

HAL114, HAL115 Hall Effect Sensor Family

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Hall Effect Sensor Family in CMOS technology

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

1. Introduction

The HAL11x family consists of different Hall switches produced in CMOS technology.

All sensors include a temperature-compensated Hall plate, a comparator, and an open-drain output transistor. 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 sensors of this family differ in the switching behavior.

The sensors are designed for industrial and automotive applications and operate with supply voltages from 4.5 V to 24 V in the ambient temperature range from -40 °C up to 125 °C.

All sensors are available in an SMD-package (SOT-89B) and in a leaded version (TO-92UA).

1.1. Features

- operates from 4.5 V to 24 V supply voltage
- overvoltage protection
- reverse-voltage protection at V_{DD} -pin
- short-circuit protected open-drain output by thermal shut down
- operates with static magnetic fields and dynamic magnetic fields up to 20 kHz
- stable switching points over a wide supply voltage range
- the decrease of magnetic flux density caused by rising temperature in the sensor system is compensated by a built-in negative temperature coefficient of the magnetic characteristics

1.2. Family Overview

The types differ according to the mode of switching.

Type	Switching Behavior	see Page
HAL 114	unipolar	10
HAL 115	bipolar	12

Bipolar Switching Sensors:

The output turns low with the magnetic south pole on the branded side of the package and turns high with the magnetic north pole on the branded side. The output state is not defined for all sensors if the magnetic field is removed again. Some sensors will change the output state and some sensors will not.

Unipolar Switching Sensors:

The output turns low with the magnetic south pole on the branded side of the package and turns high if the magnetic field is removed. The sensor does not respond to the magnetic north pole on the branded side.

1.3. Marking Code

All Hall sensors have a marking on the package surface (branded side). This marking includes the name of the sensor and the temperature range.

Type	Temperature Range		
	K	E	C
HAL 114	114K	114E	114C
HAL 115	115K	115E	115C

1.4. Operating Junction Temperature Range

The Hall sensors from MICRONAS are specified to the chip temperature (junction temperature T_J).

K: $T_J = -40\text{ °C to }+140\text{ °C}$

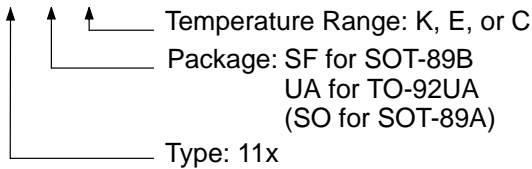
E: $T_J = -40\text{ °C to }+100\text{ °C}$

C: $T_J = 0\text{ °C to }+100\text{ °C}$

The relationship between ambient temperature (T_A) and junction temperature is explained in section 5.2. on page 14.

1.5. Hall Sensor Package Codes

HALXXXPA-T



Example: **HAL 114UA-E**

→ Type: 114

→ Package: TO-92UA

→ Temperature Range: $T_J = -40\text{ °C to }+100\text{ °C}$

Hall sensors are available in a wide variety of packaging versions and quantities. For more detailed information, please refer to the brochure: "Ordering Codes for Hall Sensors".

1.6. Solderability

all packages: according to IEC68-2-58

During soldering reflow processing and manual reworking, a component body temperature of 260 °C should not be exceeded.

Components stored in the original packaging should provide a shelf life of at least 12 months, starting from the date code printed on the labels, even in environments as extreme as 40 °C and 90% relative humidity.

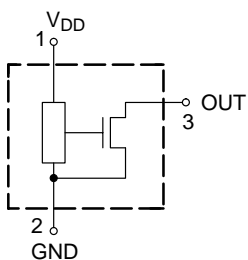


Fig. 1-1: Pin configuration

2. Functional Description

The HAL 11x sensors are monolithic integrated circuits which switch 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. The temperature-dependent bias increases the supply voltage of the Hall plates and adjusts the switching points to the decreasing induction of magnets at higher temperatures. If the magnetic field exceeds the threshold levels, the open drain output switches to the appropriate state. The built-in hysteresis eliminates oscillation and provides switching behavior of output without bouncing.

Shunt protection devices clamp voltage peaks at the Output-pin and V_{DD} -pin together with external series resistors. Reverse current is limited at the V_{DD} -pin by an internal series resistor up to -15 V . No external reverse protection diode is needed at the V_{DD} -pin for reverse voltages ranging from 0 V to -15 V .

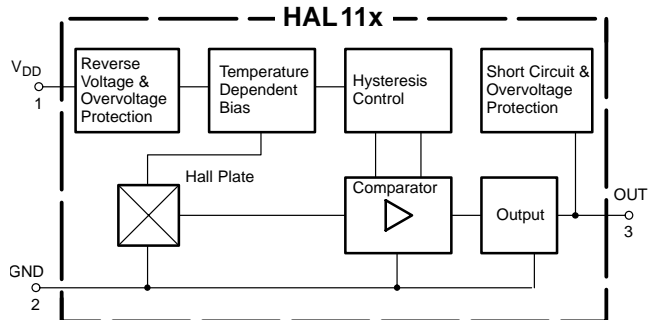


Fig. 2-1: HAL 11x block diagram

3. Specifications

3.1. Outline Dimensions

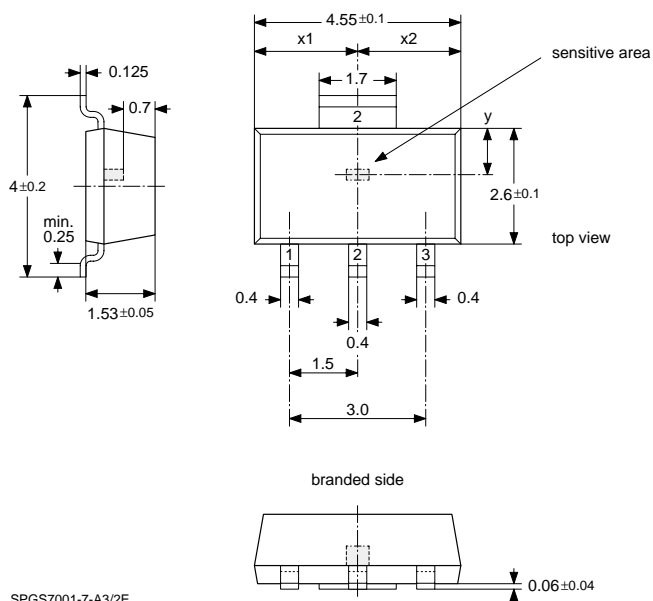


Fig. 3-1:
Plastic Small Outline Transistor Package
(SOT-89A)
Weight approximately 0.04 g
Dimensions in mm

Note: The SOT-89A package will be discontinued in 2000 and be replaced by the SOT-89B package.

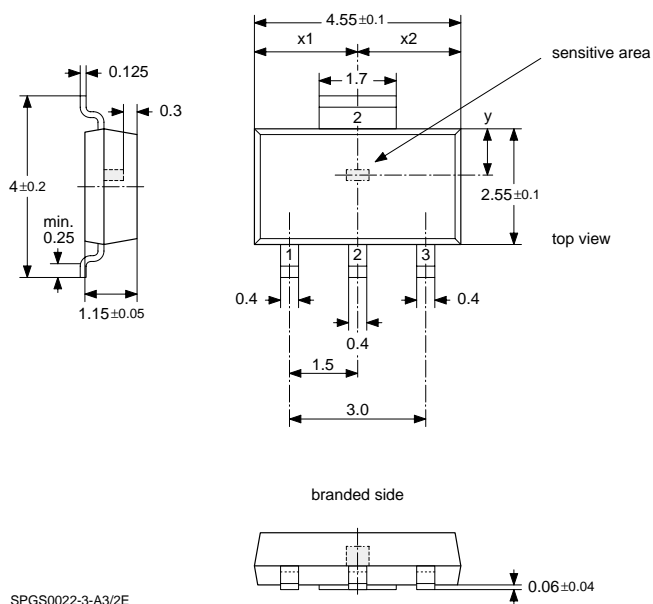


Fig. 3-2:
Plastic Small Outline Transistor Package
(SOT-89B)
Weight approximately 0.035 g
Dimensions in mm

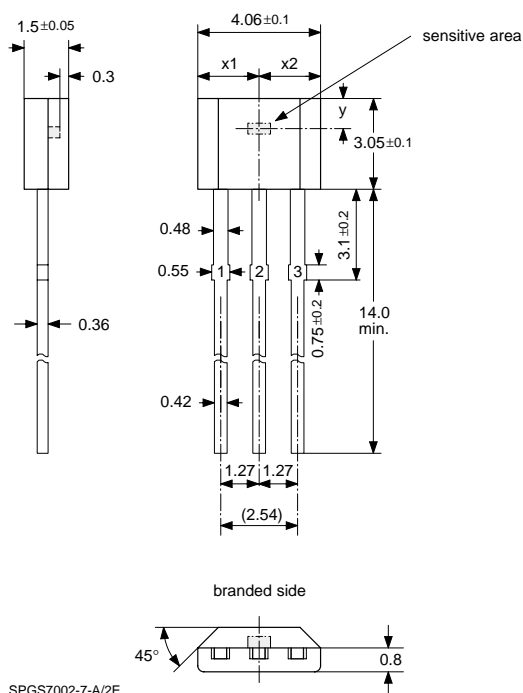


Fig. 3-3:
Plastic Transistor Single Outline Package
(TO-92UA)
Weight approximately 0.12 g
Dimensions in mm

Note: For all package diagrams, a mechanical tolerance of $\pm 50 \mu\text{m}$ applies to all dimensions where no tolerance is explicitly given.

3.2. Dimensions of Sensitive Area

0.4 mm x 0.2 mm

3.3. Positions of Sensitive Areas

SOT-89A	SOT-89B	TO-92UA
$ x_2 - x_1 / 2 < 0.2 \text{ mm}$		
$y = 0.98 \text{ mm} \pm 0.2 \text{ mm}$	$y = 0.95 \text{ mm} \pm 0.2 \text{ mm}$	$y = 1.0 \text{ mm} \pm 0.2 \text{ mm}$

3.4. Absolute Maximum Ratings

Symbol	Parameter	Pin No.	Min.	Max.	Unit
V_{DD}	Supply Voltage	1	-15	28 ¹⁾	V
$-V_P$	Test Voltage for Supply	1	-24 ²⁾	-	V
$-I_{DD}$	Reverse Supply Current	1	-	50 ¹⁾	mA
I_{DDZ}, I_{OZ}	Current through Protection Devices	1 or 3	-200 ³⁾	200 ³⁾	mA
V_O	Output Voltage	3	-0.3	28 ¹⁾	V
I_O	Continuous Output On Current	3	-	30 ¹⁾	mA
I_{Omax}	Peak Output On Current	3	-	250 ³⁾	mA
T_S	Storage Temperature Range		-65	150	°C
T_J	Junction Temperature Range		-40	150	°C

¹⁾ as long as T_{Jmax} is not exceeded
²⁾ with a 220 Ω series resistor at pin 1
³⁾ $t < 2$ ms

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 or any other conditions beyond those indicated in the “Recommended Operating Conditions/Characteristics” of this specification is not implied. Exposure to absolute maximum ratings conditions for extended periods may affect device reliability.

3.5. Recommended Operating Conditions

Symbol	Parameter	Pin No.	Min.	Max.	Unit
V_{DD}	Supply Voltage	1	4.5	24	V
I_O	Continuous Output On Current	3	0	20	mA
V_O	Output Voltage (output switched off)	3	0	24	V
R_V	Series Resistor ¹⁾	1		270	Ω

¹⁾ see Fig. 5-1 on page 14

3.6. Electrical Characteristics at $T_J = -40\text{ }^\circ\text{C}$ to $+140\text{ }^\circ\text{C}$, $V_{DD} = 4.5\text{ V}$ to 24 V , as not otherwise specified in Conditions
 Typical Characteristics for $T_J = 25\text{ }^\circ\text{C}$ and $V_{DD} = 12\text{ V}$

Symbol	Parameter	Pin No.	Min.	Typ.	Max.	Unit	Conditions
I_{DD}	Supply Current	1	6	8.2	11	mA	$T_J = 25\text{ }^\circ\text{C}$
I_{DD}	Supply Current over Temperature Range	1	3.9	8.2	12	mA	
V_{OL}	Output Voltage over Temperature Range	3	–	120	400	mV	$I_{OL} = 12.5\text{ mA}$
V_{OL}	Output Voltage over Temperature Range	3	–	190	500	mV	$I_{OL} = 20\text{ mA}$
I_{OH}	Output Leakage Current	3	–	0.06	1	μA	$B < B_{off}$, $T_J = 25\text{ }^\circ\text{C}$, $V_{OH} = 0$ to 24 V
I_{OH}	Output Leakage Current over Temperature Range	3	–	–	10	μA	$B < B_{off}$, $V_{OH} = 0$ to 24 V
$t_{en(O)}$	Enable Time of Output after Setting of V_{DD}	1	–	6	10	μs	$V_{DD} = 12\text{ V}$ $B > B_{ON} + 2\text{ mT}$ or $B < B_{OFF} - 2\text{ mT}$
t_r	Output Rise Time	3	–	0.08	0.4	μs	$V_{DD} = 12\text{ V}$, $R_L = 820\text{ Ohm}$, $C_L = 20\text{ pF}$
t_f	Output Fall Time	3	–	0.06	0.4	μs	$V_{DD} = 12\text{ V}$, $R_L = 820\text{ Ohm}$, $C_L = 20\text{ pF}$
R_{thJSB} case SOT-89A SOT-89B	Thermal Resistance Junction to Substrate Backside	–	–	150	200	K/W	Fiberglass Substrate 30 mm x 10 mm x 1.5mm, pad size see Fig. 3–4
R_{thJA} case TO-92UA	Thermal Resistance Junction to Soldering Point	–	–	150	200	K/W	

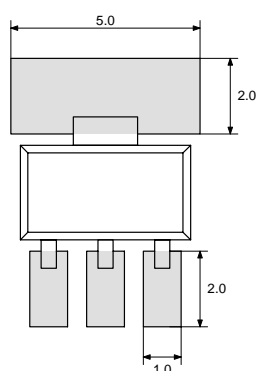


Fig. 3–4: Recommended pad size SOT-89x
 Dimensions in mm

3.7. Magnetic Characteristics at $T_J = -40\text{ °C}$ to $+140\text{ °C}$, $V_{DD} = 4.5\text{ V}$ to 24 V , Typical Characteristics for $V_{DD} = 12\text{ V}$

Magnetic flux density values of switching points.

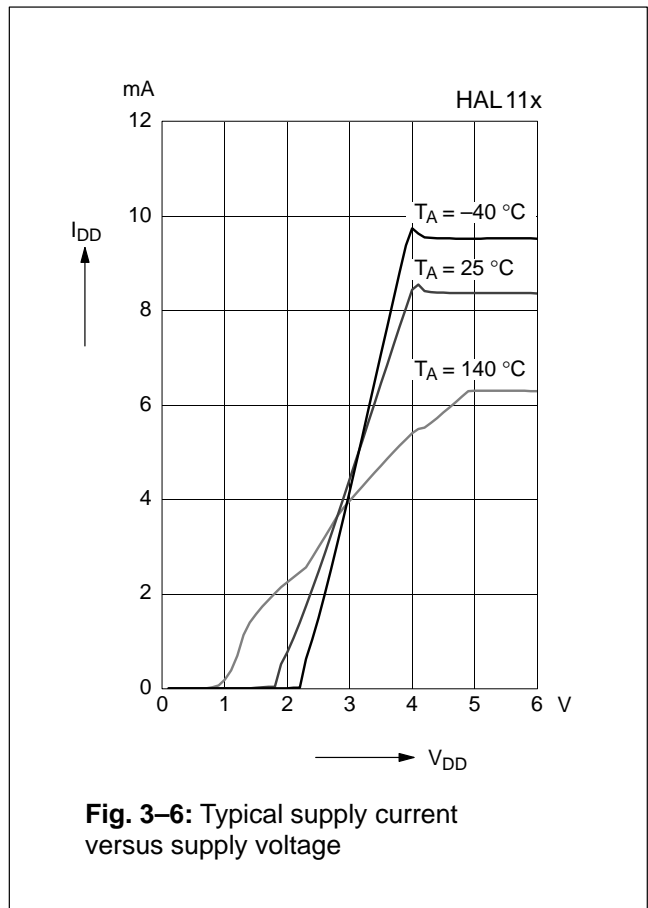
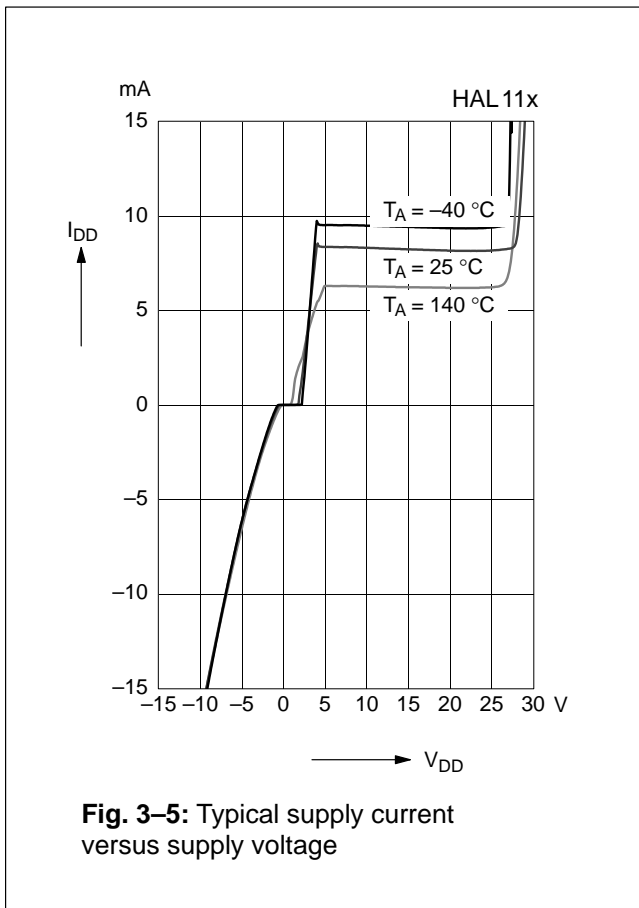
Positive flux density values refer to the magnetic south pole at the branded side of the package.

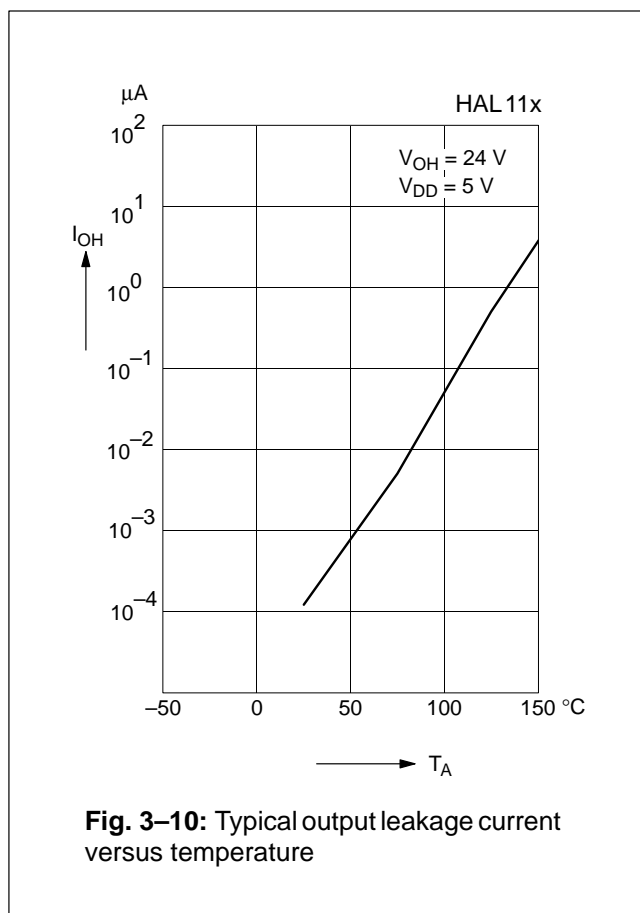
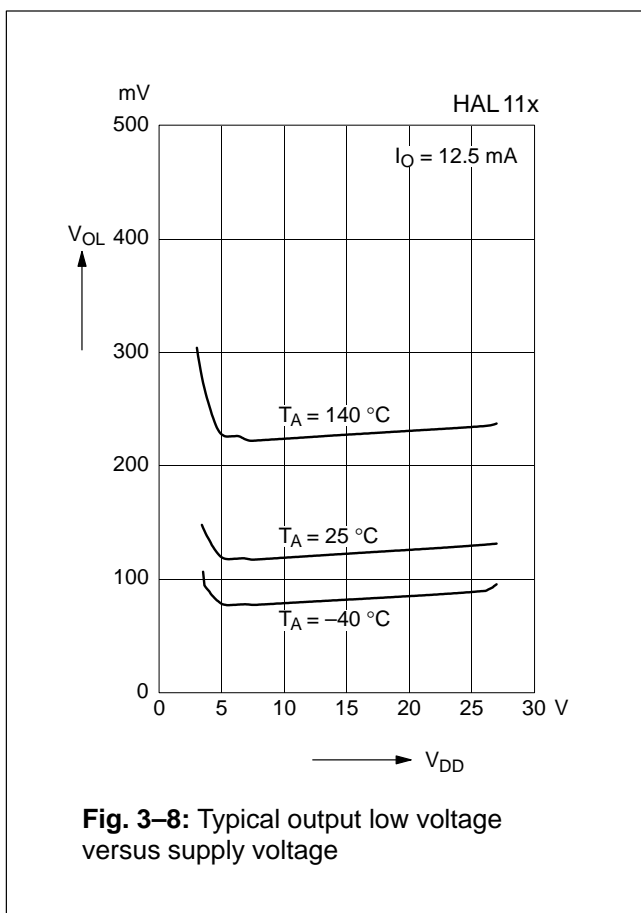
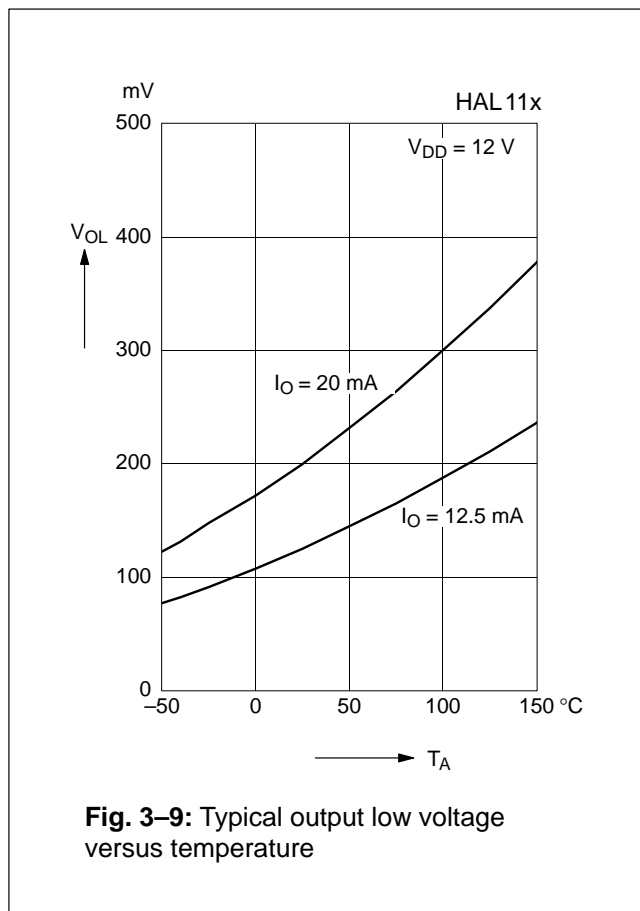
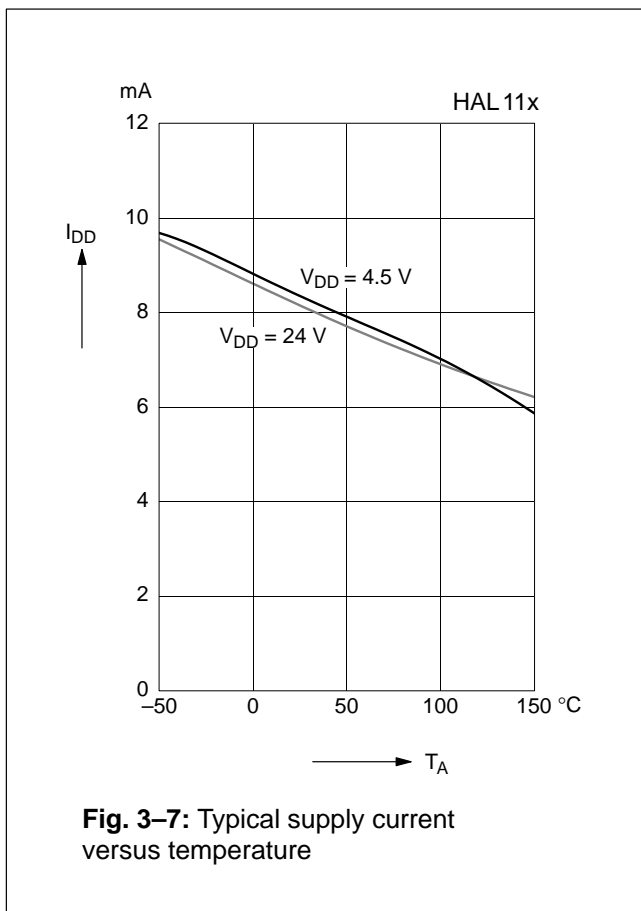
Sensor Switching type	Parameter T_J	On point B_{ON}			Off point B_{OFF}			Hysteresis B_{HYS}			Unit
		Min.	Typ.	Max.	Min.	Typ.	Max.	Min.	Typ.	Max.	
HAL 114 unipolar	-40 °C	7.5	21.5	36	4.3	17.4	33.2	2.8	4.1	5	mT
	25 °C	7	21.1	34	4	17.1	31.2	2.8	4	4.5	mT
	140 °C	6.1	19.4	31.3	3.6	16.1	28.8	2.2	3.3	4	mT
HAL 115 bipolar	-40 °C	-10.7	1.4	12.5	-12.5	-1.4	10.7	1.8	2.8	7	mT
	25 °C	-10.7	1.2	12.5	-12.5	-1.2	10.7	1.8	2.4	7	mT
	140 °C	-10.7	0.9	12.5	-12.5	-0.9	10.7	1	1.8	7	mT

Note: For detailed descriptions of the individual types, see pages 10 and following.

The magnetic limits given above refer to parts in the original packaging. Mechanical stress on the hall sensitive areas on the chip surface may generate an additional magnetic offset, which can slightly change the magnetic switching points. This behavior is a physical phenomenon and not a malfunction of the sensor. Mechanical stress on the hall plates can be caused, for example, by overmoulding the plastic package or by wide range temperature changes like soldering or operating the parts at extreme temperatures.

Please use a sensor of the HAL5xx family if higher robustness against mechanical stress is required.





4. Type Description

4.1. HAL 114

The HAL 114 is a unipolar switching sensor (see Fig. 4–1).

The output turns low with the magnetic south pole on the branded side of the package and turns high if the magnetic field is removed. The sensor does not respond to the magnetic north pole on the branded side.

For correct functioning in the application, the sensor requires only the magnetic south pole on the branded side of the package.

Magnetic Features:

- switching type: unipolar
- typical B_{ON} : 21.1 mT at room temperature
- typical B_{OFF} : 17.1 mT at room temperature
- operates with static magnetic fields and dynamic magnetic fields up to 20 kHz

Applications

The HAL 114 is the optimal sensor for applications with one magnetic polarity such as:

- solid state switches,
- contactless solution to replace micro switches,
- position and end-point detection, and
- rotating speed measurement.

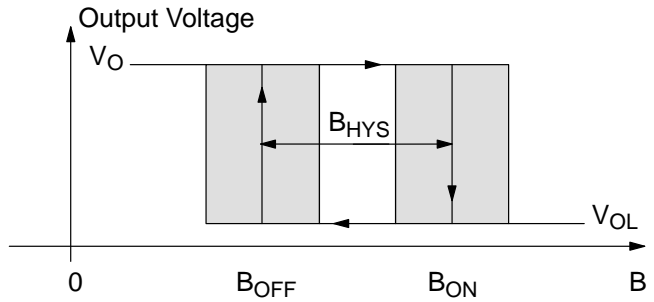


Fig. 4–1: Definition of magnetic switching points for the HAL 114

Magnetic Characteristics at $T_J = -40\text{ °C}$ to $+140\text{ °C}$, $V_{DD} = 4.5\text{ V}$ to 24 V , Typical Characteristics for $V_{DD} = 12\text{ V}$

Magnetic flux density values of switching points.

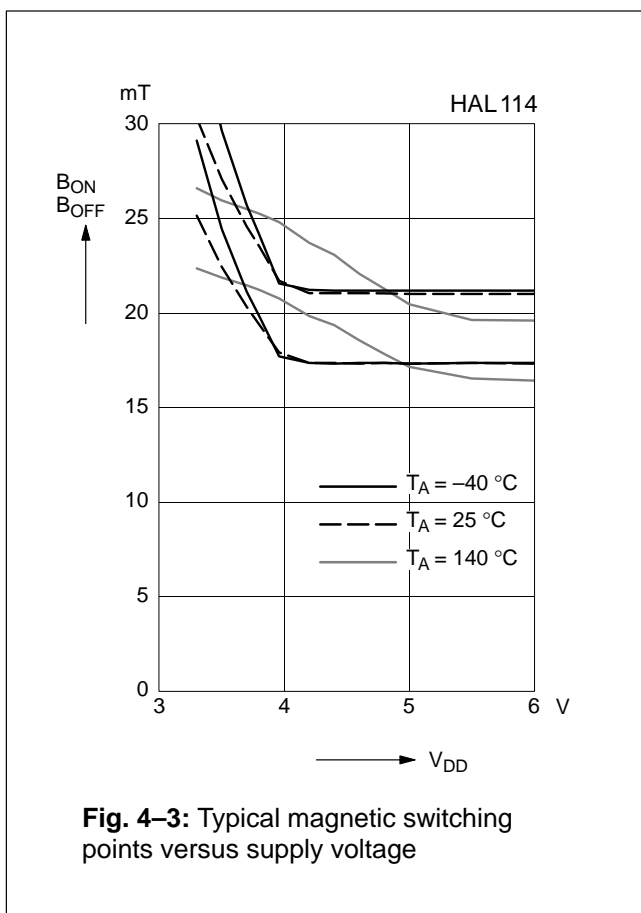
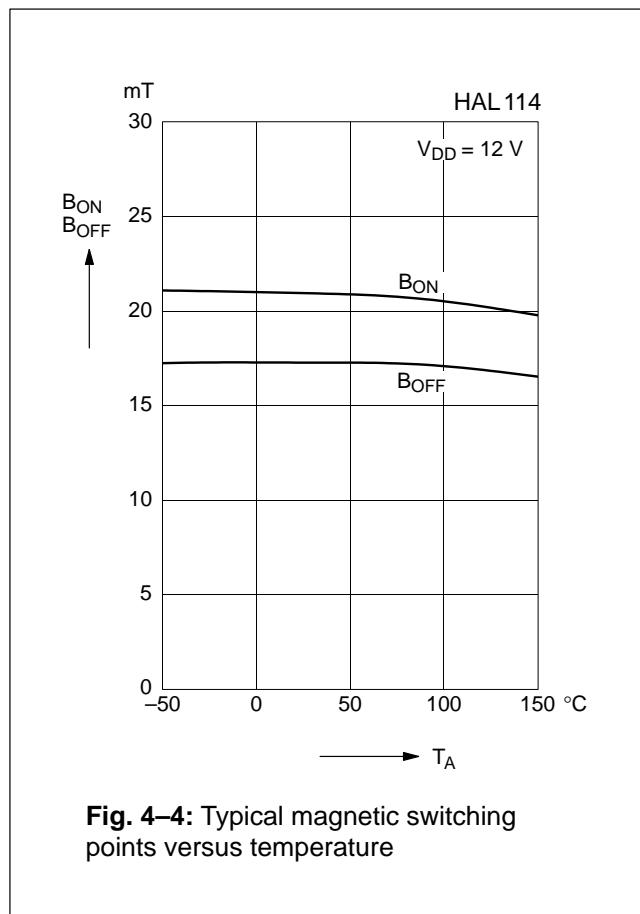
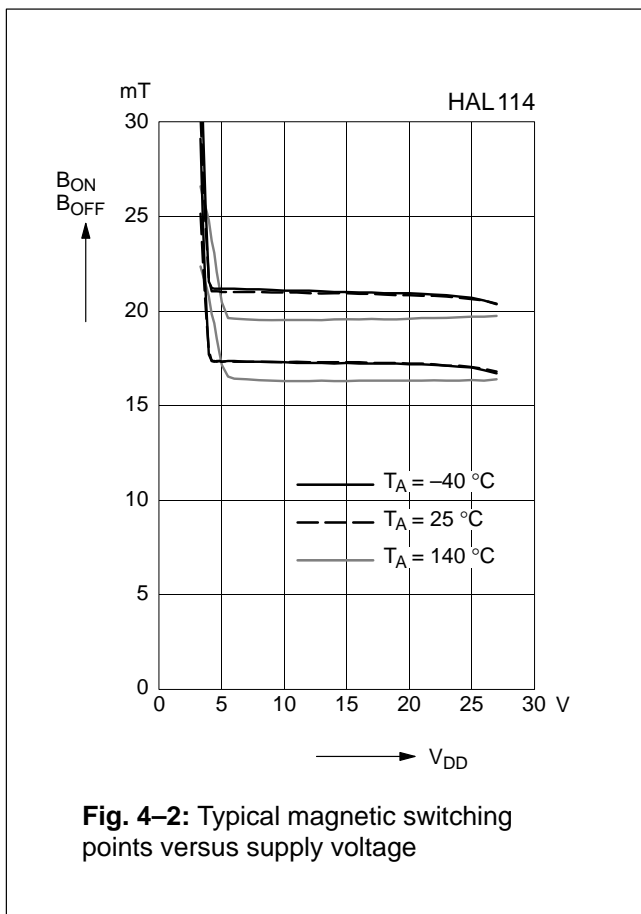
Positive flux density values refer to the magnetic south pole at the branded side of the package.

Parameter T_J	On point B_{ON}			Off point B_{OFF}			Hysteresis B_{HYS}			Unit
	Min.	Typ.	Max.	Min.	Typ.	Max.	Min.	Typ.	Max.	
-40 °C	7.5	21.5	36	4.3	17.4	33.2	2.8	4.1	5	mT
25 °C	7	21.1	34	4	17.1	31.2	2.8	4	4.5	mT
100 °C	6.3	19.9	31.5	3.6	16.4	28.9	2.6	3.5	4	mT
140 °C	6.1	19.4	31.3	3.6	16.1	28.8	2.2	3.3	4	mT

The hysteresis is the difference between the switching points $B_{HYS} = B_{ON} - B_{OFF}$

The magnetic limits given above refer to parts in the original packaging. Mechanical stress on the hall sensitive areas on the chip surface may generate an additional magnetic offset, which can slightly change the magnetic switching points. This behavior is a physical phenomenon and not a malfunction of the sensor. Mechanical stress on the hall plates can be caused, for example, by overmoulding the plastic package or by wide range temperature changes like soldering or operating the parts at extreme temperatures.

Please use a sensor of the HAL 5xx family if a robustness against mechanical stress is required.



4.2. HAL 115

The HAL 115 is a bipolar switching sensor (see Fig. 4–5).

The output turns low with the magnetic south pole on the branded side of the package and turns high with the magnetic north pole on the branded side. The output state is not defined for all sensors if the magnetic field is removed again. Some sensors will change the output state and some sensors will not.

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

Magnetic Features:

- switching type: bipolar
- high sensitivity
- typical B_{ON} : 1.2 mT at room temperature
- typical B_{OFF} : -1.2 mT at room temperature
- operates with static magnetic fields and dynamic magnetic fields up to 20 kHz

Applications

The HAL 115 is the optimal sensor for all applications with alternating magnetic signals at the sensor position such as:

- rotating speed measurement,
- commutation of brushless DC-motors and cooling fans.

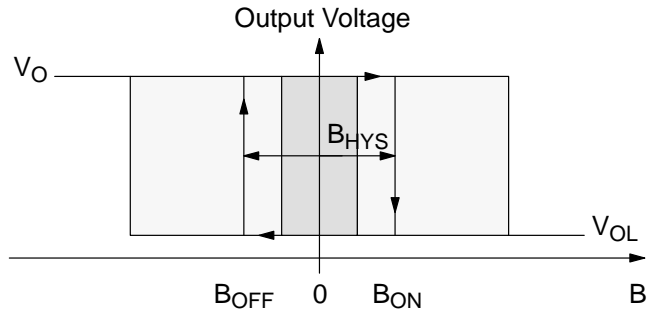


Fig. 4–5: Definition of magnetic switching points for the HAL 115

Magnetic Characteristics at $T_J = -40\text{ °C}$ to $+140\text{ °C}$, $V_{DD} = 4.5\text{ V}$ to 24 V ,
Typical Characteristics for $V_{DD} = 12\text{ V}$

Magnetic flux density values of switching points.

Positive flux density values refer to the magnetic south pole at the branded side of the package.

Parameter T_J	On point B_{ON}			Off point B_{OFF}			Hysteresis B_{HYS}			Unit
	Min.	Typ.	Max.	Min.	Typ.	Max.	Min.	Typ.	Max.	
-40 °C	-10.7	1.4	12.5	-12.5	-1.4	10.7	1.8	2.8	7	mT
25 °C	-10.7	1.2	12.5	-12.5	-1.2	10.7	1.8	2.4	7	mT
100 °C	-10.7	1	12.5	-12.5	-1	10.7	1.5	2	7	mT
140 °C	-10.7	0.9	12.5	-12.5	-0.9	10.7	1	1.8	7	mT

The hysteresis is the difference between the switching points $B_{HYS} = B_{ON} - B_{OFF}$

The magnetic limits given above refer to parts in the original packaging. Mechanical stress on the hall sensitive areas on the chip surface may generate an additional magnetic offset, which can slightly change the magnetic switching points. This behavior is a physical phenomenon and not a malfunction of the sensor. Mechanical stress on the hall plates can be caused, for example, by overmoulding the plastic package or by wide range temperature changes like soldering or operating the parts at extreme temperatures.

Please use a sensor of the HAL5xx family if higher robustness against mechanical stress is required.

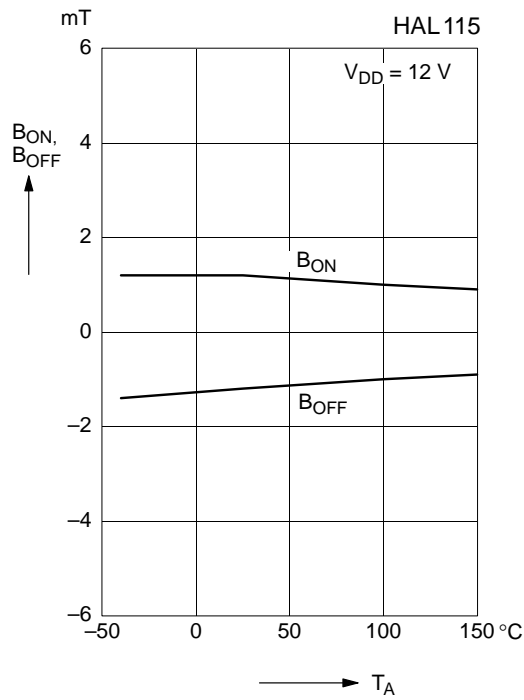


Fig. 4-6: Typical magnetic switching points versus ambient temperature

5. Application Notes

5.1. Application Circuit

The HAL 11x sensors can operate without external components. For applications with disturbances on the supply line or radiated disturbances, a series resistor and a capacitor are recommended (see Fig. 5–1).

The series resistor and the capacitor should be placed as closely as possible to the sensor.

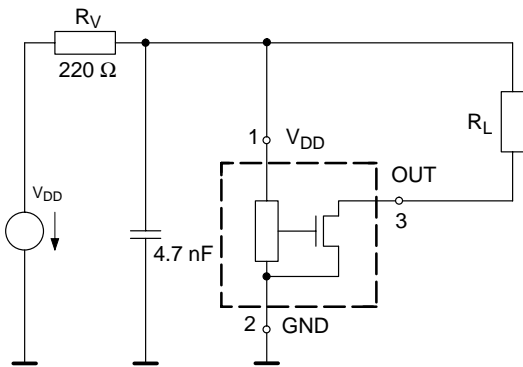


Fig. 5–1: Recommended application circuit

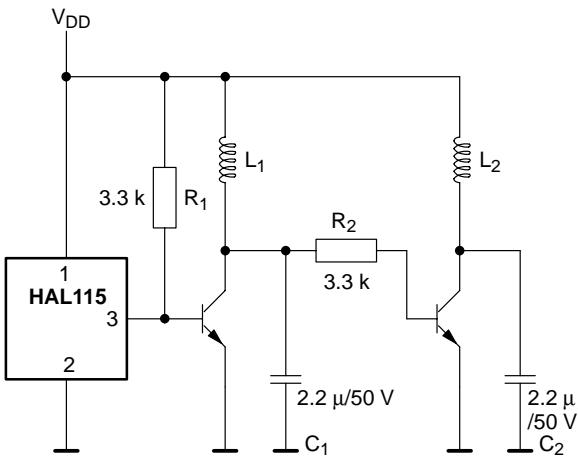


Fig. 5–2: Recommended application circuit for DC fans

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).

$$T_J = T_A + \Delta T$$

At static conditions, the following equation is valid:

$$\Delta T = I_{DD} * V_{DD} * R_{th}$$

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

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

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

5.3. Extended Operating Conditions

All sensors fulfill the electrical and magnetic characteristics when operated within the Recommended Operating Conditions (see page 6).

Please use the sensors of the HAL 5xx family if lower operation voltage, lower current consumption or tighter magnetic specifications required.

5.4. Start-up Behavior

The sensors have an initialization time (enable time $t_{en(O)}$) after applying the supply voltage. This parameter $t_{en(O)}$ is specified in the Electrical Characteristics (see page 7).

During the initialization time, the output state is not defined and can toggle. After $t_{en(O)}$, the output will be low if the applied magnetic field B is above B_{ON} or high if B is below B_{OFF} .

For magnetic fields between B_{OFF} and B_{ON} , the output state of the HAL sensor after applying V_{DD} will be either low or high. In order to achieve a well-defined output state, the applied magnetic field must be above B_{ONmax} , respectively, below B_{OFFmin} .

6. Data Sheet History

1. Final data sheet: "HAL114 Unipolar Hall Switch IC", June 10, 1998, 6251-456-1DS. First release of the final data sheet.

2. Final data sheet: "HAL115 Hall Effect Sensor IC", May 7, 1997, 6251-414-1DS. First release of the final data sheet.

3. Final data sheet: "HAL114, HAL 115 Hall Effect Sensor Family, Dec. 20, 1999, 6251-456-2DS. Second release of the final data sheet. Major changes:

- additional package SOT-89B
- temperature range "A" replaced by "K" for HAL114
- additional temperature range "K" for HAL115
- outline dimensions for SOT-89A and TO-92UA changed
- supply voltage range changed for HAL115

MICRONAS INTERMETALL GmbH
Hans-Bunte-Strasse 19
D-79108 Freiburg (Germany)
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

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