

## Data Sheet

# HAL<sup>®</sup> 710, HAL<sup>®</sup> 730

Hall-Effect Sensors with  
Direction Detection

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## Hall-Effect Sensors with Direction Detection

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

### 1. Introduction

The HAL710 and the HAL730 are monolithic integrated Hall-effect sensors manufactured in CMOS technology with two independent Hall plates S1 and S2 spaced 2.35 mm apart. The devices have two open-drain outputs:

- The Count Output operates like a single latched Hall switch according to the magnetic field present at Hall plate S1 (see Fig. 4-1).
- The Direction Output indicates the direction of a linear or rotating movement of magnetic objects.

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

The internal circuitry evaluates the direction of the movement and updates the Direction Output at every edge of the Count Signal (rising and falling). The state of the Direction Output only changes at a rising or falling edge of the Count Output.

The design ensures a setup time for the Direction Output with respect to the corresponding Count Signal edge of 1/2 clock periods (1  $\mu$ s minimum).

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. This is required by systems determining the direction from the comparison of two signals.

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 HAL710 and the HAL730 are available in the SMD-package SOT89B-2.

### 1.1. Features

- generation of Count Signals and Direction Signals
- delay of the Count Signals with respect to the Direction Signal of 1  $\mu$ s minimum
- switching type: latching
- switching offset compensation at typically 150 kHz
- operation from 3.8 V to 24 V supply voltage
- 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 behavior of the Direction Output.

Type	Direction Output: Definition of Output States
HAL 710	Output high, when edge of comparator 1 precedes edge of comparator 2
HAL 730	Output high, when edge of comparator 2 precedes edge of comparator 1

**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
HAL710	710K	710E
HAL730	730K	730E

**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**

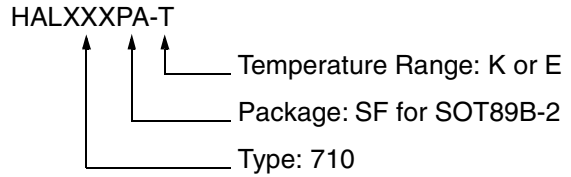
The Hall sensors from Micronas are specified to the chip temperature (junction temperature  $T_J$ ).

**K:**  $T_J = -40\text{ °C to }+140\text{ °C}$

**E:**  $T_J = -40\text{ °C to }+100\text{ °C}$

**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 17 for details.

**1.5. HALL Sensor Package Codes**



Example: **HAL710SF-K**

- Type: 710
- Package: SOT89B-2
- Temperature Range:  $T_J = -40\text{ °C to }+140\text{ °C}$

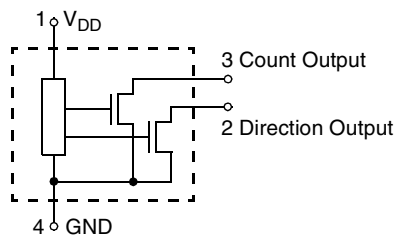
Hall sensors are available in a wide variety of packaging versions and quantities. For more detailed information, please refer to the brochure: “Hall Sensors: Ordering Codes, Packaging, Handling”.

**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**

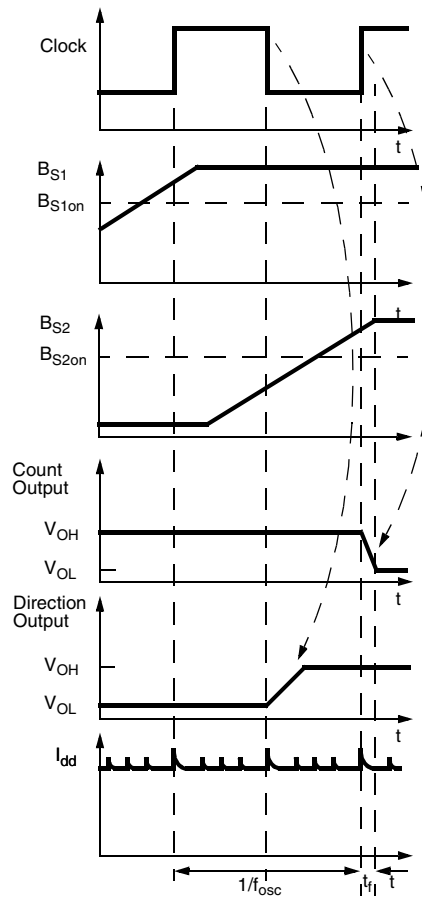
The HAL710 and the HAL730 are monolithic integrated circuits with two independent subblocks each consisting of a Hall plate and the corresponding comparator. Each subblock independently switches the comparator output in response to the magnetic field at the location of the corresponding sensitive area. 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 output of comparator 1 (connected to S1) directly controls the Count Output. The outputs of both comparators enter the Direction Detection Block controlling the state of the Direction Output. The Direction Output is updated at every edge of comparator 1 (rising and falling). The previous state of the Direction Output is maintained between two edges of the Count Output and in case the edges at comparator 1 and comparator 2 occur in the same clock period. The subblocks are designed to have closely matched switching points.

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.

In order to achieve good matching of the switching points of both subblocks, 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  $-15\text{ V}$ . No external reverse protection diode is needed at the  $V_{DD}$ -pin for reverse voltages ranging from  $0\text{ V}$  to  $-15\text{ V}$ .



**Fig. 2-1:** HAL710 timing diagram with respect to the clock phase

Fig. 2-2 and Fig. 2-3 on page 7 show how the output signals are generated by the HAL710 and the HAL730. The magnetic flux density at the locations of the two Hall plates is shown by the two sinusoidal curves at the top of each diagram. The magnetic switching points are depicted as dashed lines for each Hall plate separately.

At the time  $t = 0$ , the signal S2 precedes the signal S1. The Direction Output is in the correct state according to the definition of the sensor type.

When the phase of the magnetic signal changes its sign, the Direction-Output switches its state with the next signal edge of the Count Output.

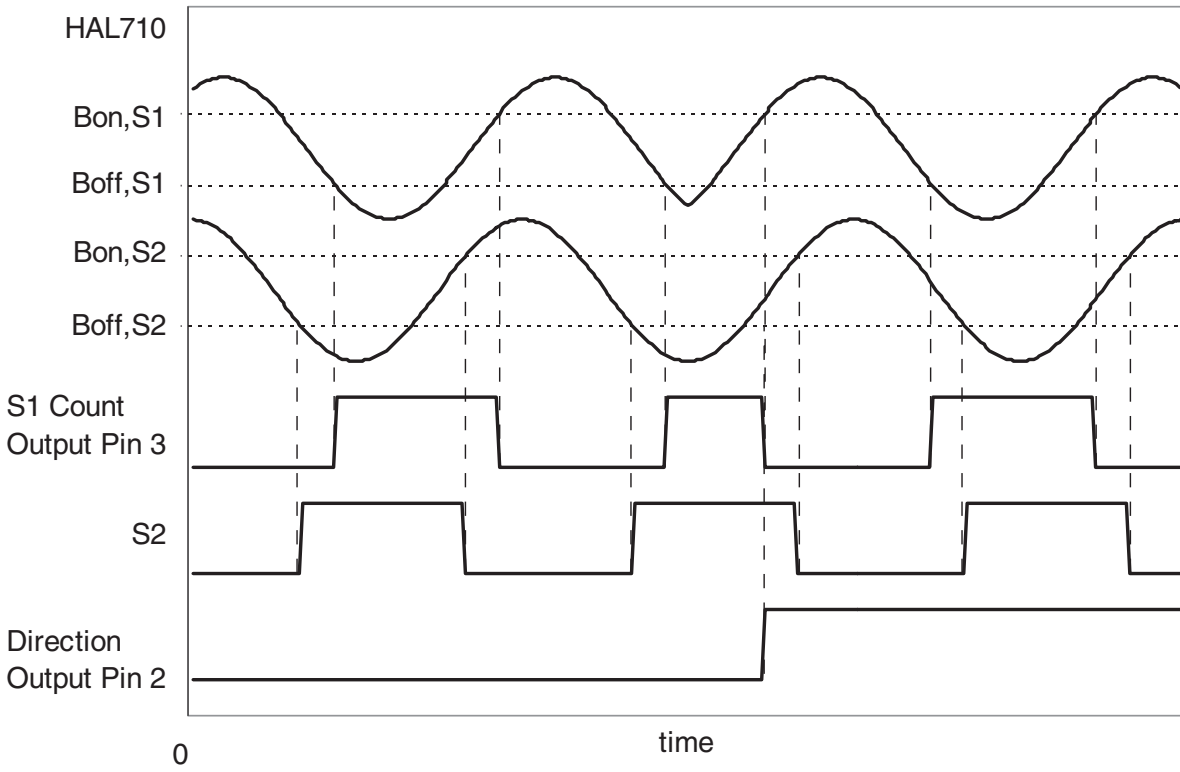


Fig. 2-2: HAL710 timing diagram

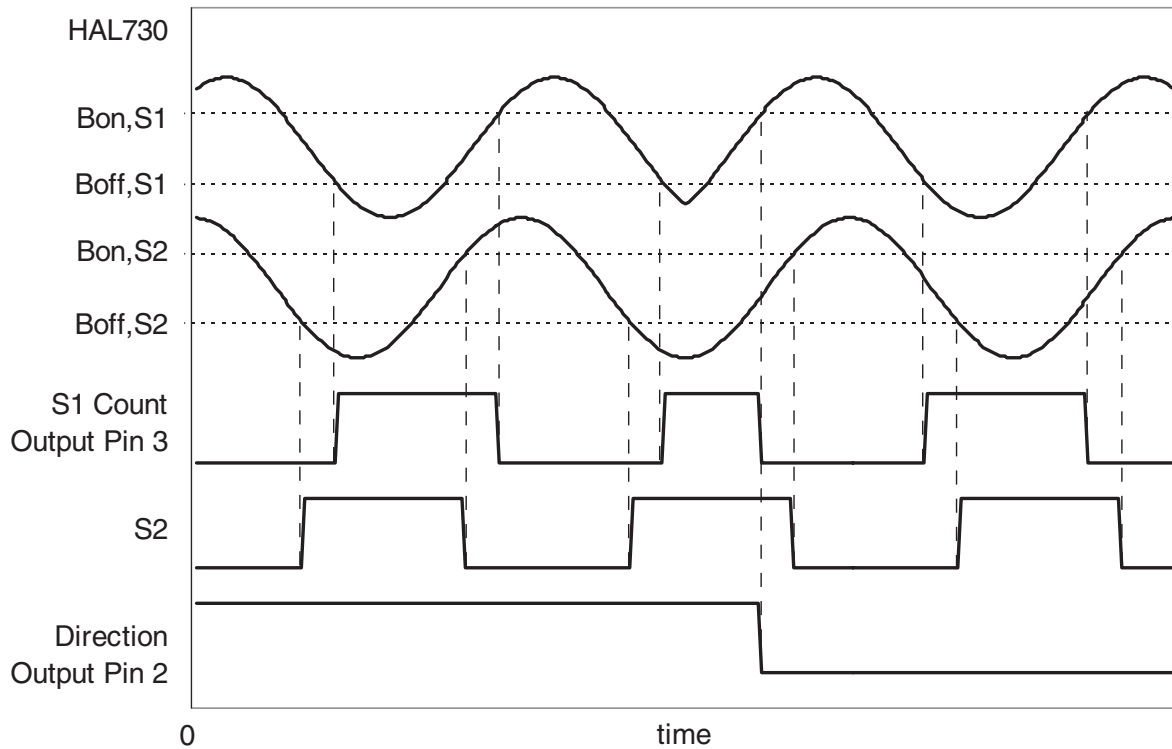


Fig. 2-3: HAL730 timing diagram

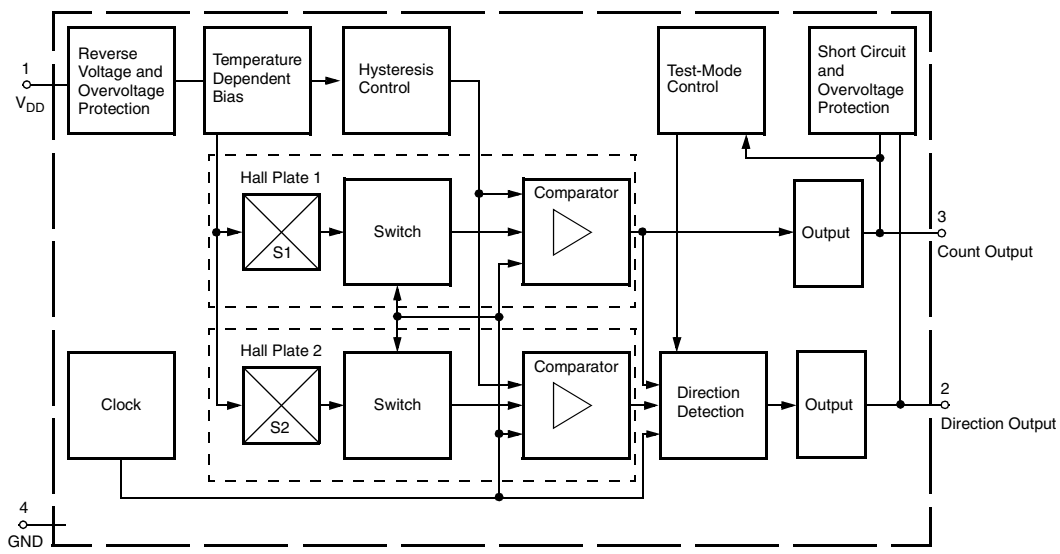
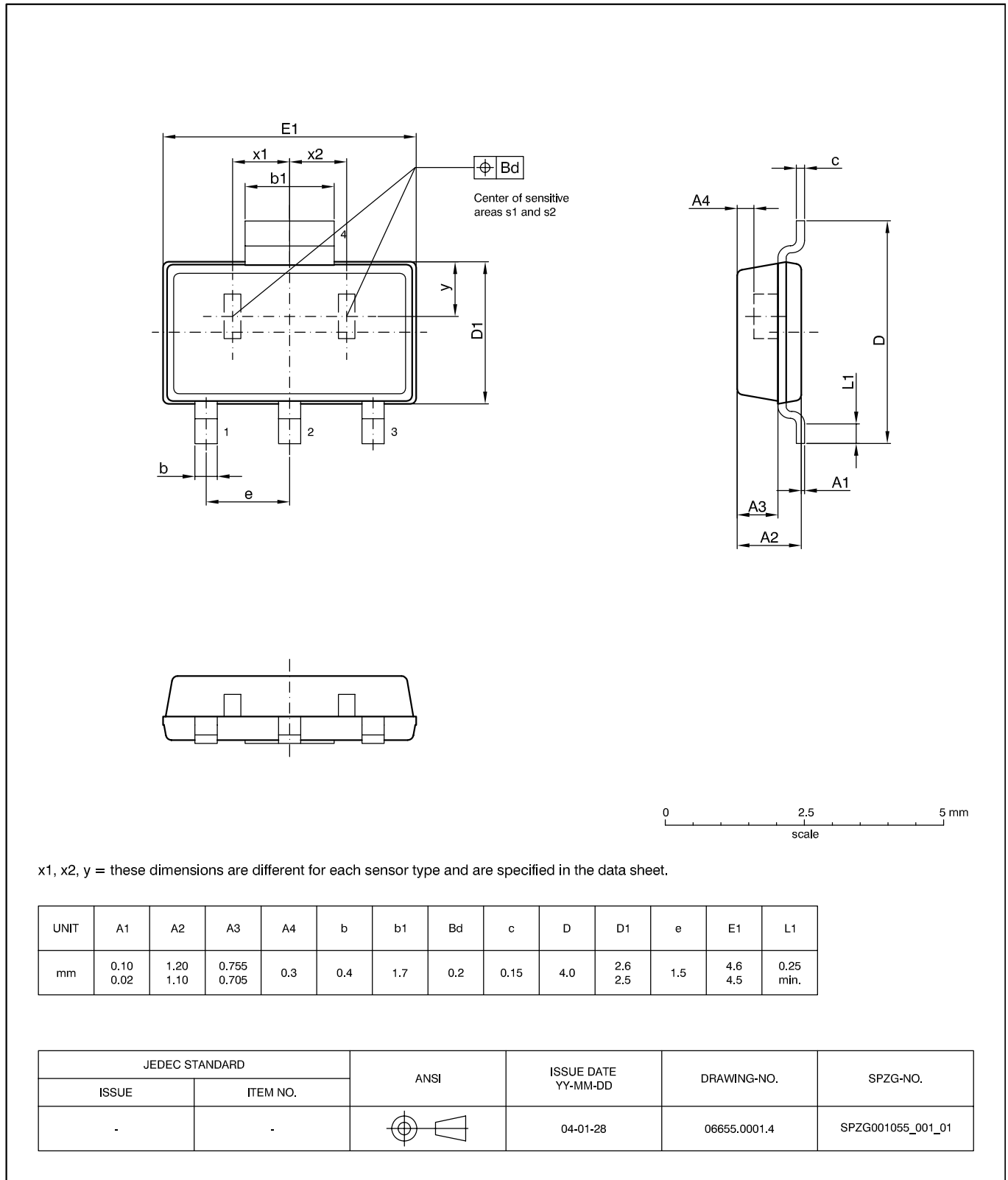


Fig. 2-4: HAL710 and HAL730 block diagram



3. Specifications

3.1. Outline Dimensions



**Fig. 3-1:**  
**SOT89B-2:** Plastic Small Outline Transistor 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
y	0.975 mm

### 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 <sup>1)</sup>	V
$V_O$	Output Voltage	2, 3	-0.3	28 <sup>1)</sup>	V
$I_O$	Continuous Output Current	2, 3	-	20 <sup>1)</sup>	mA
$T_J$	Junction Temperature Range		-40	170	°C
<sup>1)</sup> 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

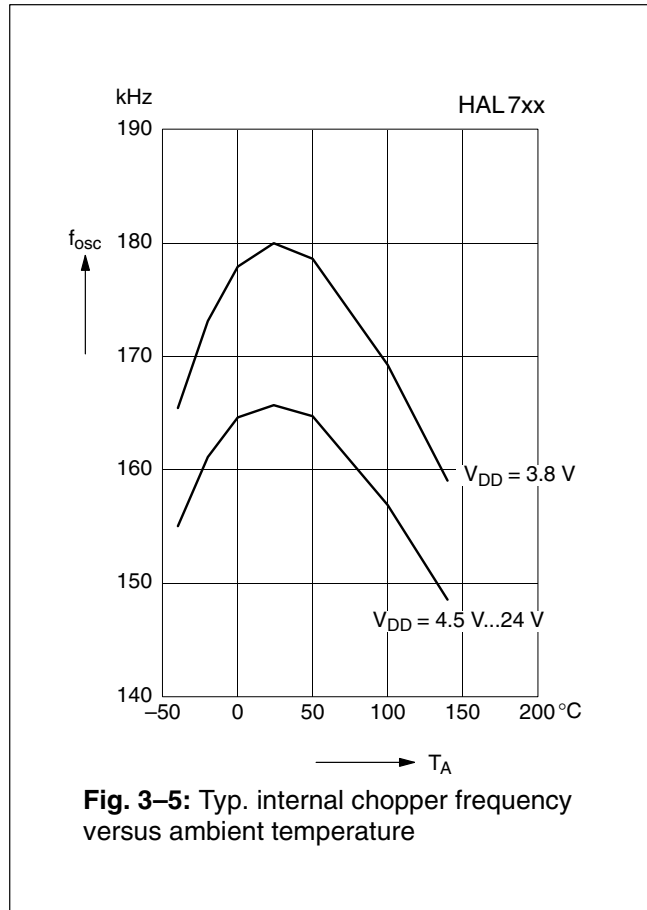
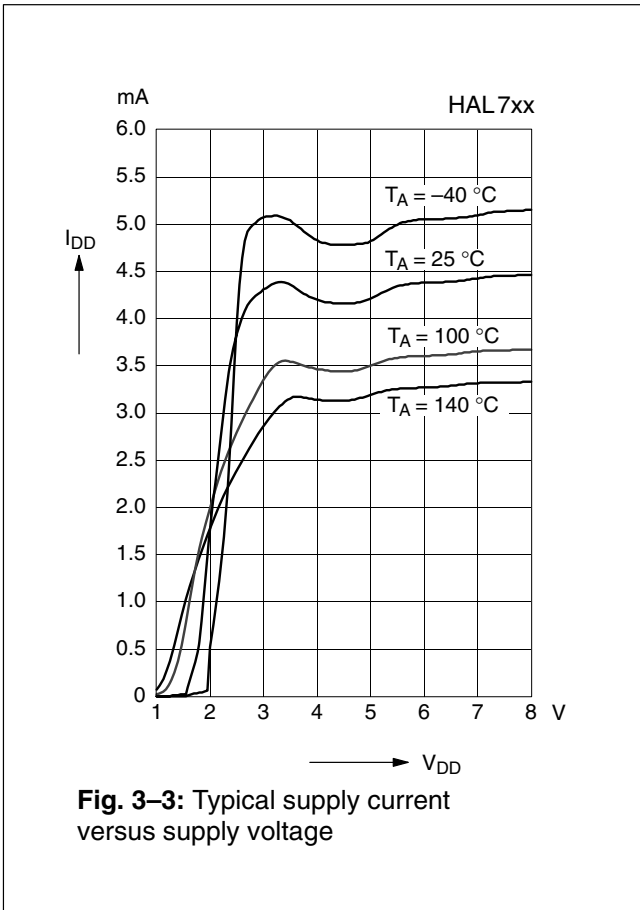
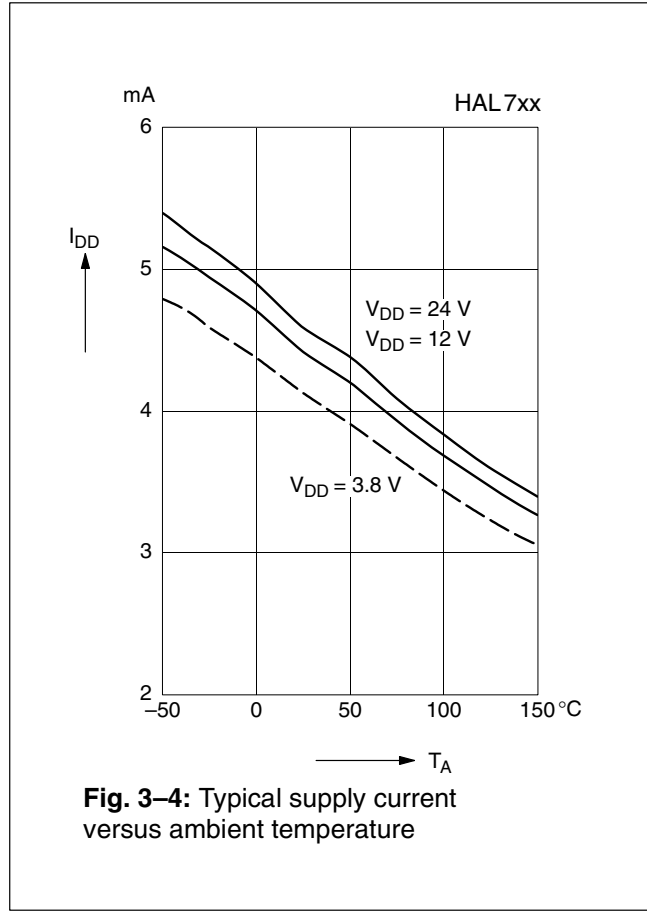
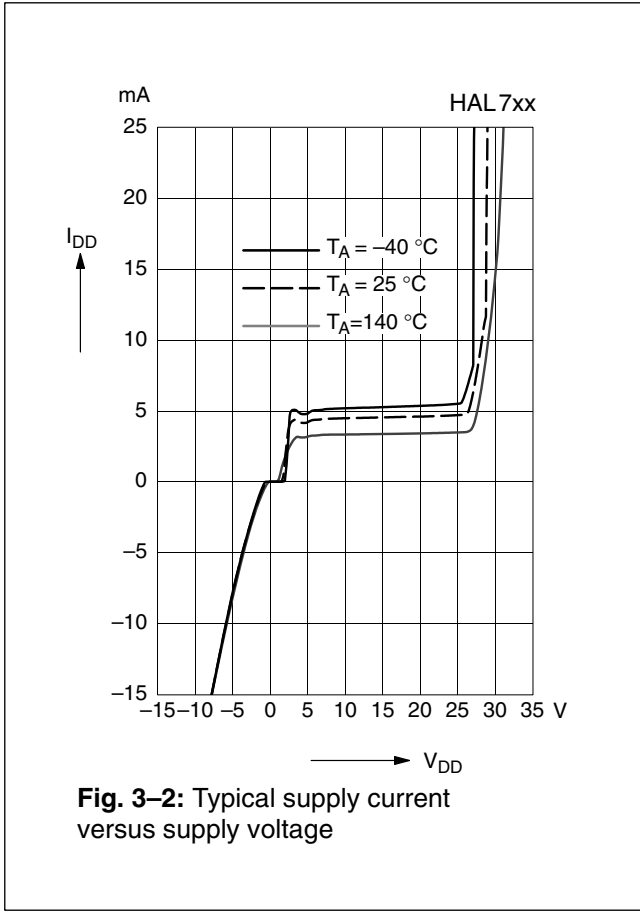
### 3.6. Characteristics

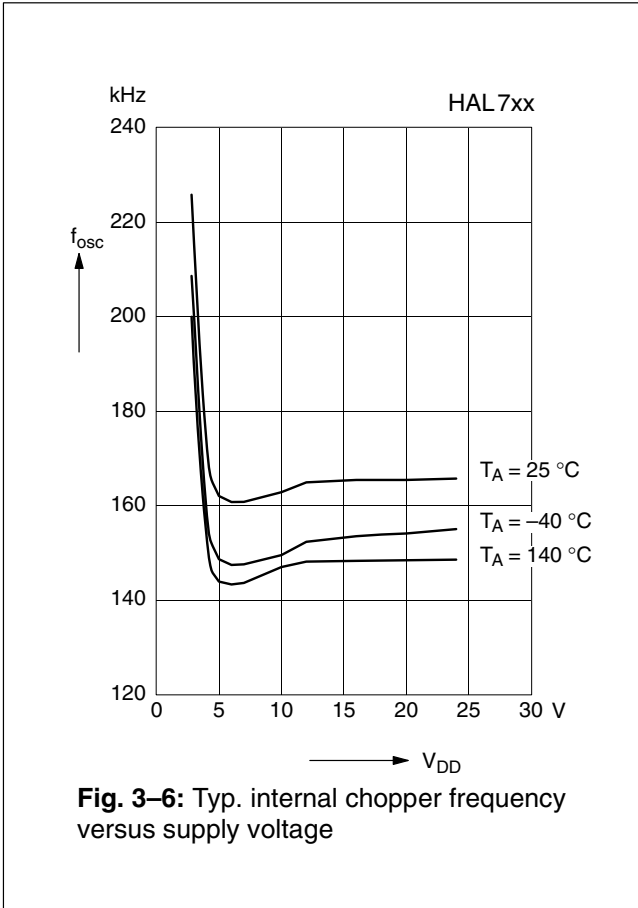
at  $T_J = -40\text{ °C}$  to  $+140\text{ °C}$ ,  $V_{DD} = 3.8\text{ V}$  to  $24\text{ V}$ ,  $GND = 0\text{ V}$

at Recommended Operation Conditions if not otherwise specified in the column “Conditions”.

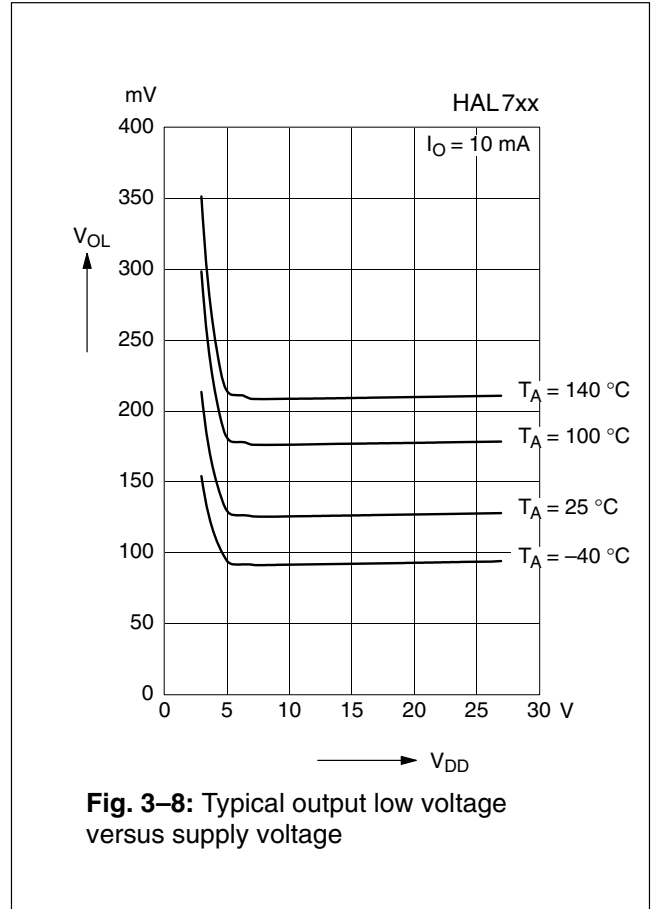
Typical Characteristics for  $T_J = 25\text{ °C}$  and  $V_{DD} = 5\text{ V}$ .

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

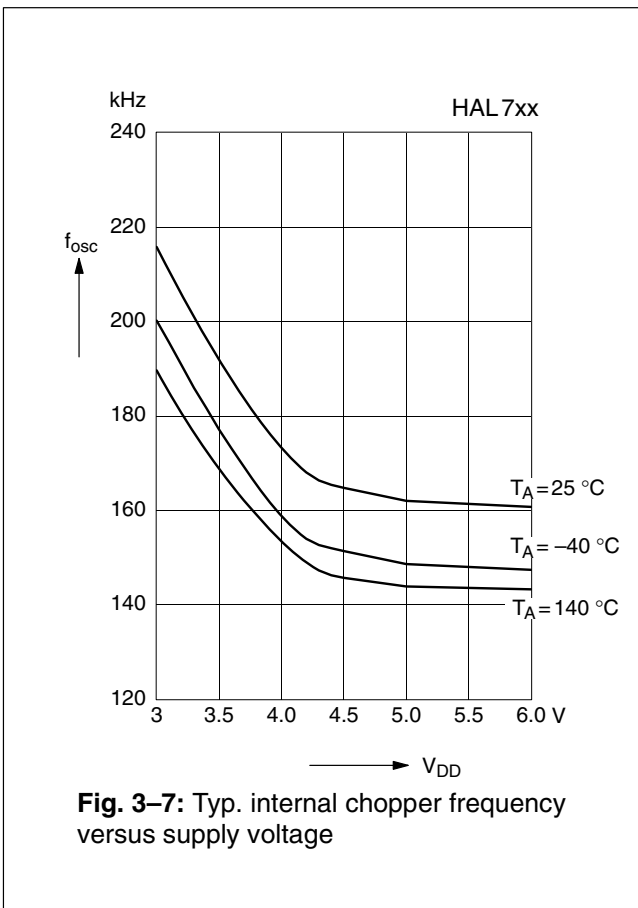




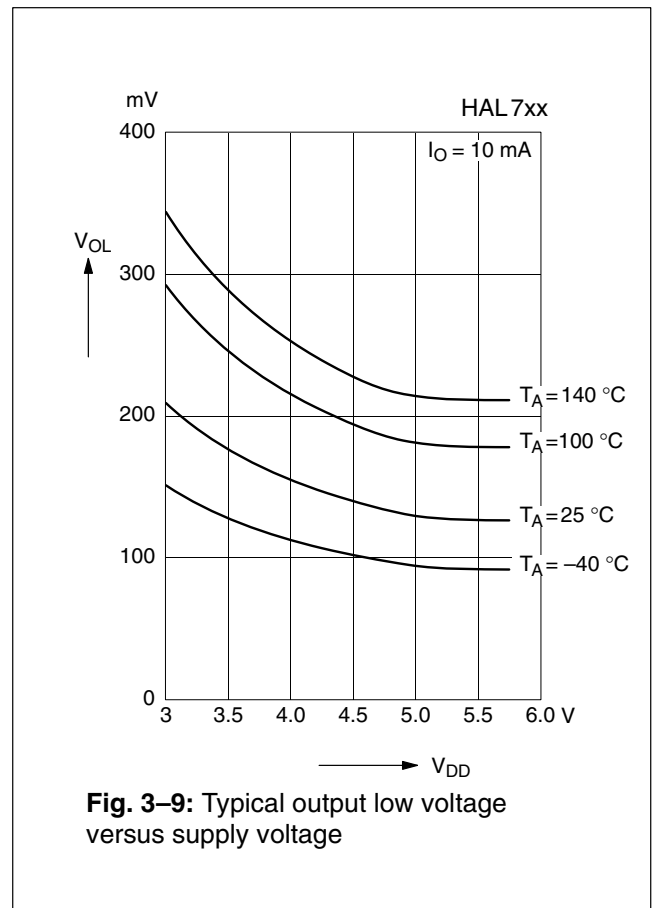
**Fig. 3-6:** Typ. internal chopper frequency versus supply voltage



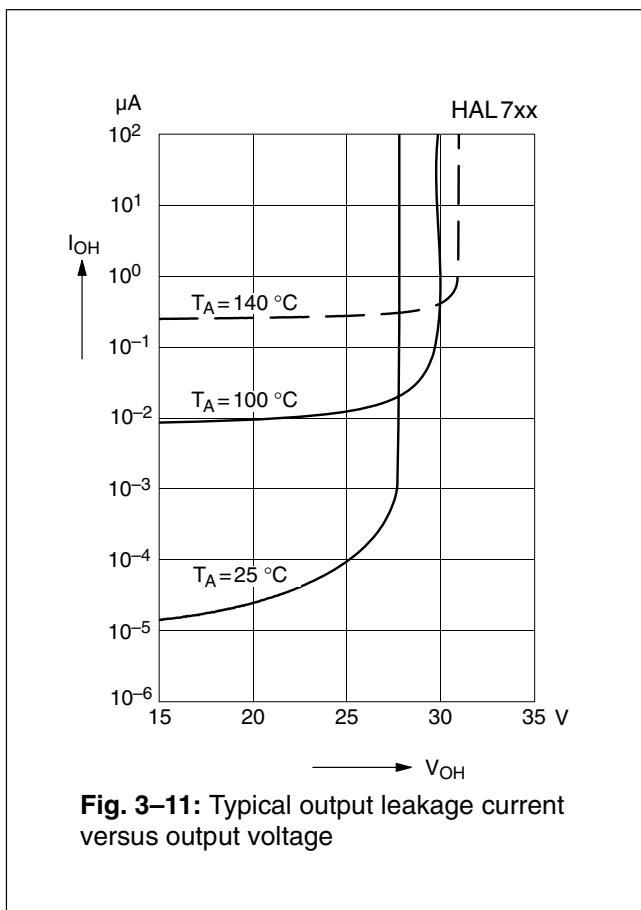
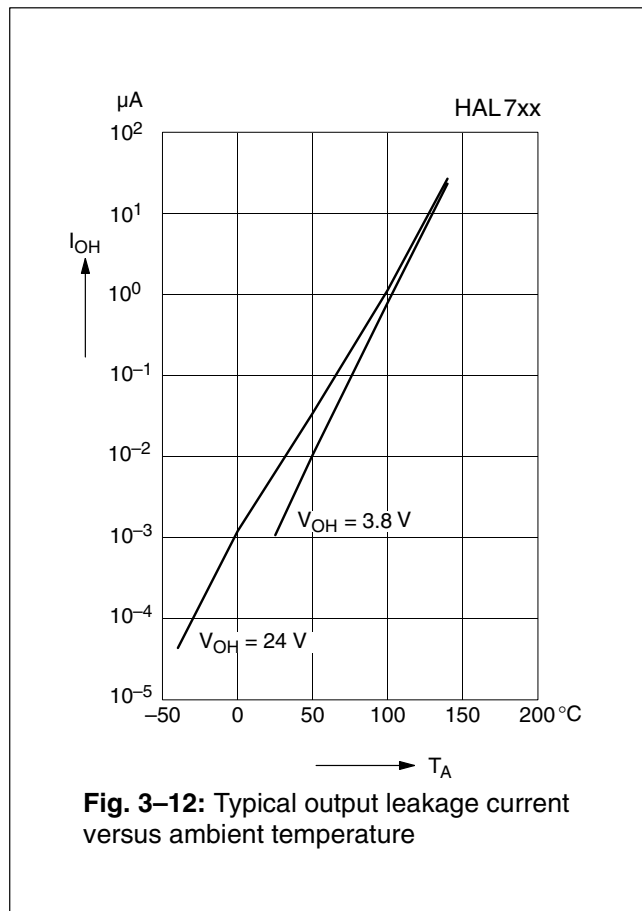
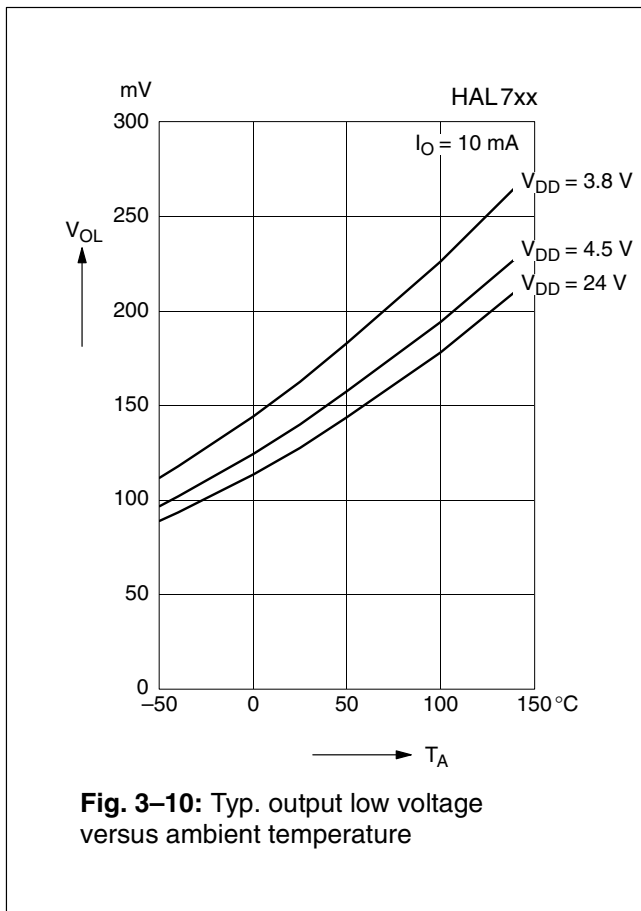
**Fig. 3-8:** Typical output low voltage versus supply voltage



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



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



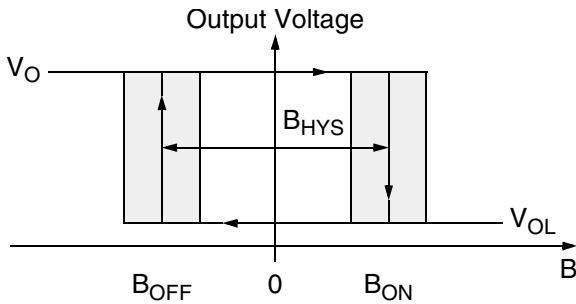
**4. Type Description**

**4.1. HAL710, HAL730**

The types differ according to the behavior of the Direction Output (see Section 1.2. on page 4).

**Magnetic Features**

- 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 HAL710

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

**Applications**

The HAL710 and the HAL730 are the optimal 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
	Min.	Typ.	Max.	Min.	Typ.	Max.	
$T_J$							
-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
	Min.	Typ.	Max.	Min.	Typ.	Max.	
$T_J$							
-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

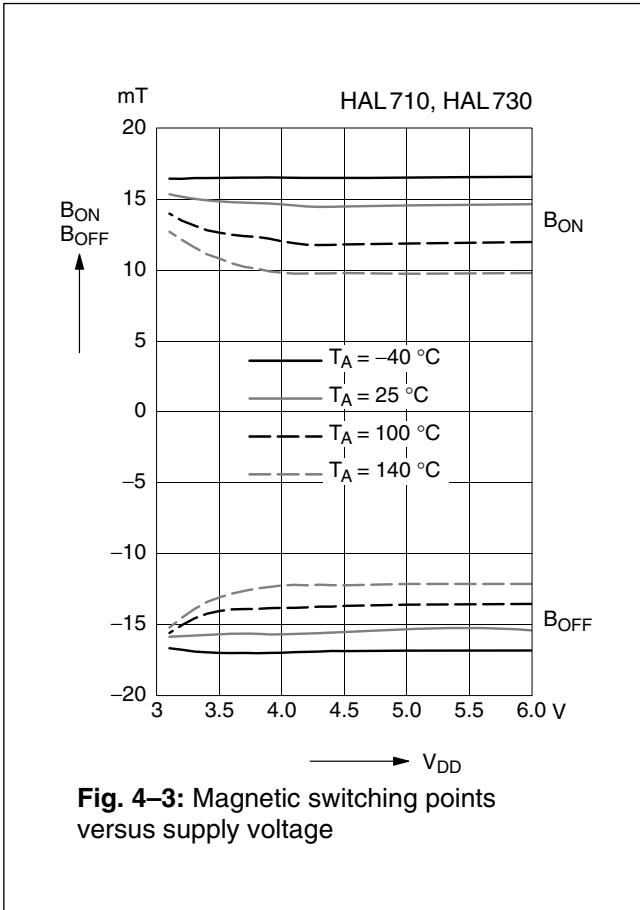
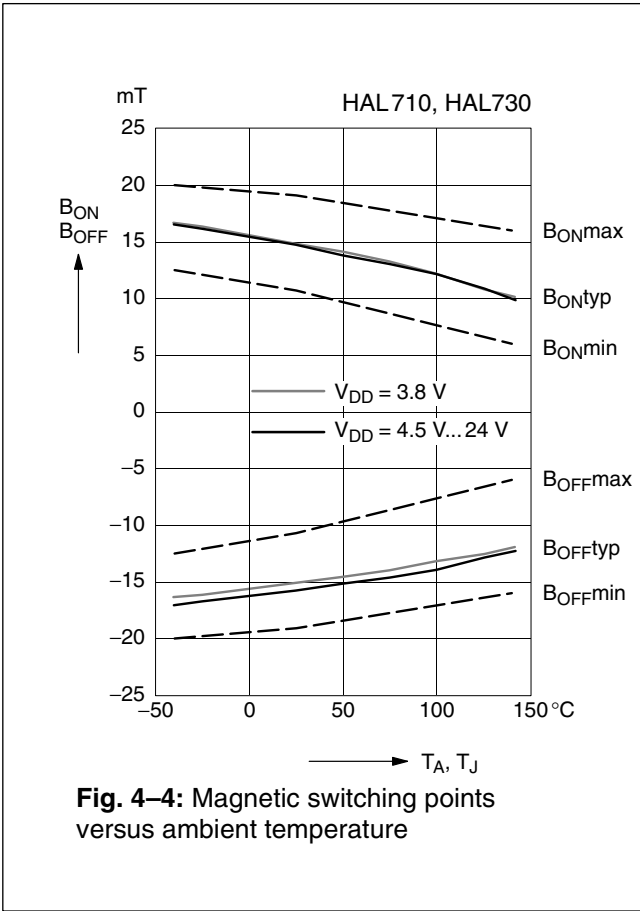
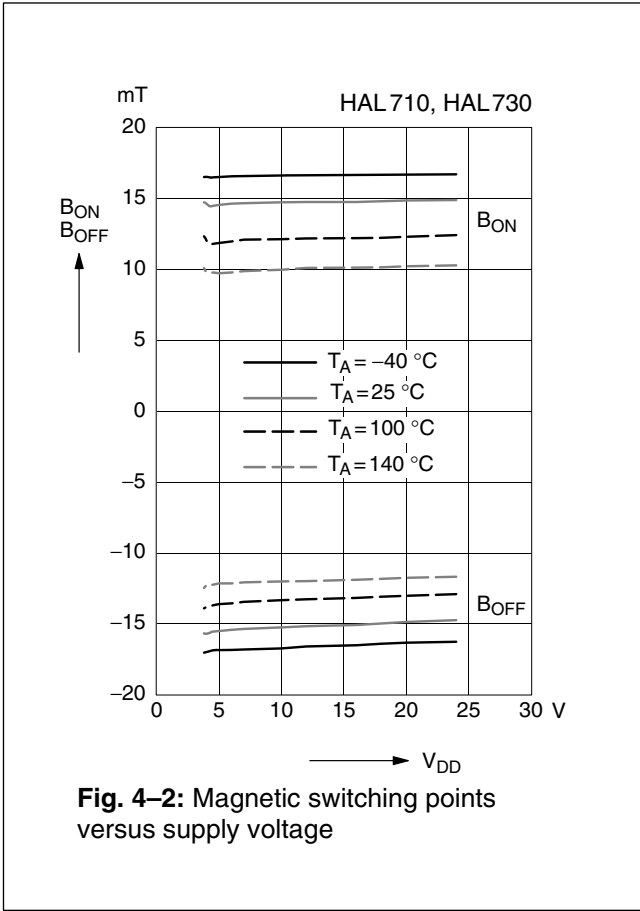
**Hysteresis Matching**

(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
	Min.	Typ.	Max.	
$T_J$				
-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	-





## 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:

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

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 11).

#### 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. Signal Delay

The extra circuitry required for the direction detection increases the latency of the Count and Direction Sig-

nal compared to a simple switch (e.g. HAL 525). This extra delay corresponds to 0.5 and 1 clock period for the Direction Signal and Count Signal respectively.

### 5.4. Test Mode Activation

In order to obtain the normal operation as described above, two external pull-up resistors with appropriate values are required to connect each output to an external supply, such that the potential at the open-drain output rises to at least 3 V in less than 10  $\mu$ s after having turned off the corresponding pull-down transistor or after having applied  $V_{DD}$ .

If the Direction Output is pulled low externally (the potential does not rise after the internal pull-down transistor has been turned off), the device enters Manufacturer Test Mode.

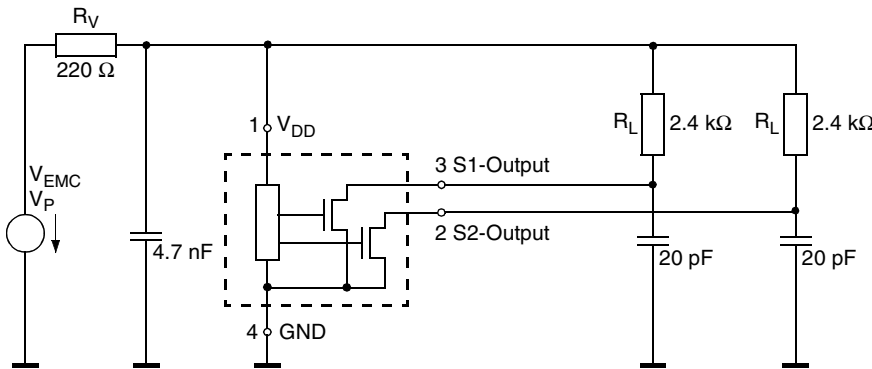
Direction detection is not functional in Manufacturer Test Mode. The device returns to normal operation as soon as the Count Output goes high.

**Note:** The presence of a Manufacturer Test Mode requires appropriate measures to prevent accidental activation (e.g. in response to EMC events).

**5.5. 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.



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

**5.6. 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 11).

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) and the Count Output will be low if the applied magnetic field  $B$  exceeds  $B_{ON}$ . The Count Output will be high if  $B$  drops below  $B_{OFF}$ . The Direction Output will have the correct state after the second edge (rising or falling) in the same direction.

The device contains a Power-On Reset circuit (POR) generating a reset when  $V_{DD}$  rises. This signal is used to disable Test Mode. The generation of this reset signal is guaranteed when  $V_{DD}$  at the chip rises to a minimum  $3.8 \text{ V}$  in less than  $4 \mu\text{s}$  monotonically. If this condition is violated, the internal reset signal might be missing. Under these circumstances, the chip will still operate according to the specification, but the risk of toggling outputs during  $t_{en(O)}$  increases; and 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 field then must exceed  $B_{ONmax}$ , respectively, drop below  $B_{OFFmin}$ .



**6. Data Sheet History**

1. Data Sheet: "HAL710, HAL730 Hall-Effect Sensors with Direction Detection", May 13, 2002, 6251-478-1DS. First release of the data sheet.
2. Data Sheet: "HAL710, HAL730 Hall-Effect Sensors with Direction Detection", sept. 15, 2004, 6251-478-2DS. Second release of the data sheet. Major changes:
  - new package diagram for SOT89B-2
3. Data Sheet: "HAL710, HAL730 Hall-Effect Sensors with Direction Detection", July 31, 2006, 6251-478-3DS. Third release of the data sheet. Major changes:
  - section 5.5 EMC and ESD added

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