PRELIMINARY DATA SHEET

HAL400
Linear Hall Effect
Sensor IC

Edition Jan. 23, 1997
6251-346-3PD

ITT INTERMETALL

Linear Hall Effect Sensor IC
in CMOS technology

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

Features:

The linear CMOS Hall Sensor is used for precise measurements of the magnetic flux. The differential output voltage is proportional to the magnetic flux density at a right angle to the sensitive area. Due to chopper compensation, low magnetic offset and offset drift is achieved. It can be used as a current sensor or can detect any mechanical movement. Very accurate angle measurements or distance measurements can be done. The sensor is very robust and can be used in an electrically and mechanically hostile environment.

– low magnetic offset
– extremely sensitive
– 4.8 to 12 Volt operation
– wide temperature range T_A = –40 to +150 °C
– over-voltage protection
– differential output
– accurate absolute measurements of DC and low frequency magnetic flux densities
– on-chip temperature compensation
– low 1/f-noise

Specifications

Marking Code

Type	Temperature Range		
	A	E	C
HAL 400S	400A	400E	400C

Operating Junction Temperature Range

A: T_J = –40 °C to +170 °C

E: T_J = –40 °C to +100 °C

C: T_J = 0 °C to +100 °C

Designation of Hall Sensors

HAL XXXPP-T

Temperature Range: A, E, or C
Package: S for SOT-89A
Type: 400

Example: **HAL 400S-E**

→ Type: 400
→ Package: SOT-89A
→ Temperature Range: T_J = –40 °C to +100 °C

Solderability

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

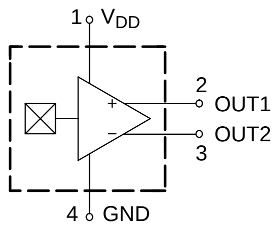


Fig. 1: Pin configuration

Functional Description

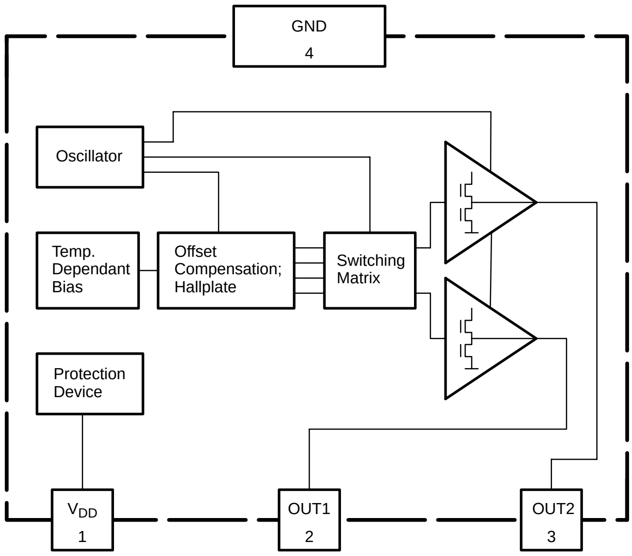


Fig. 2: Block diagram of the HAL 400 (top view)

The Linear Hall Sensor measures accurate constant and low frequency magnetic flux densities. The differential output voltage is proportional to the magnetic flux density passing vertically through the sensitive area of the chip. The common mode voltage (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 an 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. So 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)

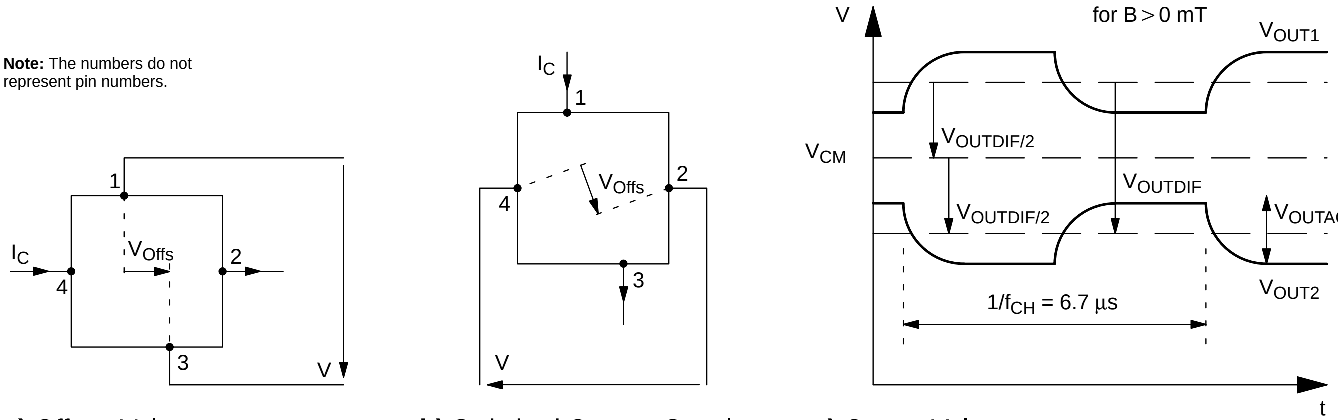
The Hall Offset Voltage is the residual voltage measured in absence of a magnetic field (zero-field residual voltage). This voltage is caused by mechanical stress and can be modeled by a displacement of the connections for voltage measurement and/or current supply.

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 the 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 the points 1 and 3. In the absence of a magnetic field V_{24} is the Hall Offset Voltage with negativ polarity ($-V_{Offs}$). In case of a magnetic field, V_{24} is the difference of the Hall voltage (V_H) and V_{Offs}.
  $V_{24} = V_{H} - V_{Offs}$

The output shows in the first cycle 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. 3: Hall Offset Compensation

Outline Dimensions

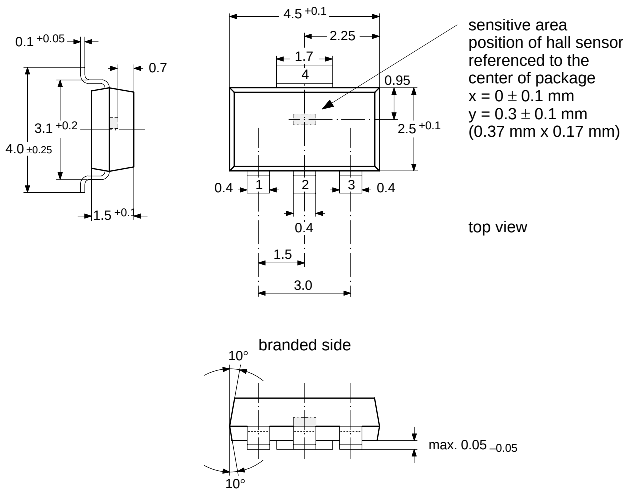


Fig. 4: Plastic Package SOT-89A

Weight approximately 0.04 g
Dimensions in mm

Absolute Maximum Ratings

Symbol	Parameter	Pin No.	Min.	Max.	Unit
V_{DD}	Supply Voltage	1	–15	12	V
I_{DDZ}	Supply Current through Protection Device	1	–400[1)]	400[1)]	mA
I_{OUT}	Output Current	2, 3	–5	5	mA
I_{OUTZ}	Output Current through Protection Device	1	–300[1)]	300[1)]	mA
T_S	Storage Temperature Range		–65	150	°C
T_J	Junction Temperature Range		–40 –40	150 170[2)]	°C °C

1) $t \leq 2$ ms
2) $t < 1000$ 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_{OUT}	Continuous Output Current	2, 3	–2.25	2.25	mA	T_J = 25 °C
I_{OUT}	Continuous Output Current	2, 3	–1	1	mA	T_J = 170 °C
C_L	Load Capacitance	2, 3	–	1	nF	

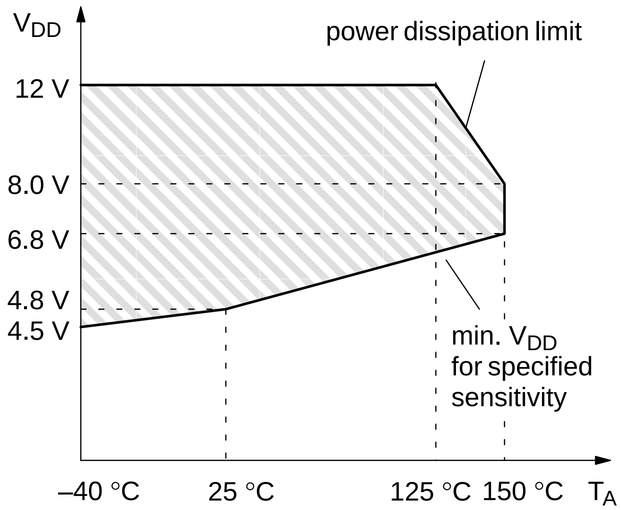


Fig. 5: Recommended Operating Supply Voltage

Extended Operational Range

Within the extended operating range, the ICs operate as mentioned in the functional description. The functionality has been tested on samples, whereby the characteristics may lie outside the specified limits.

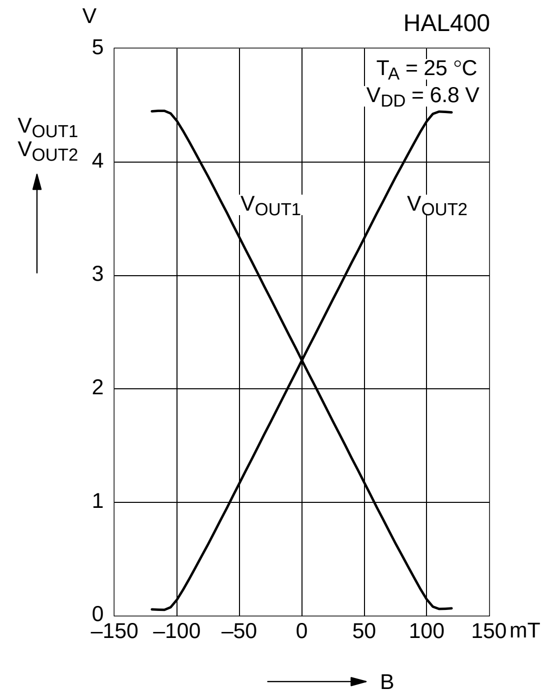
Symbol	Parameter	Pin No.	Min.	Max.	Unit	Remarks
V_{DD}	Supply Voltage	1	4.3	12	V	
I_{OUT}	Output Current	2,3	–3	3	mA	T_J = –40 °C to +170 °C

Electrical and Magnetic Characteristics
see Fig. 5 for T_A and V_{DD} as not otherwise specified; Typical characteristics for T_J = 25 °C, –75 mT < B < 75 mT and V_{DD} = 6.8 V

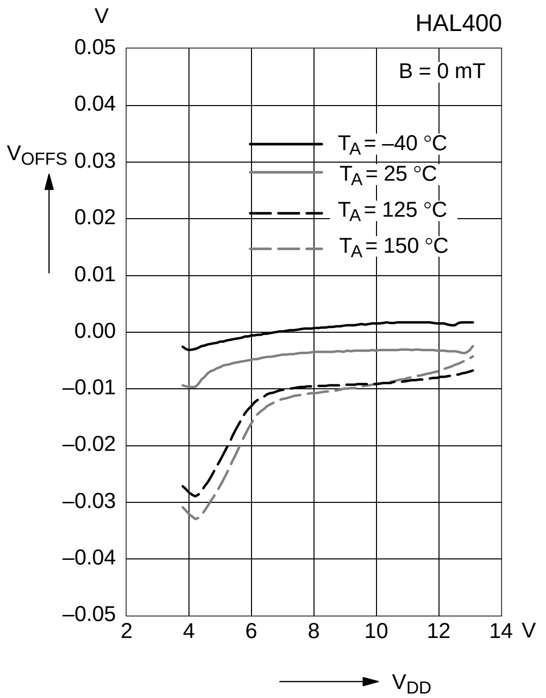
Symbol	Parameter	Pin No.	Min.	Typ.	Max.	Unit	Test Conditions
I_{DD}	Supply Current	1	11.8	14.5	17.1	mA	T_J = 25 °C; $I_{OUT1,2}$ = 0 mA
I_{DD}	Supply Current under Recommended Operating Conditions	1	9.3	14.5	18.5	mA	$I_{OUT1,2}$ = 0 mA
V_{CM}	Common Mode Output Voltage	2, 3	2.1	2.2	2.3	V	$I_{OUT1,2}$ = 0 mA $V_{CM} = (V_{OUT1} + V_{OUT2}) / 2$
CMRR	Common Mode Rejection Ratio	2, 3	–2	0	2	mV/V	$I_{OUT1,2}$ = 0 mA CMRR is limited by the influence of power dissipation
$S_B = \Delta V_{OUTDIF}/\Delta B$	Differential Magnetic Sensitivity	2–3	37	42.5	49.5	mV/mT	B = ±60 mT ; T_J = 25 °C $V_{OUTDIF} = V_{OUT1} - V_{OUT2}$
S_B	Differential Magnetic Sensitivity under Recommended Operating Conditions	2–3	33	42.5	49.5	mV/mT	B = ±60 mT $V_{OUTDIF} = V_{OUT1} - V_{OUT2}$
B_{offset}	Magnetic Offset	2–3	–1.0	–0.2	1.0	mT	B = 0 mT, $I_{OUT1,2}$ = 0 mA T_J = 25 °C
B_{offset}	Magnetic Offset over Temperature	2–3	–1.25	–0.2	1.25	mT	B = 0 mT, $I_{OUT1,2}$ = 0 mA
$\Delta B_{OFFSET}/\Delta T$	Magnetic Offset Change due to T_A		–15	0	15	µT/K	B = 0 mT, $I_{OUT1,2}$ = 0 mA
BW	Bandwidth (–3 dB)	2–3	–	10	–	kHz	1)
NL_{dif}	Non Linearity of Differential Output	2–3	–	0.2	1	%	B = ±40 mT, B = ±60 mT
NL_{single}	Non Linearity of Single Ended Output	2, 3	–	2	3	%	
f_{CH}	Chopper Frequency	2, 3	114	147	166	kHz	T_J = 25 °C
f_{CH}	Chopper Frequency over Temp.	2, 3	90	147	166	kHz	
$V_{OUTACpp}$	Peak-to-Peak AC Output Voltage	2, 3	0	0.32	0.8	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 = 65 mT
R_{OUT}	Output Resistance	2, 3	0	30	50	Ω	$I_{OUT1,2}$ ≤ 2.5 mA ; T_J = 25 °C V_{DD} = 6.8 V
R_{OUT}	Output Resistance over Temperature	2, 3	0	30	150	Ω	$I_{OUT1,2}$ ≤ 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. 6

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

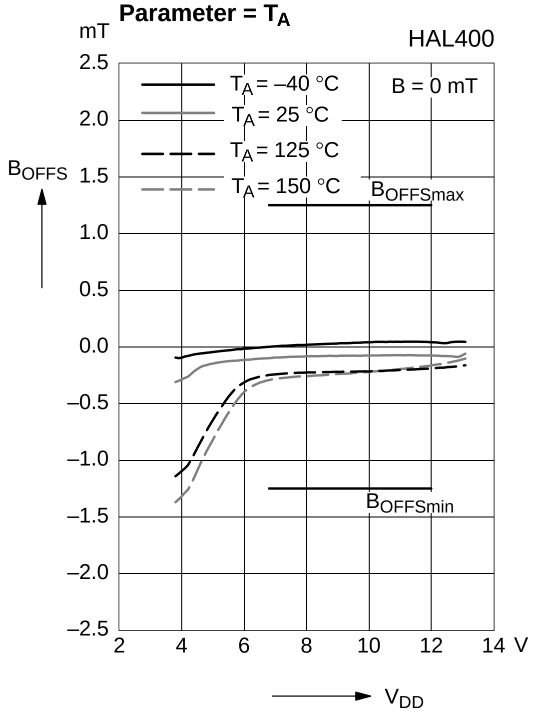
Typical output voltages versus magnetic flux density



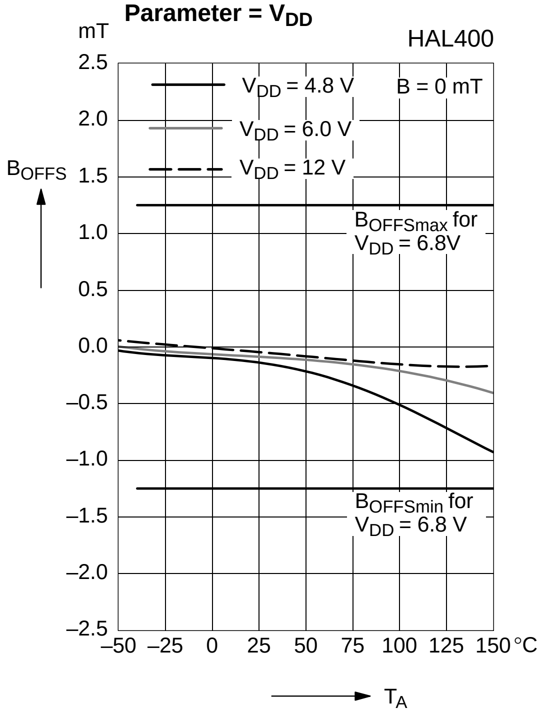
Typical differential output offset voltage versus supply voltage Parameter = T_A

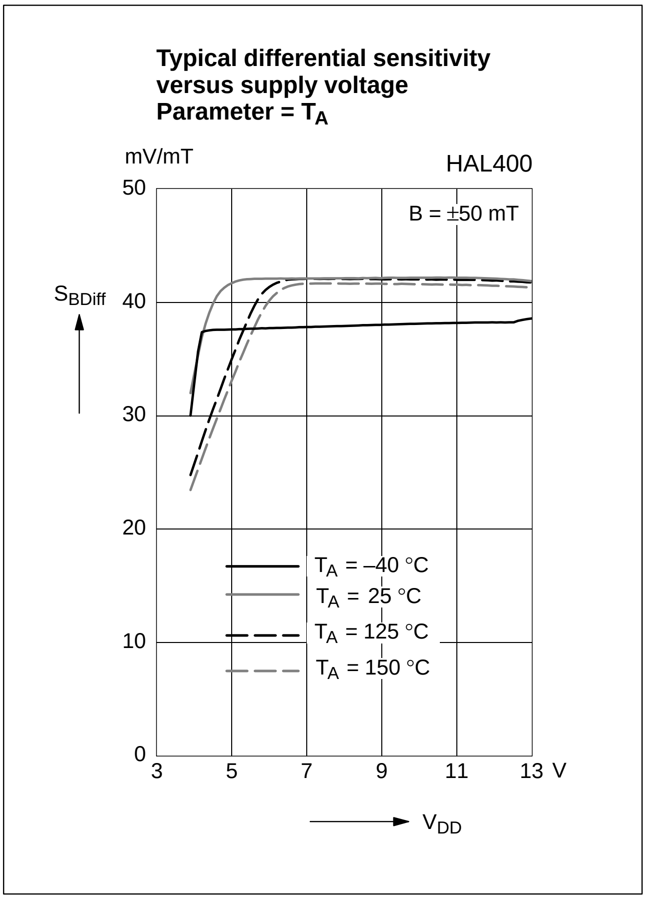


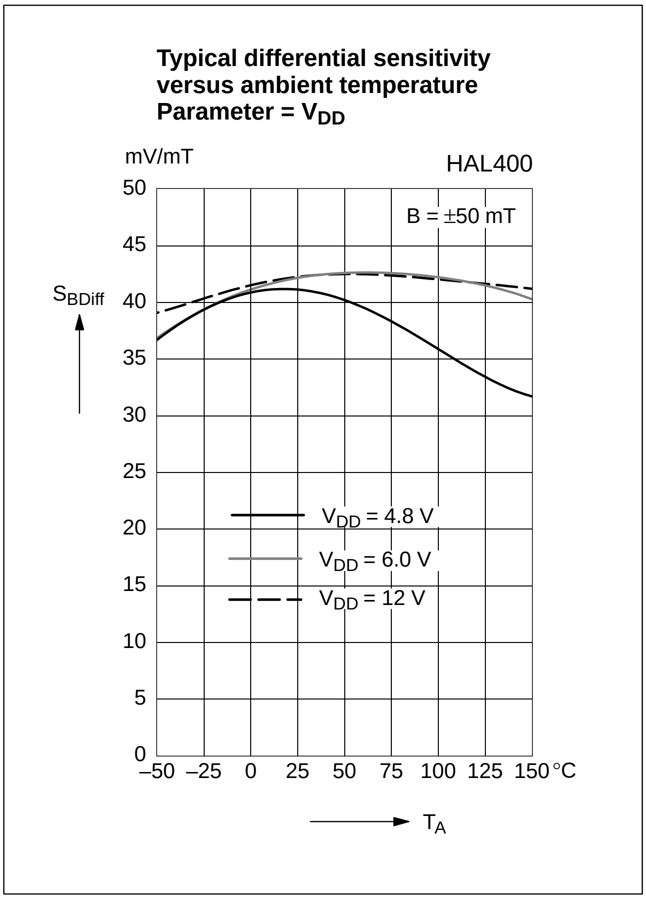
Typical magnetic offset of differential output versus supply voltage Parameter = T_A

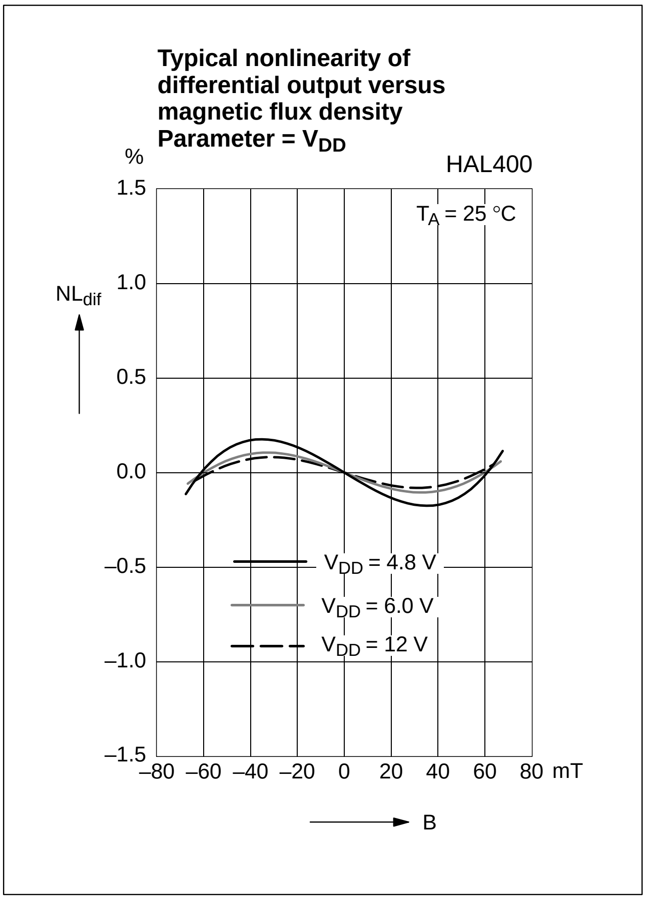


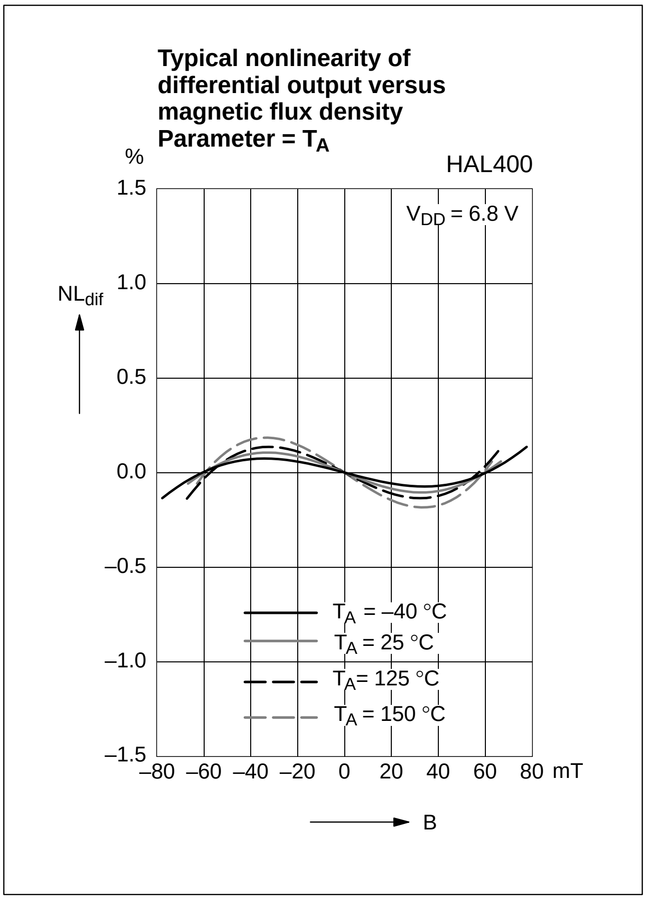
Typical magnetic offset of differential output versus ambient temperature Parameter = V_{DD}



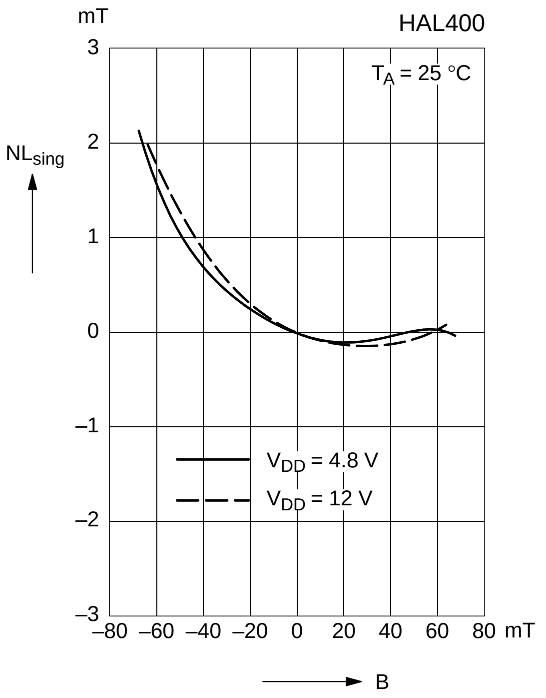

Typical differential sensitivity
versus supply voltage
Parameter = T_A
mV/mT
HAL400
B = ±50 mT
S_{BDiff}
50
40
30
20
10
0
3
5
7
9
11
13 V
T_A = –40 °C
T_A = 25 °C
T_A = 125 °C
T_A = 150 °C
V_{DD}


Typical differential sensitivity
versus ambient temperature
Parameter = V_{DD}
mV/mT
HAL400
B = ±50 mT
S_{BDiff}
50
45
40
35
30
25
20
15
10
5
0
–50 –25 0 25 50 75 100 125 150 °C
V_{DD} = 4.8 V
V_{DD} = 6.0 V
V_{DD} = 12 V
T_A

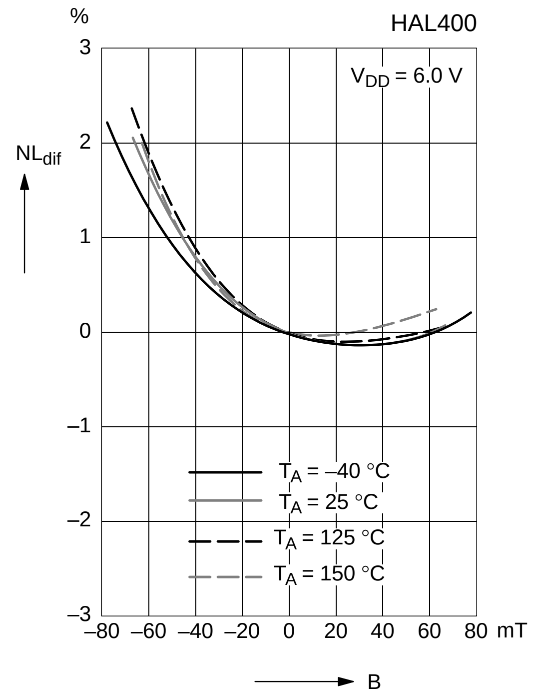

Typical nonlinearity of
differential output versus
magnetic flux density
Parameter = V_{DD}
%
HAL400
T_A = 25 °C
NL_{dif}
1.5
1.0
0.5
0.0
–0.5
–1.0
–1.5
–80 –60 –40 –20 0 20 40 60 80 mT
V_{DD} = 4.8 V
V_{DD} = 6.0 V
V_{DD} = 12 V
B


Typical nonlinearity of
differential output versus
magnetic flux density
Parameter = T_A
%
HAL400
V_{DD} = 6.8 V
NL_{dif}
1.5
1.0
0.5
0.0
–0.5
–1.0
–1.5
–80 –60 –40 –20 0 20 40 60 80 mT
T_A = –40 °C
T_A = 25 °C
T_A= 125 °C
T_A = 150 °C
B

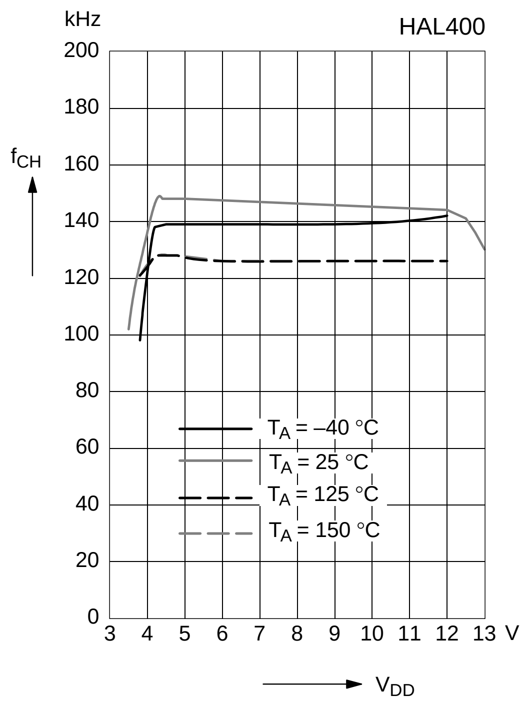
Typical single endend nonlinearity versus magnetic flux density, Parameter = V_{DD}



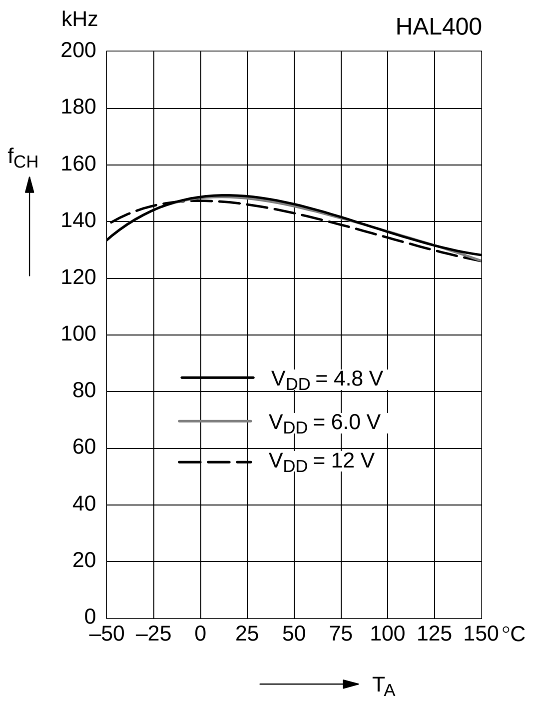
Typical nonlinearity of single ended output versus magnetic flux density, Parameter = T_A



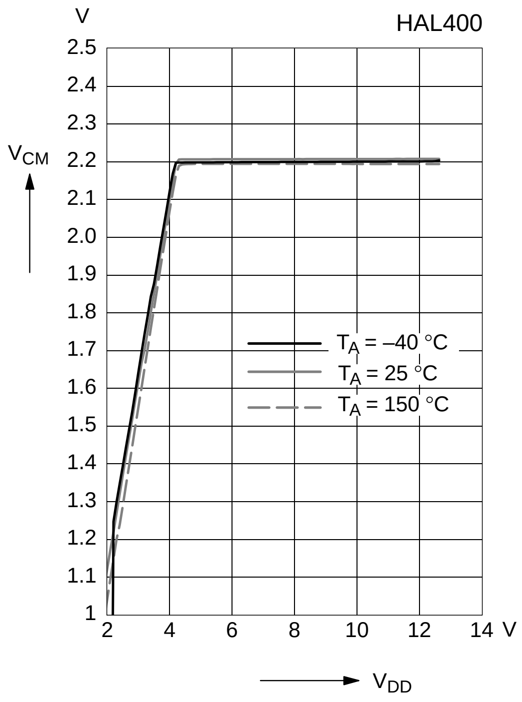
Typical chopper frequency versus supply voltage Parameter = T_A



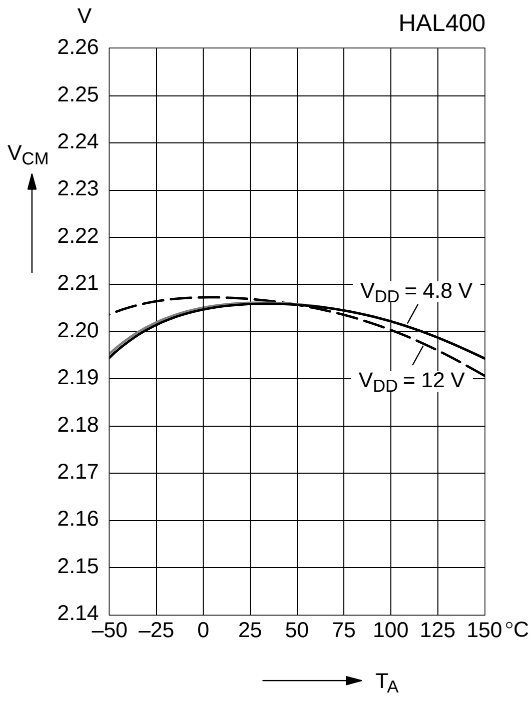
Typical chopper frequency versus ambient temperature Parameter = V_{DD}



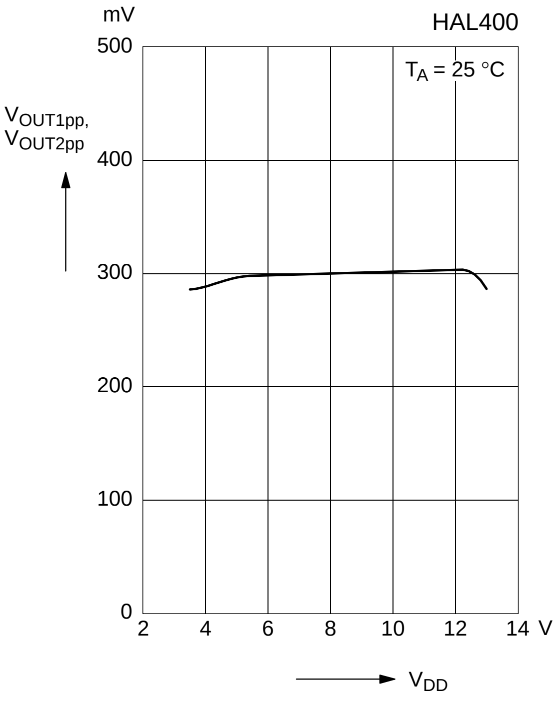
Typical common mode output voltage versus supply voltage Parameter = T_A



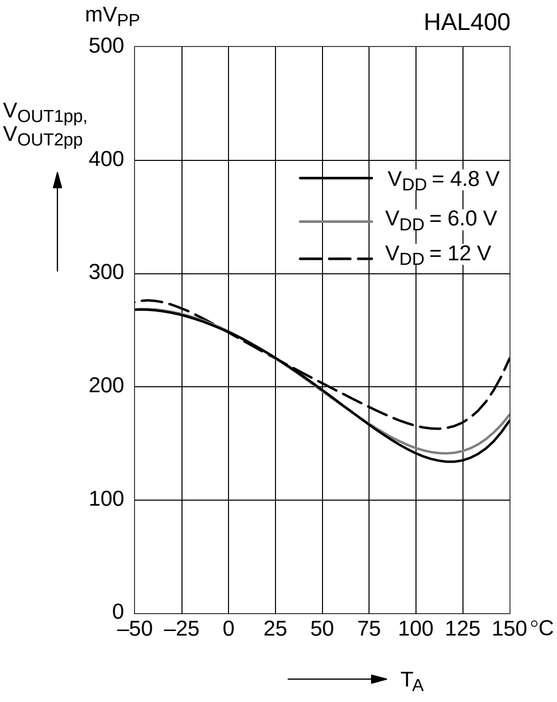
Typical common mode output voltage versus ambient temperature Parameter = V_{DD}



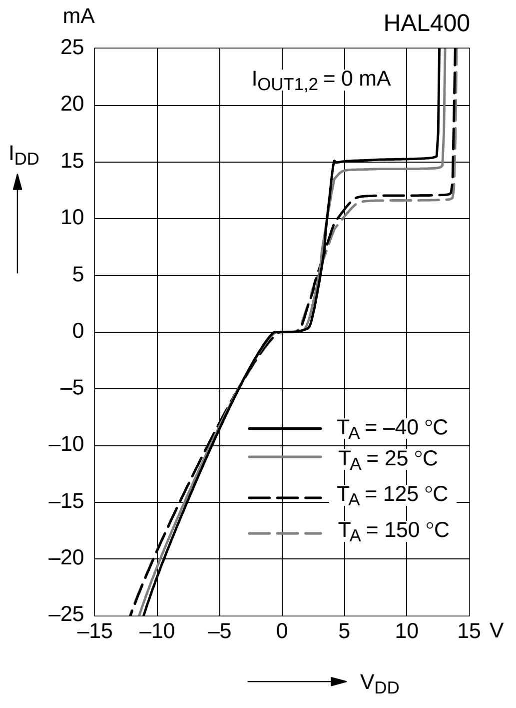
Typical output AC voltage versus supply voltage



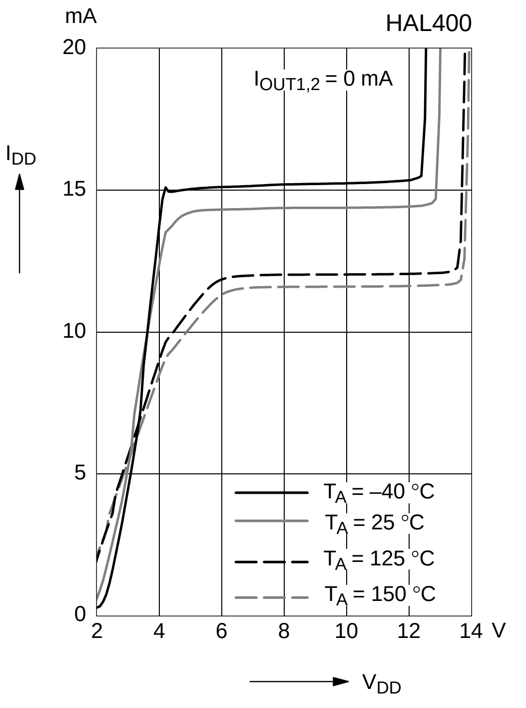
Typical output AC voltage versus ambient temperature Parameter = V_{DD}



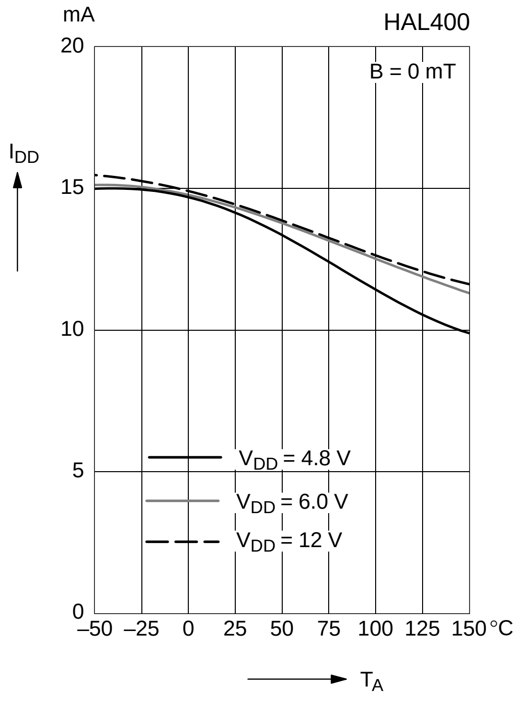
Typical supply current versus supply voltage
Parameter = T_A



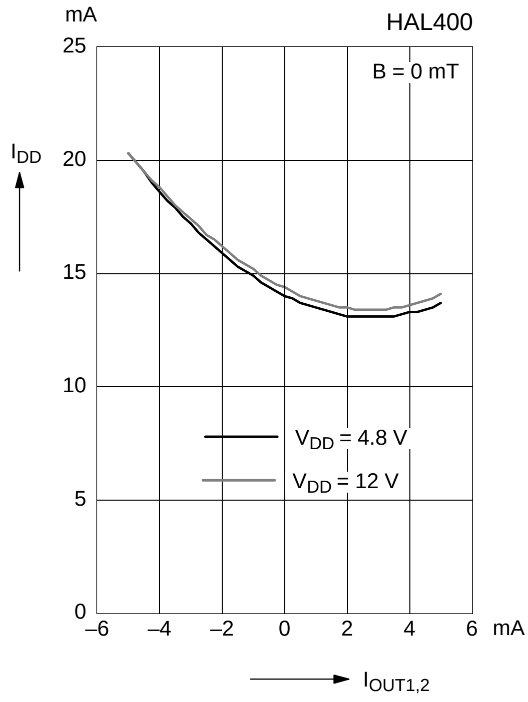
Typical supply current versus supply voltage
Parameter = T_A

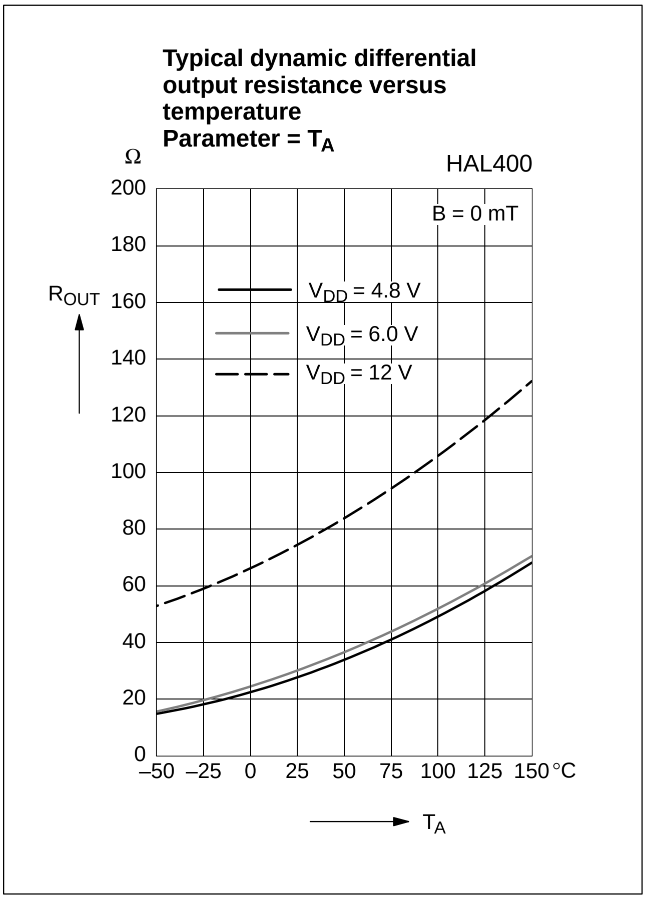


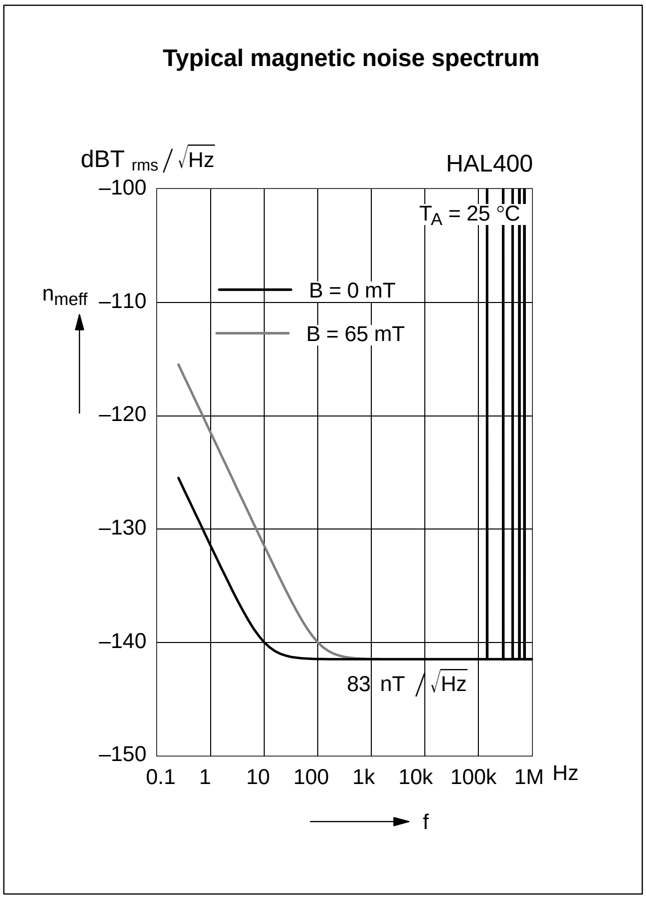
Typical supply current versus temperature
Parameter = T_A

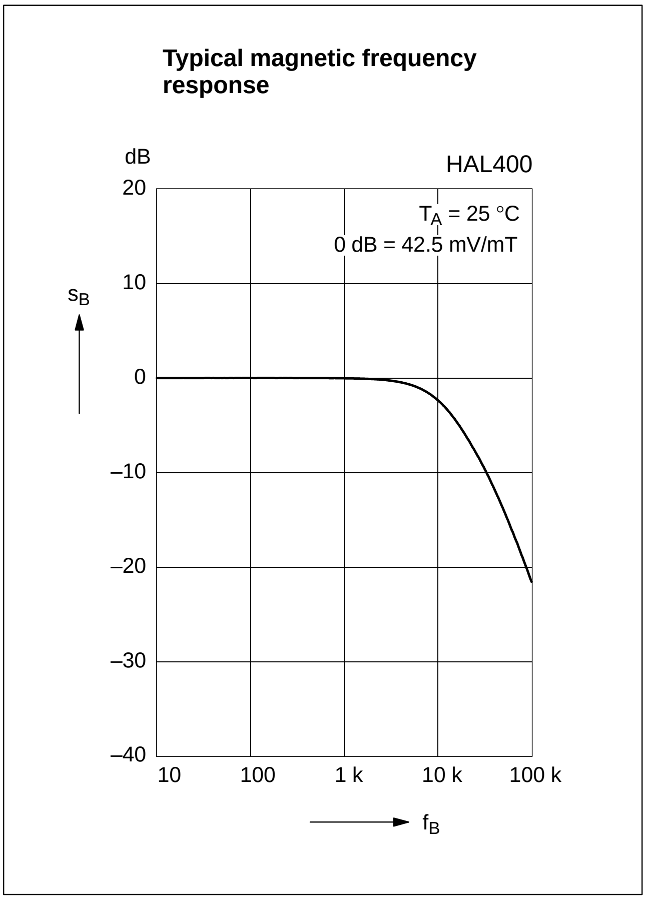


Typical supply current versus output current
Parameter = V_{DD}









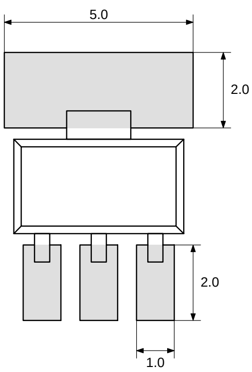


Fig. 6: Recommended pad size SOT-89A
Dimensions in mm

Application Circuits

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

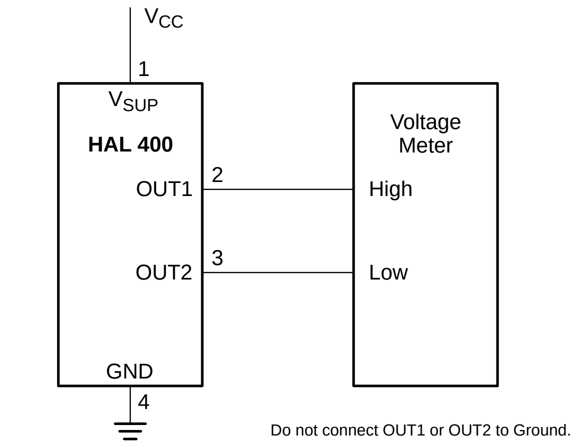


Fig. 7: Flux density measurement with voltmeter

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.

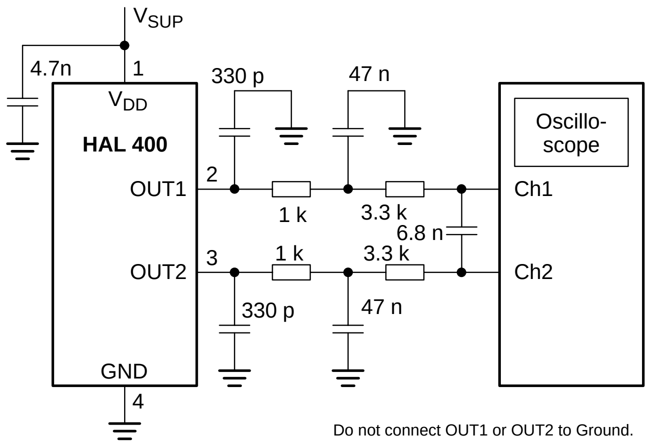


Fig. 8: Filtering of output signals

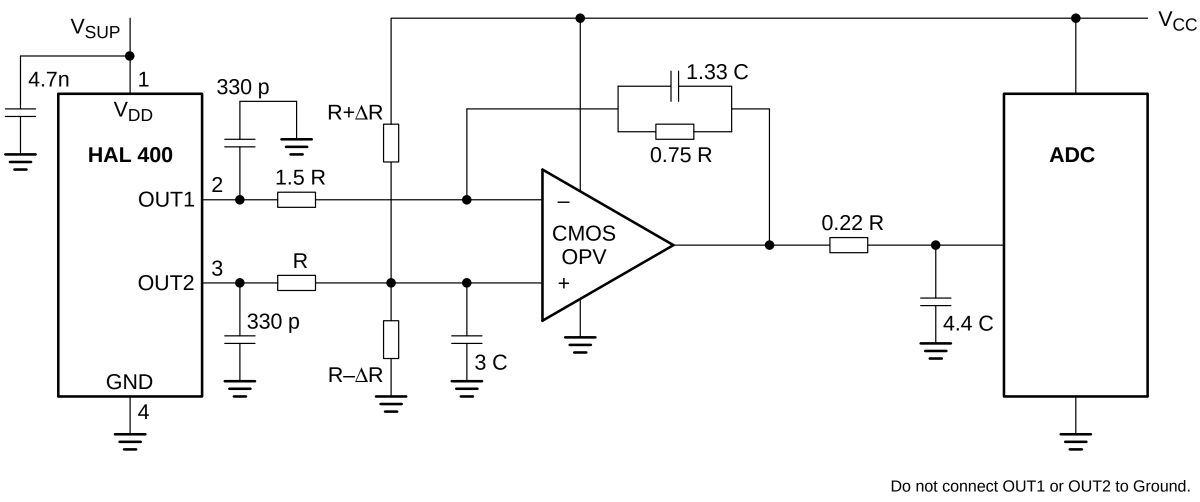


Fig. 9: Differential HAL400 output to single-ended output
R = 10 kΩ, C = 7.5 nF, ΔR for offset adjustment, BW_{-3dB} = 1.3 kHz

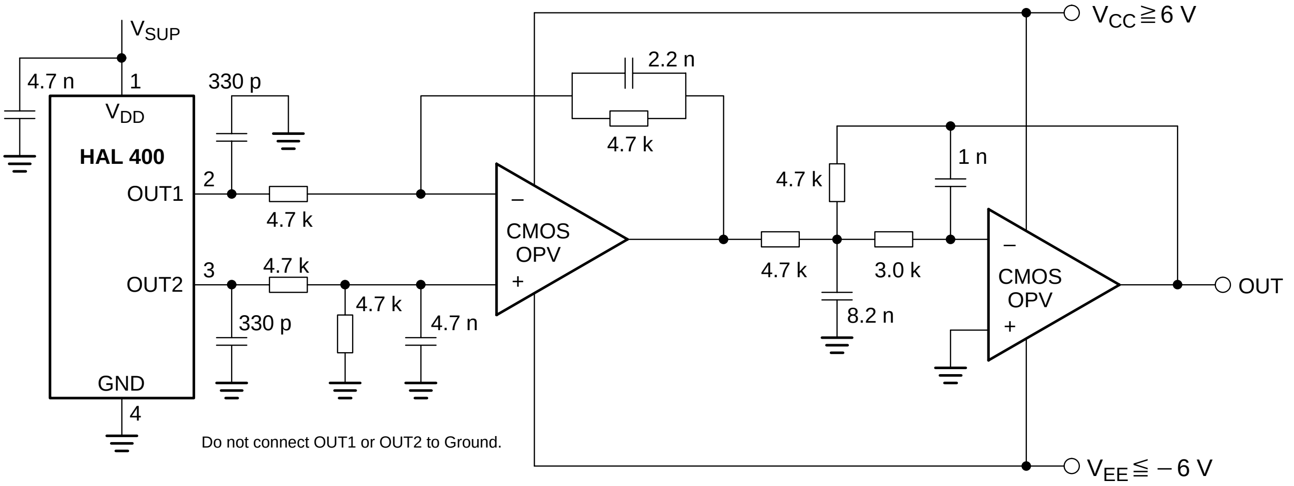


Fig. 10: Differential HAL400 output to single-ended output (referenced to ground), filter – BW_{-3dB} = 14.7 kHz

HAL 400 Documentation History

1. Preliminary data sheet: “HAL 400 Linear Hall Effect Sensor IC”, March 29, 1994, 6251-346-1PD. First release of the preliminary data sheet.

2. Preliminary data sheet: “HAL 400 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: “HAL 400 Linear Hall Effect Sensor IC”, Jan. 23, 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

ITT Semiconductors Group
World Headquarters
INTERMETALL
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

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