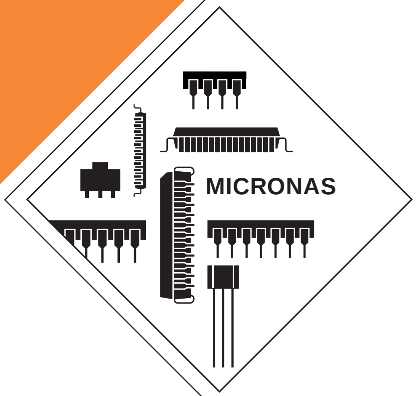
DATA SHEET



HAL401
Linear Hall Effect Sensor IC

Edition June 26, 2002
6251-470-1DS

MICRONAS

Contents

Linear Hall Effect Sensor IC
in CMOS technology

1. Introduction

The HAL 401 is a Linear Hall Effect Sensor produced in CMOS technology. The sensor includes a temperature-compensated Hall plate with choppered offset compensation, two linear output stages, and protection devices (see Fig. 2–1).

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

The HAL 401 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 sensor is designed for industrial and automotive applications and operates in the ambient temperature range from –40 °C up to 150 °C and is available in the SMD-package SOT-89B.

1.1. 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

1.2. Marking Code

Type	Temperature Range	
	A	K
HAL401	401A	401K

1.2.1. Special Marking of Prototype Parts

Prototype parts are coded with an underscore beneath the temperature range letter on each IC. They may be used for lab experiments and design-ins but are not intended to be used for qualification tests or as production parts.

1.3. Operating Junction Temperature Range

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

A: T_J = –40 °C to +170 °C

K: T_J = –40 °C to +140 °C

Note: Due to the high power dissipation at high current consumption, there is a difference between the ambient temperature (T_A) and junction temperature. Please refer section 4.1. on page 14 for details.

1.4. Hall Sensor Package Codes

HAL XXXPA-T

- Temperature Range: A or K
- Package: SF for SOT-89B
- Type: 401

Example: **HAL 401SF-K**

→ Type: 401
→ Package: SOT-89B
→ Temperature Range: T_J = –40 °C to +140 °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”.

1.5. 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.

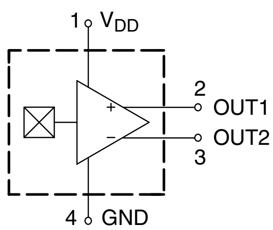


Fig. 1–1: Pin configuration

2. Functional Description

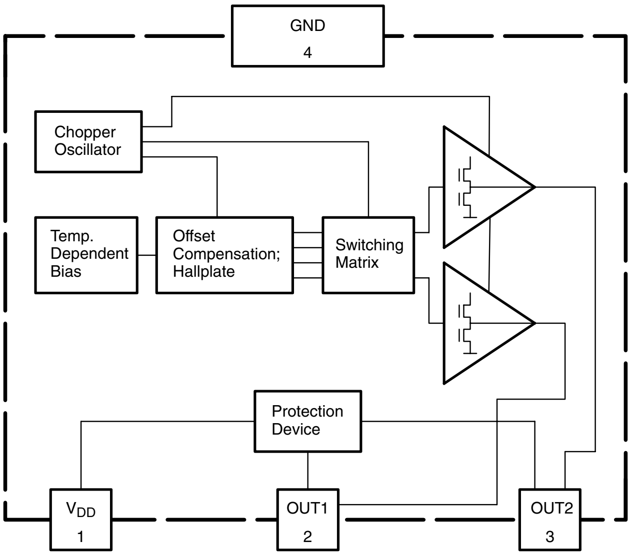


Fig. 2–1: Block diagram of the HAL 401 (top view)

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. 2–2)

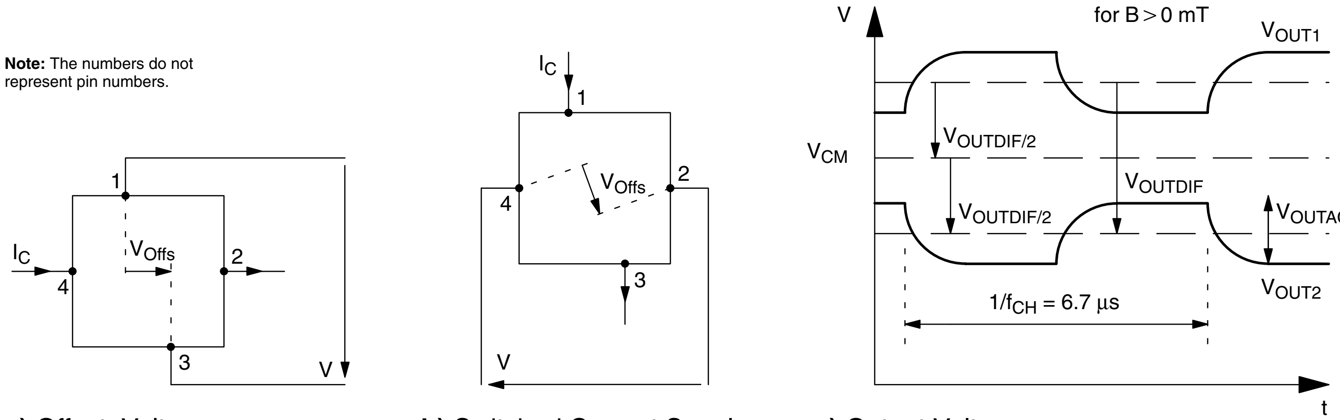
The Hall Offset Voltage is the residual voltage measured in absence of a magnetic field (zero-field residual voltage). This voltage is caused by mechanical stress and can be modeled by a displacement of the connections for voltage measurement and/or current supply.

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}.



a) Offset Voltage **b)** Switched Current Supply **c)** Output Voltage

Fig. 2–2: Hall Offset Compensation

3. Specifications

3.1. Outline Dimensions

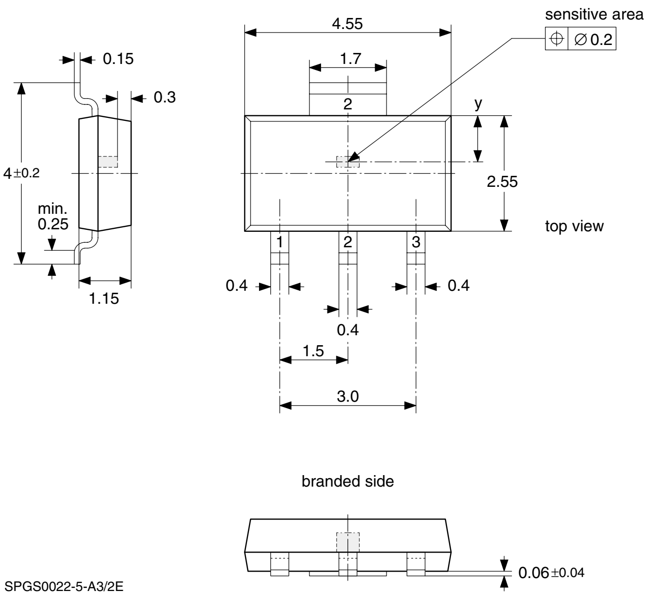


Fig. 3–1:
Plastic Small Outline Transistor Package
(SOT-89B)
Weight approximately 0.035 g
Dimensions in mm

3.2. Dimensions of Sensitive Area

0.37 mm x 0.17 mm

3.3. Positions of Sensitive Areas

	SOT-89B
x	center of the package
y	0.95 mm nominal

Note: For all package diagrams, a mechanical tolerance of ±0.05 mm applies to all dimensions where no tolerance is explicitly given.

3.4. Absolute Maximum Ratings

Symbol	Parameter	Pin No.	Min.	Max.	Unit
V_{DD}	Supply Voltage	1	–12	12	V
V_O	Output Voltage	2, 3	–0.3	12	V
I_O	Continuous Output Current	2, 3	–5	5	mA
T_J	Junction Temperature Range		–40	170	°C

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.

3.4.1. Storage, Moisture Sensitivity Class, and Shelf Life

Storage has no influence on the electrical and magnetic characteristics of the sensors. However, under disadvantageous conditions, extended storage time can lead to alteration of the lead plating, which affects the soldering process.

Moisture Sensitivity Class:

The package SOT-89B achieves level 1 according to J-STD-020A “Moisture/Reflow Sensitivity Classification for Non-hermetic Solid State Surface Mount Devices”. If the sensors are stored at maximum 30 °C and maximum 90% relative humidity no Dry Pack is required.

The permissible storage time (shelf life) of the sensors would be minimum 12 months, beginning from the date of manufacturing, if they are stored in the original packaging at maximum 40 °C ambient temperature and maximum 90% relative humidity.

3.5. 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 °C
I_O	Continuous Output Current	2, 3	–1	1	mA	T_J = 170 °C
C_L	Load Capacitance	2, 3	–	1	nF	
B	Magnetic Field Range		–50	50	mT	

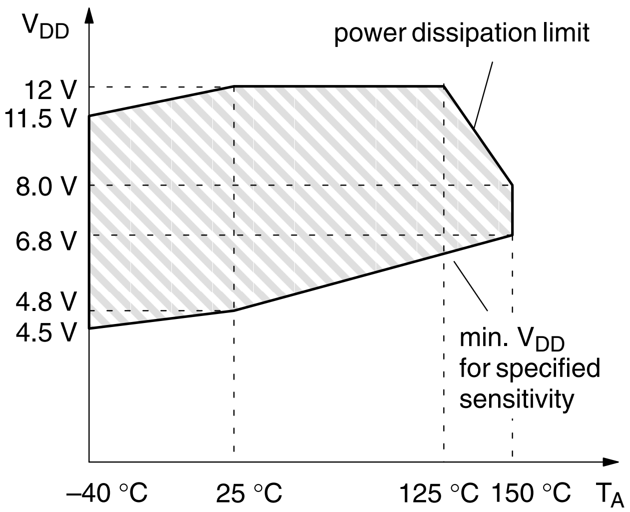


Fig. 3–2: Recommended Operating Supply Voltage

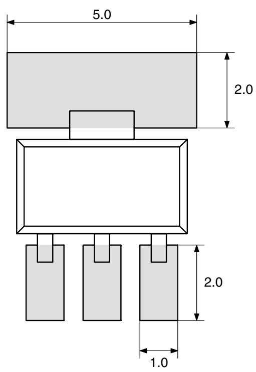


Fig. 3–3: Recommended pad size SOT-89B
Dimensions in mm

3.6. Electrical and Magnetic Characteristics

at Recommended Operation Conditions (Fig. 3–2 for T_A and V_{DD}) as not otherwise specified in the column "Conditions".
Typical characteristics for T_J = 25 °C, V_{DD} = 6.8 V and –50 mT < B < 50 mT

Symbol	Parameter	Pin No.	Min.	Typ.	Max.	Unit	Conditions
I_{DD}	Supply Current	1	11	14.5	17.1	mA	T_J = 25 °C, $I_{OUT1,2}$ = 0 mA
I_{DD}	Supply Current over Temperature Range	1	9	14.5	18.5	mA	$I_{OUT1,2}$ = 0 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 mA,
CMRR	Common Mode Rejection Ratio	2, 3	–2.5	0	2.5	mV/V	$I_{OUT1,2}$ = 0 mA, CMRR is limited by the influence of power dissipation.
S_B	Differential Magnetic Sensitivity	2–3	42	48.5	55	mV/mT	–50 mT < B < 50 mT T_J = 25 °C
S_B	Differential Magnetic Sensitivity over Temperature Range	2–3	37.5	46.5	55	mV/mT	–50 mT < B < 50 mT
B_{offset}	Magnetic Offset over Temperature	2–3	–1.5	–0.2	1.5	mT	B = 0 mT, $I_{OUT1,2}$ = 0 mA
$\Delta B_{OFFSET}/\Delta T$	Magnetic Offset Change		–25	0	25	µT/K	B = 0 mT, $I_{OUT1,2}$ = 0 mA
BW	Bandwidth (–3 dB)	2–3	–	10	–	kHz	without external Filter[1)]
NL_{dif}	Non-Linearity of Differential Output	2–3	–	0.5	2	%	–50 mT < B < 50 mT
NL_{single}	Non-Linearity of Single Ended Output	2, 3	–	2	–	%	
f_{CH}	Chopper Frequency over Temp.	2, 3	–	147	–	kHz	
$V_{OUTACpp}$	Peak-to-Peak AC Output Voltage	2, 3	–	0.6	1.3	V	
n_{meff}	Magnetic RMS Differential Broadband Noise	2–3	–	10	–	µT	BW = 10 Hz to 10 kHz
$f_{Cflicker}$	Corner Frequency of 1/f Noise	2–3	–	10	–	Hz	B = 0 mT
$f_{Cflicker}$	Corner Frequency of 1/f Noise	2–3	–	100	–	Hz	B = 50 mT
R_{OUT}	Output Impedance	2, 3	–	30	50	Ω	$I_{OUT1,2} \leq$ 2.5 mA, T_J = 25 °C, V_{DD} = 6.8 V
R_{OUT}	Output Impedance over Temperature	2, 3	–	30	150	Ω	$I_{OUT1,2} \leq$ 2.5 mA
R_{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. 3–3

[1)] with external 2 pole filter (f_{3db} = 5 kHz), V_{OUTAC} is reduced to less than 1 mV by limiting the bandwith

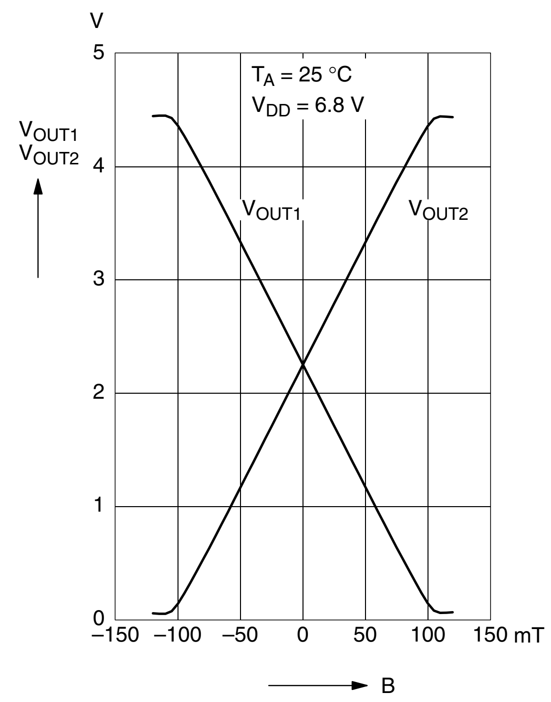


Fig. 3–4: Typical output voltages versus magnetic flux density

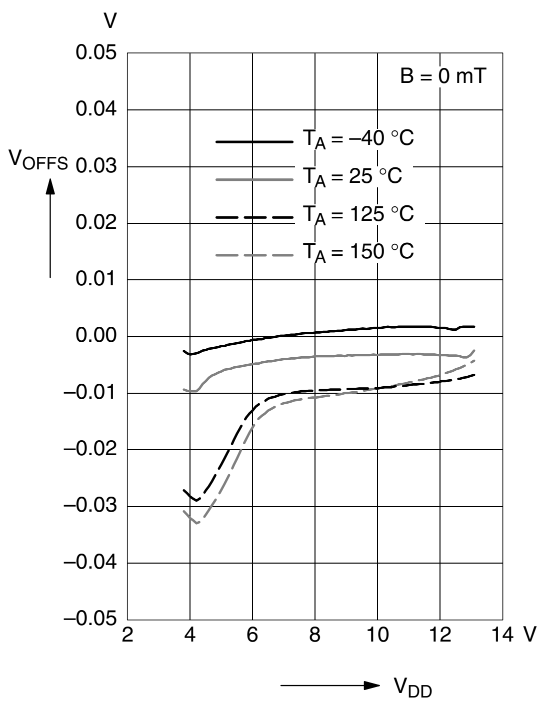


Fig. 3–6: Typical differential output offset voltage versus supply voltage

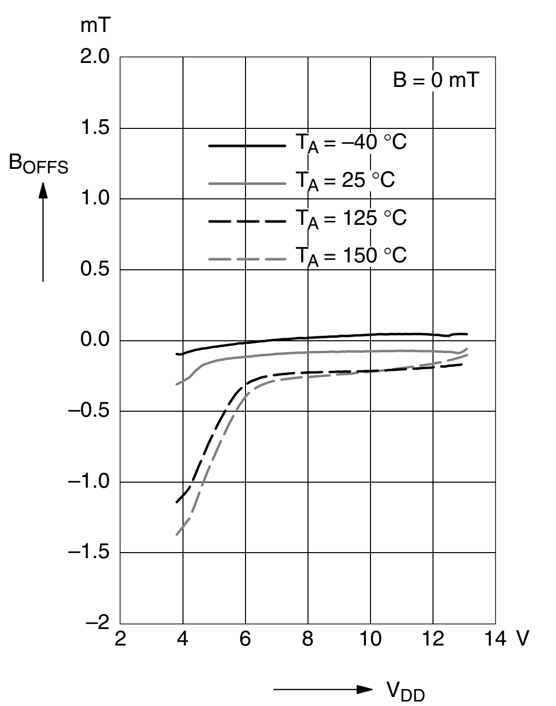


Fig. 3–5: Typical magnetic offset of differential output versus supply voltage

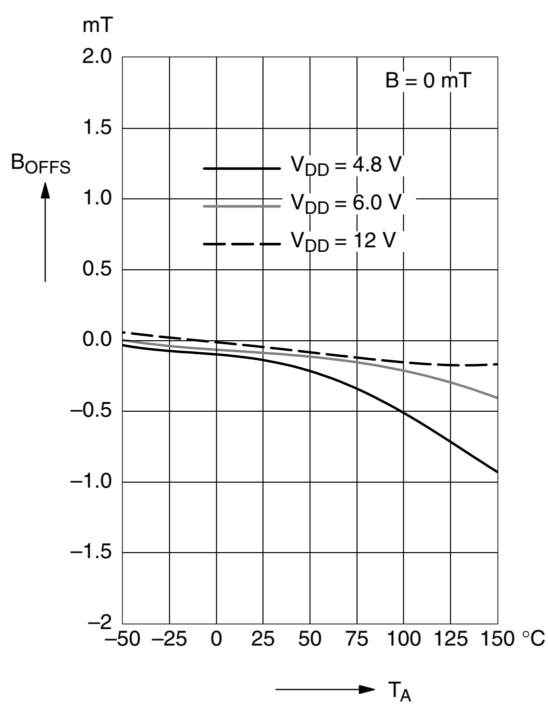


Fig. 3–7: Typical magnetic offset of differential output versus ambient temperature

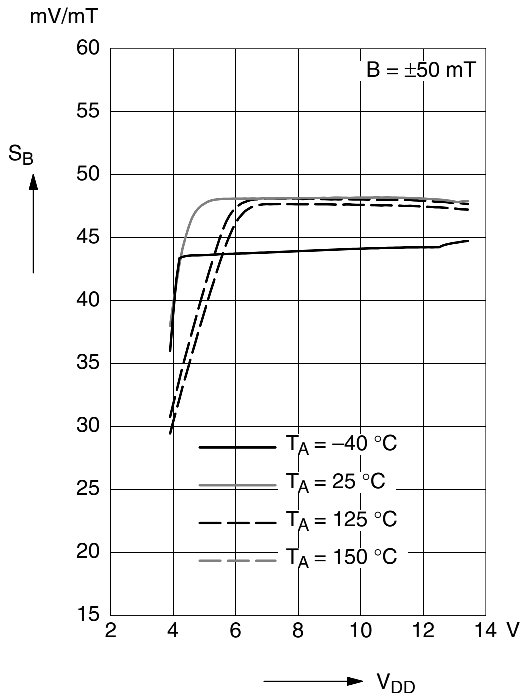


Fig. 3–8: Typical differential magnetic sensitivity versus supply voltage

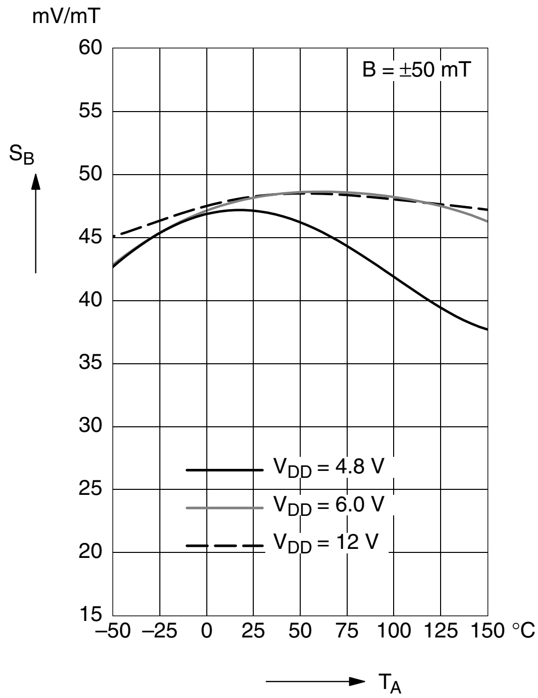


Fig. 3–10: Typical differential magnetic sensitivity versus ambient temperature

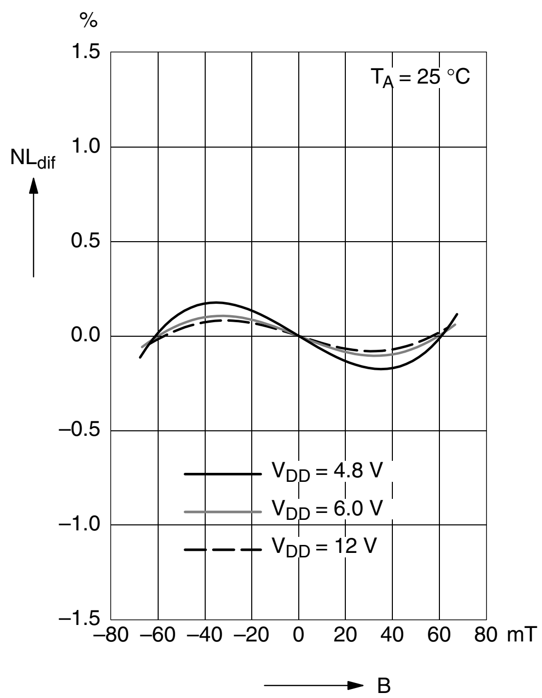


Fig. 3–9: Typical non-linearity of differential output versus magnetic flux density

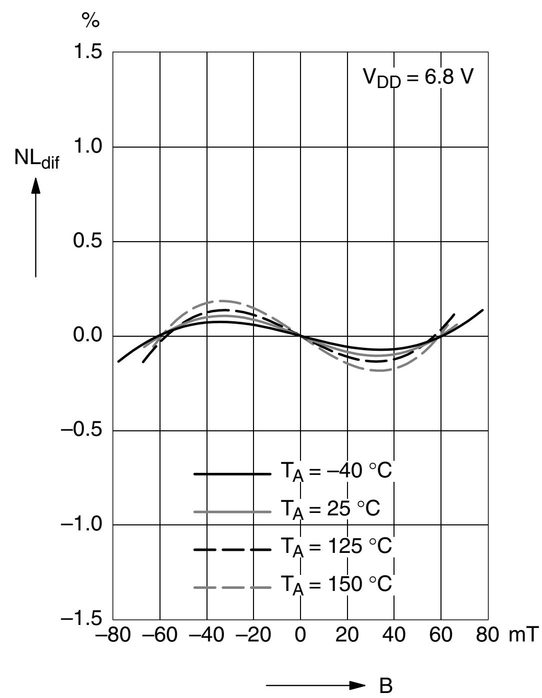


Fig. 3–11: Typical non-linearity of differential output versus magnetic flux density

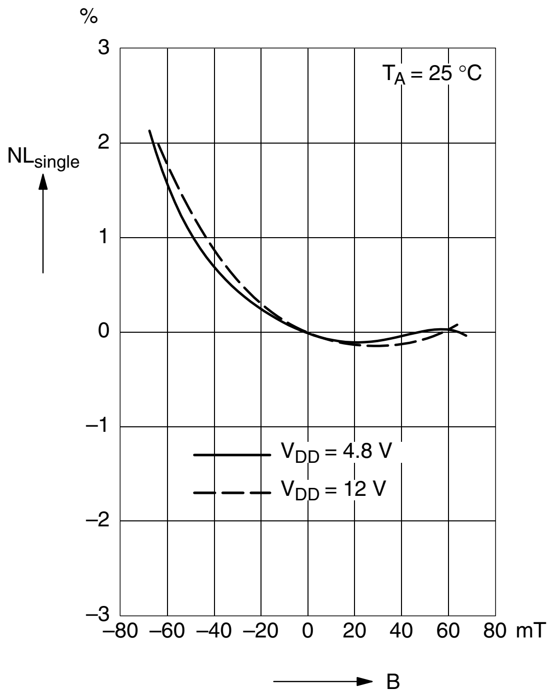


Fig. 3–12: Typical single-ended non-linearity versus magnetic flux density

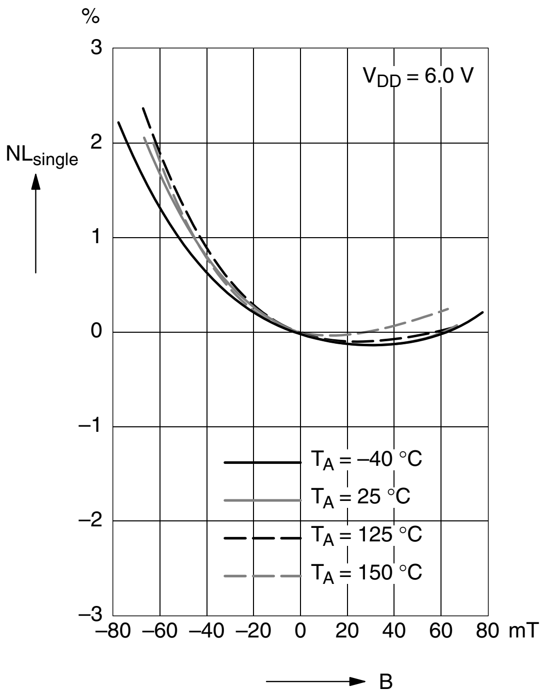


Fig. 3–14: Typical non-linearity of single-ended output versus magnetic flux density

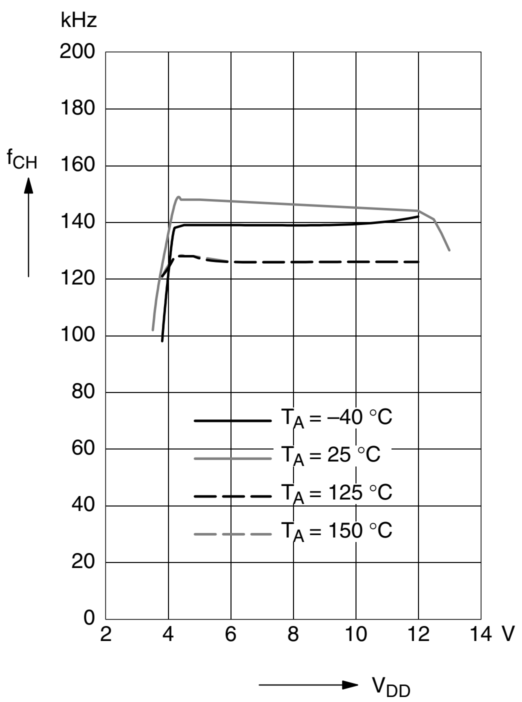


Fig. 3–13: Typical chopper frequency versus supply voltage

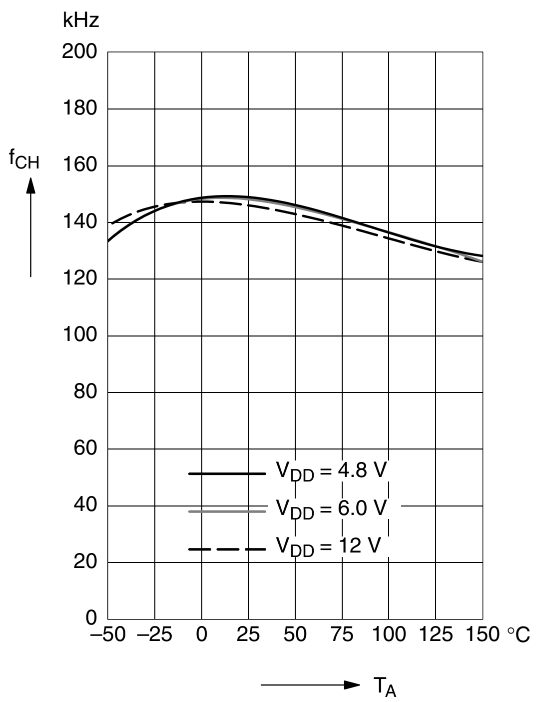


Fig. 3–15: Typical chopper frequency versus ambient temperature

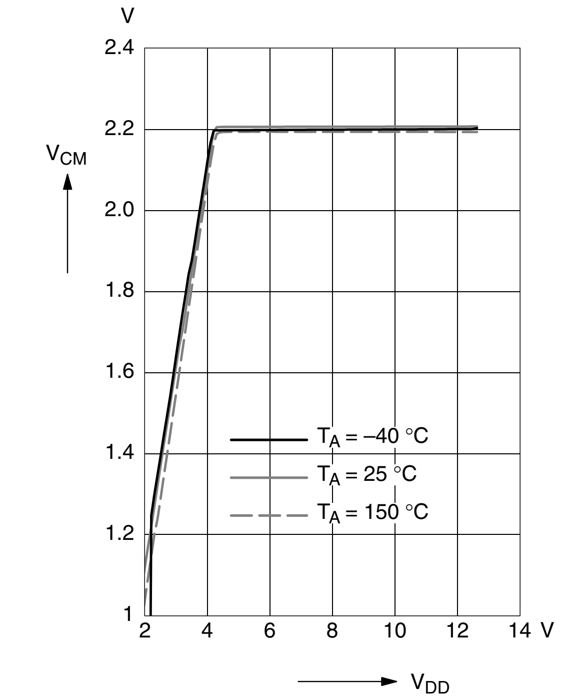


Fig. 3–16: Typical common mode output voltage versus supply voltage

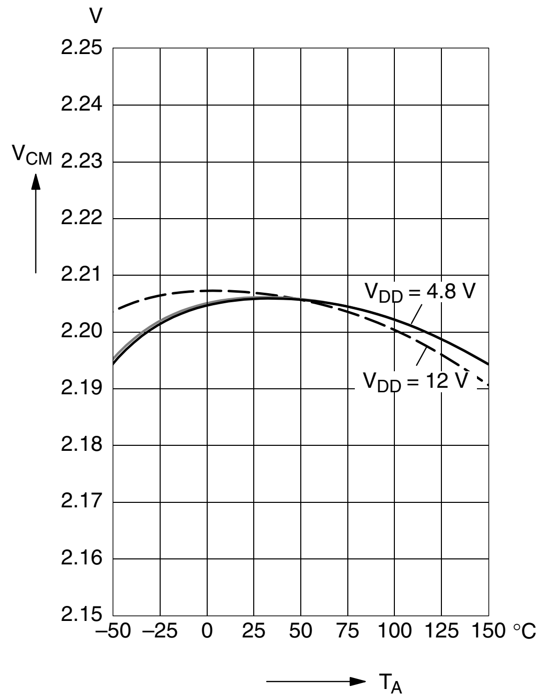


Fig. 3–18: Typical common mode output voltage versus ambient temperature

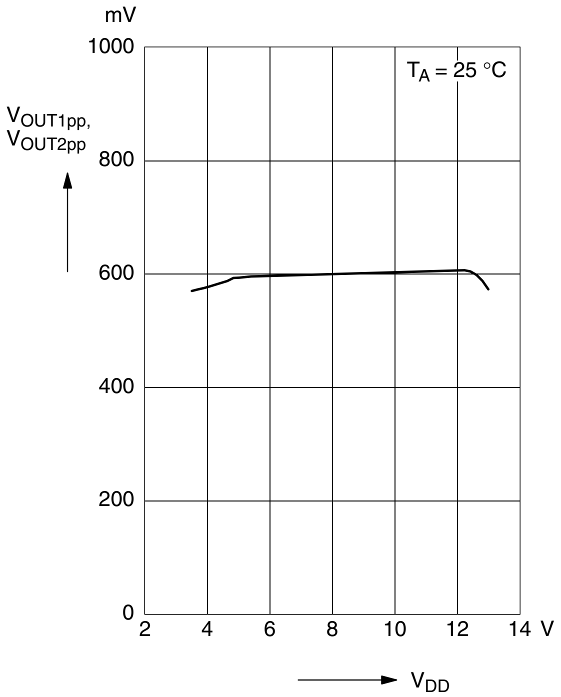


Fig. 3–17: Typical output AC voltage versus supply voltage

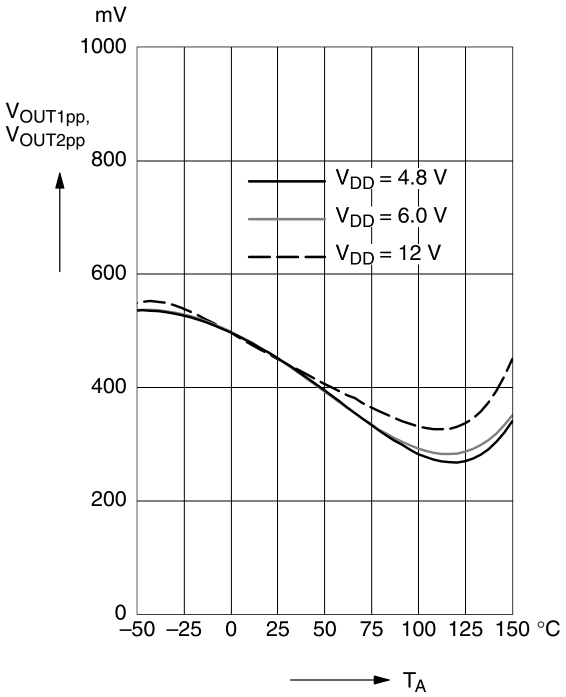


Fig. 3–19: Typical output AC voltage versus ambient temperature

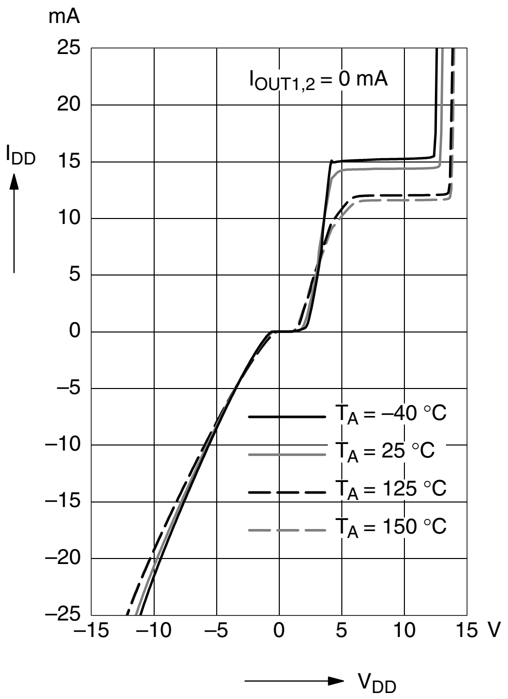


Fig. 3–20: Typical supply current versus supply voltage

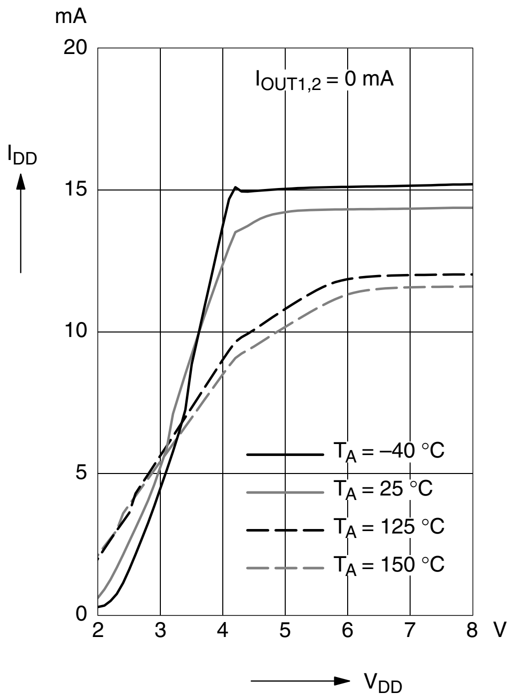


Fig. 3–22: Typical supply current versus supply voltage

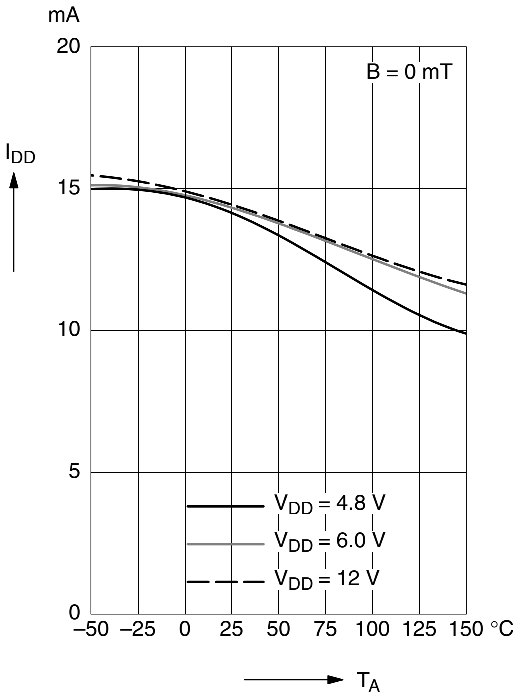


Fig. 3–21: Typical supply current versus temperature

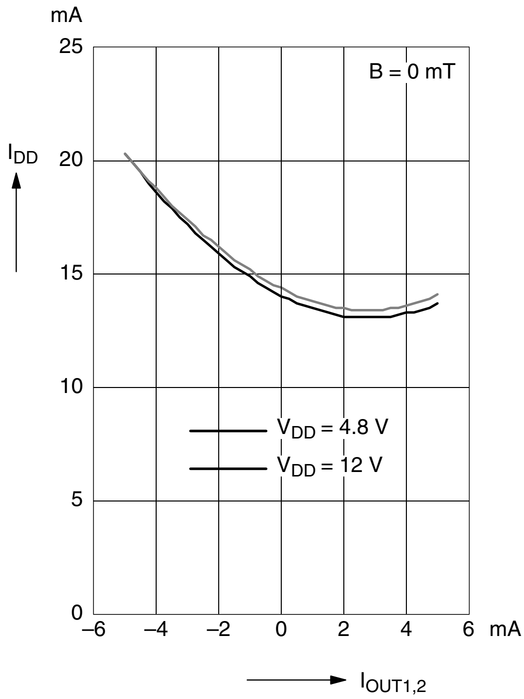


Fig. 3–23: Typical supply current versus output current

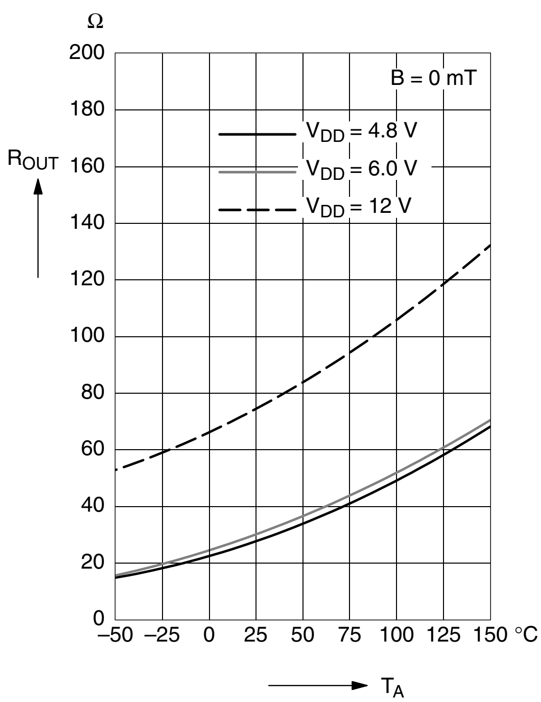


Fig. 3–24: Typical dynamic differential output resistance versus temperature

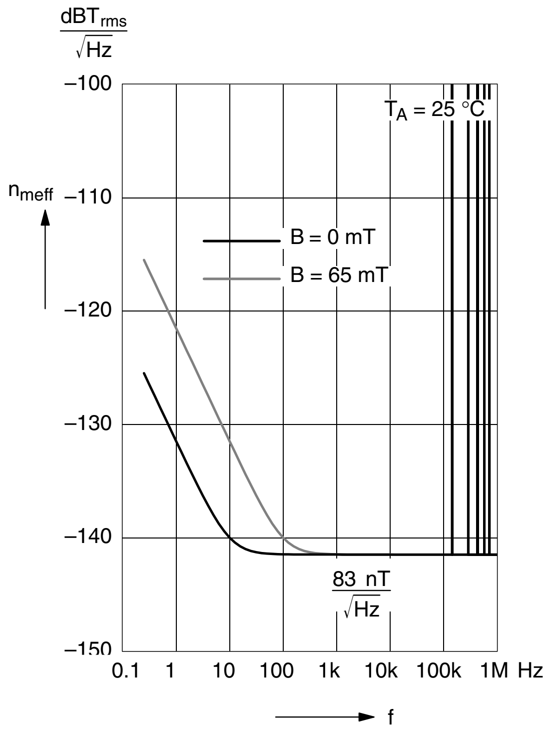


Fig. 3–26: Typical magnetic noise spectrum

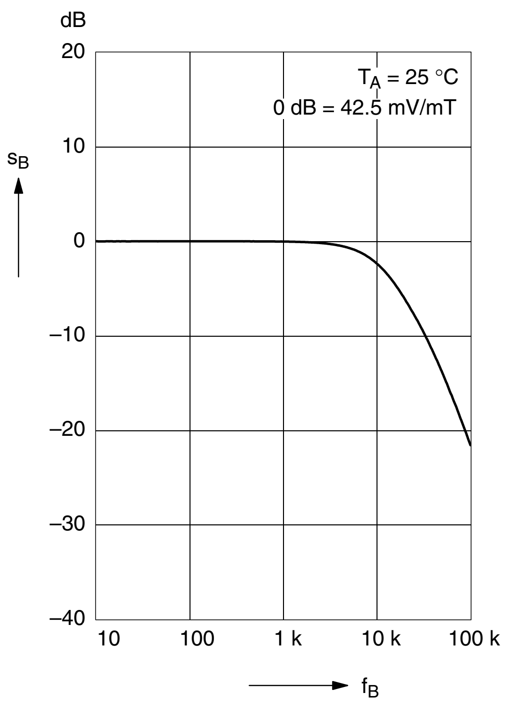


Fig. 3–25: Typical magnetic frequency response

4. 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. 2–2) increases with external mechanical stress. This can cause linearity errors at the limits of the recommended operation conditions.

4.1. Ambient Temperature

Due to 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:

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

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_{DD} and R_{th}, and the max. value for V_{DD} from the application.

4.2. EMC and ESD

Please contact Micronas for detailed information on EMC and ESD results.

4.3. Application Circuit

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

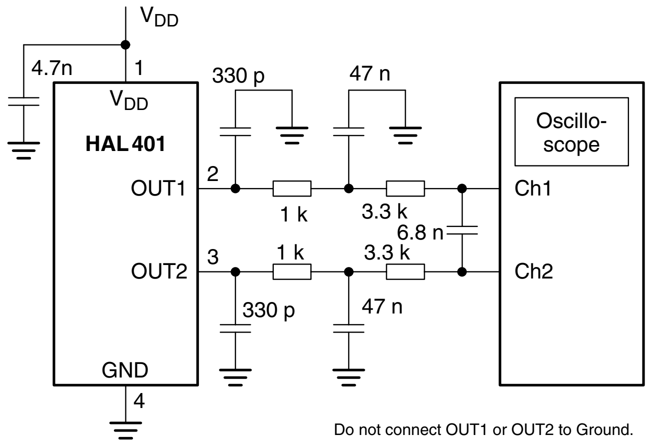


Fig. 4–1: Filtering of output signals

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.

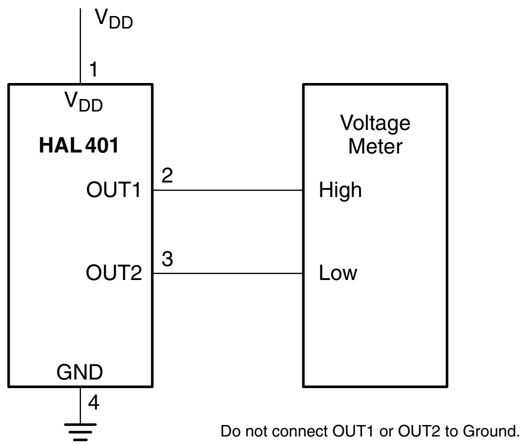


Fig. 4–2: Flux density measurement with voltmeter

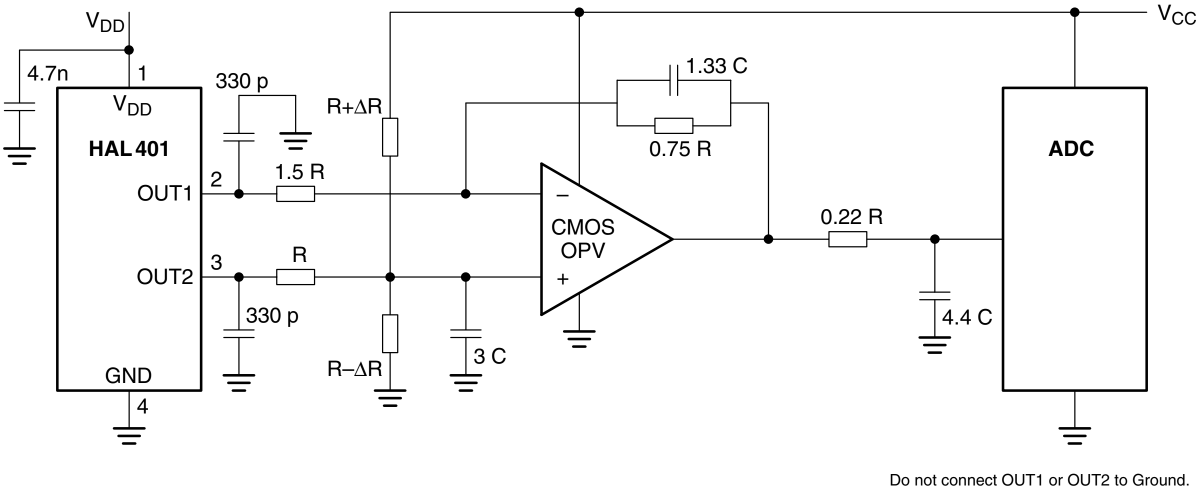


Fig. 4–3: Differential HAL 40x output to single-ended output
R = 10 kΩ, C = 7.5 nF, ΔR for offset adjustment, BW_{-3dB} = 1.3 kHz

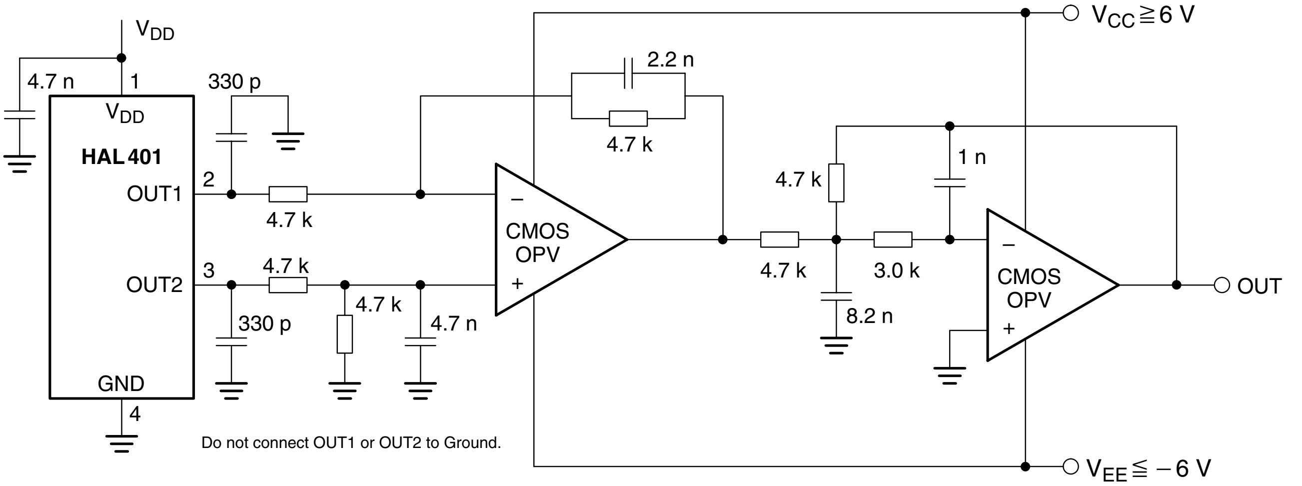


Fig. 4–4: Differential HAL 401 output to single-ended output (referenced to ground), filter – BW_{-3dB} = 14.7 kHz

5. Data Sheet History

1. Final Data Sheet: "HAL 401 Linear Hall Effect Sensor IC", June 26, 2002, 6251-470-1DS.
   First release of the final data sheet.

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