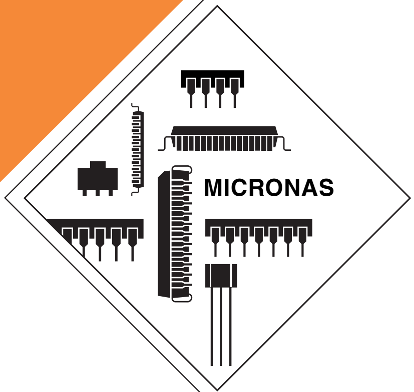


HAL525, HAL535
Hall Effect Sensor IC

Edition Aug. 30, 2000
6251-465-3DS

MICRONAS

Contents

Hall Effect Sensor Family

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

1. Introduction

The HAL 525 and HAL 535 are Hall switches produced in CMOS technology. The sensors include a temperature-compensated Hall plate with active offset compensation, a comparator, and an open-drain output transistor. The comparator compares the actual magnetic flux through the Hall plate (Hall voltage) with the fixed reference values (switching points). Accordingly, the output transistor is switched on or off.

The active offset compensation leads to magnetic parameters which are robust against mechanical stress effects. In addition, the magnetic characteristics are constant in the full supply voltage and temperature 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 150 °C.

The HAL 525 and HAL 535 are available in the SMD-package SOT-89B and in the leaded version TO-92UA.

1.1. Features

– switching offset compensation at typically 115 kHz

– operates from 3.8 V to 24 V supply voltage

– operates with static magnetic fields and dynamic magnetic fields up to 10 kHz

– overvoltage protection at all pins

– reverse-voltage protection at V_{DD}-pin

– magnetic characteristics are robust against mechanical stress effects

– short-circuit protected open-drain output by thermal shut down

– constant switching points over a wide supply voltage range

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

– ideal sensor for window lifter, ignition timing, and revolution counting in extreme automotive and industrial environments

– EMC corresponding to DIN 40839

1.2. Family Overview

Both sensors have a latching behavior with typically the same sensitivity. The difference between HAL 525 and HAL 535 is the temperature coefficient of the magnetic switching points.

Type	Switching Behavior	Typical Temperature Coefficient	see Page
525	latching	–2000 ppm/K	14
535	latching	–1000 ppm/K	16

Latching Sensors:

Both sensors have a latching behavior and requires a magnetic north and south pole for correct functioning. The output turns low with the magnetic south pole on the branded side of the package and turns high with the magnetic north pole on the branded side. The output does not change if the magnetic field is removed. For changing the output state, the opposite magnetic field polarity must be applied.

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		
	A	K	E
HAL 525	525A	525K	525E
HAL 535	535A	535K	535E

1.4. Operating Junction Temperature Range

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

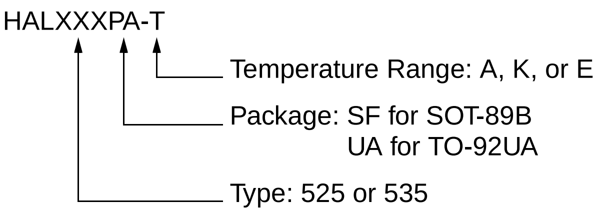
A: T_J = –40 °C to +170 °C

K: T_J = –40 °C to +140 °C

E: T_J = –40 °C to +100 °C

The relationship between ambient temperature (T_A) and junction temperature is explained in Section 5.1. on page 18.

1.5. Hall Sensor Package Codes



Example: **HAL525UA-E**

→ Type: 525
→ Package: TO-92UA
→ Temperature Range: T_J = –40 °C to +100 °C

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

1.6. 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.

Components stored in the original packaging should provide a shelf life of at least 12 months, starting from the date code printed on the labels, even in environments as extreme as 40 °C and 90% relative humidity.

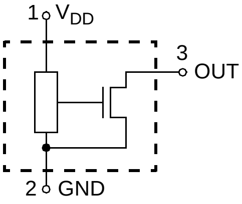


Fig. 1–1: Pin configuration

2. Functional Description

The Hall effect sensor is a monolithic integrated circuit that switches in response to magnetic fields. If a magnetic field with flux lines perpendicular 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 bouncing.

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 actual 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 switching 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 reverse voltages ranging from 0 V to –15 V.

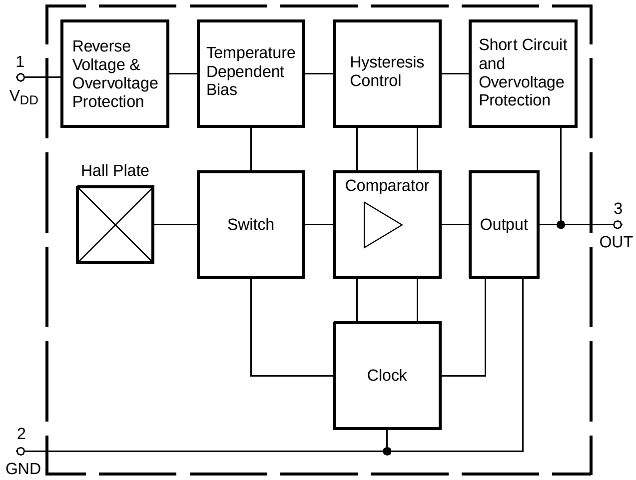


Fig. 2–1: HAL 525, HAL 535 block diagram

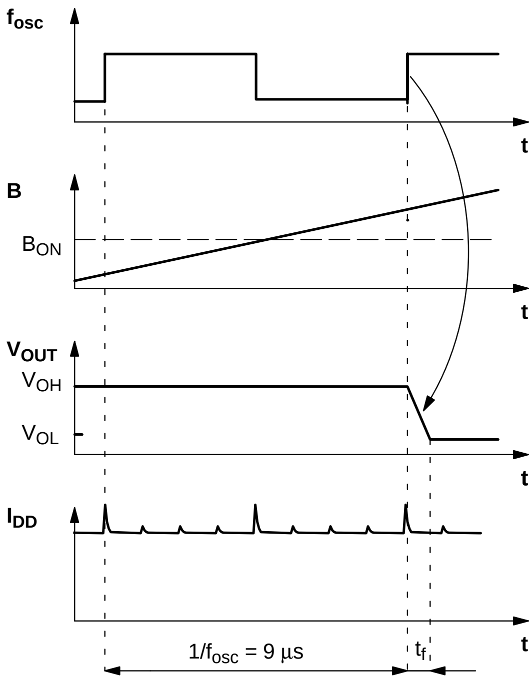


Fig. 2–2: Timing diagram

3. Specifications

3.1. Outline Dimensions

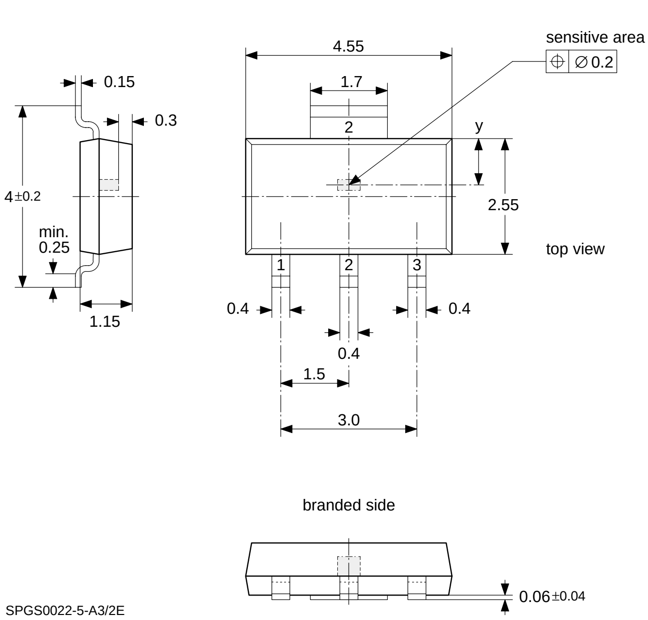


Fig. 3–1:
Plastic Small Outline Transistor Package **(SOT-89B)**
Weight approximately 0.035 g
Dimensions in mm

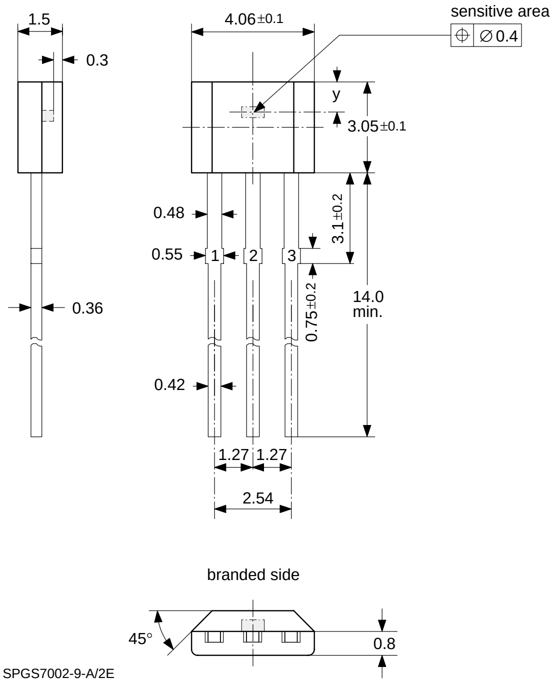


Fig. 3–2: Plastic Transistor Single Outline Package **(TO-92UA)**
Weight approximately 0.12 g
Dimensions in mm

3.2. Dimensions of Sensitive Area

0.25 mm × 0.12 mm

3.3. Positions of Sensitive Areas

	SOT-89B	TO-92UA
x	center of the package	center of the package
y	0.95 mm nominal	1.0 mm nominal

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

The improvement of the TO-92UA package with the reduced tolerances will be introduced end of 2001.

3.4. Absolute Maximum Ratings

Symbol	Parameter	Pin Name	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	–200[3)]	200[3)]	mA
V_O	Output Voltage	3	–0.3	28[1)]	V
I_O	Continuous Output On Current	3	–	50[1)]	mA
I_{Omax}	Peak Output On Current	3	–	250[3)]	mA
I_{OZ}	Output Current through Protection Device	3	–200[3)]	200[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 the test circuit (see Fig. 5–1)
3) t<2 ms
4) 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.

3.5. Recommended Operating Conditions

Symbol	Parameter	Pin Name	Min.	Max.	Unit
V_{DD}	Supply Voltage	1	3.8	24	V
I_O	Continuous Output On Current	3	0	20	mA
V_O	Output Voltage (output switched off)	3	0	24	V

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

Symbol	Parameter	Pin No.	Min.	Typ.	Max.	Unit	Conditions
I_{DD}	Supply Current	1	2.3	3	4.2	mA	T_J = 25 °C
I_{DD}	Supply Current over Temperature Range	1	1.6	3	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	280	mV	I_{OL} = 20 mA, T_J = 25 °C
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	Output switched off, T_J = 25 °C, V_{OH} = 3.8 to 24 V
I_{OH}	Output Leakage Current over Temperature Range	3	–	–	10	µA	Output switched off, T_J ≤150 °C, V_{OH} = 3.8 to 24V
f_{osc}	Internal Oscillator Chopper Frequency	–	95	115	–	kHz	T_J = 25 °C,
f_{osc}	Internal Oscillator Chopper Frequency over Temperature Range	–	85	115	–	kHz	T_J = –30 °C to 100 °C
f_{osc}	Internal Oscillator Chopper Frequency over Temperature Range	–	73	115	–	kHz	
$t_{en(O)}$	Enable Time of Output after Setting of V_{DD}	1	–	30	70	µs	V_{DD} = 12 V B > B_{ON} + 2 mT or B < B_{OFF} – 2 mT
t_r	Output Rise Time	3	–	75	400	ns	V_{DD} = 12 V, R_L = 820 Ohm, C_L = 20 pF
t_f	Output Fall Time	3	–	50	400	ns	
R_{thJSB} case SOT-89B	Thermal Resistance Junction to Substrate Backside	–	–	150	200	K/W	Fiberglass Substrate 30 mm x 10 mm x 1.5 mm, pad size (see Fig. 3–3)
R_{thJA} case TO-92UA	Thermal Resistance Junction to Soldering Point	–	–	150	200	K/W	

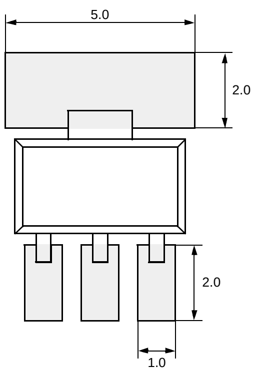


Fig. 3–3: Recommended pad size SOT-89B
Dimensions in mm

3.7. Magnetic Characteristics Overview 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.

Sensor	Parameter	On point B_{ON}			Off point B_{OFF}			Hysteresis B_{HYS}			Unit
Switching Type	T_J	Min.	Typ.	Max.	Min.	Typ.	Max.	Min.	Typ.	Max.	
HAL 525	–40 °C	11.8	15.8	19.2	–19.2	–15.8	–11.8	27.4	31.6	35.8	mT
latching	25 °C	11	14	17	–17	–14	–11	24	28	32	mT
	170 °C	5	8.5	13	–13	–8.5	–5	12	17	25	mT
HAL 535	–40 °C	12	15	18	–18	–15	–12	25	30	35	mT
latching	25 °C	11	13.8	17	–17	–13.8	–11	23	27.6	32	mT
	170 °C	6	12	18	–18	–12	–6	17	24	31	mT

Note: For detailed descriptions of the individual types, see pages 14 and following.

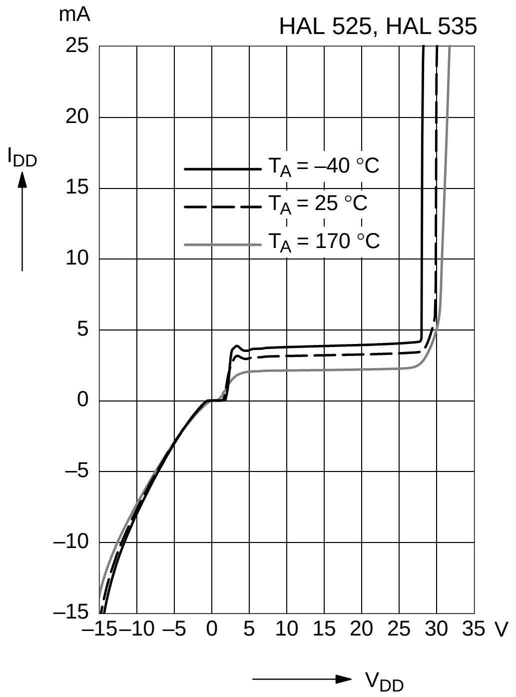


Fig. 3–4: Typical supply current versus supply voltage

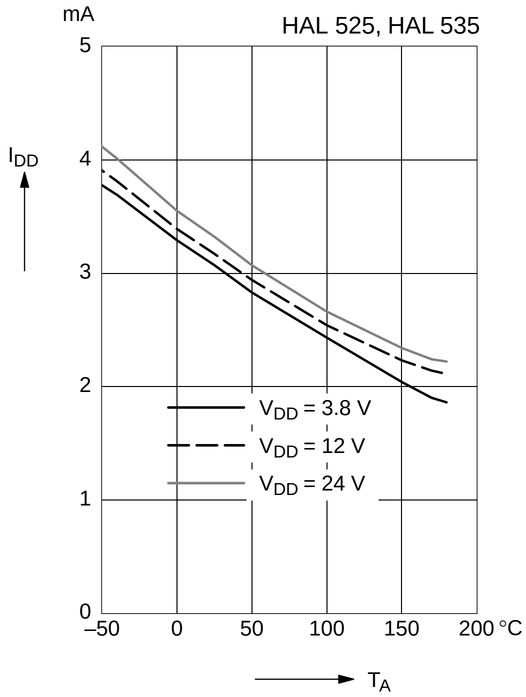


Fig. 3–6: Typical supply current versus ambient temperature

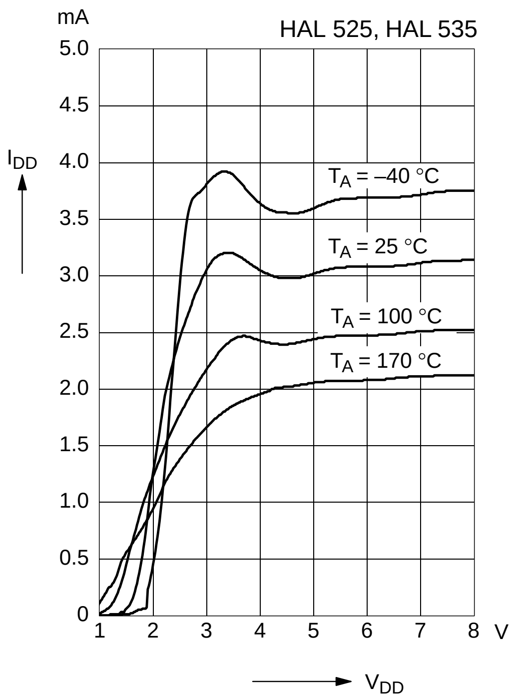


Fig. 3–5: Typical supply current versus supply voltage

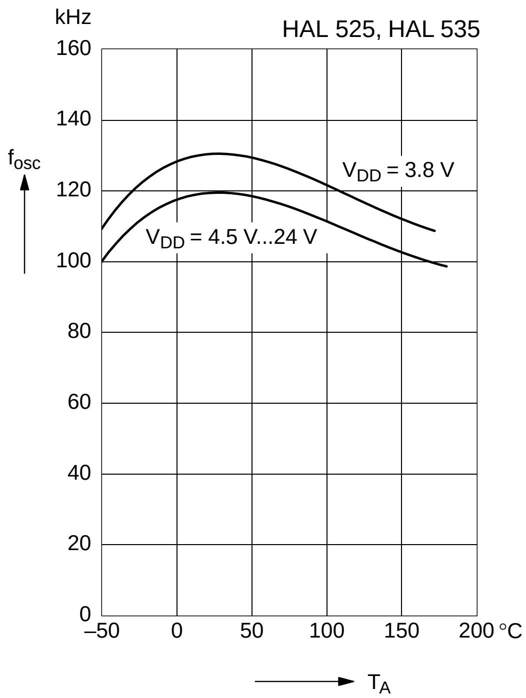


Fig. 3–7: Typ. internal chopper frequency versus ambient temperature

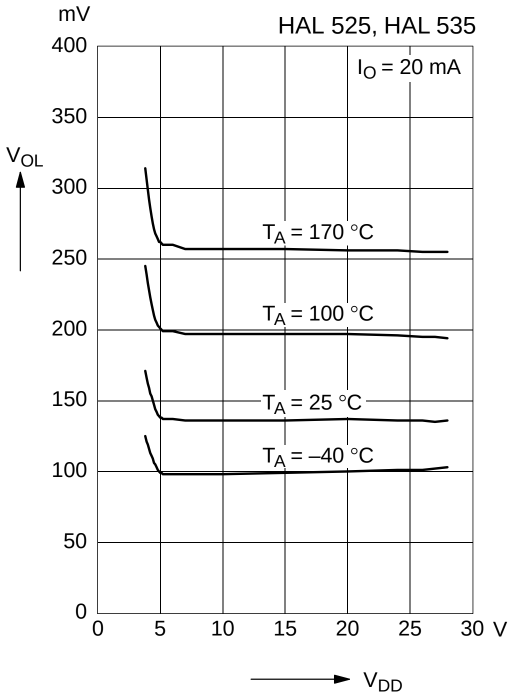


Fig. 3–8: Typical output low voltage versus supply voltage

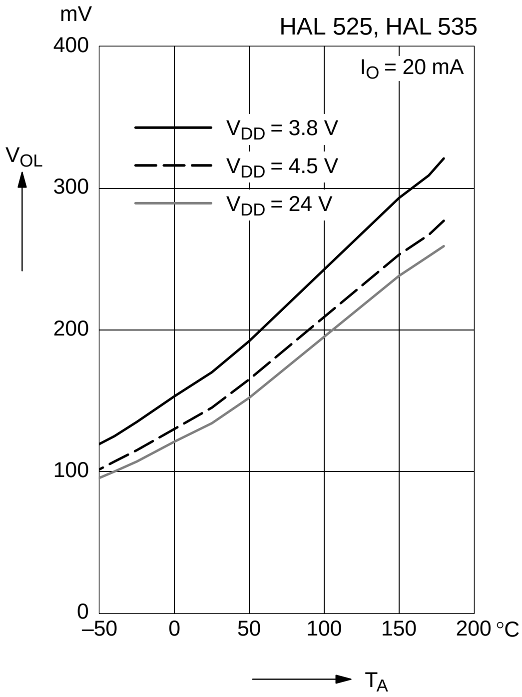


Fig. 3–10: Typical output low voltage versus ambient temperature

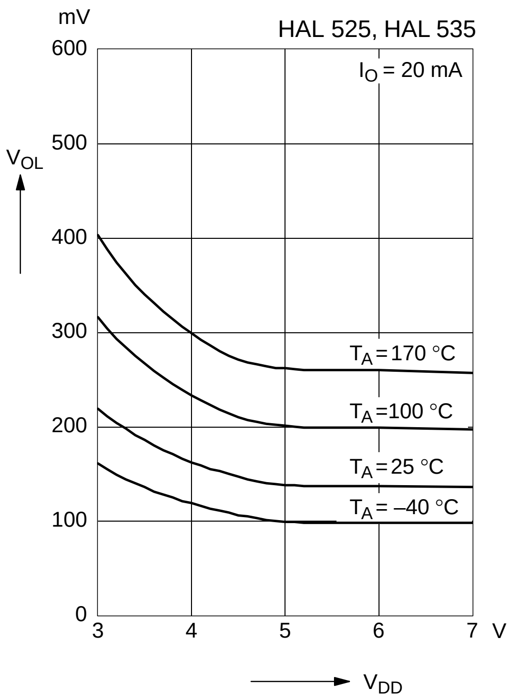


Fig. 3–9: Typical output low voltage versus supply voltage

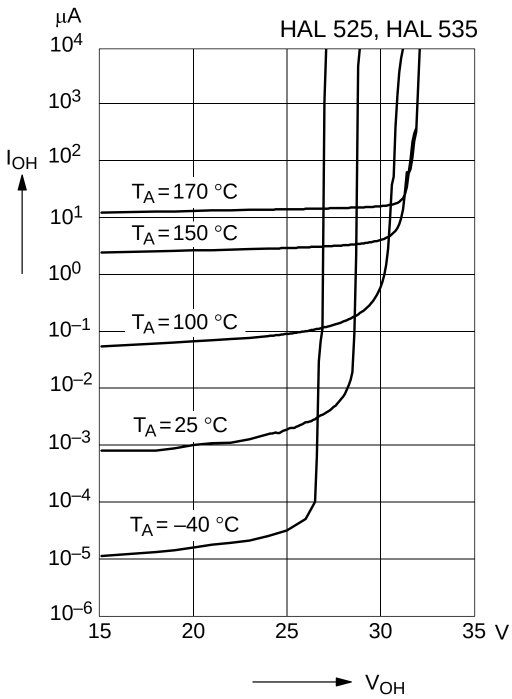


Fig. 3–11: Typ. output high current versus output voltage

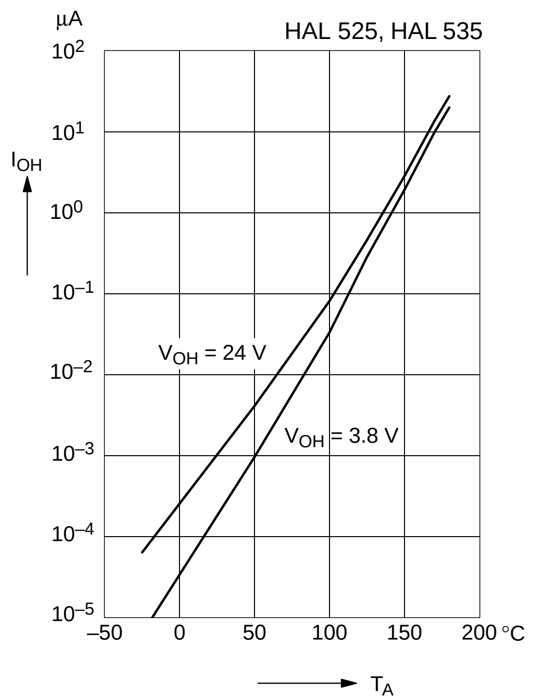


Fig. 3–12: Typical output leakage current versus ambient temperature

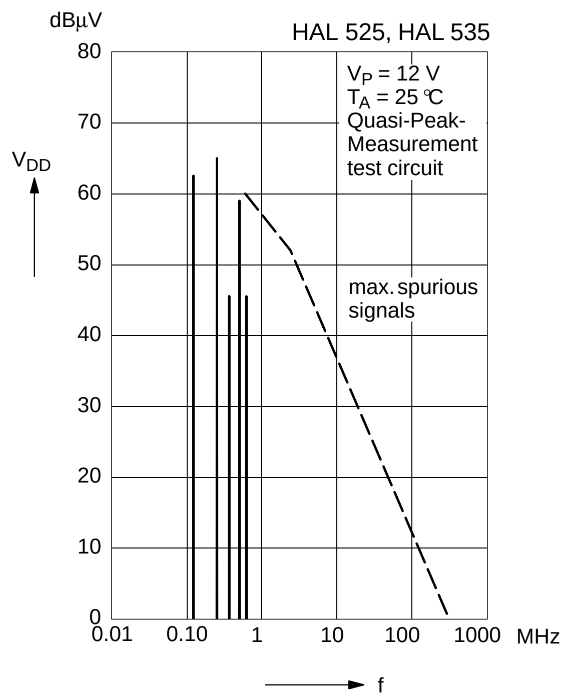


Fig. 3–14: Typ. spectrum of supply voltage

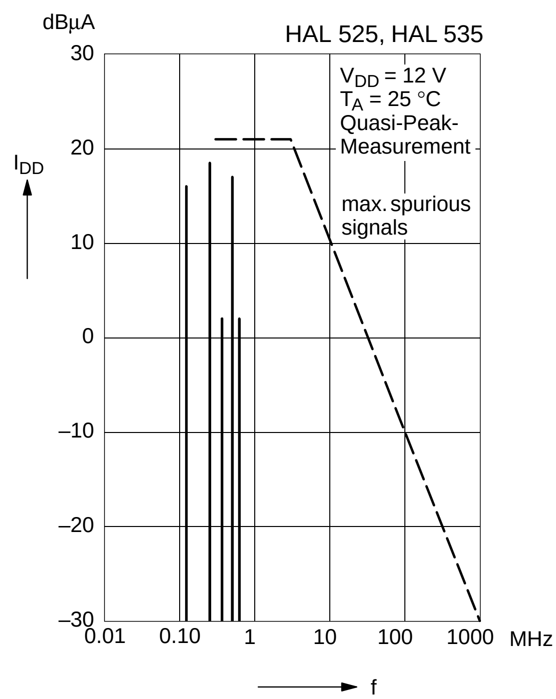


Fig. 3–13: Typ. spectrum of supply current

4. Type Description

4.1. HAL 525

The HAL 525 is a latching sensor (see Fig. 4–1).

The output turns low with the magnetic south pole on the branded side of the package and turns high with the magnetic north pole on the branded side. The output does not change if the magnetic field is removed. For changing the output state, the opposite magnetic field polarity must be applied.

For correct functioning in the application, the sensor requires both magnetic polarities (north and south) on the branded side of the package.

Magnetic Features:

– switching type: latching
– low sensitivity
– typical B_{ON}: 14 mT at room temperature
– typical B_{OFF}: –14 mT at room temperature
– operates with static magnetic fields and dynamic magnetic fields up to 10 kHz
– typical temperature coefficient of magnetic switching points is –2000 ppm/K

Applications

The HAL 525 is the optimal sensor for applications with alternating magnetic signals such as:

– multipole magnet applications,
– rotating speed measurement,
– commutation of brushless DC motors, and
– window lifter.

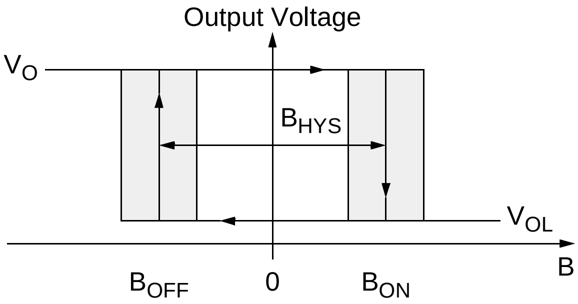


Fig. 4–1: Definition of magnetic switching points for the HAL 525

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	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	11.8	15.8	19.2	–19.2	–15.8	–11.8	27.4	31.6	35.8		0		mT
25 °C	11	14	17	–17	–14	–11	24	28	32	–2	0	2	mT
100 °C	8	11	15.5	–15.5	–11	–8	18.5	22	28.7		0		mT
140 °C	6.5	10	14	–14	–10	–6.5	16	20	26		0		mT
170 °C	5	8.5	13	–13	–8.5	–5	12	17	25		0		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 $B_{OFFSET} = (B_{ON} + B_{OFF}) / 2$

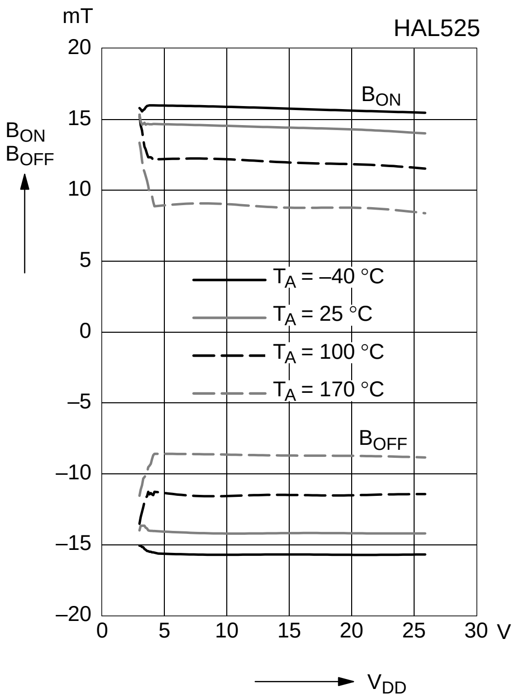


Fig. 4–2: Typ. magnetic switching points versus supply voltage

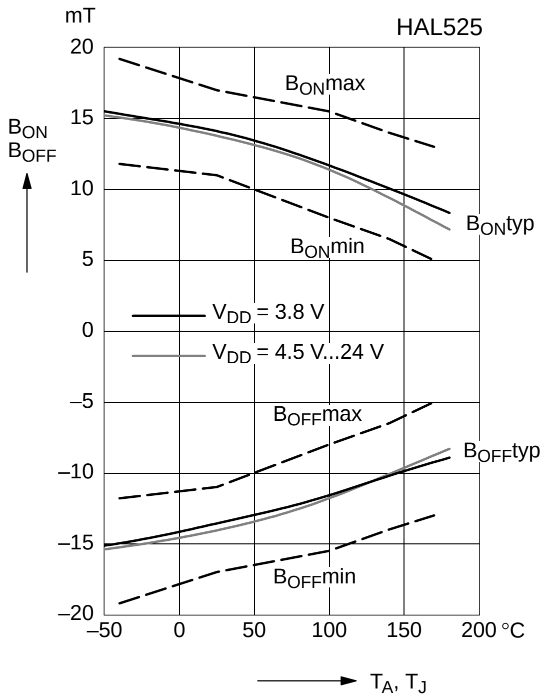


Fig. 4–4: Magnetic switching points versus temperature

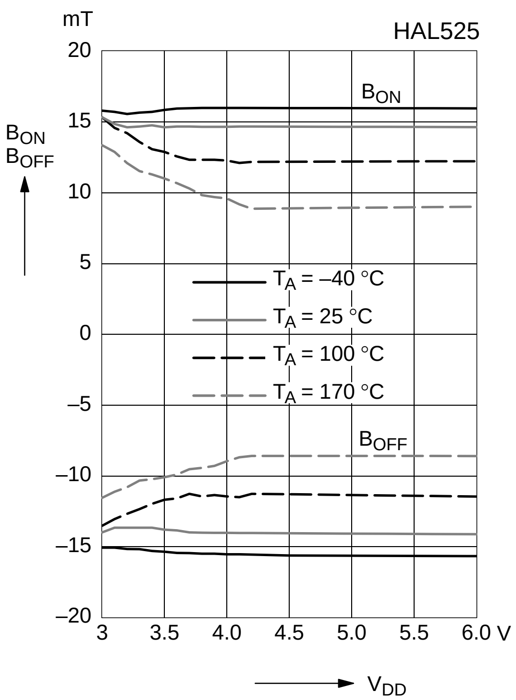


Fig. 4–3: Typ. magnetic switching points versus supply voltage

Note: In the diagram "Magnetic switching points versus ambient temperature" 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.

4.2. HAL 535

The HAL 535 is a latching sensor (see Fig. 4–5).

The output turns low with the magnetic south pole on the branded side of the package and turns high with the magnetic north pole on the branded side. The output does not change if the magnetic field is removed. For changing the output state, the opposite magnetic field polarity must be applied.

For correct functioning in the application, the sensor requires both magnetic polarities (north and south) on the branded side of the package.

Magnetic Features:

– switching type: latching
– low sensitivity
– typical B_{ON}: 13.5 mT at room temperature
– typical B_{OFF}: –13.5 mT at room temperature
– operates with static magnetic fields and dynamic magnetic fields up to 10 kHz
– typical temperature coefficient of magnetic switching points is –1000 ppm/K

Applications

The HAL 535 is the optimal sensor for applications with alternating magnetic signals such as:

– multipole magnet applications,
– rotating speed measurement,
– commutation of brushless DC motors, and
– window lifter.

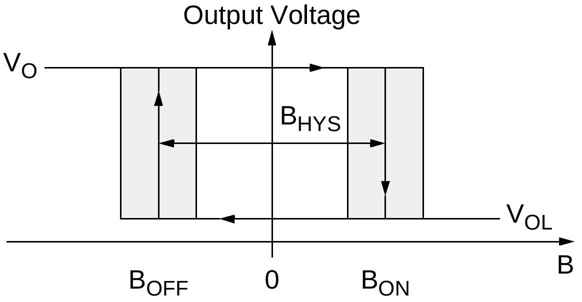


Fig. 4–5: Definition of magnetic switching points for the HAL 535

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	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	12	15	18	–18	–15	–12	25	30	35		0		mT
25 °C	11	13.8	17	–17	–13.8	–11	23	27.6	32		0		mT
100 °C	9	13	17	–17	–13	–9	20	26	31.5		0		mT
140 °C	7	12.5	17	–17	–12.5	–7	18	25	31		0		mT
170 °C	6	12	18	–18	–12	–6	17	24	31		0		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 $B_{OFFSET} = (B_{ON} + B_{OFF}) / 2$

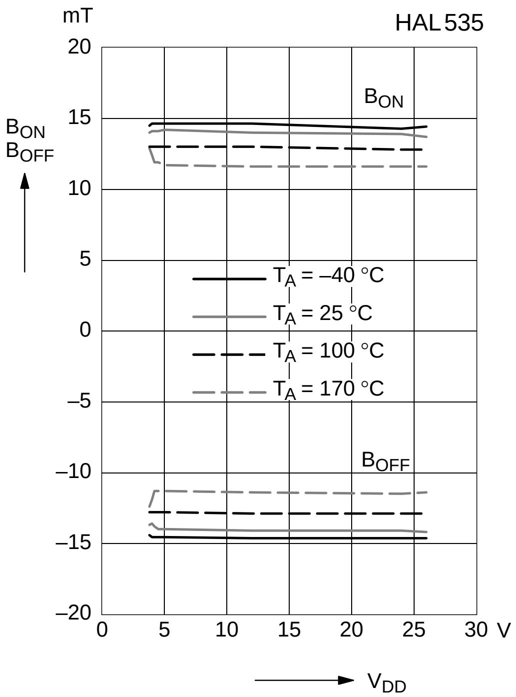


Fig. 4–6: Typ. magnetic switching points versus supply voltage

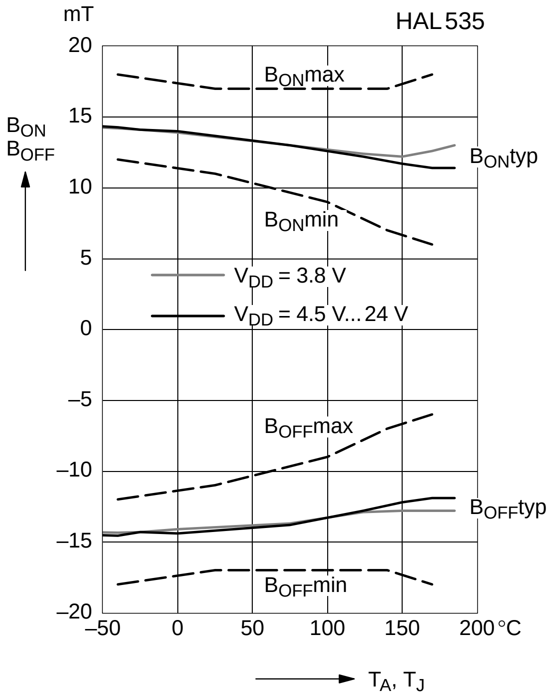


Fig. 4–8: Magnetic switching points versus temperature

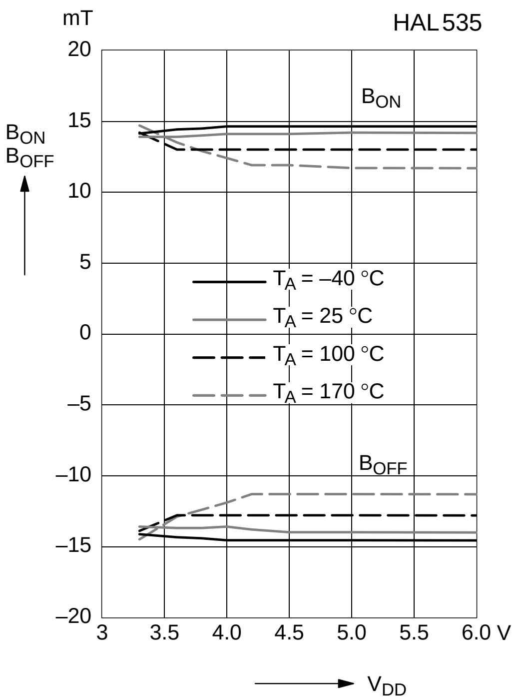


Fig. 4–7: Typ. magnetic switching points versus supply voltage

Note: In the diagram “Magnetic switching points versus ambient temperature” 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.

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, the following equation is valid:

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

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 page 7).

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 Electrical Characteristics (see page 8).

During the initialization time, the output state is not defined and the output can toggle. After $t_{en(O)}$, the output will be low if the applied magnetic field B is above B_{ON}. The output will be high if B is below B_{OFF}.

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

5.4. EMC and ESD

For applications with 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 HAL sensor.

Applications with this arrangement passed the EMC tests according to the product standards DIN 40839).

Note: The international standard ISO 7637 is similar to the used product standard DIN 40839.

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

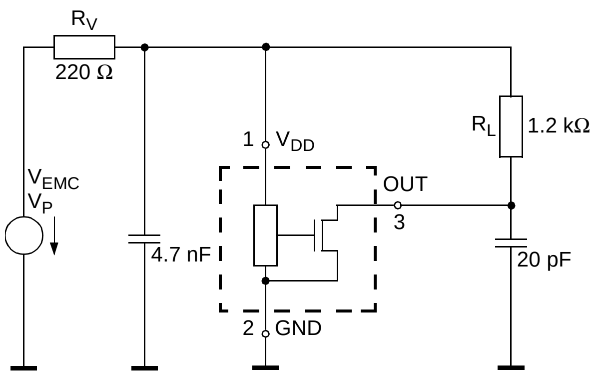


Fig. 5–1: Test circuit for EMC investigations

6. Data Sheet History

1. Final data sheet: "HAL 525 Hall Effect Sensor IC", April 23, 1997, 6251-465-1DS. First release of the final data sheet.

2. Final data sheet: "HAL 525 Hall Effect Sensor IC", March 10, 1999, 6251-465-2DS. Second release of the final data sheet. Major changes:

- additional package SOT-89B
- outline dimensions for SOT-89A and TO-92UA changed
- electrical characteristics changed
- section 4.2.: Extended Operating Conditions added
- section 4.3.: Start-up Behavior added

3. Final data sheet: "HAL 525, HAL 535 Hall Effect Sensor Family", Aug. 30, 2000, 6251-465-3DS. Third release of the final data sheet. Major changes:

- new sensor HAL 535 added
- outline dimensions for SOT-89B: reduced tolerances
- SMD package SOT-89A removed
- temperature range "C" removed

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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Data Sheet Supplement

Subject:	Improvement of SOT-89B Package
Data Sheet Concerned:	HAL 114, 115, 6251-456-2DS, Dec. 20, 1999 HAL 50x, 51x, 6251-485-1DS, Feb. 16, 1999 HAL 55x, 56x, 6251-425-1DS, April 6, 1999 HAL 621, 629, 6251-504-1DS, Feb. 3, 2000
Supplement:	No. 1/ 6251-531-1DSS
Edition:	July 4, 2000

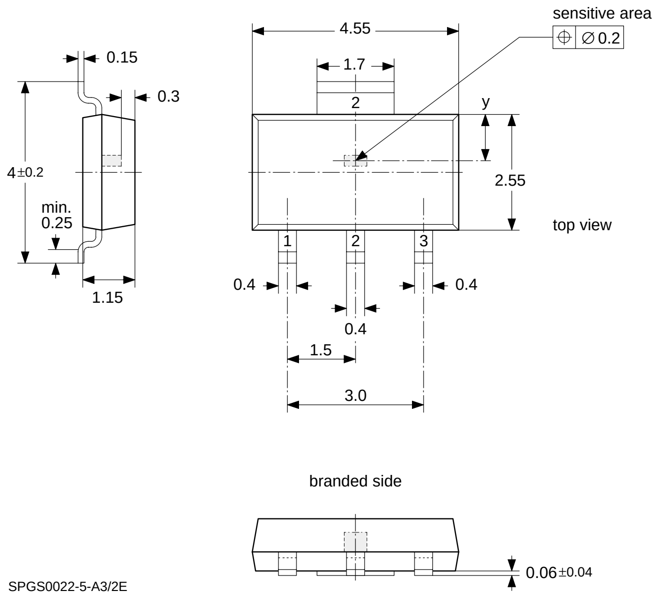
Changes:

– position tolerance of the sensitive area reduced

– tolerances of the outline dimensions reduced

– thickness of the leadframe changed to 0.15 mm (old 0.125 mm)

– SOT-89A will be discontinued in December 2000



Position of sensitive area

	HAL 114, 115 HAL 50x, 51x HAL 621, 629	HAL 55x, HAL 56x
x	center of the package	center of the package
y	0.95 mm nominal	0.85 mm nominal

Note: A mechanical tolerance of ±0.05 mm applies to all dimensions where no tolerance is explicitly given. Position tolerance of the sensitive area is defined in the package diagram.