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MICRONAS

Hardware Documentation

Data Sheet

HAR 24xy

High-Precision Dual-Die Programmable Linear Hall-Effect Sensor Family

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Contents

High-Precision Dual-Die Programmable Linear Hall-Effect Sensor Family

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

1. Introduction

HAR 24xy is a dual-die programmable linear Hall-effect sensor family. It provides redundancy as it consists of two independent dies stacked in a single package, each bonded to a separate side of the leadframe. The stacked-die architecture ensures that both dies occupy the same magnetic field position, thus generating synchronous measurement outputs.

The integrated dies are two HAL 24xy, universal magnetic field sensors with linear analog or PWM outputs based on the Hall effect. For both dies major characteristics like magnetic field range, sensitivity, output quiescent voltage (output voltage at B=0 mT), and output voltage range are programmable in non-volatile memories. The output characteristics are ratiometric, which means that the output voltages are proportional to the magnetic flux and the supply voltage. Additionally, both dies offer wire-break detection.

Each die of the HAR 24xy offers 16 setpoints to change the output characteristics from linear to arbitrary or vice versa. They feature temperature-compensated Hall plates with spinning current offset compensation, A/D converters, digital signal processing, D/A converters with output driver (HAR 2425), programmable PWM output modules (HAR 2455), EEPROMs with redundancy and lock function for calibration data, serial interfaces for programming the EEPROMs, and protection devices at all pins. The internal digital signal processing prevents the signal being influenced by analog offsets, temperature shifts, and mechanical stress.

The easy programmability allows individual adjustment of each HAR 24xy during the final manufacturing process by means of a 2-point calibration, by adjusting the output signals directly to the input signal (like mechanical angle, distance, or current). With this calibration procedure, the tolerances of the sensor, the magnet-, and the mechanical positioning can be compensated in the final assembly.

In addition, the temperature compensation of the Hall ICs can be fit to all common magnetic materials by programming first- and second-order temperature coefficients of the Hall sensor sensitivity.

It is also possible to compensate offset drift over temperature generated by the customer application with a first-order temperature coefficient for the sensors offset. This enables operation over the full temperature range with a high accuracy.

The calculation of the individual sensors characteristics and the programming of the corresponding EEPROMs can easily be done with a PC and the application kit from Micronas.

The sensors are designed for stringent industrial and automotive applications and are AECQ100 qualified. They operate with typically 5 V supply voltage in the junction temperature range from −40 °C up to 170 °C. The HAL 24xy is available in the ultra-thin shrink small outline 14 leads package TSSOP14-1.

1.1. Major Applications

Thanks to its redundancy capability, HAR 24xy can address safety-critical applications. The sensors' versatile programming characteristics and low temperature drifts make the HAR 24xy the optimal system solution for:

– Angular measurements: throttle position, pedal position, steering torque and EGR applications;
– Distance and linear movement measurements in safety-critical applications
– Magnetic field and current measurement with specific resolution over different ranges, by appropriate sensitivity programming for each die.

1.2. Features

High-precision, redundant, linear Hall-effect sensor with two independent 12-bit analog outputs (HAR 2425) or with two independent PWM outputs up to 2 kHz (HAR 2455).

Each die provides:

– 16 setpoints for various output signal shapes
– 16 bit digital signal processing
– Multiple customer-programmable magnetic characteristics in a non-volatile memory with redundancy and lock function
– Programmable temperature compensation for sensitivity and offset
– Magnetic field measurements in the range up to ±200 mT
– Low output voltage drifts over temperature
– Active open-circuit (ground and supply line break detection) with 5 kΩ pull-up and pull-down resistor, overvoltage and undervoltage detection
– Programmable clamping function
– Digital readout of temperature and magnetic field information in calibration mode
– Programming and operation of multiple sensors at the same supply line
– Active detection of output short between two sensors
– High immunity against mechanical stress, ESD, and EMC
– Operation from T_J=–40 °C up to 170 °C
– Operation from 4.5 V up to 5.5 V supply voltage in specification and functions up to 8.5 V
– Operation with static magnetic fields and dynamic magnetic fields up to 2 kHz
– Overvoltage and reverse-voltage protection at all pins
– Short-circuit protected push-pull output

2. Ordering Information

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

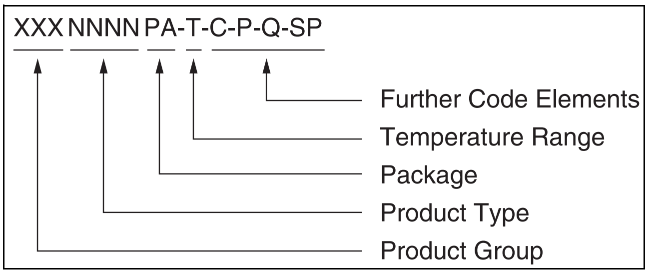


Fig. 2–1: Ordering Code Principle

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

2.1. Device-Specific Ordering Codes

The HAR 24xy is available in the following package and temperature variants.

Table 2–1: Available packages

Package Code (PA)	Package Type
GP	TSSOP14-1

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 5.3. on page 30.

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

Ordering Code	Package Marking
HAR2425GP-A-[C-P-Q-SP]	HAR2425A
HAR2455GP-A-[C-P-Q-SP]	HAR2455A

3. Functional Description

3.1. General Function

HAR 24xy is a dual-die integrated circuit. The two dies have independent pins for power supply, ground, and output to guaranty full redundancy. Due to the stacked assembly they are in the same magnetic field position, and thereby generating synchronous measurement outputs. The HAR 2425 provides redundant output voltages proportional to the magnetic flux through the Hall plates and proportional to the supply voltage (ratiometric behavior). The HAR 2455 offers PWM outputs.

The external magnetic field component perpendicular to the branded side of the package generates a Hall voltage. The Hall IC is sensitive to magnetic north and south polarity. For each die this voltage is converted to a digital value, processed in the Digital Signal Processing unit (DSP) according to the settings of the EEPROM registers, converted back to an analog voltage with ratiometric behavior and buffered by a push-pull output transistor stage (HAR 2425) or output as PWM signal (HAR 2455).

The setting of a LOCK bit disables the programming of the EEPROM memory for all time. This bit cannot be reset by the customer.

As long as the LOCK bit is not set, the output characteristic can be adjusted by programming the EEPROM registers. The IC is addressed by modulating the output voltage.

In the supply voltage range from 4.5 V up to 5.5 V, the sensor generates an analog output voltage (HAR 2425) or a PWM signal (HAR 2455). After detecting a command, the sensor reads or writes the memory and answers with a digital signal on the output pin. The analog output is switched off during the communication.

Several sensors in parallel to the same supply and ground line can be programmed individually. The selection of each sensor is done via its output pin. See Programming Guide HAL 24xy and HAR 24xy.

The open-circuit detection provides a defined output voltage if the VSUP or GND line is broken.

Internal temperature compensation circuitry and the spinning-current offset compensation enable operation over the full temperature range with minimal changes in accuracy and high offset stability. The circuitry also reduces offset shifts due to mechanical stress from the package. In addition, the sensor IC is equipped with overvoltage and reverse-voltage protection at all pins.

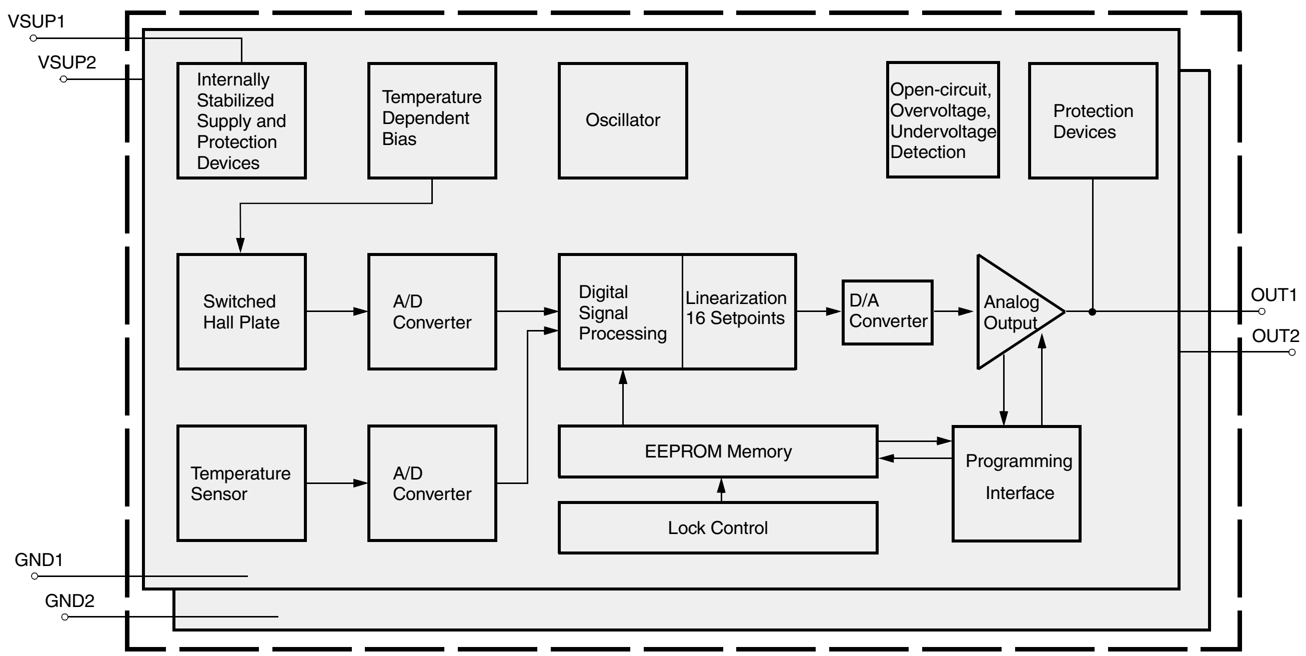


Fig. 3–1: HAR2425 block diagram

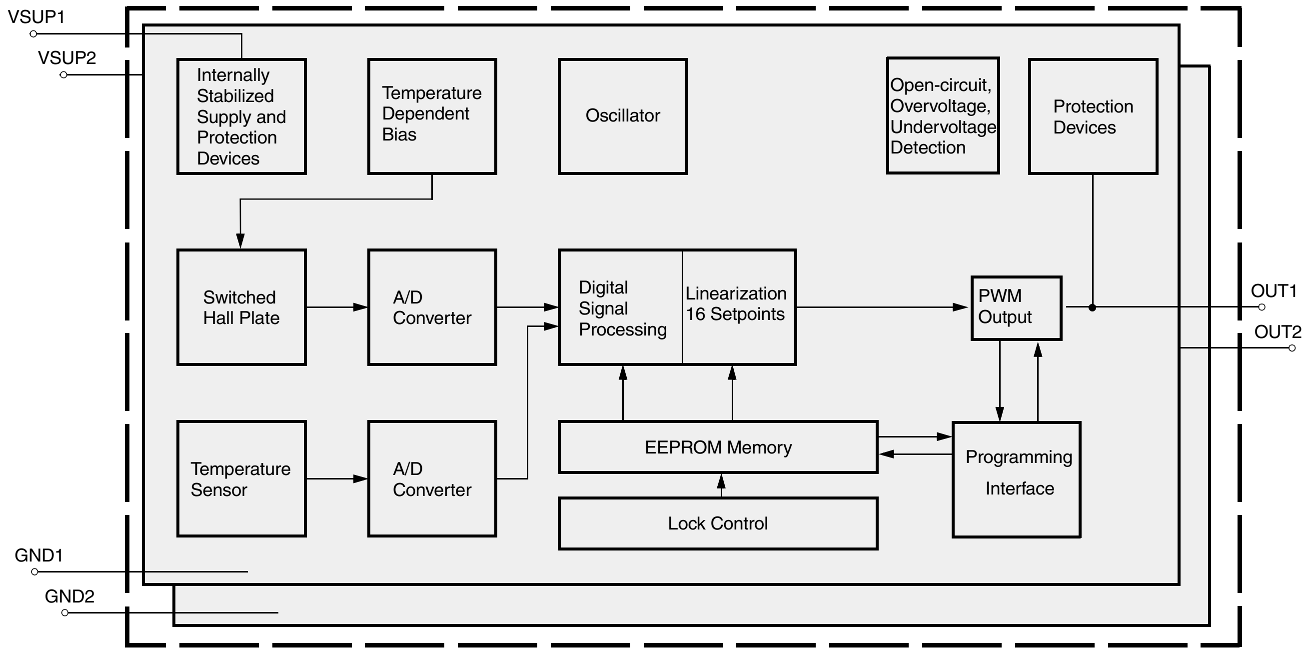


Fig. 3–2: HAR 2455 block diagram

3.2. Signal Path and Register Definition

3.2.1. Signal Path

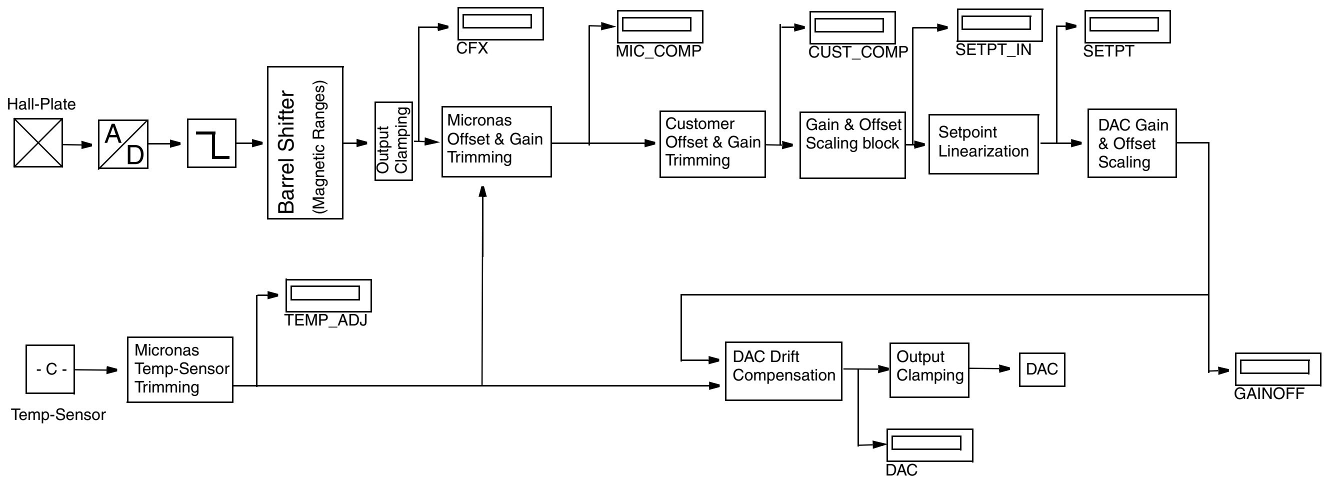


Fig. 3–3: Signal path of HAR2425 (identical for both dies)

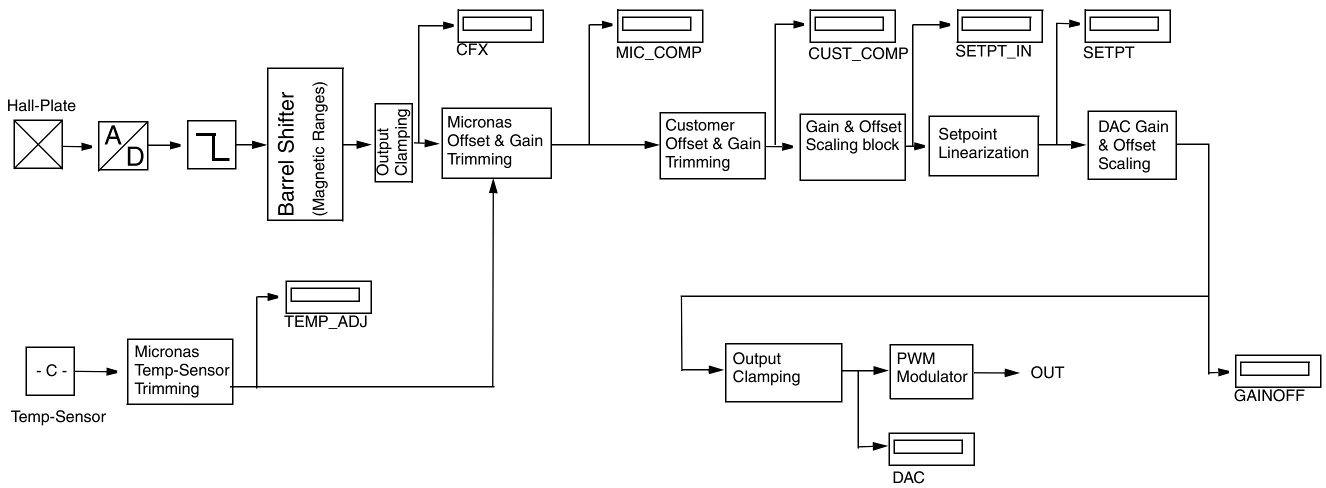


Fig. 3–4: Signal path of HAR 2455 (identical for both dies)

3.2.2. Register Definition

The DSP is the major part of each die and performs the signal conditioning. The parameters for the DSP are stored in the EEPROM registers. The details are shown in Fig. 3–5 and Fig. 3–7.

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 & NVRAM). The RAM registers contain measurement data at certain positions of the signal path and the EEPROM registers have influence on the sensors signal processing.

3.2.2.1. RAM registers

TEMP_ADJ

The TEMP_ADJ register contains the calibrated temperature sensor information. TEMP_ADJ can be used for the sensor calibration over temperature. This register has a length of 16 bit and it is two's-complement coded. Therefore the register value can vary between –32768...32767.

CFX

The CFX register is representing the magnetic field information directly after A/D conversion, decimation filter and magnetic range (barrel shifter) selection. The register content is not temperature compensated. The temperature variation of this register is specified in Section 4.14. on page 28 by the parameter $RANGE_{ABS}$.

Note: During application design, it must be taken into consideration that CFX should never overflow in the operational range of the specific application and especially over the full temperature range. In case of a potential overflow the barrel shifter should be switched to the next higher range.

This register has a length of 16 bit and it is two's-complement coded. Therefore the register value can vary between –32768...32767. CFX register values will increase for positive magnetic fields (south pole) on the branded side of the package (positive CFX values) and it will decrease with negative magnetic field polarity.

MIC_COMP

The MIC_COMP register is representing the magnetic field information directly after the Micronas temperature trimming. The register content is temperature compensated and has a typical gain drift over temperature of 0 ppm/k. Also the offset and its drift over temperature is typically zero. The register has a length of 16 bit and it is two's-complement coded. Therefore the register value can vary between –32768...32767.

CUST_COMP

The CUST_COMP register is representing the magnetic field information after the customer temperature trimming. For HAR 2425 it is possible to set a customer specific gain of second order over temperature as well as a customer specific offset of first order over temperature. The customer gain and offset can be set with the EEPROM registers TCCO0, TCCO1 for offset and TCCG0...TCCG2 for gain. Details of these registers are described on the following pages.

The register has a length of 16 bit and it is two's-complement coded. Therefore the register value can vary between –32768...32767.

SETPT_IN

The SETPT_IN register offers the possibility to read the magnetic field information after the scaling of the input signal to the input range of the linearization block. For further details see the description of the EEPROM registers SCALE_GAIN and SCALE_OFFSET that are described in the next chapter.

The register has a length of 16 bit and it is two's-complement coded. Therefor the register value can vary between –32768...32767.

SETPT

The SETPT register offers the possibility to read the magnetic field information after the linearization of the magnetic field information with 16 setpoints. This information is also required for the correct setting of the sensors DAC GAIN and OFFSET in the following block.

The register has a length of 16 bit and it is two's-complement coded. Therefore the register value can vary between –32768...32767.

GAINOFF

The GAINOFF register offers the possibility to read the magnetic field information after the DAC GAIN and OFFSET scaling.

This register has a length of 16 bit and it is two's-complement coded. Therefore the register value can vary between –32768...32767.

DAC

The DAC register offers the possibility to read the magnetic field information at the end of the complete signal path. The value of this register is then converted into an analog output voltage.

The register has a length of 16 bit and it is two's-complement coded. Therefore the register value can vary between –32768...32767.

MIC_ID1 and MIC_ID2

The two registers MIC_ID1 and MIC_ID2 are used by Micronas to store production information like, wafer number, die position on wafer, production lot, etc. Both registers have a length of 16 bit each and are readout only.

PWM Frequency

The PWM frequency is selectable by 2 bits, which are part of the CUSTOMER SETUP register (bits 11:10). The CUSTOMER SETUP register is described on the following pages. The following four different frequencies can be used:

Table 3–1: Selectable PWM frequencies

PWM_FREQ		Frequency	Resolution
Bit 11	Bit 10		
1	1	2 kHz	11 bit
0	0	1 kHz	12 bit
0	1	500 Hz	12 bit
1	0	250 Hz	12 bit

DIAGNOSIS

The DIAGNOSIS register enables the customer to identify certain failures detected by the sensor. HAR 2425 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.

Bit no.	Function	Description
15:6	None	Reserved
5	State Machine (DSP) Self test	This bit is set to 1 in case that the statemachine self test fails. (continuously running)
4	EEPROM Self test	This bit is set to 1 in case that the EEPROM self test fails. (Performed during power-up only)
3	ROM Check	This bit is set to 1 in case that ROM parity check fails. (continuously running)
2	AD converter overflow	This bit is set to 1 in case the input signal is too high, indicating a problem with the magnetic range.
1:0	None	Reserved

Details on the sensor self tests can be found in Section 3.3. on page 16.

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 either check the status of this register after each write or program command or alternatively the second acknowledge. Please check the Programming Guide for HAL 24xy.

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

Bit No.	Function	Description
15:11	None	Reserved
10	Charge Pump Error	This bit is set to 1 in case that the internal programming voltage was to low
9	Voltage Error during Program/ Erase	This bit is set to 1 in case that the internal supply voltage was to low during program or erase
8	NVRAM Error	This bit is set to 1 in case that the programming of the NVRAM failed
7:0	Memory Programming	For further information please refer to the Programming Guide for HAL 242x

3.2.2.2. EEPROM Registers

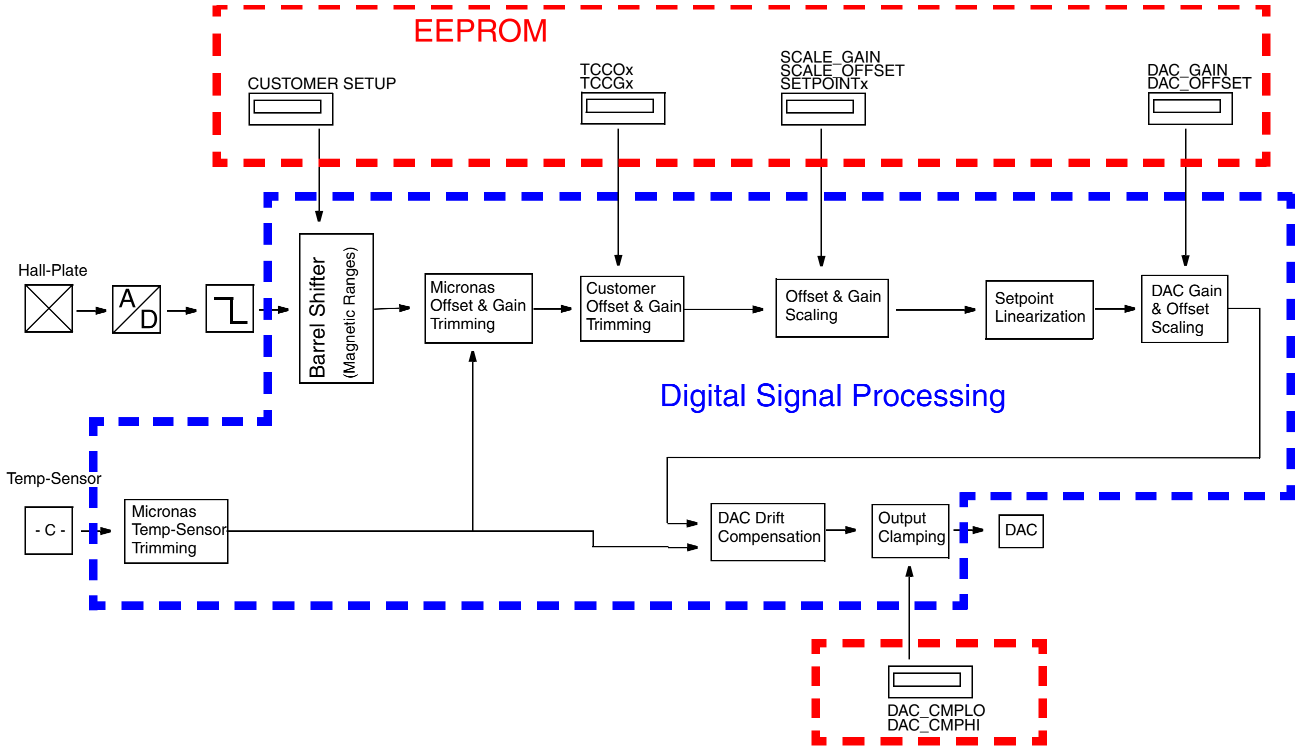


Fig. 3–5: Details of EEPROM and Digital Signal Processing for HAR 2425 (equal for both dies).

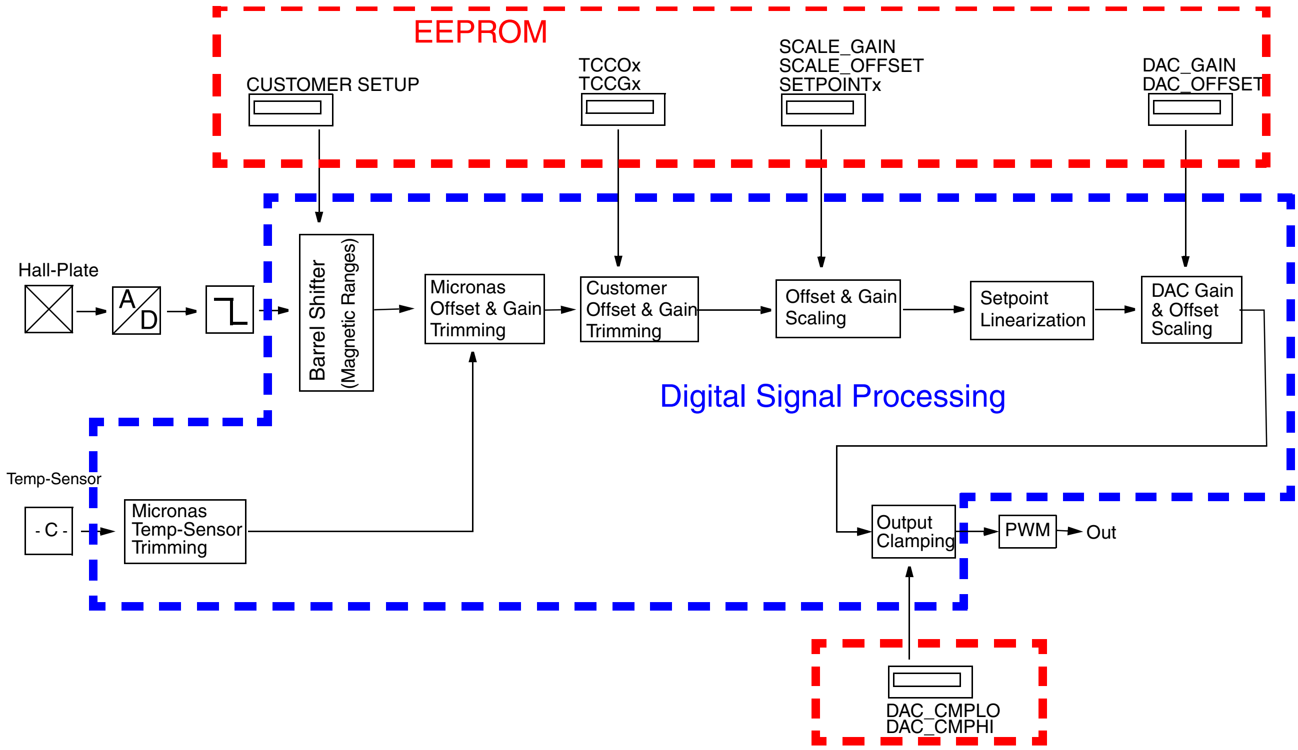


Fig. 3–6: Details of EEPROM and Digital Signal Processing for HAR 2455 (equal for both dies).

CUST_ID1 and CUST_ID2

The two registers CUST_ID1 and CUST_ID2 can be used to store customer information. Both registers have a length of 16 bit each.

Barrel Shifter (Magnetic Ranges)

The signal path of HAR 24xy contains a Barrel Shifter to emulate magnetic ranges. The customer can select between different magnetic ranges by changing the Barrel Shifter setting. After decimation filter the signal path has a word length of 22 bit. The Barrel Shifter selects 16 bit out of the available 22 bit.

The Barrel Shifter bits are part of the CUSTOMER SETUP register (bits 14...12). The CUSTOMER SETUP register is described on the following pages.

Note: In case that the external field exceeds the magnetic field range the CFX register will be clamped either to –32768 or 32767 depending on the sign of the magnetic field.

Table 3–2: Relation between Barrel Shifter setting and emulated magnetic range

BARREL SHIFTER	Used bits	Typ. magnetic range
0	22...7	not used
1	21...6	± 200 mT
2	20...5	± 100 mT
3	19...4	± 50 mT
4	18...3	± 25 mT
5	17...2	± 12 mT
6	16...1	± 6 mT

Magnetic Sensitivity TCCG

The TCCG (Sensitivity) registers (TCCG0...TCCG2) contain the customer setting temperature dependant gain factor. The multiplication factor is a second order polynomial of the temperature.

All three polynomial coefficients have a bit length of 16 bit and they are two's-complement coded. Therefore the register values can vary between –32768...32767. In case that the target polynomial is based on normalized values, then each coefficient can vary between –4 ... +4. To store each coefficient into the EEPROM it is necessary to multiply the normalized coefficients with 32768.

Example:

– Tccg0 = 0.5102 => TCCG0 = 16719
– Tccg1 = –0.0163 => TCCG1 = –536
– Tccg2 = 0.0144 => TCCG2 = 471

In case that the polynomial was calculated based on not normalized values of TEMP_ADJ and MIC_COMP, then it is not necessary to multiply the polynomial coefficients with a factor of 32768.

Magnetic Sensitivity TCCO

The TCCO (Offset) registers (TCCO0 and TCCO1) contain the parameters for temperature dependant offset correction. The offset value is a first order polynomial of the temperature.

Both polynomial coefficients have a bit length of 16 bit and they are two's-complement coded. Therefore the register values can vary between –32768...32767.
In case that the target polynomial is based on normalized values, then each coefficient can vary between –4 ... +4. To store each coefficient into the EEPROM it is necessary to multiply the normalized coefficients with 32768.

In case that the polynomial was calculated based on not normalized values of TEMP_ADJ and MIC_COMP, then it is not necessary to multiply the polynomial coefficients.

In addition HAR 24xy features a linearization function based on 16 setpoints. The setpoint linearization in general allows to linearize a given output characteristic by applying the inverse compensation curve.

Each of the 16 setpoints (SETPT) registers have a length of 16 bit. The setpoints have to be computed and stored in a differential way. This means that if all setpoints are set to 0, then the linearization is set to neutral and a linear curve is used.

Sensitivity and Offset Scaling before Setpoint Linearization SCALE_GAIN/SCALE_OFFSET

The setpoint linearization uses the full 16 bit number range 0...32767 (only positive values possible). So the signal path should be properly scaled for optimal usage of all 16 setpoints.

For optimum usage of the number range an additional scaling stage is added in front of the set point algorithm. The setpoint algorithm allows positive input numbers only.

The input scaling for the linearization stage is done with the EEPROM registers SCALE_GAIN and SCALE_OFFSET. The register content is calculated based on the calibration angles. Both registers have a bit length of 16 bit and are two's-complemented coded.

Analog Output Signal Scaling with DAC_GAIN/ DAC_OFFSET (HAR 2425)

The required output voltage range of the analog output is defined by the registers DAC_GAIN (Gain of the output) and DAC_OFFSET (Offset of the output signal). Both register values can be calculated based on the angular range and the required output voltage range. They have a bit length of 16 bit and are two's-complemented coded.

Output Signal Scaling with DAC_GAIN/ DAC_OFFSET (HAR 2455)

The required output duty cycle of the output is defined by the registers DAC_GAIN (Gain of the output) and DAC_OFFSET (Offset of the output signal). Both register values can be calculated based on the angular range and the required output PWM duty cycle range. They have a bit length of 16 bit and are two's-complemented coded.

Clamping Levels

The clamping levels DAC_CMPHI and DAC_CMPLO 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 V_{SUP}.

3.2.2.3. NVRAM Registers

Customer Setup

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

Table 3–3: Functions in CUST_SETUP register

Table 3–3: Functions in CUST_SETUP register

Bit No.	Function	Description
15	None	Reserved
14:12	Barrel Shifter	Magnetic Range (see Section Table 3–2: on page 13)
11:10	None (HAR 2425)	Reserved
	PWM frequency setting (HAR 2455)	PWM frequency selection (see Table 3–1 on page 11)
9:8	Output Short Detection	0: Disabled 1: High & low side over current detection -> OUT = V_{SUP} in error case 2: High & low side over current detection -> OUT = GND in error case 3: Low side over current detection -> OUT = Tristate in error case
7	Error Band (HAR 2425)	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). (see Section 4.13. on page 27)
	PWM Output Polarity (OP) (HAR 2455)	0: PWM period starts with a high pulse 1: PWM period starts with a low pulse (effective after LC=1)
6	None	Reserved
5	Functionality Mode	Supply voltage supervision 0: extended: undervoltage (POR) 3.8 V, overvoltage 9 V 1: normal: undervoltage (POR) 4.2 V, overvoltage 6 V
4	Communication Mode (POUT)	Communication via output pin 0: Disabled 1: Enabled
3	Overvoltage Detection	0: Overvoltage detection active 1: Overvoltage detection disabled
2	Diagnosis Latch	Latching of diagnosis bits 0: No latching 1: Latched till next POR (power-on reset)
1	Diagnosis (HAR 2425)	0: Diagnosis errors force output to the selected error band 1: Diagnosis errors do not force output to the selected error band
	Diagnosis (HAR 2455)	0: Diagnosis errors force the PWM output into error mode (see Table 3–5 on page 18) 1: Diagnosis errors do not force the PWM output into error mode
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 4.12. on page 27.

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.

3.2.2.4. Setpoint Linearization Accuracy

The set point linearization in general allows to linearize a given output characteristic by applying the inverse compensation curve.

For this purpose the compensation curve will be divided into 16 segments with equal distance. Each segment is defined by two setpoints, which are stored in EEPROM. Within the interval, the output is calculated by linear interpolation according to the position within the interval.

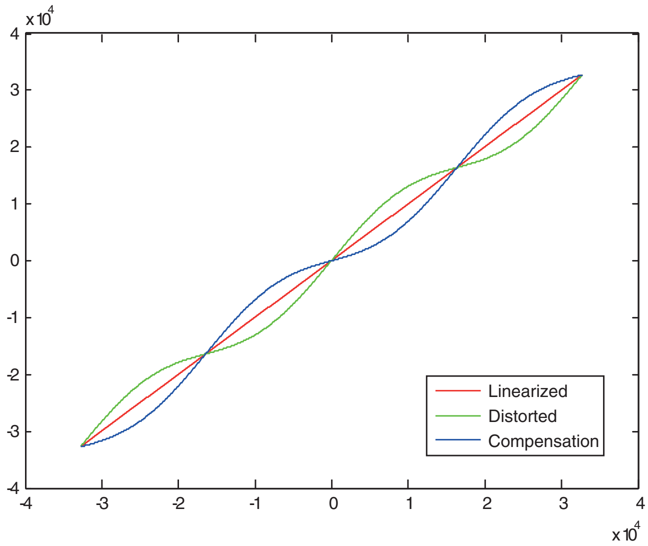


Fig. 3–7: Linearization - Principle

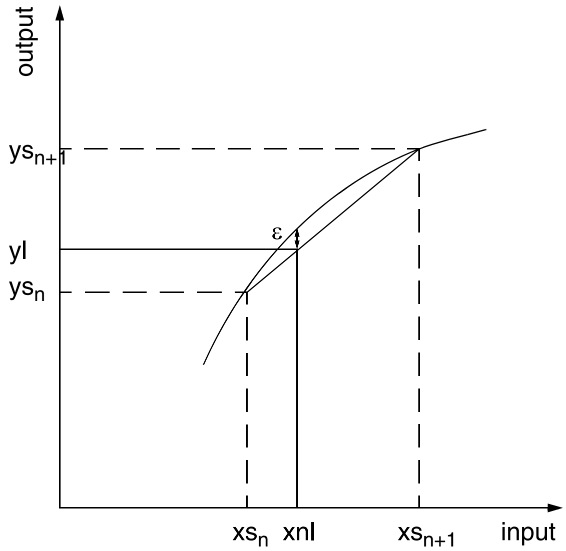


Fig. 3–8: Linearization - Detail

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

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

3.3. On-Board Diagnostic Features

The HAR 24xy is made of two completely separated dies, each featuring 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.

Table 3–4 describes the HAR 24xy overall behavior in case of wiring faults.

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. (HAR 2455)

Diagnostic Features that can be Activated by Customer:

- Overvoltage detection
- EEPROM self-test at power-on
- Continuous ROM parity check
- Continuous state machine self-test
- Adder overflow

Failure Indication for HAR 24xy

Each die 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 3–3 on page 14). Further details can be found in Section 4.13. on page 27.

The sensor switches the output to tristate if an over temperature is detected by the thermal supervision. The sensor switches the output to ground in case of a VSUP wire break.

Table 3–4: HAR 24xy behavior in case of faults

	Short Circuit to 5 V Supply	**Short Circuit to GND**	**Short Circuit to Signal/s**	**Short Circuit to Battery (12 V)**	**Open Circuit**
Component Power Supply	Normal	Component is not supplied: Wire break is active → output is tied to ground.	Voltage drop across extern pull up resistor is too big to supply component. Output is not predictable because device operates below recommended operating condition.	Supply above recommended operating condition. See "Absolute Maximum Ratings" for stress rating. Output is in overvoltage condition.	Component is not supplied: Wire break is active → output is tied to ground.
Component Out Signal/s	External pull-up resistor is bypassed by short which is below allowed minimal pull-up resistance. See "Recommended Operating Conditions" for stress rating. Out = 5 V supply	Output stage of component is short circuit to ground. See "Recommended Operating Conditions" for stress rating. Out = GND	Normal	Excess of Output Voltage over Supply Voltage. See "Absolute Maximum Ratings" for stress rating.	Component output is disconnected from signal line. Signal line is pulled up to 5 V by external pull-up resistor.
Component Ground	Component is not supplied: Wire break is active → output is tied to 5 V supply.	Normal	Component is not supplied: Wire break is active → output is tied to 5 V supply.	Component is reversed biased. See "Absolute Maximum Ratings" for stress rating. Wire break is active → Out ? 8.5 V	Component is not supplied: Wire break is active → output is tied to 5 V supply.

Failure Indication for HAR 2455

The HAR 2455 indicates a failure by changing the PWM frequency. The different errors are then coded in different duty-cycles.

Table 3–5: Failure indication for HAR 2455

Failure Mode	Frequency	Duty-Cycle
EEPROM and state machine self-test	50%	95%
Adder overflow	50%	85%
Overvoltage	50%	75%
Undervoltage	50%	100%

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

3.4. Calibration of the Sensor

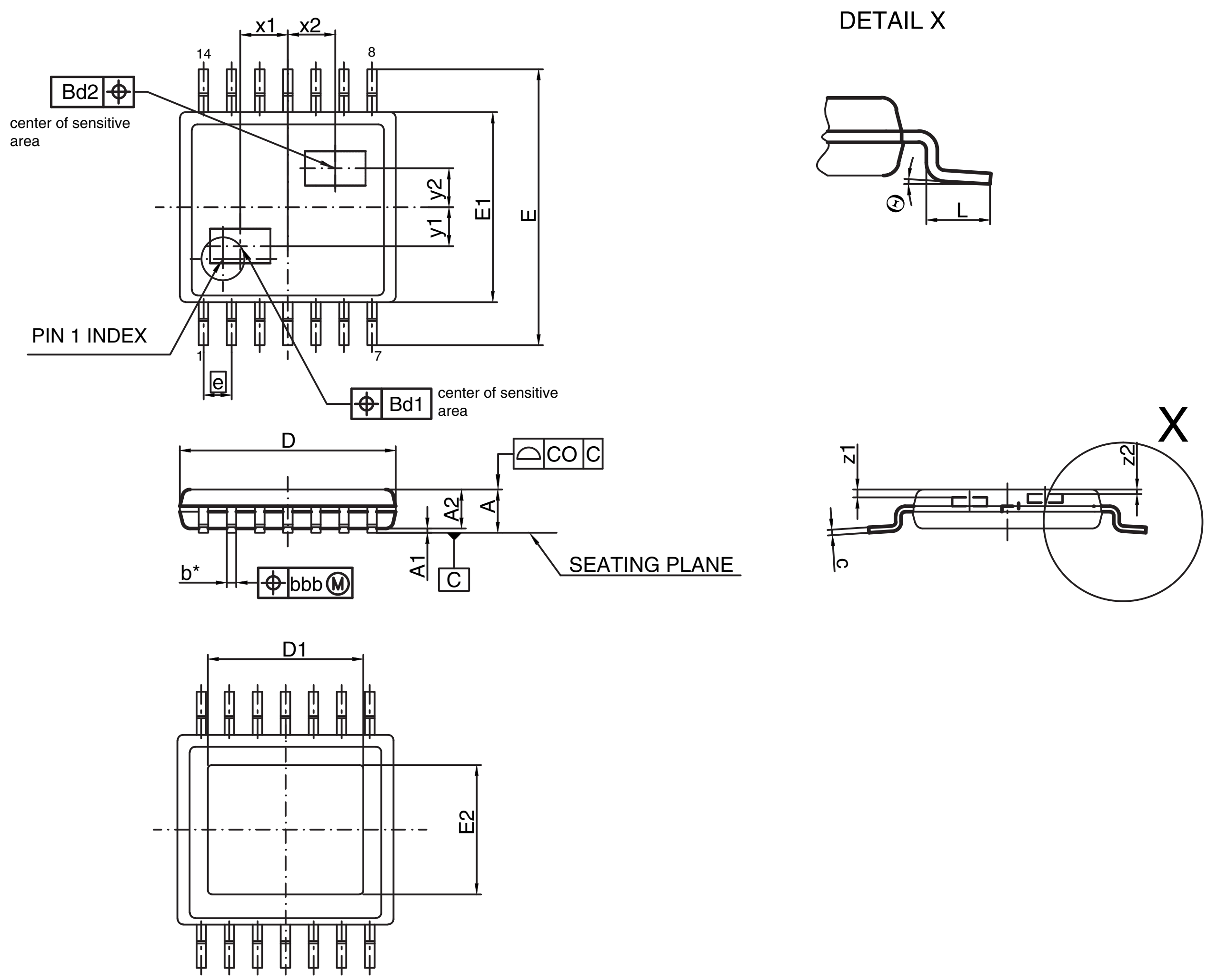
For calibration in the system environment, the application kit from Micronas is recommended. It contains the hardware for the generation of the serial telegram for programming and the corresponding LabView based programming environment for the input of the register values (see Section 6.2. on page 32).

For the individual calibration of each sensor in the customer application, a two point calibration is recommended.

A detailed description of the calibration software example provided by Micronas, calibration algorithm, programming sequences and register value calculation can be found in the Application Note “HAL 24xy Programming Guide”.

4. Specifications

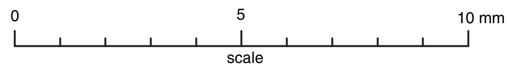
4.1. Outline Dimensions



"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

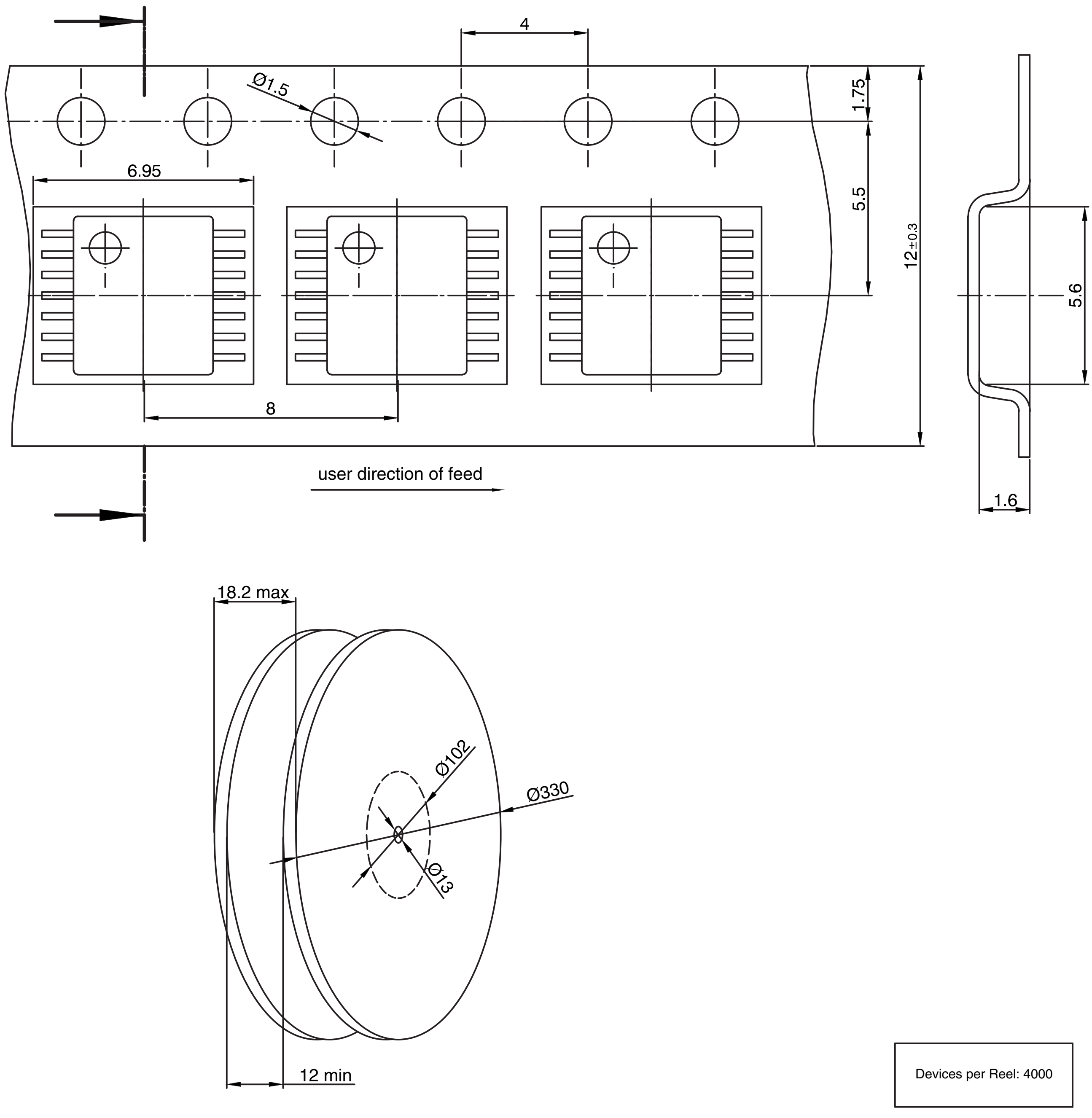
x1, x2, y1, y2, z1, z2, Bd1, Bd2=these dimensions are different for each sensor type and are specified in the data sheet



UNIT	A	A1	A2	b	bbb	c	CO	D	D1	E	E1	E2	e	L	Θ
mm	1.1 max.	0.05 0.15	0.85 0.95	0.19 0.30	0.2	0.09 0.20	0.1	4.9 5.1	3.5 3.7	6.4	4.3 4.5	2.9 3.1	0.65	0.5 0.7	8° max.

JEDEC STANDARD			ISSUE DATE YY-MM-DD	DRAWING-NO.	ZG-NO.
ISSUE	ITEM NO.				
F	MO-153		13-11-12	06903.0001.4	ZG001098_Ver.02

Fig. 4–1:
TSSOP14-1: Plastic **T**hin **S**hrink **S**mall **O**utline **P**ackage; 14 pins; 0.9 mm thickness
Weight approximately 0.055 g



IEC STANDARD		ANSI	ISSUE DATE YY-MM-DD	DRAWING-NO.	ZG-NO.
ISSUE	ITEM NO.				
4th	60286-3		15-05-11	06838.0001.4	ZG002041_001_01

Fig. 4–2:
TSSOP14: Tape and reel finishing

4.2. Soldering, Welding and 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 Micronas website (http://www.micronas.com/en/service-center/downloads) or on the service portal (http://service.micronas.com).

4.3. Pin Connections and Short Descriptions

Pin No	Pin Name	Type	Short Description
Die 1			
2	VSUP1	SUPPLY	Supply Voltage die 1
3	GND1	GND	Ground die 1
4	GNDePad	GNDePad	Ground ePad
6	OUT1	I/O	Push-Pull Output (HAR 2425) or PWM Output (HAR 2455) and Programming Pin Die 1
Die 2			
9	VSUP2	SUPPLY	Supply Voltage die 2
11	GNDePad	GNDePad	Ground ePad
12	GND2	GND	Ground die 2
13	OUT2	I/O	Push-Pull Output (HAR 2425) or PWM Output (HAR 2455) and Programming Pin Die 2

All not connected (NC) pins must be connected to GND. In case of redundancy requirements Micronas recommends the following grounding:

- GND plane1: Pin 1, 3, 5, 7
- GND plane2: Pin 8, 10, 12, 14
- GND plane3: Pin 4, 11

To avoid a separate GND plane3, please connect either pin 4 or pin 11 to the nearest GND and leave the other pin not connected.

Note: To minimize mechanical stress to the dies, the exposed pad should not be soldered!

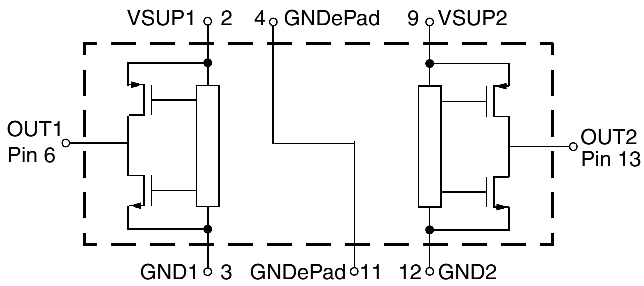


Fig. 4–3: Pin configuration

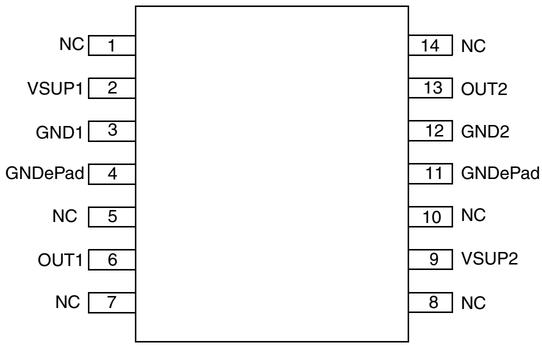


Fig. 4–4: Top/side view of the package.

4.4. Dimensions of Sensitive Area

250 x 250 μm^2

4.5. Package Parameter and Position of Sensitive Areas

	TSSOP14-1
x1 = x2	0 mm nominal
y1 = y2	0.21 mm nominal
z1	0.55 mm nominal
z2	0.33 mm nominal
Bd1	0.3 mm
Bd2	0.3 mm

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 circuit.

All voltages listed are referenced to ground (GND1=GND2=GNDePad).

Symbol	Parameter	Pin	Min.	Max.	Unit	Condition
V_{SUP}	Supply Voltage	VSUPx	–8.5 –18	10 18	V V	t < 96 h[4)] t < 1 h[4)]
V_{OUT}	Output Voltage	OUTx	–6[1)]	18	V	t < 1 h[4)]
$V_{OUT} - V_{SUP}$	Excess of Output Voltage over Supply Voltage	OUTx – VSUPx	–	7	V	t < 1 h[4)]
T_J	Junction Temperature under Bias		–50	190[2)]	°C	[4)]
$V_{die\text{-}to\text{-}die\ isolation}$	Dielectric Strength between Both Dies	–	–500	500	V	[5)6)]
V_{ESD}	ESD Protection for Single Die	VSUP1 OUT1 GND1	–8	+8	kV	[3)]
		VSUP2 OUT2 GND2				

1) Internal protection resistor = 50 Ω
2) For 96h, please contact Micronas for other temperature requirements.
3) AEC-Q-100-002 (100 pF and 1.5 kΩ)
4) No cumulated stress
5) GNDs galvanic isolation not tested
6) Characterized on small sample size

4.7. 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 Micronas website (http://www.micronas.com/en/service-center/downloads) or on the service portal (http://service.micronas.com).

4.8. Recommended Operating Conditions

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

All voltages listed are referenced to ground (GND1=GND2=GNDePad).

Symbol	Parameter	Pin	Min.	Typ.	Max.	Unit	Remarks
V_{SUP}	Supply Voltage	VSUPx	4.5 5.7	5 6	5.5 6.5	V	Normal operation During programming
I_{OUT}	Continuous Output Current	OUTx	–1.2	–	1.2	mA	
R_L	Load Resistor	OUTx	5.0	–	–	kΩ	Can be pull-up or pull-down resistor
C_L	Load Capacitance	OUTx	0.33	47	600	nF	for HAR 2425 (analog output)
			–	0.18	10	nF	for HAR 2455 (PWM)
N_{PRG}	Number of Memory Programming Cycles[1)]	–	–	–	100	cycles	0°C < T_{amb} < 55°C
T_J	Junction Temperature[2)]	–	–40 –40 –40	–	125 150 170	°C	8000 h [3)] 2000 h [3)] 1000 h [3)]

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. Time values are not additive

3) Time values are not cumulative

4.9. Characteristics

at T_J = –40 °C to +170 °C, V_{SUP1}=V_{SUP2} = 4.5 V to 5.5 V, GND1=GND2=GNDePad = 0 V after programming and locking, at Recommended Operating Conditions if not otherwise specified in the column “Conditions”.
Typical Characteristics for T_J = 25 °C and V_{SUP} = 5 V.

Symbol	Parameter	Pin	Min.	Typ.	Max.	Unit	Conditions
I_{SUP}	Supply Current over Temperature Range	VSUPx	–	7	10	mA	
	Resolution[5]	OUTx	–	12	–	bit	HAR 2425: ratiometric to V_{SUP} [1] HAR 2455: depends on PWM Period
$t_{r(O)}$	HAR 2425: Step Response Time of Output[6]	OUTx	–	0.5	0.6	ms	C_L = 10 nF, time from 10% to 90% of final output voltage for a step like signal B_{step} from 0 mT to B_{max}
	HAR 2455: Response Time of Output[2)6]	OUTx	– – – –	1.5 2.5 4.5 8.5	1.8 3 5.4 10.2	ms	f_{PWM} = 2 kHz f_{PWM} = 1 kHz f_{PWM} = 500 Hz f_{PWM} = 250 Hz
DNL	Differential Non-Linearity of D/A Converter[4]	OUTx	–0.9	0	0.9	LSB	Test limit at 25 °C ambient temperature
INL	Non-Linearity of Output Voltage over Temperature[6]	OUTx	–0.3	–	0.3	%V_{SUP}	[2]For V_{out} = 0.35 V ... 4.65 V; V_{SUP} = 5 V ; Linear Setpoint Characteristics
E_R	Ratiometric Error of Output over Temperature (Error in V_{OUT} / V_{SUP})	OUTx	–0.25		0.25	%	Max of [V_{OUT5} – $V_{OUT4.5}$ and $V_{OUT5.5}$ – V_{OUT5}] at V_{OUT} = 10% and 90% V_{SUP}
V_{offset}	Offset Drift over Temperature Range[6] $V_{OUT}(B = 0\ mT)_{25°C}$ – $V_{OUT}(B = 0\ mT)_{max}$	OUTx	0	0.1	0.2	%V_{SUP}	V_{SUP} = 5 V ; BARREL SHIFTER = 3 (±50 mT)
ΔV_{OUTCL}	Accuracy of Output Voltage at Clamping Low Voltage over Temperature Range[5]	OUTx	–11	–	11	mV	R_L = 5 kΩ, V_{SUP} = 5 V Spec values are derived from resolution of the registers DAC_CMPHI/LO and V_{offset}.
ΔV_{OUTCH}	Accuracy of Output Voltage at Clamping High Voltage over Temperature Range[5]	OUTx	–11	–	11	mV	
V_{OUTH}	Upper Limit of Signal Band[3]	OUTx	93	–	–	%V_{SUP}	V_{SUP} = 5 V, –1 mA ≤ I_{OUT} ≤ 1 mA
V_{OUTL}	Lower Limit of Signal Band[3]	OUTx	–	–	7	%V_{SUP}	V_{SUP} = 5 V, –1 mA ≤ I_{OUT} ≤ 1 mA

[1] Output DAC full scale = 5 V ratiometric, Output DAC offset = 0 V, Output DAC LSB = V_{SUP}/4096

[2] If more than 50% of the selected magnetic field range is used and the temperature compensation is suitable.
INL = V_{OUT} - V_{OUTLSF} with V_{OUTLSF} = Least Square Fit through measured output voltage

[3] Signal Band Area with full accuracy is located between V_{OUTL} and V_{OUTH}. The sensor accuracy is reduced below V_{OUTL} and above V_{OUTH}

[4] External package stress or overmolding might change this parameter

[5] Guaranteed by Design

[6] Characterized on small sample size, not tested

Symbol	Parameter	Pin	Min.	Typ.	Max.	Unit	Conditions
t_{POD}	Power-Up Time (Time to Reach Certain Output Accuracy)[6]	OUTx	– –	– –	1.7 8.0	ms ms	Additional error of 1% Full-Scale Full accuracy
BW	Small Signal Bandwidth (–3 dB)[6]	OUTx	–	2	–	kHz	
V_{OUTrms}	Output Noise Voltage RMS[6]	OUT	–	–	4	mV	BARREL SHIFTER=3 Overall gain in signal path =1 External circuitry according to Fig. 5–1 on page 30 with low-noise supply
f_{PWM}	PWM Frequency (HAR 2455 only)[2][6]	OUT	1.7 0.85 0.425 0.213	2 1 0.5 0.25	2.3 1.15 0.575 0.288	kHz	Customer programmable
J_{PWM}	RMS PWM Jitter (HAR 2455 only)[2][6]	OUT	–	1	2	LSB_{12}	f_{PWM} = 1 kHz
R_{OUT}	Output Resistance over Recommended Operating Range	OUTx	–	1	10	Ω	$V_{OUTLmax} \leq V_{OUT} \leq V_{OUTHmin}$
TSSOP14-1 Package							
 R_{thja} R_{thja} R_{thjc} R_{thjc}	Thermal resistance Junction to Ambient Junction to Ambient Junction to Case Junction to Case	–	–	–	 146 187 47 49	 K/W K/W K/W K/W	 measured on 2s2p board measured on 1s0p board measured on 2s2p board measured on 1s0p board

[1] Output DAC full scale = 5 V ratiometric, Output DAC offset = 0 V, Output DAC LSB = V_{SUP}/4096

[2] If more than 50% of the selected magnetic field range is used and the temperature compensation is suitable.
INL = V_{OUT} - V_{OUTLSF} with V_{OUTLSF} = Least Square Fit through measured output voltage

[3] Signal Band Area with full accuracy is located between V_{OUTL} and V_{OUTH}. The sensor accuracy is reduced below V_{OUTL} and above V_{OUTH}

[4] External package stress or overmolding might change this parameter

[5] Guaranteed by Design

[6] Characterized on small sample size, not tested