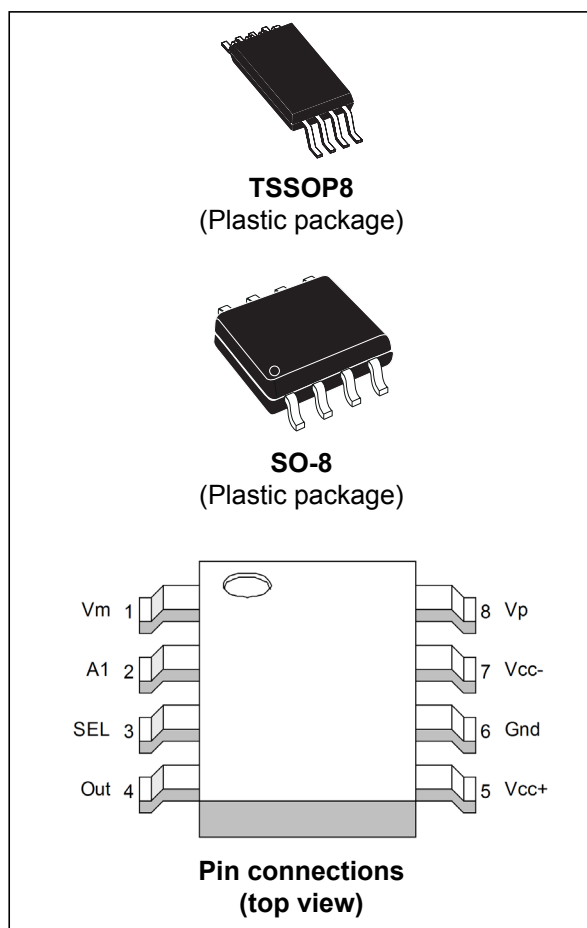


## High-voltage, high-side current sense amplifier

Datasheet - production data



### Features

- Independent supply and input common-mode voltages
- Wide common-mode operating range:  
2.9 to 70 V in single-supply configuration  
-2.1 to 65 V in dual-supply configuration
- Wide common-mode surviving range:  
-16 to 75 V (reversed battery and load-dump conditions)
- Supply voltage range:  
2.7 to 5.5 V in single supply configuration

- Low current consumption:  $I_{CC}$  max = 360  $\mu$ A
- Pin selectable gain: 50 V/V or 100 V/V
- Buffered output
- EMI filtering

### Applications

- Automotive current monitoring
- DC motor control
- Photovoltaic systems
- Battery chargers
- Precision current sources
- Current monitoring of notebook computers
- Uninterruptible power supplies
- High-end power supplies

### Description

The TSC1031 measures a small differential voltage on a high-side shunt resistor and translates it into a ground-referenced output voltage. The TSC1031's dedicated schematic eases the implementation of EMI filtering in harsh environments. The gain is adjustable to 50 V/V or 100 V/V by a selection pin.

Wide input common-mode voltage range, low quiescent current, and tiny TSSOP8 packaging enable use in a wide variety of applications.

The input common-mode and power supply voltages are independent. The common-mode voltage can range from 2.9 to 70 V in the single-supply configuration or be offset by an adjustable voltage supplied on the Vcc- pin in the dual-supply configuration.

With a current consumption lower than 360  $\mu$ A and a virtually null input leakage current in standby mode, the power consumption in the applications is minimized.

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# 1 Application schematic and pin description

The TSC1031 high-side current sense amplifier can be used in either single- or dual-supply mode. In the single-supply configuration, the TSC1031 features a wide 2.9 V to 70 V input common-mode range totally independent of the supply voltage. In the dual-supply range, the common-mode range is shifted by the value of the negative voltage applied on the  $V_{CC-}$  pin. For instance, with  $V_{CC+} = 5\text{ V}$  and  $V_{CC-} = -5\text{ V}$ , then the input common-mode range is -2.1 V to 65 V.

**Figure 1. Single-supply configuration schematic**

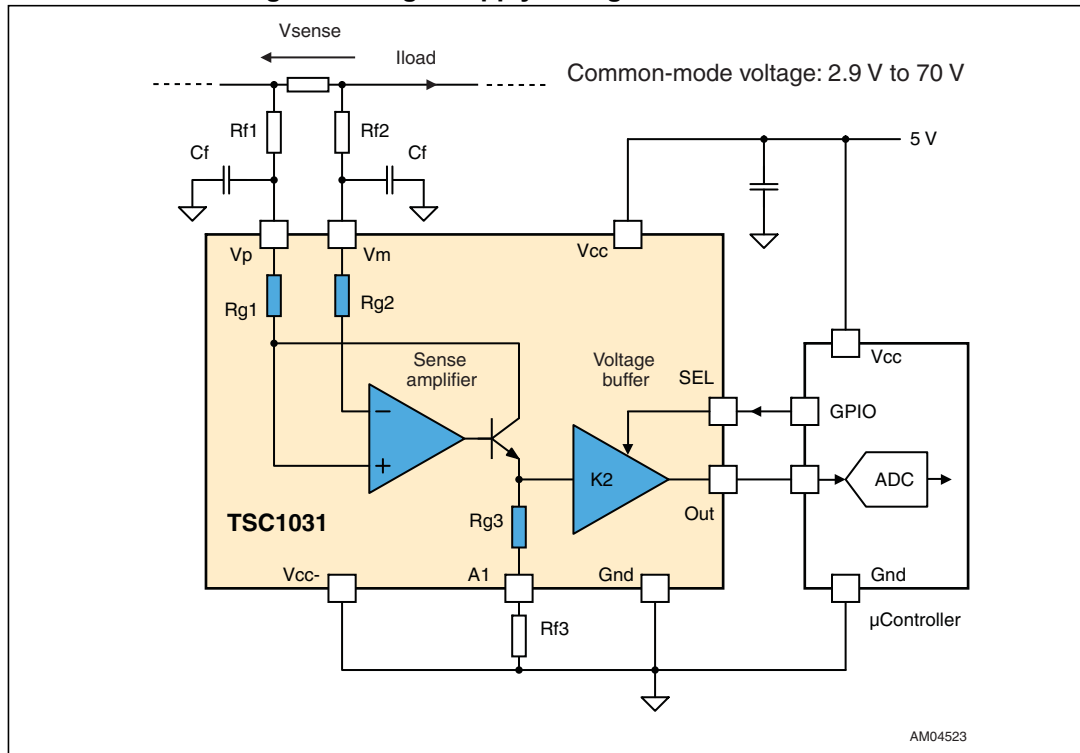
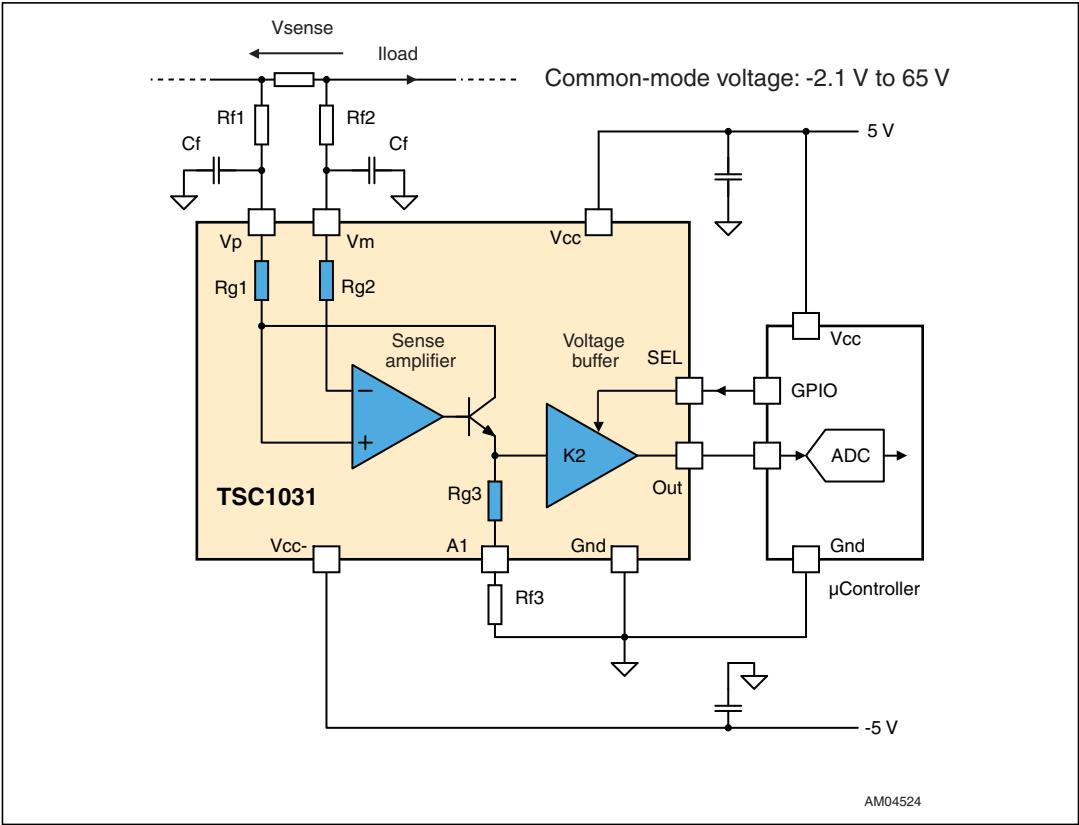
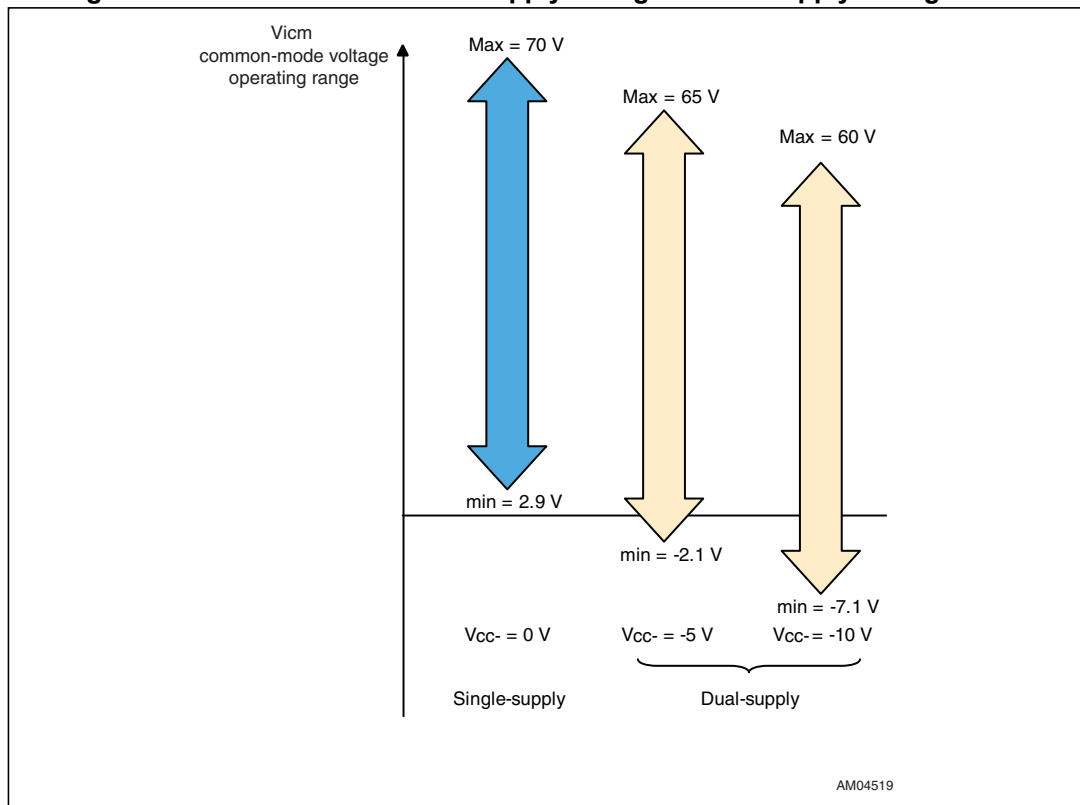


Figure 2. Dual-supply configuration schematic



**Figure 3. Common-mode versus supply voltage in dual-supply configuration**

[Table 1](#) describes the function of each pin. Their position is shown in the illustration on the cover page and in [Figure 1 on page 3](#).

**Table 1. Pin description**

| Symbol | Type          | Function                                                                                             |
|--------|---------------|------------------------------------------------------------------------------------------------------|
| Out    | Analog output | The Out voltage is proportional to the magnitude of the sense voltage $V_p - V_m$ .                  |
| Gnd    | Power supply  | Ground line.                                                                                         |
| Vcc+   | Power supply  | Positive power supply line.                                                                          |
| Vcc-   | Power supply  | Negative power supply line.                                                                          |
| Vp     | Analog input  | Connection for the external sense resistor. The measured current enters the shunt on the $V_p$ side. |
| Vm     | Analog input  | Connection for the external sense resistor. The measured current exits the shunt on the $V_m$ side.  |
| SEL    | Digital input | Gain-select pin.                                                                                     |
| A1     | Analog output | Connection to the output resistor.                                                                   |

## 2 Absolute maximum ratings and operating conditions

**Table 2. Absolute maximum ratings**

| Symbol              | Parameter                                                 | Value                   | Unit |
|---------------------|-----------------------------------------------------------|-------------------------|------|
| $V_{id}$            | Input pins differential voltage ( $V_p - V_m$ )           | $\pm 20$                | V    |
| $V_{in\_sense}$     | Sensing pins input voltages ( $V_p, V_m$ ) <sup>(1)</sup> | -16 to 75               | V    |
| $V_{in\_sel}$       | Gain selection pin input voltage (SEL) <sup>(2)</sup>     | -0.3 to $V_{CC+} + 0.3$ | V    |
| $V_{in\_A1}$        | A1 pin input voltage <sup>(2)</sup>                       | -0.3 to $V_{CC+} + 0.3$ | V    |
| $V_{CC+}$           | Positive supply voltage <sup>(2)</sup>                    | -0.3 to 7               | V    |
| $V_{CC+} - V_{CC-}$ | DC supply voltage                                         | 0 to 15                 | V    |
| $V_{out}$           | DC output pin voltage <sup>(2)</sup>                      | -0.3 to $V_{CC+} + 0.3$ | V    |
| $T_{stg}$           | Storage temperature                                       | -55 to 150              | °C   |
| $T_j$               | Maximum junction temperature                              | 150                     | °C   |
| $R_{thja}$          | TSSOP8 thermal resistance junction to ambient             | 120                     | °C/W |
|                     | SO-8 thermal resistance junction to ambient               | 125                     | °C/W |
| ESD                 | HBM: human body model <sup>(3)</sup>                      | 2.5                     | kV   |
|                     | MM: machine model <sup>(4)</sup>                          | 150                     | V    |
|                     | CDM: charged device model <sup>(5)</sup>                  | 1.5                     | kV   |

1. These voltage values are measured with respect to the  $V_{CC-}$  pin.
2. These voltage values are measured with respect to the Gnd pin.
3. Human body model: a 100 pF capacitor is charged to the specified voltage, then discharged through a 1.5 k $\Omega$  resistor between two pins of the device. This is done for all couples of connected pin combinations while the other pins are floating.
4. Machine model: a 200 pF capacitor is charged to the specified voltage, then discharged directly between two pins of the device with no external series resistor (internal resistor < 5  $\Omega$ ). This is done for all couples of connected pin combinations while the other pins are floating.
5. Charged device model: all pins plus package are charged together to the specified voltage and then discharged directly to ground.

**Table 3. Operating conditions**

| Symbol     | Parameter                                                                                                        | Value      | Unit |
|------------|------------------------------------------------------------------------------------------------------------------|------------|------|
| $V_{CC+}$  | DC supply voltage in single-supply configuration from $T_{min}$ to $T_{max}$ ( $V_{CC-}$ connected to Gnd = 0 V) | 2.7 to 5.5 | V    |
| $V_{CC-}$  | Negative supply voltage in dual-supply configuration from $T_{min}$ to $T_{max}$                                 |            |      |
|            | $V_{CC+} = 5.5$ V max                                                                                            | -8 to 0    | V    |
|            | $V_{CC+} = 3$ V max                                                                                              | -11 to 0   | V    |
| $V_{icm}$  | Common-mode voltage range referred to pin $V_{CC-}$ ( $T_{min}$ to $T_{max}$ )                                   | 2.9 to 70  | V    |
| $T_{oper}$ | Operational temperature range ( $T_{min}$ to $T_{max}$ )                                                         | -40 to 125 | °C   |

### 3 Electrical characteristics

The electrical characteristics given in the following tables are measured under the following test conditions unless otherwise specified.

- $T_{amb} = 25^{\circ}\text{C}$ ,  $V_{CC+} = 5\text{ V}$ ,  $V_{CC-}$  connected to Gnd (single-supply configuration).
- $V_{sense} = V_p - V_m = 50\text{ mV}$ ,  $V_m = 12\text{ V}$ , no load on Out, all gain configurations.
- Rf1, Rf2 and Rf3 resistors are short-circuited.

**Table 4. Supply**

| Symbol    | Parameter            | Test conditions                                                                   | Min. | Typ. | Max. | Unit          |
|-----------|----------------------|-----------------------------------------------------------------------------------|------|------|------|---------------|
| $I_{CC}$  | Total supply current | $V_{sense} = 0\text{ V}$ , $T_{min} < T_{amb} < T_{max}$                          |      | 200  | 360  | $\mu\text{A}$ |
| $I_{CC1}$ | Total supply current | $V_{sense} = 50\text{ mV}$ $A_v = 50\text{ V/V}$<br>$T_{min} < T_{amb} < T_{max}$ |      | 300  | 480  | $\mu\text{A}$ |

**Table 5. Input**

| Symbol       | Parameter                                                                                                                    | Test conditions                                                                                                              | Min. | Typ. | Max.                    | Unit                           |
|--------------|------------------------------------------------------------------------------------------------------------------------------|------------------------------------------------------------------------------------------------------------------------------|------|------|-------------------------|--------------------------------|
| DC CMR       | DC common-mode rejection<br>Variation of $V_{out}$ versus $V_{icm}$<br>referred to input <sup>(1)</sup>                      | $2.9\text{ V} < V_m < 70\text{ V}$ , $T_{min} < T_{amb} < T_{max}$                                                           | 90   | 105  |                         | dB                             |
| AC CMR       | AC common-mode rejection<br>Variation of $V_{out}$ versus $V_{icm}$<br>referred to input (peak-to-peak<br>voltage variation) | $A_v = 50\text{ V/V}$ or $100\text{ V/V}$<br>$2.9\text{ V} < V_{icm} < 30\text{ V}$ , $1\text{ kHz}$ sine wave               |      | 95   |                         | dB                             |
| SVR          | Supply voltage rejection<br>Variation of $V_{out}$ versus $V_{CC}$ <sup>(2)</sup>                                            | $A_v = 50\text{ V/V}$ , $2.7\text{ V} < V_{CC} < 5.5\text{ V}$<br>$V_{sense} = 30\text{ mV}$ , $T_{min} < T_{amb} < T_{max}$ | 85   | 100  |                         | dB                             |
| $V_{os}$     | Input offset voltage <sup>(3)</sup>                                                                                          | $T_{amb} = 25^{\circ}\text{C}$<br>$T_{min} < T_{amb} < T_{max}$                                                              |      |      | $\pm 500$<br>$\pm 1100$ | $\mu\text{V}$                  |
| $dV_{os}/dT$ | Input offset drift vs. T                                                                                                     | $A_v = 50\text{ V/V}$<br>$T_{min} < T_{amb} < T_{max}$                                                                       | -20  |      | +5                      | $\mu\text{V}/^{\circ}\text{C}$ |
| $I_{lk}$     | Input leakage current                                                                                                        | $V_{CC} = 0\text{ V}$<br>$T_{min} < T_{amb} < T_{max}$                                                                       |      |      | 1                       | $\mu\text{A}$                  |
| $I_{ib}$     | Input bias current                                                                                                           | $V_{sense} = 0\text{ V}$<br>$T_{min} < T_{amb} < T_{max}$                                                                    |      | 10   | 15                      | $\mu\text{A}$                  |
| Rg           | Input resistor value                                                                                                         | Valid for $R_{g1}$ and $R_{g2}$                                                                                              |      | 5    |                         | $\text{k}\Omega$               |
| $V_{IL}$     | Logic low voltage (SEL)                                                                                                      | $V_{CCmin} < V_{CC} < V_{CCmax}$<br>$T_{min} < T_{amb} < T_{max}$                                                            | -0.3 |      | 0.5                     | V                              |
| $V_{IH}$     | Logic high voltage (SEL)                                                                                                     | $V_{CCmin} < V_{CC} < V_{CCmax}$<br>$T_{min} < T_{amb} < T_{max}$                                                            | 1.2  |      | $V_{CC}$                | V                              |
| $I_{sel}$    | Gain-select pins (SEL)<br>leakage input current                                                                              | SEL pin connected to GND or $V_{CC}$<br>$T_{min} < T_{amb} < T_{max}$                                                        |      | 400  |                         | nA                             |

1. See [Chapter 5: Parameter definitions on page 13](#) for the definition of CMR.

2. See [Chapter 5](#) for the definition of SVR.

3. See [Chapter 5](#) for the definition of  $V_{os}$ .

Table 6. Output

| Symbol                          | Parameter                                                                 | Test conditions                                                                                             | Min. | Typ.      | Max.       | Unit   |
|---------------------------------|---------------------------------------------------------------------------|-------------------------------------------------------------------------------------------------------------|------|-----------|------------|--------|
| K1                              | Sense amplifier gain<br>( $K1 = R_{g3}/R_{g1}$ )                          |                                                                                                             |      | 10        |            |        |
| K2                              | Current multiplier gain                                                   | SEL= Gnd<br>SEL= Vcc+                                                                                       |      | 2.5<br>5  |            |        |
| Av                              | Total gain ( $Av = 2.K1.K2$ )                                             | SEL= Gnd<br>SEL= Vcc+                                                                                       |      | 50<br>100 |            | V/V    |
| $\Delta V_{out}/\Delta T$       | Output voltage drift vs. T <sup>(1)</sup>                                 | Av = 50 V/V<br>$T_{min} < T_{amb} < T_{max}$                                                                |      |           | ±240       | ppm/°C |
| $\Delta V_{out}/\Delta I_{out}$ | Output stage load regulation                                              | -10 mA < $I_{out}$ < 10 mA<br>$I_{out}$ sink or source current<br>Av = 50 V/V, $T_{amb} = 25^\circ\text{C}$ |      | 0.3       | ±1.5       | mV/mA  |
| $\Delta V_{out}$                | Total output voltage accuracy <sup>(2)</sup>                              | $V_{sense} = 50\text{ mV}^{(3)}$ $T_{amb} = 25^\circ\text{C}$<br>$T_{min} < T_{amb} < T_{max}$              |      |           | ±2.5<br>±4 | %      |
| $\Delta V_{out}$                | Total output voltage accuracy                                             | $V_{sense} = 90\text{ mV}^{(3)}$ $T_{amb} = 25^\circ\text{C}$<br>$T_{min} < T_{amb} < T_{max}$              |      |           | ±3.5<br>±5 | %      |
| $\Delta V_{out}$                | Total output voltage accuracy                                             | $V_{sense} = 20\text{ mV}$ $T_{amb} = 25^\circ\text{C}$<br>$T_{min} < T_{amb} < T_{max}$                    |      |           | ±3.5<br>±5 | %      |
| $\Delta V_{out}$                | Total output voltage accuracy                                             | $V_{sense} = 10\text{ mV}$ $T_{amb} = 25^\circ\text{C}$<br>$T_{min} < T_{amb} < T_{max}$                    |      |           | ±5.5<br>±8 | %      |
| $\Delta V_{out}$                | Total output voltage accuracy                                             | $V_{sense} = 5\text{ mV}$ $T_{amb} = 25^\circ\text{C}$<br>$T_{min} < T_{amb} < T_{max}$                     |      |           | ±10<br>±22 | %      |
| $I_{sc}$                        | Short-circuit current                                                     | OUT connected to V <sub>CC</sub> or GND                                                                     | 15   | 26        |            | mA     |
| V <sub>OH</sub>                 | Output stage high-state saturation voltage<br>$V_{OH} = V_{CC} - V_{out}$ | $V_{sense} = 1\text{ V}$<br>$I_{out} = 1\text{ mA}$                                                         |      | 85        | 135        | mV     |
| V <sub>OL</sub>                 | Output stage low-state saturation voltage                                 | $V_{sense} = -1\text{ V}$<br>$I_{out} = 1\text{ mA}$                                                        |      | 80        | 125        | mV     |

1. See [Chapter 5: Parameter definitions on page 13](#) for the definition of output voltage drift versus temperature.
2. The output voltage accuracy is the difference with the expected theoretical output voltage  $V_{out-th} = Av \cdot V_{sense}$ . See [Chapter 5](#) for a more detailed definition.
3. Except for Av = 100 V/V.

Table 7. Frequency response

| Symbol           | Parameter                                                                       | Test conditions                                                                                                                   | Min. | Typ. | Max. | Unit             |
|------------------|---------------------------------------------------------------------------------|-----------------------------------------------------------------------------------------------------------------------------------|------|------|------|------------------|
| ts               | Output settling to 1% of final value                                            | $V_{\text{sense}} = 10 \text{ mV to } 100 \text{ mV}$ ,<br>$C_{\text{load}} = 47 \text{ pF}$                                      |      |      |      |                  |
|                  |                                                                                 | $A_v = 50 \text{ V/V}$                                                                                                            |      | 6    |      | $\mu\text{s}$    |
|                  |                                                                                 | $A_v = 100 \text{ V/V}$                                                                                                           |      | 10   |      | $\mu\text{s}$    |
| t <sub>SEL</sub> | Output settling to 1% of final value                                            | Any change of state of SEL                                                                                                        |      | 1    |      | $\mu\text{s}$    |
| t <sub>rec</sub> | Response to common-mode voltage change.<br>Output settling to 1% of final value | $V_{\text{CC}+} = 5 \text{ V}$ , $V_{\text{CC}-} = -5 \text{ V}$<br>$V_m$ step change from -2 V to 30 V or 30 V to -2 V           |      | 20   |      | $\mu\text{s}$    |
| SR               | Slew rate                                                                       | $V_{\text{sense}} = 10 \text{ mV to } 100 \text{ mV}$                                                                             | 0.4  | 0.6  |      | V/ $\mu\text{s}$ |
| BW               | 3 dB bandwidth                                                                  | $C_{\text{load}} = 47 \text{ pF}$ $V_{\text{icm}} = 12 \text{ V}$<br>$V_{\text{sense}} = 50 \text{ mV}$<br>$A_v = 50 \text{ V/V}$ |      | 700  |      | kHz              |

Table 8. Noise

| Symbol | Parameter                      | Test conditions     | Min. | Typ. | Max. | Unit                         |
|--------|--------------------------------|---------------------|------|------|------|------------------------------|
| eN     | Equivalent input noise voltage | $f = 1 \text{ kHz}$ |      | 40   |      | $\text{nV}/\sqrt{\text{Hz}}$ |

## 4 Electrical characteristics curves: current sense amplifier

Unless otherwise specified, the test conditions for the following curves are:

- $T_{amb} = 25^{\circ}\text{C}$ ,  $V_{CC} = 5\text{ V}$ ,  $V_{sense} = V_p - V_m = 50\text{ mV}$ ,  $V_m = 12\text{ V}$ .
- No load on Out pin.

Figure 4. Output voltage vs.  $V_{sense}$

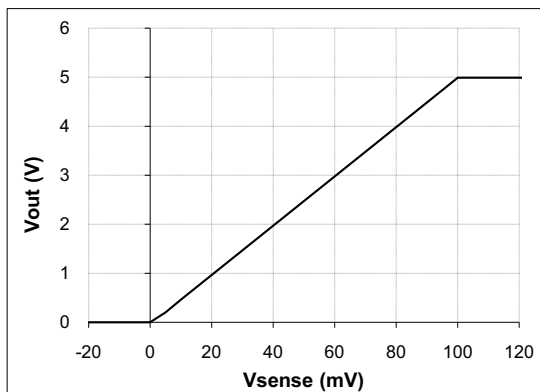


Figure 5. Output voltage accuracy vs.  $V_{sense}$

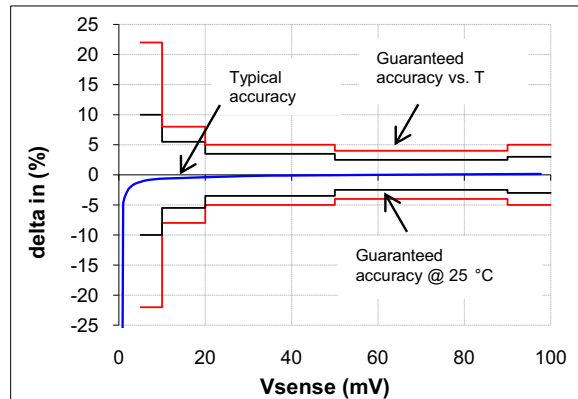


Figure 6. Supply current vs. supply voltage

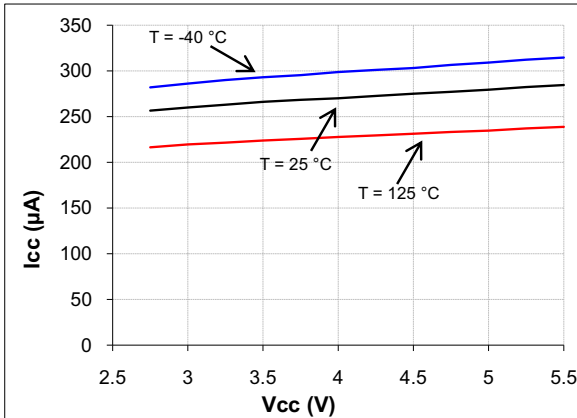


Figure 7. Supply current vs.  $V_{sense}$

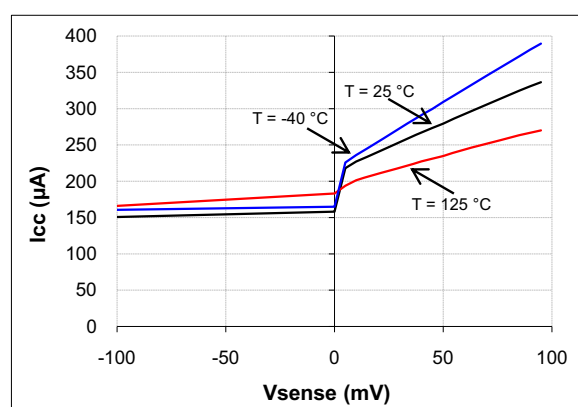


Figure 8. Vp pin input current vs. Vsense

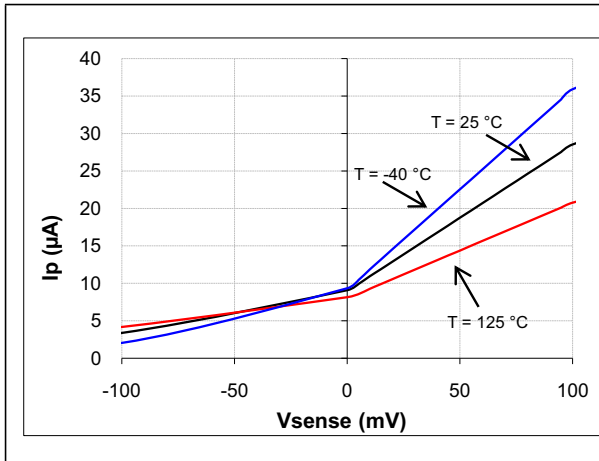


Figure 9. Vn pin input current vs. Vsense

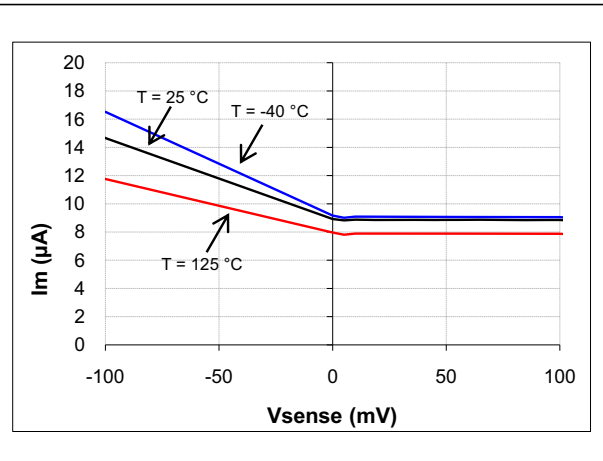


Figure 10. Output stage low-state saturation voltage vs. output current (Vsense = -1 V)

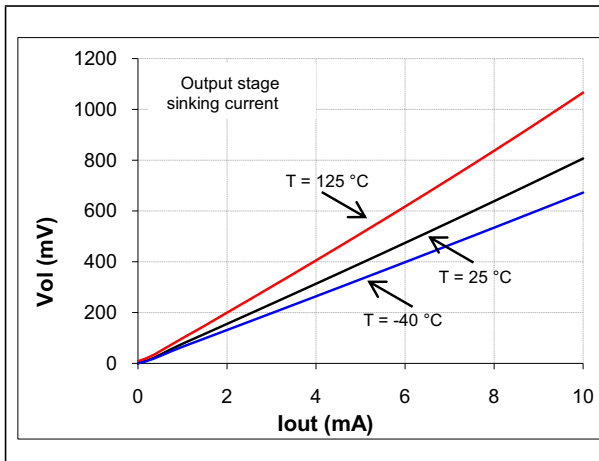


Figure 11. Output stage high-state saturation voltage vs. output current (Vsense = +1 V)

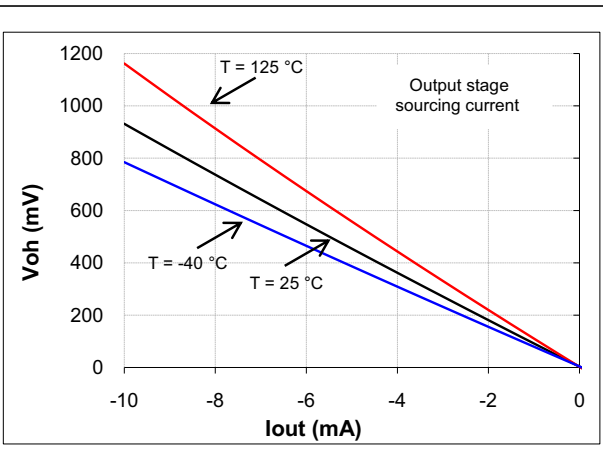


Figure 12. Output stage load regulation

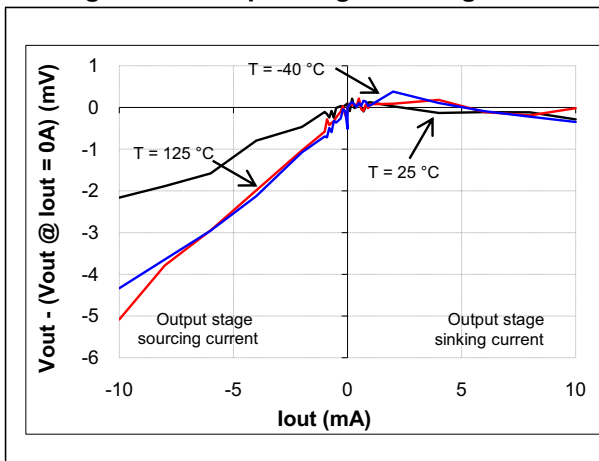


Figure 13. Step response

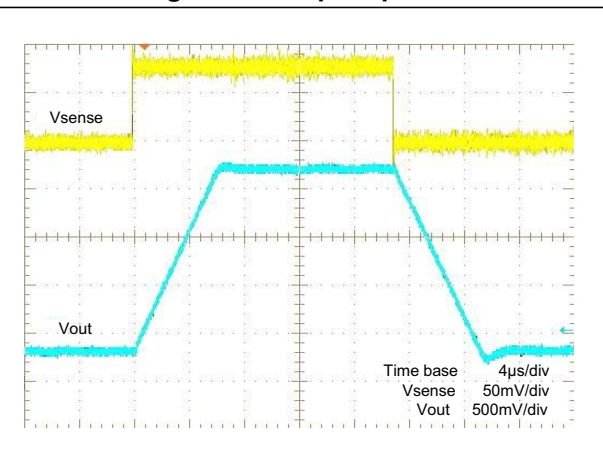


Figure 14. Bode diagram

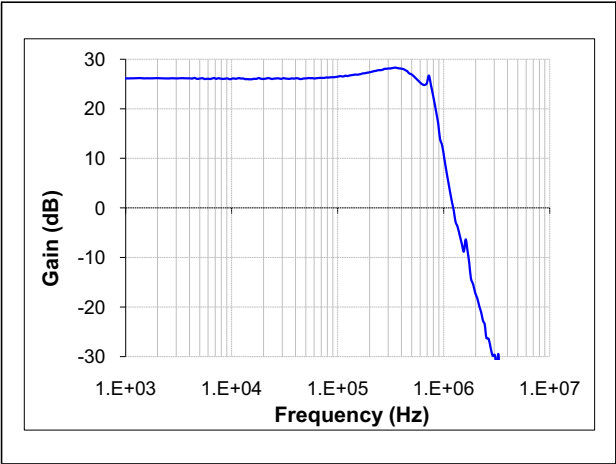


Figure 15. Power supply rejection ratio

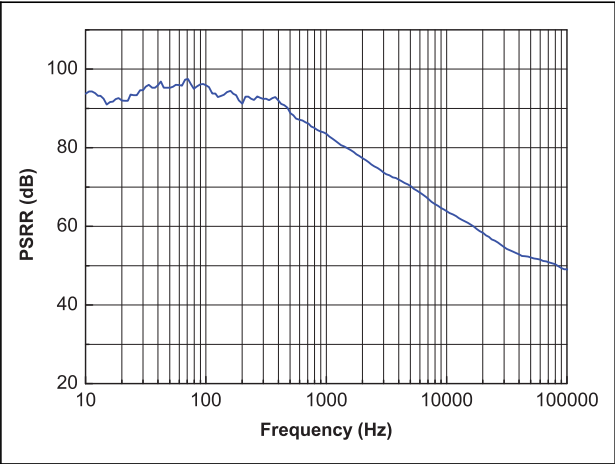
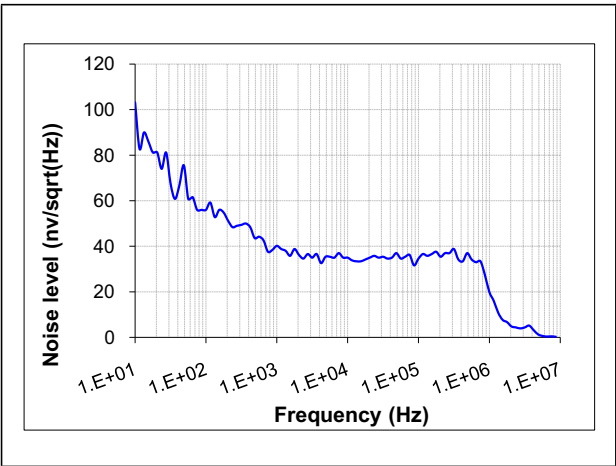


Figure 16. Noise level



## 5 Parameter definitions

### 5.1 Common mode rejection ratio (CMR)

The common mode rejection ratio (CMR) measures the ability of the current sensing amplifier to reject any DC voltage applied on both inputs  $V_p$  and  $V_m$ . The CMR is referred back to the input so that its effect can be compared with the applied differential signal. The CMR is defined by the formula:

$$\text{CMR} = -20 \cdot \log \frac{\Delta V_{\text{out}}}{\Delta V_{\text{icm}} \cdot A_v}$$

### 5.2 Supply voltage rejection ratio (SVR)

The supply voltage rejection ratio (SVR) measures the ability of the current-sensing amplifier to reject any variation of the supply voltage  $V_{CC}$ . The SVR is referred back to the input so that its effect can be compared with the applied differential signal. The SVR is defined by the formula:

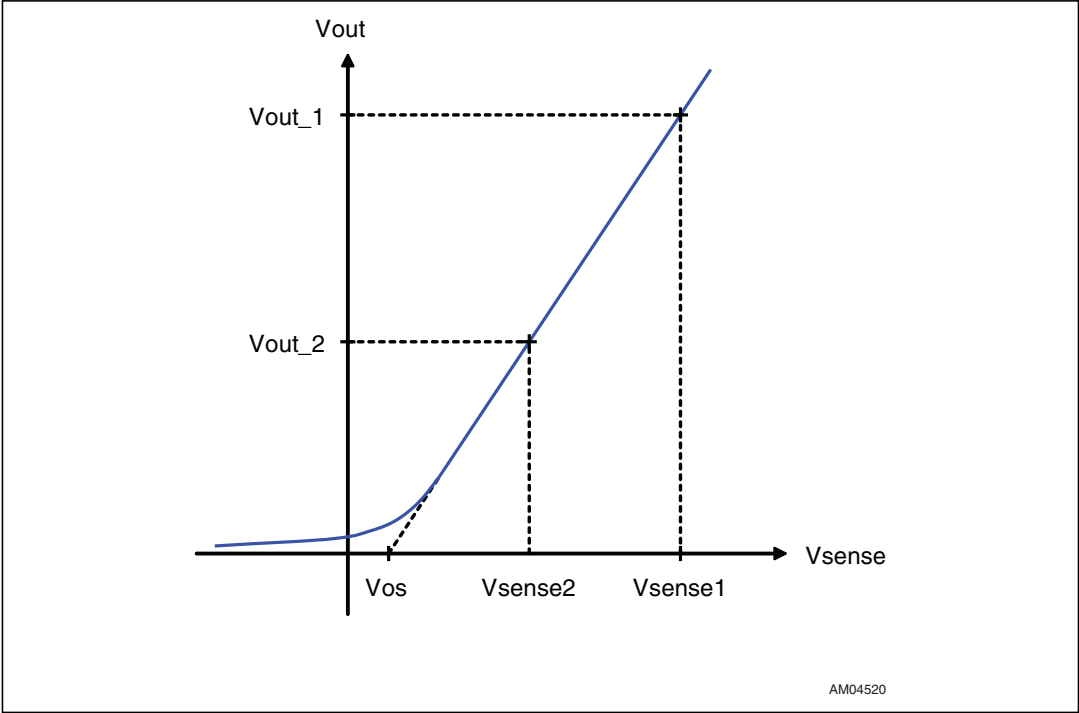
$$\text{SVR} = -20 \cdot \log \frac{\Delta V_{\text{out}}}{\Delta V_{CC} \cdot A_v}$$

### 5.3 Gain ( $A_v$ ) and input offset voltage ( $V_{os}$ )

The input offset voltage is defined as the intersection between the linear regression of the  $V_{\text{out}}$  vs.  $V_{\text{sense}}$  curve with the X-axis (see [Figure 17.](#)). If  $V_{\text{out1}}$  is the output voltage with  $V_{\text{sense}} = V_{\text{sense1}}$  and  $V_{\text{out2}}$  is the output voltage with  $V_{\text{sense}} = V_{\text{sense2}}$ , then  $V_{os}$  can be calculated with the following formula.

$$V_{os} = V_{\text{sense1}} - \left( \frac{V_{\text{sense1}} - V_{\text{sense2}}}{V_{\text{out1}} - V_{\text{out2}}} \cdot V_{\text{out1}} \right)$$

Figure 17.  $V_{out}$  versus  $V_{sense}$  characteristics: detail for low  $V_{sense}$  values



The values of  $V_{sense1}$  and  $V_{sense2}$  used for the input offset calculations are detailed in [Table 9](#).

Table 9. Test conditions for  $V_{os}$  voltage calculation

| $A_v$ (V/V) | $V_{sense1}$ (mV) | $V_{sense2}$ (mV) |
|-------------|-------------------|-------------------|
| 50          | 50                | 5                 |
| 100         | 40                | 5                 |

## 5.4 Output voltage drift versus temperature

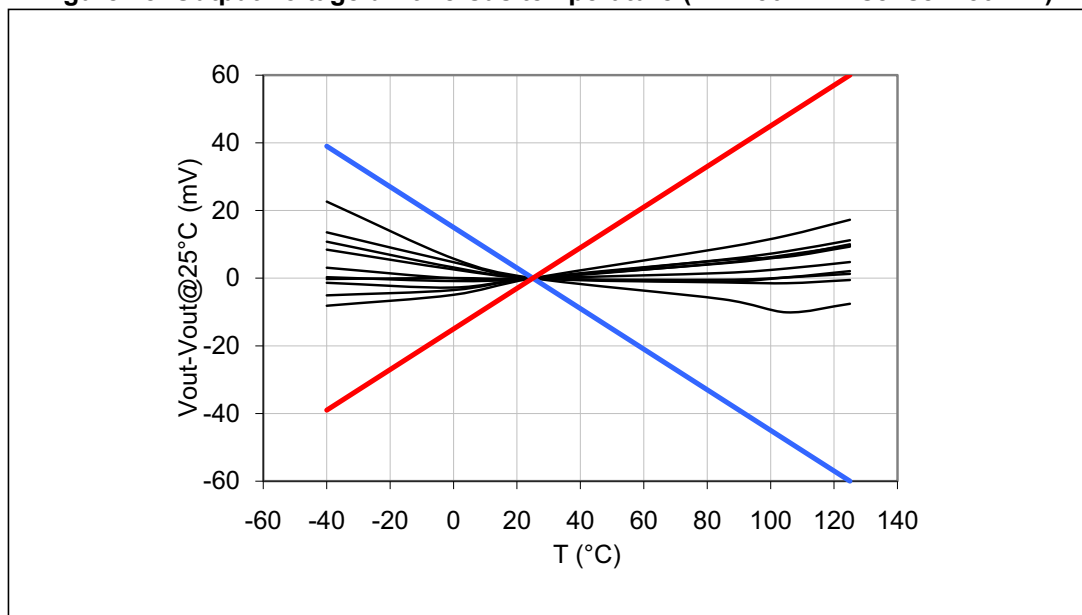
The output voltage drift versus temperature is defined as the maximum variation of  $V_{out}$  with respect to its value at 25° C over the temperature range. It is calculated as follows:

$$\frac{\Delta V_{out}}{\Delta T} = \max \frac{V_{out}(T_{amb}) - V_{out}(25^{\circ}\text{C})}{T_{amb} - 25^{\circ}\text{C}}$$

with  $T_{min} < T_{amb} < T_{max}$ .

*Figure 18* provides a graphical definition of the output voltage drift versus temperature. On this chart  $V_{out}$  is always within the area defined by the maximum and minimum variation of  $V_{out}$  versus  $T$ , and  $T = 25^{\circ}\text{C}$  is considered to be the reference.

**Figure 18. Output voltage drift versus temperature ( $A_v = 50\text{ V/V}$   $V_{sense} = 50\text{ mV}$ )**



## 5.5 Input offset drift versus temperature

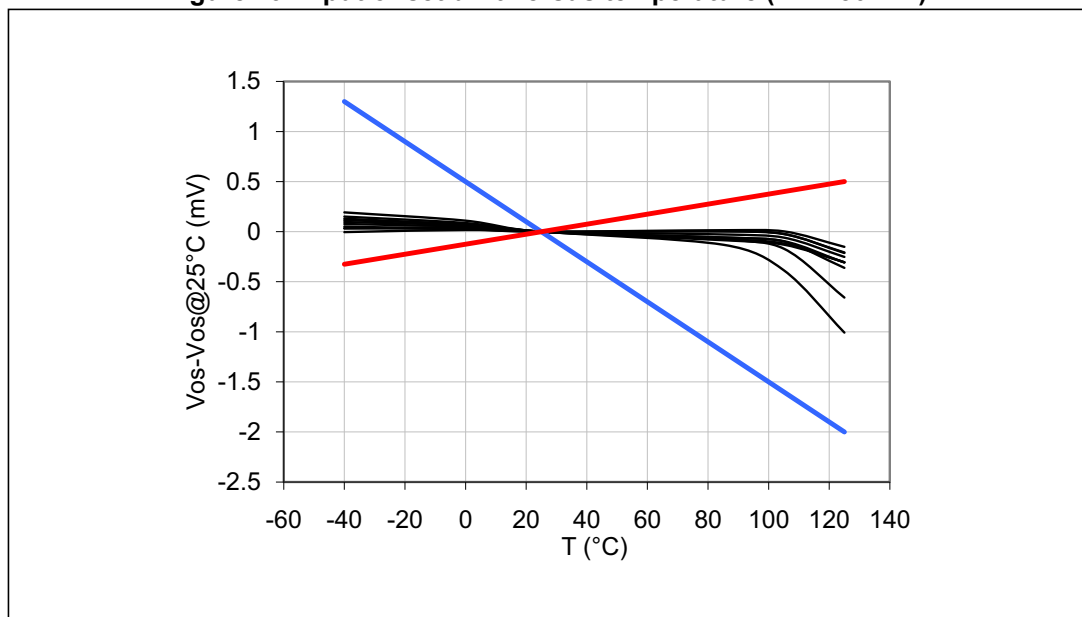
The input voltage drift versus temperature is defined as the maximum variation of  $V_{os}$  with respect to its value at 25° C over the temperature range. It is calculated as follows:

$$\frac{\Delta V_{os}}{\Delta T} = \max \frac{V_{os}(T_{amb}) - V_{os}(25^{\circ}\text{C})}{T_{amb} - 25^{\circ}\text{C}}$$

with  $T_{min} < T_{amb} < T_{max}$ .

*Figure 19.* provides a graphical definition of the input offset drift versus temperature. On this chart  $V_{os}$  is always comprised in the area defined by the maximum and minimum variation of  $V_{os}$  versus  $T$ , and  $T = 25^{\circ}\text{C}$  is considered to be the reference.

**Figure 19. Input offset drift versus temperature ( $A_v = 50\text{ V/V}$ )**



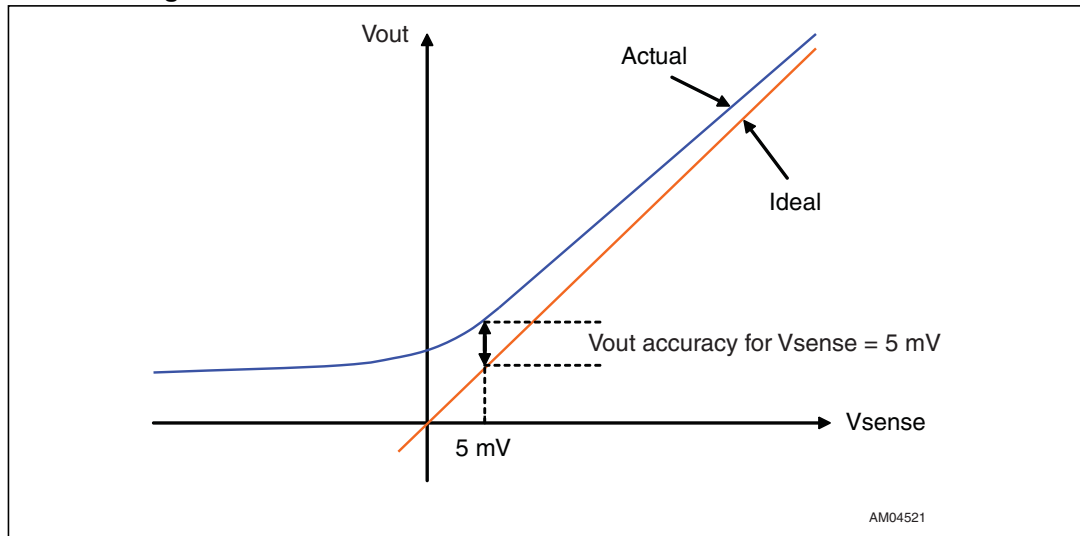
## 5.6 Output voltage accuracy

The output voltage accuracy is the difference between the actual output voltage and the theoretical output voltage. Ideally, the current sensing output voltage should be equal to the input differential voltage multiplied by the theoretical gain, as in the following formula.

$$V_{out-th} = A_v \cdot V_{sense}$$

The actual value is very slightly different, mainly due to the effects of:

- the input offset voltage  $V_{os}$ ,
- the non-linearity.

**Figure 20. Vout vs. Vsense theoretical and actual characteristics**

The output voltage accuracy, expressed as a percentage, can be calculated with the following formula,

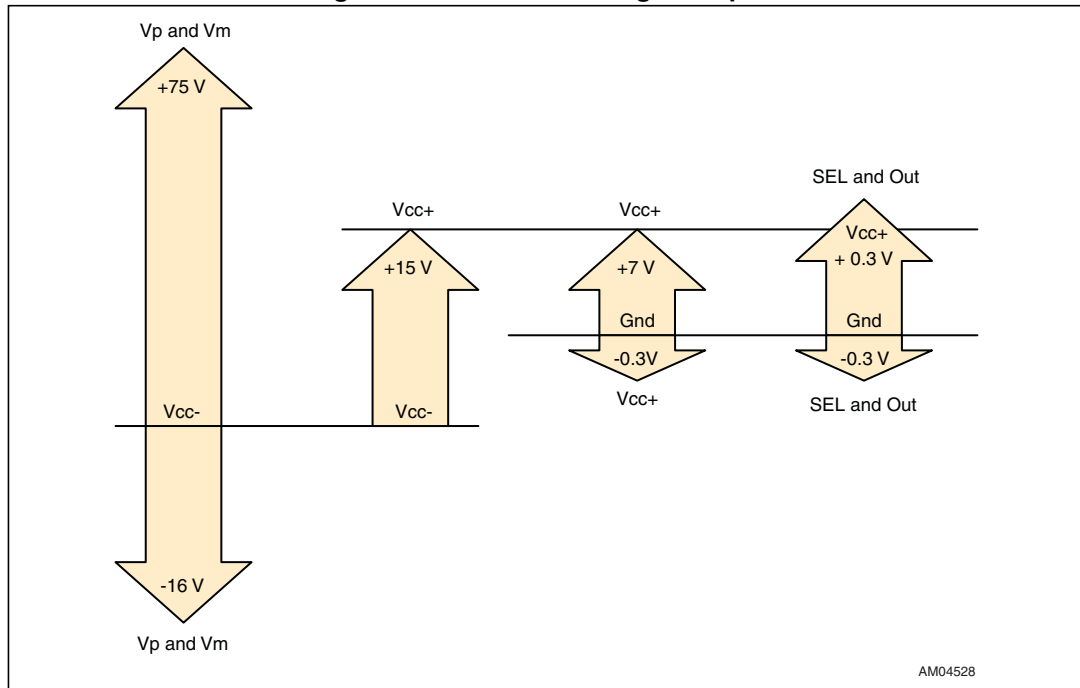
$$\Delta V_{\text{out}} = \frac{\text{abs}(V_{\text{out}} - (A_v \cdot V_{\text{sense}}))}{A_v \cdot V_{\text{sense}}}$$

with 50 V/V or 100 V/V depending on the configuration of the SEL pin.

## 6 Maximum permissible voltages on pins

The TSC1031 can be used in either single or dual supply configuration. The dual-supply configuration is achieved by disconnecting  $V_{CC-}$  and Gnd, and connecting  $V_{CC-}$  to a negative supply. [Figure 21](#) illustrates how the absolute maximum voltages on input pins  $V_p$  and  $V_m$  are referred to the  $V_{CC-}$  potential, while the maximum voltages on the positive supply pin, gain selection pins and output pins are referred to the Gnd pin. It should also be noted that the maximum voltage between  $V_{CC-}$  and  $V_{CC+}$  is limited to 15 V.

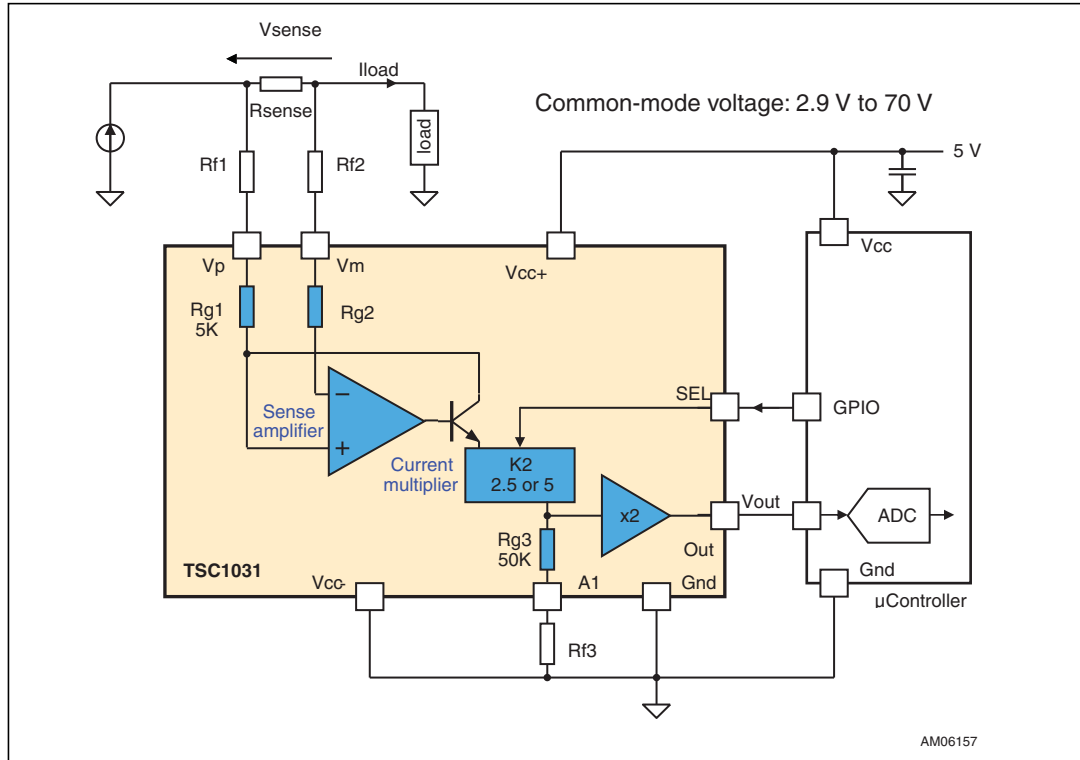
**Figure 21. Maximum voltages on pins**



## 7 Application information

The TSC1031 can be used to measure current and to feed back the information to a microcontroller.

**Figure 22. Typical application**



The current from the supply flows to the load through the  $R_{sense}$  resistor causing a voltage drop equal to  $V_{sense}$  across  $R_{sense}$ . The amplifier's input currents are negligible, therefore its inverting input voltage is equal to  $V_m$ . The amplifier's open-loop gain forces its non-inverting input to the same voltage as the inverting input. As a consequence, the amplifier adjusts current flowing through  $R_{g1}$  so that the voltage drop across  $R_{g1}$  exactly matches  $V_{sense}$ .

Therefore, the drop across  $R_{g1}$  is:

$$V_{Rg1} = V_{sense} = R_{sense} \cdot I_{load}$$

If  $I_{Rg1}$  is the current flowing through  $R_{g1}$ , then  $I_{Rg1}$  is given by the formula:

$$I_{Rg1} = V_{sense} / R_{g1}$$

The  $I_{Rg1}$  current flows is multiplied by a ratio  $K2$  and the resulting current flows into resistor  $R_{g3}$ . Therefore, the voltage drop on the  $R_{g3}$  resistor can be calculated as follows.

$$V_{Rg3} = R_{g3} \cdot K2 \cdot I_{Rg1} = (R_{g3} / R_{g1}) \cdot K2 \cdot V_{sense} = K1 \cdot K2 \cdot V_{sense} \text{ with } K1 = R_{g3} / R_{g1} = 10.$$

The voltage across the  $R_{g3}$  resistor is buffered to the Out pin by the voltage buffer, featuring a gain equal to 2. Therefore  $V_{out}$  can be expressed as:

$$V_{out} = 2 \cdot K1 \cdot K2 \cdot V_{sense} = A_v \cdot V_{sense} \text{ with } A_v = 2 \cdot K1 \cdot K2$$

$$\text{or: } V_{out} = A_v \cdot R_{sense} \cdot I_{load}$$

The current multiplier gain K2 can be set to 2.5 or 5 depending on the voltage applied on the SEL pin.

Since they define the full-scale output range of the application, the  $R_{\text{sense}}$  resistor and the amplification gain  $A_v$  are important parameters and must therefore be selected carefully.

The TSC1031's dedicated schematic eases the implementation of EMI filtering in harsh environments. A simple filter is described in [Figure 22](#), where the input filtering is performed by  $R_{f1}$ ,  $R_{f2}$  and  $C_f$ . For more details concerning input filtering, please refer to application note AN4304 "How to filter the input of a high-side current sensing".

The values of  $R_{f1}$  and  $R_{f2}$  should be equal so as to balance the contribution on both amplifier inputs. The value of the  $C_f$  capacitor should be selected so that the cut-off frequency of the first-order low-pass filter provides enough attenuation to the high frequency interferences.

To balance the contribution of  $R_{f1}$  and  $R_{f2}$  in the current sense amplifier gain, an output resistor  $R_{f3}$  should be connected between pin A1 and Gnd. The value of  $R_{f3}$  should be chosen according to the following formula.

$$K1 = 10 = R_{g3}/R_{g1} = R_{f3}/R_{f1} = R_{f3}/R_{f2}$$

Please refer to application note AN4369 "Adjustable gain with a current sensing" for details concerning the influence of additional resistances.

## 8 Package information

In order to meet environmental requirements, ST offers these devices in different grades of ECOPACK<sup>®</sup> packages, depending on their level of environmental compliance. ECOPACK<sup>®</sup> specifications, grade definitions and product status are available at: [www.st.com](http://www.st.com). ECOPACK<sup>®</sup> is an ST trademark.

## 8.1 SO-8 package information

Figure 23. SO-8 package mechanical drawing

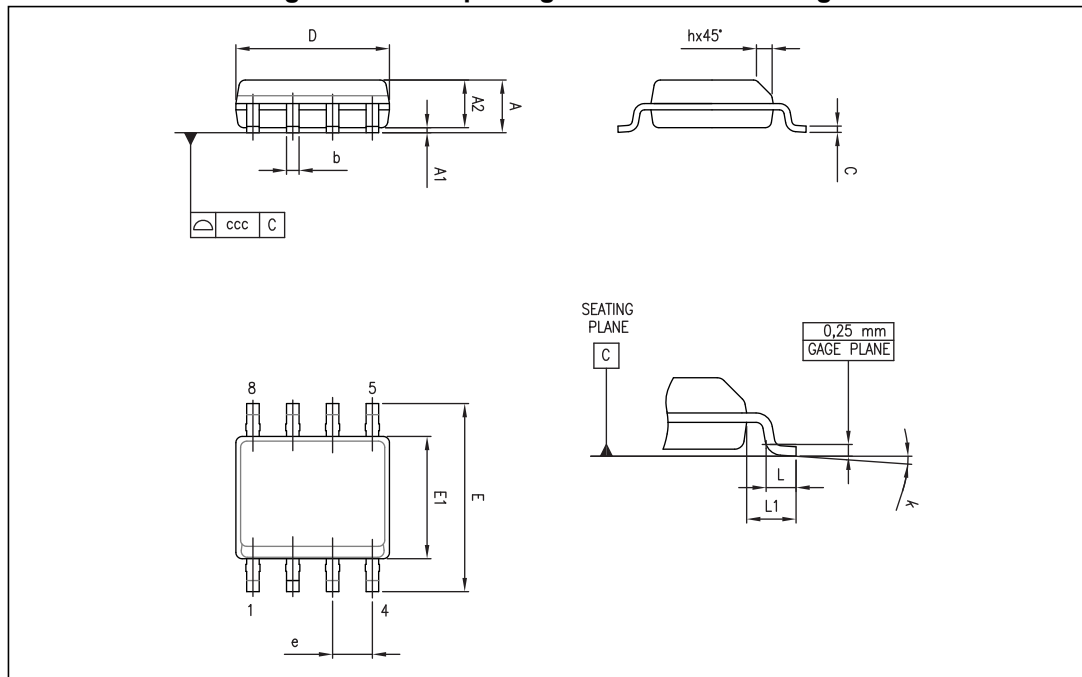


Table 10. SO-8 package mechanical data

| Ref. | Dimensions  |      |      |        |       |       |
|------|-------------|------|------|--------|-------|-------|
|      | Millimeters |      |      | Inches |       |       |
|      | Min.        | Typ. | Max. | Min.   | Typ.  | Max.  |
| A    |             |      | 1.75 |        |       | 0.069 |
| A1   | 0.10        |      | 0.25 | 0.004  |       | 0.010 |
| A2   | 1.25        |      |      | 0.049  |       |       |
| b    | 0.28        |      | 0.48 | 0.011  |       | 0.019 |
| c    | 0.17        |      | 0.23 | 0.007  |       | 0.010 |
| D    | 4.80        | 4.90 | 5.00 | 0.189  | 0.193 | 0.197 |
| E    | 5.80        | 6.00 | 6.20 | 0.228  | 0.236 | 0.244 |
| E1   | 3.80        | 3.90 | 4.00 | 0.150  | 0.154 | 0.157 |
| e    |             | 1.27 |      |        | 0.050 |       |
| h    | 0.25        |      | 0.50 | 0.010  |       | 0.020 |
| L    | 0.40        |      | 1.27 | 0.016  |       | 0.050 |
| L1   |             | 1.04 |      |        | 0.040 |       |
| k    | 0           |      | 8°   | 1°     |       | 8°    |
| ccc  |             |      | 0.10 |        |       | 0.004 |

## 8.2 TSSOP-8 package information

Figure 24. TSSOP8 package mechanical drawing

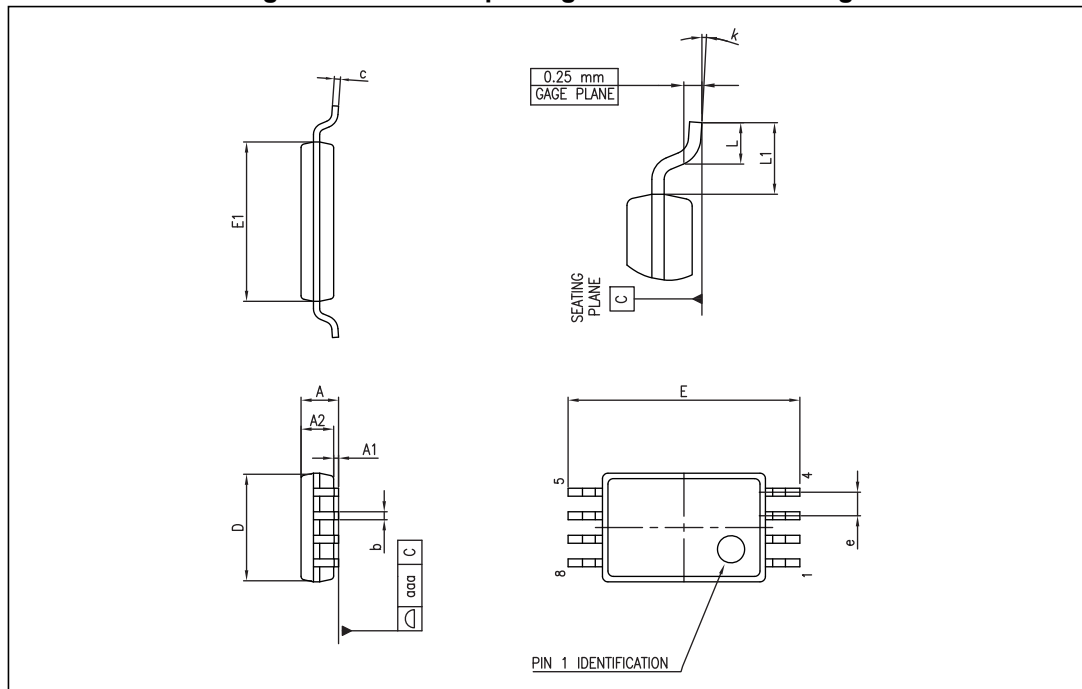


Table 11. TSSOP8 package mechanical data

| Ref. | Dimensions  |      |      |        |        |       |
|------|-------------|------|------|--------|--------|-------|
|      | Millimeters |      |      | Inches |        |       |
|      | Min.        | Typ. | Max. | Min.   | Typ.   | Max.  |
| A    |             |      | 1.20 |        |        | 0.047 |
| A1   | 0.05        |      | 0.15 | 0.002  |        | 0.006 |
| A2   | 0.80        | 1.00 | 1.05 | 0.031  | 0.039  | 0.041 |
| b    | 0.19        |      | 0.30 | 0.007  |        | 0.012 |
| c    | 0.09        |      | 0.20 | 0.004  |        | 0.008 |
| D    | 2.90        | 3.00 | 3.10 | 0.114  | 0.118  | 0.122 |
| E    | 6.20        | 6.40 | 6.60 | 0.244  | 0.252  | 0.260 |
| E1   | 4.30        | 4.40 | 4.50 | 0.169  | 0.173  | 0.177 |
| e    |             | 0.65 |      |        | 0.0256 |       |
| k    | 0°          |      | 8°   | 0°     |        | 8°    |
| L    | 0.45        | 0.60 | 0.75 | 0.018  | 0.024  | 0.030 |
| L1   |             | 1    |      |        | 0.039  |       |
| aaa  |             |      | 0.10 |        |        | 0.004 |

## 9 Ordering information

Table 12. Order codes

| Part number | Temperature range                 | Package               | Packaging   | Marking  |
|-------------|-----------------------------------|-----------------------|-------------|----------|
| TSC1031IPT  | -40°C, +125°C                     | TSSOP8                | Tape & reel | 1031I    |
| TSC1031IDT  |                                   | SO-8                  | Tape & reel | TSC1031I |
| TSC1031IYPT | -40°C, +125°C<br>Automotive grade | TSSOP8 <sup>(1)</sup> | Tape & reel | 1031Y    |
| TSC1031IYDT |                                   | SO-8 <sup>(1)</sup>   | Tape & reel | TSC1031Y |

1. Qualification and characterization according to AEC Q100 and Q003 or equivalent, advanced screening according to AEC Q001 & Q002 or equivalent.

## 10 Revision history

**Table 13. Document revision history**

| Date        | Revision | Changes                                                                                                                                                                                                                                                                              |
|-------------|----------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| 04-Jan-2010 | 1        | Initial release.                                                                                                                                                                                                                                                                     |
| 29-Apr-2011 | 2        | Added <i>Chapter 4: Electrical characteristics curves: current sense amplifier</i> .<br>Changed <i>Figure 4</i> to <i>Figure 16</i> .<br>Modified <i>Figure 22: Typical application</i> .<br>Added automotive grade qualification for SO-8 package in <i>Table 12: Order codes</i> . |
| 12-Mar-2014 | 3        | Updated footnote <i>1</i> of <i>Table 12: Order codes</i> .<br>Updated <i>Figure 15: Power supply rejection ratio</i> .<br>Added references to complementary application notes in <i>Section 7: Application information</i> .                                                        |

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