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HAL320
Differential Hall Effect
Sensor IC

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Differential Hall Effect Sensor IC
in CMOS technology

Introduction

The HAL320 is a differential Hall switch produced in CMOS technology. The sensor includes 2 temperature-compensated Hall plates (2.25 mm apart) with active offset compensation, a differential amplifier with a Schmitt trigger, and an open-drain output transistor (see Fig. 2).

The HAL320 is a differential sensor which responds to spatial differences of the magnetic field. The Hall voltages at the two Hall plates, S_1 and S_2, are amplified with a differential amplifier. The differential signal is compared with the actual switching level of the internal Schmitt trigger. Accordingly, the output transistor is switched on or off. The sensor has a bipolar switching behavior and requires positive and negative values of $\Delta B = B_{S1} - B_{S2}$ for correct operation.

Basically, there are two ways to generate the differential signal ΔB:

– Rotating a multi-pole-ring in front of the branded side of the package (see Fig. 4, Fig. 5, and Fig. 6).

– Back-bias applications:
A magnet on the back side of the package generates a back-bias field at both Hall plates. The differential signal ΔB results from the magnetic modulation of the back-bias field by a rotating ferromagnetic target.

The active offset compensation leads to constant magnetic characteristics over supply voltage and temperature.

The sensor is designed for industrial and automotive applications and operates with supply voltages from 4.5 V to 24 V in the ambient temperature range from –40 °C up to 150 °C.

The HAL320 is an ideal sensor for target wheel applications, ignition timing, anti-lock brake systems, and revolution counting in extreme automotive and industrial environments

The HAL320 is available in two SMD-packages (SOT-89A and SOT-89B) and in a leaded version (TO-92UA).

Features:

– distance between Hall plates: 2.25 mm

– operates from 4.5 V to 24 V supply voltage

– switching offset compensation at 62 kHz

– overvoltage protection

– reverse-voltage protection of V_{DD}-pin

– short-circuit protected open-drain output by thermal shutdown

– operates with magnetic fields from DC to 10 kHz

– output turns low with magnetic south pole on branded side of package and with a higher magnetic flux density in sensitive area S1 as in S2

– on-chip temperature compensation circuitry minimizes shifts of the magnetic parameters over temperature and supply voltage range

– EMC corresponding to DIN 40839

Marking Code

Type	Temperature Range		
	A	E	C
HAL320SF, HAL320SO, HAL320UA	320A	320E	320C

Operating Junction Temperature Range (T_J)

A: T_J = –40 °C to +170 °C

E: T_J = –40 °C to +100 °C

C: T_J = 0 °C to +100 °C

The relationship between ambient temperature (T_A) and junction temperature (T_J) is explained on page 11.

Hall Sensor Package Codes

HALXXXPA-T

Temperature Range: A, E, or C
Package: SF for SOT-89B
SO for SOT-89A
UA for TO-92UA
Type: 320
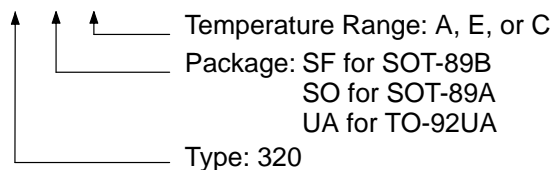
Example: **HAL320UA-E**

$\rightarrow$ Type: 320
$\rightarrow$ Package: TO-92UA
$\rightarrow$ Temperature Range: T_J = –40 °C to +100 °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".

Solderability

– Package SOT-89A and SOT-89B: according to IEC68-2-58

– Package TO-92UA: according to IEC68-2-20
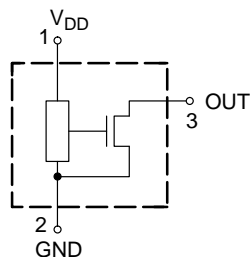
Fig. 1: Pin configuration

**Fig. 2:** HAL320 block diagram

Functional Description

This Hall effect sensor is a monolithic integrated circuit with 2 Hall plates 2.25 mm apart that switches in response to differential magnetic fields. If magnetic fields with flux lines at right angles to the sensitive areas are applied to the sensor, the biased Hall plates force Hall voltages proportional to these fields. The difference of the Hall voltages 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 differential 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 the output without oscillation.

Magnetic offset caused by mechanical stress at the Hall plates is compensated for by using the "switching offset compensation technique": An internal oscillator provides a two phase clock (see Fig. 3). The difference of the Hall voltages is sampled at the end of the first phase. At the end of the second phase, both sampled differential Hall voltages are averaged and compared with the actual switching point. Subsequently, the open drain output switches to the appropriate state. The amount of time that elapses from crossing the magnetic switch level to the actual switching of the output can vary between zero and $1/f_{osc}$.

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 values ranging from 0 V to –15 V.
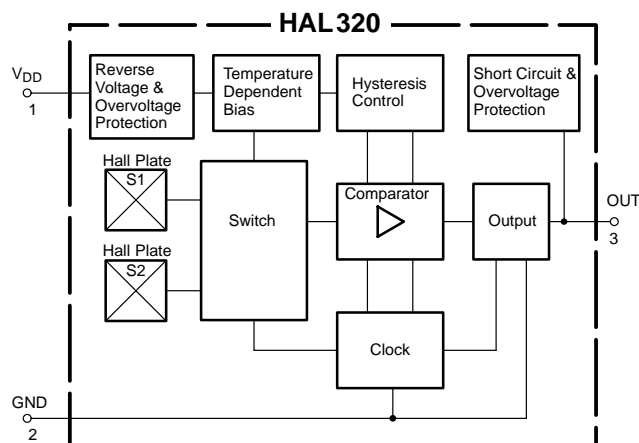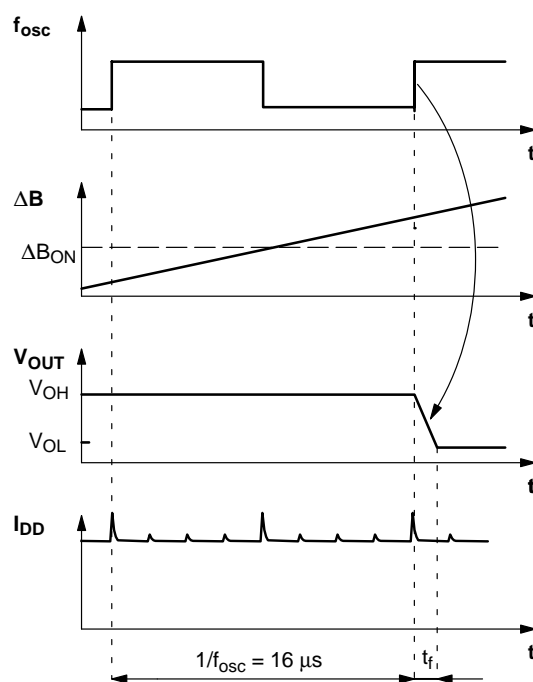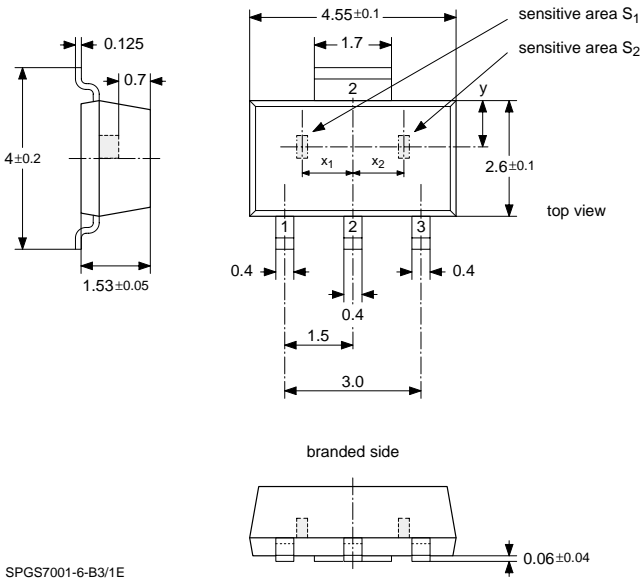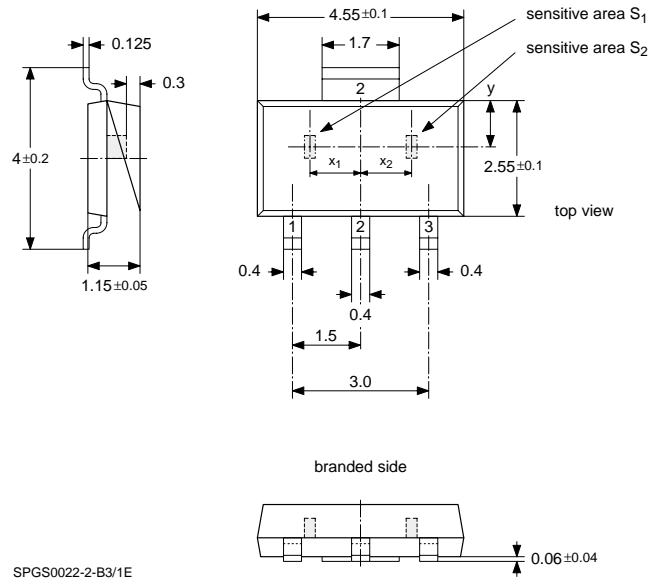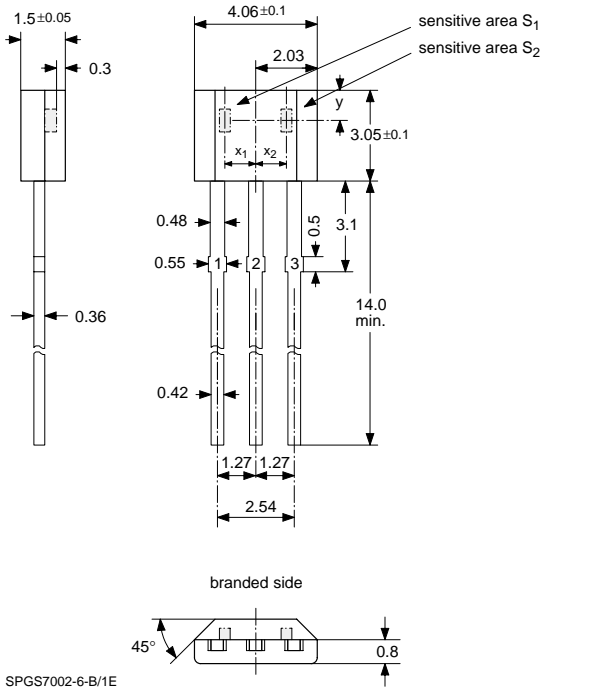

Fig. 3: Timing diagram

Outline Dimensions

Fig. 4:
Plastic Small Outline Transistor Package
(SOT-89A)
Weight approximately 0.04 g
Dimensions in mm

Fig. 6:
Plastic Small Outline Transistor Package
(SOT-89B)
Weight approximately 0.04 g
Dimensions in mm

Dimensions of Sensitive Areas

0.08 mm x 0.17 mm (each)

Positions of Sensitive Areas

SOT-89A	SOT-89B	TO-92UA
$x_1 = -1.125$ mm $\pm$ 0.2 mm		
$x_2 = 1.125$ mm $\pm$ 0.2 mm		
$x_2 - x_1 = 2.25$ mm $\pm$ 0.01 mm		
y = 0.98 mm $\pm$ 0.2 mm	y = 0.95 mm $\pm$ 0.2 mm	y = 1.0 mm $\pm$ 0.2 mm

x_1 and x_2 are referenced to the center of the package

Fig. 5:
Plastic Transistor Single Outline Package
(TO-92UA)
Weight approximately 0.12 g
Dimensions in mm

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}	Supply Current through Protection Device	1	−200[3]	200[3]	mA
V_O	Output Voltage	3	−0.3	28[1]	V
I_O	Continuous Output On Current	3	−	30	mA
I_{Omax}	Peak Output On Current	3	−	250[3]	mA
I_{OZ}	Output Current through Protection Device	3	−200[3]	200[3]	mA
T_S	Storage Temperature Range		−65	150	°C
T_J	Junction Temperature Range		−40 −40	150 170[4]	°C

[1] as long as $T_J$max is not exceeded
[2] with a 220 Ω series resistance at pin 1 corresponding to test circuit 1
[3] t < 2 ms
[4] t < 1000h

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.

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	−	20	mA
V_O	Output Voltage	3	−	24	V
R_v	Series Resistor	1	−	270	Ω

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Electrical Characteristics at $T_J = -40\ °C$ to $+170\ °C$, $V_{DD} = 4.5\ V$ to $24\ V$, as not otherwise specified in Conditions
Typical Characteristics for $T_J = 25\ °C$ and $V_{DD} = 12\ V$

Symbol	Parameter	Pin No.	Min.	Typ.	Max.	Unit	Conditions
I_{DD}	Supply Current	1	2.8	4.7	6.8	mA	$T_J = 25\ °C$
I_{DD}	Supply Current over Temperature Range	1	1.8	4.7	7.5	mA	
V_{DDZ}	Overvoltage Protection at Supply	1	–	28.5	32.5	V	$I_{DD} = 25\ mA$, $T_J = 25\ °C$, $t = 20\ ms$
V_{OZ}	Overvoltage Protection at Output	3	–	28	32.5	V	$I_{OH} = 25\ mA$, $T_J = 25\ °C$, $t = 20\ ms$
V_{OL}	Output Voltage	3	–	170	250	mV	$V_{DD} = 12\ V$, $I_O = 20\ mA$, $T_J = 25\ °C$
V_{OL}	Output Voltage over Temperature Range	3	–	170	400	mV	$I_O = 20\ mA$
V_{OL}	Output Voltage over Temperature Range	3	–	210	500	mV	$I_O = 25\ mA$
I_{OH}	Output Leakage Current	3	–	–	1	μA	$V_{OH} = 4.5\ V...24\ V$, $\Delta B < \Delta B_{OFF}$, $T_J = 25\ °C$
I_{OH}	Output Leakage Current over Temperature Range	3	–	–	10	μA	$V_{OH} = 4.5\ V...24\ V$, $\Delta B < \Delta B_{OFF}$, $T_J \leq 150\ °C$
f_{osc}	Internal Oscillator Chopper Frequency	–	42	62	75	kHz	$T_J = 25\ °C$
f_{osc}	Internal Oscillator Chopper Frequency over Temperature Range	–	40	62	80	kHz	
$t_{en(O)}$	Enable Time of Output after Setting of V_{DD}	3	–	35	–	μs	$V_{DD} = 12\ V$, $\Delta B > \Delta B_{ON} + 2mT$ or $\Delta B < \Delta B_{OFF} - 2mT$
t_r	Output Rise Time	3	–	80	400	ns	$V_{DD} = 12\ V$, $RL = 820\ \Omega$, $CL = 20\ pF$
t_f	Output Fall Time	3	–	50	400	ns	$V_{DD} = 12\ V$, $RL = 820\ \Omega$, $CL = 20\ pF$
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. 8
R_{thJS} case TO-92UA	Thermal Resistance Junction to Soldering Point		–	150	200	K/W	

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Magnetic Characteristics at T_J = –40 °C to +170 °C, V_{DD} = 4.5 V to 24 V
Typical Characteristics for V_{DD} = 12 V

Magnetic flux density values of switching points (Condition: –10 mT < B_0 < 10 mT)
Positive flux density values refer to the magnetic south pole at the branded side ot the package. $\Delta B = B_{S1} - B_{S2}$

Parameter	–40 °C			25 °C			100 °C			170 °C			Unit
	Min.	Typ.	Max.	Min.	Typ.	Max.	Min.	Typ.	Max.	Min.	Typ.	Max.	
On point ΔB_{ON} $\Delta B > \Delta B_{ON}$	–1.5	1.2	2.5	-1.5	1.2	2.5	–2	1.2	3	–2.5	1.1	3.5	mT
Off point ΔB_{OFF} $\Delta B < \Delta B_{OFF}$	–2.5	–0.6	1.5	–2.5	–0.6	1.5	–3	–0.5	2	–3.5	–0.4	2.5	mT
Hysteresis $\Delta B_{HYS} = \Delta B_{ON} - \Delta B_{OFF}$	1	1.8	4	1	1.8	4	1	1.7	4	0.8	1.5	4	mT
Offset $\Delta B_{OFFSET} = (\Delta B_{ON} + \Delta B_{OFF})/2$	–2	0.3	2	–2	0.3	2	–2.5	0.4	2.5	–3	0.4	3	mT

In back-biased applications, sensitivity mismatch between the two Hall plates S_1 and S_2 can lead to an additional offset of the magnetic switching points. In back-biased applications with the magnetic preinduction B_0, this sensitivity mismatch generates the magnetic offset $\Delta B_{OFFSETbb} = |S_1 - S_2|/S_1 \cdot B_0 + \Delta B_{OFFSET}$.

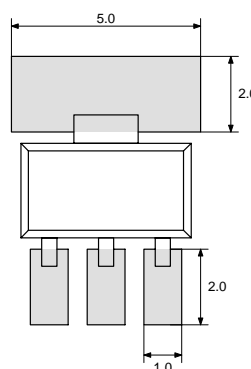| Parameter	–40 °C	25 °C	100 °C	170 °C	Unit
Sensitivity mismatch[1] $\quad$ $|S_1 - S_2|/S_1$	1.5[2]	1.0[2]	1.0[2]	0.5[2]	%
[1] Mechanical stress from packaging can influence sensitivity mismatch. [2] All values are typical values.					

The magnetic switching points are checked at room temperature at a magnetic preinduction of B_0 = 150 mT. These magnetic parameters may change under external pressure and during the lifetime of the sensor.

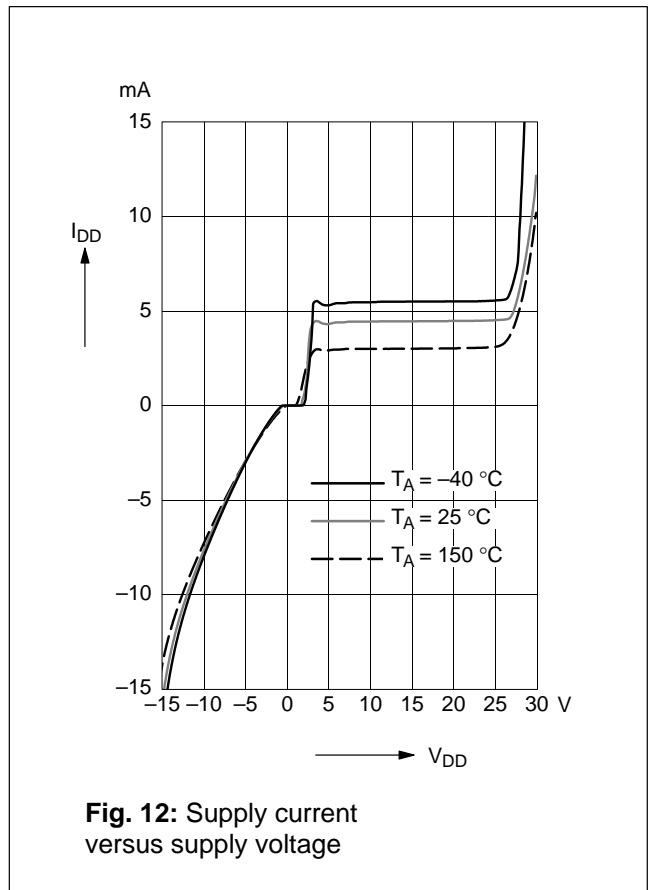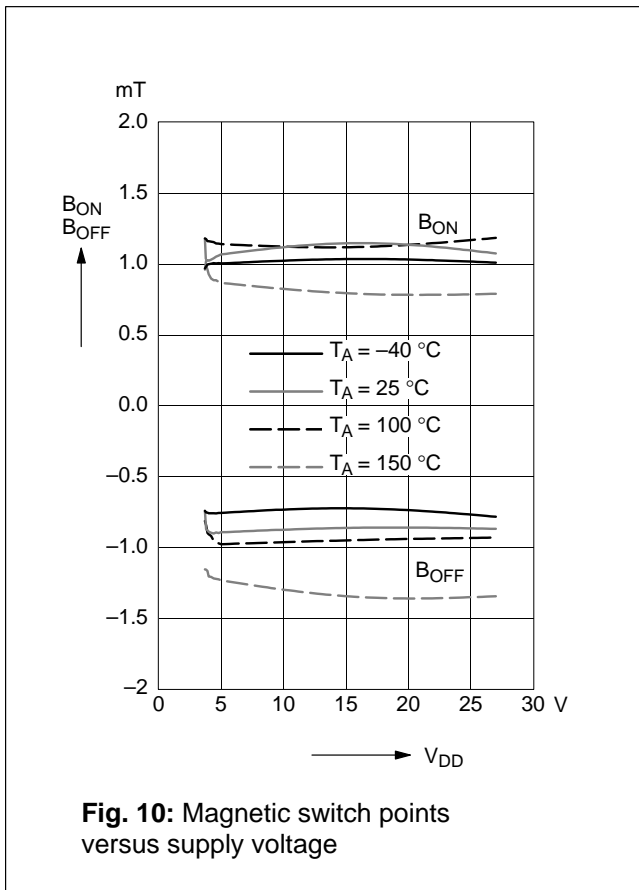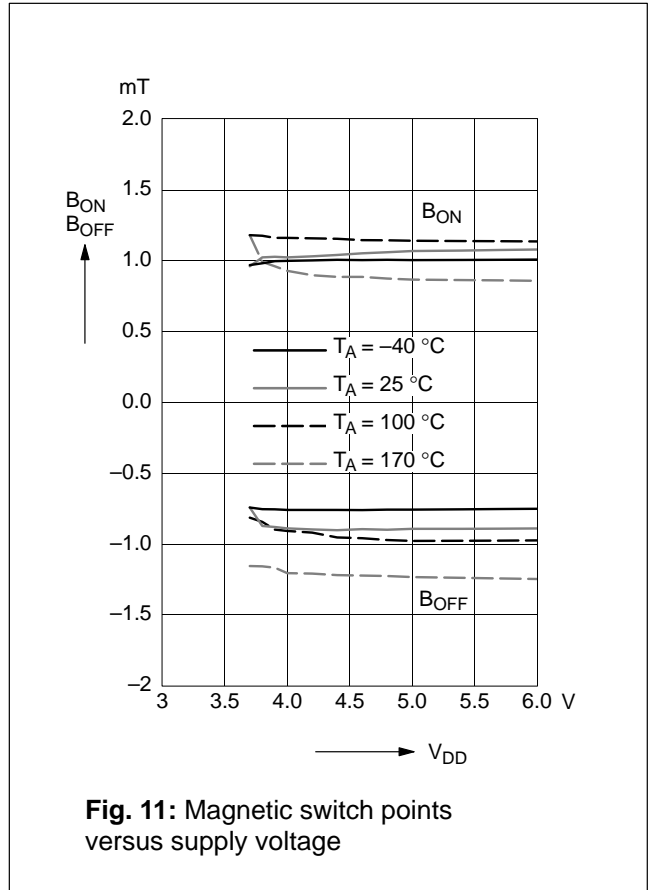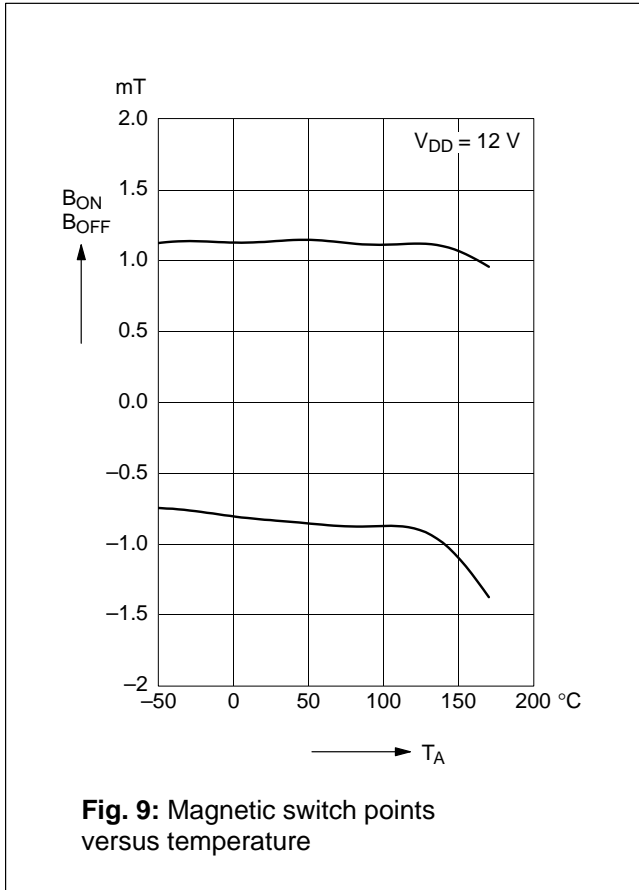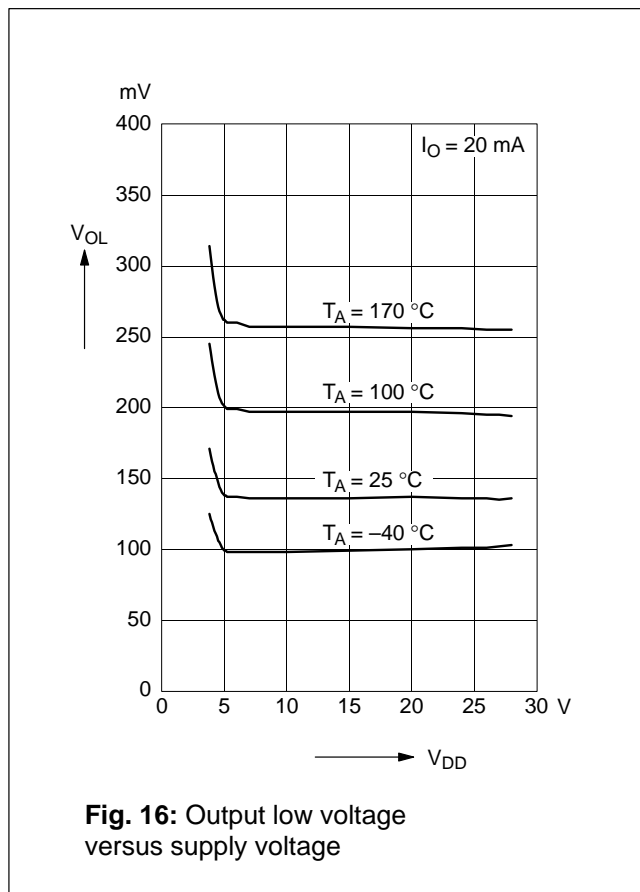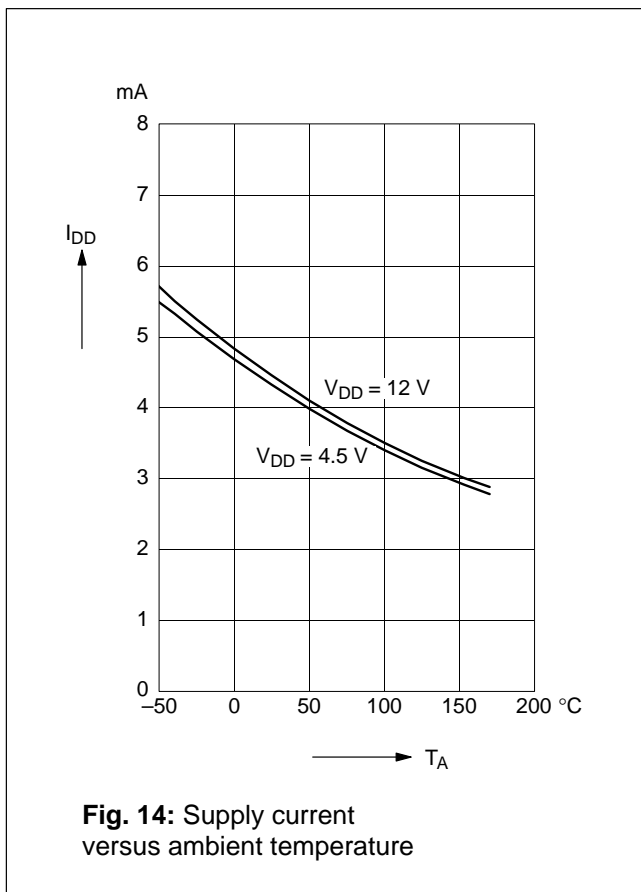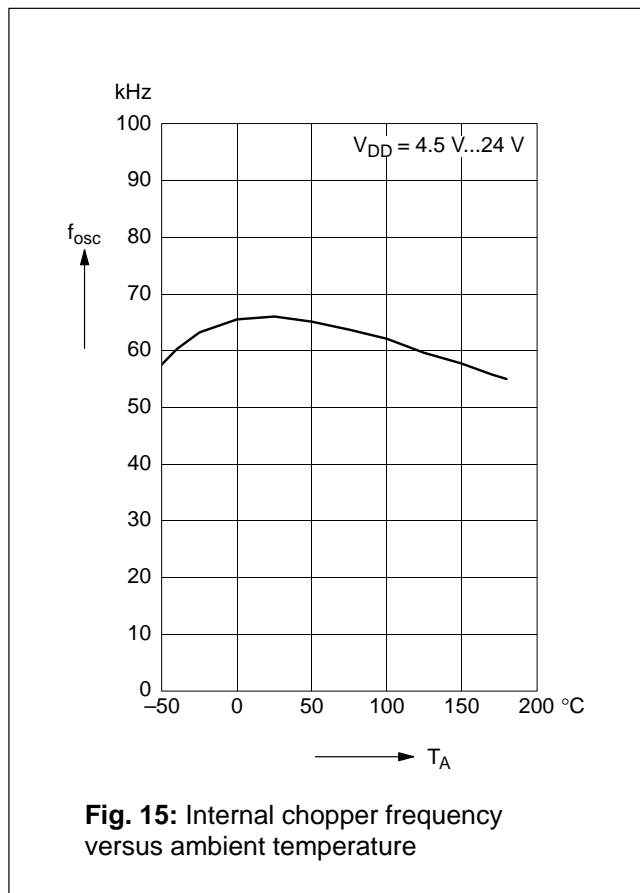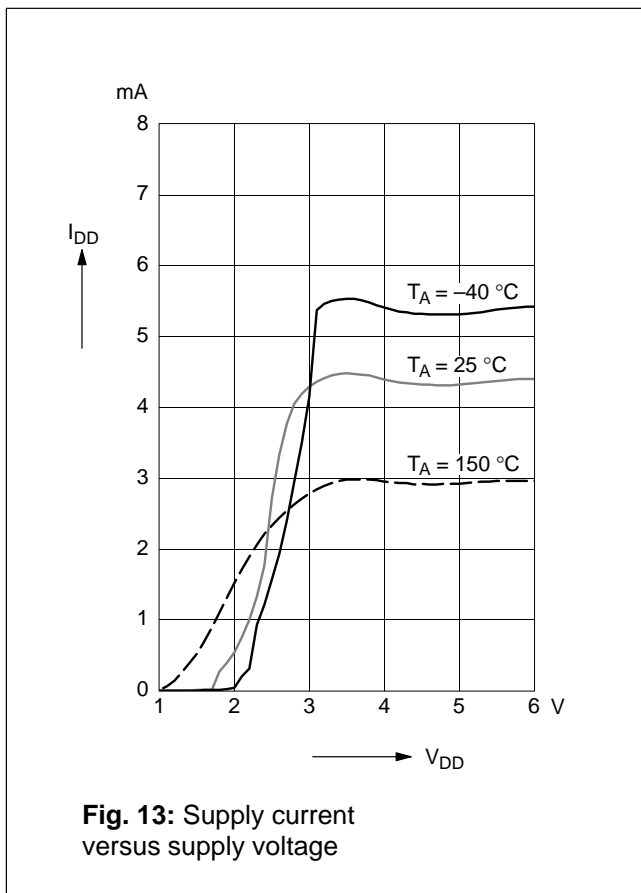| Parameter	25 °C			Unit
	Min.	Typ.	Max.	
On point ΔB_{ONbb}	–4.5	1.5	5.5	mT
Off point ΔB_{OFFbb}	–5.5	–0.3	4.5	mT
Hysteresis ΔB_{HYS}	1	1.8	4	mT
Offset $\Delta B_{OFFSETbb}$	–5	0.6	+5	mT
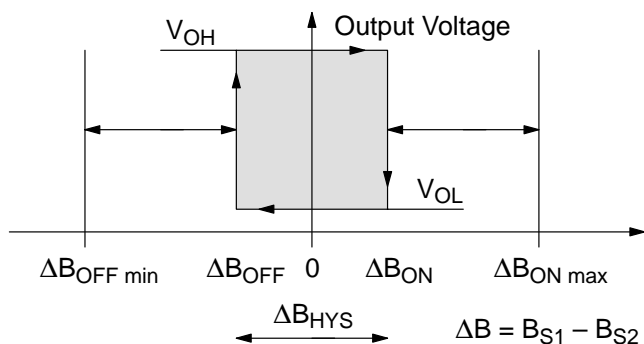
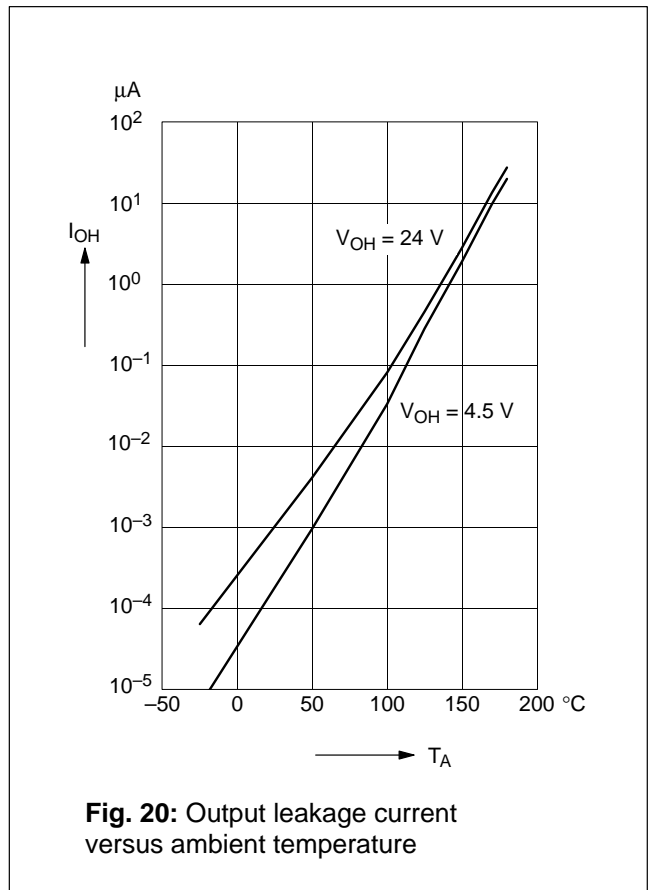**Fig. 7:** Definition of switching points and hysteresis

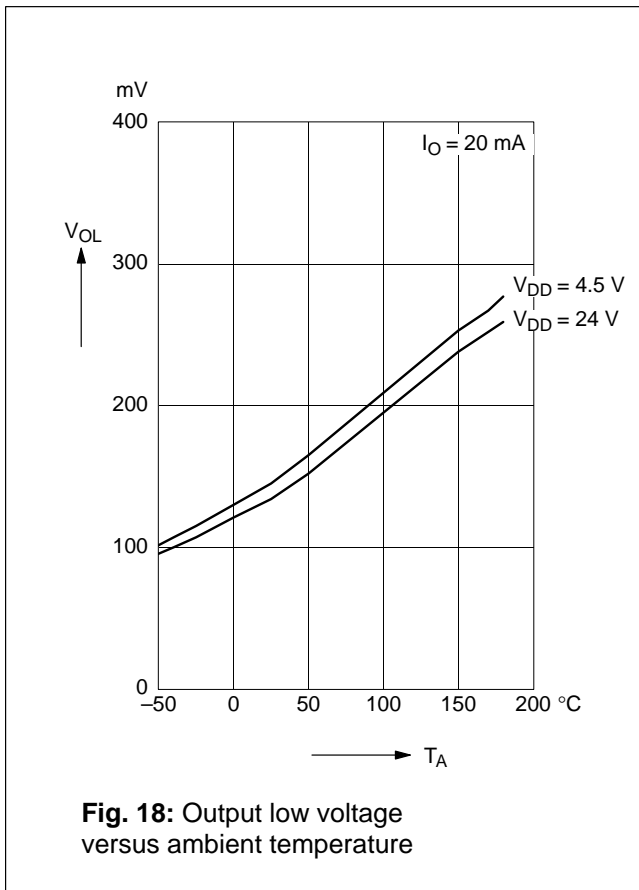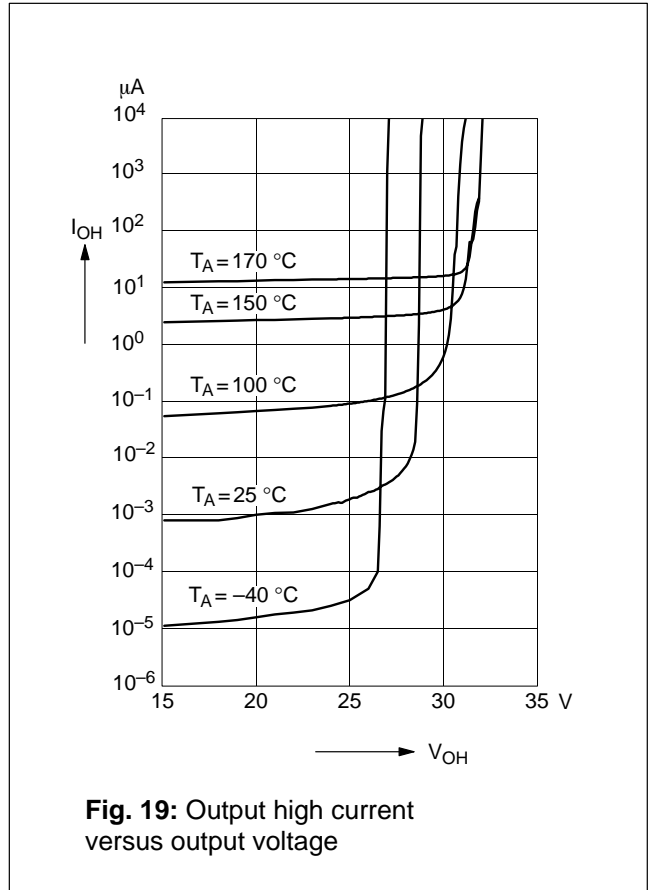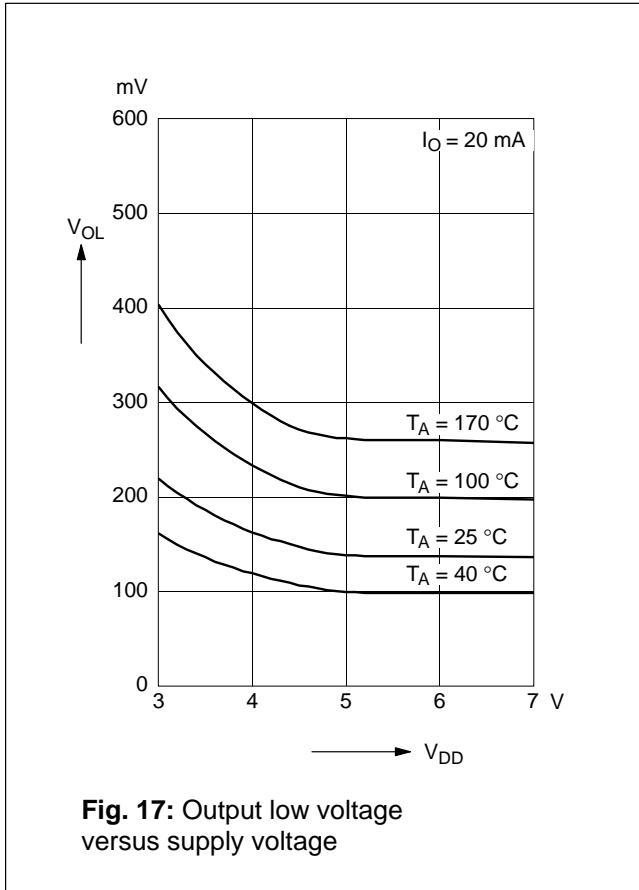**Fig. 8:** Recommended pad size for SOT-89A and SOT-89B; Dimensions in mm

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Fig. 9: Magnetic switch points versus temperature

Fig. 11: Magnetic switch points versus supply voltage

Fig. 10: Magnetic switch points versus supply voltage

Fig. 12: Supply current versus supply voltage

Fig. 13: Supply current versus supply voltage

Fig. 15: Internal chopper frequency versus ambient temperature

Fig. 14: Supply current versus ambient temperature

Fig. 16: Output low voltage versus supply voltage

Fig. 17: Output low voltage
versus supply voltage

Fig. 19: Output high current
versus output voltage

Fig. 18: Output low voltage
versus ambient temperature

Fig. 20: Output leakage current
versus ambient temperature

Application Notes

Mechanical stress can change the sensitivity of the Hall plates and an offset of the magnetic switching points may result. External mechanical stress on the sensor must be avoided if the sensor is used under back-biased conditions. This piezo sensitivity of the sensor IC cannot be completely compensated for by the switching offset compensation technique.

In order to assure switching the sensor on and off in a back-biased application, the minimum magnetic modulation of the differential field should amount to more than 10% of the magnetic preinduction.

If the HAL320 sensor IC is used in back-biased applications, please contact our Application Department. They will provide assistance in avoiding applications which may induce stress to the ICs. This stress may cause drifts of the magnetic parameters indicated in this data sheet.

For electromagnetic immunity, it is recommended to apply a 4.7 nF capacitor between V_{DD} (pin 1) and Ground (pin 2). For automotive applications, a 220 Ω series resistor to pin 1 is recommended. Because of the I_{DD} peak at 3.5 V, the series resistor should not be greater than 270 Ω. The series resistor and the capacitor should be placed as close as possible to the IC. For optimal EMC behavior, the test circuits in Fig. 21 and Fig. 22 are recommended.

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 equations are valid:

– for SOT-89x: $\Delta T = I_{DD} * V_{DD} * R_{thJSB}$

– for TO-92UA: $\Delta T = I_{DD} * V_{DD} * R_{thJA}$

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.

Recommended Test Circuits
for Electromagnetic Compatibility

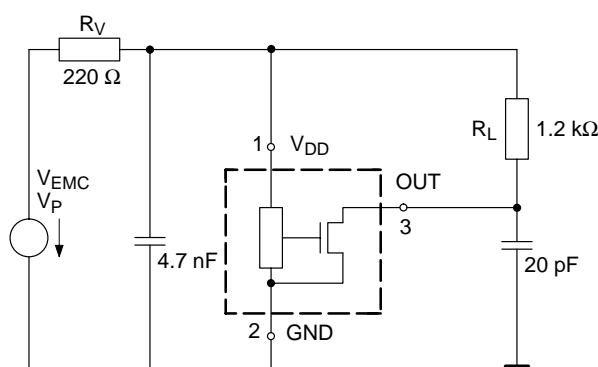Test pulses V_{EMC} corresponding to DIN 40839.

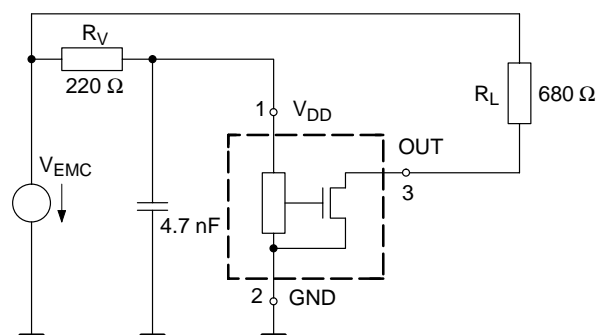**Fig. 21:** Test circuit 2: test procedure for class A

Fig. 22: Test circuit 1: test procedure for class C

Data Sheet History

1. Final data sheet: "HAL 320 Differential Hall Effect Sensor IC", July 15, 1998, 6251-439-1DS. First release of the final data sheet.