HAL501...HAL506, HAL508
Hall Effect Sensor ICs

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MICRONAS
INTERMETALL

Hall Effect Sensor IC
in CMOS technology

Common Features:

– switching offset compensation at 62 kHz

– operates from 3.8 V to 24 V supply voltage

– overvoltage and reverse-voltage protection

– extremely robust against mechanical stress

– short-circuit protected open-drain output

– operates with magnetic fields from DC to 10 kHz

– on-chip temperature compensation circuitry minimizes shifts in on and off points and hysteresis over temperature and supply voltage

– the decrease of magnetic flux density caused by rising temperature in the sensor system is compensated by a built-in negative temperature coefficient of hysteresis

– ideal sensor for ignition timing, anti-lock brake systems and revolution counting in extreme automotive and industrial environments

– EMC corresponding to DIN 40839

Specifications

The types differ according to the magnetic flux density values for the magnetic switching points, the temperature behavior of the magnetic switching points, and the mode of switching.

HAL 501

– switching type: bipolar, very sensitive

– output turns low with magnetic south pole on branded side of package

– output state can change if magnetic field is removed

HAL 502, HAL 503, HAL 505

– switching type: latch

– output turns low with magnetic south pole on branded side of package

– output state does not change if magnetic field is removed

HAL 504, HAL 506, HAL 508

– switching type: unipolar

– output turns low with magnetic south pole on branded side of package

– output turns high if magnetic field is removed

Marking Code

Type	Temperature Range		
	A	E	C
HAL 501S, HAL 501UA	501A	501E	501C
HAL 502S, HAL 502UA	502A	502E	502C
HAL 503S, HAL 503UA	503A	503E	503C
HAL 504S, HAL 504UA	504A	504E	504C
HAL 505S, HAL 505UA	505A	505E	505C
HAL 506S, HAL 506UA	506A	506E	506C
HAL 508S, HAL 508UA	508A	508E	508C

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: UA for TO-92UA, S for SOT-89A
- Type: 501...506, 508

Example: **HAL 501UA-E**

→ Type: 501
→ Package: TO-92UA
→ Temperature Range: T_J = –40 °C to +100 °C

Solderability

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

– Package TO-92UA: according to IEC68-2-20

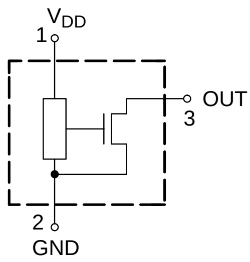


Fig. 1: Pin configuration

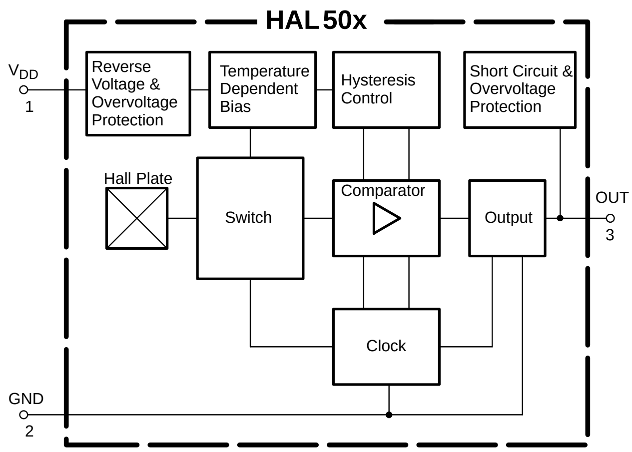


Fig. 2: HAL 50x block diagram

Functional Description

This Hall effect sensor is a monolithic integrated circuit that switches in response to magnetic fields. If a magnetic field with flux lines at right angles 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 bounce.

Magnetic offset caused by mechanical stress is compensated for by using the “switching offset compensation technique”. Therefore, an internal oscillator provides a two phase clock. The hall voltage is sampled at the end of the first phase. At the end of the second phase, both sampled and momentary hall voltages are averaged and compared with the actual switching point. Subsequently, the open drain output switches to the appropriate state. The time from crossing the magnetic switch level to switching of 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.

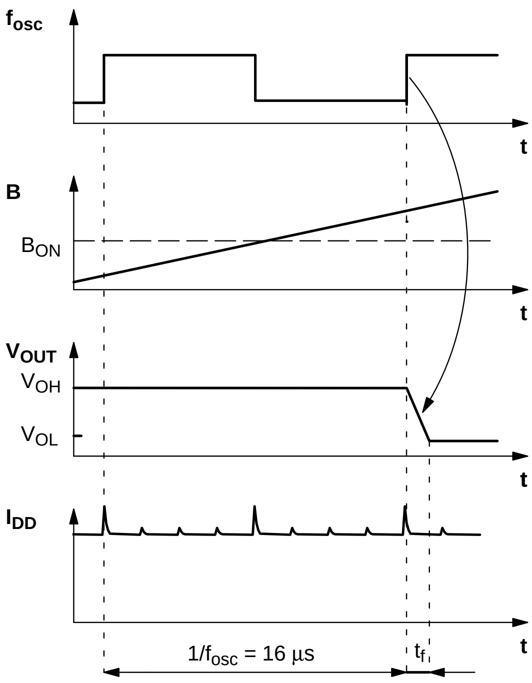


Fig. 3: Timing diagram

Outline Dimensions

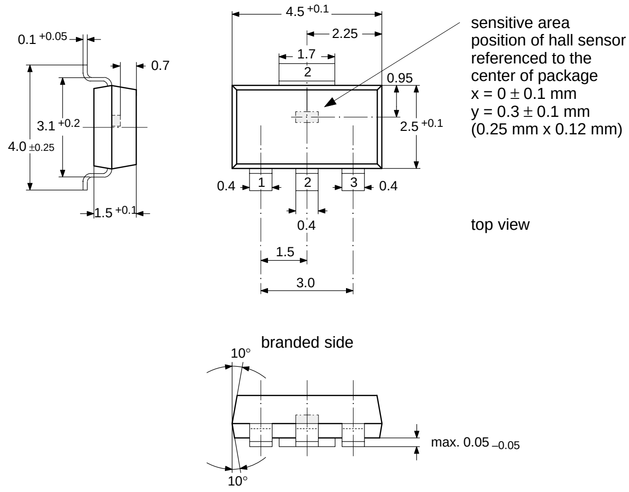


Fig. 4:
Plastic Small Outline Transistor Package
(SOT-89A)
Weight approximately 0.04 g
Dimensions in mm

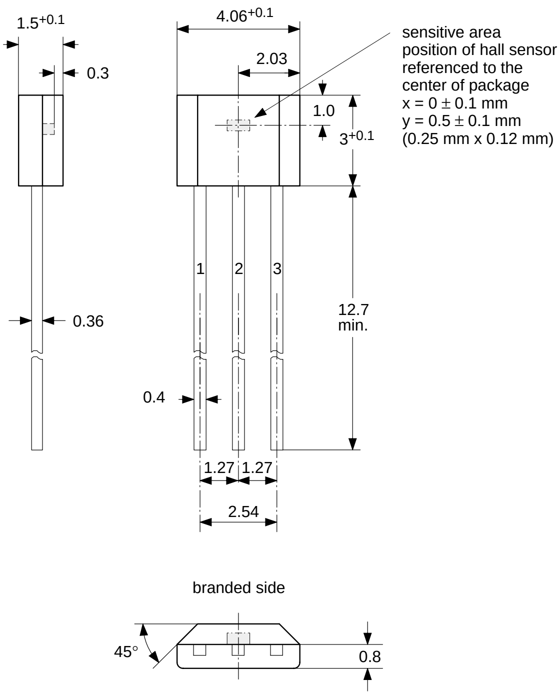


Fig. 5:
Plastic Transistor Single Outline Package
(TO-92UA)
Weight approximately 0.12 g
Dimensions in mm

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	–300[3)]	300[3)]	mA
V_{OH}	Output High Voltage	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	–300[3)]	300[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.	Typ.	Max.	Unit
V_{DD}	Supply Voltage	1	3.8	–	24	V
I_O	Continuous Output On Current	3	0	–	20	mA

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.	Typ.	Max.	Unit
V_{DD}	Supply Voltage	1	3.3	–	25	V
I_O	Continuous Output On Current	3	–	–	30	mA

Electrical Characteristics at T_J = –40 °C to +170 °C , V_{DD} = 3.8 V to 24 V, as not otherwise specified
Typical Characteristics for T_J = 25 °C and V_{DD} = 12 V

Symbol	Parameter	Pin No.	Min.	Typ.	Max.	Unit	Test Conditions
I_{DD}	Supply Current	1	2.6	3.2	3.8	mA	T_J = 25 °C
I_{DD}	Supply Current over Temperature Range	1	1.6	3.2	5.2	mA	
V_{DDZ}	Overvoltage Protection at Supply	1	–	28.5	32	V	I_{DD} = 25 mA , T_J = 25 °C, t = 20 ms
V_{OZ}	Overvoltage Protection at Output	3	–	28	32	V	I_{OH} = 25 mA , T_J = 25 °C, t = 20 ms
V_{OL}	Output Voltage	3	–	130	180	mV	I_{OL} = 20 mA, T_J = 25 °C, V_{DD} = 4.5 V to 24 V
V_{OL}	Output Voltage over Temperature Range	3	–	130	400	mV	I_{OL} = 20 mA
I_{OH}	Output Leakage Current	3	–	0.06	0.1	µA	B< B_{OFF}, T_J = 25 °C, V_{OH} = 3.8 to 24 V
I_{OH}	Output Leakage Current over Temperature Range	3	–	–	10	µA	B< B_{OFF}, T_J ≤ 150 °C, V_{OH} = 3.8 to 24 V
f_{osc}	Internal Oscillator Chopper Frequency	–	52	62.5	73	kHz	T_J = 25 °C, V_{DD} = 4.5 V to 24 V
f_{osc}	Internal Oscillator Chopper Frequency over Temperature Range	–	45	62.5	79	kHz	V_{DD} = 3.8 V to 24 V
$t_{en(O)}$	Enable Time of Output after Setting of V_{DD}	1	–	30	70	µs	V_{DD} = 12 V, B < B_{ON} – 2 mT, B > B_{OFF} + 2 mT
t_r	Output Rise Time	3	–	75	400	ns	V_{DD} = 12 V, RL = 820 Ohm, C_L = 20 pF
t_f	Output Fall Time	3	–	50	400	ns	V_{DD} = 12 V, RL = 820 Ohm, C_L = 20 pF
R_{thJSB} case SOT-89A	Thermal Resistance Junction to Substrate Backside	–	–	150	200	K/W	Fiberglass Substrate 30 mm x 10 mm x 1.5mm, pad size see Fig. 7
R_{thJA} case TO-92UA	Thermal Resistance Junction to Soldering Point	–	–	150	200	K/W	

Magnetic Characteristics at T_J = –40 °C to +170 °C, V_{DD} = 3.8 V to 24 V,
Typical Characteristics for V_{DD} = 12 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	–40 °C			25 °C			100 °C			170 °C			Unit
	Min.	Typ.	Max.	Min.	Typ.	Max.	Min.	Typ.	Max.	Min.	Typ.	Max.	
On point B_{ON}													
HAL501	–0.8	0.65	2.5	–0.35	0.63	2.25	–0.88	0.59	2.5	–0.9	0.55	2.5	mT
HAL502	1	3	5	1	2.75	4.5	0.95	2.6	4.4	0.9	2.4	4.3	mT
HAL503	6.4	8.6	10.8	6	8	10	5.6	7.2	9.7	5.1	6.4	9.3	mT
HAL504	10.3	13	15.7	9.5	12	14.5	9	11.1	14.1	8.5	10.2	13.7	mT
HAL505	11.8	15	18.3	11	14	17	10.2	13	16.6	9.4	12	16.1	mT
HAL506	4.3	5.9	7.7	3.8	5.5	7.2	3.6	5.1	7	3.4	4.7	6.8	mT
HAL508	15.5	19.2	21.9	15	18	20.7	13.9	16.65	20.4	12.7	15.3	20	mT
Off point B_{OFF}													
HAL501	–2.5	–0.65	0.8	–2.25	–0.63	0.35	–2.5	–0.59	0.88	–2.5	–0.55	0.9	mT
HAL502	–5	–3	–1	–4.5	–2.75	–1	–4.4	–2.6	–0.95	–4.3	–2.4	–0.9	mT
HAL503	–10.8	–8.6	–6.4	–10	–8	–6	–9.7	–7.2	–5.6	–9.3	–6.4	–5.1	mT
HAL504	5.3	7.5	9.6	5	7	9	4.6	6.45	8.75	4.2	5.9	8.5	mT
HAL505	–18.3	–15	–11.8	–17	–14	–11	–16.6	–13	–10.2	–16.1	–12	–9.4	mT
HAL506	2.1	3.8	5.4	2	3.5	5	1.85	3.3	4.9	1.7	3	4.7	mT
HAL508	14	17	20	13.5	16	19	12.5	14.8	18.7	11.4	13.6	18.3	mT
Hysteresis B_{HYS}													
HAL501	0.5	1.3	2	0.5	1.25	1.9	0.5	1.18	1.85	0.5	1.1	1.8	mT
HAL502	4.5	6	7.2	4.5	5.5	7	4	5.2	6.8	3.5	4.8	6.8	mT
HAL503	14.6	17.2	20.6	13.6	16	18	12.3	14.8	17.6	11	13.6	17.6	mT
HAL504	4.4	5.4	6.5	4	5	6.5	3.6	4.7	6.4	3.2	4.3	6.4	mT
HAL505	26	30	34	24	28	32	22	26	31.3	20	24	31.3	mT
HAL506	1.6	2.1	2.8	1.5	2	2.7	1.2	1.9	2.6	1.0	1.7	2.6	mT
HAL508	1.6	2.1	2.8	1.5	2	2.7	1.2	1.85	2.6	1.0	1.7	2.6	mT
Magnetic Offset $(B_{ON} + B_{OFF})/2$													
HAL501	–	0	–	–1.3	0	1.3	–	0	–	–	0	–	mT
HAL502	–	0	–	–1.5	0	1.5	–	0	–	–	0	–	mT
HAL503	–	0	–	–1.5	0	1.5	–	0	–	–	0	–	mT
HAL504	–	10.1	–	7.2	9.5	11.8	–	8.75	–	–	8	–	mT
HAL505	–	0	–	–1.5	0	1.5	–	0	–	–	0	–	mT
HAL506	–	4.8	–	3	4.5	6.2	–	4.18	–	–	3.85	–	mT
HAL508	–	18.1	–	14	17	20	–	15.8	–	–	14.5	–	mT

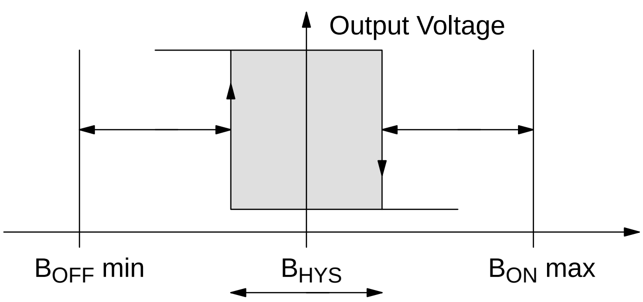


Fig. 6: Definition of magnetic switching points and hysteresis

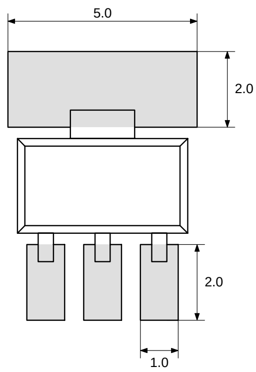
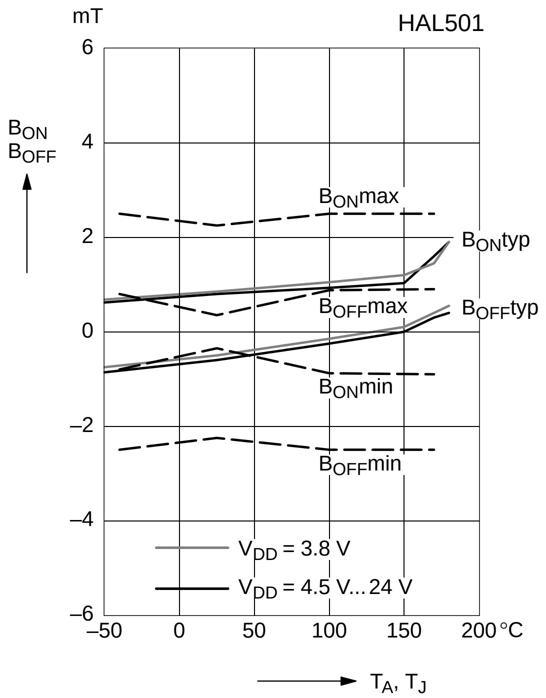


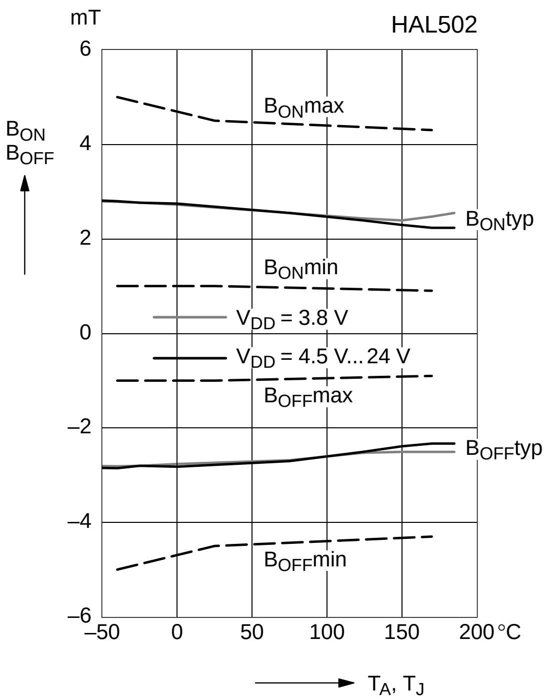
Fig. 7: Recommended pad size SOT-89A
Dimensions in mm

Note: In the following diagrams "Magnetic switch points versus ambient temperature" on pages 8 and 9, the curves for B_{ON}min, B_{ON}max, B_{OFF}min, and B_{OFF}max refer to junction temperature, whereas typical curves refer to ambient temperature.

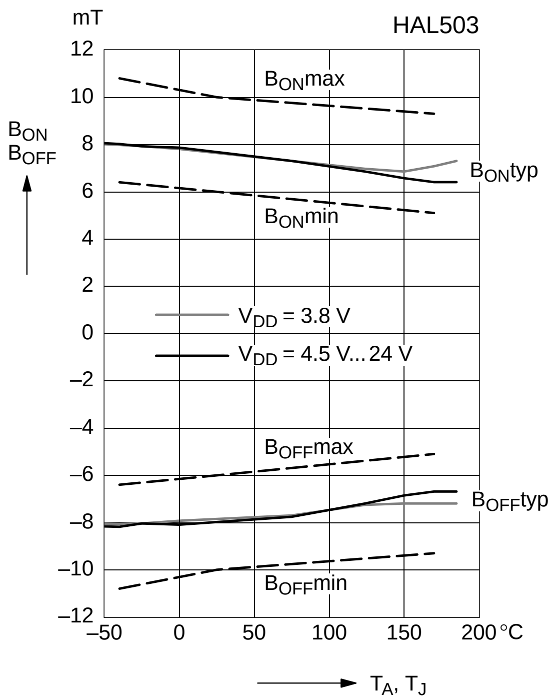
Magnetic switch points versus temperature



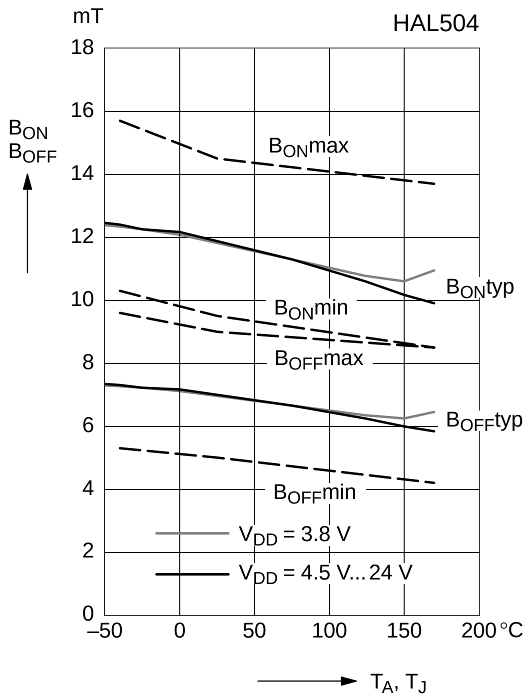
Magnetic switch points versus temperature



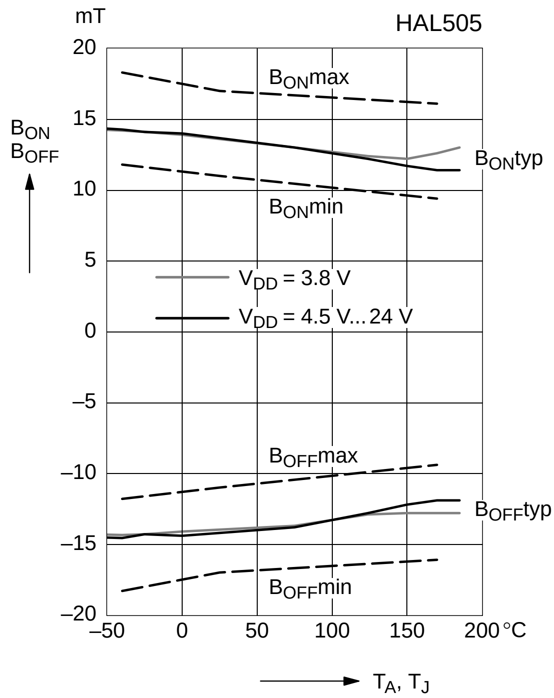
Magnetic switch points versus temperature



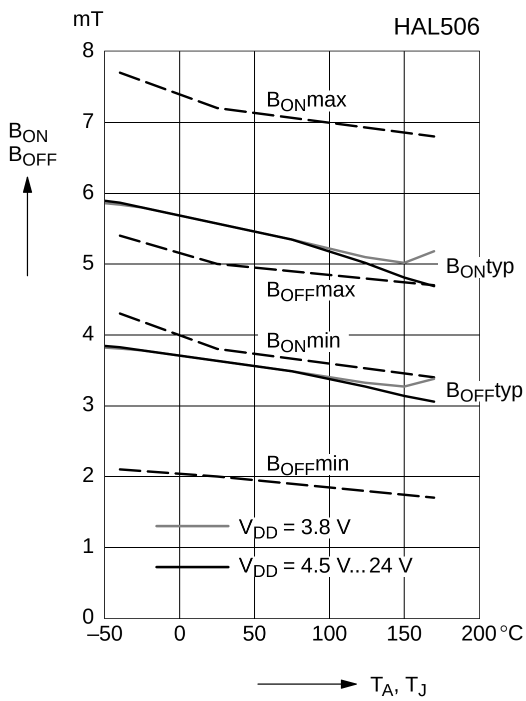
Magnetic switch points versus temperature



Magnetic switch points versus temperature



Magnetic switch points versus temperature



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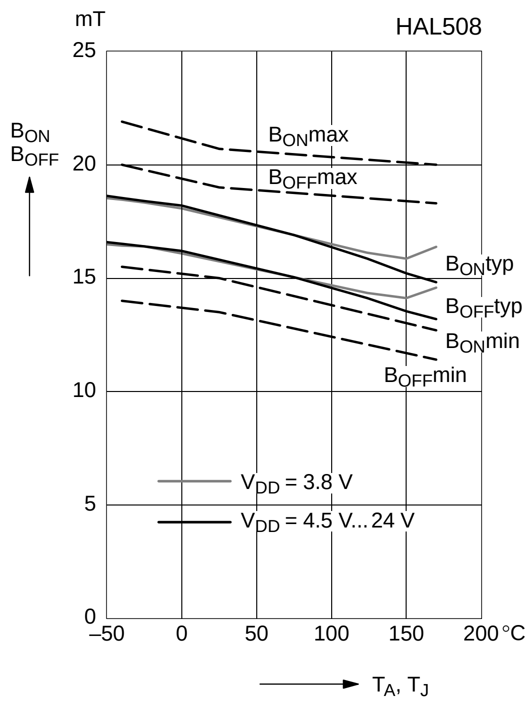
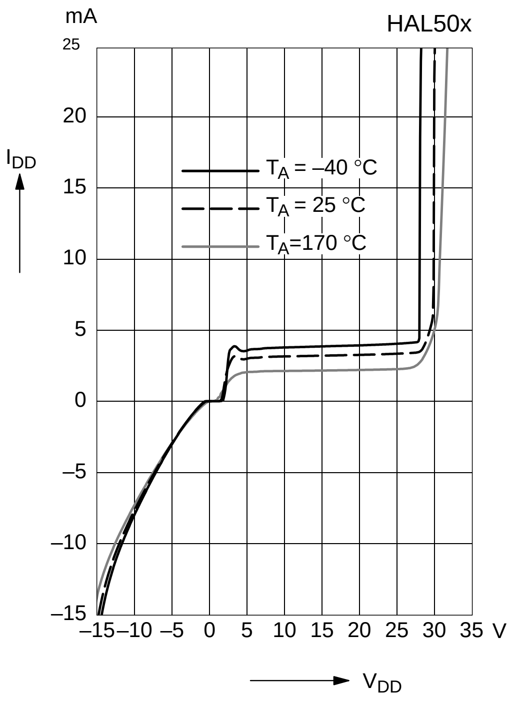
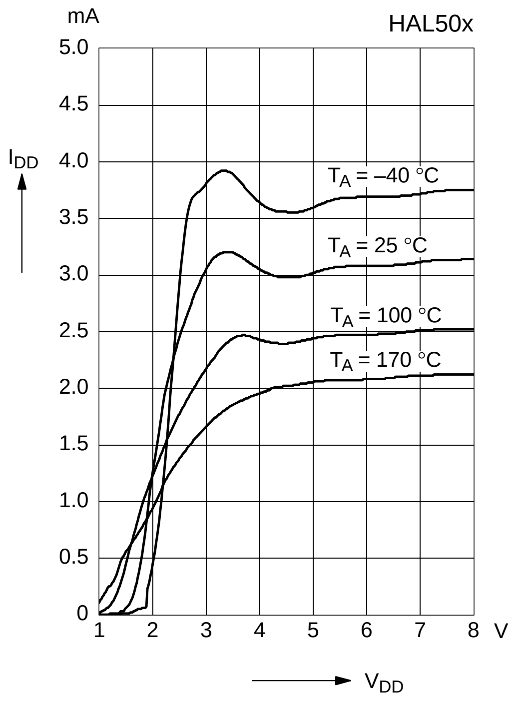


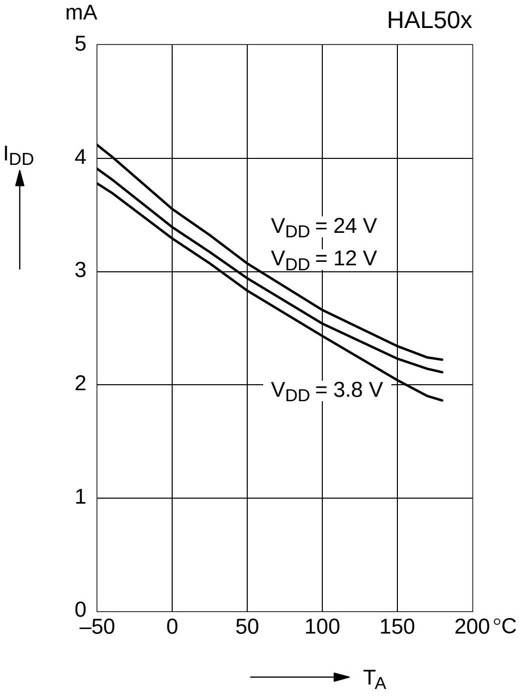
Supply current versus supply voltage



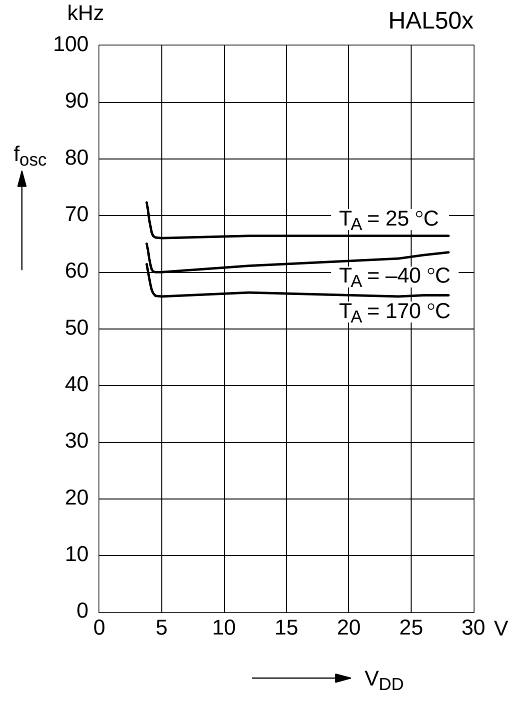
Supply current versus supply voltage



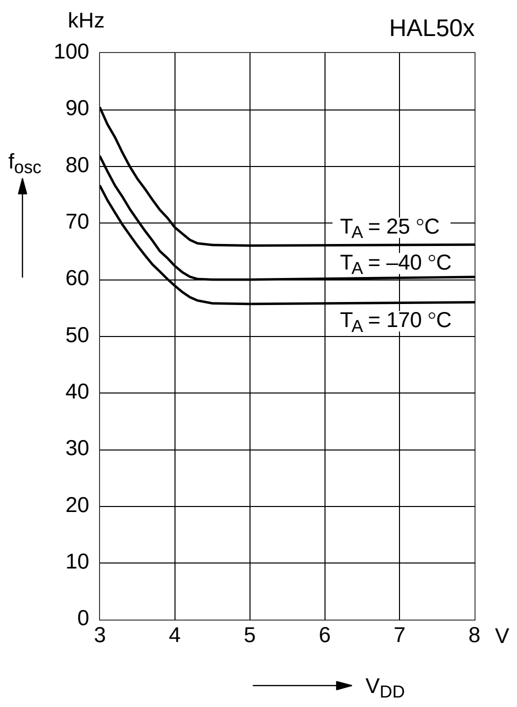
Supply current versus ambient temperature



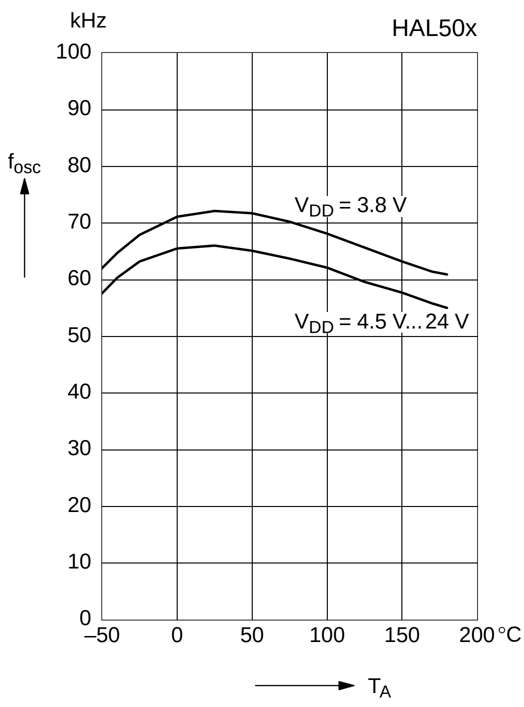
Internal chopper frequency versus supply voltage



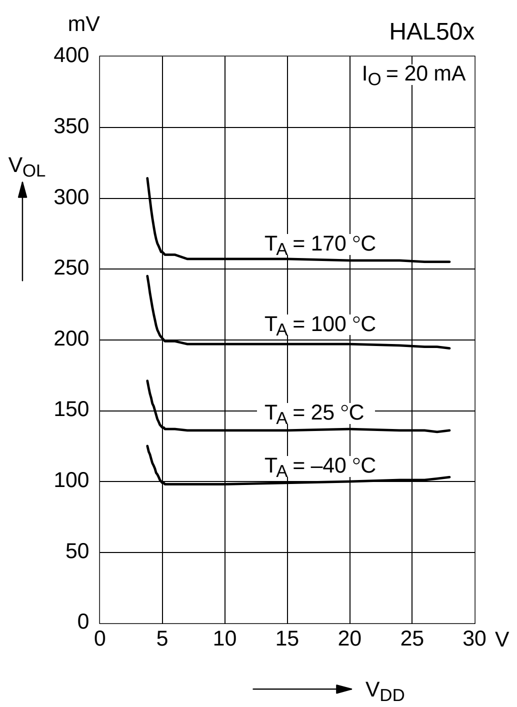
Internal chopper frequency versus supply voltage



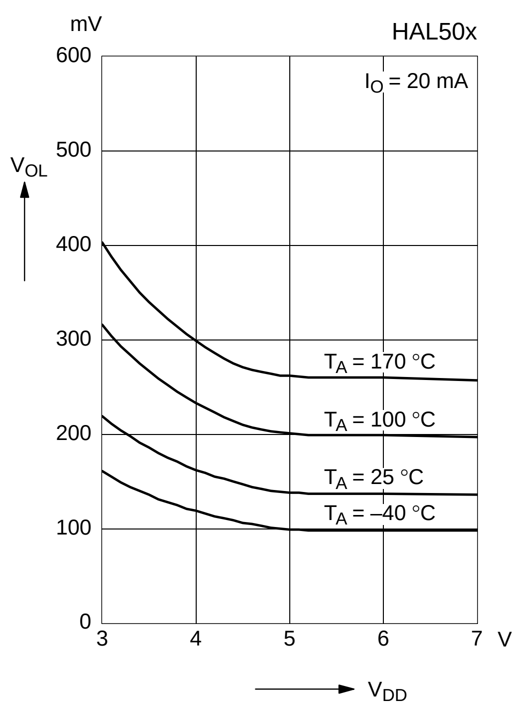
Internal chopper frequency versus ambient temperature



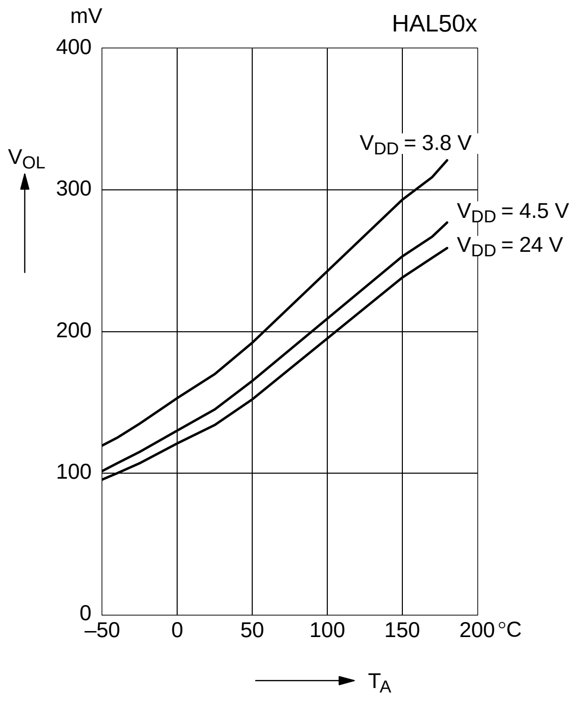
Output low voltage versus supply voltage



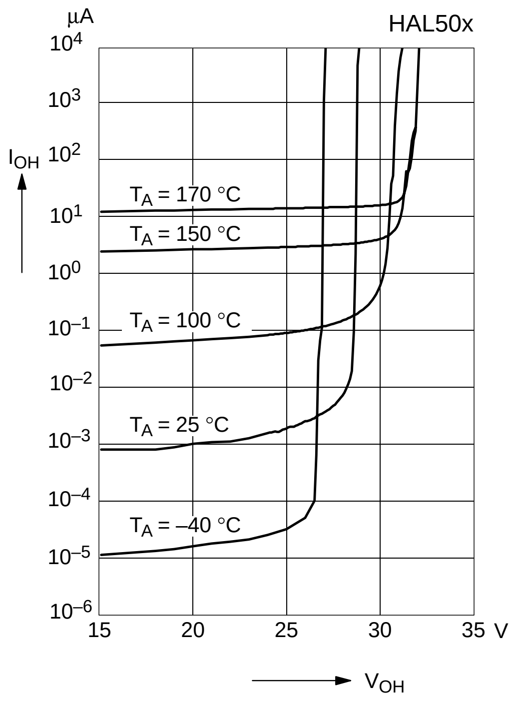
Output low voltage versus supply voltage



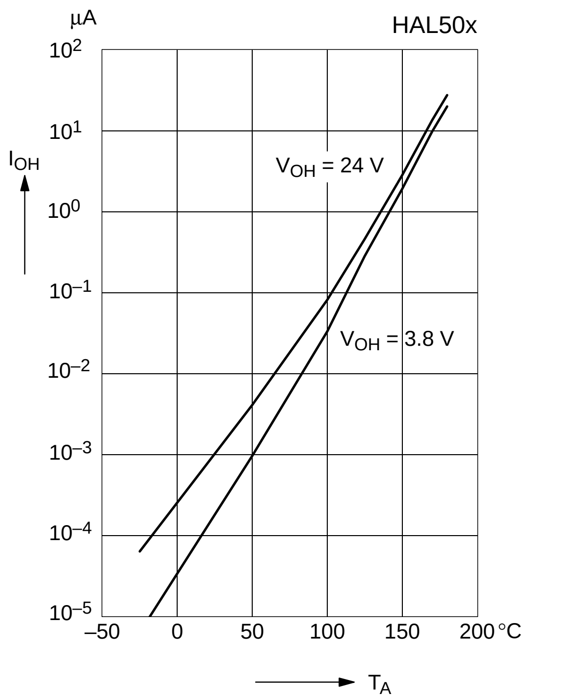
Output low voltage
versus ambient temperature



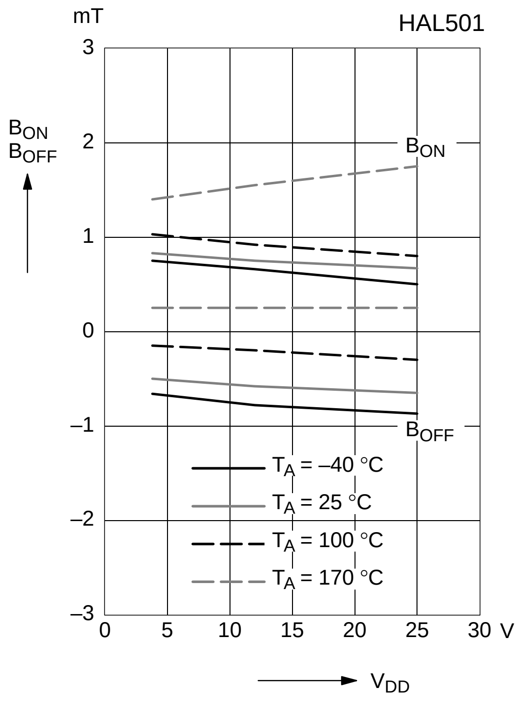
Output high current
versus output voltage



Output leakage current
versus ambient temperature



Magnetic switch points versus supply voltage



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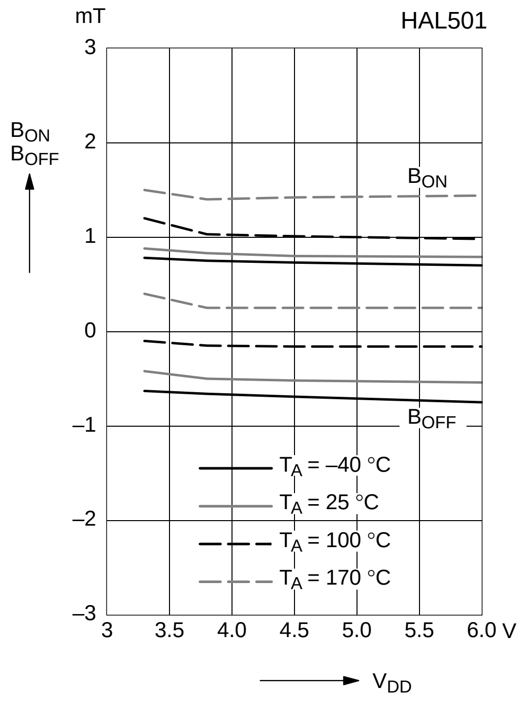

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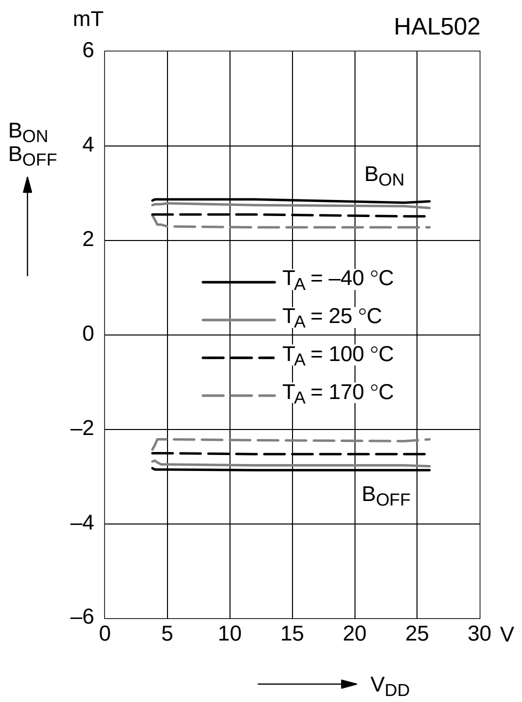

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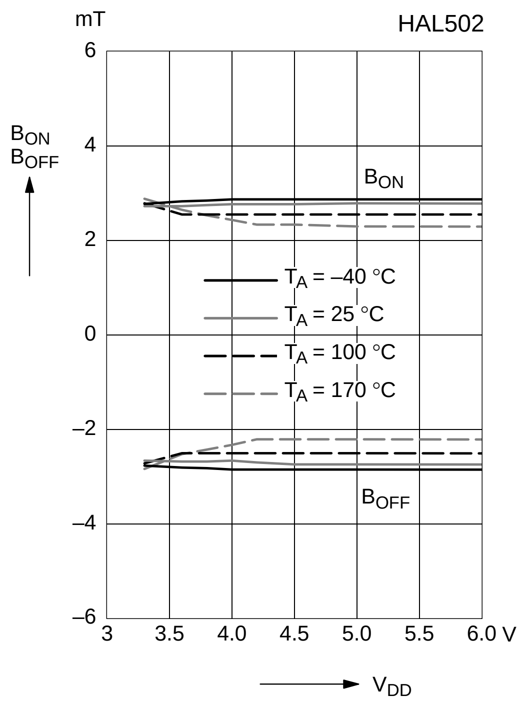
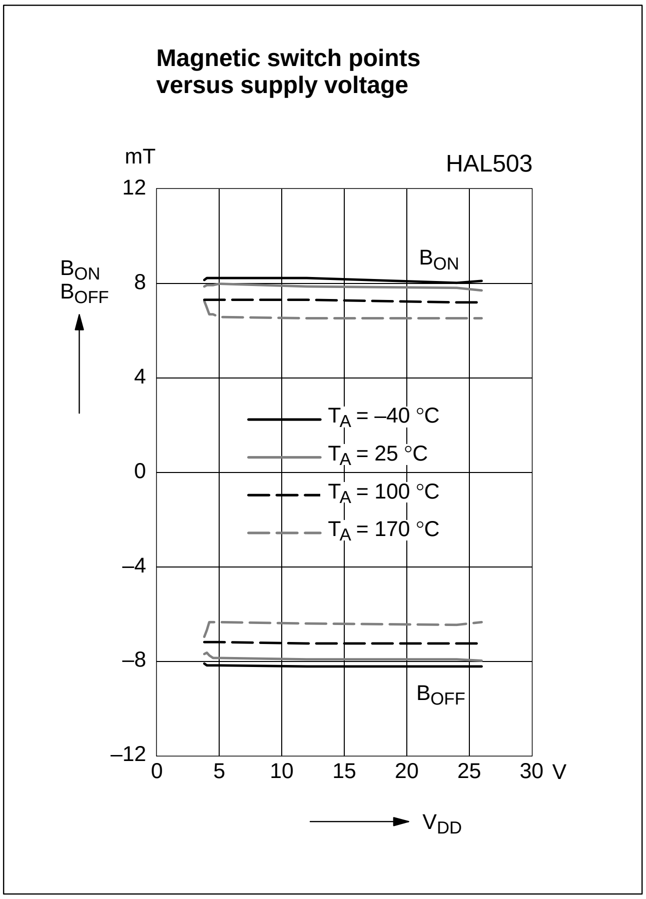
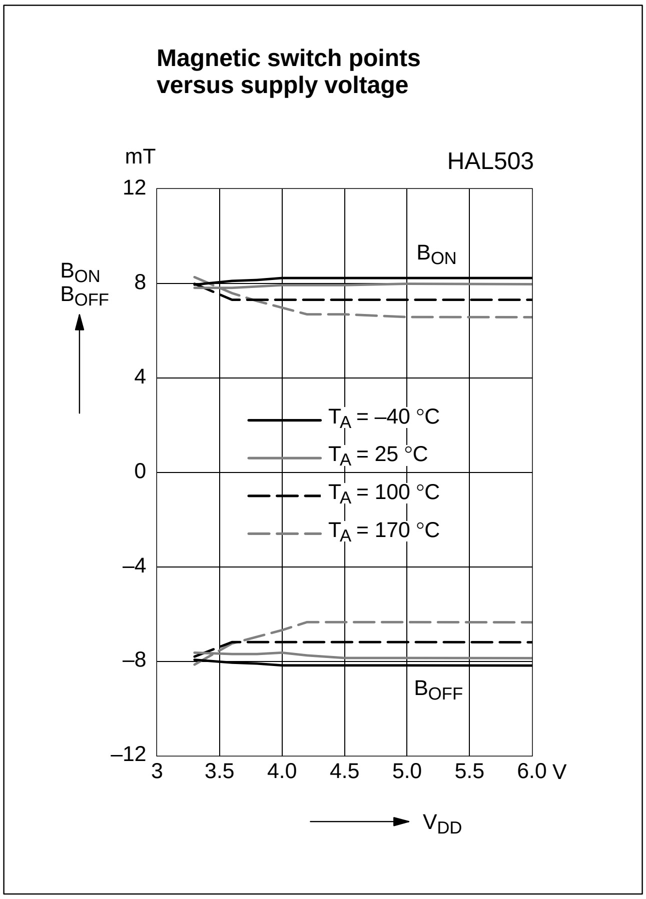



Magnetic switch points
versus supply voltage
mT
HAL503
BON
BOFF
TA = –40 °C
TA = 25 °C
TA = 100 °C
TA = 170 °C
VDD
V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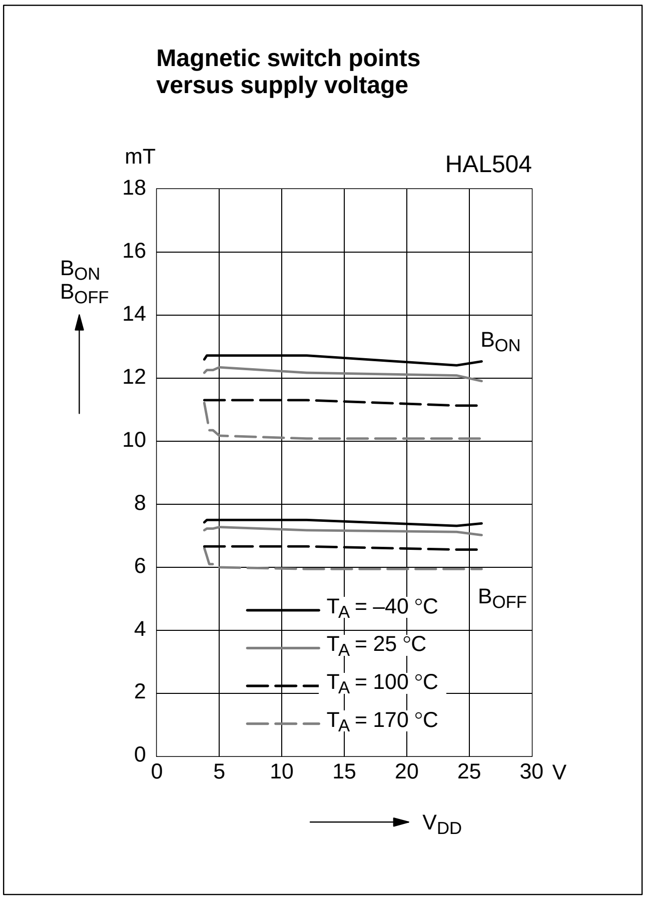
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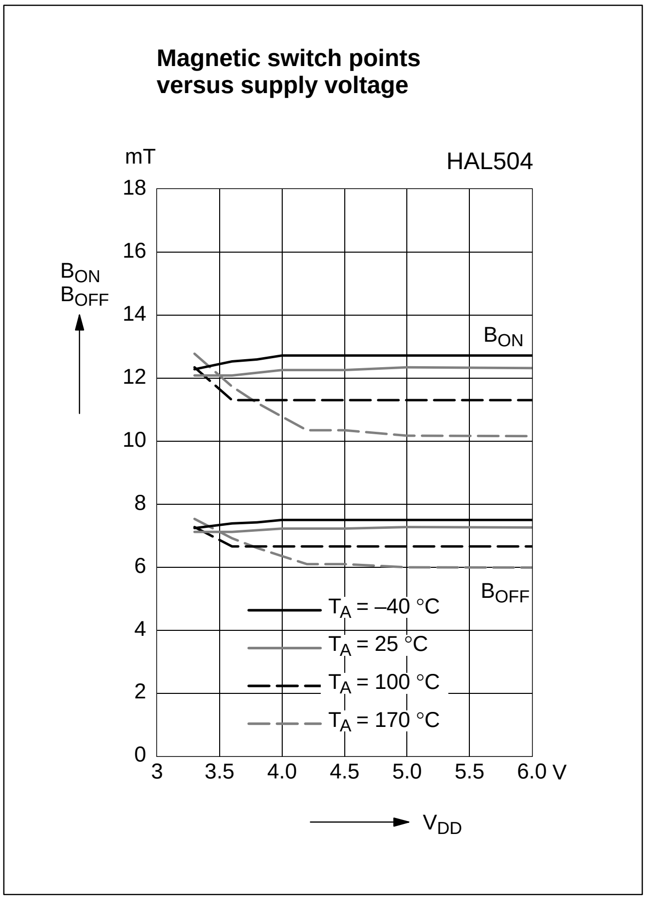
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versus supply voltage
mT
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VDD
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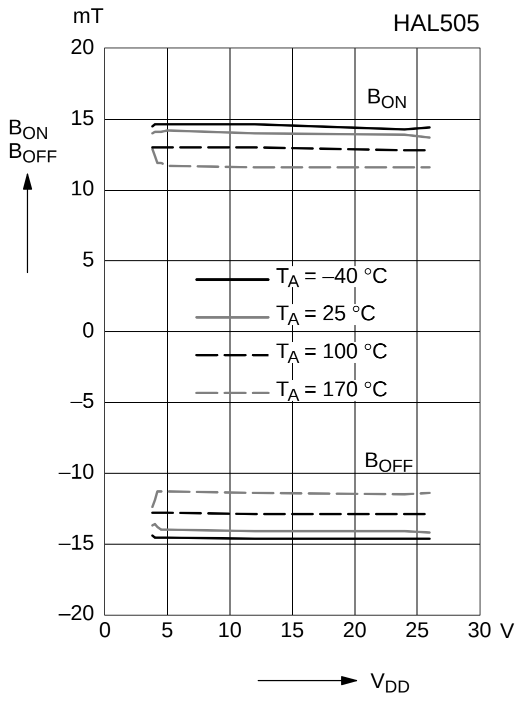
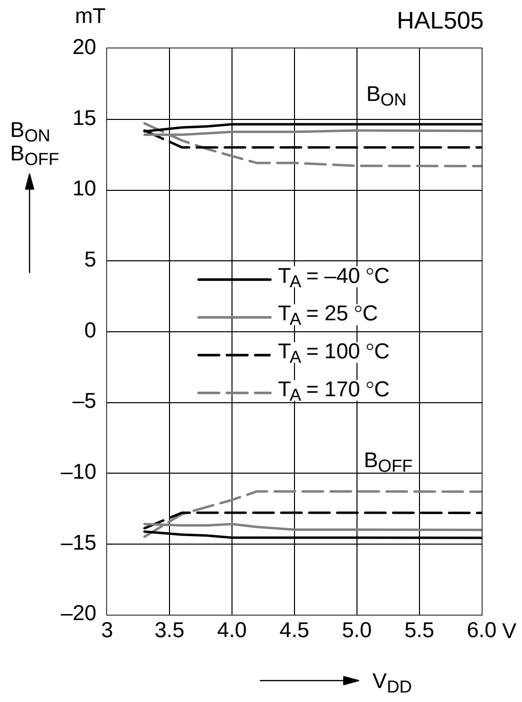
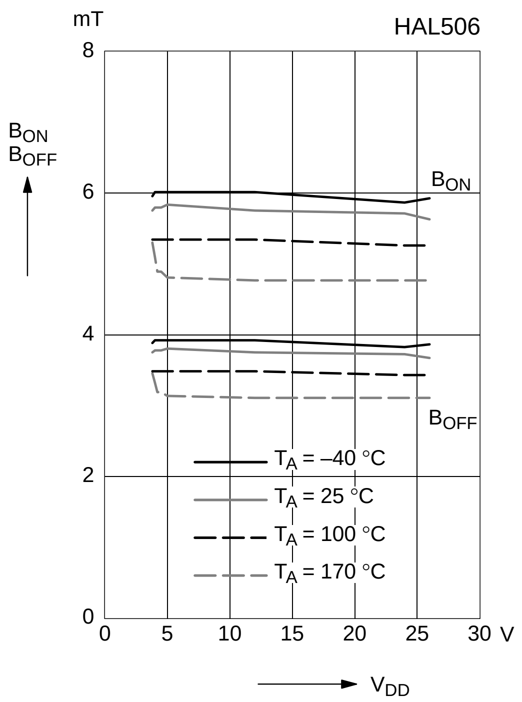
Magnetic switch points versus supply voltage



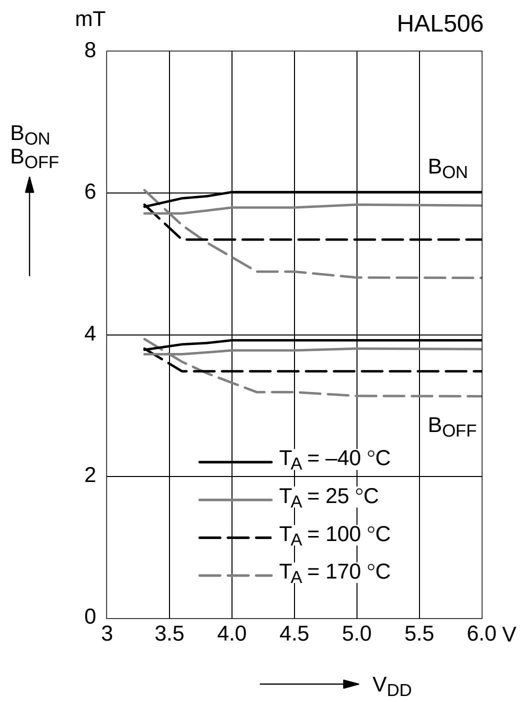
Magnetic switch points versus supply voltage

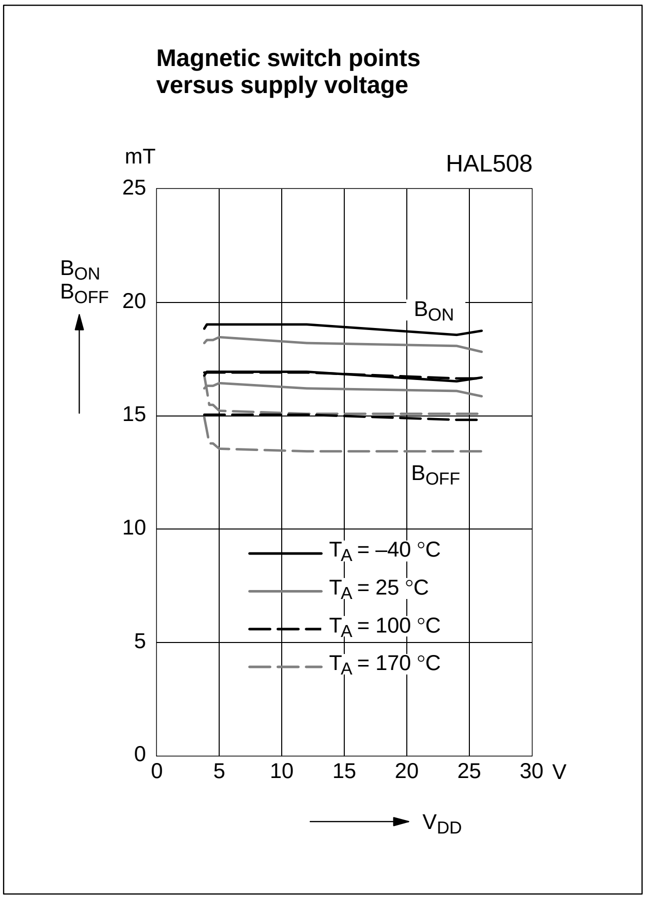


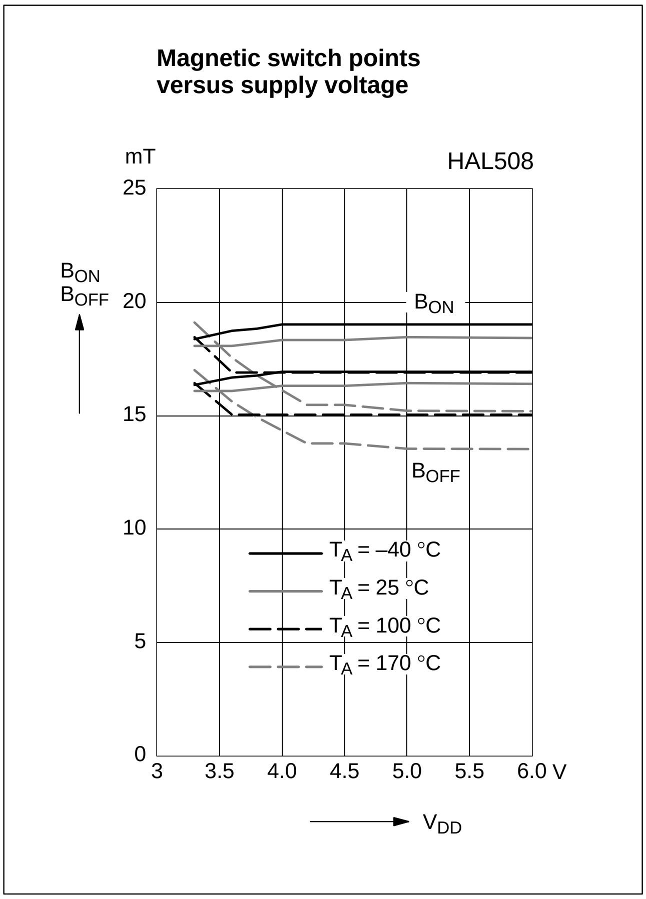
Magnetic switch points versus supply voltage

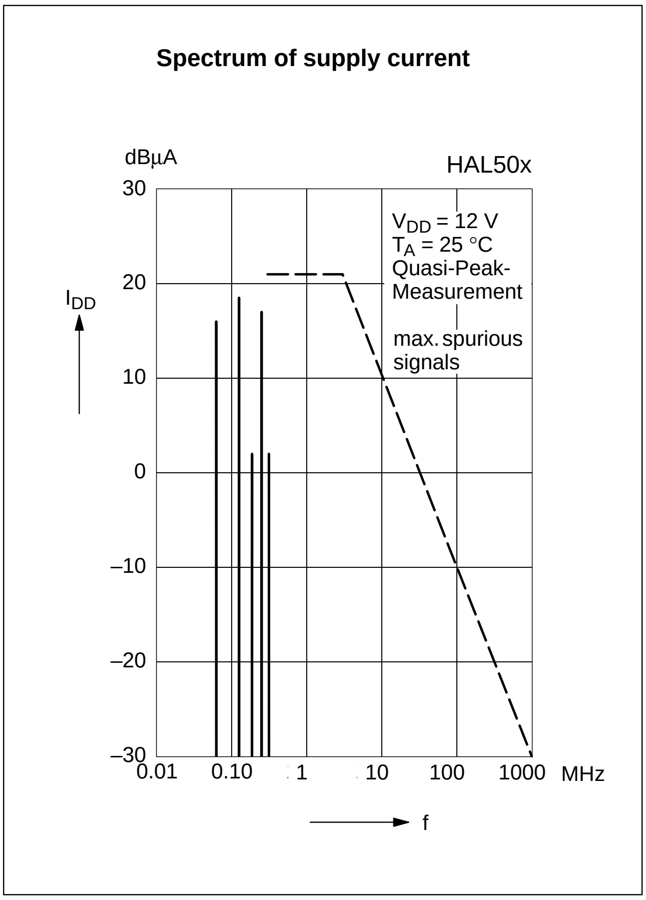


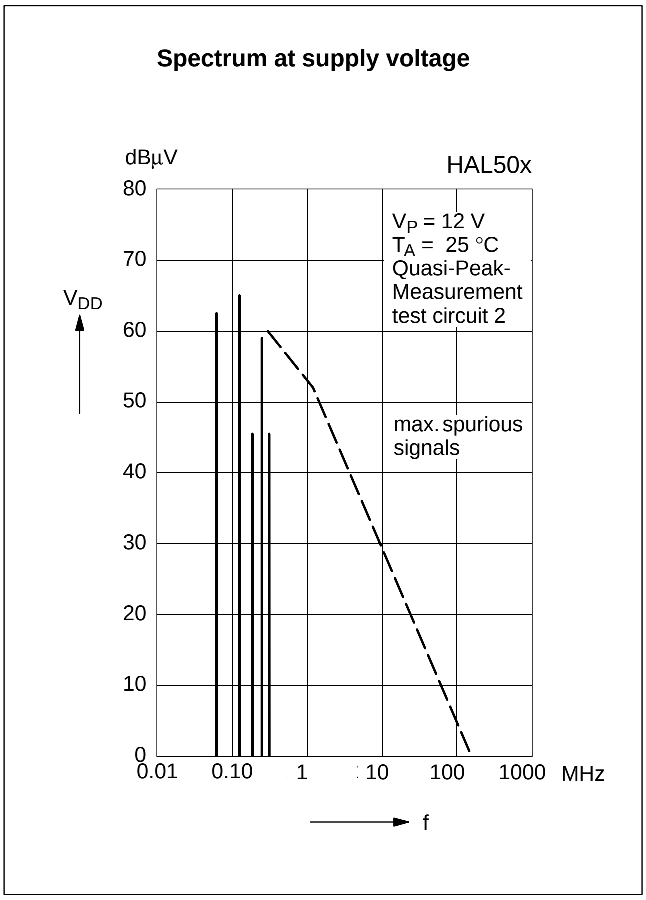
Magnetic switch points versus supply voltage




Magnetic switch points
versus supply voltage
mT
HAL508
BON
BOFF
TA = –40 °C
TA = 25 °C
TA = 100 °C
TA = 170 °C
VDD
V


Magnetic switch points
versus supply voltage
mT
HAL508
BON
BOFF
TA = –40 °C
TA = 25 °C
TA = 100 °C
TA = 170 °C
VDD
V


Spectrum of supply current
dBµA
HAL50x
IDD
VDD = 12 V
TA = 25 °C
Quasi-Peak-Measurement
max. spurious signals
f
MHz


Spectrum at supply voltage
dBµV
HAL50x
VDD
VP = 12 V
TA = 25 °C
Quasi-Peak-Measurement
test circuit 2
max. spurious signals
f
MHz

Application Note

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.

The series resistor and the capacitor should be placed as close as possible to the IC.

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-89A: $\Delta T = I_{DD} * V_{DD} * R_{thJSB}$

– 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.

Test Circuits for Electromagnetic Compatibility

Test pulses V_{EMC} corresponding to DIN 40839.

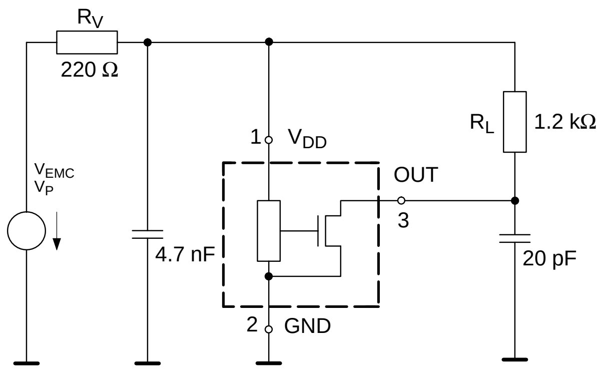


Fig. 8: Test circuit 2: test procedure for class A

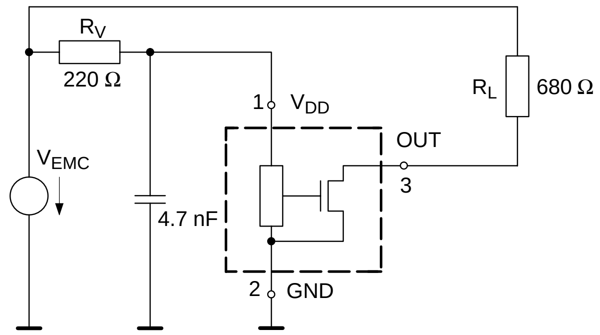


Fig. 9: Test circuit 1: test procedure for class C

Interferences conducted along supply lines in 12 V onboard systems

Product standard: DIN 40839 part 1

Pulse	Level	U_S in V	Test circuit	Pulses/ Time	Function Class	Remarks
1	IV	–100	1	5000	C	5 s pulse interval
2	IV	100	1	5000	C	0.5 s pulse interval
3a	IV	–150	2	1 h	A	
3b	IV	100	2	1h	A	
4	IV	–7	2	5	A	
5	IV	86.5	1	10	C	10 s pulse interval

Electrical transient transmission by capacitive and inductive coupling via lines other than the supply lines

Product standard: DIN 40839 part3

Pulse	Level	U_S in V	Test circuit	Pulses/ Time	Function Class	Remarks
1	IV	–30	2	500	A	5 s pulse interval
2	IV	30	2	500	A	0.5 s pulse interval
3a	IV	–60	2	10 min	A	
3b	IV	40	2	10 min	A	

Radiated Disturbances

Product standard: DIN 40839 part4

Test Conditions

– Temperature: Room temperature (22...25 °C)
– Supply voltage: 13 V
– Lab Equipment: TEM cell 220 MHz (VW standard)
with adaptor board 455 mm, device 80 mm over ground
– Frequency range: 5...220 MHz; 1 MHz steps
– Test circuit 2 with R_L = 1.2 kΩ
– tested with static magnetic fields

Tested Devices and Results

Type	Field Strength	Modulation	Result
HAL 50x	> 200 V/m	–	output voltage stable on the level high or low[1)]
HAL 50x	> 200 V/m	1 kHz 80 %	output voltage stable on the level high or low[1)]
[1)] low level < 0.4 V, high level > 90% of V_{DD}			

Data Sheet History

1. Final data sheet: “HAL 501...HAL 506, HAL 508 Hall Effect Sensor ICs”, May 5, 1997, 6251-405-1DS. First release of the final data sheet.

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End of Data Sheet