

## Features

- VOLTAGE OFFSET: **±100uV (MAX)**
- WIDE COMMON MODE VOLTAGE: **-0.3V to +36V**
- SUPPLY VOLTAGE: **2.7V to +30V**
- ACCURACY and ZERO-DRIFT PERFORMANCE
  - ◆ **±1% Gain Error (Max over temperature)**
  - ◆ **0.5μV/°C Offset Drift (Max)**
  - ◆ **10ppm/°C Gain Drift (Max)**
- THREE GAIN OPTIONS for VOLTAGE OUTPUT
  - ◆ TP181A1: 50V/V
  - ◆ TP181A2: 100V/V
  - ◆ TP181A3: 200V/V
- LOW SUPPLY CURRENT: 120uA (TYP)
- **Rail-to-Rail Output**
- PACKAGE: SC70-6
- Industrial -40°C to 125°C Operation Range
- ESD Rating: Robust 3KV – HBM, 2KV – CDM
- Higher performance Drop-In Compatible With INA213, INA214, INA199, NCS199 Products

## Applications

- CURRENT SENSING (High-Side/Low-Side)
- BATTERY CHARGERS
- POWER MANAGEMENT
- CELL PHONE CHARGER
- ELECTRICAL CIGARATE
- WIRELESS CHARGER
- TELECOM EQUIPMENT

## Description

The TP181 series of zero-drift, bi-directional current sense amplifier can sense voltage drops across shunts at common-mode voltages from -0.3V to 36V, independent of the supply voltage. Three fixed gains are available: 50V/V, 100V/V and 200V/V. The low offset of the zero-drift architecture enables current sensing with maximum drops across the shunt as low as **10mV** full-scale.

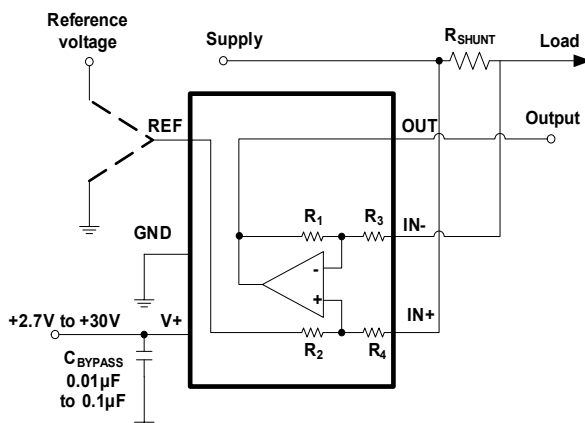
TP181 devices operate from a single +2.7V to 30V power supply, with drawing a typical of 120uA of supply current. All versions are specified from -40°C +125°C, and offered in SC70-6 packages.

### GAIN OPTIONS TABLE

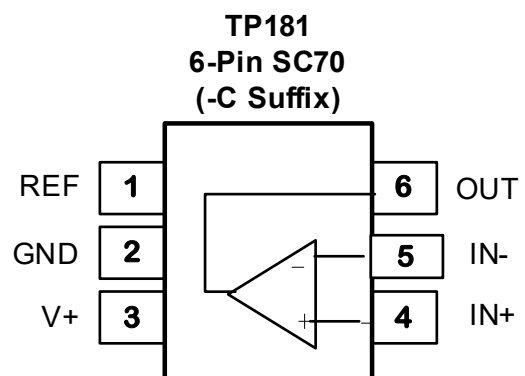
| PRODUCT | GAIN | R3 and R4 | R1 and R2 |
|---------|------|-----------|-----------|
| TP181A1 | 50   | 20kΩ      | 1MΩ       |
| TP181A2 | 100  | 10kΩ      | 1MΩ       |
| TP181A3 | 200  | 5kΩ       | 1MΩ       |

$$V_{OUT} = (I_{LOAD} \times R_{SHUNT})GAIN + V_{REF}$$

## Application schematic



## Pin Configuration



## Order Information

| Model Name | Order Number | Gain   | Package    | Transport Media, Quantity | Package Marking |
|------------|--------------|--------|------------|---------------------------|-----------------|
| TP181      | TP181A1-CR   | 50V/V  | 6-Pin SC70 | Tape and Reel, 3,000      | 9A1             |
|            | TP181A2-CR   | 100V/V | 6-Pin SC70 | Tape and Reel, 3,000      | 9A2             |
|            | TP181A3-CR   | 200V/V | 6-Pin SC70 | Tape and Reel, 3,000      | 9A3             |

## Absolute Maximum Ratings Note 1

Supply Voltage Note 2 .....42.0V  
 Input Voltage.....GND– 0.3 to 42V  
 Input Current: +IN, –IN Note 3.....±5mA  
 Output Current: OUT..... ±35mA

Current at Supply Pins..... ±60mA  
 Operating Temperature Range.....–40°C to 125°C  
 Maximum Junction Temperature..... 150°C  
 Storage Temperature Range..... –65°C to 150°C  
 Lead Temperature (Soldering, 10 sec) ..... 260°C

**Note 1:** Stresses beyond those listed under Absolute Maximum Ratings may cause permanent damage to the device. Exposure to any Absolute Maximum Rating condition for extended periods may affect device reliability and lifetime.

**Note 2:** The op amp supplies must be established simultaneously, with, or before, the application of any input signals.

**Note 3:** The inputs are protected by ESD protection diodes to each power supply. If the input extends more than 500mV beyond the power supply, the input current should be limited to less than 10mA.

## ESD, Electrostatic Discharge Protection

| Symbol | Parameter                | Condition              | Minimum Level | Unit |
|--------|--------------------------|------------------------|---------------|------|
| HBM    | Human Body Model ESD     | ANSI/ESDA/JEDEC JS-001 | ±2            | kV   |
| CDM    | Charged Device Model ESD | ANSI/ESDA/JEDEC JS-002 | ±2            | kV   |

## Thermal Resistance

| Package Type | $\theta_{JA}$ | $\theta_{JC}$ | Unit |
|--------------|---------------|---------------|------|
| 6-Pin SC70   | 227           | 80            | °C/W |

## Electrical Characteristics

The specifications are at  $T_A = 25^\circ\text{C}$ ,  $V_{\text{SENSE}} = V_{\text{IN}+} - V_{\text{IN}-}$ ,  $V_S = 5\text{ V}$ ,  $V_{\text{IN}+} = 12\text{ V}$ , and  $V_{\text{REF}} = V_S / 2$ , unless otherwise noted

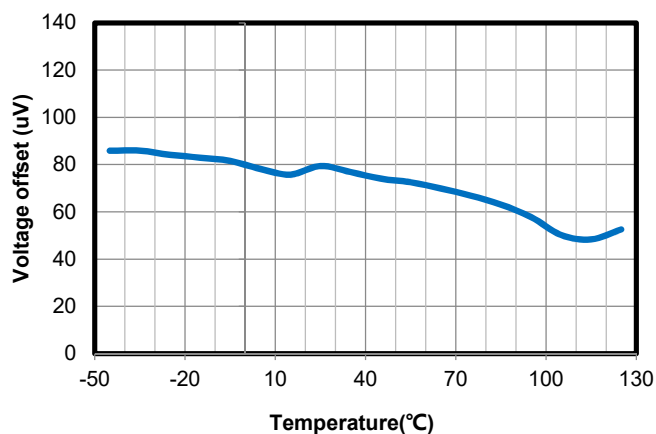
| Symbol                                 | Parameter                     | Conditions                                                                                                           | Min  | Typ         | Max                         | Unit                         |
|----------------------------------------|-------------------------------|----------------------------------------------------------------------------------------------------------------------|------|-------------|-----------------------------|------------------------------|
| <b>INPUT</b>                           |                               |                                                                                                                      |      |             |                             |                              |
| $V_{\text{OS}}$                        | Input Offset Voltage          | $V_{\text{SENSE}} = 0\text{ mV}$                                                                                     |      | $\pm 10$    | <b><math>\pm 100</math></b> | $\mu\text{V}$                |
| $V_{\text{OS TC}}$                     | Input Offset Voltage Drift    | $V_{\text{SENSE}} = 0\text{ mV}$ , $-40^\circ\text{C}$ to $125^\circ\text{C}$                                        |      | 0.1         | 0.5                         | $\mu\text{V}/^\circ\text{C}$ |
| $V_{\text{CM}}$                        | Common-mode Input Range       | $-40^\circ\text{C}$ to $125^\circ\text{C}$                                                                           | -0.3 |             | <b>36</b>                   | V                            |
| CMRR                                   | Common Mode Rejection Ratio   | $V_{\text{IN}+} = 5\sim 26\text{ V}$ , $V_{\text{SENSE}} = 0\text{ mV}$ , $-40^\circ\text{C}$ to $125^\circ\text{C}$ | 95   | 120         |                             | dB                           |
| $I_B$                                  | Input Bias Current            | $V_{\text{SENSE}} = 0\text{ mV}$                                                                                     |      | 35          |                             | $\mu\text{A}$                |
| $I_{\text{OS}}$                        | Input Offset Current          | $V_{\text{SENSE}} = 0\text{ mV}$                                                                                     |      | 0.4         |                             | $\mu\text{A}$                |
| PSRR                                   | Power Supply Rejection Ratio  | $V_S = +2.7\sim 18\text{ V}$ , $V_{\text{IN}+} = +18\text{ V}$ , $V_{\text{SENSE}} = 0\text{ mV}$                    |      | $\pm 1$     |                             | $\mu\text{V}/\text{V}$       |
| <b>NOISE RTI</b> <small>Note 4</small> |                               |                                                                                                                      |      |             |                             |                              |
| $e_n$                                  | Input Voltage Noise Density   | $f = 1\text{ kHz}$                                                                                                   |      | 30          |                             | $\text{nV}/\sqrt{\text{Hz}}$ |
| <b>OUTPUT</b>                          |                               |                                                                                                                      |      |             |                             |                              |
| G                                      | Gain                          | TP181A1                                                                                                              |      | 50          |                             | V/V                          |
|                                        |                               | TP181A2                                                                                                              |      | 100         |                             | V/V                          |
|                                        |                               | TP181A3                                                                                                              |      | 200         |                             | V/V                          |
| GE                                     | Gain Error                    | $V_{\text{SENSE}} = -5\sim 5\text{ mV}$ , $-40^\circ\text{C}$ to $125^\circ\text{C}$                                 |      | $\pm 0.1\%$ | $\pm 1\%$                   |                              |
| GE TC                                  | Gain Error Vs Temperature     | $-40^\circ\text{C}$ to $125^\circ\text{C}$                                                                           |      | 3           | 10                          | ppm                          |
| $C_{\text{LOAD}}$                      | Maxim capacitive load         | No oscillation                                                                                                       |      | 1           |                             | nF                           |
| $V_{\text{OH}}$                        | Output Swing from Supply Rail | $R_{\text{LOAD}} = 10\text{ k}\Omega$ to REF, $-40^\circ\text{C}$ to $125^\circ\text{C}$                             |      | 0.02        | 0.05                        | V                            |
| $V_{\text{OL}}$                        | Output Swing from Supply Rail | $R_{\text{LOAD}} = 10\text{ k}\Omega$ to REF, $-40^\circ\text{C}$ to $125^\circ\text{C}$                             |      | 0.01        | 0.05                        | V                            |
| <b>FREQUENCY RESPONSE</b>              |                               |                                                                                                                      |      |             |                             |                              |
| BW                                     | Bandwidth                     | $C_{\text{LOAD}} = 10\text{ pF}$ , TP181A1                                                                           |      | 48          |                             | kHz                          |
|                                        |                               | $C_{\text{LOAD}} = 10\text{ pF}$ , TP181A2                                                                           |      | 30          |                             | kHz                          |
|                                        |                               | $C_{\text{LOAD}} = 10\text{ pF}$ , TP181A3                                                                           |      | 20          |                             | kHz                          |
| SR                                     | Slew Rate                     |                                                                                                                      |      | 0.6         |                             | $\text{V}/\mu\text{s}$       |
| <b>POWER SUPPLY</b>                    |                               |                                                                                                                      |      |             |                             |                              |
| $V_+$                                  | Supply Voltage                |                                                                                                                      | 2.7  |             | 30                          | V                            |
| $I_Q$                                  | Quiescent Current             | $V_{\text{SENSE}} = 0\text{ mV}$                                                                                     |      | 120         | 150                         | $\mu\text{A}$                |
| <b>TEMPERATURE RANGE</b>               |                               |                                                                                                                      |      |             |                             |                              |
| Specified range                        |                               |                                                                                                                      | -40  |             | 125                         | $^\circ\text{C}$             |
| Operating range                        |                               |                                                                                                                      | -55  |             | 150                         | $^\circ\text{C}$             |

**Note 4:** RTI = referred to input

## Typical Performance Characteristics

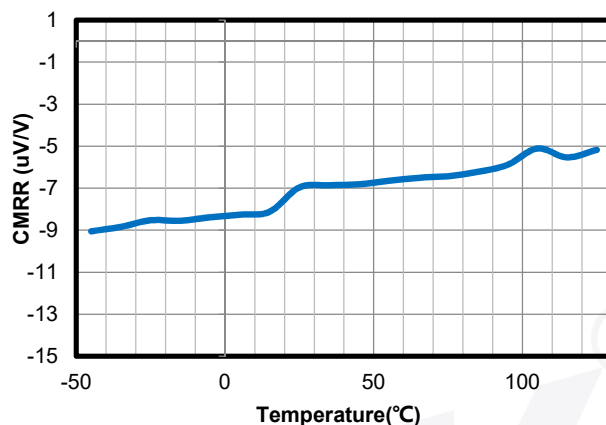
The TP181A1 is used for characteristics at  $T_A = 25^\circ\text{C}$ ,  $V_S = 5\text{V}$ ,  $V_{IN+} = 12\text{V}$ , and  $V_{REF} = V_S/2$ , unless otherwise noted

**Voltage Offset vs Temperature**



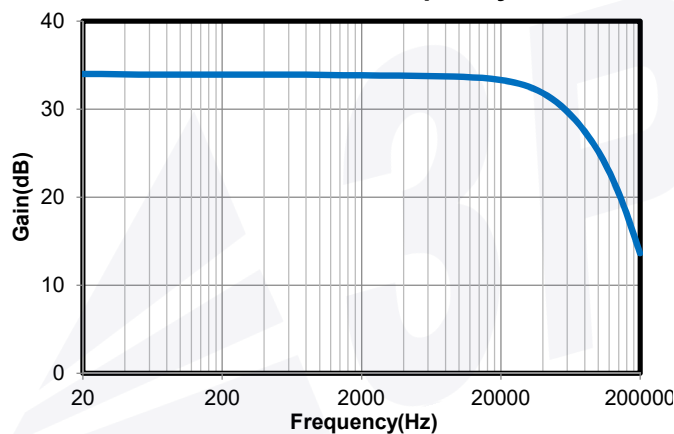
**Figure 1**

**CMRR vs. Temperature**



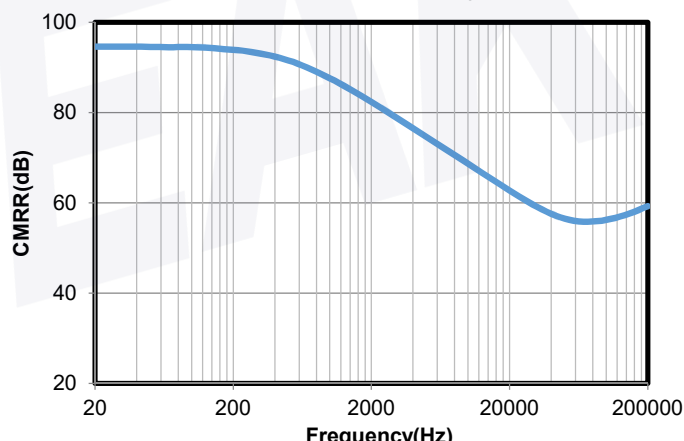
**Figure 2**

**Gain vs. Frequency**



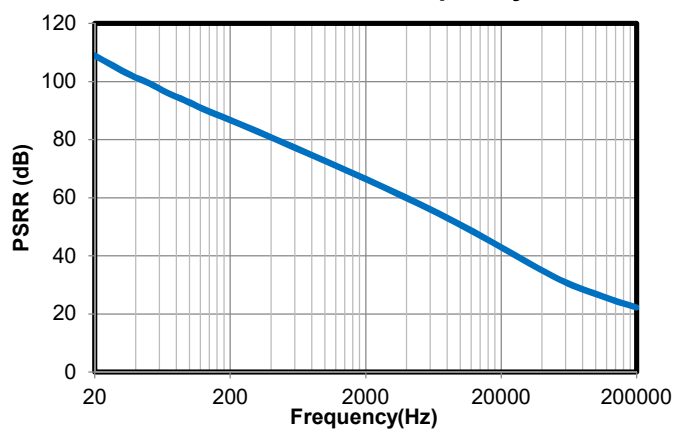
**Figure 3**

**CMRR Vs Frequency**



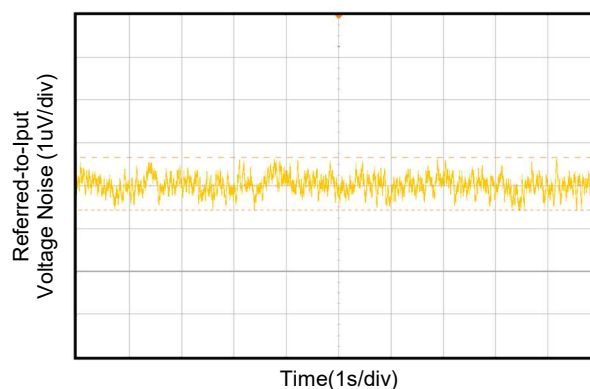
**Figure 4**

**PSRR vs. Frequency**



**Figure 5**

**0.1-Hz to 10Hz Voltage Noise (Referred-to-Input)**

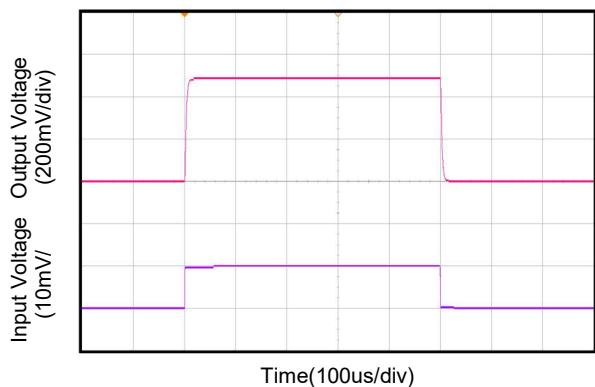


**Figure 6**

## Typical Performance Characteristics

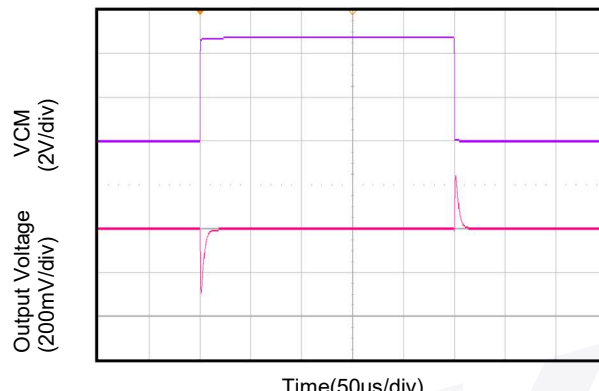
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**Step response (10-mVpp Input Step)**



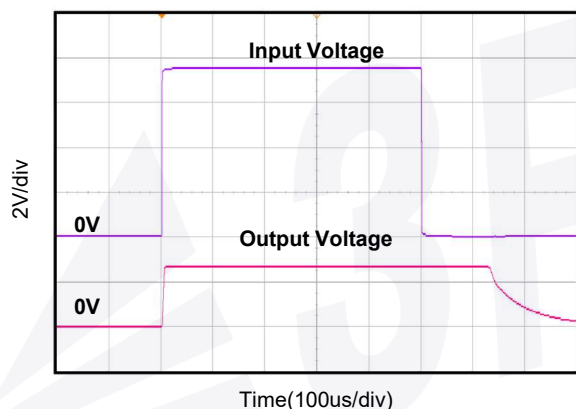
**Figure 7**

**Common-Mode Voltage Transient Response**



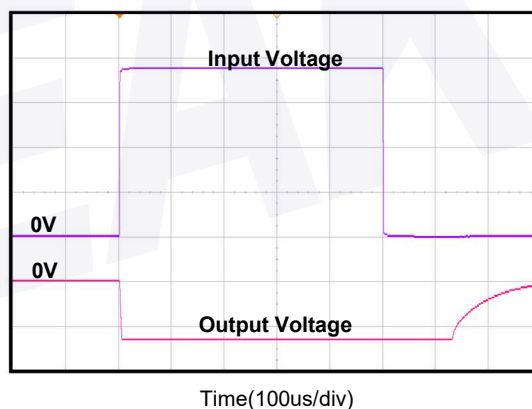
**Figure 8**

**Noninverting Differential Input Overload**



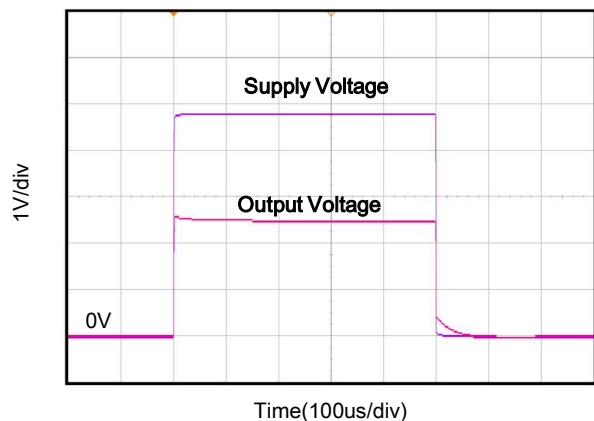
**Figure 9**

**Inverting Differential Input Overload**



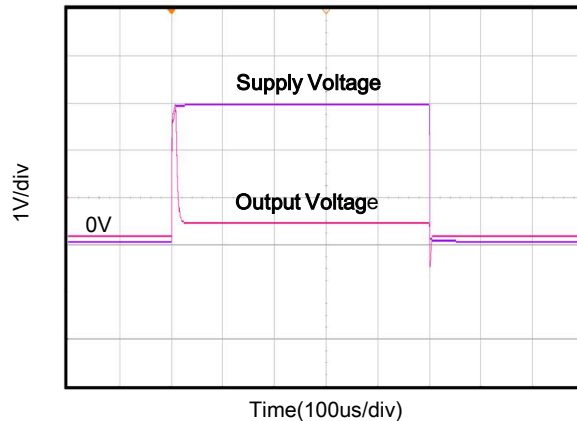
**Figure 10**

**Start-up Response**



**Figure 11**

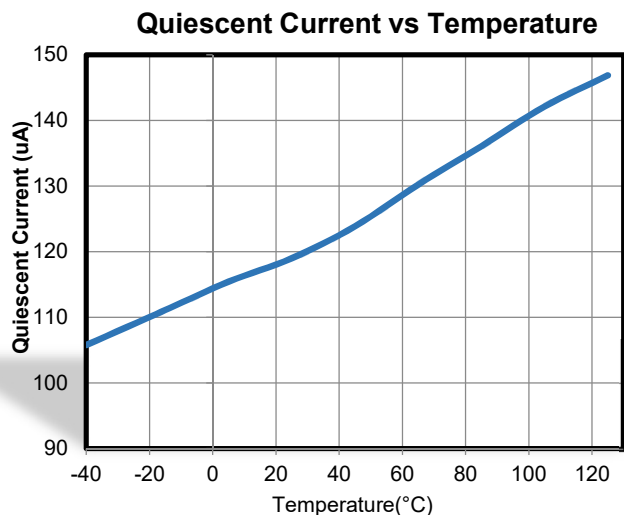
**Brownout Recovery**



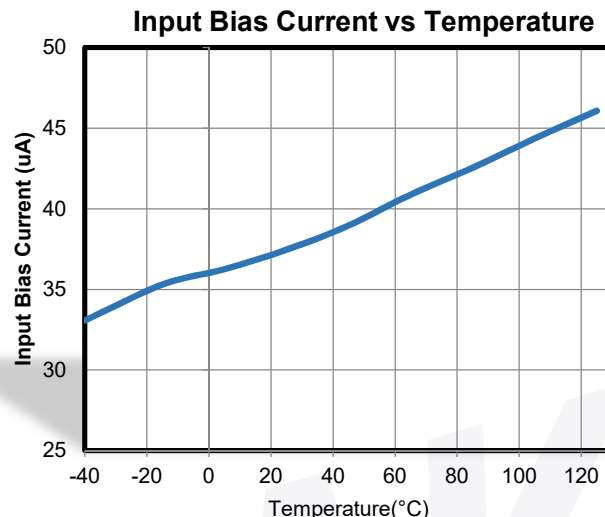
**Figure 12**

## Typical Performance Characteristics

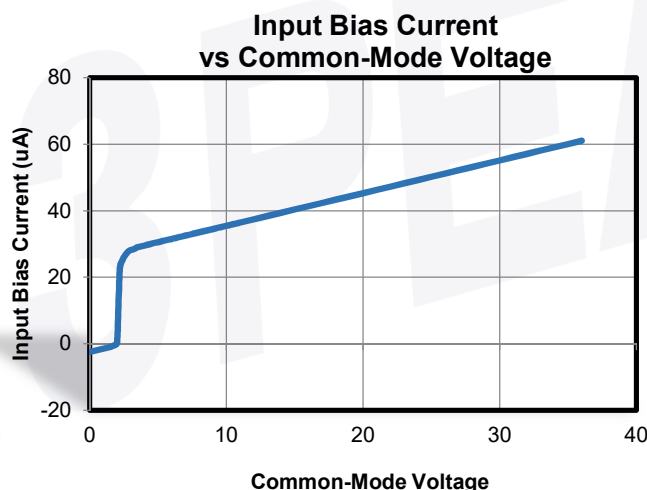
The TP181A1 is used for characteristics at  $T_A = 25^\circ\text{C}$ ,  $V_S = 5\text{V}$ ,  $V_{IN+} = 12\text{V}$ , and  $V_{REF} = V_S/2$ , unless otherwise noted



**Figure 13**



**Figure 14**



**Figure 15**

## Pin Functions

**IN-:** Inverting Input of the Amplifier.

**IN+:** Non-Inverting Input of Amplifier.

**OUT:** Amplifier Output. The voltage range extends to within mV of each supply rail.

**REF:** Reference voltage

**V+:** Positive Power Supply. Typically, the voltage is from 2.7V to 30V. A bypass capacitor of 0.1μF as close to the part as possible should be used between power supply pin and ground pin.

**GND:** Negative Power Supply.

## Operation Overview

The TP181 family is 36V common-mode, zero-drift topology, current-sensing amplifiers that can be used in both low-side and high-side configurations. These specially-designed, current-sensing amplifiers are able to accurately measure voltages developed across current-sensing resistors on common-mode voltages that far exceed the supply voltage powering the device. Current can be

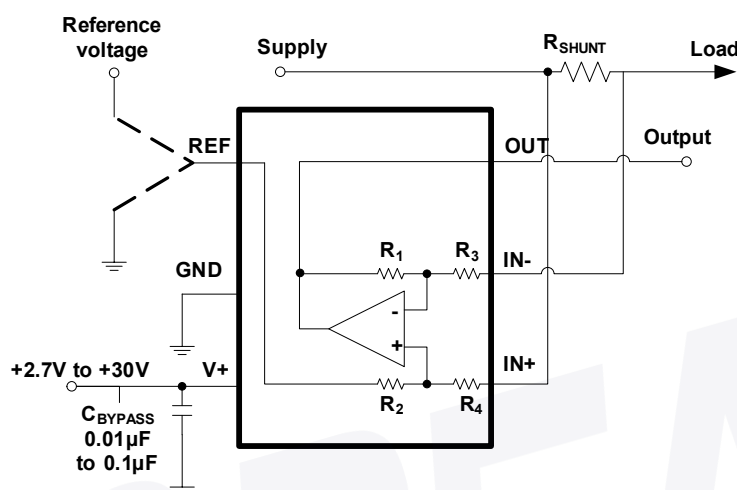
## Zero-Drift, Bi-directional Current Sense Amplifier

measured on input voltage rails as high as 36 V while the device can be powered from supply voltages as low as 2.7 V.

The zero-drift topology enables high-precision measurements with maximum input offset voltages as low as 100 $\mu$ V with a maximum temperature contribution of 0.5  $\mu$ V/ $^{\circ}$ C over the full temperature range of  $-40^{\circ}$ C to 125 $^{\circ}$ C.

## Applications Information

### Application schematic



Above figure shows the basic connections of the TP181. The input pins, IN+ and IN-, should be connected as closely as possible to the shunt resistor to minimize any resistance in series with the shunt resistor.

Power-supply bypass capacitors are required for stability. Applications with noisy or high-impedance power supplies may require additional decoupling capacitors to reject power-supply noise. Connect bypass capacitors close to the device pins.

### Selecting RSHUNT

The zero-drift offset performance of the TP181 offers several benefits. Most often, the primary advantage of the low offset characteristic enables lower full-scale drops across the shunt. For example, nonzero-drift current shunt monitors typically require a full-scale range of 100 mV.

The TP181 family gives equivalent accuracy at a full-scale range on the order of 10 mV. This accuracy reduces shunt dissipation by an order of magnitude with many additional benefits.

Alternatively, there are applications that must measure current over a wide dynamic range that can take advantage of the low offset on the low end of the measurement. Most often, these applications can use the lower gains of the TP181 to accommodate larger shunt drops on the upper end of the scale. For instance, an TP181A1 operating on a 3.3-V supply could easily handle a full-scale shunt drop of 60 mV, with only 100 $\mu$ V of offset.

### REF Input Impedance Effects

As with any difference amplifier, the TP181 family common-mode rejection ratio is affected by any impedance present at the REF input. This concern is not a problem when the REF pin is connected directly to most references or power supplies. When using resistive dividers from the power supply or a reference voltage, the REF pin should be buffered by an op amp.

### Power Supply Recommendation

The input circuitry of the TP181 can accurately measure beyond its power-supply voltage, V+. For example, the V+ power supply

## Zero-Drift, Bi-directional Current Sense Amplifier

can be 5 V, whereas the load power-supply voltage can be as high as 30 V. However, the output voltage range of the OUT pin is limited by the voltages on the power-supply pin. Note also that the TP181 can withstand the full input signal range up to 36 V at the input pins, regardless of whether the device has power applied or not.

### Proper Board Layout

To ensure optimum performance at the PCB level, care must be taken in the design of the board layout. To avoid leakage currents, the surface of the board should be kept clean and free of moisture. Coating the surface creates a barrier to moisture accumulation and helps reduce parasitic resistance on the board.

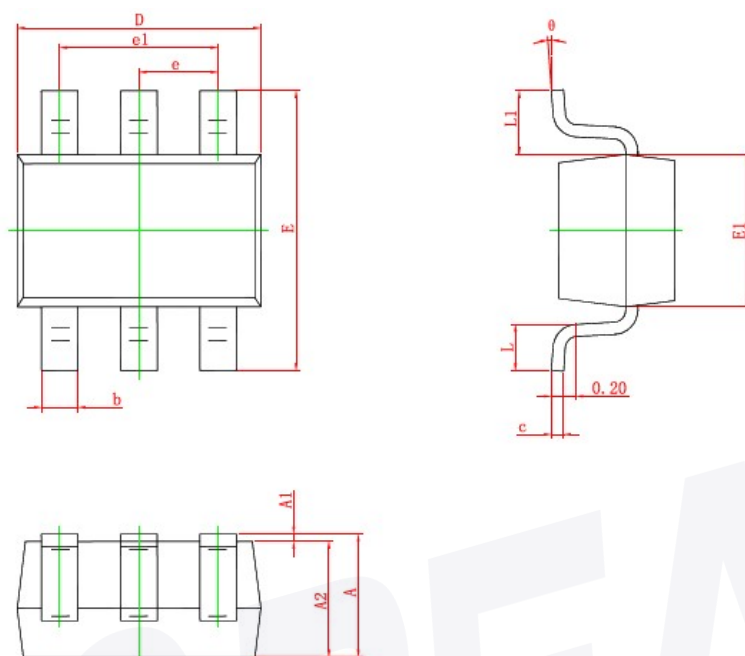
Keeping supply traces short and properly bypassing the power supplies minimizes power supply disturbances due to output current variation, such as when driving an ac signal into a heavy load. Bypass capacitors should be connected as closely as possible to the device supply pins. Stray capacitances are a concern at the outputs and the inputs of the amplifier. It is recommended that signal traces be kept at least 5mm from supply lines to minimize coupling.

A variation in temperature across the PCB can cause a mismatch in the Seebeck voltages at solder joints and other points where dissimilar metals are in contact, resulting in thermal voltage errors. To minimize these thermocouple effects, orient resistors so heat sources warm both ends equally. Input signal paths should contain matching numbers and types of components, where possible to match the number and type of thermocouple junctions. For example, dummy components such as zero value resistors can be used to match real resistors in the opposite input path. Matching components should be located in close proximity and should be oriented in the same manner. Ensure leads are of equal length so that thermal conduction is in equilibrium. Keep heat sources on the PCB as far away from amplifier input circuitry as is practical.

The use of a ground plane is highly recommended. A ground plane reduces EMI noise and also helps to maintain a constant temperature across the circuit board.

## Package Outline Dimensions

SC70-6 /SOT-363



| Symbol   | Dimensions In Millimeters |       | Dimensions In Inches |       |
|----------|---------------------------|-------|----------------------|-------|
|          | Min.                      | Max.  | Min.                 | Max.  |
| A        | 0.900                     | 1.100 | 0.035                | 0.043 |
| A1       | 0.000                     | 0.100 | 0.000                | 0.004 |
| A2       | 0.900                     | 1.000 | 0.035                | 0.039 |
| b        | 0.150                     | 0.350 | 0.006                | 0.014 |
| c        | 0.110                     | 0.175 | 0.004                | 0.007 |
| D        | 2.000                     | 2.200 | 0.079                | 0.087 |
| E        | 2.150                     | 2.450 | 0.085                | 0.096 |
| E1       | 1.150                     | 1.350 | 0.045                | 0.053 |
| e        | 0.650 TYP.                |       | 0.026 TYP.           |       |
| e1       | 1.200                     | 1.400 | 0.047                | 0.055 |
| L        | 0.260                     | 0.460 | 0.010                | 0.018 |
| L1       | 0.525 REF.                |       | 0.021 REF.           |       |
| $\theta$ | 0°                        | 8°    | 0°                   | 8°    |

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