

Bidirectional low-side current sensing amplifier



SOT23-6

Features

Wide supply voltage range: 2.0 V to 5.5 V

Fixed gain: 20 V/V

• Total output error < 0.5%

Offset voltage: ±200 μV max.

Gain error: 0.1% max.Bandwidth: 2.1 MHz

Extended temperature range: -40 °C to +125 °C

Automotive grade version available

Benefits:

Total error guaranteed

Reduced bill of material

Applications

- High bandwidth low-side current sensing
- Low-side motor control
- Power management in Solar Powered Systems
- Power management in HEV and EV

Description

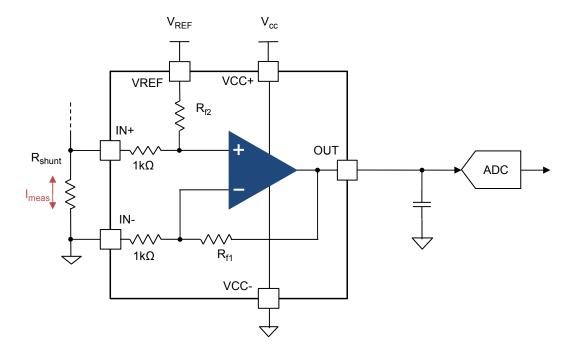
The TSC1801 is a low-side current measurement amplifier. The TSC1801 is designed to sense drops across shunt resistors at low common-mode voltages. The gain value is set to 20 V/V, selectable by part number.

Maturity status link

TSC1801

1 Schematic diagram

Figure 1. Internal schematic diagram

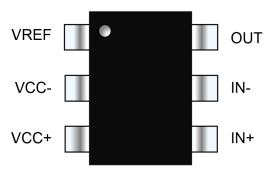


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Pin description

Figure 2. Pin connections (top view)



SOT23-6

Table 1. Pin description

| Pin n° | Pin name | Description |
|--------|----------|--|
| 1 | VREF | Voltage reference input for zero-current mid-point setting |
| 2 | VCC- | Negative supply voltage |
| 3 | VCC+ | Positive supply voltage |
| 4 | IN+ | Non-inverting input channel |
| 5 | IN- | Inverting input channel |
| 6 | OUT | Output channel |

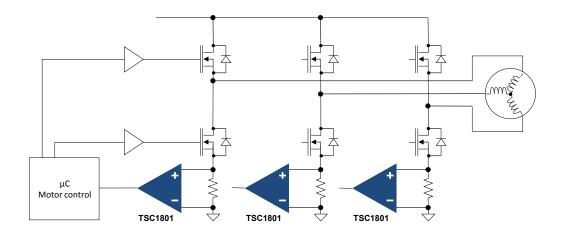
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3 Typical application schematic

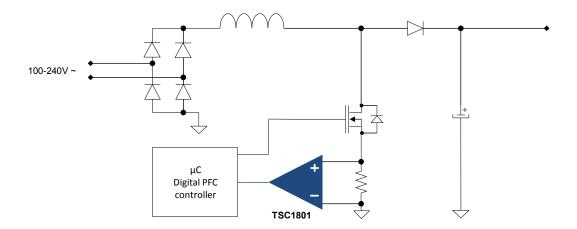
3.1 Motor control

Figure 3. 3-phase motor-control with low-side current measurement by TSC1801



3.2 PFC converter

Figure 4. Power Factor Corrector with low-side current measurement by TSC1801



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4 Maximum ratings and operating conditions

Table 2. Absolute maximum ratings

| Symbol | Parameter ⁽¹⁾ | Value | Unit | |
|------------------|---|------------------------------|--------|--|
| VCC | Supply voltage | 6 | V | |
| Vid | Input voltage differential (V _{IN+} - V _{IN-}) (2) | ±V _{CC} | V | |
| Vin | Input voltage: IN+, IN-, VREF pins (2) | (VCC-) - 0.4 to (VCC+) + 0.3 | V | |
| lin | Input current | ±10 | mA | |
| T _{stg} | Storage temperature | -65 to +150 | °C | |
| Tj | Maximum junction temperature | 150 | | |
| Rth-ja (3) | Thermal resistance junction-to-ambient SOT23-6 | 240 | °C / W | |
| | HBM: human body model (industrial grade) (4) | 4 | kV | |
| ESD | HBM: human body model (automotive grade) (5) | 4 | kV | |
| | CDM: charged device model ⁽⁶⁾ | 1.5 | kV | |

- 1. All voltage values are with respect to the VCC- pin, unless otherwise specified.
- 2. The maximum input voltage value may be extended to the condition that the input current is limited to ±10 mA.
- 3. Rth-ja is a typical value, obtained with PCB according to JEDEC 2s2p without vias.
- 4. Human body model: HBM test according to the standard ESDA-JS-001-2017.
- 5. Human body model: HBM test according to the standard AEC-Q100-002.
- 6. Charged device model: the CDM test is done according to the standard AEC-Q100-011.

Table 3. Operating conditions

| Symbol | Parameter | Value |
|--------------------|---|--|
| V _{CC} | Supply voltage | 2.0 V to 5.5 V |
| V _{ref} | VREF pin voltage | V _{CC-} to V _{CC+} |
| V _{icm} | Common-mode input voltage range | V_{CC-} – 0.1 V to V_{CC+} - 1.5 V |
| V | $V_{\text{IN+}}$ - $V_{\text{IN-}}$ operating range with total error < 0.3% | |
| V _{sense} | Gain 20 V/V | ± 122 mV |
| T _{oper} | Operating free air temperature range | -40 °C to +125 °C |

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5 Electrical characteristics

Table 4. DC electrical characteristics at V_{CC} = 3.3 V and V_{CC} = 5 V, V_{ref} = $V_{CC}/2$, V_{IN_-} = 0 V, V_{sense} = V_{IN_+} - V_{IN_-} = 0 V, V_{cense} = V_{cense

| Symbol | Parameter | Conditions | Min. | Тур. | Max. | Unit | |
|---------------------------------|---|--|--------|-------|-------|--------|--|
| Gain | TSC1801B | | | 20 | | V/V | |
| ۸۱/ | Total output error Gain = 20, V _{CC} = 5 V, | T = 25 °C | | | ± 0.5 | 0/ | |
| ΔV _{OUT} | Vsense = +/-100 mV (1) | -40 °C ≤ T ≤ 125 °C | | | ± 1 | % | |
| | | 100 mV < V _{out} < V _{cc} - 150 mV, T = 25 °C | | 0.1 | | | |
| Eg | Gain error | 100 mV < V _{out} < V _{cc} - 150 mV, | | | 0.45 | % | |
| | | -40 °C ≤ T ≤ 125 °C | | | 0.15 | | |
| V _{io} | Input offset voltage, referred to input | T = 25 °C | | ± 50 | ± 200 | \/ | |
| V iO | input onset voltage, referred to input | -40 °C ≤ T ≤ 125 °C | | | ± 700 | μV | |
| $\Delta V_{io}/\Delta T$ | Input offset voltage temperature drift | -40 °C ≤ T ≤ 125 °C | | | ± 5 | μV/°C | |
| R _{diff} | Differential input resistor | | | 2 | | kΩ | |
| ΔEg/ΔT | Gain error drift | | | | 10 | ppm/°C | |
| NLE | Non-linearity error | 100 mV < V _{out} < V _{cc} - 150 mV | | ±0.01 | | % | |
| | | V _{CC} - ≤ V _{icm} ≤ V _{CC+} - 1.5 V, T = 25 °C | 83 | 100 | | | |
| CMR | Common-mode rejection ratio 20.log (ΔV _{io} /ΔV _{icm}) | $V_{CC-} \le V_{icm} \le V_{CC+} - 1.5 \text{ V},$ | 83 100 | 400 | | dB | |
| | 20.109 (AV ₁₀ /AV _{1cm}) | -40 °C ≤ T ≤ 125 °C | | | | | |
| | Peferance voltage rejection ratio | 10%.V _{CC} ≤ V _{ref} ≤ 90%.V _{CC} , T = 25 °C | 85 | 100 | | dB | |
| REFR | Reference voltage rejection ratio 20.log (ΔV _{io} /ΔV _{ref}) | $10\%.V_{CC} \le V_{ref} \le 90\%.V_{CC}$ | 05 | 100 | | | |
| | 20.10g (AV ₁₀ /AV _{ref}) | -40 °C ≤ T ≤ 125 °C | 85 | 100 | | | |
| 0) /D | Supply-voltage rejection ratio | 2.0 V ≤ V _{CC} ≤ 5.5 V, T = 25 °C | | 109 | | -ID | |
| SVR | $20.\log(\Delta V_{io}/\Delta V_{CC})$ | 2.0 V ≤ V _{CC} ≤ 5.5 V, -40 °C ≤ T ≤ 125 °C | 90 | 108 | | dB | |
| ., | High-level output voltage drop | V _{sense} = 1 V, T = 25 °C | | | 20 | | |
| V_{OH} | $(V_{OH} = V_{CC+} - V_{OUT})$ | V _{sense} = 1 V, -40 °C ≤ T ≤ 125 °C | | | 25 | mV | |
| | Low-level output voltage drop | V _{sense} = - 1 V, T = 25 °C | | | 10 | | |
| V_{OL} | (V _{OL} = V _{OUT}) | V _{sense} = - 1 V, -40 °C ≤ T ≤ 125 °C | | | 20 | mV | |
| | | Output shorted to V _{CC+} , T = 25 °C | 55 | 70 | | | |
| | I _{SINK} , V _{sense} = - 1 V | Output shorted to V _{CC+} , -40 °C ≤ T ≤ 125 °C | 40 | | | - | |
| Гоит | | Output shorted to V _{CC-} , T = 25 °C | 50 | 63 | | mA | |
| | I _{SOURCE} , V _{sense} = 1 V | Output shorted to V _{CC-} , -40 °C ≤ T ≤ 125 °C | 40 | | | | |
| C _{Lmax} | Maximum capacitive load Gain = 20 | No sustained oscillations | | 1 | | nF | |
| $\Delta V_{out}/\Delta I_{out}$ | Load regulation | -10 mA ≤ I _{out} ≤ 10 mA | | 0.3 | 2 | mV/mA | |
| outout | | Power supply | | | | | |
| | | T = 25 °C | | 3.3 | 3.6 | | |
| I _{CC} | Supply current $V_{IN+} = V_{IN-} = V_{CC}/2$ | -40 °C ≤ T ≤ 125 °C | | 0.0 | 3.6 | mA | |
| | | 10 3 = 1 = 120 0 | | | | | |

^{1.} Total output error defined by the formula: $\Delta Vout = \frac{Voutmeas - Vsense \cdot Gain - Vref}{Vsense \cdot Gain}$

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Table 5. AC electrical characteristics at V_{CC} = 3.3 V and V_{CC} = 5 V, V_{ref} = $V_{CC}/2$, V_{IN_-} = 0 V, V_{sense} = V_{IN_+} - V_{IN_-} = 0 V, V_{sense} = V_{IN_+} - V_{IN_-} = 0 V, V_{sense} = V_{IN_+} = 0 V, V_{IN_+}

| Symbol | Parameter | Conditions | Min. | Тур. | Max. | Unit | |
|-------------------|---|--|------|------|------|------------------|--|
| | AC performance | | | | | | |
| BW | Bandwidth at -3 dB | Gain 20 V/V | | 2.1 | | MHz | |
| SR | Slew rate, V _{out} 10% to 90% | V _{out} from 300 mV to V _{cc} - 300 mV | | 14 | | V/µs | |
| | | f = 10 Hz | | 170 | | | |
| en | Input voltage noise density | f = 100 Hz | | 50 | | nV/√Hz | |
| | | f = 10 kHz | | 9 | | | |
| en p-p | Input noise voltage Gain = 20 | 0.1 Hz ≤ f ≤ 10 Hz | | 8 | | μV _{pp} | |
| t _S | Settling time | V _{sense} = 0 to 40 mV, V _{out} ± 1% | | 300 | | ns | |
| t _{init} | Initialization time | V _{sense} = 40 mV, V _{out} ± 1% | | 25 | | μs | |
| | | V _{RF} = 200 mV _{peak-peak} , f = 400 MHz | | 60 | | | |
| EMIRR | EMI rejection ratio | V _{RF} = 200 mV _{peak-peak} , f = 900 MHz | | 85 | | dB | |
| | EMIRR = 20 log $(V_{RF}/\Delta V_{io})$ | V _{RF} = 200 mV _{peak-peak} , f = 1800 MHz | | 90 | | | |
| | | V _{RF} = 200 mV _{peak-peak} , f = 2400 MHz | | 90 | | | |

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6 Application information

6.1 PCB layout recommendations

Particular attention must be paid to the layout of the PCB tracks connected to the amplifier, load, and power supply. The power and ground traces are critical as they must provide adequate energy and grounding for all circuits. The best practice is to use short and wide PCB traces to minimize voltage drops and parasitic inductance. In addition, to minimize parasitic impedance over the entire surface, a multi-via technique that connects the bottom and top layer ground planes together in many locations is often used. The copper traces that connect the output pins to the load and supply pins should be as wide as possible to minimize trace resistance.

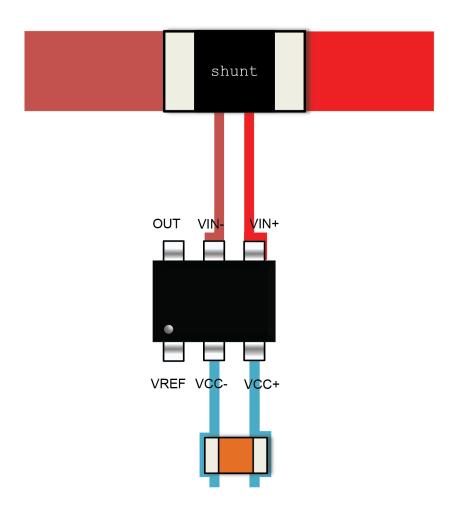


Figure 5. PCB traces

6.2 Decoupling capacitor

In order to ensure op amp full functionality, it is mandatory to place a decoupling capacitor of at least 22 nF as close as possible to the op amp supply pin. A good decoupling helps to reduce electromagnetic interference impact.

6.3 Macromodel

Accurate macromodels of the TSC1801 device are available on the STMicroelectronics' website at: www.st.com. These models are a trade-off between accuracy and complexity (that is, time simulation) of the TSC1801 operational amplifier. They emulate the nominal performance of a typical device within the specified operating conditions mentioned in the datasheet. They also help to validate a design approach and to select the right operational amplifier, but they do not replace on-board measurements.

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7 Package information

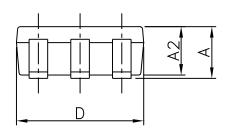
To meet environmental requirements, ST offers these devices in different grades of ECOPACK packages, depending on their level of environmental compliance. ECOPACK specifications, grade definitions, and product status are available at: www.st.com. ECOPACK is an ST trademark.

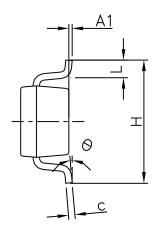
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7.1 SOT23-6 package information

Figure 6. SOT23-6 package outline





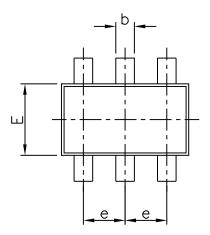


Table 6. SOT23-6 mechanical data

| | Dimensions | | | | | |
|------|-------------|------|------|--------|-------|-------|
| Ref. | Millimeters | | | Inches | | |
| | Min. | Тур. | Max. | Min. | Тур. | Max. |
| А | 0.90 | | 1.45 | 0.035 | | 0.057 |
| A1 | | | 0.10 | | | 0.004 |
| A2 | 0.90 | | 1.30 | 0.035 | | 0.051 |
| b | 0.35 | | 0.50 | 0.013 | | 0.019 |
| С | 0.09 | | 0.20 | 0.003 | | 0.008 |
| D | 2.80 | | 3.05 | 0.110 | | 0.120 |
| E | 1.50 | | 1.75 | 0.060 | | 0.069 |
| е | | 0.95 | | | 0.037 | |
| Н | 2.60 | | 3.00 | 0.102 | | 0.118 |
| L | 0.10 | | 0.60 | 0.004 | | 0.024 |
| θ | 0 ° | | 10 ° | 0 ° | | 10 ° |

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8 Ordering information

Table 7. Order codes

| Order code | Temperature range | Package | Marking |
|--------------|--|---------|---------|
| TSC1801BILT | -40 °C to 125 °C | SOT23-6 | K314 |
| TSC1801BIYLT | -40 °C to 125 °C automotive grade ⁽¹⁾ | SOT23-6 | K317 |

Qualified and characterized according to AEC-Q100 and Q003 or equivalent, advanced screening according to AEC Q001 and Q002 or equivalent. For qualification status details, click on the "Maturity Status Link" on the datasheet first page. On the product page in www.st.com, check "Quality and Reliability" tab.

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Revision history

Table 8. Document revision history

| Date | Revision | Changes |
|-------------|----------|------------------|
| 11-Dec-2024 | 1 | Initial release. |

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