Hardware Documentation

# Data Sheet

# HAL® 700, HAL® 740

## Dual Hall-Effect Sensors with Independend Outputs

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6251-477-2DS

## Contents

**Dual Hall-Effect Sensors with Independent Outputs**

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

## 1. Introduction

The HAL 700 and the HAL 740 are monolithic CMOS Hall-effect sensors consisting of two independent switches controlling two independent open-drain outputs. The Hall plates of the two switches are spaced 2.35 mm apart.

The devices include temperature compensation and active offset compensation. These features provide excellent stability and matching of the switching points in the presence of mechanical stress over the whole temperature and supply voltage range.

The sensors are designed for industrial and automotive applications and operate with supply voltages from 3.8 V to 24 V in the ambient temperature range from –40 °C up to 125 °C.

The HAL 700 and the HAL 740 are available in the SMD-package SOT89B-2.

### 1.1. Features

- two independent Hall-switches
- distance of Hall plates: 2.35 mm
- switching offset compensation at typically 150 kHz
- operation from 3.8 V to 24 V supply voltage
- operation with static and dynamic magnetic fields up to 10 kHz
- overvoltage protection at all pins
- reverse-voltage protection at $V_{DD}$-pin
- robustness of magnetic characteristics against mechanical stress
- short-circuit protected open-drain outputs by thermal shut down
- constant switching points over a wide supply voltage range
- EMC corresponding to ISO 7637

### 1.2. Family Overview

The types differ according to the switching behavior of the magnetic switching points at the both Hall plates S1 and S2.

| Type | Switching Behavior | See Page |
|---|---|---|
| HAL 700 | S1: latching<br>S2: latching | 14 |
| HAL 740 | S1: unipolar north sensitive<br>S2: unipolar south sensitive | 16 |

**Latching Sensors:**

The output turns low with the magnetic south pole on the branded side of the package. The output maintains its previous state if the magnetic field is removed. For changing the output state, the opposite magnetic field polarity must be applied.

**Unipolar Sensors:**

In case of a south-sensitive switch, the output turns low with the magnetic south pole on the branded side of the package and turns high if the magnetic field is removed. The switch does not respond to the magnetic north pole on the branded side.

In case of a north-sensitive switch, the output turns low with the magnetic north pole on the branded side of the package and turns high if the magnetic field is removed. The switch does not respond to the magnetic south pole on the branded side.

### 1.3. Marking Code

All Hall sensors have a marking on the package surface (branded side). This marking includes the name of the sensor and the temperature range.

| Type | Temperature Range | |
|---|---|---|
| | K | E |
| HAL 700 | 700K | 700E |
| HAL 740 | 740K | 740E |

#### 1.3.1. 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.

### 1.4. Operating Junction Temperature Range

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

**K:** $T_J$ = –40 °C to +140 °C

**E:** $T_J$ = –40 °C to +100 °C

**Note:** Due to power dissipation, there is a difference between the ambient temperature ($T_A$) and junction temperature. Please refer to section 5.1. on page 18 for details.

### 1.5. Hall Sensor Package Codes

HALXXXPA-T

- Temperature Range: K or E
- Package: SF for SOT89B-2
- Type: 700

Example: **HAL 700SF-K**

→ Type: 700
→ Package: SOT89B-2
→ 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: "Hall Sensors: Ordering Codes, Packaging, Handling".

### 1.6. 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.

### 1.7. Pin Connections

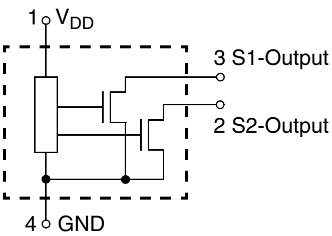



**Fig. 1–1:** Pin configuration

## 2. Functional Description

The HAL 700 and the HAL 740 are monolithic integrated circuits with two independent subblocks each consisting of a Hall plate and the corresponding comparator. Each subblock independently switches the comparator output in response to the magnetic field at the location of the corresponding sensitive area. If a magnetic field with flux lines perpendicular to the sensitive area is present, the biased Hall plate generates a Hall voltage proportional to this field. The Hall voltage is compared with the actual threshold level in the comparator. The subblocks are designed to have closely matched switching points. The output of comparator 1 attached to S1 controls the open drain output at Pin 3. Pin 2 is set according to the state of comparator 2 connected to S2.

The temperature-dependent bias – common to both subblocks – 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 comparator switches to the appropriate state. The built-in hysteresis prevents oscillations of the outputs.

The magnetic offset caused by mechanical stress is compensated for by use of “switching offset compensation techniques”. Therefore, an internal oscillator provides a two-phase clock to both subblocks. For each subblock, the Hall voltage is sampled at the end of the first phase. At the end of the second phase, both sampled and actual Hall voltages are averaged and compared with the actual switching point.

Shunt protection devices clamp voltage peaks at the output pins 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 reverse voltages ranging from 0 V to −15 V.

Fig. 2–2 and Fig. 2–3 on page 6 show how the output signals are generated by the HAL 700 and the HAL 740. The magnetic flux density at the locations of the two Hall plates is shown by the two sinusodial curves at the top of each diagram. The magnetic switching points are depicted as dashed lines for each Hall plate separately.

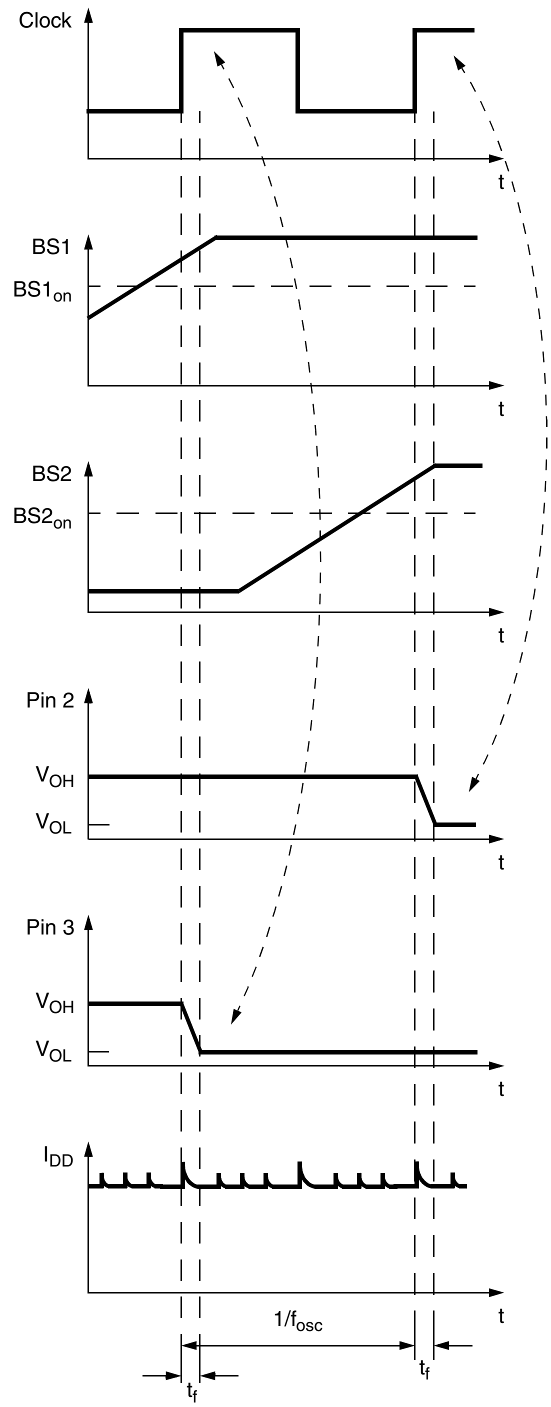



**Fig. 2–1:** HAL 700 timing diagram with respect to the clock phase

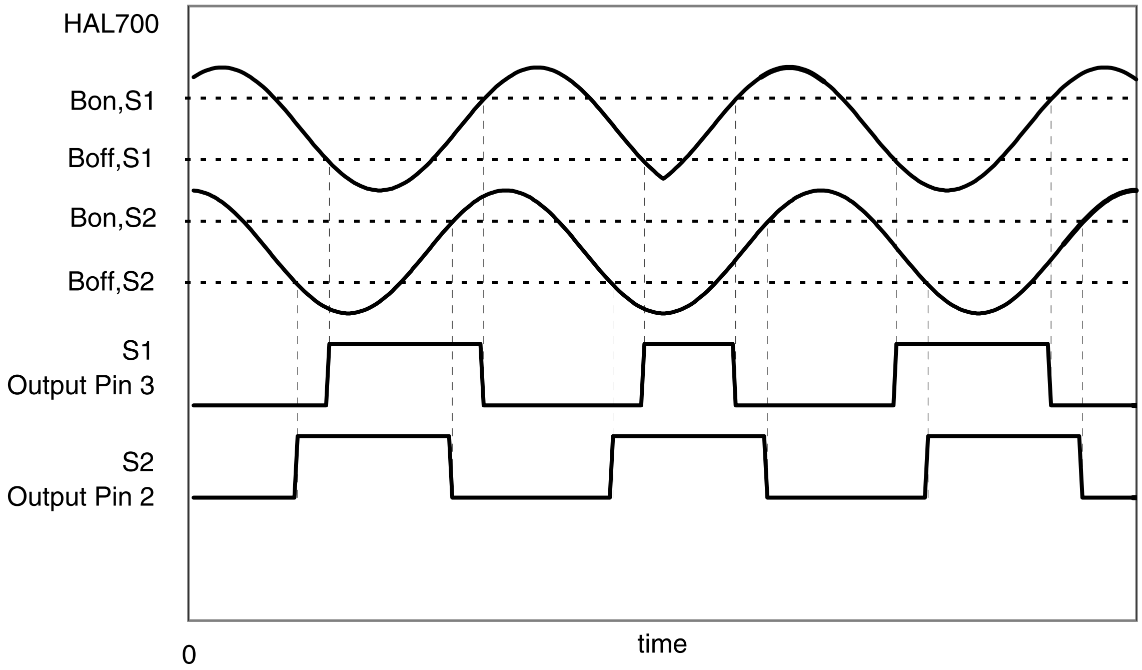



**Fig. 2–2:** HAL700 timing diagram

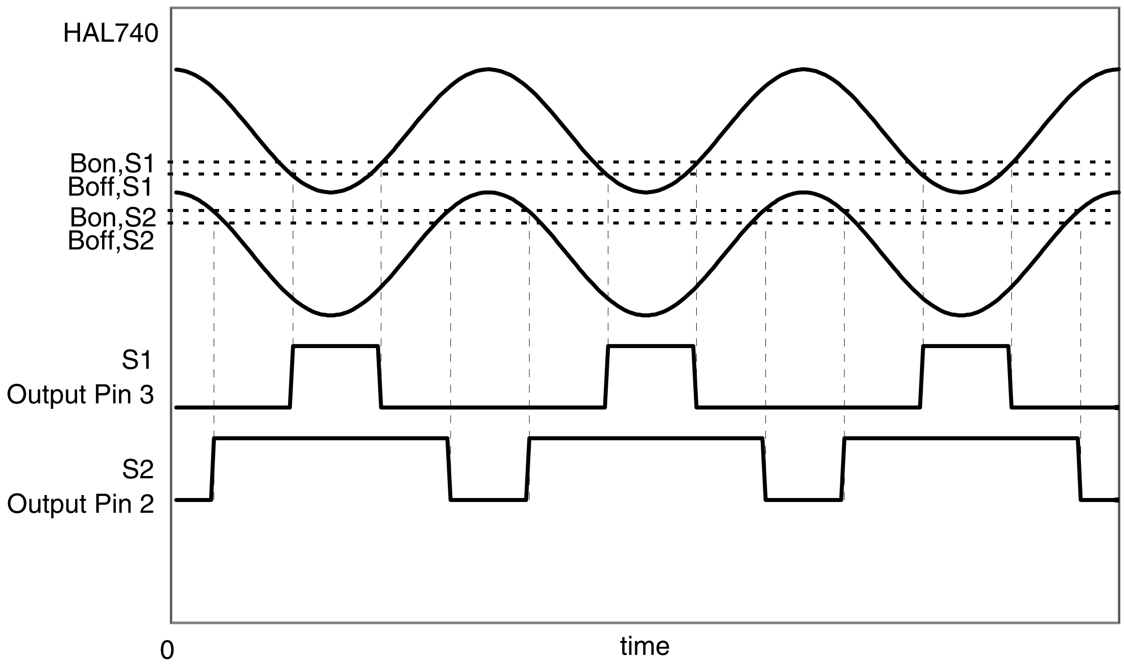



**Fig. 2–3:** HAL740 timing diagram

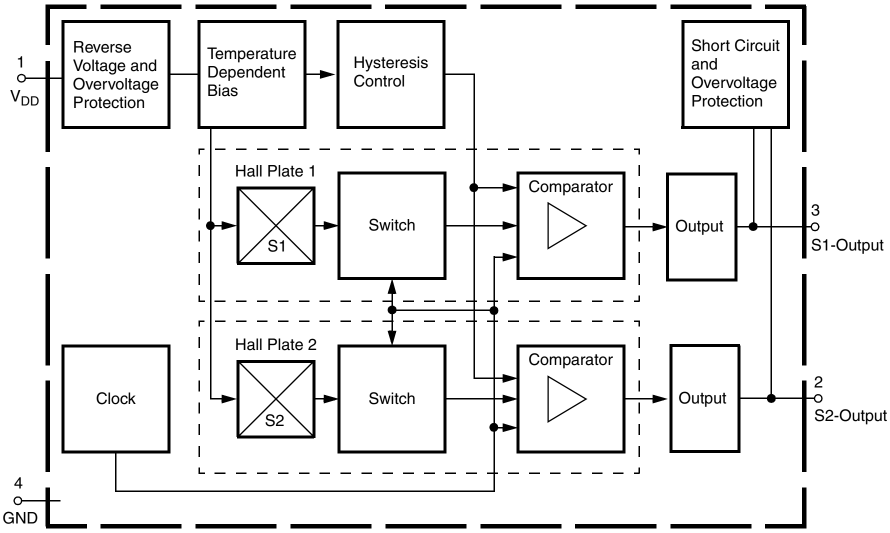
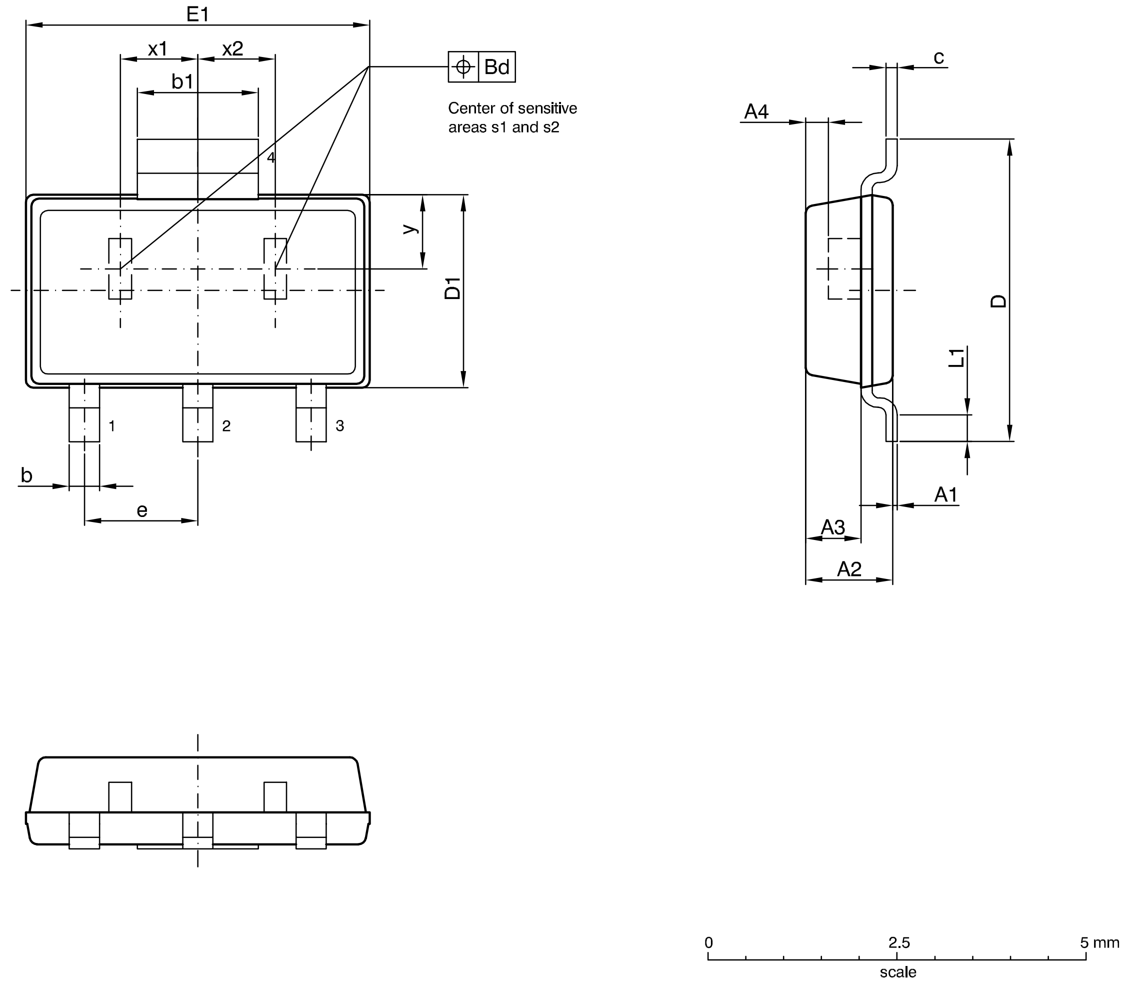



**Fig. 2–4:** HAL 700 and HAL 740 block diagram

## 3. Specifications

### 3.1. Outline Dimensions




x1, x2, y = these dimensions are different for each sensor type and are specified in the data sheet.

| UNIT | A1 | A2 | A3 | A4 | b | b1 | Bd | c | D | D1 | e | E1 | L1 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| mm | 0.10<br>0.02 | 1.20<br>1.10 | 0.755<br>0.705 | 0.3 | 0.4 | 1.7 | 0.2 | 0.15 | 4.0 | 2.6<br>2.5 | 1.5 | 4.6<br>4.5 | 0.25<br>min. |

| JEDEC STANDARD | | ANSI | ISSUE DATE YY-MM-DD | DRAWING-NO. | SPZG-NO. |
|---|---|---|---|---|---|
| ISSUE | ITEM NO. | | | | |
| - | - | | 04-01-28 | 06655.0001.4 | SPZG001055_001_01 |

**Fig. 3–1:**
**SOT89B-2**: Plastic **S**mall **O**utline **T**ransistor package, 4 leads, with two sensitive areas
Weight approximately 0.039 g

### 3.2. Dimensions of Sensitive Area

0.25 mm × 0.12 mm

### 3.3. Positions of Sensitive Areas

| | SOT89B-2 |
|---|---|
| $x_1+x_2$ | (2.35±0.001) mm |
| $x_1=x_2$ | 1.175 mm nominal |
| y | 0.975 mm nominal |

### 3.4. Absolute Maximum Ratings

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 conditions is not implied. Exposure to absolute maximum rating conditions for extended periods will affect device reliability.

This device contains circuitry to protect the inputs and outputs against damage due to high static voltages or electric fields; however, it is advised that normal precautions be taken to avoid application of any voltage higher than absolute maximum-rated voltages to this high-impedance circuit.

All voltages listed are referenced to ground (GND).

| Symbol | Parameter | Pin No. | Min. | Max. | Unit |
|---|---|---|---|---|---|
| $V_{DD}$ | Supply Voltage | 1 | –15 | 28[1)] | V |
| $V_O$ | Output Voltage | 2, 3 | –0.3 | 28[1)] | V |
| $I_O$ | Continuous Output Current | 2, 3 | – | 20[1)] | mA |
| $T_J$ | Junction Temperature Range | | –40 | 170 | °C |

1) as long as $T_{Jmax}$ is not exceeded

#### 3.4.1. Storage and Shelf Life

The permissible storage time (shelf life) of the sensors is unlimited, provided the sensors are stored at a maximum of 30 °C and a maximum of 85% relative humidity. At these conditions, no Dry Pack is required.

Solderability is guaranteed for one year from the date code on the package. Solderability has been tested after storing the devices for 16 hours at 155 °C. The wettability was more than 95%.

### 3.5. Recommended Operating Conditions

Functional operation of the device beyond those indicated in the “Recommended Operating Conditions” of this specification is not implied, may result in unpredictable behavior of the device and may reduce reliability and lifetime.

All voltages listed are referenced to ground (GND).

| Symbol | Parameter | Pin No. | Min. | Typ. | Max. | Unit |
|---|---|---|---|---|---|---|
| $V_{DD}$ | Supply Voltage | 1 | 3.8 | – | 24 | V |
| $I_O$ | Continuous Output Current | 3 | 0 | – | 10 | mA |
| $V_O$ | Output Voltage (output switch off) | 3 | 0 | – | 24 | V |

### 3.6. Characteristics

at $T_J$ = –40 °C to +140 °C, $V_{DD}$ = 3.8 V to 24 V, GND = 0 V
at Recommended Operation Conditions if not otherwise specified in the column “Conditions”.
Typical Characteristics for $T_J$ = 25 °C and $V_{DD}$ = 5 V.

| Symbol | Parameter | Pin No. | Min. | Typ. | Max. | Unit | Test Conditions |
|---|---|---|---|---|---|---|---|
| $I_{DD}$ | Supply Current | 1 | 3 | 5.5 | 9 | mA | $T_J$ = 25 °C |
| $I_{DD}$ | Supply Current over Temperature Range | 1 | 2 | 7 | 10 | mA | |
| $V_{DDZ}$ | Overvoltage Protection at Supply | 1 | – | 28.5 | 32 | V | $I_{DD}$ = 25 mA, $T_J$ = 25 °C, t = 2 ms |
| $V_{OZ}$ | Overvoltage Protection at Output | 2, 3 | – | 28 | 32 | V | $I_O$ = 20 mA, $T_J$ = 25 °C, t = 15 ms |
| $V_{OL}$ | Output Voltage | 2, 3 | – | 130 | 280 | mV | $I_{OL}$ = 10 mA, $T_J$ = 25 °C |
| $V_{OL}$ | Output Voltage over Temperature Range | 2, 3 | – | 130 | 400 | mV | $I_{OL}$ = 10 mA |
| $I_{OH}$ | Output Leakage Current | 2, 3 | – | 0.06 | 0.1 | µA | Output switched off, $T_J$ = 25 °C, $V_{OH}$ = 3.8 V to 24 V |
| $I_{OH}$ | Output Leakage Current over Temperature Range | 2, 3 | – | – | 10 | µA | Output switched off, $T_J \leq$ 140 °C, $V_{OH}$ = 3.8 V to 24 V |
| $f_{osc}$ | Internal Sampling Frequency over Temperature Range | – | 100 | 150 | – | kHz | |
| $t_{en}(O)$ | Enable Time of Output after Setting of $V_{DD}$ | 1 | – | 50 | – | µs | $V_{DD}$ = 12 V, $B > B_{on}$ + 2 mT or $B < B_{off}$ – 2 mT |
| $t_r$ | Output Rise Time | 2, 3 | – | 0.2 | – | µs | $V_{DD}$ = 12 V, $R_L$ = 2.4 kΩ, $C_L$ = 20 pF |
| $t_f$ | Output FallTime | 2, 3 | – | 0.2 | – | µs | $V_{DD}$ = 12 V, $R_L$ = 2.4 kΩ, $C_L$ = 20 pF |
| $R_{thJSB}$ case SOT89B-2 | Thermal Resistance Junction to Substrate Backside | – | – | 150 | 200 | K/W | Fiberglass Substrate 30 mm x 10 mm x 1.5 mm, pad size |

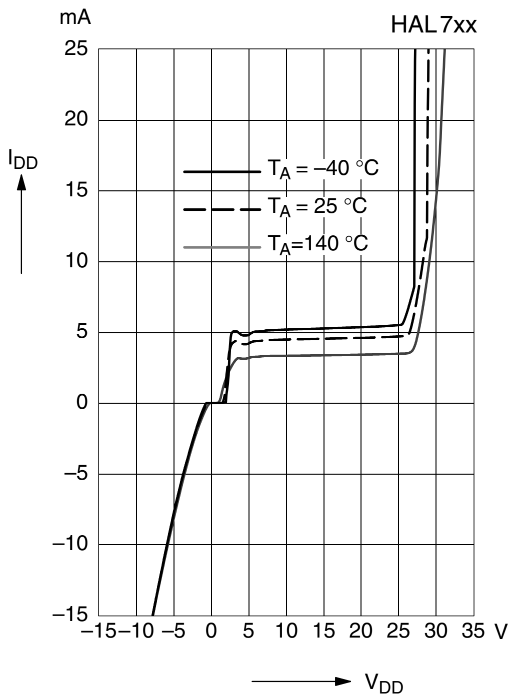



**Fig. 3–2:** Typical supply current versus supply voltage

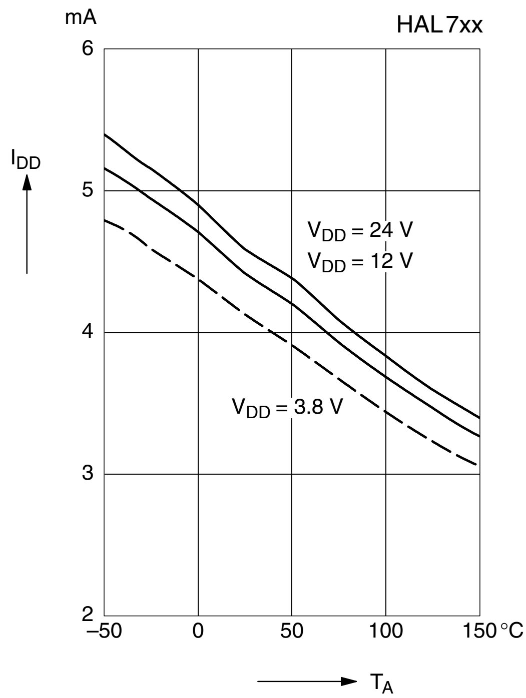



**Fig. 3–4:** Typical supply current versus ambient temperature

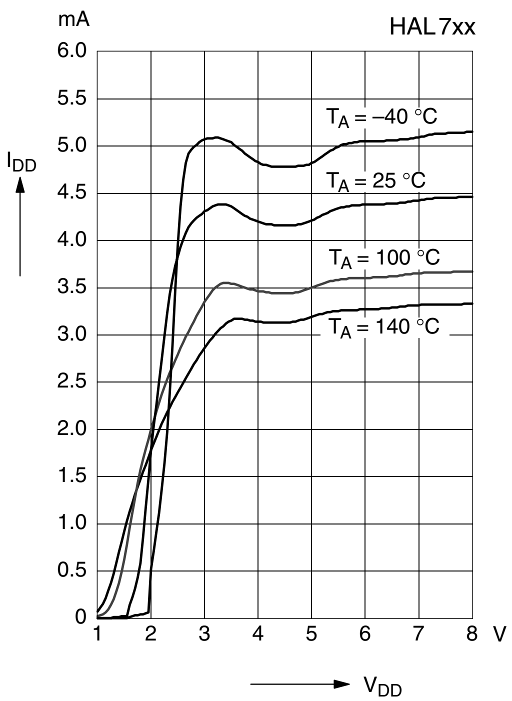



**Fig. 3–3:** Typical supply current versus supply voltage

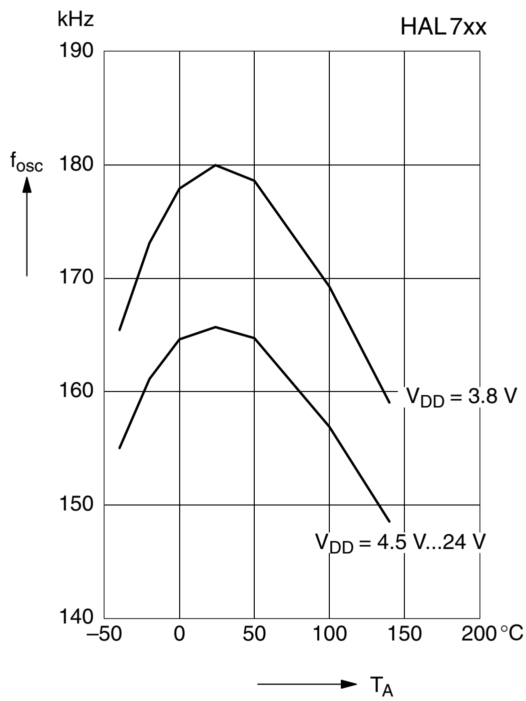



**Fig. 3–5:** Typ. internal chopper frequency versus ambient temperature

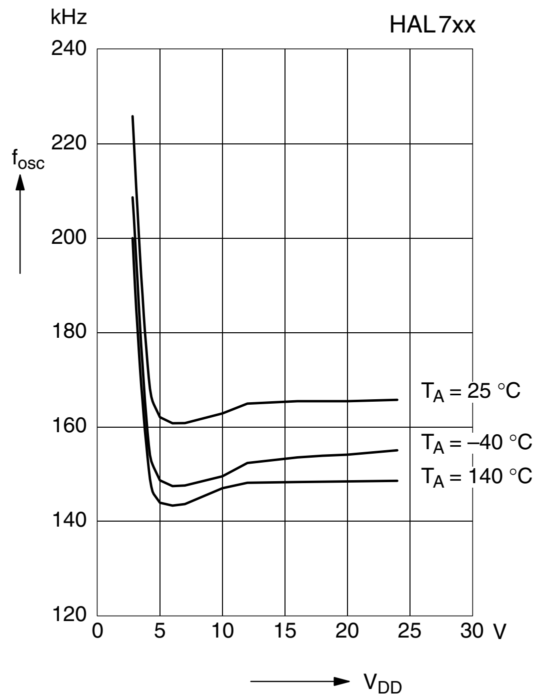



**Fig. 3–6:** Typ. internal chopper frequency versus supply voltage

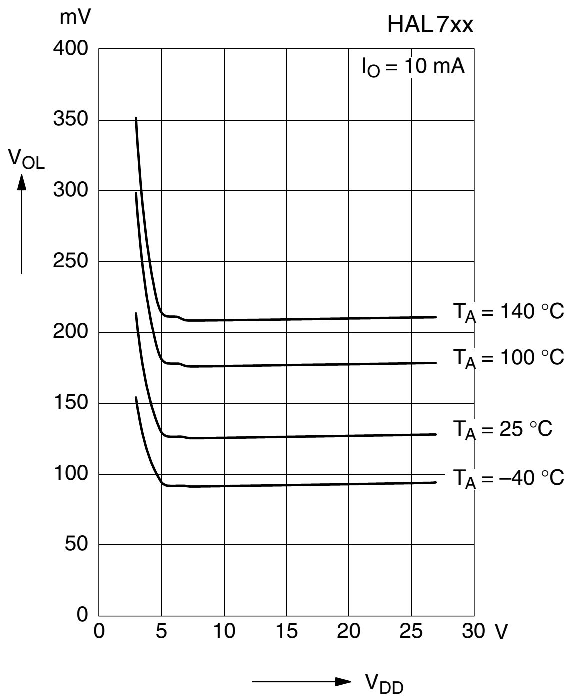



**Fig. 3–8:** Typical output low voltage versus supply voltage

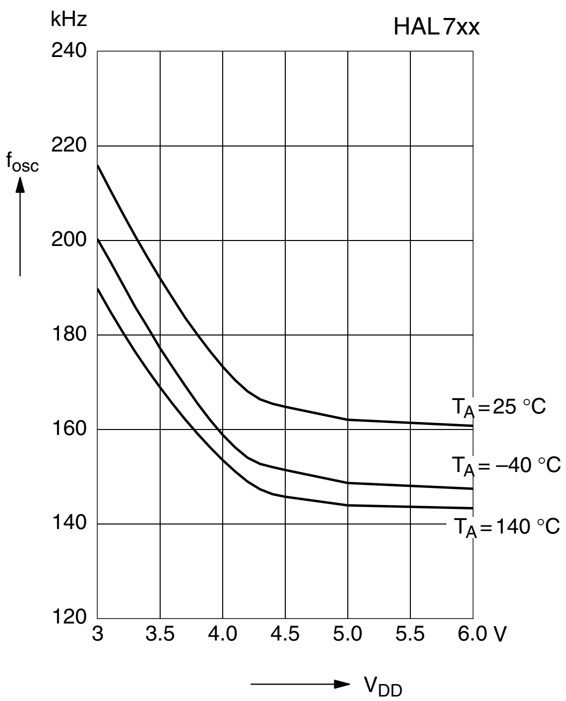



**Fig. 3–7:** Typ. internal chopper frequency versus supply voltage

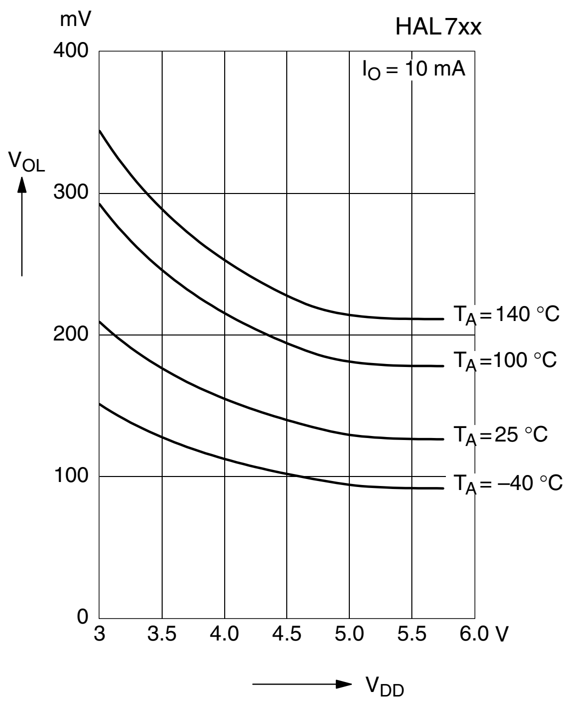



**Fig. 3–9:** Typical output low voltage versus supply voltage

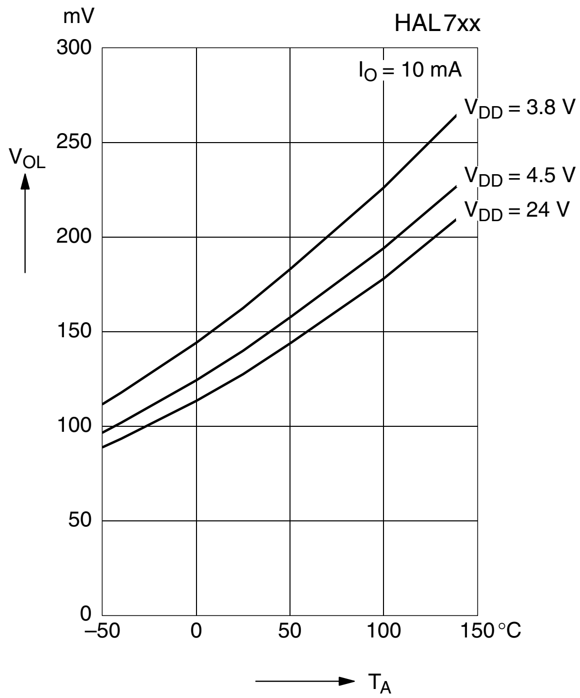



**Fig. 3–10:** Typ. output low voltage versus ambient temperature

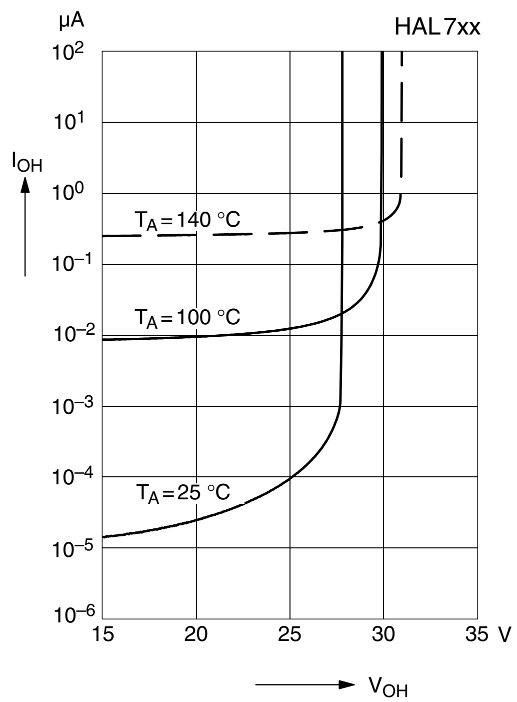



**Fig. 3–11:** Typical output leakage current versus output voltage

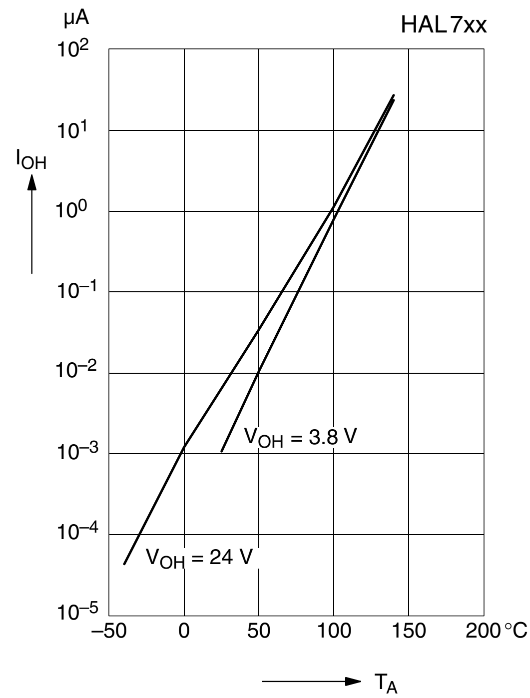



**Fig. 3–12:** Typical output leakage current versus ambient temperature

## 4. Type Description

### 4.1. HAL 700

The HAL 700 consists of two independent latched switches (see Fig. 4–1) with closely matched magnetic characteristics controlling two independent open-drain outputs. The Hall plates of the two switches are spaced 2.35 mm apart.

In combination with an active target providing a sequence of alternating magnetic north and south poles, the sensor forms a system generating the signals required to control position, speed, and direction of the target movement.

### Magnetic Features

– two independent Hall-switches
– distance of Hall plates: 2.35 mm
– typical $B_{ON}$: 14.9 mT at room temperature
– typical $B_{OFF}$: –14.9 mT at room temperature
– temperature coefficient of –2000 ppm/K in all magnetic characteristics
– operation with static magnetic fields and dynamic magnetic fields up to 10 kHz

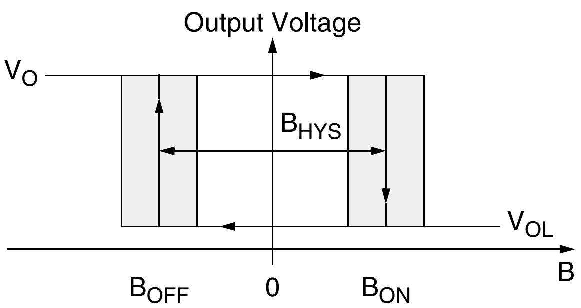



**Fig. 4–1:** Definition of magnetic switching points for the HAL 700

Positive flux density values refer to magnetic south pole at the branded side of the package.

### Applications

The HAL 700 is the ideal sensors for position-control applications with direction detection and alternating magnetic signals such as:

– multipole magnet applications,
– rotating speed and direction measurement, position tracking (active targets), and
– window lifters.

### Magnetic Thresholds

(quasistationary: dB/dt<0.5 mT/ms)

at $T_J$ = –40 °C to +140 °C, $V_{DD}$ = 3.8 V to 24 V, as not otherwise specified

Typical characteristics for $T_J$ = 25 °C and $V_{DD}$ = 5 V

| Parameter | On-Point $B_{S1on}$, $B_{S2on}$ | | | Off-Point $B_{S1off}$, $B_{S2off}$ | | | Unit |
|---|---|---|---|---|---|---|---|
| $T_j$ | Min. | Typ. | Max. | Min. | Typ. | Max. | |
| –40 °C | 12.5 | 16.3 | 20 | –20 | –16.3 | –12.5 | mT |
| 25 °C | 10.7 | 14.9 | 19.1 | –19.1 | –14.9 | –10.7 | mT |
| 100 °C | 7.7 | 12.5 | 17.3 | –17.3 | –12.5 | –7.7 | mT |
| 140 °C | 6.0 | 10.9 | 16.0 | –16.0 | –10.9 | –6.0 | mT |

### Matching $B_{S1}$ and $B_{S2}$

(quasistationary: dB/dt<0.5 mT/ms)

at $T_J$ = –40 °C to +140 °C, $V_{DD}$ = 3.8 V to 24 V, as not otherwise specified

Typical characteristics for $T_J$ = 25 °C and $V_{DD}$ = 5 V

| Parameter | $B_{S1on} - B_{S2on}$ | | | $B_{S1off} - B_{S2off}$ | | | Unit |
|---|---|---|---|---|---|---|---|
| $T_j$ | Min. | Typ | Max. | Min. | Typ | Max. | |
| –40 °C | –7.5 | 0 | 7.5 | –7.5 | 0 | 7.5 | mT |
| 25 °C | –7.5 | 0 | 7.5 | –7.5 | 0 | 7.5 | mT |
| 100 °C | –7.5 | 0 | 7.5 | –7.5 | 0 | 7.5 | mT |
| 140 °C | –7.5 | 0 | 7.5 | –7.5 | 0 | 7.5 | mT |

### Hysteresis Matching

(quasistationary: dB/dt<0.5 mT/ms)

at $T_J$ = –40 °C to +140 °C, $V_{DD}$ = 3.8 V to 24 V, as not otherwise specified

Typical characteristics for $T_J$ = 25 °C and $V_{DD}$ = 5 V

| Parameter | $(B_{S1on} - B_{S1off}) / (B_{S2on} - B_{S2off})$ | | | Unit |
|---|---|---|---|---|
| $T_j$ | Min. | Typ. | Max. | |
| –40 °C | 0.85 | 1.0 | 1.2 | – |
| 25 °C | 0.85 | 1.0 | 1.2 | – |
| 100 °C | 0.85 | 1.0 | 1.2 | – |
| 140 °C | 0.85 | 1.0 | 1.2 | – |

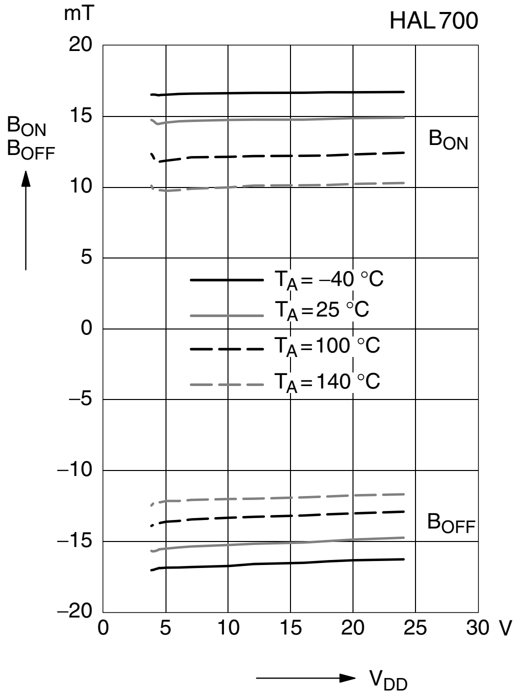



**Fig. 4–2:** Magnetic switching points versus supply voltage

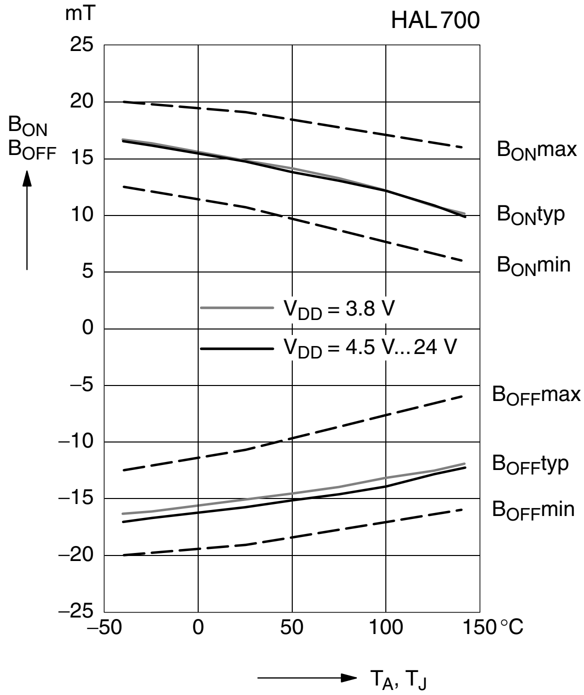



**Fig. 4–4:** Magnetic switching points versus ambient temperature

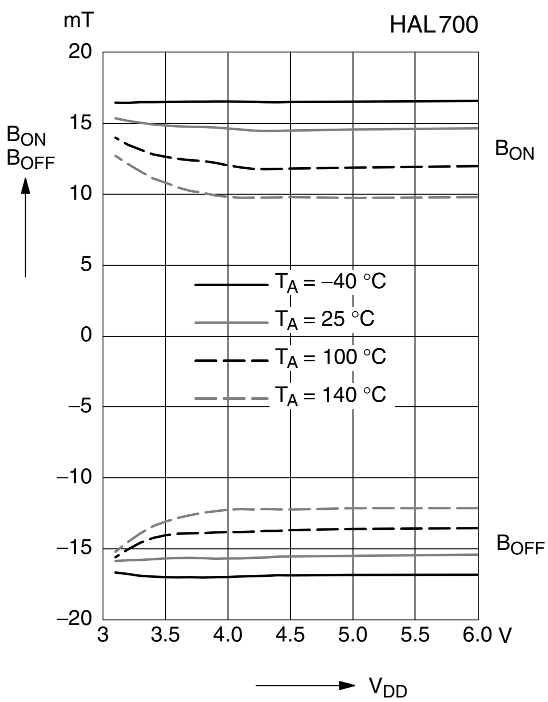



**Fig. 4–3:** Magnetic switching points versus supply voltage

## 4.2. HAL740

The HAL740 consists of two independent unipolar switches (see Fig. 4–5) with complementary magnetic characteristics controlling two independent open-drain outputs. The Hall plates of the two switches are spaced 2.35 mm apart.

The S1-Output turns low with the magnetic south pole on the branded side of the package and turns high if the magnetic field is removed. It does not respond to the magnetic north pole on the branded side.

The S2-Output turns low with the magnetic north pole on the branded side of the package and turns high if the magnetic field is removed. It does not respond to the magnetic south pole on the branded side.

### Magnetic Features

– two independent Hall-switches
– distance of Hall plates: 2.35 mm
– temperature coefficient of –2000 ppm/K in all magnetic characteristics
– operation with static magnetic fields and dynamic magnetic fields up to 10 kHz

### Applications

The HAL740 is the ideal sensor for applications which require both magnetic polarities, such as:

– position and direction detection, or
– position and end point detection with either magnetic pole (omnipolar switch).

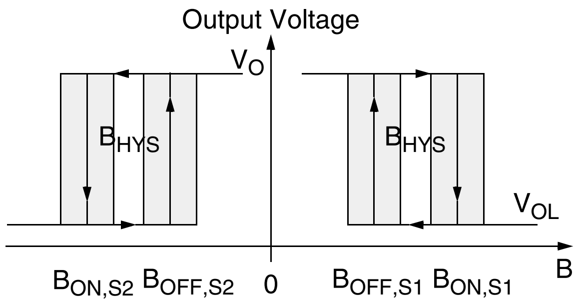



**Fig. 4–5:** Definition of magnetic switching points for the HAL740

### Magnetic Characteristics

(quasistationary: dB/dT < 0.5 T/ms) at $T_J$ = –40 °C to +100 °C, $V_{DD}$ = 3.8 V to 24 V,
Typical Characteristics for $V_{DD}$ = 12 V. Absolute values common to both Hall switches. The Hall switches S1 and S2 only differ in sign. For S1 the sign is positive, for S2 negative. Positive flux density values refer to the magnetic south pole at the branded side of the package.

| Parameter | On point $B_{ON}$ | | | Off point $B_{OFF}$ | | | Hysteresis $B_{HYS}$ | | | Magnetic Offset | | | Unit |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| $T_J$ | Min. | Typ. | Max. | Min. | Typ. | Max. | Min. | Typ. | Max. | Min. | Typ. | Max. | |
| –40 °C | 8.5 | 12.3 | 16.0 | 5.0 | 8.8 | 12.5 | 2.0 | – | 5.5 | – | 10.6 | – | mT |
| 25 °C | 7.0 | 11.5 | 16.0 | 3.5 | 8.0 | 12.5 | 2.0 | – | 6.0 | – | 9.8 | – | mT |
| 100 °C | 5.5 | 10.8 | 16.0 | 2.0 | 7.0 | 12.5 | 1.5 | – | 6.5 | – | 8.9 | – | mT |
| 140 °C | 4.6 | 10.4 | 16.0 | 1.1 | 6.8 | 12.5 | 1.0 | – | 7.0 | – | 8.6 | – | mT |

The hysteresis is the difference between the switching points $B_{HYS} = B_{ON} - B_{OFF}$
The magnetic offset is the mean value of the switching points $B_{OFFSET} = (B_{ON} + B_{OFF}) / 2$

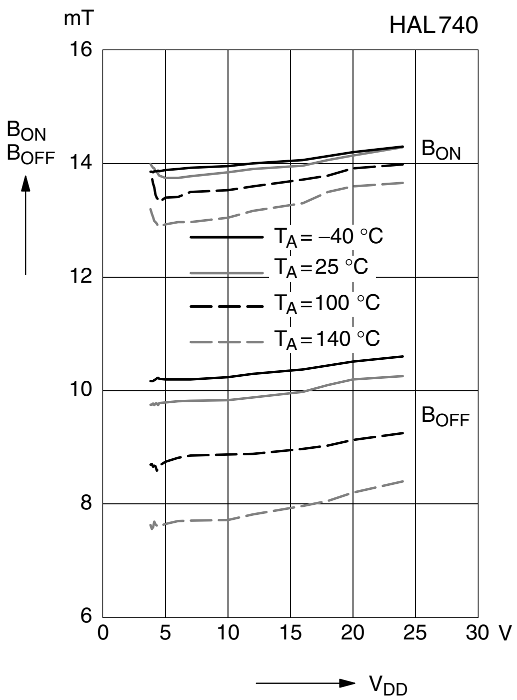



**Fig. 4–6:** Magnetic switching points versus supply voltage

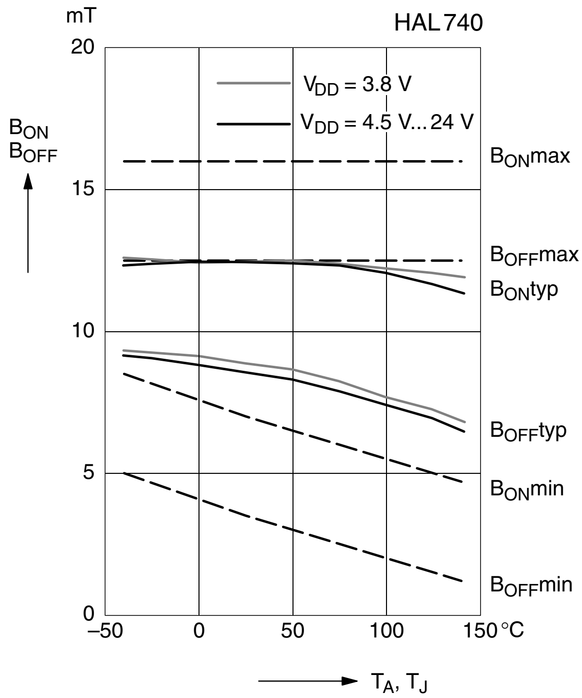



**Fig. 4–8:** Magnetic switching points versus ambient temperature

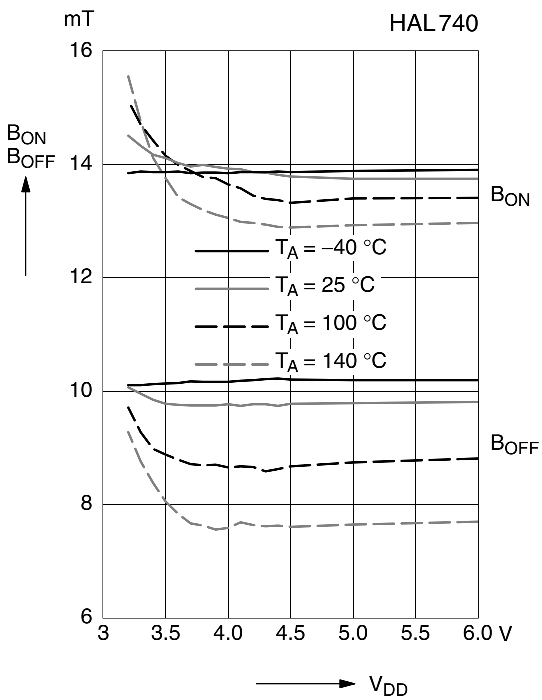



**Fig. 4–7:** Magnetic switching points versus supply voltage

## 5. Application Notes

### 5.1. 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 and continuous operation, the following equation applies:

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

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.

For all sensors, the junction temperature range $T_J$ is specified. The maximum ambient temperature $T_{Amax}$ can be calculated as:

$T_{Amax} = T_{Jmax} - \Delta T$

### 5.2. Extended Operating Conditions

All sensors fulfill the electrical and magnetic characteristics when operated within the Recommended Operating Conditions (see Section 3.5. on page 10).

#### Supply Voltage Below 3.8 V

Typically, the sensors operate with supply voltages above 3 V, however, below 3.8 V some characteristics may be outside the specification.

**Note:** The functionality of the sensor below 3.8 V is not tested. For special test conditions, please contact Micronas.

### 5.3. Start-up Behavior

Due to the active offset compensation, the sensors have an initialization time (enable time $t_{en(O)}$) after applying the supply voltage. The parameter $t_{en(O)}$ is specified in the "Characteristics" (see Section 3.6. on page 10).

During the initialization time, the output states are not defined and the outputs can toggle. After $t_{en(O)}$, both outputs will be either high or low for a stable magnetic field (no toggling). The outputs will be low if the applied magnetic flux density B exceeds $B_{ON}$ and high if B drops below $B_{OFF}$.

For magnetic fields between $B_{OFF}$ and $B_{ON}$, the output states of the Hall sensor after applying $V_{DD}$ will be either low or high. In order to achieve a well-defined output state, the applied magnetic flux density must be above $B_{ONmax}$, respectively, below $B_{OFFmin}$.

### 5.4. EMC and ESD

For applications that cause disturbances on the supply line or radiated disturbances, a series resistor and a capacitor are recommended (see Fig. 5–1). The series resistor and the capacitor should be placed as closely as possible to the Hall sensor.

Please contact Micronas for detailed investigation reports with EMC and ESD results.

**WARNING:**
DO NOT USE THESE SENSORS IN LIFE-SUPPORTING SYSTEMS, AVIATION, AND AEROSPACE APPLICATIONS.

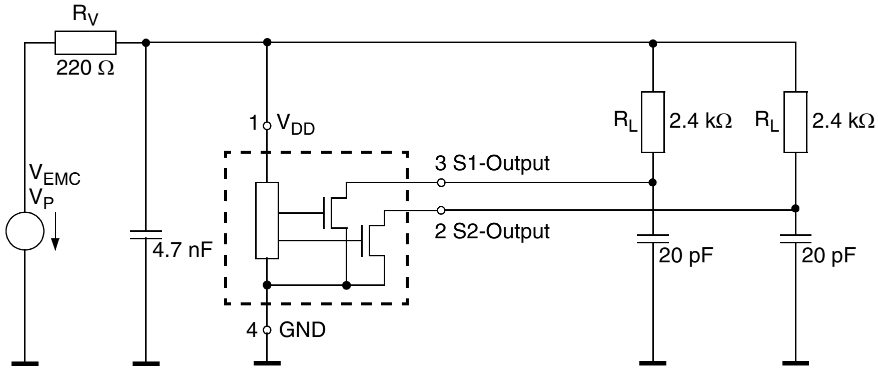



**Fig. 5–1:** Test circuit for EMC investigations

## 6. Data Sheet History

1. Data sheet: “HAL700, HAL740 Dual Hall-Effect Sensors with Independent Outputs”, June 13, 2002, 6251-477-1DS. First release of the data sheet.

2. Data Sheet: “HAL700, HAL740 Dual Hall-Effect Sensors with Independent Outputs”, Sept. 13, 2004, 6251-477-2DS. Second release of the data sheet. Major changes:

– new package diagram for SOT89B-2

Micronas GmbH
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
E-mail: docservice@micronas.com
Internet: www.micronas.com

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