additional guidance for programming of the sensors
   • Tighter noise specification
   • Update of application circuit for HAL3675
   • Update of package drawings
   • Customer Setup register description updated
   • Characteristics: Output Noise RMS specified