MICRONAS

Hardware
Documentation

Preliminary Data Sheet

HAL® 1502

Hall-Effect Switch

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Hall-Effect Switch

1. Introduction

The HAL 1502 Hall-latch produced in CMOS technology as 3-wire device with open-drain output transistor includes a temperature-compensated Hall plate with active offset compensation, a comparator, and an output stage.

The comparator compares the actual magnetic flux through the Hall plate (Hall voltage) with the fixed reference values (switching points). Accordingly the output transistor is switched on or off.

The active offset compensation leads to constant magnetic characteristics over supply voltage and temperature range. In addition, the magnetic parameters are robust against mechanical stress effects.

The sensor is designed for industrial and automotive applications and operates with supply voltages from 2.7 V to 24 V in junction temperature range from –40 °C up to 170 °C.

HAL 1502 is available in a JEDEC TO236-compliant SMD-package 3-lead SOT23.

1.1. Features of HAL 1502

- Tiny SOT23-3L JEDEC TO236-compliant package
- ISO 26262 compliant as ASIL A ready device
- Short-circuit protected open-drain output and thermal shutdown
- Very low current consumption of typ. 1.6 mA
- Operates from 2.7 V to 24 V supply voltage
- Overvoltage protection capability up to 40 V
- Reverse-voltage protection (–18 V)
- High ESD performance of ±8 kV (HBM)
- Power-on self test
- Maximum sample frequency of 500 kHz, 2 µs output refresh time
- Operates with static and dynamic magnetic fields up to 12 kHz
- High resistance to mechanical stress by active offset compensation
- Constant switching points over a wide supply voltage and temperature range
- Wide junction temperature range from –40 °C to 170 °C
- The decrease of magnetic flux density caused by rising temperature in the sensor system is compensated by a built-in temperature coefficient of the magnetic characteristics
- Reverse-voltage protected VSUP-pin
- Optimized for applications in extreme automotive and industrial environments
- Qualified according to AEC-Q100 test standard for automotive electronics industry to provide high-quality performance
- Robust EMC performances, corresponding to different standards, such as ISO 7637, ISO 16750, IEC 61967, ISO 11452, and ISO 62132

2. Ordering Information

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

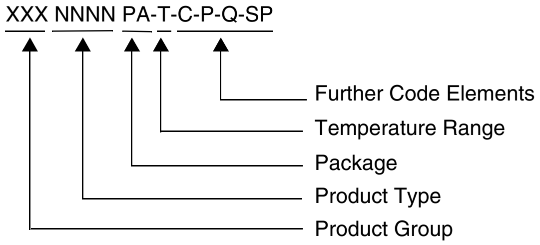


Fig. 2–1: Ordering Code Principle

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

2.1. Device-Specific Ordering Codes

HAL 1502 is available in the following package and temperature range.

Table 2–1: Available packages

Package Code (PA)	Package Type
SU	SOT23

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 5.2. on page 16**.

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

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

Available Ordering Codes	Package Marking
HAL1502SU-A-[C-P-Q-SP]	1502

3. Functional Description of HAL 1502

The HAL 1502 sensor is a monolithic integrated circuit which switches in response to magnetic fields. If a magnetic field with flux lines perpendicular to the sensitive area is applied to the sensor, the biased Hall plate forces a Hall voltage proportional to this field. The Hall voltage is compared with the actual threshold level in the comparator. If the magnetic field exceeds the threshold levels, the output stage is switched to the appropriate state.

The built-in hysteresis eliminates oscillation and provides switching behavior of the output without bouncing.

Offsets caused by mechanical stress are compensated by using the “switching offset compensation technique”.

A diode on the supply line is not required thanks to the built-in reverse voltage protection.

The open drain output is forced to a safe, high-impedance state (tri-state), in any of the following fault conditions: overtemperature, undervoltage and functional safety related diagnoses (see Section 3.1.). In addition, the output current is limited (short-circuit protection).

The device is able to withstand a maximum supply voltage of 24 V for unlimited time and features overvoltage capability (40V load dump).

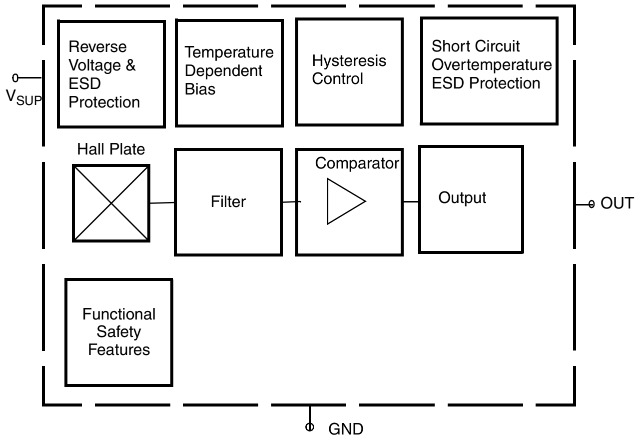


Fig. 3–1: HAL 1502 block diagram

3.1. Functional Safety According to ISO 26262

The HAL 1502 is ISO 26262 compliant as ASIL A ready device.

Magnetic and switching performance is defined as hardware safety requirement.

The safe state is defined as tri-state.

3.1.1. Diagnostic Features

Internal states are monitored and in an error condition flagged with a tri-state at the output:

- Internal voltage regulator: under and over voltage detection
- Monitoring of internal bias and current levels
- Monitoring of the internal reference voltage
- Monitoring of the Hall plate voltage

Note: For further documentation regarding functional safety please contact Micronas.

3.2. Power-On Self-Test

The power-on self-test allows the customer to execute a functional check of the device, as well as to detect wire breaks as long as the host controls the power supply of the device.

The self-test can be enabled only once after power-on.

In order to start the test, the host has to power off the sensor and to pull down its output pin. Afterwards, the host needs to power on the sensor again (sensor in tristate mode, after waking up) and then to release its output pin. This order of events is the criteria for the sensor to start the power-on self-test.

After releasing the output pin, the sensor simulates a magnetic field for a pre-defined period of time (see first observation window in Fig. 5–1), driving the sensor's output to low level, detected by the host.

Subsequently, the sensor simulates an opposite magnetic field during the second observation window (see Fig. 5–1), driving the sensor's output to high level, also detected by the host. The described self-test behavior is not impacted by external magnetic fields up to about 500 mT.

In case of no malfunction of the signal path the sensor returns to normal operation after self test completion.

By positioning the pull-up resistor close to the control unit, wire breaks at all pins VSUP, OUT, and GND can be detected.

It is also possible to enable the power-on self-test in application systems, consisting of several HAL 15xy sensors, as long, as the output pins are not connected to each other.

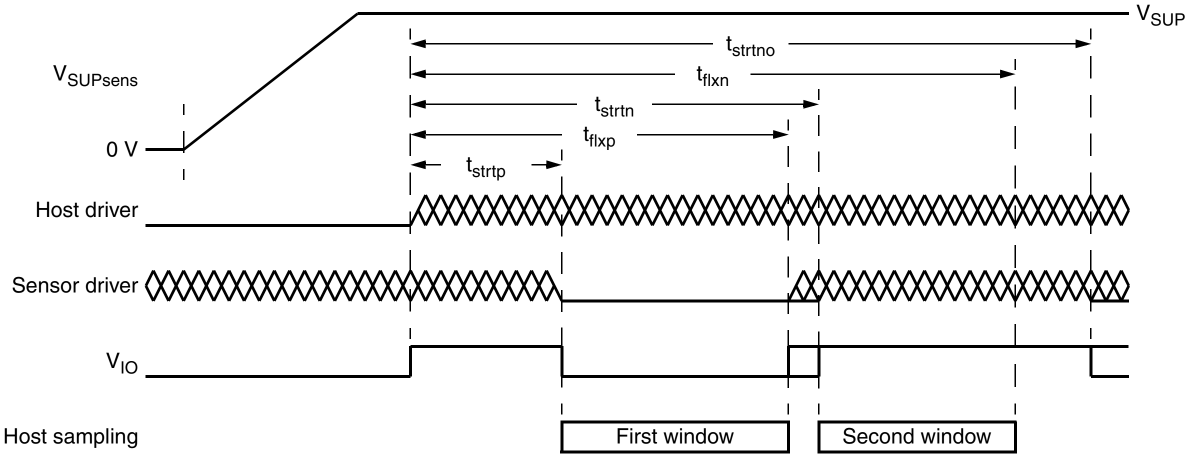


Fig. 3–2: Self-test timing diagram

3.3. Power-on Self-Test Characteristics

at T_J = –40 °C to +170 °C, V_{SUP} = 2.7 V to 24 V, at Recommended Operation Conditions,
Typical Characteristics for T_J = 25 °C and V_{SUP} = 12 V

Symbol	Parameter	Min.	Typ.	Max.	Unit
t_{dsamp}	Double sample period	3.2	4	5.3	µs
t_{strtp}	Start of first sampling window			3	t_{dsamp}
t_{flxp}	End of first sampling window	9			t_{dsamp}
t_{strtn}	Start of second sampling window			19	t_{dsamp}
t_{flxn}	End of second sampling window	31			t_{dsamp}
t_{strtno}	Start of first normal operation value		36.5	37	t_{dsamp}

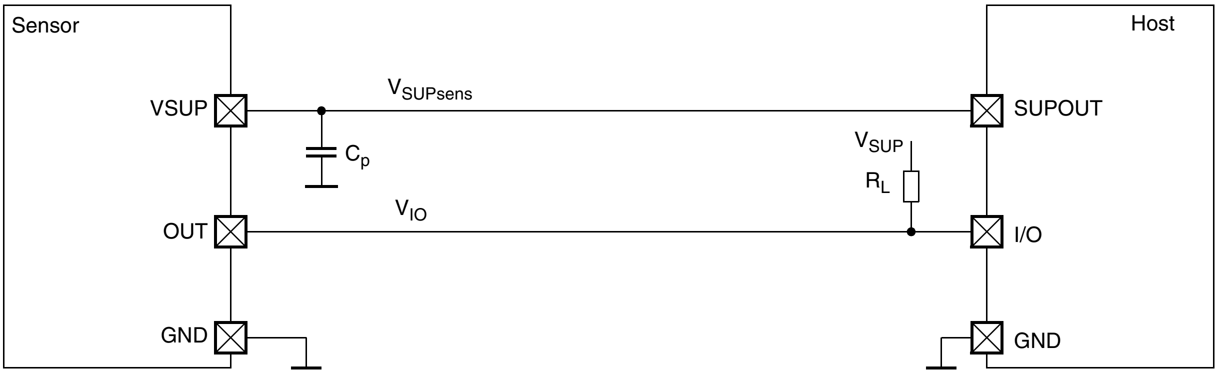
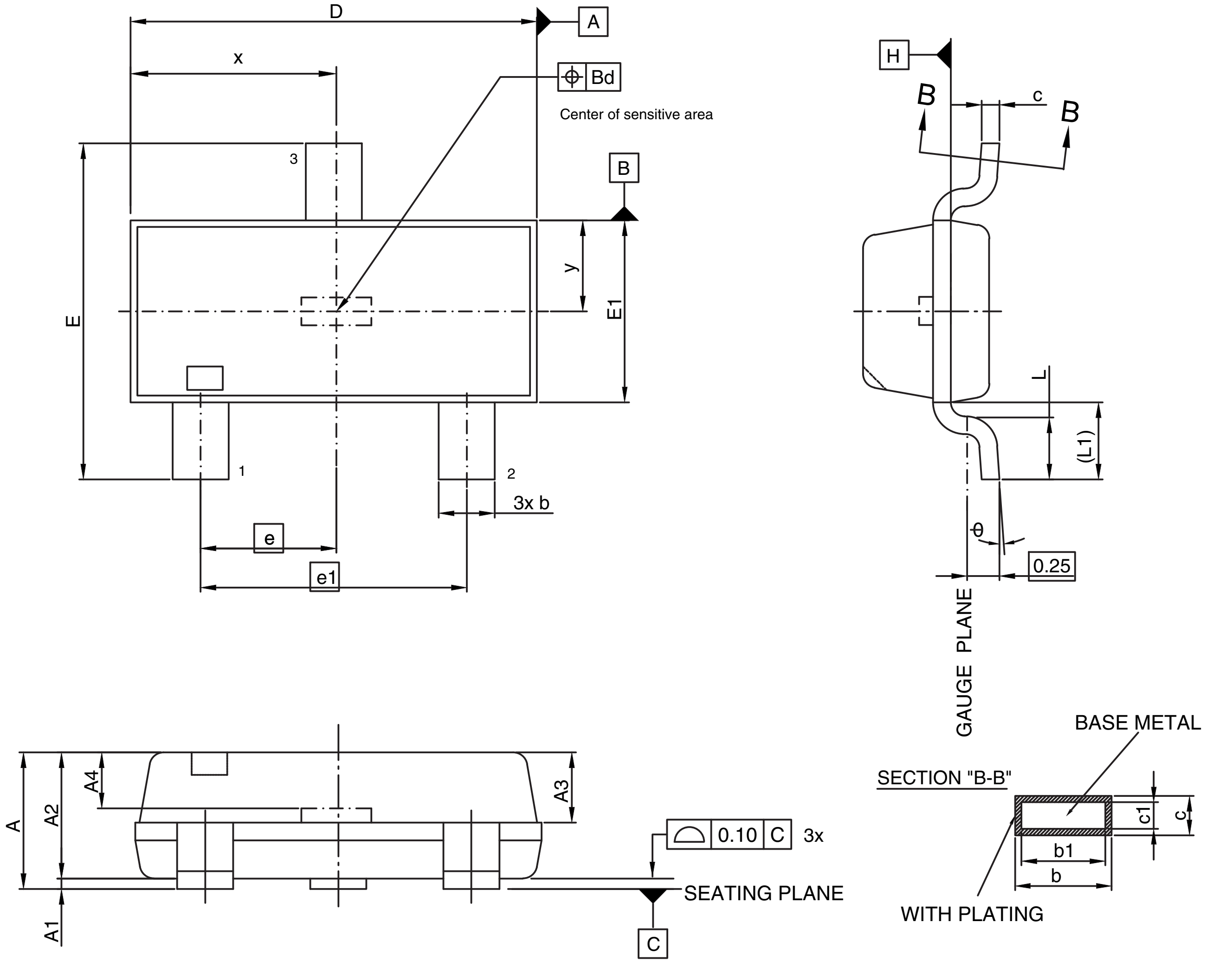


Fig. 3–3: External circuit diagram with switchable supply

4. Specifications

4.1. Outline Dimensions



physical dimensions do not include moldflash.

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

UNIT	A	A1	A2	A3	b	b1	c	c1	D	E	E1	e	e1	L	L1	θ
mm	1.10 max.	0.05 0.10	0.88 1.02	0.5	0.3 0.48	0.3 0.45	0.1 0.18	0.1 0.15	2.8 3.0	2.1 2.5	1.2 1.4	0.95	1.9	0.4 0.6	0.55	0° 8°

JEDEC STANDARD		ANSI	ISSUE DATE YY-MM-DD	DRAWING-NO.	ZG-NO.
ISSUE	ITEM NO.				
-	TO-236	⊕ ⊲	13-05-10	06902.0001.4	ZG001101_Ver.01

Fig. 4–1:
SOT23: Plastic **S**mall **O**utline **T**ransistor package, 3 leads
Ordering code: SU
Weight approximately 0.01094 g

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

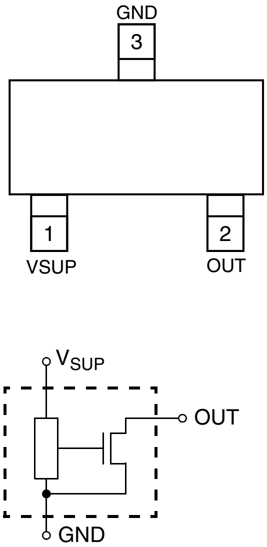


Fig. 4–2: Pin configuration

Table 4–1: Pin assignment.

Pin number	Name	Function
1	VSUP	Supply voltage
2	OUT	Output
3	GND	Ground

4.3.1. Dimension and Position of Sensitive Area

Parameter	Min.	Typ.	Max.	Unit
Dimension of sensitive area		100 x 100		μm^2
SOT-23 JEDEC				
A4 (denotes the distance of die to top package surface in Z-direction)		0.272		mm
x (denotes the nominal distance of the center of the Bd circle to the package border in x-direction)		1.45		mm
y (denotes the nominal distance of the center of the Bd circle to the package border in y-direction)		0.65		mm
Bd (denotes the diameter of the circuit in which the center of the sensitive area is located)			0.226	mm

4.4. 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 (GND).

Symbol	Parameter	Pin No	Min.	Max.	Unit	Conditions
T_J	Junction temperature range A	–	–40	190	°C	t < 96 h[1]
V_{SUP}	Supply voltage	1	–18	28	V	t < 96 h[1]
			–	32	V	t < 5 min[1]
			–	40	V	t < 10 x 400 ms "Load-Dump"[1] with series resistor R_V > 100 Ω.
V_{OUT}	Output voltage	2	–0.5	28	V	t < 96 h[1]
I_O	Output current	2	–	65	mA	
I_{OR}	Reverse output current	2	–50		mA	
[1] No cumulative stress						

4.5. ESD and Latch-up

The output pin has to be in tri-state (high impedance) for ESD measurements.

Table 4–2: ESD and latch-up

Symbol	Parameter	Min.	Max.	Unit
I_{latch}	Maximum latch-up free current at any pin (measurement according to AEC Q100-004), class 1	–100	100	mA
V_{HBM}	Human body model (according to AEC Q100-002)	–8	8	kV
V_{CDM}	Charged device model (according to AEC Q100-011)	–1	1	kV
V_{SYSTEM_LEVEL}	Unpowered Gun test (150 pF/330 Ω or 330 pF/2 kΩ) according to ISO 10605-2008 [1]	–15	15	kV
[1]with circuit as shown in Fig. 5–3				

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

4.7. Recommended Operating Conditions

Functional operation of the device beyond those indicated in the “Recommended Operating Conditions” of this specification is not implied, 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	Conditions
V_{SUP}	Supply voltage	1	2.7		24	V	
T_J	Junction temperature range A [1]	–	–40		170 150 125	°C	t < 1000 h[2] t < 2500 h[2] t < 8000 h[2]
V_{OUT}	Output voltage	2			24	V	
I_{OUT}	Output current	2			25	mA	

[1] Depends on the temperature profile of the application. Please contact Micronas for life time calculations.
[2] No cumulative stress

4.8. Characteristics

at T_J = –40 °C to +170 °C, V_{SUP} = 2.7 V to 24 V,
at Recommended Operating Conditions if not otherwise specified in the column “Conditions”.
Typical Characteristics for T_J = 25 °C and V_{SUP} = 12 V

Symbol	Parameter	Pin No.	Min.	Typ.	Max.	Unit	Conditions
Supply							
I_{SUP}	Supply current	1	1.1	1.6	2.4	mA	
I_{SUPR}	Reverse current	1			1	mA	for V_{SUP} = -18 V
Port Output							
V_{ol}	Port low output voltage	2		0.13	0.4	V	I_O = 20 mA
					0.5	V	I_O = 25 mA
t_f	Output fall time[1]	–			1	µs	V_{SUP} = 12V; R_L = 820 Ω; C_L = 20 pF
t_r	Output rise time[1]	–			1	µs	
B_{noise}	Effective noise of magnetic switching points[2]	–		72		µT	For square wave signal with 12 kHz
t_j	Output jitter (RMS)[1]	–		±0.58	±0.72	µs	For square wave signal with 1 kHz. Jitter is evenly distributed between –1 µs and +1 µs
t_d	Delay time[2] [3]	–		16	21	µs	
t_{samp}	Output refresh period	–	1.6	2	2.66	µs	
t_{en}	Enable time of output after settling of V_{SUP} [4]	–		50	60	µs	V_{SUP} = 12V B > B_{on} + 2 mT or B < B_{off} - 2 mT
Package SOT-23 JEDEC							
R_{thja}	Thermal Resistance junction to air	–	–		300	K/W	Measured with a 1s0p
R_{thja}	Thermal Resistance junction to air	–	–		250	K/W	Measured with a 1s1p
R_{thja}	Thermal Resistance junction to air	–	–		210	K/W	Measured with a 2s2p

[1] Not tested, characterized only
[2] Guaranteed by design
[3] Systematic delay between magnetic threshold reached and output switching
[4] If power-on self-test is executed, t_{en} will be extended by power-on self-test period (see Section 3.3.)

4.9. HAL 1502 Magnetic Characteristics

The HAL 1502 Hall-latch provides highest sensitivity (see Fig. 4–3).

The output turns low with the magnetic south pole on the top side of the package and turns high with the magnetic north pole on the top side. The output does not change if the magnetic field is removed. For changing the output state, the opposite magnetic field polarity must be applied.

For correct functioning in the application, the sensor requires both magnetic polarities (north and south) on the top side of the package.

Magnetic Features:

– switching type: latching

– high sensitivity

– typical B_{ON}: 2.5 mT at room temperature

– typical B_{OFF}: –2.5 mT at room temperature

– operates with static magnetic fields and dynamic magnetic fields up to 12 kHz

– typical temperature coefficient of magnetic switching points is –1000 ppm/K

Applications

The HAL 1502 is the optimal sensor for all applications with alternating magnetic signals and weak magnetic amplitude at the sensor position such as:

– applications with large air gap or weak magnets

– revolutions per minute (RPM) or other counting measurement

– commutation of brushless DC motors

– endposition detection

– magnetic encoders

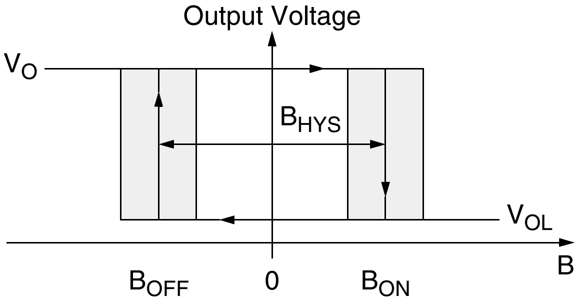


Fig. 4–3: Definition of magnetic switching points for the HAL 1502

Magnetic Characteristics at T_J = –40 °C to +170 °C, V_{DD} = 2.7 V to 24 V,
Typical Characteristics for V_{DD} = 12 V

Magnetic flux density values of switching points.
Positive flux density values refer to the magnetic south pole at the top side of the package.

Parameter	On point B_{ON}			Off point B_{OFF}			Hysteresis B_{HYS}			Unit
T_J	Min.	Typ.	Max.	Min.	Typ.	Max.	Min.	Typ.	Max.	
–40 °C	1.3	2.8	4.3	–4.3	–2.8	–1.3	–	5.6	–	mT
25 °C	1	2.5	4	–4	–2.5	–1	–	5	–	mT
170 °C	0.8	2.3	3.8	–3.8	–2.3	–0.8	–	4.6	–	mT

The hysteresis is the difference between the switching points $B_{HYS} = B_{ON} - B_{OFF}$
The magnetic offset is the mean value of the switching points $B_{OFFSET} = (B_{ON} + B_{OFF}) / 2$

Note: Regarding switching points, temperature coefficients, and B-field switching frequency, customized derivatives via mask option are possible. For more information contact Micronas.

5. Application Notes

5.1. Application Circuits

Typical application circuit (see Fig. 5–1)

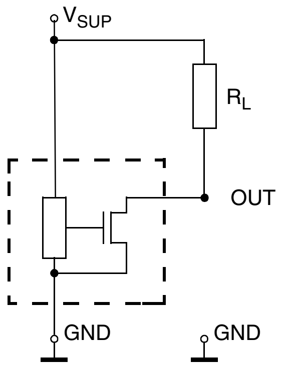


Fig. 5–1: Example application circuit 1

For applications with disturbances on the supply line or radiated disturbances, a series resistor R_V and two capacitors C_P and C_L all placed close to the sensor are recommended (see Fig. 5–2).
For example: R_V =100 Ω, C_P = 10 nF, and C_L = 4.7 nF.

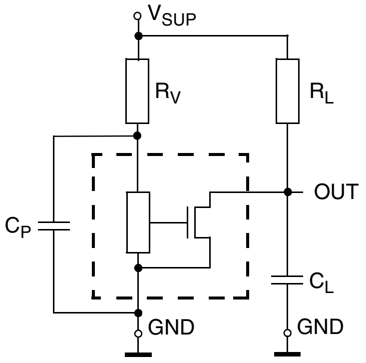
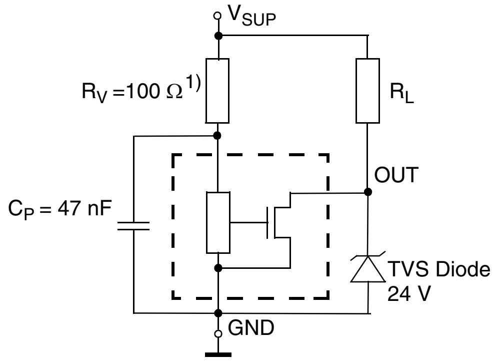


Fig. 5–2: Example application circuit 2

R_L is the open-drain pull-up resistor and has to be placed close to the input of the host controller to enable wire-break detection.

5.1.1. ESD System Level Application Circuit (ISO10605-2008)

For an ESD system level application circuit according to ISO10605-2008 an additional TVS diode is recommended.



[1] required for 40 V load dump capability

Fig. 5–3: Application circuit with external resistor

5.2. 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).

$$T_J = T_A + \Delta T$$

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

$$\Delta T = (I_{SUP} \times V_{SUP} \times R_{th}) + (I_{OUT} \times V_{OUT} \times R_{th})$$

For all sensors, the junction temperature range T_J is specified. The maximum ambient temperature T_{Amax} can be calculated as:

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

For typical values, use the typical parameters. For worst case calculation, use the max. parameters for I_{SUP}, I_{OUT}, and R_{th}, and the max. value for V_{OUT} and V_{SUP} from the application.

5.3. Start-Up Behavior

The sensors have an initialization time (enable time t_{en}) after applying the supply voltage. The parameter t_{en} is specified in the Electrical Characteristics (see page 13).

During the initialization time, the output state is defined as tri-state.

After t_{en}, the output will be low if the applied magnetic field B is above B_{ON}. The output will be high if B is below B_{OFF}. In case of sensors with an inverted switching behavior, the output state will be high if $B > B_{OFF}$ and low if $B < B_{ON}$.

Note: For magnetic fields between B_{OFF} and B_{ON} after applying V_{SUP}, the output state of the device will be tri-state.

5.4. EMC and ESD

For applications with disturbances on the supply line or radiated disturbances, a series resistor and a capacitor are recommended. The series resistor and the capacitor should be placed as closely as possible to the HAL sensor.

Special applications arrangements were evaluated to pass EMC tests according to different standards, such as ISO 7637, ISO 16750, IEC 61967, ISO 11452 and ISO 62132.

6. Data Sheet History

1. Preliminary Data Sheet: “HAL 1502, Hall-Effect Switch”, July 31, 2015; PD000219_001E. First release of the Preliminary Data Sheet.

Micronas GmbH
Hans-Bunte-Strasse 19 · D-79108 Freiburg · P.O. Box 840 · D-79008 Freiburg, Germany
Tel. +49-761-517-0 · Fax +49-761-517-2174 · E-mail: docservice@micronas.com · Internet: www.micronas.com