3-V to 120-V V_{CM}, High-Precision, Current-Sense Amplifier

Features

- Voltage Offset: ±100 μV (Max)
- Wide Common-Mode Voltage: 3.0 V to 120 V
- Supply Voltage: 3.0 V to 5.5 V
- Accuracy and Zero-Drift Performance
  - ±0.7% Gain Error (Max over temperature)
  - 0.5-μV/°C Offset Drift (Max, −40°C to 125°C)
  - 12-ppm/°C Gain Drift (Max)
- Available Gain Options
  - TPA148A1: 20 V/V
  - TPA148A2: 50 V/V
  - TPA148A3: 100 V/V
  - TPA148A4: 200 V/V
  - TPA148A5: 500 V/V
- Rail-to-Rail Output
- Industrial Operation Range: –40°C to 125°C

Applications

- Current Sensing (High−Side)
- Battery Chargers
- Power Management
- Automotive
- Server Backplanes
- Base Stations and Telecom Equipment
- Industrial Control and Automation

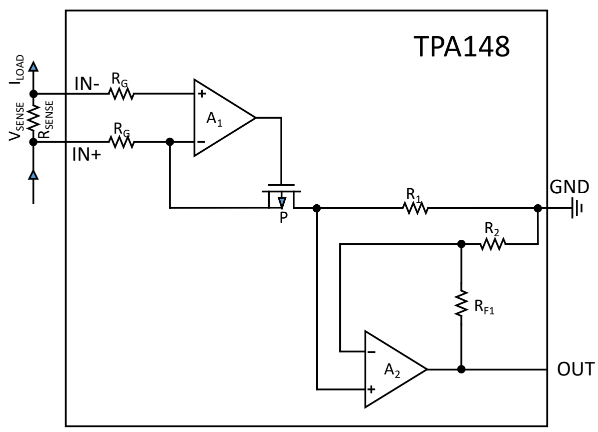
Description

The TPA148 is a series of high-common-voltage, high-side current-sense amplifiers, which has very high precision and accuracy specifications of V_{OS} less than 100 μV (max) and gain error less than 0.7% (max). Five fixed gains are available: 20 V/V, 50 V/V, 100 V/V, 200 V/V, and 500 V/V. These gain options provide a wide dynamic range for current-sensing applications.

The TPA148 features an input common-mode voltage range from 3.0 V to 120 V with 80 kHz of small-signal bandwidth, which makes it ideal for small-signal conditioning interfacing with a SAR ADC.

The TPA148 offers breakthrough performance throughout the −40°C to +125°C temperature range. It features a zero-drift core, which leads to a maximum offset drift of 0.5 μV/°C throughout the operating temperature range and the common-mode voltage range. The package of TPA148 is SOT23-5.

Functional Block Diagram



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Revision History

Date	Revision	Notes
2024-12-04	Rev.A.0	Initial version.

Pin Configuration and Functions

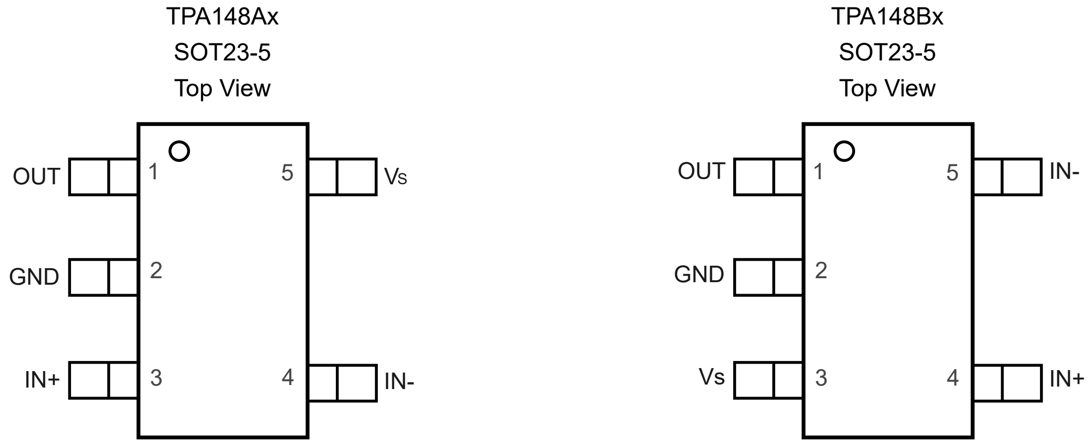


Table 1. Pin Functions: TPA148

Pin No.		Name	I/O	Description
TPA148Ax	TPA148Bx			
1	1	OUT	O	Output voltage.
2	2	GND		Ground.
3	4	IN+	I	Noninverting input.
4	5	IN−	I	Inverting input.
5	3	V_S		Power supply.

Specifications

Absolute Maximum Ratings (1)

Parameter		Min	Max	Unit
	Supply Voltage		6	V
	Input Common Voltage	−0.3	130	V
	Input Current IN+, IN−	−10	10	mA
	Operating Temperature Range	−40	125	°C
T_J	Maximum Junction Temperature		150	°C
T_{STG}	Storage Temperature Range	−65	150	°C
T_L	Lead Temperature (Soldering, 10 sec)		300	°C

(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.

ESD, Electrostatic Discharge Protection

Symbol	Parameter	Condition	Minimum Level	Unit
HBM	Human Body Model ESD	ANSI/ESDA/JEDEC JS-001 (1)	2	kV
CDM	Charged Device Model ESD	ANSI/ESDA/JEDEC JS-002 (2)	1.5	kV

(1) JEDEC document JEP155 states that 500-V HBM allows safe manufacturing with a standard ESD control process.
(2) JEDEC document JEP157 states that 250-V CDM allows safe manufacturing with a standard ESD control process.

Thermal Information

Package Type	θ_{JA}	θ_{JC}	Unit
SOT23-5	161	64	°C/W

Electrical Characteristics

All test conditions: T_A = 25°C, V_S = 5 V, V_{SENSE} = V_{IN+} – V_{IN-} = 0.5 V / Gain, V_{CM} = V_{IN-} = 100 V, unless otherwise noted.

Symbol	Parameter	Conditions		Min	Typ	Max	Unit
Input							
V_{OS}	Input Offset Voltage	T_A = −40°C to 125°C			±20	±100	μV
V_{OS} TC (1)	Input Offset Voltage Drift	T_A = −40°C to 125°C			0.2	0.5	μV/°C
V_{CM}	Common-Mode Input Range	T_A = −40°C to 125°C		3.0		120	V
CMRR	Common-Mode Rejection Ratio	T_A = −40°C to 125°C 3.0 V < V_{CM} < 120 V		110	130		dB
I_B	Input Bias Current	V_{SENSE} = 0 mV T_A = −40°C to 125°C			50	65	μA
I_{OS}	Input Offset Current	V_{SENSE} = 0 mV T_A = −40°C to 125°C			±0.1		μA
Noise RTI (2)							
e_n	Input Voltage Noise Density	f = 10 kHz			62		nV/√Hz
Output							
G	Gain	TPA148A1			20		V/V
		TPA148A2			50		V/V
		TPA148A3			100		V/V
		TPA148A4			200		V/V
		TPA148A5			500		V/V
GE	Gain Error	TPA148A3	T_A = −40°C to 125°C		±0.2	±0.7	%
	Nonlinearity Error	T_A = −40°C to 125°C GND + 0.5 V ≤ V_{OUT} ≤ V_S – 0.5 V			±0.01		%
GE TC (1)	Gain Error vs. Temperature	T_A = −40°C to 125°C			5	12	ppm/°C
C_{LOAD}	Maximum Capacitive Load	No oscillation			1		nF
V_{OH}	Output Swing from Supply Rail	R_L = 10 kΩ to GND T_A = −40°C to 125°C			10	30	mV
V_{OL}	Output Swing from Supply Rail	R_L = 10 kΩ to GND V_{SENSE} = 0 mV T_A = −40°C to 125°C			5	20	mV
Frequency Response							
BW	Bandwidth	All gain configuration	V_{SENSE} = 40 mV C_{LOAD} = 5 pF		80		kHz
SR	Slew Rate	V_{SENSE} = V_{IN+} – V_{IN-} = 30 mV			0.6		V/μs

Symbol	Parameter	Conditions	Min	Typ	Max	Unit
Power Supply						
V_S	Supply Voltage	T_A = −40°C to 125°C	3.0		5.5	V
I_Q	Quiescent Current	V_S = 3.0 V T_A = −40°C to 125°C		0.28	0.45	mA
		V_S = 5.5 V T_A = −40°C to 125°C		0.31	0.5	mA
PSRR	Power Supply Rejection Ratio	3.0 V < V_S < 5.5 V T_A = −40°C to 125°C	80	100		dB

(1) Provided by bench tests and design simulation.
(2) RTI = referred to input.

Typical Performance Characteristics

All test conditions: T_A = 25°C, V_S = 5 V, V_{SENSE} = V_{IN+} – V_{IN-} = 0.5 V / Gain, V_{CM} = V_{IN-} = 100 V, unless otherwise noted.

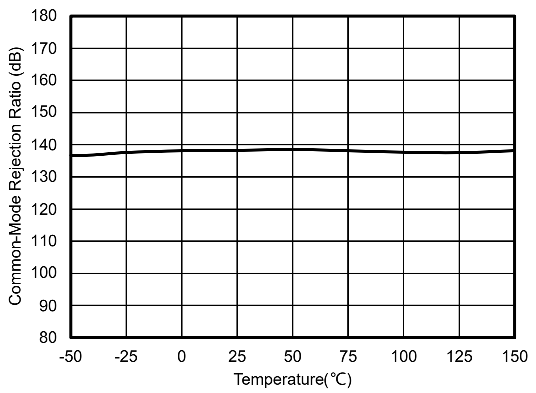


Figure 1. Common-Mode Rejection Ratio vs. Temperature

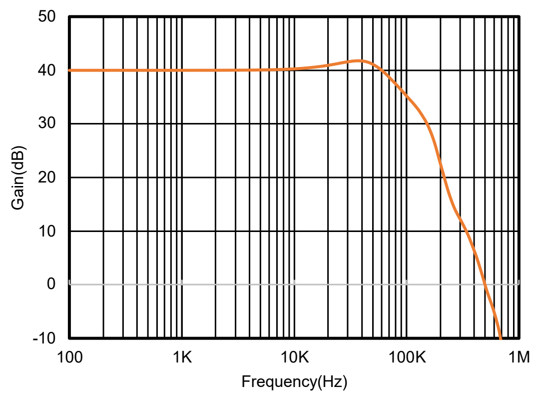


Figure 2. Gain vs. Frequency

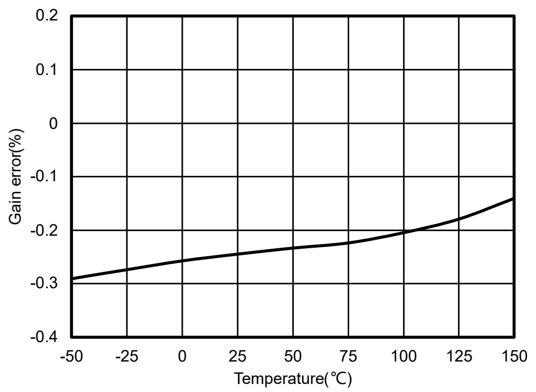


Figure 3. Gain Error vs. Temperature

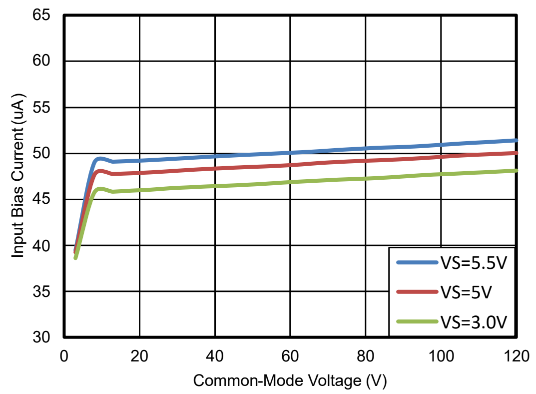


Figure 4. Input Bias Current vs. Common-Mode Voltage (V_{SENSE} = 0 V)

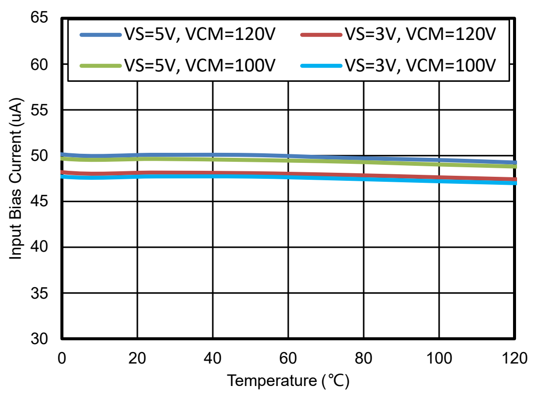


Figure 5. Input Bias Current vs. Temperature

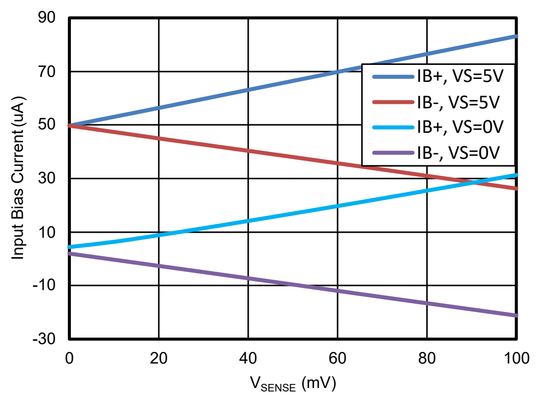


Figure 6. Input Bias Current vs. V_{SENSE}

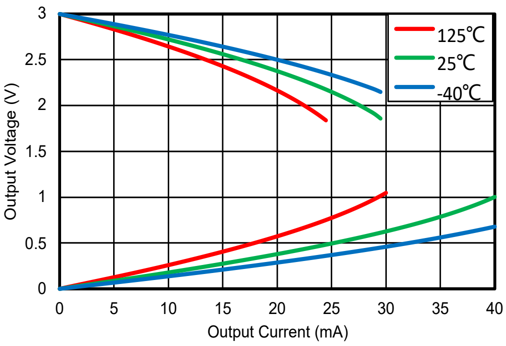


Figure 7. Output Voltage vs. Output Current (V_S = 3 V)

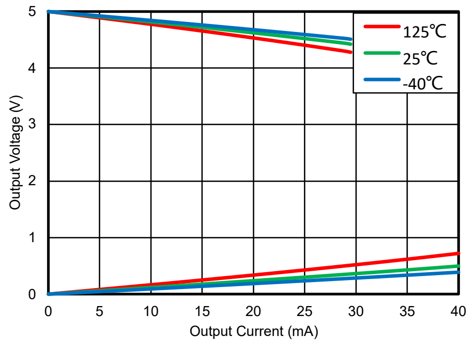


Figure 8. Output Voltage vs. Output Current (V_S = 5 V)

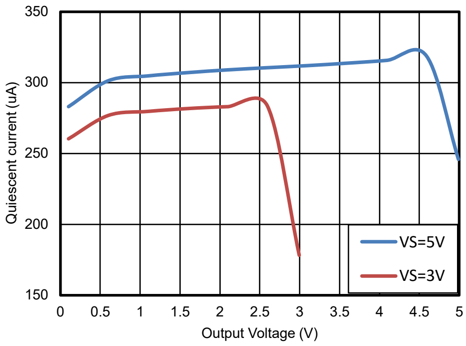


Figure 9. Quiescent Current vs. Output Voltage

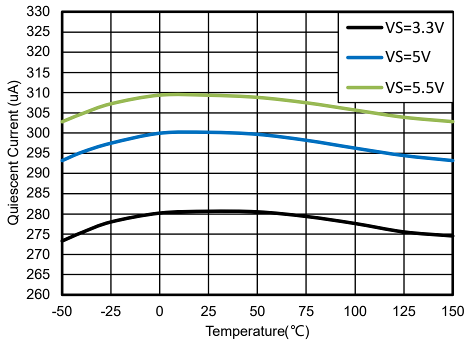


Figure 10. Quiescent Current vs. Temperature

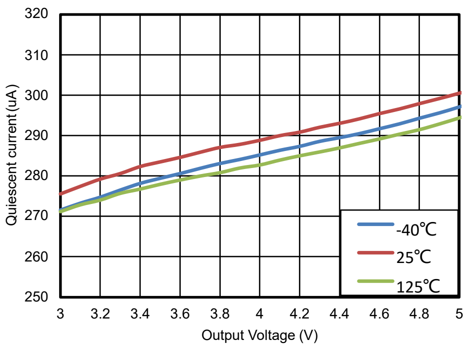


Figure 11. Quiescent Current vs. Supply Voltage

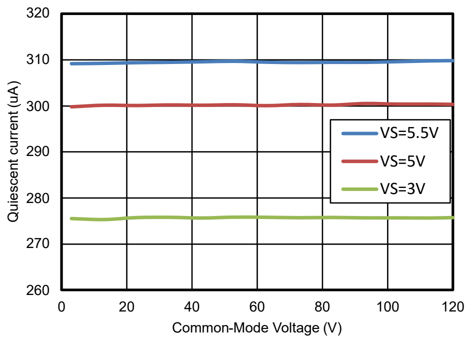


Figure 12. Quiescent Current vs. Common-Mode Voltage

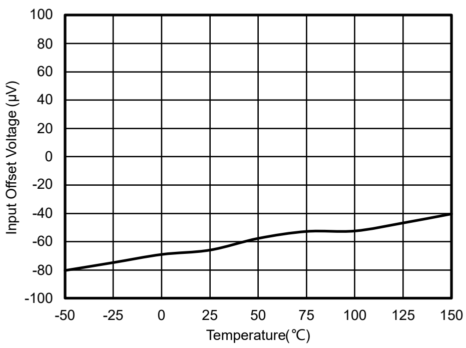


Figure 13. V_{OS} vs. Temperature

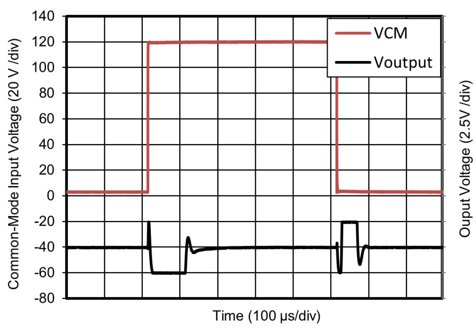


Figure 14. Common-Mode Voltage Fast Transient Pulse

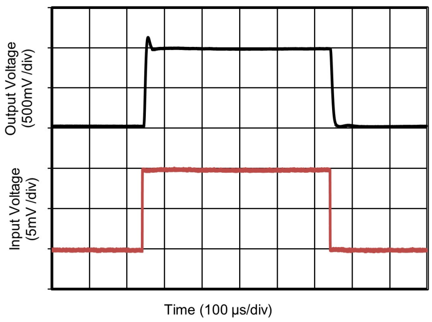


Figure 15. TPA148x3 Step Response

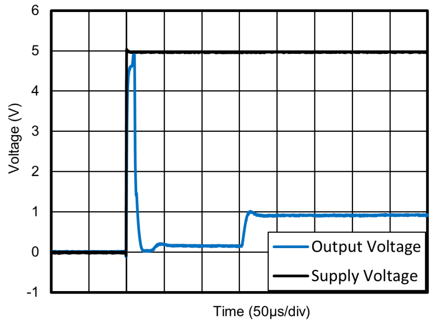


Figure 16. Start-up Response

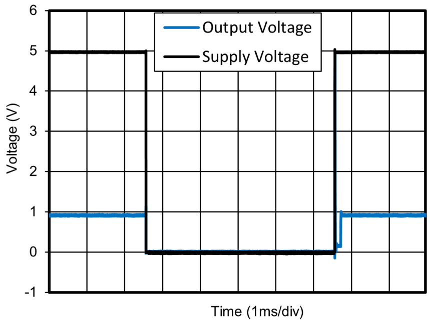


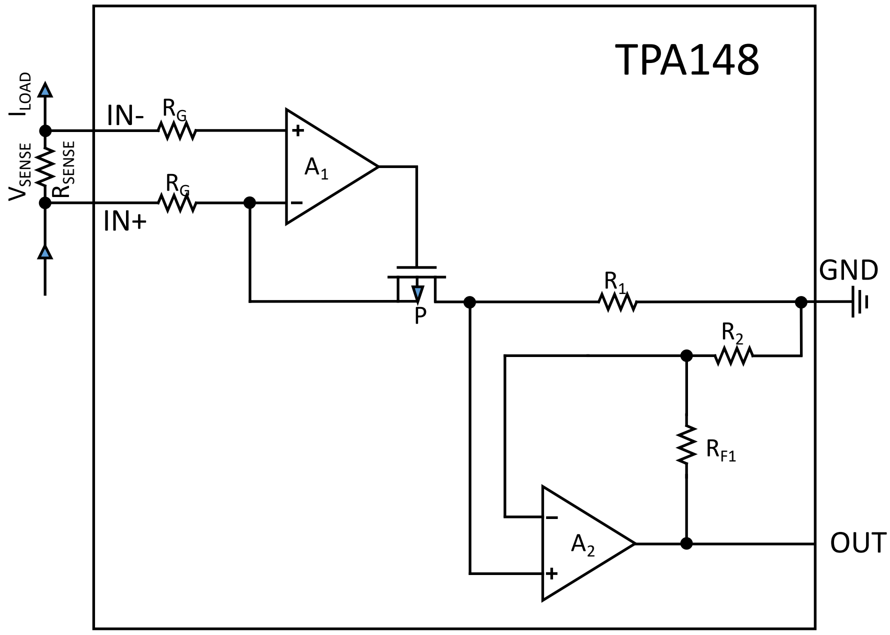
Figure 17. Supply Transient Response

Detailed Description

Overview

The TPA148 family features a high-accuracy current-sense amplifier in various gain options, and a 3-V to 120-V input common-mode range that is independent of supply voltage (V_S). The low input offset voltage, tight gain error, and low-temperature drift characteristics allow the use of small-sense resistors for current measurements to improve power supply conversion efficiency and accuracy of measurements. High-side current monitoring does not interfere with the ground path of the load measured, making the IC particularly useful in a wide range of high-reliability systems.

Functional Block Diagram



Feature Description

Recommended Component Values

Ideally, the maximum load current develops the full-scale sense voltage across the current-sense resistor. Choose the gain needed to match the maximum output voltage required for the application:

$$V_{OUT} = V_{SENSE} \times A_V \quad (1)$$

Where V_{SENSE} is the full-scale sense voltage, and A_V is the gain of the TPA148.

In applications of monitoring a high current, ensure that R_{SENSE} dissipates its own I^2R power loss. If the power of the resistor dissipation exceeds the nominal value, its value may drift or fail altogether. The TPA148 senses a wide variety of currents with different sense-resistor values.

Input Filtering

According to user design requirements, external filtering of the current signal may be desired. The initial location that can be considered for the filter is at the output of the current-sense amplifier. Although placing the filter at the output satisfies the filtering requirements, this location changes the low output impedance measured by any circuitry connected to the output voltage pin. The other location for filter placement is at the input pins of the current-sense amplifier. This location also satisfies the filtering requirements, but the components must be carefully selected to minimize the impact on device performance. Figure 18 shows a filter placed at the input pins.

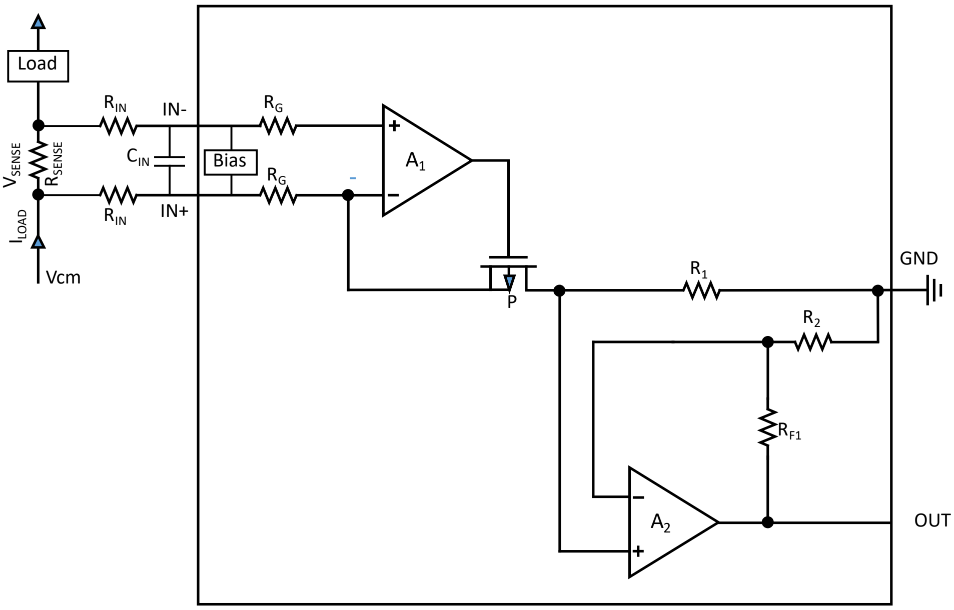


Figure 18. Filter at Input Pins

External series resistance provides a source of additional measurement error, so keep the value of these series resistors to 10 Ω or less to reduce the loss of accuracy. The internal bias network shown in Figure 18 creates a mismatch in input bias currents when the differential voltage is applied between the input pins. If additional external series filter resistors are added to the circuit, a mismatch is created in the voltage drop across the filter resistors. This voltage is a differential error in the shunt resistor voltage. In addition to the absolute resistor value, mismatch resulting from resistor tolerance can significantly impact the error because this value is calculated based on the actual measured resistance.

The measurement error expected from the additional external filter resistors and the gain error factor are calculated as follows.

$$\text{Gain Error}(\%) = 100 - (100 \times \text{Gain Error Factor}) \quad (2)$$

$$\text{Gain Error Factor} = \frac{R_B \times R_G}{(R_B \times R_G) + (R_B \times R_{IN}) + (2 \times R_{IN} \times R_G)} \quad (2)$$

Where:

R_{IN} is the external filter resistance value;

R_G is the TPA148 input resistance value specified in Table 2;

R_B is the internal bias resistance, which is 5000 Ω ± 20%.

Table 2. Fixed Gain Resistor

Gain	R_B	R_g	R_1	R_2	R_{F1}
100 V/V	10 kΩ	10 kΩ	25 kΩ	10 kΩ	390 kΩ

Layout

Layout Guideline

- Connect the input pins to the sensing resistor using a Kelvin or 4-wire connection. This connection technique makes sure that only the current-sensing resistor impedance is detected between the input pins. Poor routing of the current-sensing resistor commonly results in additional resistance present between the input pins. Given the very low value of the current resistor, any additional high-current carrying impedance can cause significant measurement errors.
- Ensure the sense resistor has ample copper trace area for effective heat dissipation. This minimizes temperature-induced changes in the value of the resistor, maintaining measurement accuracy.
- The power-supply bypass capacitor should be placed as close as possible to the supply and ground. The recommended value of this bypass capacitor is 0.1 µF. Additional decoupling capacitance can be added to compensate for noisy or high-impedance power supplies.

Layout Example

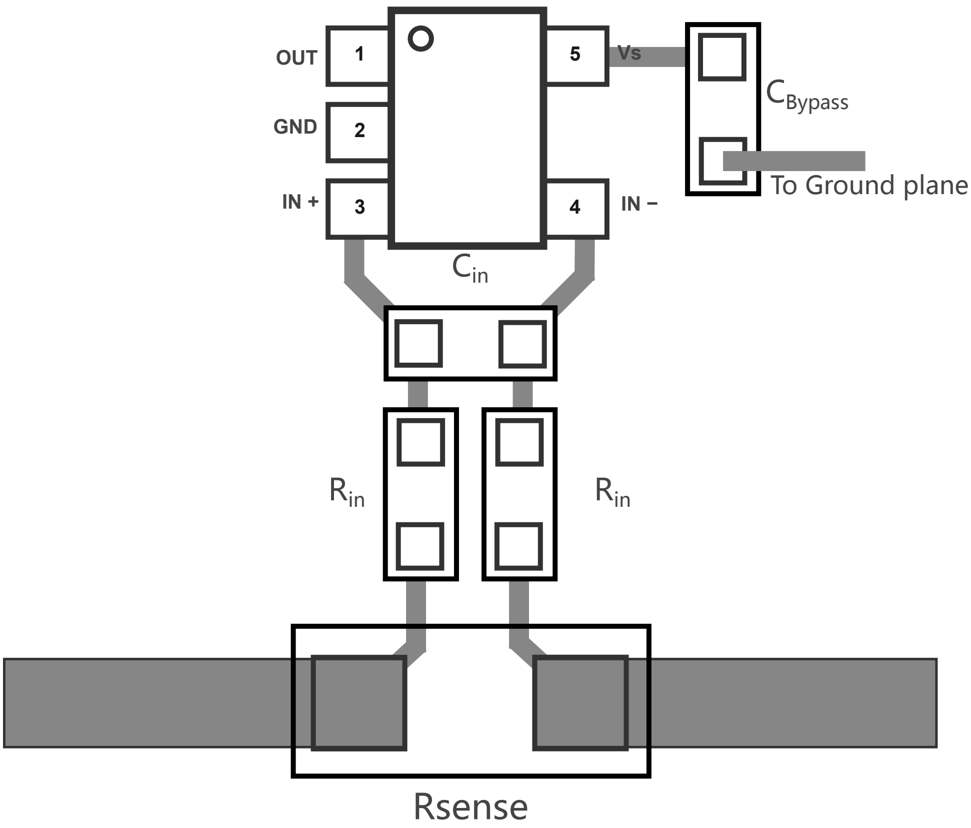


Figure 19. TPA148Ax Recommended Layout

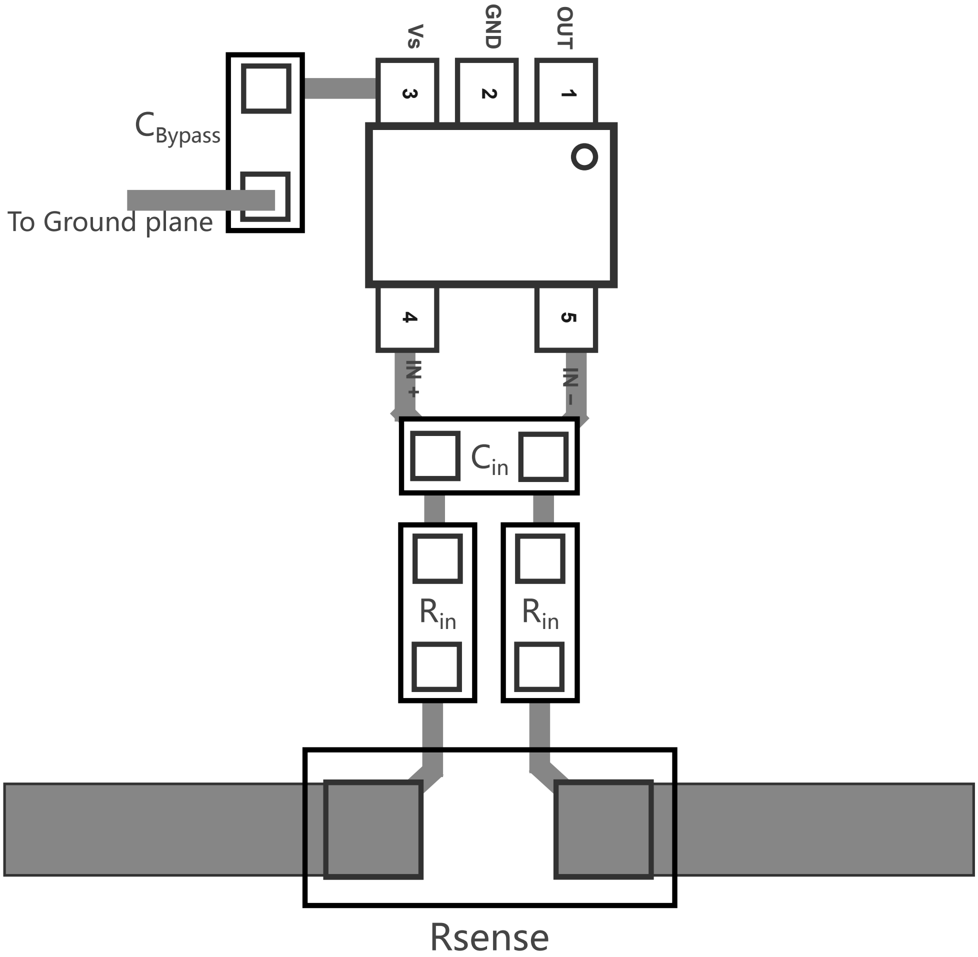
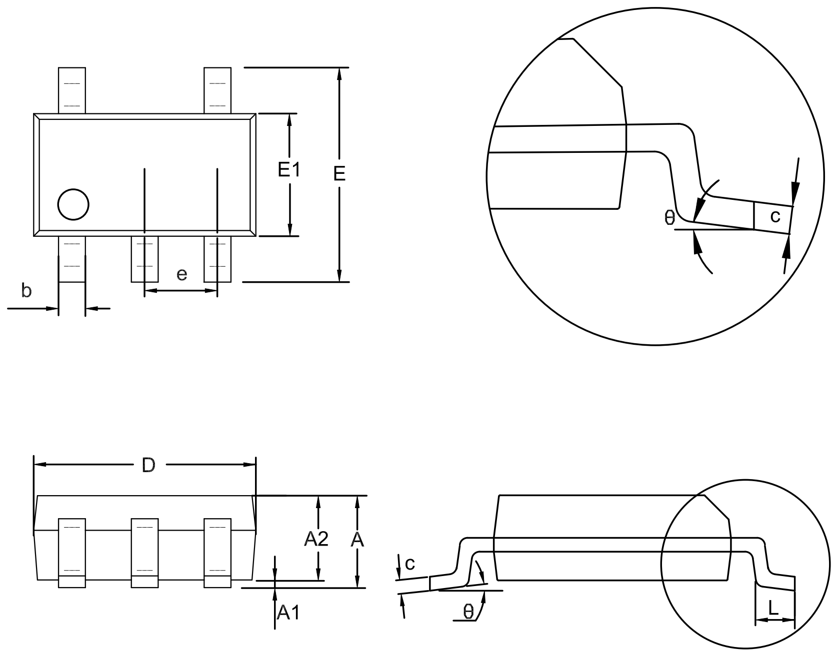


Figure 20. TPA148Bx Recommended Layout

Package Outline Dimensions

SOT23-5

Package Outline Dimensions S5T(SOT23-5-A)



Symbol	Dimensions In Millimeters		Dimensions In Inches	
	MIN	MAX	MIN	MAX
A	1.050	1.250	0.041	0.049
A1	0.000	0.150	0.000	0.006
A2	1.000	1.200	0.039	0.047
b	0.280	0.500	0.011	0.020
c	0.100	0.230	0.004	0.009
D	2.820	3.020	0.111	0.119
E	2.600	3.000	0.102	0.118
E1	1.500	1.720	0.059	0.068
e	0.950 BSC		0.037 BSC	
L	0.300	0.600	0.012	0.024
θ	0	8°	0	8°

NOTES

1. Do not include mold flash or protrusion.
2. This drawing is subject to change without notice.

Order Information

Order Number	Gain	Operating Temperature Range	Package	Marking Information	MSL	Transport Media, Quantity	Eco Plan
TPA148A1-S5TR-S (1)	20 V/V	−40 to 125 °C	SOT23-5	A81	MSL3	Tape and Reel, 3,000	Green
TPA148A2-S5TR-S (1)	50 V/V	−40 to 125 °C	SOT23-5	A82	MSL3	Tape and Reel, 3,000	Green
TPA148A3-S5TR-S	100 V/V	−40 to 125 °C	SOT23-5	A83	MSL3	Tape and Reel, 3,000	Green
TPA148A4-S5TR-S (1)	200 V/V	−40 to 125 °C	SOT23-5	A84	MSL3	Tape and Reel, 3,000	Green
TPA148A5-S5TR-S (1)	500 V/V	−40 to 125 °C	SOT23-5	A85	MSL3	Tape and Reel, 3,000	Green
TPA148B1-S5TR-S (1)	20 V/V	−40 to 125 °C	SOT23-5	A91	MSL3	Tape and Reel, 3,000	Green
TPA148B2-S5TR-S (1)	50 V/V	−40 to 125 °C	SOT23-5	A92	MSL3	Tape and Reel, 3,000	Green
TPA148B3-S5TR-S (1)	100 V/V	−40 to 125 °C	SOT23-5	A93	MSL3	Tape and Reel, 3,000	Green
TPA148B4-S5TR-S (1)	200 V/V	−40 to 125 °C	SOT23-5	A94	MSL3	Tape and Reel, 3,000	Green
TPA148B5-S5TR-S (1)	500 V/V	−40 to 125 °C	SOT23-5	A95	MSL3	Tape and Reel, 3,000	Green

(1) For future products, contact the 3PEAK factory for more information and samples.

Green: 3PEAK defines "Green" to mean RoHS compatible and free of halogen substances.

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