Linear Hall Effect Sensor IC
in CMOS technology

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

Features:

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

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

Specifications

Marking Code

<table>
<thead>
<tr>
<th>Type</th>
<th>Temperature Range</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>A</td>
</tr>
<tr>
<td>HAL400S</td>
<td>400A</td>
</tr>
</tbody>
</table>

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

HALXXXPP-T

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

Example: HAL400S-E

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

Solderability

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

Fig. 1: Pin configuration
Functional Description

The Linear Hall Sensor measures accurate constant and low frequency magnetic flux densities. The differential output voltage is proportional to the magnetic flux density passing vertically through the sensitive area of the chip. The common mode voltage (average of the voltages on pin 2 and pin 3) of the differential output amplifier is a constant 2.2 V.

The differential output voltage consists of two components due to the switching offset compensation technique. The average of the differential output voltage represents the magnetic flux density. This component is overlaid by an differential AC signal at a typical frequency of 147 kHz. The AC signal represents the internal offset voltages of amplifiers and hall plates, that are influenced by mechanical stress and temperature cycling.

External filtering or integrating measurement can be done to eliminate the AC component of the signal. So the influence of mechanical stress and temperature cycling is suppressed. No adjustment of magnetic offset is needed.

The sensitivity is stabilized over a wide range of temperature and supply voltage due to internal voltage regulation and circuits for temperature compensation.

Offset Compensation (see Fig. 3)

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

Compensation of this kind of offset is done by cyclic commutating the connections for current flow and voltage measurement.

– First cycle:
  The hall supply current flows between the points 4 and 2. In the absence of a magnetic field $V_{13}$ is the Hall Offset Voltage ($+V_{\text{Offs}}$). In case of a magnetic field, $V_{13}$ is the sum of the Hall voltage ($V_H$) and $V_{\text{Offs}}$.
  $V_{13} = V_H + V_{\text{Offs}}$

– Second cycle:
  The hall supply current flows between the points 1 and 3. In the absence of a magnetic field $V_{24}$ is the Hall Offset Voltage with negative polarity ($-V_{\text{Offs}}$). In case of a magnetic field, $V_{24}$ is the difference of the Hall voltage ($V_H$) and $V_{\text{Offs}}$.
  $V_{24} = V_H - V_{\text{Offs}}$

The output shows in the first cycle the sum of the Hall voltage and the offset, in the second the difference of both. The difference of the mean values of $V_{\text{OUT1}}$ and $V_{\text{OUT2}}$ ($V_{\text{OUTdif}}$) is equivalent to $V_{\text{Hall}}$.

Note: The numbers do not represent pin numbers.

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

Fig. 3: Hall Offset Compensation
Outline Dimensions

![Outline Dimensions Diagram]

Fig. 4: Plastic Package SOT-89A

Weight approximately 0.04 g
Dimensions in mm

Absolute Maximum Ratings

<table>
<thead>
<tr>
<th>Symbol</th>
<th>Parameter</th>
<th>Pin No.</th>
<th>Min.</th>
<th>Max.</th>
<th>Unit</th>
</tr>
</thead>
<tbody>
<tr>
<td>V_{DD}</td>
<td>Supply Voltage</td>
<td>1</td>
<td>–15</td>
<td>12</td>
<td>V</td>
</tr>
<tr>
<td>I_{DDZ}</td>
<td>Supply Current through Protection Device</td>
<td>1</td>
<td>–400(^1)</td>
<td>400(^1)</td>
<td>mA</td>
</tr>
<tr>
<td>I_{OUT}</td>
<td>Output Current</td>
<td>2, 3</td>
<td>–5</td>
<td>5</td>
<td>mA</td>
</tr>
<tr>
<td>I_{OUTZ}</td>
<td>Output Current through Protection Device</td>
<td>1</td>
<td>–300(^1)</td>
<td>300(^1)</td>
<td>mA</td>
</tr>
<tr>
<td>T_{S}</td>
<td>Storage Temperature Range</td>
<td></td>
<td>–65</td>
<td>150</td>
<td>°C</td>
</tr>
<tr>
<td>T_{J}</td>
<td>Junction Temperature Range</td>
<td></td>
<td>–40</td>
<td>150(^2)</td>
<td>°C</td>
</tr>
</tbody>
</table>

\(^1\) t ≤ 2 ms
\(^2\) t < 1000 h

Stresses beyond those listed in the “Absolute Maximum Ratings” may cause permanent damage to the device. This is a stress rating only. Functional operation of the device at these or any other conditions beyond those indicated in the “Recommended Operating Conditions/Characteristics” of this specification is not implied. Exposure to absolute maximum ratings conditions for extended periods may affect device reliability.
### Recommended Operating Conditions

<table>
<thead>
<tr>
<th>Symbol</th>
<th>Parameter</th>
<th>Pin No.</th>
<th>Min.</th>
<th>Max.</th>
<th>Unit</th>
<th>Remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td>$I_{OUT}$</td>
<td>Continuous Output Current</td>
<td>2, 3</td>
<td>–2.25</td>
<td>2.25</td>
<td>mA</td>
<td>$T_J = 25 ^\circ C$</td>
</tr>
<tr>
<td>$I_{OUT}$</td>
<td>Continuous Output Current</td>
<td>2, 3</td>
<td>–1</td>
<td>1</td>
<td>mA</td>
<td>$T_J = 170 ^\circ C$</td>
</tr>
<tr>
<td>$C_L$</td>
<td>Load Capacitance</td>
<td>2, 3</td>
<td>–</td>
<td>1</td>
<td>nF</td>
<td></td>
</tr>
</tbody>
</table>

**Fig. 5: Recommended Operating Supply Voltage**

### Extended Operational Range

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

<table>
<thead>
<tr>
<th>Symbol</th>
<th>Parameter</th>
<th>Pin No.</th>
<th>Min.</th>
<th>Max.</th>
<th>Unit</th>
<th>Remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td>$V_{DD}$</td>
<td>Supply Voltage</td>
<td>1</td>
<td>4.3</td>
<td>12</td>
<td>V</td>
<td></td>
</tr>
<tr>
<td>$I_{OUT}$</td>
<td>Output Current</td>
<td>2, 3</td>
<td>–3</td>
<td>3</td>
<td>mA</td>
<td>$T_J = –40 ^\circ C to +170 ^\circ C$</td>
</tr>
</tbody>
</table>
## Electrical and Magnetic Characteristics

see Fig. 5 for $T_A$ and $V_{DD}$ as not otherwise specified; Typical characteristics for $T_J = 25 \, ^\circ C$, $-75 \, mT < B < 75 \, mT$ and $V_{DD} = 6.8 \, V$

<table>
<thead>
<tr>
<th>Symbol</th>
<th>Parameter</th>
<th>Pin No.</th>
<th>Min.</th>
<th>Typ.</th>
<th>Max.</th>
<th>Unit</th>
<th>Test Conditions</th>
</tr>
</thead>
<tbody>
<tr>
<td>$I_{DD}$</td>
<td>Supply Current</td>
<td>1</td>
<td>11.8</td>
<td>14.5</td>
<td>17.1</td>
<td>mA</td>
<td>$T_J = 25 , ^\circ C$; $I_{OUT,1,2} = 0 , mA$</td>
</tr>
<tr>
<td>$I_{DD}$</td>
<td>Supply Current under Recommended Operating Conditions</td>
<td>1</td>
<td>9.3</td>
<td>14.5</td>
<td>18.5</td>
<td>mA</td>
<td>$I_{OUT,1,2} = 0 , mA$</td>
</tr>
<tr>
<td>$V_{CM}$</td>
<td>Common Mode Output Voltage</td>
<td>2, 3</td>
<td>2.1</td>
<td>2.2</td>
<td>2.3</td>
<td>V</td>
<td>$I_{OUT,1,2} = 0 , mA$ $V_{CM} = (V_{OUT1} + V_{OUT2}) / 2$</td>
</tr>
<tr>
<td>CMRR</td>
<td>Common Mode Rejection Ratio</td>
<td>2, 3</td>
<td>-2</td>
<td>0</td>
<td>2</td>
<td>mV/V</td>
<td>$I_{OUT,1,2} = 0 , mA$ $CMRR$ is limited by the influence of power dissipation</td>
</tr>
<tr>
<td>$S_B = \Delta V_{OUTDIFF}/\Delta B$</td>
<td>Differential Magnetic Sensitivity</td>
<td>2–3</td>
<td>37</td>
<td>42.5</td>
<td>49.5</td>
<td>mV/mT</td>
<td>$B = \pm 60 , mT$ $V_{OUTDIFF} = V_{OUT1} - V_{OUT2}$</td>
</tr>
<tr>
<td>$S_B$</td>
<td>Differential Magnetic Sensitivity under Recommended Operating Conditions</td>
<td>2–3</td>
<td>33</td>
<td>42.5</td>
<td>49.5</td>
<td>mV/mT</td>
<td>$B = \pm 60 , mT$ $V_{OUTDIFF} = V_{OUT1} - V_{OUT2}$</td>
</tr>
<tr>
<td>$B_{offset}$</td>
<td>Magnetic Offset</td>
<td>2–3</td>
<td>-1.0</td>
<td>-0.2</td>
<td>1.0</td>
<td>mT</td>
<td>$B = 0 , mT, I_{OUT,1,2} = 0 , mA$ $T_J = 25 , ^\circ C$</td>
</tr>
<tr>
<td>$B_{offset}$</td>
<td>Magnetic Offset over Temperature</td>
<td>2–3</td>
<td>-1.25</td>
<td>-0.2</td>
<td>1.25</td>
<td>mT</td>
<td>$B = 0 , mT, I_{OUT,1,2} = 0 , mA$</td>
</tr>
<tr>
<td>$\Delta B_{OFFSET}/\Delta T$</td>
<td>Magnetic Offset Change due to $T_A$</td>
<td></td>
<td>-15</td>
<td>0</td>
<td>15</td>
<td>$\mu T/K$</td>
<td>$B = 0 , mT, I_{OUT,1,2} = 0 , mA$</td>
</tr>
<tr>
<td>BW</td>
<td>Bandwidth (–3 dB)</td>
<td>2–3</td>
<td>–</td>
<td>10</td>
<td>–</td>
<td>kHz</td>
<td>1)</td>
</tr>
<tr>
<td>NL-diff</td>
<td>Non Linearity of Differential Output</td>
<td>2–3</td>
<td>–</td>
<td>0.2</td>
<td>1</td>
<td>%</td>
<td>$B = \pm 40 , mT, B = \pm 60 , mT$</td>
</tr>
<tr>
<td>NL-single</td>
<td>Non Linearity of Single Ended Output</td>
<td>2, 3</td>
<td>–</td>
<td>2</td>
<td>3</td>
<td>%</td>
<td></td>
</tr>
<tr>
<td>$f_{CH}$</td>
<td>Chopper Frequency</td>
<td>2, 3</td>
<td>114</td>
<td>147</td>
<td>166</td>
<td>kHz</td>
<td>$T_J = 25 , ^\circ C$</td>
</tr>
<tr>
<td>$f_{CH}$</td>
<td>Chopper Frequency over Temp.</td>
<td>2, 3</td>
<td>90</td>
<td>147</td>
<td>166</td>
<td>kHz</td>
<td></td>
</tr>
<tr>
<td>$V_{OUTACpp}$</td>
<td>Peak-to-Peak AC Output Voltage</td>
<td>2, 3</td>
<td>0</td>
<td>0.32</td>
<td>0.8</td>
<td>V</td>
<td></td>
</tr>
<tr>
<td>$n_{meff}$</td>
<td>Magnetic RMS Differential Broadband Noise</td>
<td>2–3</td>
<td>–</td>
<td>10</td>
<td>–</td>
<td>$\mu T$</td>
<td>BW = 10 Hz to 10 kHz</td>
</tr>
<tr>
<td>$f_{Clk}$</td>
<td>Corner Frequency of 1/f Noise</td>
<td>2–3</td>
<td>–</td>
<td>10</td>
<td></td>
<td>Hz</td>
<td>$B = 0 , mT$</td>
</tr>
<tr>
<td>$f_{Clk}$</td>
<td>Corner Frequency of 1/f Noise</td>
<td>2–3</td>
<td>–</td>
<td>100</td>
<td></td>
<td>Hz</td>
<td>$B = 65 , mT$</td>
</tr>
<tr>
<td>$R_{OUT}$</td>
<td>Output Resistance</td>
<td>2, 3</td>
<td>0</td>
<td>30</td>
<td>50</td>
<td>$\Omega$</td>
<td>$I_{OUT,1,2} \leq 2.5 , mA$ $T_J = 25 , ^\circ C$ $V_{DD} = 6.8 , V$</td>
</tr>
<tr>
<td>$R_{OUT}$</td>
<td>Output Resistance over Temperature</td>
<td>2, 3</td>
<td>0</td>
<td>30</td>
<td>150</td>
<td>$\Omega$</td>
<td>$I_{OUT,1,2} \leq 2.5 , mA$</td>
</tr>
<tr>
<td>$R_{RUSB}$</td>
<td>Thermal Resistance Junction to Substrate Backside</td>
<td></td>
<td></td>
<td>–</td>
<td>150</td>
<td>200</td>
<td>K/W</td>
</tr>
</tbody>
</table>

1) with external 2 pole filter ($f_{3db} = 5 \, kHz$), $V_{OUTAC}$ is reduced to less than 1 mV
Typical output voltages versus magnetic flux density

Typical differential output offset voltage versus supply voltage
Parameter = $T_A$

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

Typical magnetic offset of differential output versus ambient temperature
Parameter = $V_{DD}$
HAL400

Typical differential sensitivity versus supply voltage
Parameter = $T_A$

$S_{BDiff}$

$B = \pm 50 \text{ mT}$

$V_{DD}$

$V_{DD}$ vs $T_A$

$V_{DD} = 4.8 \text{ V}$
$V_{DD} = 6.0 \text{ V}$
$V_{DD} = 12 \text{ V}$

Typical differential sensitivity versus ambient temperature
Parameter = $V_{DD}$

$S_{BDiff}$

$B = \pm 50 \text{ mT}$

$T_A$

$T_A = -40 \degree \text{ C}$
$T_A = 25 \degree \text{ C}$
$T_A = 150 \degree \text{ C}$

Typical nonlinearity of differential output versus magnetic flux density
Parameter = $V_{DD}$

$NL_{dif}$

$B$

$V_{DD} = 4.8 \text{ V}$
$V_{DD} = 6.0 \text{ V}$
$V_{DD} = 12 \text{ V}$

Typical nonlinearity of differential output versus magnetic flux density
Parameter = $T_A$

$NL_{dif}$

$B$

$V_{DD} = 6.8 \text{ V}$
$T_A = -40 \degree \text{ C}$
$T_A = 25 \degree \text{ C}$
$T_A = 125 \degree \text{ C}$
$T_A = 150 \degree \text{ C}$
**Typical single ended nonlinearity versus magnetic flux density, Parameter = V_{DD}**

- \( V_{DD} = 4.8 \, \text{V} \)
- \( V_{DD} = 12 \, \text{V} \)

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

- \( T_A = -40 \, ^\circ \text{C} \)
- \( T_A = 25 \, ^\circ \text{C} \)
- \( T_A = 125 \, ^\circ \text{C} \)
- \( T_A = 150 \, ^\circ \text{C} \)

**Typical chopper frequency versus supply voltage**

- Parameter = \( V_{DD} \)

**Typical chopper frequency versus ambient temperature**

- Parameter = \( T_A \)
Typical supply current versus supply voltage
Parameter = $T_A$

Typical supply current versus temperature
Parameter = $T_A$

Typical supply current versus output current
Parameter = $V_{DD}$
HAL400

Typical dynamic differential output resistance versus temperature
Parameter = $T_A$

\[ R_{OUT} \text{ (Ω)} \]

\[ T_A \text{ (°C)} \]

$V_{DD} = 4.8 \text{ V}$
$V_{DD} = 6.0 \text{ V}$
$V_{DD} = 12 \text{ V}$

Typical magnetic noise spectrum

\[ dB_{T_{rms} / \sqrt{Hz}} \]

\[ T_A = 25 \text{ °C} \]

\[ B = 0 \text{ mT} \]
\[ B = 65 \text{ mT} \]

Typical magnetic frequency response

\[ dB_{S_B} \]

\[ f \text{ (Hz)} \]

$T_A = 25 \text{ °C}$

0 dB = 42.5 mV/mT

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

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

Display the difference between channel 1 and channel 2 to show the Hall voltage. Capacitors 4.7 nF and 330 pF for electromagnetic immunity are recommended.

Do not connect OUT1 or OUT2 to Ground.

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Display the difference between channel 1 and channel 2 to show the Hall voltage. Capacitors 4.7 nF and 330 pF for electromagnetic immunity are recommended.

Do not connect OUT1 or OUT2 to Ground.

Do not connect OUT1 or OUT2 to Ground.

Fig. 7: Flux density measurement with voltmeter

Fig. 8: Filtering of output signals

Fig. 9: Differential HAL400 output to single-ended output

R = 10 kΩ, C = 7.5 nF, ΔR for offset adjustment, BW_{3dB} = 1.3 kHz
Do not connect OUT1 or OUT2 to Ground.

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


   Major changes:
   – Marking code

   Major changes:
   – Electrical and Magnetic Characteristics
   – diagram: Typical output voltages versus magnetic flux density

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