MICRONAS

Hardware
Documentation

Data Sheet

HAL® 1881, HAL 1882, HAL 1883

Preprogrammed Linear Hall-Effect Sensors in TO92 Package

ASIL ready

Edition July 7, 2020
DSH000199_002EN

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Contents

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

Programmable Linear Hall-Effect Sensors in TO92 Package

1. Introduction

HAL 188x is a preprogrammed Hall-effect sensor family with a ratiometric, linear analog output proportional to the magnetic flux density applied to the sensor surface. The sensor can be used for magnetic-field measurements such as current measurements and detection of mechanical movement, like for small-angle or distance measurements. The sensor is robust and can be used in harsh electrical and mechanical environments.

The spinning-current offset compensation leads to stable magnetic characteristics over supply voltage and temperature. Furthermore, the first and seconds order temperature coefficients of the sensor sensitivity can be used to compensate the temperature drift of all common magnetic materials. This enables operation over the full temperature range with high accuracy.

The different family members vary by sensitivity (25 mV/mT, 31.25 mV/mT, and 50 mV/mT). The output voltage response for zero magnetic field (apart from offset) is 50% of supply voltage for all product family members.

Type	Offset	Sensitivity	see Page
1881	50% of V_{SUP}	50 mV/mT	20
1882	50% of V_{SUP}	31.25 mV/mT	20
1883	50% of V_{SUP}	25 mV/mT	20

The sensors are designed for industrial and automotive applications, are AEC-Q100 qualified, and operate in the junction temperature range from –40 °C up to 170 °C. HAL 188x is available in the very small leaded package TO92UA-1 and TO92UA-2.

1.1. Major Applications

Thanks to the sensors' robust and cost-effective design, HAL 188x is the optimal system solution for applications such as:

– Small-angle or linear position measurements

– Gear position detection in transmission application

– Current sensing for battery management

– Rotary selector

1.2. Features

– Ratiometric linear output proportional to the magnetic field
– Digital signal processing
– Diagnostic feature: overflow or underflow
– Pre-set temperature characteristics for matching all common magnetic materials
– Diagnostic feature: overflow or underflow
– On-chip temperature compensation
– Active offset compensation
– Operates from –40 °C up to 170 °C junction temperature
– Operates from 4.5 V up to 5.5 V supply voltage in specification
– Operates with static and dynamic magnetic fields up to 2.25 kHz
– Pre-set sampling rate
– Reverse-voltage protection at VSUP pin
– Magnetic characteristics extremely robust against mechanical stress
– Short-circuit protected push-pull output
– EMC and ESD optimized design
– AEC-Q100 qualified

2. Ordering Information

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

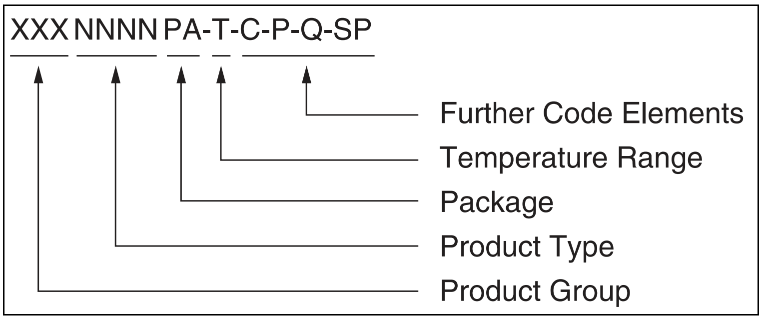


Fig. 2–1: Ordering code principle

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

2.1. Device-Specific Ordering Codes

HAL 188x is available in the following package and temperature variants.

Table 2–1: Available packages

Package Code (PA)	Package Type
UA	TO92UA

Table 2–2: Available temperature ranges

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

The relationship between ambient temperature (T_A) and junction temperature (T_J) is explained in Section 5.1. on page 21.

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

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

Available Ordering Codes	Package Marking
HAL 1881UA-A-[C-P-Q-SP]	1881A
HAL 1882UA-A-[C-P-Q-SP]	1882A
HAL 1883UA-A-[C-P-Q-SP]	1883A

3. Functional Description

3.1. General Function

HAL 188x is a monolithic integrated circuit (IC) which provides an output voltage proportional to the magnetic flux through the Hall plate and proportional to the supply voltage (ratiometric behavior).

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.

This Hall voltage is converted to a digital value, processed by the Digital Signal Processing unit (DSP), converted back to an analog voltage by a D/A converter and buffered by a push-pull output stage. The function and the parameters for the DSP are explained in Section 3.3. on page 8. Internal temperature compensation circuitry and the spinning-current offset compensation enable operation over the full temperature range with minimal degradation in accuracy and offset. The circuitry also rejects offset shifts due to mechanical stress from the package. In addition, the sensor IC is protected against reverse polarity at supply pin.

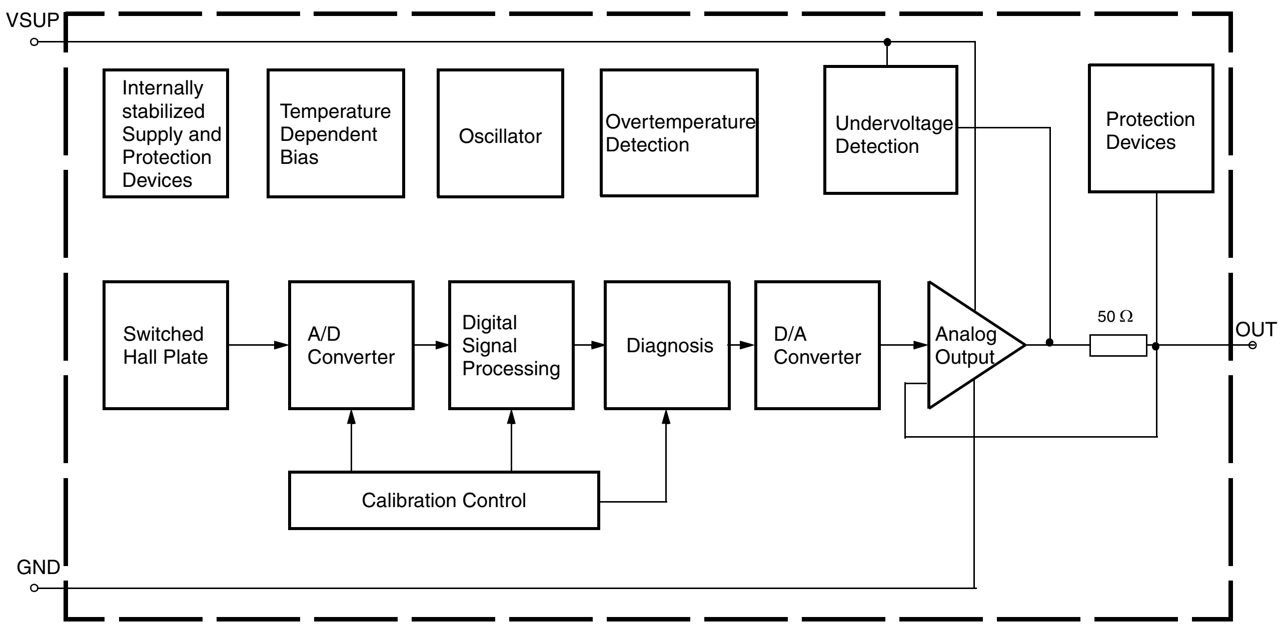


Fig. 3–1: HAL 188x block diagram

3.2. Output/Magnetic Field Polarity

Applying a south-pole magnetic field perpendicular to the branded side of the package will increase the output voltage (for Sensitivity <0) from the quiescent (offset) voltage towards the supply voltage. A north-pole magnetic field will decrease the output voltage.

3.3. On-board Diagnostic Features

HAL 188x features the following five diagnostic functions controlled by the DSP:

– Magnetic signal amplitude out of range (overflow or underflow in signal path)

– Over-/underflow in adder or multiplier

– Over-/underflow in A/D converter
  These faults are visible at the output as long as present. The occurrence of these faults forces the output to the error band (see V_{DIAG_L} or V_{DIAG_H} in Section 4.9. on page 18).

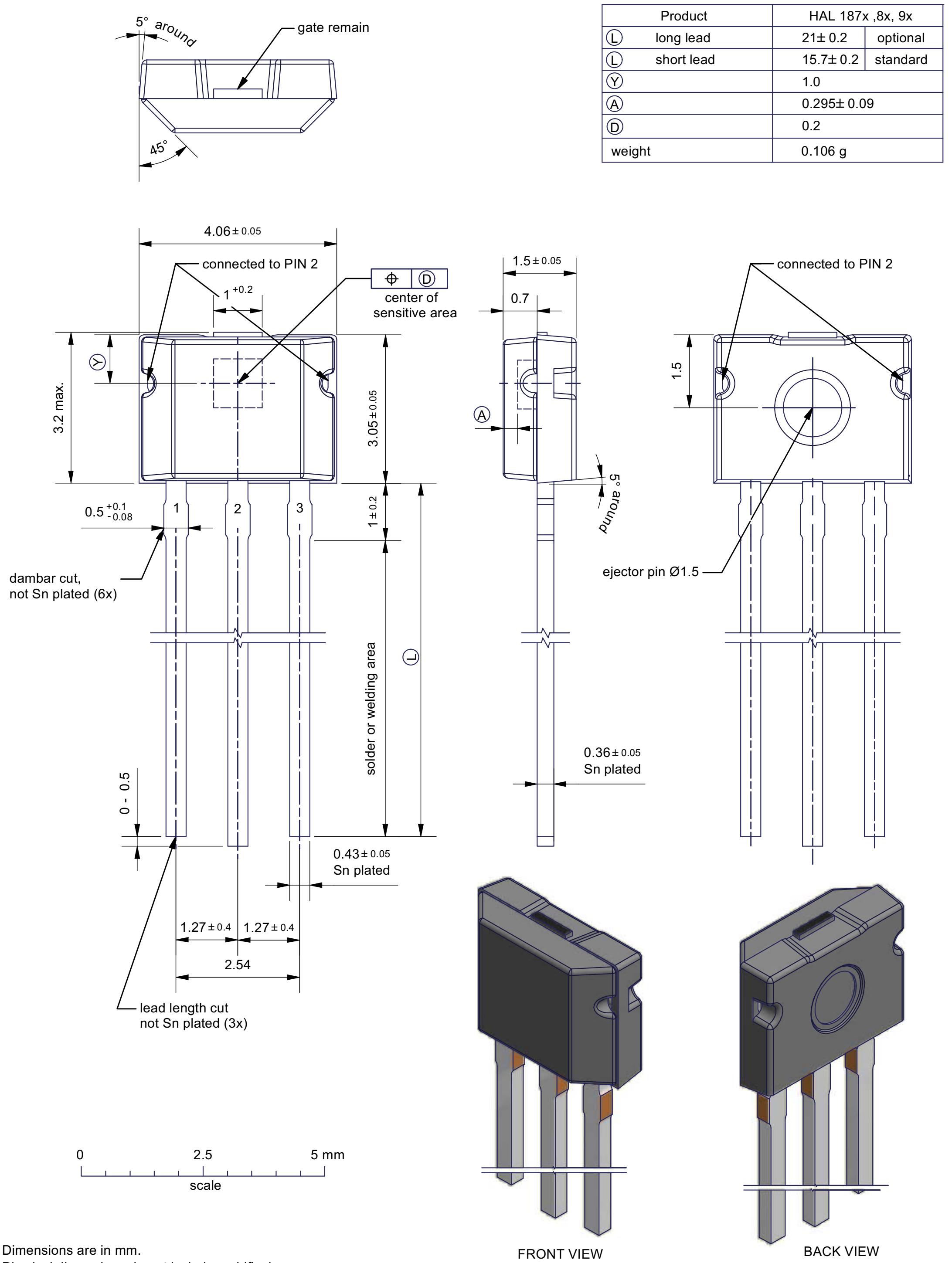
– Undervoltage detection with internal reset
  The occurrence of an undervoltage is indicated immediately by switching the output to ground.

– Overtemperature: Thermal supervision of the output stage (overcurrent, short circuit, etc.)
  The sensor switches the output to tristate if an overtemperature is detected by the thermal supervision.

4. Specifications

4.1. Outline Dimensions

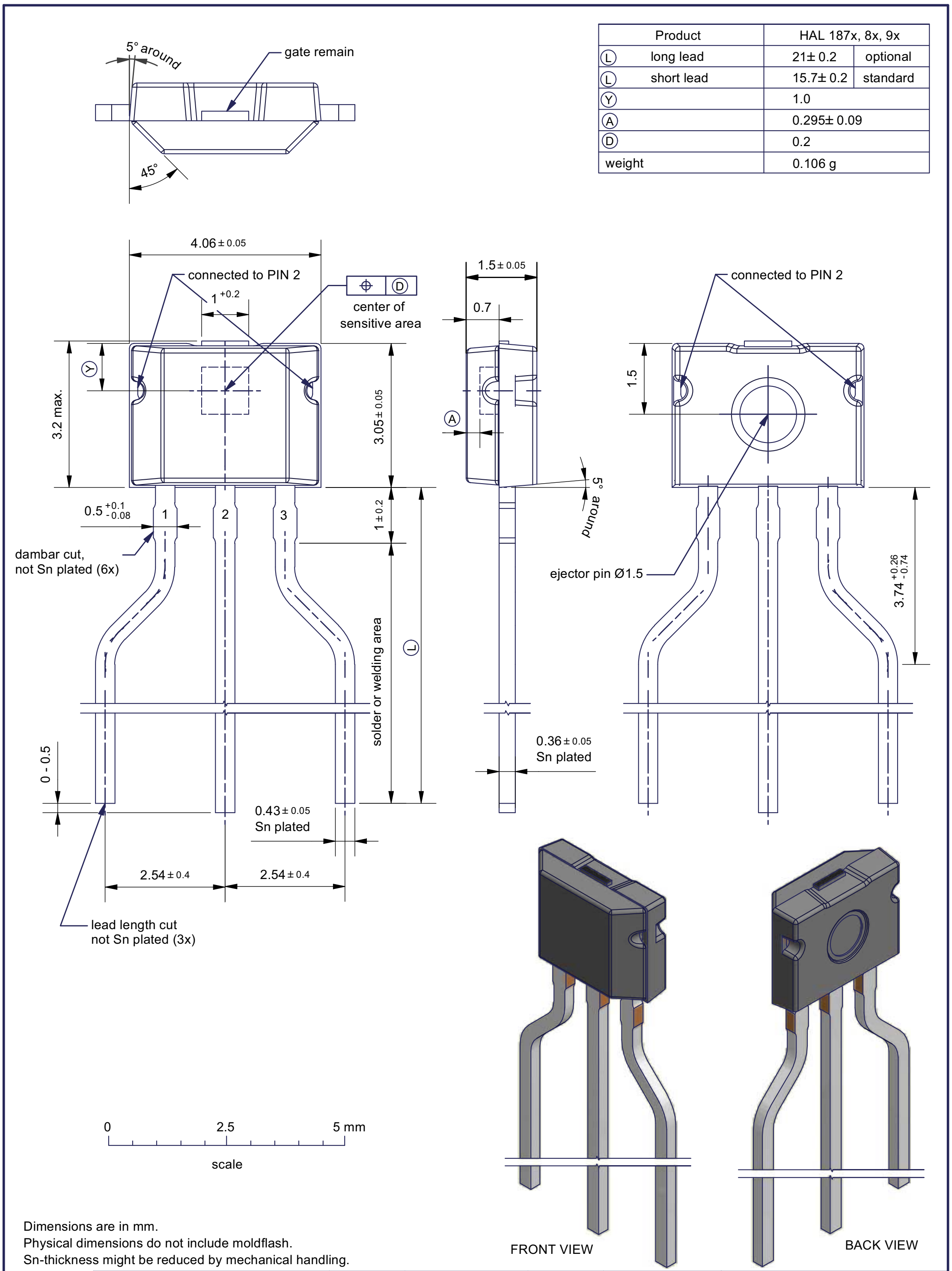
Product	HAL 187x ,8x, 9x	
Ⓛ long lead	21± 0.2	optional
Ⓛ short lead	15.7± 0.2	standard
Ⓨ	1.0	
Ⓐ	0.295± 0.09	
Ⓓ	0.2	
weight	0.106 g	



Dimensions are in mm.
Physical dimensions do not include moldflash.
Sn-thickness might be reduced by mechanical handling.

PACKAGE	ISSUE DATE (YY-MM-DD)	JEDEC STANDARD ITEM NO.	JEDEC STANDARD ISSUE	ANSI	REVISION DATE (YY-MM-DD)	REV.NO.	DRAWING-NO.	SPECIFICATION TYPE	SPECIFICATION NO.
TO92UA-2	18-09-24				20-04-07	2	CUAI00031033.1	ZG	2101_Ver.02

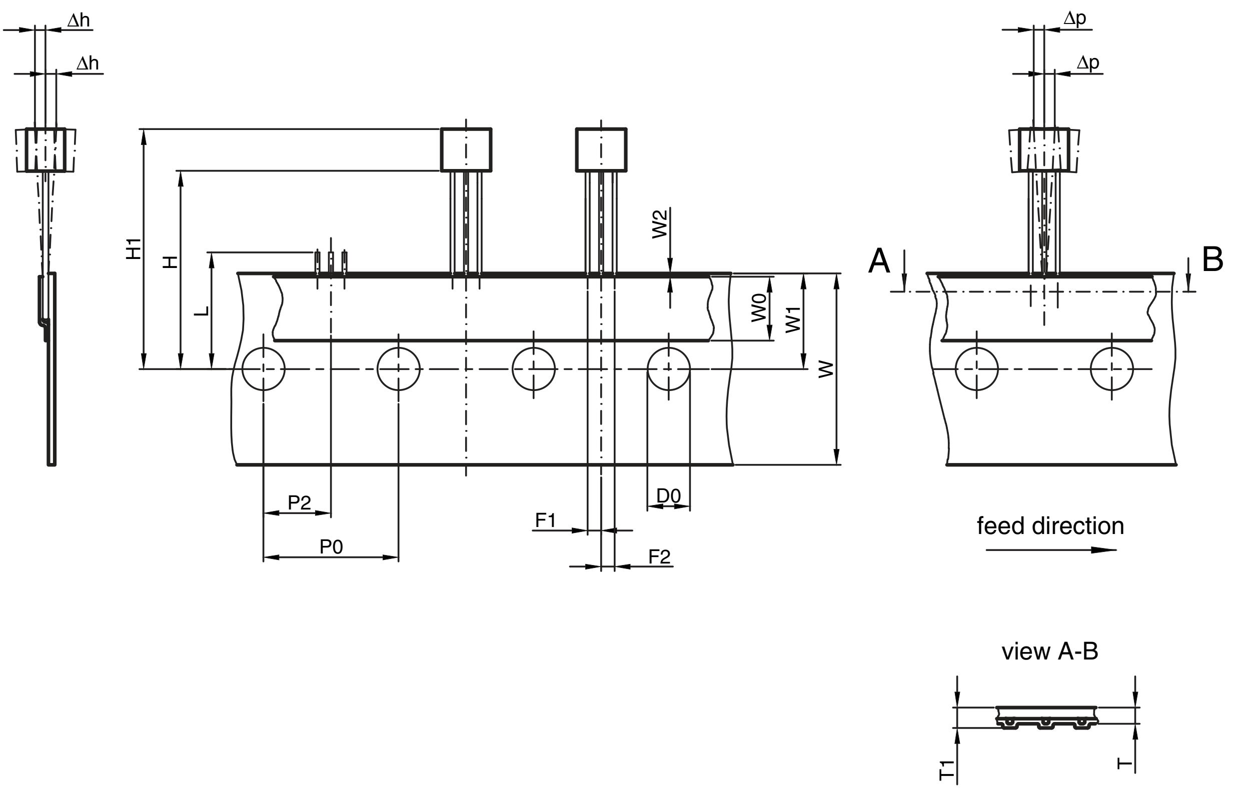
Fig. 4–1:
TO92UA-2 Plastic Transistor Standard UA package, 3 leads, non-spread



Product	HAL 187x, 8x, 9x	
(L) long lead	21± 0.2	optional
(L) short lead	15.7± 0.2	standard
(Y)	1.0	
(A)	0.295± 0.09	
(D)	0.2	
weight	0.106 g	

PACKAGE	ISSUE DATE (YY-MM-DD)	JEDEC STANDARD ITEM NO.	JEDEC STANDARD ISSUE	ANSI	REVISION DATE (YY-MM-DD)	REV.NO.	DRAWING-NO.	SPECIFICATION TYPE	SPECIFICATION NO.
TO92UA-1	18-09-24				20-04-07	2	CUAS00031034.1	ZG	2102_Ver.02

Fig. 4–2:
TO92UA-1 Plastic Transistor Standard UA package, 3 leads, spread



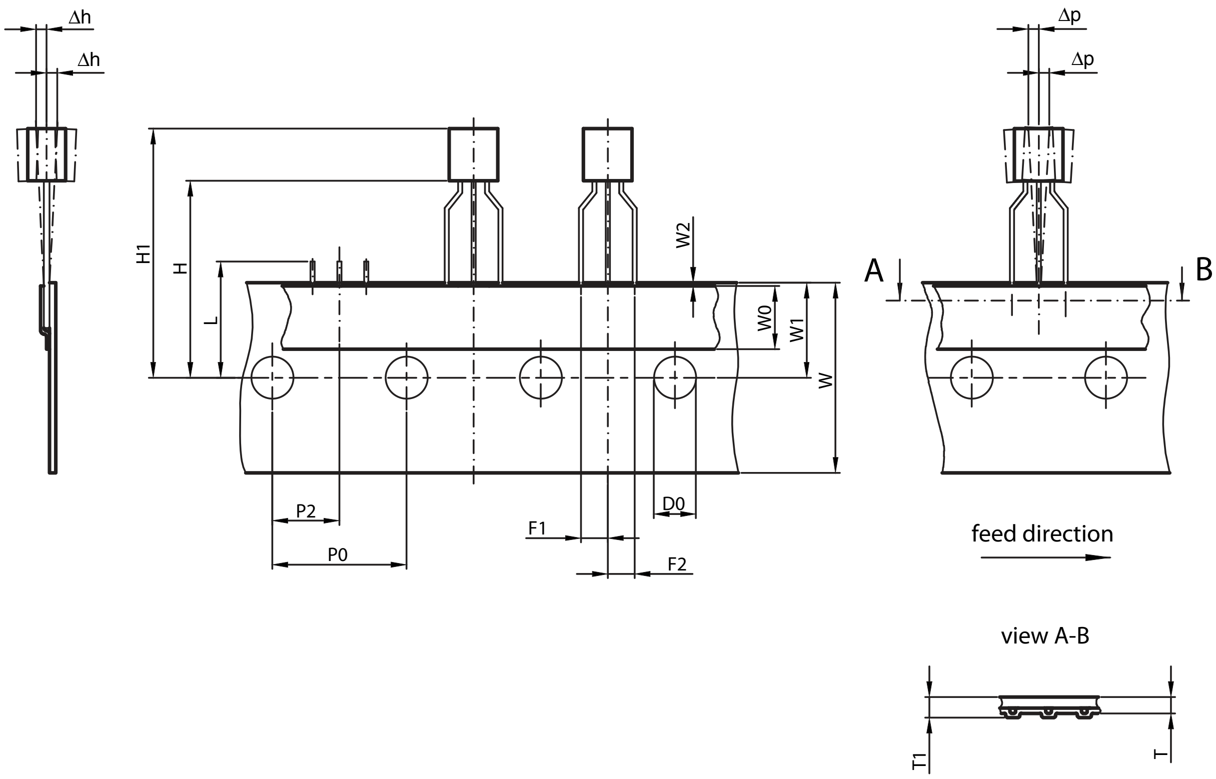
all dimensions in mm
other dimensions see drawing of bulk
max. allowed tolerance over 20 hole spacings ±1.0

	H	H1	
		TO92UA	TO92UT
Short leads	18 - 20	21 - 23.1	22 - 24.1
Long leads	24 - 26	27 - 29.1	28 - 30.1

UNIT	D0	F1	F2	Δh	L	P0	P2	Δp	T	T1	W	W0	W1	W2
mm	4.0	1.47 1.07	1.47 1.07	±1.0	11.0 max	13.2 12.2	7.05 5.65	±1.0	0.5	0.9	18.0	6.0	9.0	0.3

STANDARD		ANSI	ISSUE DATE YY-MM-DD	DRAWING-NO.	ZG-NO.
ISSUE	ITEM NO.				
-	IEC 60286-2		16-07-18	06631.0001.4	ZG001031_Ver.05

Fig. 4–3:
TO92UA: Dimensions ammopack inline, not spread, standard lead length



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

	H	H1	
		TO92UA	TO92UT
Short leads	18 - 20	21 - 23.1	22 - 24.1
Long leads	24 - 26	27 - 29.1	28 - 30.1

UNIT	D0	F1	F2	Δh	L	P0	P2	Δp	T	T1	W	W0	W1	W2
mm	4.0	2.74 2.34	2.74 2.34	±1.0	11.0 max	13.2 12.2	7.05 5.65	±1.0	0.5	0.9	18.0	6.0	9.0	0.3

JEDEC STANDARD		ANSI	ISSUE DATE YY-MM-DD	DRAWING-NO.	ZG-NO.
ISSUE	ITEM NO.				
-	ICE 60286-2		16-07-18	06632.0001.4	ZG001032_Ver.06

Fig. 4–4:
TO92UA: Dimensions ammopack inline, spread, standard lead length

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

4.3. Pin Connections and Short Descriptions

Pin No.	Pin Name	Short Description
1	VSUP	Supply Voltage Pin
2	GND	Ground
3	OUT	Push-Pull Output

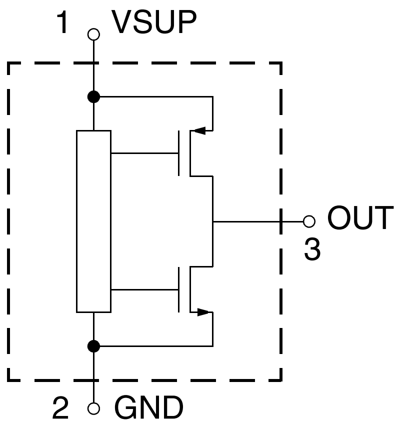


Fig. 4–5: Pin configuration

4.4. Dimensions of Sensitive Area

Hall plate area = 0.2 mm × 0.1 mm

See Fig. 4–1 on page 9 for more information on the Hall plate position.

4.5. Absolute Maximum Ratings

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

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

All voltages listed are referenced to ground (GND).

Symbol	Parameter	Pin No.	Min.	Max.	Unit	Notes
V_{SUP}	Supply Voltage	1	–8.5 –14.4 –15	8.5 14.4 16	V	t < 96 h[2)] t < 10 min[2)3)] t < 1 min[2)3)]
V_{OUT}	Output Voltage	3	–0.5[1)] –0.5[1)] –0.5[1)]	8.5 14.4 16	V	t < 96 h[2)] t < 10 min[2)] t < 1 min[2)]
$V_{OUT}-V_{SUP}$	Excess of Output Voltage over Supply Voltage	1, 3	–	0.5	V	
I_{OUT}	Continuous Output Current	3	–5	5	mA	
t_{sh}	Output Short Circuit Duration	3	–	10	min	
T_J	Junction Temperature under Bias		–40	190	°C	[4)]
$T_{STORAGE}$	Transportation/Short-Term Storage Temperature		–55	150	°C	Device only without packing material
V_{ESD}	ESD Protection at VSUP[5)]	1	–4.0	4.0	kV	
	ESD Protection at OUT[5)]	3	–8.0	8.0	kV	

1) Internal protection resistor = 50 Ω
2) No cumulated stress
3) As long as T_{Jmax} is not exceeded
4) For 96 h - Please contact TDK-Micronas for other temperature requirements
5) AEC-Q100-002 (100 pF and 1.5 kΩ)

4.6. Storage and Shelf Life

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

4.7. Recommended Operating Conditions

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

All voltages listed are referenced to ground (GND).

Symbol	Parameter	Pin No.	Min.	Typ.	Max.	Unit	Notes
V_{SUP}	Supply Voltage	1	4.5	5	5.5	V	
I_{OUT}	Continuous Output Current	3	–1	–	1	mA	
R_L	Load Resistor	3	5.5	10	–	kΩ	
C_L	Load Capacitance	3	0.33	–	47	nF	
T_J	Junction Operating Temperature[1)]	–	–40 –40 –40	– – –	125 150 170	°C	for 8000 h[2)] for 2000 h[2)] for 1000 h[2)]

[1)] Depends on the temperature profile of the application. Please contact TDK-Micronas for life time calculations.
[2)] Time values are not cumulative.

4.8. Characteristics

at T_J = –40 °C to 170 °C, V_{SUP} = 4.5 V to 5.5 V, GND = 0 V, at Recommended Operation Conditions if not otherwise specified in the column "Notes". Typical characteristics for T_J = 25 °C and V_{SUP} = 5 V.

Symbol	Parameter	Pin No.	Min.	Typ.	Max.	Unit	Notes
I_{SUP}	Supply Current over Temperature Range	1	5	6.75	8.5	mA	
Signal							
–	Resolution	3	–	10	–	Bit	
f_s	Sampling Frequency	–	–	8	–	kHz	
INL	Non-Linearity of Output Voltage over Temperature[2)]	3	–1.0	0	1.0	%	% of Supply Voltage (Linear regression) T_J = 25 °C
E_R	Ratiometric Error of Output over Temperature (Error in VOUT/VSUP)	3	–1.0	0	1.0	%	
V_{OUTH}	Analog Output High Voltage limit of linear range output	3	4.7	4.9	–	V	V_{SUP} = 5 V, I_{OUT} = ±1 mA
V_{OUTL}	Analog Output Low Voltage limit of linear range output	3	–	0.1	0.3	V	V_{SUP} = 5 V, I_{OUT} = ±1 mA
BW	Small Signal Band-width (–3 dB)[2)]	3	2.25	2.5	–	kHz	B_{AC} <10 mT, f_s = 8 kHz

1) Guaranteed by design
2) Characterized on small sample size, not tested

Symbol	Parameter	Pin No.	Min.	Typ.	Max.	Unit	Notes
$t_{r(O)}$	Response Time of Output[2]	3	–	125	360	µs	C_L = 10 nF, time from 10% to 90% of final output voltage for a magnetic input signal step from 0 mT to more than 50% of the magnetic range of the device.
t_{POD}	Power-Up Time (time to reach stabilized output voltage, ±10mV)[2]	3	–	400	500	µs	C_L = 10 nF, 90% of V_{OUT}
V_{OUTn}	Output RMS Noise[2]	3	–	1.2	3.0	mV	B = 5% to 95% of RANGE
R_{OUT}	ESD Protection Resistance[1]	3	–	60	–	Ω	
TO92UA Package							
	Thermal Resistance						Determined with a 1s0p board
R_{thja}	Junction to Air	–	–	–	250	K/W	
R_{thjc}	Junction to Case	–	–	–	70	K/W	

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

4.8.1. Definition of t_{POD}

t_{POD} is the power-up time to reach a stabilized output (±10 mV).

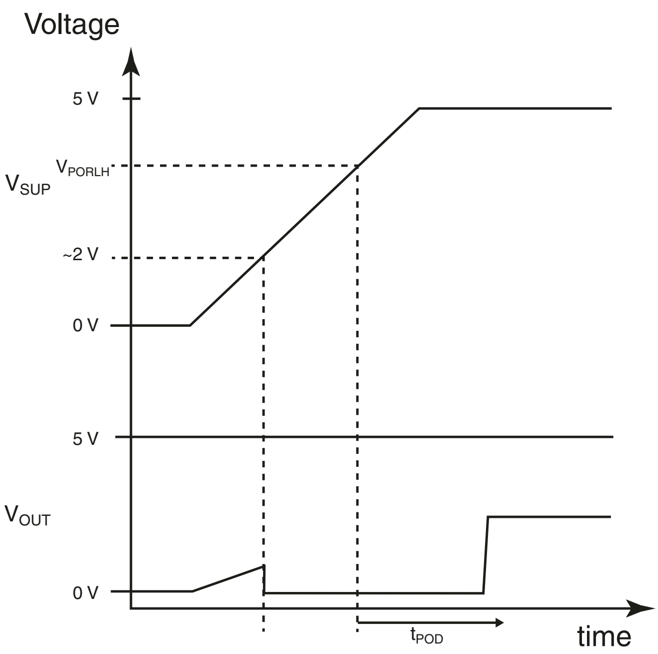


Fig. 4–6: Definition of t_{POD}

4.9. Power-On Reset / Undervoltage Detection

at T_J = –40 °C to 170 °C, GND=0 V, typical characteristics for T_J = 25 °C

Symbol	Parameter	Pin	Min.	Typ.	Max.	Unit	Test Conditions
V_{POR_LH}	Undervoltage Detection Level (Power-On Reset, Rising Supply)[1)]	1	4.15	4.3	4.45	V	
V_{POR_HL}	Undervoltage Detection Level (Power-On Reset, Falling Supply)[1)]	1	3.9	4.05	4.25	V	
V_{POR_HYS}	Undervoltage/POR Detection Level Hysteresis[1)]	1	150	225	300	mV	

[1)] Characterized on small sample size, not tested

4.10. Output Voltage in Case of Error Detection

at T_J = –40 °C to 170 °C, typical characteristics for T_J = 25 °C.

Symbol	Parameter	Pin	Min.	Typ.	Max.	Unit	Notes
V_{DIAG_L}	Output Voltage in case of Error Detection	3	0	0.02	0.1	V	V_{SUP} = 5 V R_L = 5 kΩ pull-up
V_{DIAG_H}	Output Voltage in case of Error Detection	3	4.7	4.9	5	V	V_{SUP} = 5 V R_L = 5 kΩ pull-down

4.11. Magnetic Characteristics

at Recommended Operating Conditions if not otherwise specified in the column 'Notes', T_J = –40 °C to 170 °C, V_{SUP} = 4.5 V to 5.5 V. Typical Characteristics for T_A = 25 °C and V_{SUP} = 5 V.

Symbol	Parameter	Pin No.	Values			Unit	Notes
			Min.	Typ.	Max.		
SENS	Sensitivity[1]	3	47.5 30.0 24.0	50.0 31.25 25.0	52.5 32.5 26.0	mV/mT	HAL 1881; T_J = 25 °C HAL 1882; T_J = 25 °C HAL 1883; T_J = 25 °C
$\Delta Sens_{trim}$	Trim Stepf for Absolute Sensitivity	3	0.3		1	mV/mT	At min. sensitivity At max. sensitivity
$\Delta Offset_{trim}$	OffseT Trim	3	±2.5 ±10		±312 ±1250	mV	OALN = 0 OALN = 1
ES	Sensitivity Error over Temperature Range[1]	3	–6	0	6	%	Part to part variation for certain combinations of TC and TCSQ (see Section 4.11.1.)
B_{OFFSET}	Magnetic Offset	3	–2	0	2	mT	B = 0 mT, T_A = 25 °C
ΔB_{OFFSET}	Magnetic Offset Drift over temperature range[1] $B_{OFFSET}(T) - B_{OFFSET}$ (25 °C)	3	–400	0	400	µT	B = 0 mT,
$B_{Hysteresis}$	Magnetic Hysteresis[1]	3	–20	0	20	µT	Range = ±40 mT

[1] Characterized on small sample size, not tested

4.11.1. Definition of Sensitivity Error ES

ES is the maximum of the absolute value of the quotient of the normalized measured value[1)] over the normalized ideal linear value[2)] minus 1:

$$ES = \max\left(\text{abs}\left(\frac{\text{meas}}{\text{ideal}} - 1\right)\right)\Bigg|_{[\text{Tmin, Tmax}]}$$

In the example shown in Fig. 4–7 the maximum error occurs at –10 °C:

$$ES = \frac{1.001}{0.993} - 1 = 0.8\%$$

1) normalized to achieve a least-square-fit straight-line that has a value of 1 at 25 °C
2) normalized to achieve a value of 1 at 25 °C

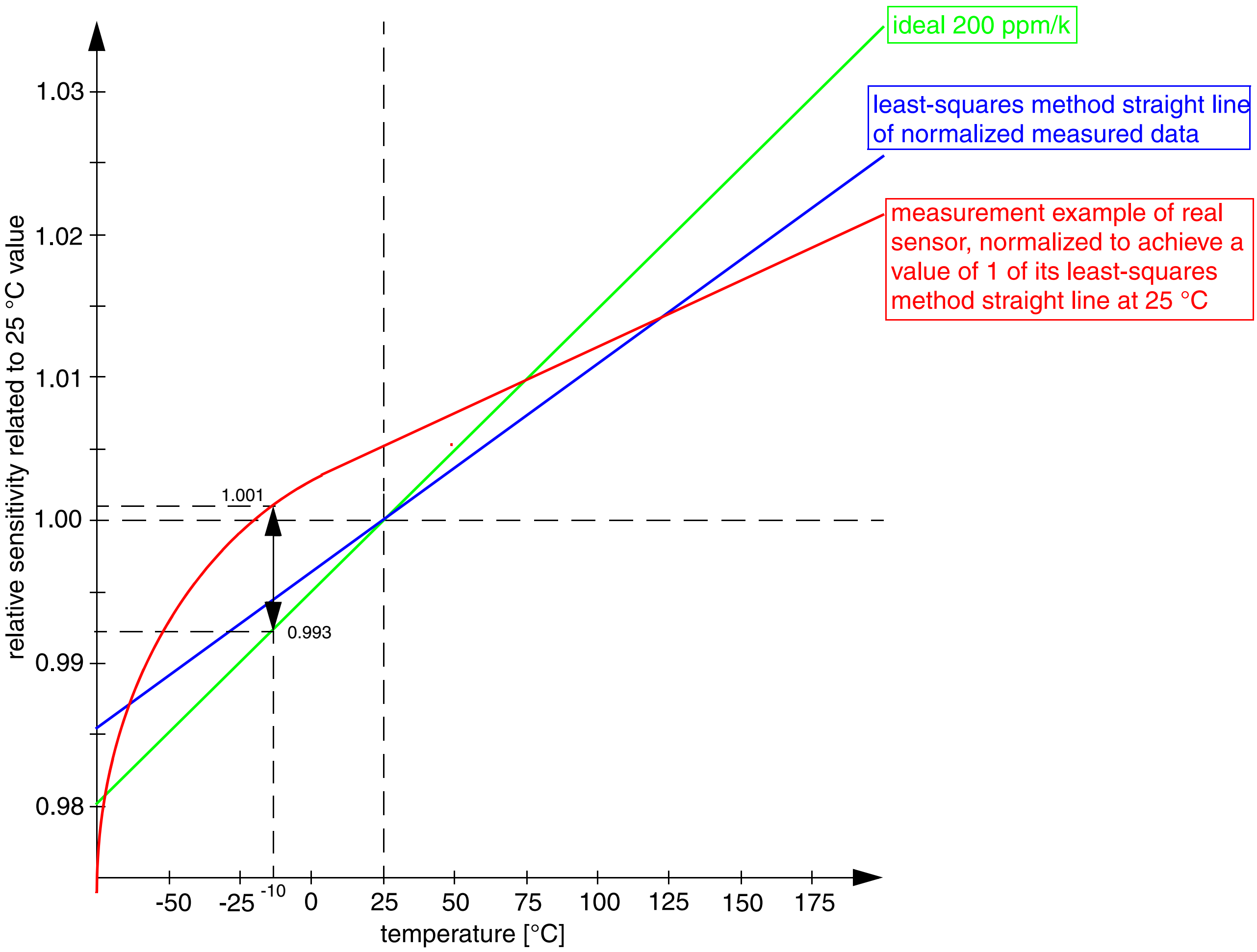


Fig. 4–7: Definition of Sensitivity Error ES

5. Application Notes

5.1. Ambient Temperature

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

$T_J = T_A + \Delta T$

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

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

The X represents junction to air or to case.

In order to estimate the temperature difference ΔT between the junction and the respective reference (e.g. air, case, or solder point) use the max. parameters for I_{SUP}, R_{thX}, and the max. value for V_{SUP} from the application.

The following example shows the result for junction to air conditions. V_{SUP} = 5.5 V, R_{thja} = 250 K/W and I_{SUP} = 10 mA the temperature difference ΔT = 13.75 K.

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

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

Note The calculated self-heating of the devices is only valid for the Rth test boards. Depending on the application setup the final results in an application environment might deviate from these values.

5.2. EMC

HAL 1880 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 circuit shown in Fig. 5–1 on page 22 is recommended. Applications with this arrangement should pass the EMC tests according to the product standards ISO 7637 part 3 (electrical transient transmission by capacitive or inductive coupling).

5.3. Application Circuit

For EMC protection, it is recommended to connect a 47 nF capacitor between ground and output voltage pin as well as a 100 nF capacitor between supply and ground as shown in Fig. 5–1.

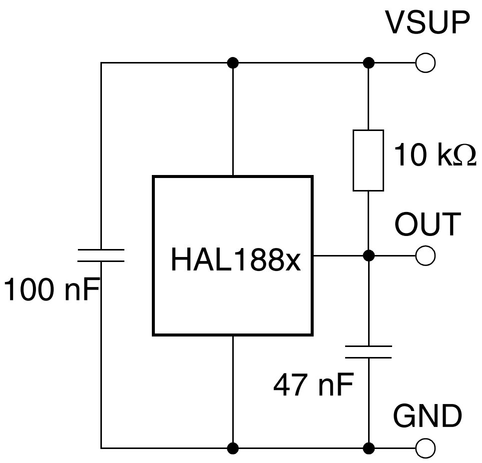


Fig. 5–1: Recommended application circuit

6. Document History

1. Advance Information: “HAL 1881, HAL 1882, HAL 1883, Preprogrammed Linear Hall-Effect Sensors in TO92 Package”, Aug. 1, 2018, AI000209_001EN. First release of the Advance Information.
2. Data Sheet: “HAL 1881, HAL 1882, HAL 1883 Preprogrammed Linear Hall-Effect Sensors in TO92 Package”, March 31, 2020, DSH000199_001EN. First release of the data sheet.
3. Data Sheet: “HAL 1881, HAL 1882, HAL 1883 Preprogrammed Linear Hall-Effect Sensors in TO92 Package”, July 7, 2020, DSH000199_002EN. Second release of the data sheet.

   Major Changes:

   – Fig. 4.1 and 4.2: TO92UA package drawings updated

   – Characteristics: Response Time of Output $t_{r(O)}$ updated

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