

PRELIMINARY DATA SHEET

# HAL400, HAL401 Linear Hall Effect Sensor ICs

Edition June 29, 1998  
6251-346-4PD

 **MICRONAS**  
**INTERMETALL**

## Linear Hall Effect Sensor ICs in CMOS technology

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

### Introduction

The HAL400 and HAL401 are Linear Hall Effect Sensors produced in CMOS technology. The sensors include a temperature-compensated Hall plate with chopped offset compensation, two linear output stages, and protection devices (see Fig. 2).

The output voltage is proportional to the magnetic flux density through the hall plate. The chopped offset compensation leads to stable magnetic characteristics over supply voltage and temperature.

The HAL400 and HAL401 can be used for magnetic field measurements, current measurements, and detection of any mechanical movement. Very accurate angle measurements or distance measurements can also be done. The sensor is very robust and can be used in electrical and mechanical hostile environments.

The HAL400 operates linear in the magnetic field range from  $-75$  mT up to  $75$  mT.

The HAL401 operates linear in the magnetic field range from  $-50$  mT up to  $50$  mT.

The sensor is designed for industrial and automotive applications and operates in the ambient temperature range from  $-40$  °C up to  $150$  °C.

The HAL400 and HAL401 sensors are available in the SMD-package SOT-89A.

### Features:

- switching offset compensation at 147 kHz
- low magnetic offset
- extremely sensitive
- operates from 4.8 to 12 V supply voltage
- wide temperature range  $T_A = -40$  °C to  $+150$  °C
- overvoltage protection
- reverse voltage protection of  $V_{DD}$ -pin
- differential output
- accurate absolute measurements of DC and low frequency magnetic fields
- on-chip temperature compensation
- low  $1/f$ -noise

### Marking Code

Type	Temperature Range		
	A	E	C
HAL400SO	400A	400E	400C
HAL401SO	401A	401E	401C

### Operating Junction Temperature Range ( $T_J$ )

**A:**  $T_J = -40$  °C to  $+170$  °C

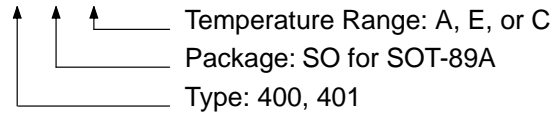
**E:**  $T_J = -40$  °C to  $+100$  °C

**C:**  $T_J = 0$  °C to  $+100$  °C

The relationship between ambient temperature ( $T_A$ ) and junction temperature ( $T_J$ ) is explained on page 15.

### Hall Sensor Package Codes

HALXXXPA-T



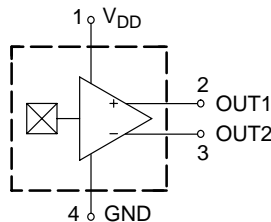
Example: **HAL401SO-E**

- Type: 401
- Package: SOT-89A
- 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".

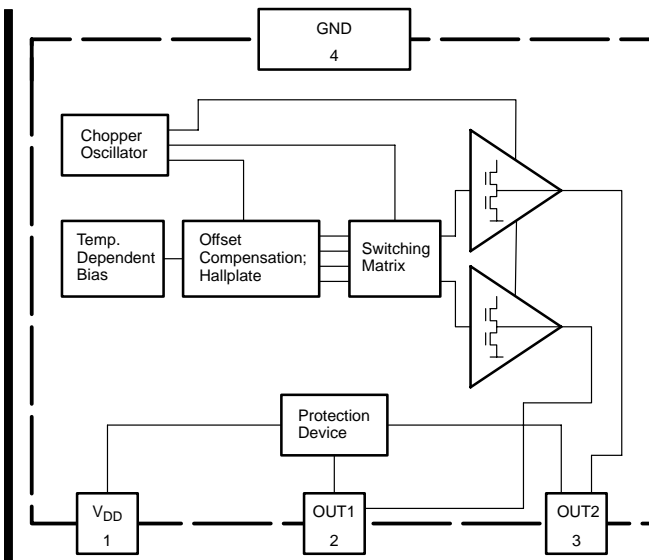
### Solderability

- Package SOT-89A: according to IEC68-2-58



**Fig. 1:** Pin configuration

**Functional Description**



**Fig. 2:** Block diagram of the HAL400 (top view)

The Linear Hall Sensor measures constant and low frequency magnetic flux densities accurately. The differential output voltage  $V_{OUTDIF}$  (difference of the voltages on pin 2 and pin 3) is proportional to the magnetic flux density passing vertically through the sensitive area of the chip. The common mode voltage  $V_{CM}$  (average of the voltages on pin 2 and pin 3) of the differential output amplifier is a constant 2.2 V.

The differential output voltage consists of two components due to the switching offset compensation technique. The average of the differential output voltage represents the magnetic flux density. This component is overlaid by a differential AC signal at a typical frequency of 147 kHz. The AC signal represents the internal offset voltages of amplifiers and hall plates that are influenced by mechanical stress and temperature cycling.

External filtering or integrating measurement can be done to eliminate the AC component of the signal. Resultingly, the influence of mechanical stress and temperature cycling is suppressed. No adjustment of magnetic offset is needed.

The sensitivity is stabilized over a wide range of temperature and supply voltage due to internal voltage regulation and circuits for temperature compensation.

**Offset Compensation (see Fig. 3)**

The Hall Offset Voltage is the residual voltage measured in absence of a magnetic field (zero-field residual voltage). This voltage is caused by mechanical stress and can be modeled by a displacement of the connections for voltage measurement and/or current supply.

Compensation of this kind of offset is done by cyclic commutating the connections for current flow and voltage measurement.

– First cycle:

The hall supply current flows between points 4 and 2. In the absence of a magnetic field,  $V_{13}$  is the Hall Offset Voltage ( $+V_{Offs}$ ). In case of a magnetic field,  $V_{13}$  is the sum of the Hall voltage ( $V_H$ ) and  $V_{Offs}$ .

$$V_{13} = V_H + V_{Offs}$$

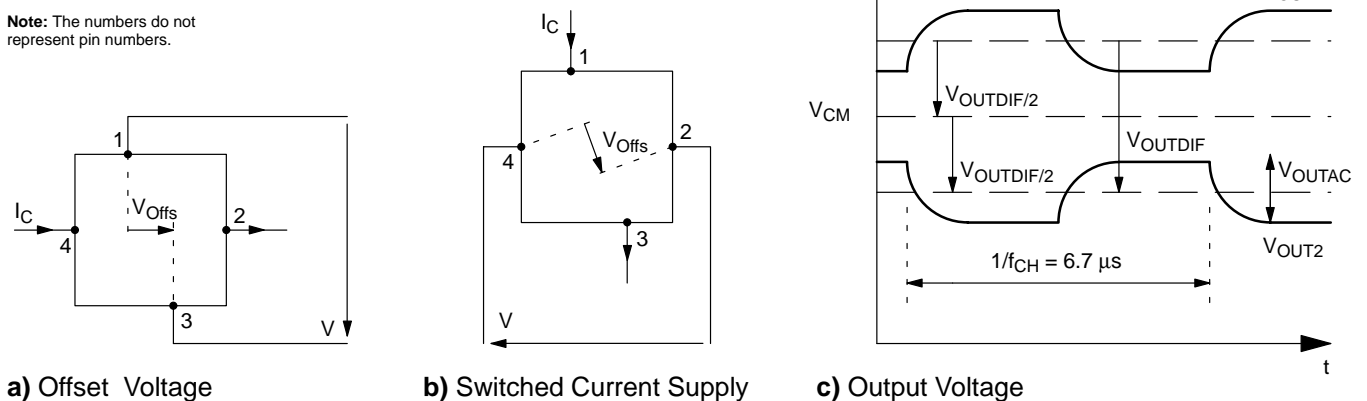
– Second cycle:

The hall supply current flows between points 1 and 3. In the absence of a magnetic field,  $V_{24}$  is the Hall Offset Voltage with negative polarity ( $-V_{Offs}$ ). In case of a magnetic field,  $V_{24}$  is the difference of the Hall voltage ( $V_H$ ) and  $V_{Offs}$ .

$$V_{24} = V_H - V_{Offs}$$

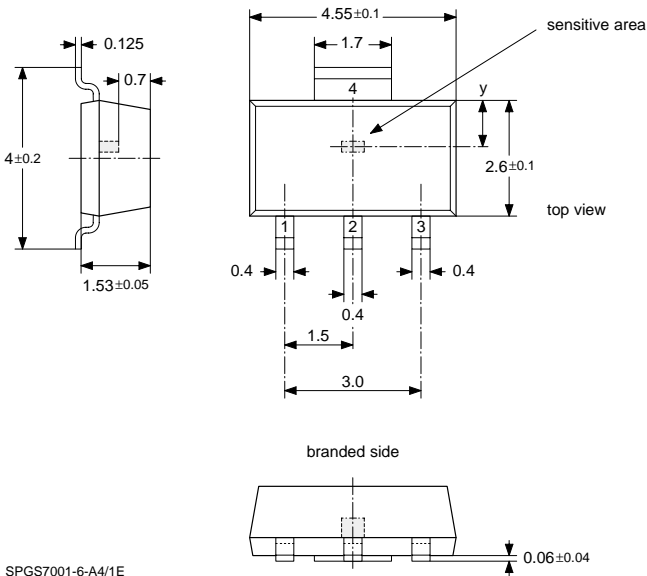
In the first cycle, the output shows the sum of the Hall voltage and the offset; in the second, the difference of both. The difference of the mean values of  $V_{OUT1}$  and  $V_{OUT2}$  ( $V_{OUTDIF}$ ) is equivalent to  $V_{Hall}$ .

**Note:** The numbers do not represent pin numbers.



**Fig. 3:** Hall Offset Compensation

### Outline Dimensions



### Dimensions of Sensitive Area

0.37 mm x 0.17 mm

### Position of Sensitive Area

#### SOT-89A

$x = 0 \pm 0.2 \text{ mm}$

$y = 0.98 \text{ mm} \pm 0.2 \text{ mm}$

x is referenced to the center of the package

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

### Absolute Maximum Ratings

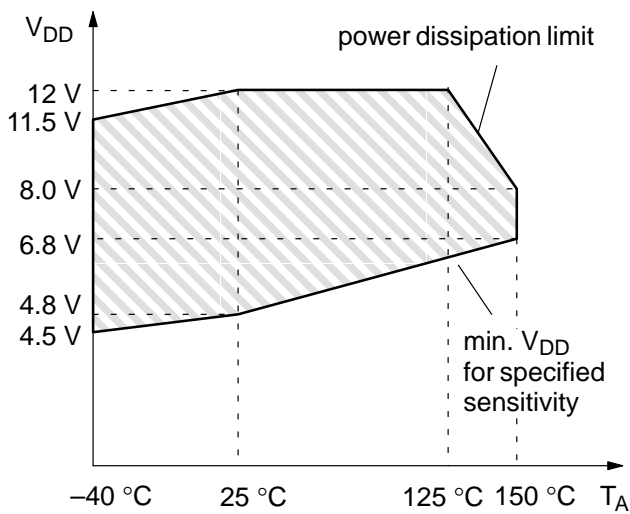
Symbol	Parameter	Pin No.	Min.	Max.	Unit
$V_{DD}$	Supply Voltage	1	-12	12	V
$-I_{DD}$	Reverse Supply Current	1	-	50 <sup>1)</sup>	mA
$I_{DDZ}$	Supply Current through Protection Device	1	-300 <sup>2)</sup>	300 <sup>2)</sup>	mA
$V_O$	Output Voltage	2, 3	-0.3	12	V
$I_O$	Continuous Output Current	2, 3	-5	5	mA
$I_{Omax}$	Peak Output Current	2, 3	-	50 <sup>2)</sup>	mA
$I_{OZ}$	Output Current through Protection Device	2, 3	-200 <sup>2)</sup>	200 <sup>2)</sup>	mA
$T_S$	Storage Temperature Range		-65	150	°C
$T_J$	Junction Temperature Range		-40 -40	150 170 <sup>3)</sup>	°C °C

1) as long as  $T_{Jmax}$  is not exceeded  
 2)  $t \leq 2 \text{ ms}$   
 3)  $t < 1000 \text{ h}$

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	Remarks
$I_O$	Continuous Output Current	2, 3	-2.25	2.25	mA	$T_J = 25\text{ }^\circ\text{C}$
$I_O$	Continuous Output Current	2, 3	-1	1	mA	$T_J = 170\text{ }^\circ\text{C}$
$C_L$	Load Capacitance	2, 3	-	1	nF	
B	Magnetic Field Range		-75	75	mT	for HAL400
B	Magnetic Field Range		-50	50	mT	for HAL401



**Fig. 5:** Recommended Operating Supply Voltage

## Electrical and Magnetic Characteristics

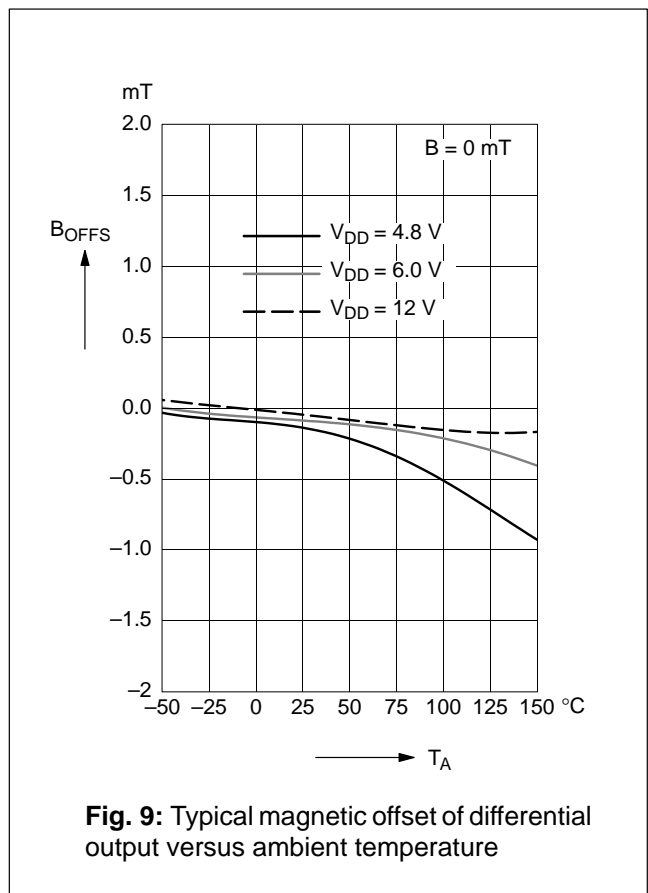
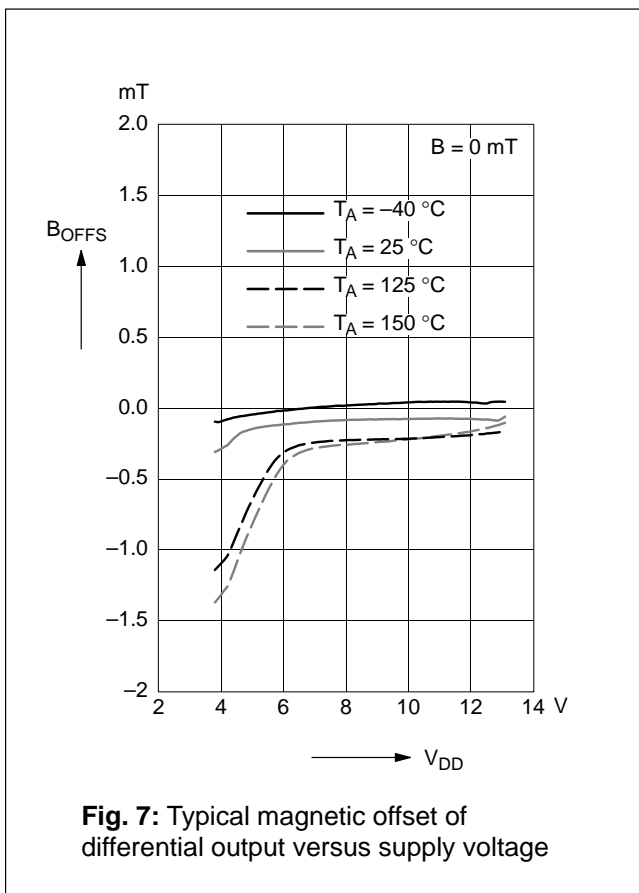
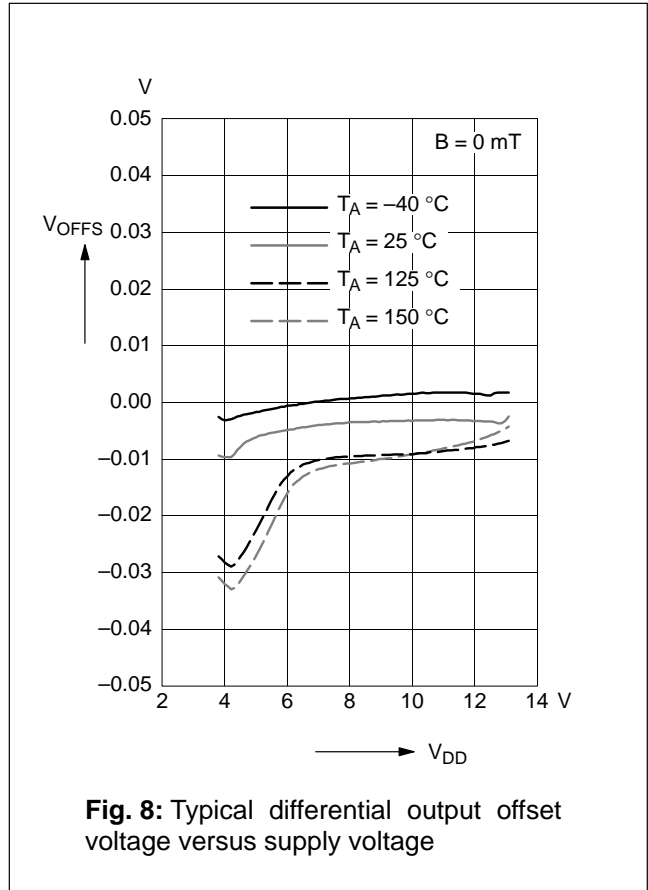
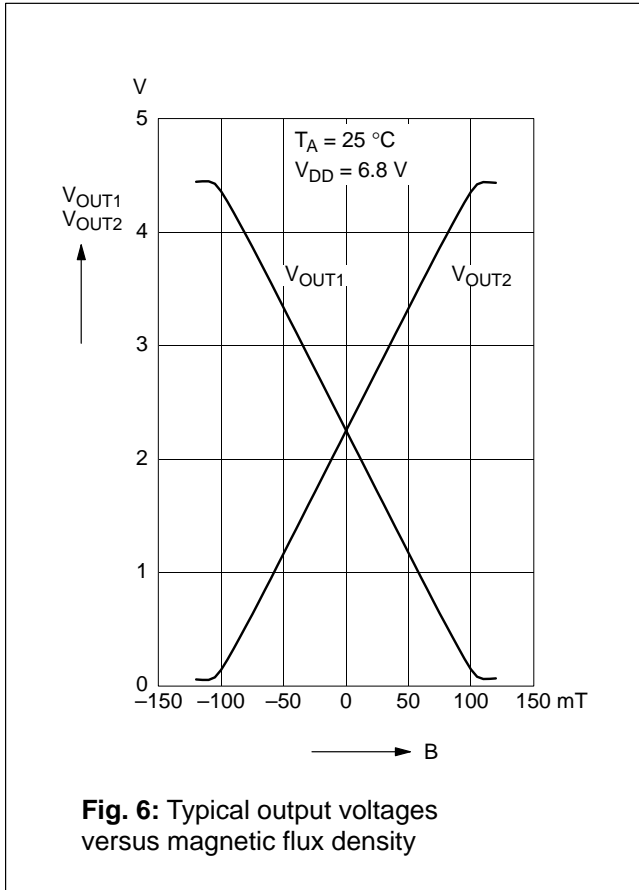
at Recommended Operation Conditions (Fig. 5 for  $T_A$  and  $V_{DD}$ ) as not otherwise specified in the column "Conditions".

Typical characteristics:  $T_J = 25\text{ }^\circ\text{C}$ ,  $V_{DD} = 6.8\text{ V}$  and  $-75\text{ mT} < B < 75\text{ mT}$  for HAL400

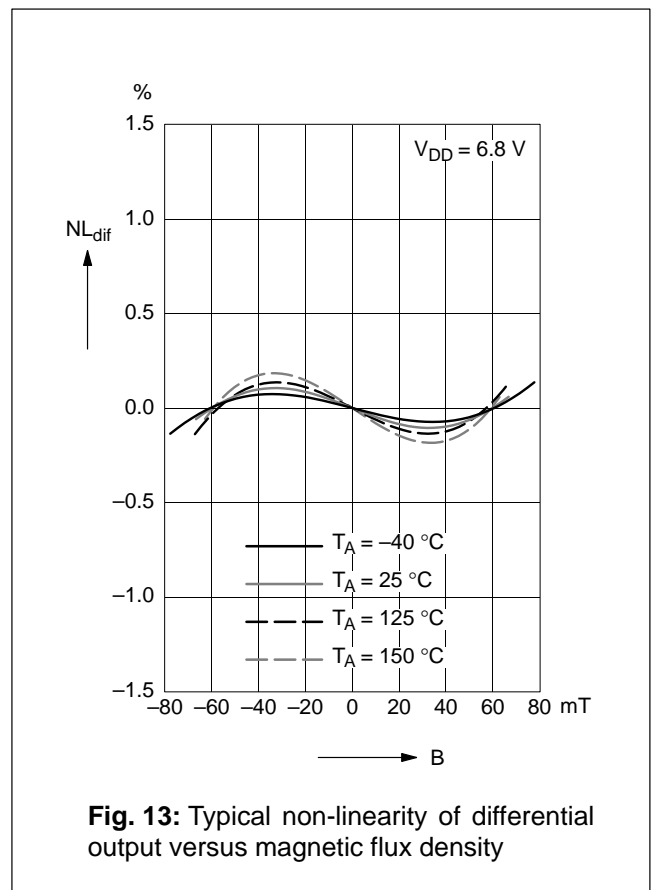
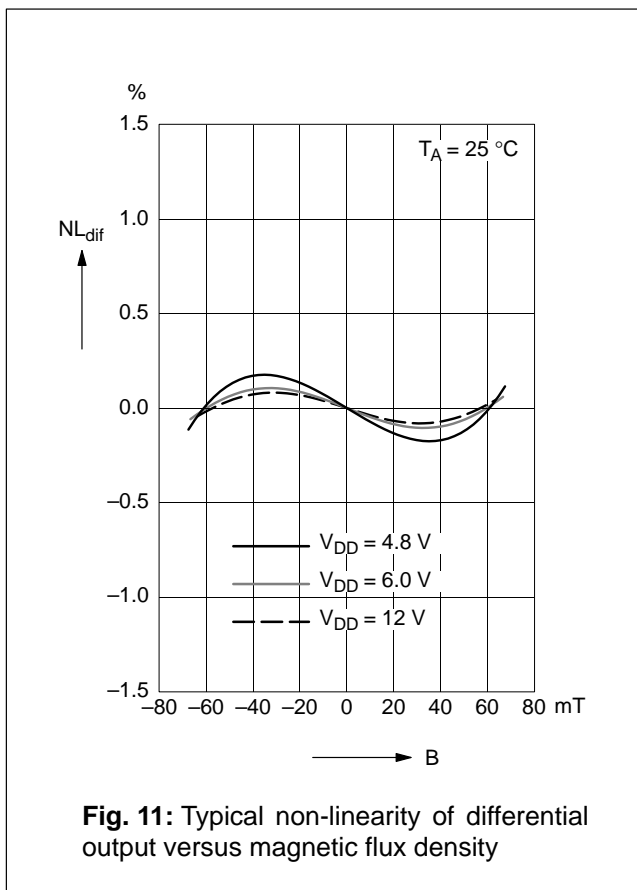
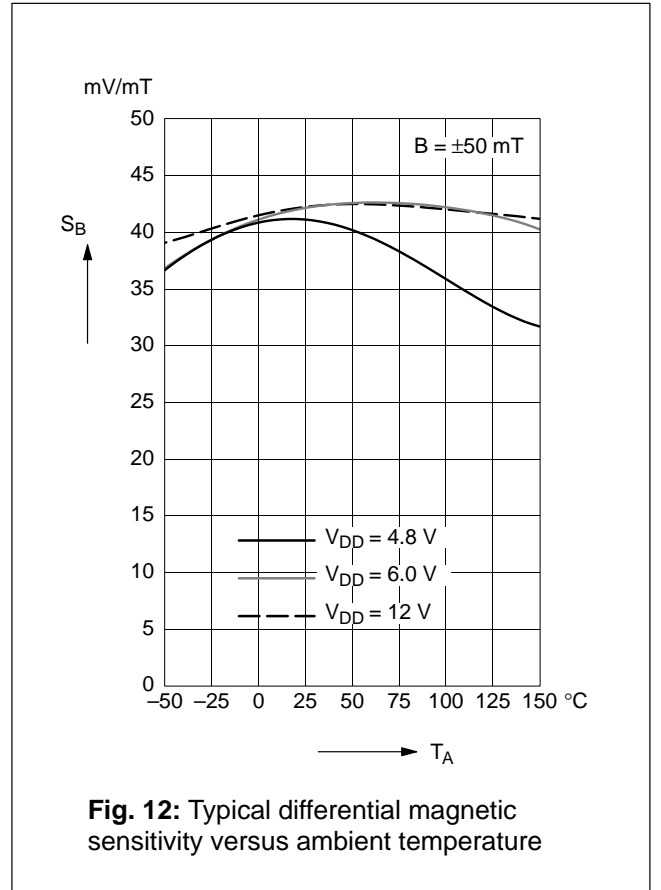
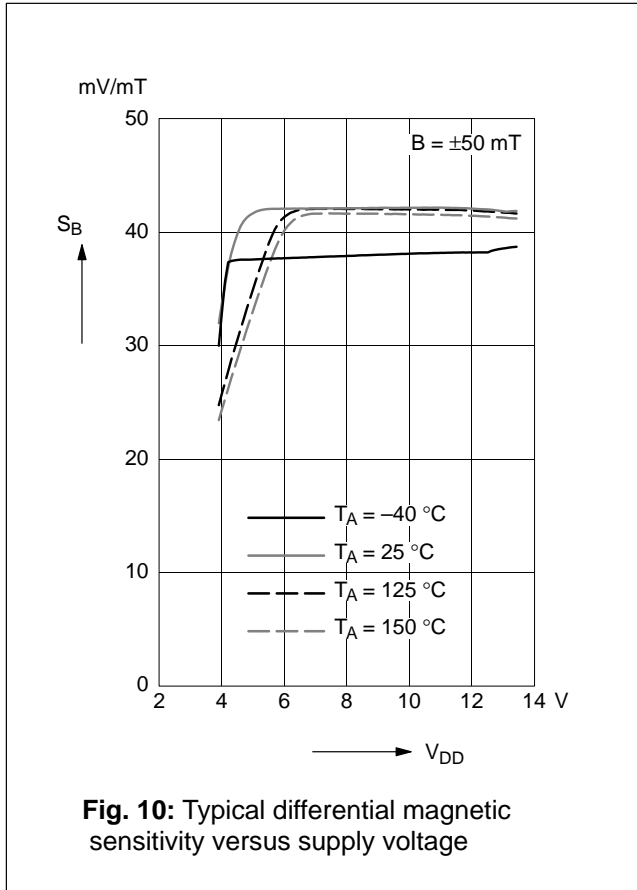
$T_J = 25\text{ }^\circ\text{C}$ ,  $V_{DD} = 6.8\text{ V}$  and  $-50\text{ mT} < B < 50\text{ mT}$  for HAL401

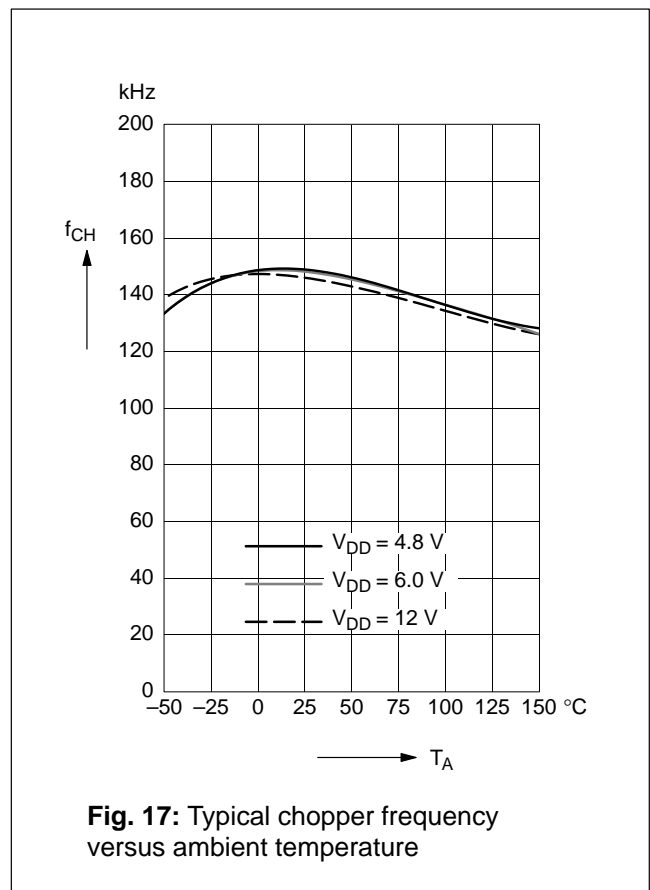
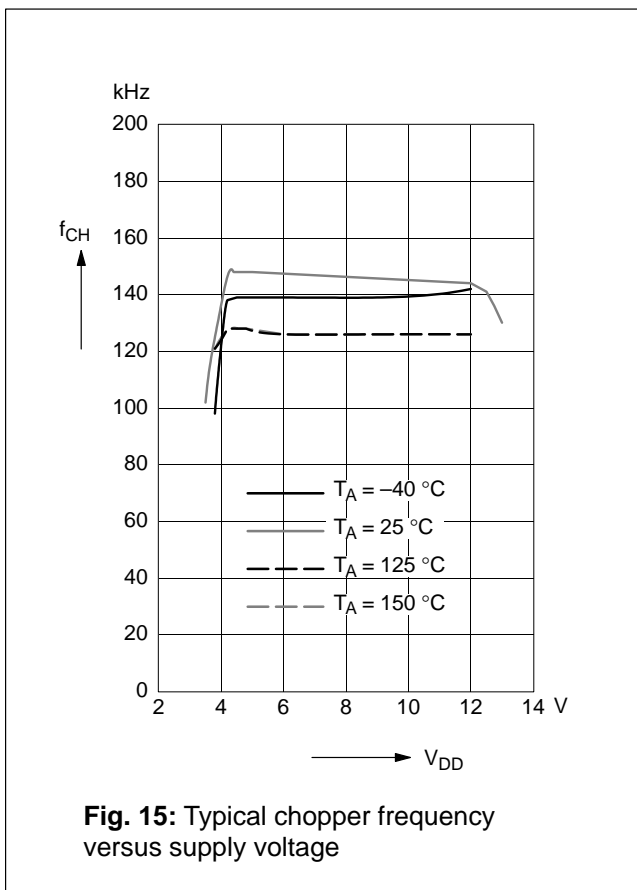
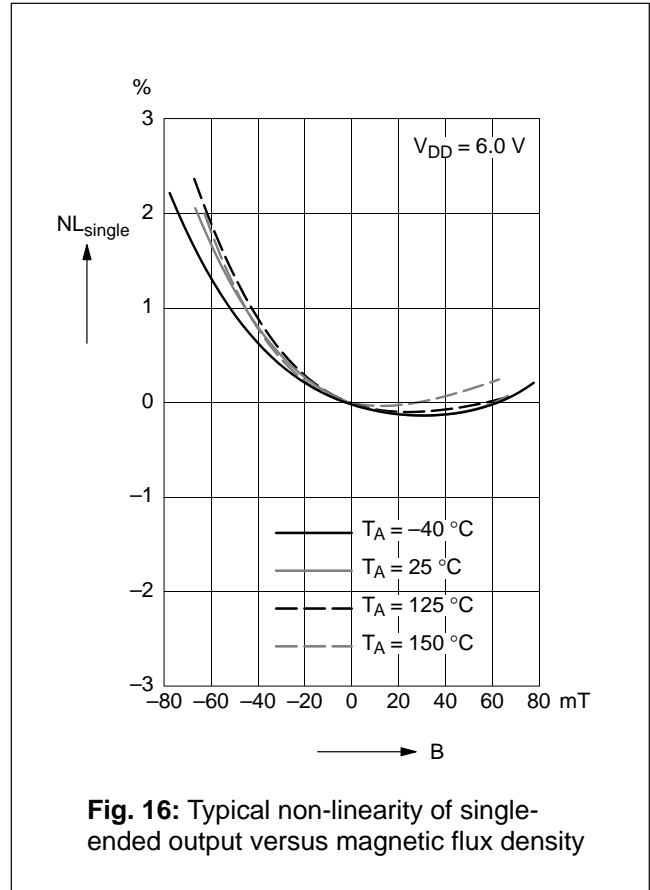
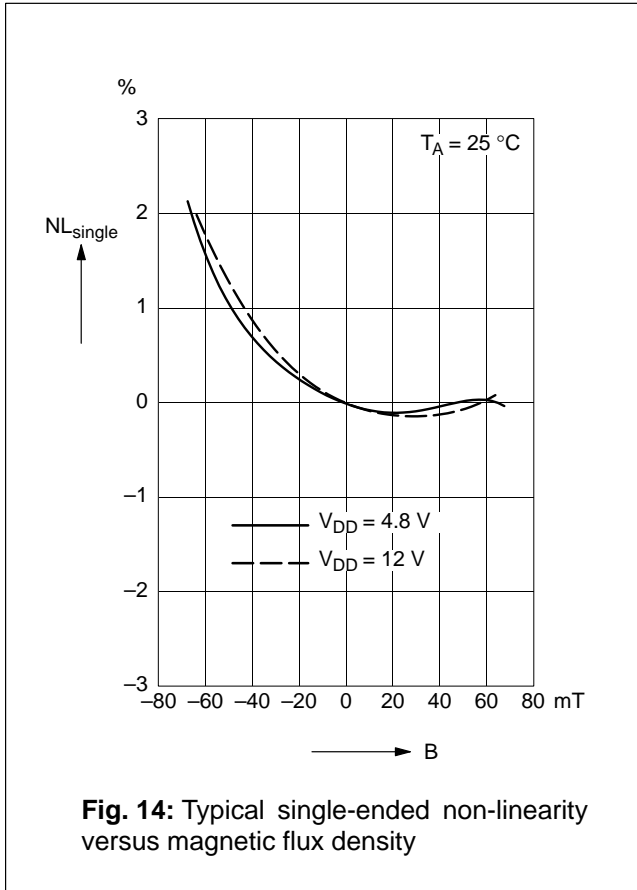
Symbol	Parameter	Pin No.	Min.	Typ.	Max.	Unit	Conditions
$I_{DD}$	Supply Current	1	11	14.5	17.1	mA	$T_J = 25\text{ }^\circ\text{C}$ , $I_{OUT1,2} = 0\text{ mA}$
$I_{DD}$	Supply Current over Temperature Range	1	9	14.5	18.5	mA	$I_{OUT1,2} = 0\text{ mA}$
$V_{CM}$	Common Mode Output Voltage $V_{CM} = (V_{OUT1} + V_{OUT2}) / 2$	2, 3	2.1	2.2	2.3	V	$I_{OUT1,2} = 0\text{ mA}$ ,
CMRR	Common Mode Rejection Ratio	2, 3	-2	0	2	mV/V	$I_{OUT1,2} = 0\text{ mA}$ , CMRR is limited by the influence of power dissipation.
$S_B$	Differential Magnetic Sensitivity $S_B = \Delta V_{OUTDIF} / \Delta B$ $V_{OUTDIF} = V_{OUT1} - V_{OUT2}$	2-3	37	42.5	50	mV/mT	<b>for HAL 400:</b> $-60\text{ mT} < B < 60\text{ mT}$ , $T_J = 25\text{ }^\circ\text{C}$
$S_B$	Differential Magnetic Sensitivity	2-3	37	42.5	50	mV/mT	<b>for HAL 401:</b> $-50\text{ mT} < B < 50\text{ mT}$ , $T_J = 25\text{ }^\circ\text{C}$
$S_B$	Differential Magnetic Sensitivity over Temperature Range	2-3	33	42.5	50	mV/mT	<b>for HAL 400:</b> $-60\text{ mT} < B < 60\text{ mT}$
$S_B$	Differential Magnetic Sensitivity over Temperature Range	2-3	33	42.5	50	mV/mT	<b>for HAL 401:</b> $-50\text{ mT} < B < 50\text{ mT}$
$B_{offset}$	Magnetic Offset	2-3	-1.0	-0.2	1.0	mT	<b>for HAL 400:</b> $B = 0\text{ mT}$ , $I_{OUT1,2} = 0\text{ mA}$ , $T_J = 25\text{ }^\circ\text{C}$
$B_{offset}$	Magnetic Offset over Temperature	2-3	-1.25	-0.2	1.25	mT	<b>for HAL 400:</b> $B = 0\text{ mT}$ , $I_{OUT1,2} = 0\text{ mA}$
$B_{offset}$	Magnetic Offset over Temperature	2-3	-1.5	-0.2	1.5	mT	<b>for HAL 401:</b> $B = 0\text{ mT}$ , $I_{OUT1,2} = 0\text{ mA}$
$\Delta B_{offset} / \Delta T$	Magnetic Offset Change		-15	0	15	$\mu\text{T/K}$	<b>for HAL 400:</b> $B = 0\text{ mT}$ , $I_{OUT1,2} = 0\text{ mA}$
$\Delta B_{offset} / \Delta T$	Magnetic Offset Change		-25	0	25	$\mu\text{T/K}$	<b>for HAL 401:</b> $B = 0\text{ mT}$ , $I_{OUT1,2} = 0\text{ mA}$
BW	Bandwidth (-3 dB)	2-3	-	10	-	kHz	without external Filter <sup>1)</sup>
$NL_{dif}$	Non-Linearity of Differential Output	2-3	-	0.5	1.5	%	<b>for HAL 400:</b> $-60\text{ mT} < B < 60\text{ mT}$
$NL_{dif}$	Non-Linearity of Differential Output	2-3	-	0.5	2	%	<b>for HAL 401:</b> $-50\text{ mT} < B < 50\text{ mT}$
$NL_{single}$	Non-Linearity of Single Ended Output	2, 3	-	2	-	%	
$f_{CH}$	Chopper Frequency	2, 3	110	147	170	kHz	$T_J = 25\text{ }^\circ\text{C}$
$f_{CH}$	Chopper Frequency over Temp.	2, 3	80	147	180	kHz	
$V_{OUTACpp}$	Peak-to-Peak AC Output Voltage	2, 3	-	0.6	0.8	V	<b>for HAL 400</b>
$V_{OUTACpp}$	Peak-to-Peak AC Output Voltage	2, 3	-	0.6	1.3	V	<b>for HAL 401</b>
$n_{meff}$	Magnetic RMS Differential Broadband Noise	2-3	-	10	-	$\mu\text{T}$	BW = 10 Hz to 10 kHz

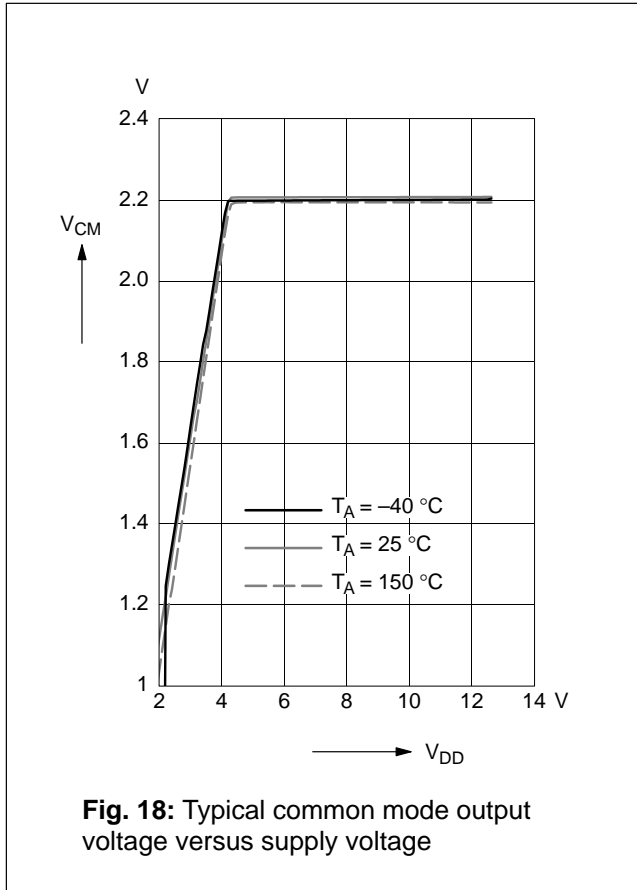
Symbol	Parameter	Pin No.	Min.	Typ.	Max.	Unit	Conditions
$f_{\text{Cflicker}}$	Corner Frequency of 1/f Noise	2-3	–	10	–	Hz	B = 0 mT
$f_{\text{Cflicker}}$	Corner Frequency of 1/f Noise	2-3	–	100	–	Hz	B = 65 mT
$R_{\text{OUT}}$	Output Impedance	2, 3	–	30	50	$\Omega$	$I_{\text{OUT}1,2} \leq 2.5 \text{ mA}$ , $T_J = 25 \text{ }^\circ\text{C}$ , $V_{\text{DD}} = 6.8 \text{ V}$
$R_{\text{OUT}}$	Output Impedance over Temperature	2, 3	–	30	150	$\Omega$	$I_{\text{OUT}1,2} \leq 2.5 \text{ mA}$
$R_{\text{thJSB case}}$	Thermal Resistance Junction to Substrate Backside		–	150	200	K/W	Fiberglass Substrate 30 mm x 10 mm x 1.5 mm pad size see Fig. 29
<sup>1)</sup> with external 2 pole filter ( $f_{3\text{db}} = 5 \text{ kHz}$ ), $V_{\text{OUTAC}}$ is reduced to less than 1 mV by limiting the bandwidth							



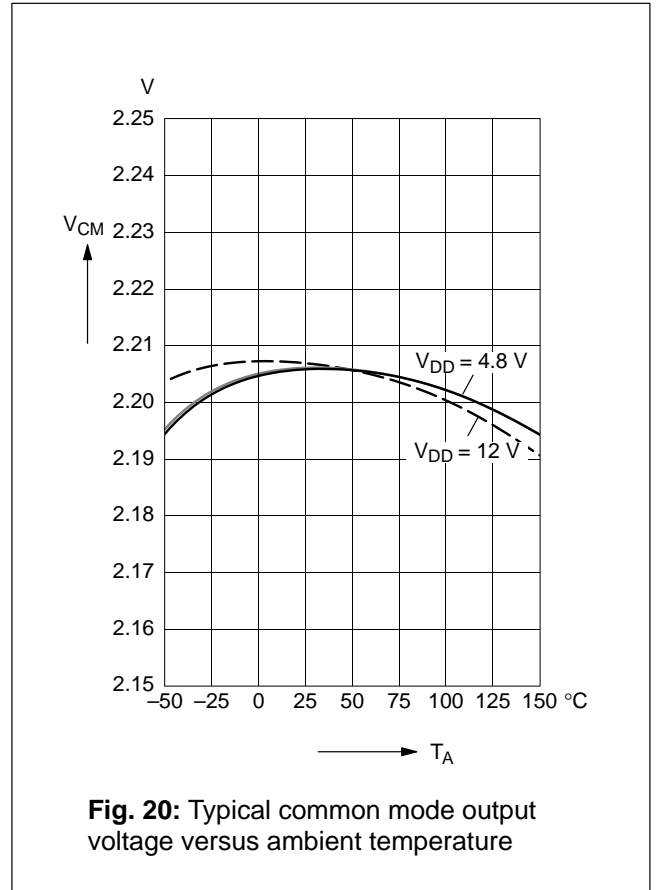




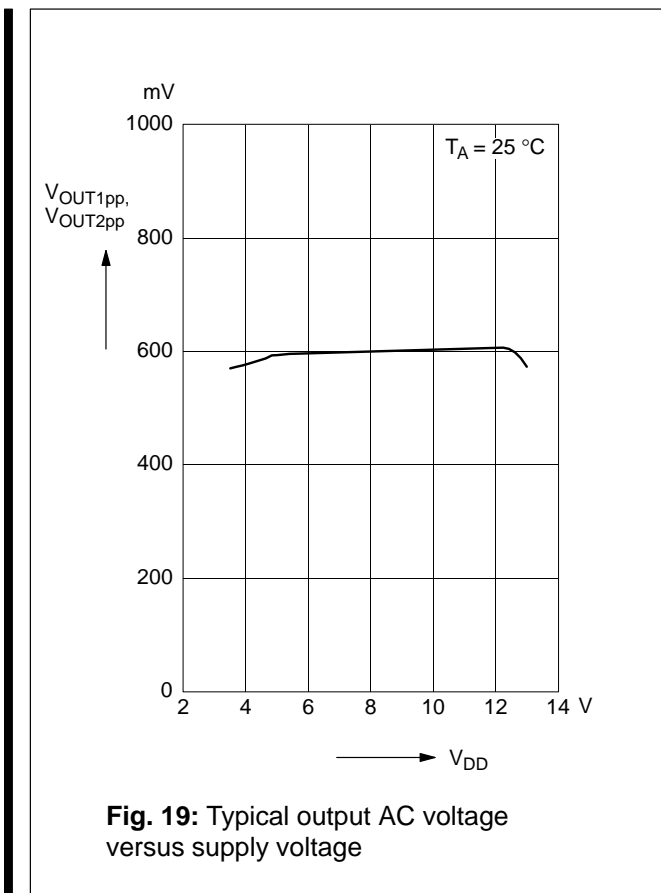




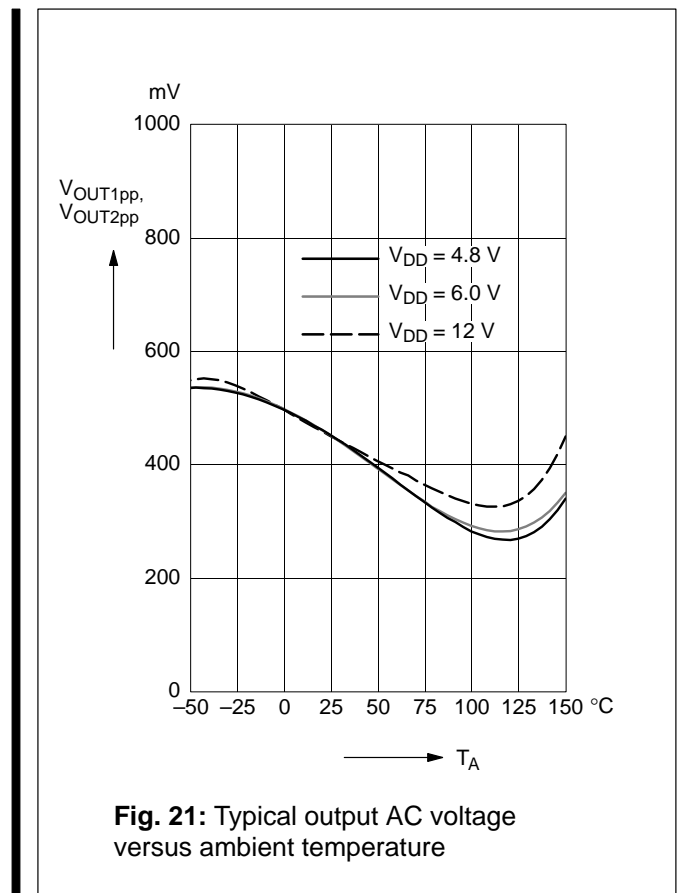
**Fig. 18:** Typical common mode output voltage versus supply voltage



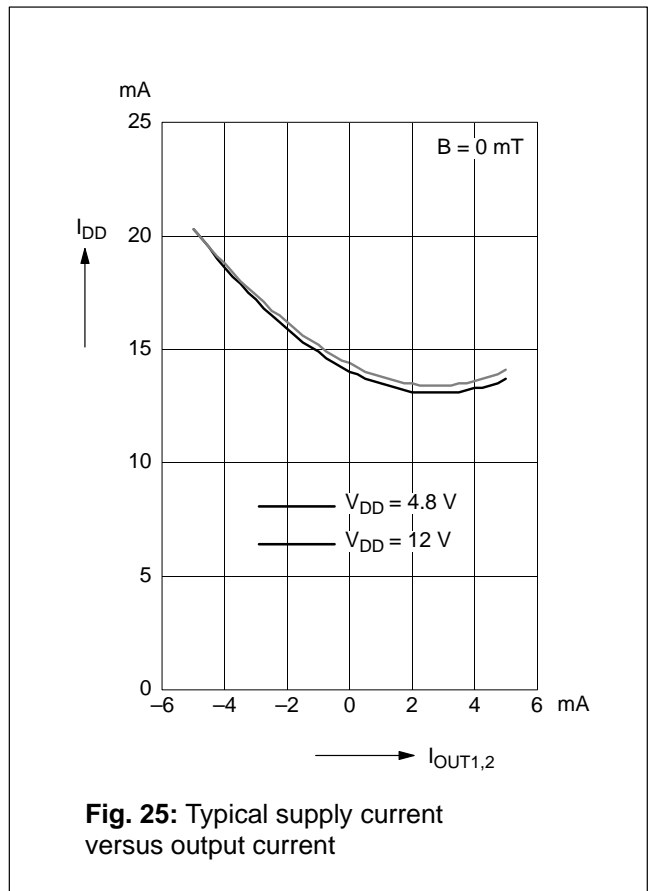
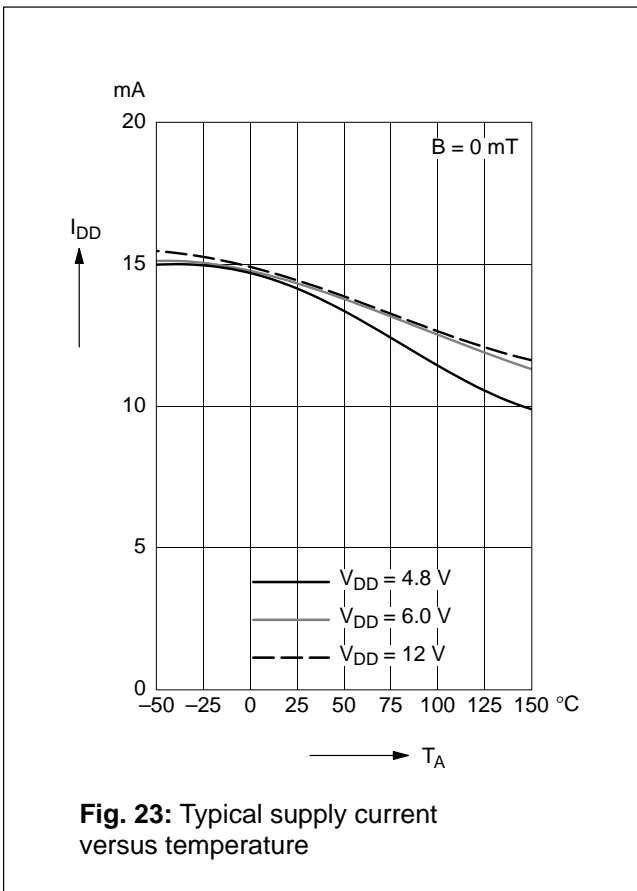
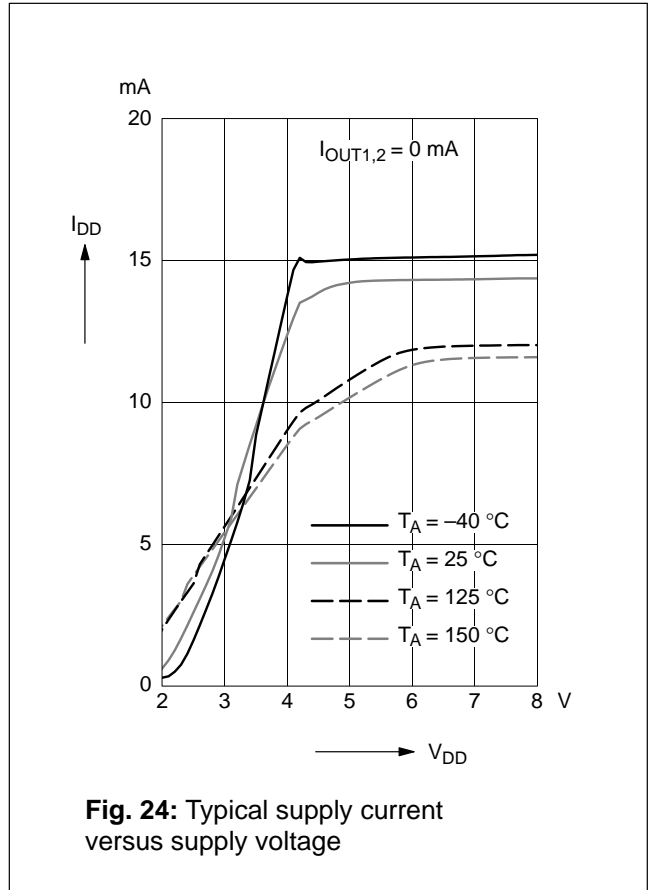
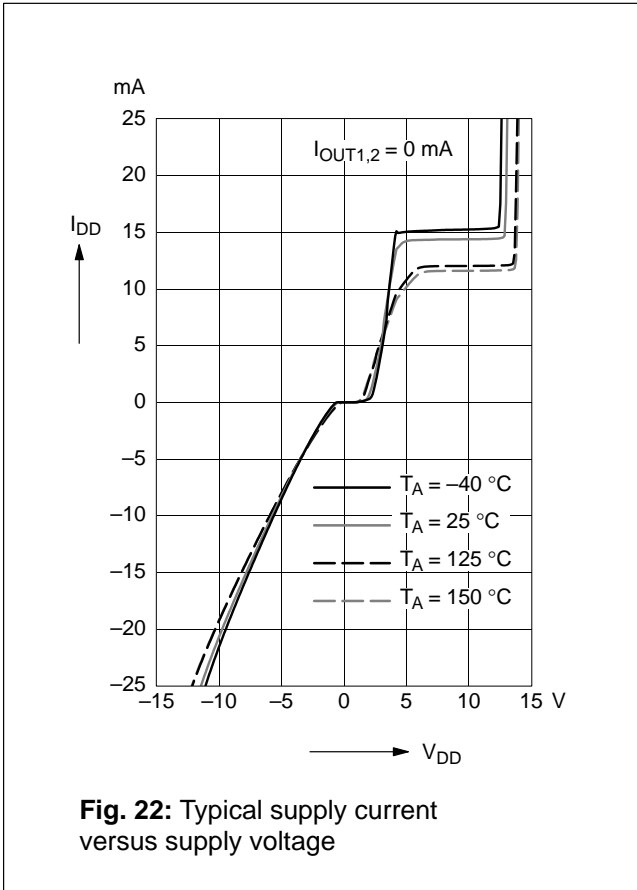
**Fig. 20:** Typical common mode output voltage versus ambient temperature

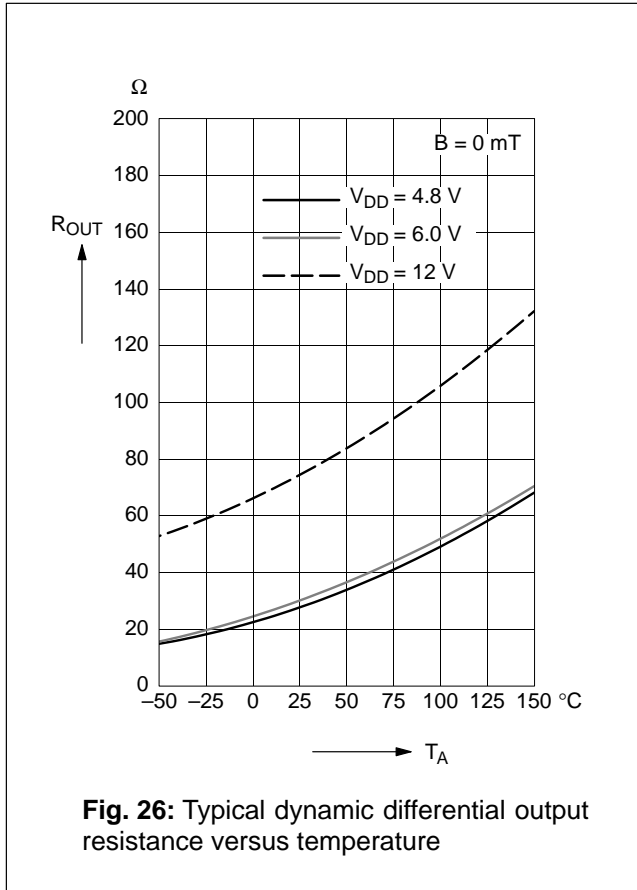


**Fig. 19:** Typical output AC voltage versus supply voltage

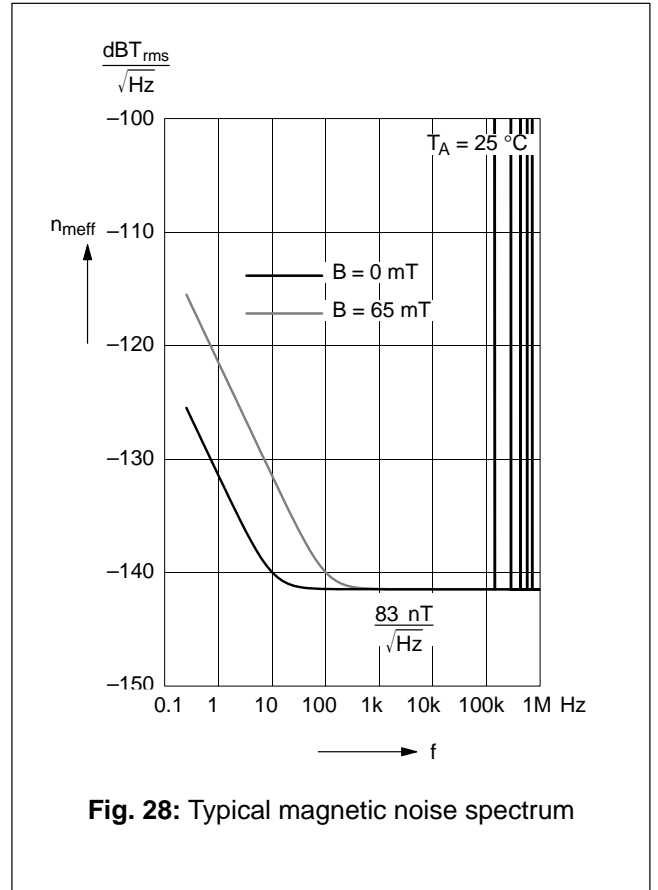


**Fig. 21:** Typical output AC voltage versus ambient temperature

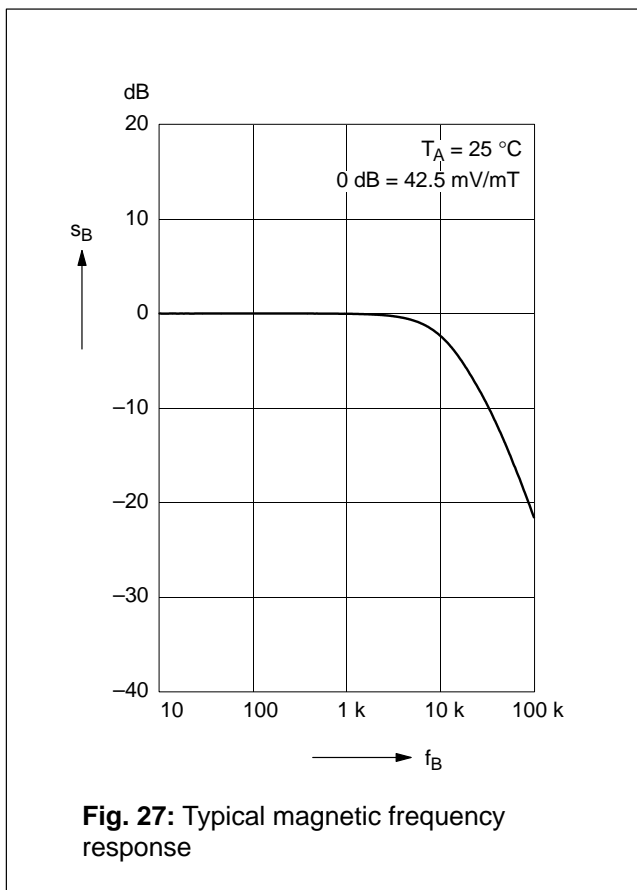




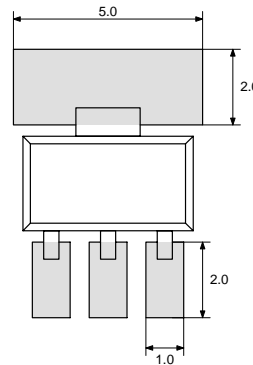
**Fig. 26:** Typical dynamic differential output resistance versus temperature



**Fig. 28:** Typical magnetic noise spectrum



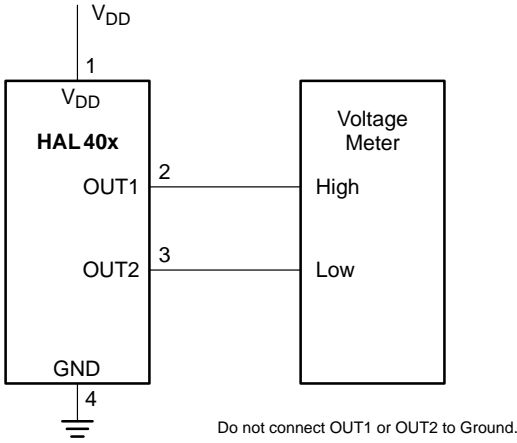
**Fig. 27:** Typical magnetic frequency response



**Fig. 29:** Recommended pad size SOT-89A  
Dimensions in mm

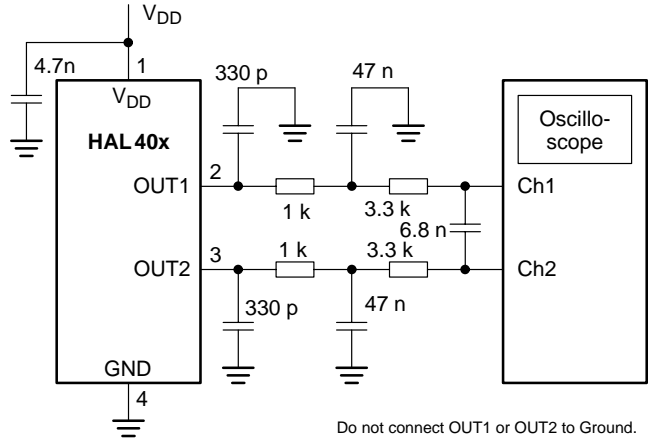
**Application Circuits**

The normal integrating characteristics of a voltmeter is sufficient for signal filtering.

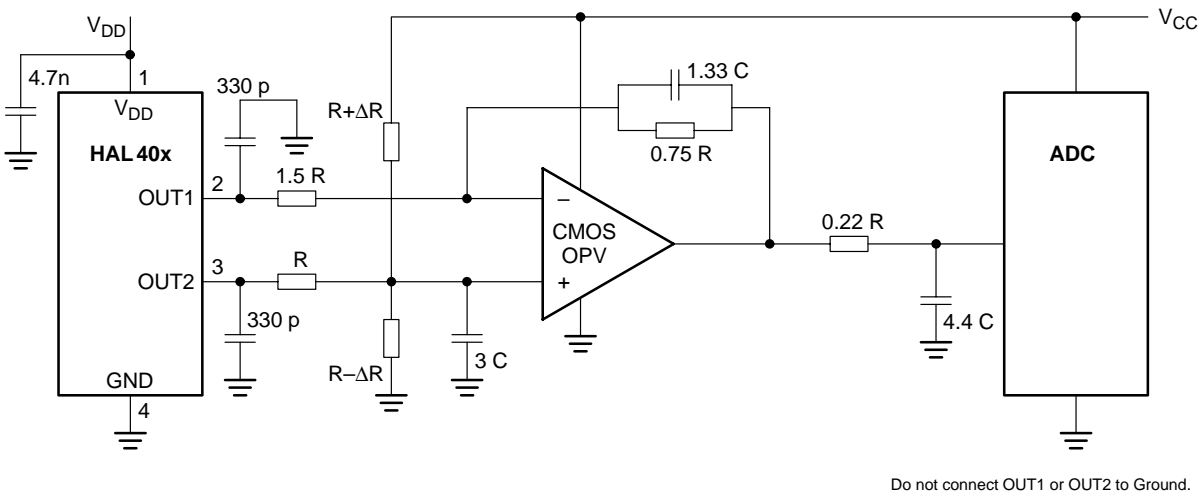


**Fig. 30:** Flux density measurement with voltmeter

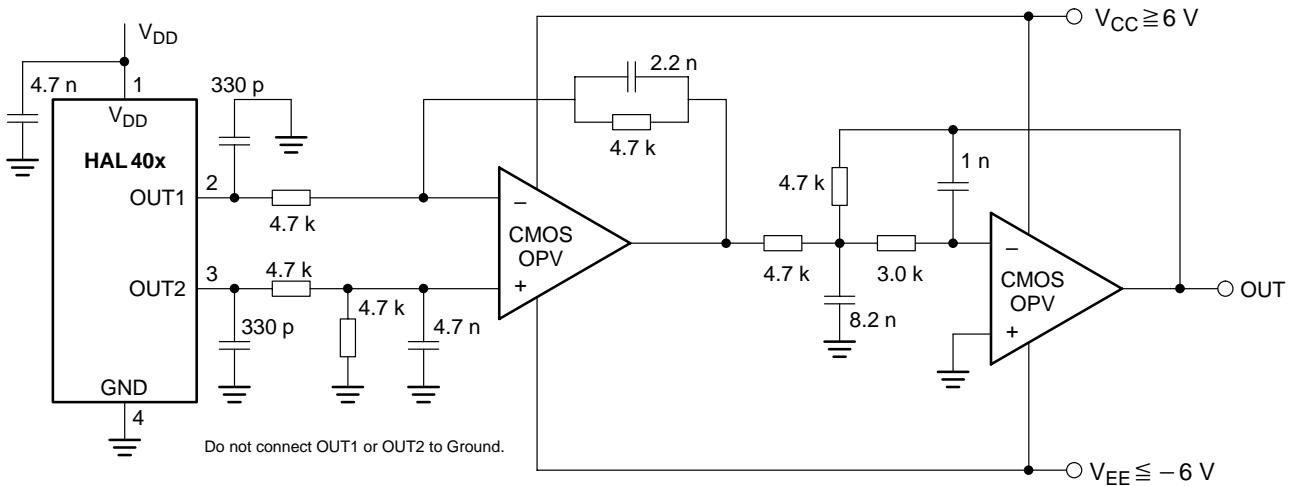
Display the difference between channel 1 and channel 2 to show the Hall voltage. Capacitors 4.7 nF and 330 pF for electromagnetic immunity are recommended.



**Fig. 31:** Filtering of output signals



**Fig. 32:** Differential HAL40x output to single-ended output  
 $R = 10\text{ k}\Omega$ ,  $C = 7.5\text{ nF}$ ,  $\Delta R$  for offset adjustment,  $BW_{-3dB} = 1.3\text{ kHz}$



**Fig. 33:** Differential HAL 40x output to single-ended output (referenced to ground), filter –  $BW_{-3dB} = 14.7 \text{ kHz}$

**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:

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

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.

**Application Notes**

Mechanical stress on the device surface (caused by the package of the sensor module or overmolding) can influence the sensor performance.

The parameter  $V_{OUTACpp}$  (see Fig. 3) increases with external mechanical stress. This can cause linearity errors at the limits of the recommended operation conditions.

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**Data Sheet History**

1. Preliminary data sheet: "HAL400 Linear Hall Effect Sensor IC", March 29, 1994, 6251-346-1PD. First release of the preliminary data sheet.

2. Preliminary data sheet: "HAL400 Linear Hall Effect Sensor IC", Aug. 1, 1995, 6251-346-2PD. Second release of the preliminary data sheet.

Major changes:

- Marking code

3. Preliminary data sheet: "HAL400 Linear Hall Effect Sensor IC", Sept. 3, 1997, 6251-346-3PD. Third release of the preliminary data sheet.

Major changes:

- Electrical and Magnetic Characteristics

- diagram: Typical output voltages versus magnetic flux density

- page 14: "Ambient Temperature"

4. Preliminary data sheet: "HAL400, HAL401 Linear Hall Effect Sensor ICs", June 29, 1998, 6251-346-4PD. Fourth release of the preliminary data sheet.

Major changes:

- additional new type HAL401

- various changes in the electrical and magnetic characteristics

- page 4: package diagram outline dimensions changed

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