Zero-Drift, Uni-Directional Current Sense Amplifier

Features

- Voltage Offset: ±350 μV (Max) at V_{CM} = 12 V
- Wide Common-Mode Voltage: −0.3 V to +36 V
- Supply Voltage: 2.7 V to 36 V
- High Bandwidth
  - TPA198A1Q: 270 kHz
  - TPA198A2Q: 210 kHz
  - TPA198A3Q: 130 kHz
- Accuracy and Zero-Drift Performance:
  - ±1% Gain Error (Max over Temperature)
  - 0.2-μV/°C Offset Drift (Typ)
  - 15-ppm/°C Gain Drift (Max)
- Gain Options for Voltage Output
  - TPA198A1Q: 20 V/V
  - TPA198A2Q: 50 V/V
  - TPA198A3Q: 100 V/V
- Low Supply Current: 160 μA (Typ)
- Rail-to-Rail Output
- Package: SOT23-5
- Industrial Operating Range: −40°C to 125°C
- Qualified for Automotive Applications with AEC-Q100 Reliability Test
  - Grade 1: −40°C to 125°C T_A

Applications

- Current Sensing (High-Side/Low-Side)
- Battery Charger
- Power Management
- Cell Phone Charger
- Electrical Cigarette
- Wireless Charger
- Telecom Equipment

Description

The TPA198Q is a series of zero-drift, uni-directional current sense amplifiers that can sense voltage drops across shunts at common-mode voltages from −0.3 V to 36 V, independent of the supply voltage. Three fixed gains are available: 20 V/V, 50 V/V, and 100 V/V. The integration-matched gain resistor network minimizes gain errors and reduces the temperature drift. The low offset of the zero-drift architecture enables current sensing with the maximum drops across the shunt as low as 10 mV full-scale.

The TPA198Q series operates from a single 2.7-V to 36-V power supply, while drawing 160-μA supply current (typical). All versions are specified from −40°C to +125°C, and offered in the SOT23-5 package.

Typical Application Circuit

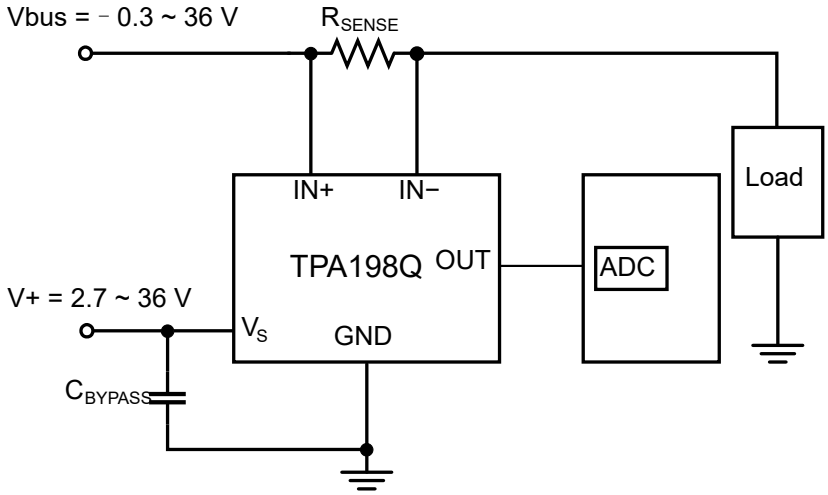


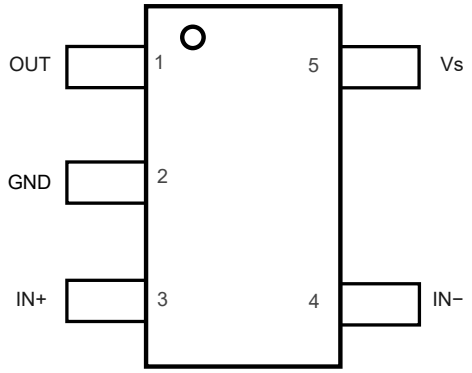
Table of Contents

Revision History

Date	Revision	Notes
2026-01	Rev.A.0	Initial version.

Pin Configuration and Functions

TPA198AxQ
SOT23-5
Top View



TPA198BxQ
SOT23-5
Top View

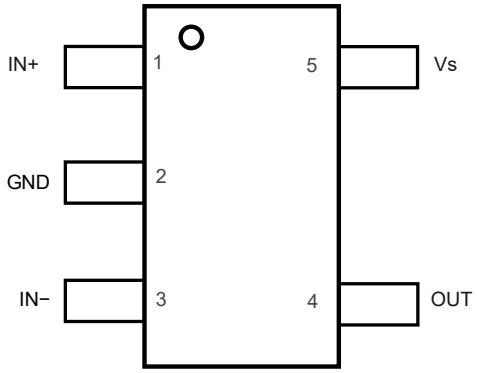


Table 1. Pin Functions: TPA198Q

Pin No.		Name	I/O	Description
TPA198AxQ	TPA198BxQ			
1	4	OUT	O	Output voltage.
2	2	GND		Ground.
3	1	IN+	I	Noninverting input.
4	3	IN−	I	Inverting input.
5	5	V_S		Power supply, 2.7-V to 36-V.

Specifications

Absolute Maximum Ratings (1)

Symbol	Parameter	Min	Max	Unit
	Supply Voltage		42	V
Analog Input, IN+, IN−	Differential (IN+) − (IN−)	−42	42	V
	Common Mode	GND − 0.3	42	V
	Output	GND − 0.3	V_S + 0.3	V
	Input Current into All Pins (2)	−10	10	mA
T_A	Operating Temperature Range	−40	125	°C
T_J	Maximum Junction Temperature		150	°C
T_{STG}	Storage Temperature Range	−65	150	°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.
(2) Input voltage at any pin can exceed the voltage shown if the current at that pin is limited to 10 mA.

ESD, Electrostatic Discharge Protection

Parameter		Condition	Minimum Level	Unit
HBM	Human Body Model ESD	AEC Q100-002	2	kV
CDM	Charged Device Model ESD	AEC Q100-011	1	kV

Recommended Operating Conditions

Parameter		Min	Typ	Max	Unit
V_S	Operating Supply Voltage	2.7		36	V
V_{CM}	Common-Mode Input Voltage	−0.3		36	V
T_A	Operating Free-Air Temperature	−40		125	°C

Thermal Information

Package Type	θ_{JA}	θ_{JC}	Unit
SOT23-5	158	61	°C/W

Electrical Characteristics

All test conditions: T_A = 27°C, V_S = 5 V, V_{IN+} = 12 V, V_{SENSE} = V_{IN+} – V_{IN-}, unless otherwise noted.

Parameter			Conditions	Min	Typ	Max	Unit
Supply Voltage and Current							
V_S	Operating Voltage Range		T_A = −40°C to 125°C	2.7		36	V
I_Q	Quiescent Current		V_{SENSE} = 0 mV, T_A = −40°C to 125°C		160	260	μA
Input							
V_{OS}	Input Offset Voltage		V_{SENSE} = 0 mV, TPA198A1Q, TPA198A2Q, TPA198A3Q	−350	±100	350	μV
			V_{IN+} = 2.75 V, V_{SENSE} = 0 mV, TPA198A1Q	−500	±50	500	
			V_{IN+} = 2.75 V, V_{SENSE} = 0 mV, TPA198A2Q, TPA198A3Q	−150	±50	150	
V_{OS} TC	Input Offset Voltage Drift		T_A = −40°C to 125°C		0.2		μV/°C
V_{CM}	Common-Mode Input Range		T_A = −40°C to 125°C	−0.3		36	V
CMRR	Common Mode Rejection Ratio		V_{IN+} = 0 V to 26 V, V_{SENSE} = 0 mV, T_A = −40°C to 125°C, TPA198A1Q	87	120		dB
			V_{IN+} = 0 V to 26 V, V_{SENSE} = 0 mV, T_A = −40°C to 125°C, TPA198A2Q, TPA198A3Q	90	120		
I_B	Input Bias Current		V_{SENSE} = 0 mV		22	30	μA
I_{OS}	Input Offset Current		V_{SENSE} = 0 mV		±0.05	2	μA
PSRR	Power Supply Rejection Ratio		V_S = 2.7 V to 18 V, V_{IN+} = 18 V, V_{SENSE} = 0 mV, T_A = −40°C to 125°C, TPA198A1Q	91	128		dB
			V_S = 2.7 V to 18 V, V_{IN+} = 18 V, V_{SENSE} = 0 mV, T_A = −40°C to 125°C, TPA198A2Q, TPA198A3Q	97	128		
Output							
G	Gain	TPA198A1Q			20		V/V
		TPA198A2Q			50		
		TPA198A3Q			100		
GE	Gain Error		V_{OUT} = 0.5 V to V_S − 0.5 V, T_A = −40°C to 125°C		±0.05	±1	%
GE TC	Gain Error vs Temperature		T_A = −40°C to 125°C		3	15	ppm/°C
NE	Nonlinearity Error		V_{OUT} = 0.5 V to V_S − 0.5 V		±0.05		%
C_{LOAD}	Maximum Capacitive Load		No sustained oscillation		1		nF

Parameter			Conditions	Min	Typ	Max	Unit
V_{OH}	Output Swing from V_S		R_L = 10 kΩ to V_S / 2, T_A = −40°C to 125°C		0.1	0.15	V
V_{OL}	Output Swing from GND		R_L = 10 kΩ to V_S / 2, T_A = −40°C to 125°C		0.03	0.07	V
Frequency Response							
BW	Bandwidth	TPA198A1Q	C_{LOAD} = 10 pF		270		kHz
		TPA198A2Q			210		
		TPA198A3Q			130		
SR	Slew Rate		T_A = −40°C to 125°C		6		V/μs
Noise, RTI							
e_n	Input Voltage Noise Density		f_{IN} = 1 kHz		40		$\frac{nV}{\sqrt{Hz}}$

Typical Performance Characteristics

All test conditions: T_A = 25°C, V_S = 5 V, V_{IN+} = 12 V, unless otherwise noted.

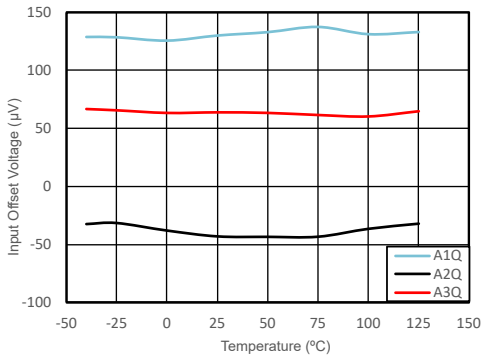


Figure 1. Offset Voltage vs. Temperature

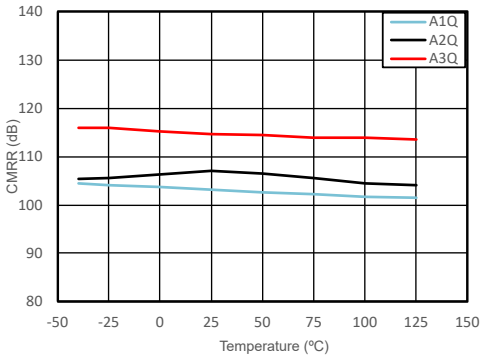


Figure 2. Common-Mode Rejection Ratio vs. Temperature

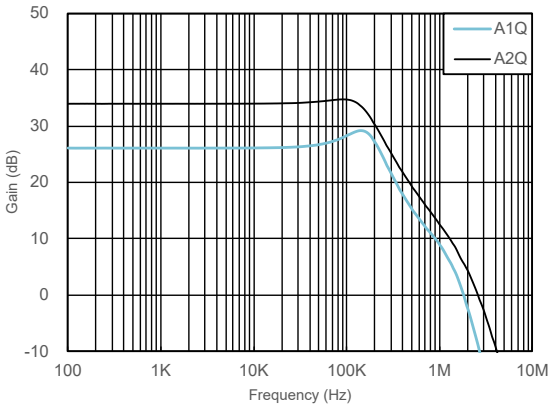


Figure 3. Gain vs. Frequency

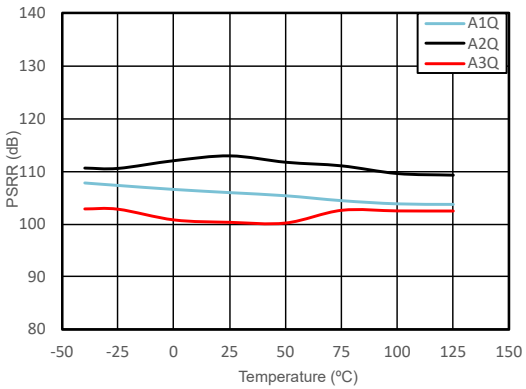


Figure 4. Power-Supply Rejection Ratio vs. Temperature

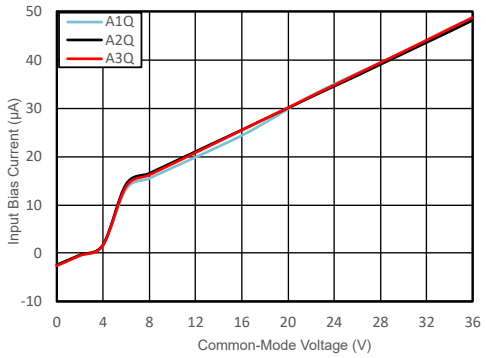


Figure 5. Input Bias Current vs. Common-Mode Voltage

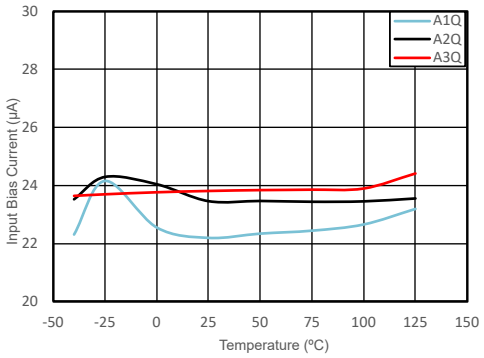


Figure 6. Input Bias Current vs. Temperature

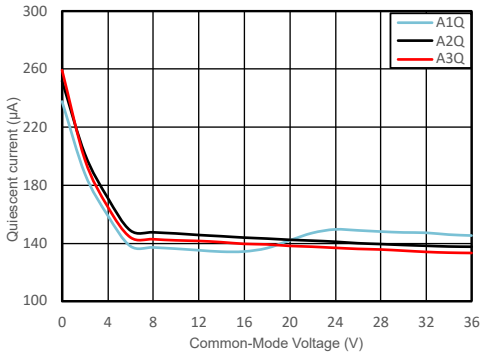


Figure 7. Quiescent Current vs. Common-Mode Voltage

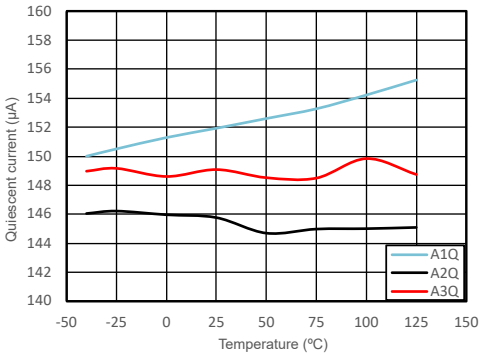


Figure 8. Quiescent Current vs. Temperature

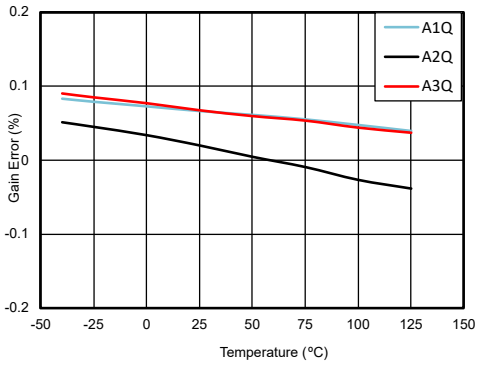


Figure 9. Gain Error vs. Temperature

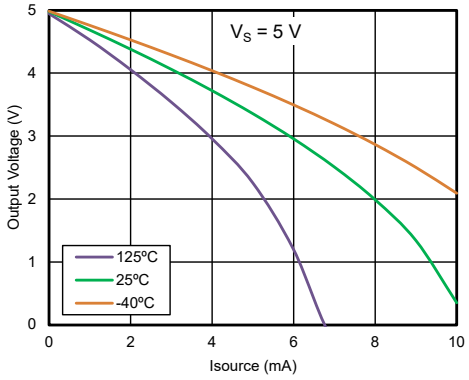


Figure 10. Output Voltage Swing vs. I_{source}

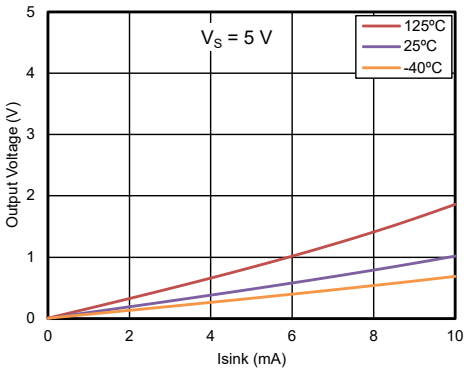


Figure 11. Output Voltage Swing vs. I_{sink}

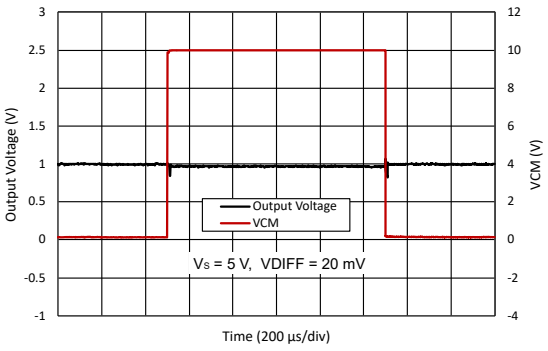


Figure 12. Common-Mode Voltage Transient Response

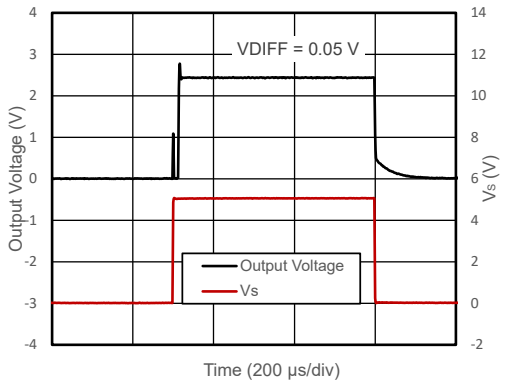


Figure 13. Start-up Response

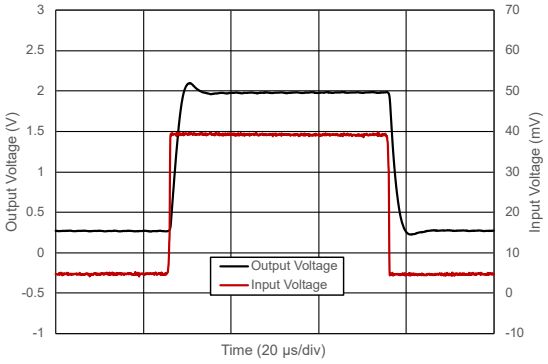


Figure 14. Step Response

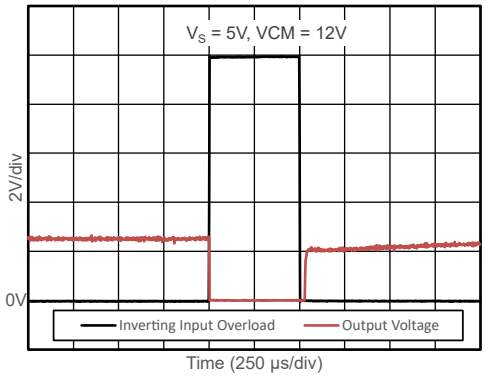


Figure 15. Inverting Differential Input Overload

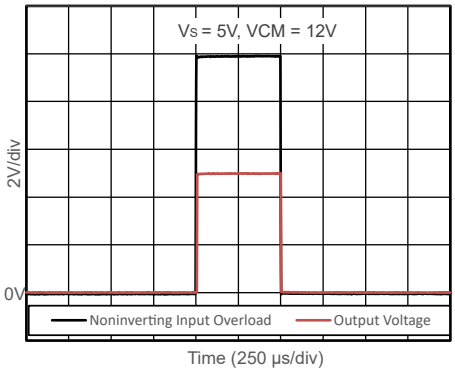


Figure 16. Noninverting Differential Input Overload

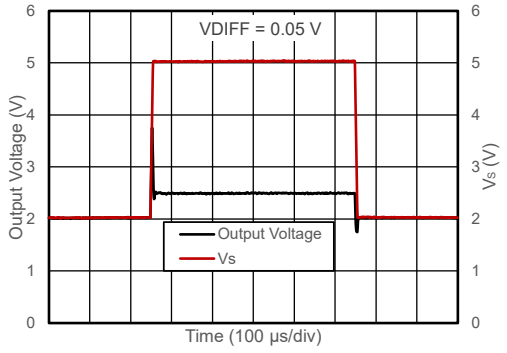


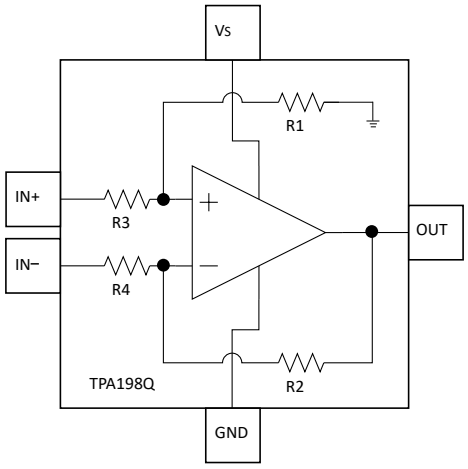
Figure 17. Brownout Recovery

Detailed Description

Overview

The TPA198Q series features a high-accuracy uni-directional, current-sense amplifier in various gain options, and a −0.3-V to 36-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. This feature allows monitoring power-supply load current even when the rail is shorted to ground. 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. Because of its extended common-mode range below ground, the TPA198Q can also be used as a low-side current sensing element.

Functional Block Diagram



PRODUCT	R1 and R2	R3 and R4
TPA198Q	1MΩ	1MΩ/GAIN

Figure 18. Functional Block Diagram

Feature Description

Wide-Input Common-Mode Voltage Range

Because of the internal topology, the TPA198Q supports −0.3-V to 36-V input common-mode voltage that is independent of the supply voltage (V_S). The ability to operate with common-mode voltages greater or less than V_S allows the TPA198Q to be used in high-side and low-side current-sensing applications.

Application and Implementation

> Note
>
> Information in the following application sections is not part of the 3PEAK's component specification and 3PEAK does not warrant its accuracy or completeness. 3PEAK's customers are responsible for determining suitability of components for their purposes. Customers should validate and test their design implementation to confirm system functionality.

Application Information

The TPA198Q monitors the current through a current-sense resistor and amplifies the voltage across the resistor. The 36-V input common-mode voltage range of the TPA198Q is independent of the supply voltage. It is a uni-directional, current-sense amplifier capable of measuring currents through a resistive shunt in one direction.

Typical Application

Figure 19 shows the typical application schematics of unidirectional applications.

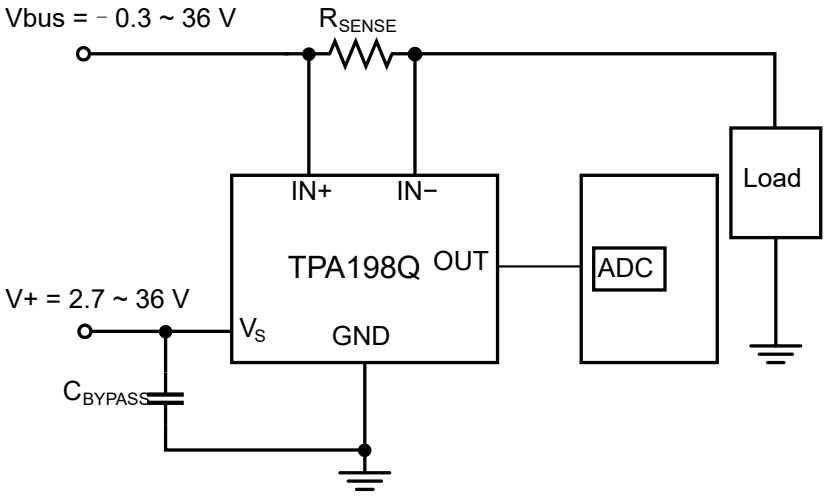


Figure 19. Unidirectional Application Schematic

Choosing the Sense Resistor

A high R_{SENSE} value causes the power-source voltage to drop due to IR loss. For the minimal voltage loss, use the lowest R_{SENSE} value. At high-current levels, the I^2R losses in R_{SENSE} can be significant. This should be taken into consideration when choosing the resistor value and its power dissipation (wattage) rating. The value of the sense resistor drifts if it is allowed to heat up excessively. A high R_{SENSE} value allows lower currents to be measured more accurately because offsets are less significant when the sense voltage is larger. Note that the tolerance and temperature coefficient of the chosen resistors directly affect the precision of any measurement system. For best performance, select R_{SENSE} to provide the approximately maximum input differential sense voltage with full-scale output voltage for each application. Sense resistors of 5 mΩ to 100 mΩ are available with 1% accuracy or better.

Layout

Layout Guideline

- Because the high currents may flow through R_{SENSE} based on the application, take care to eliminate solder and parasitic trace resistance from causing errors in the sense voltage. Either use a four-terminal current sense resistor or use Kelvin (force and sense) PCB layout techniques.
- Ensure that the sense resistor has as much copper trace area as possible to dissipate heat as the resistor value changes slightly with temperature. Also, see the resistor manufacturing datasheet or application notes for further layout guidelines.
- 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

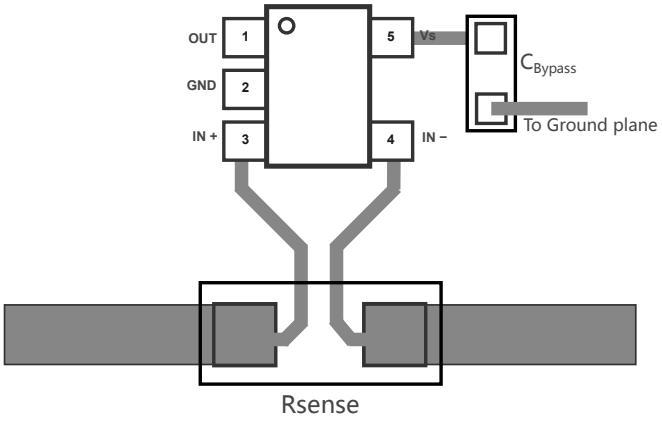


Figure 20. TPA198AxQ Recommended Layout

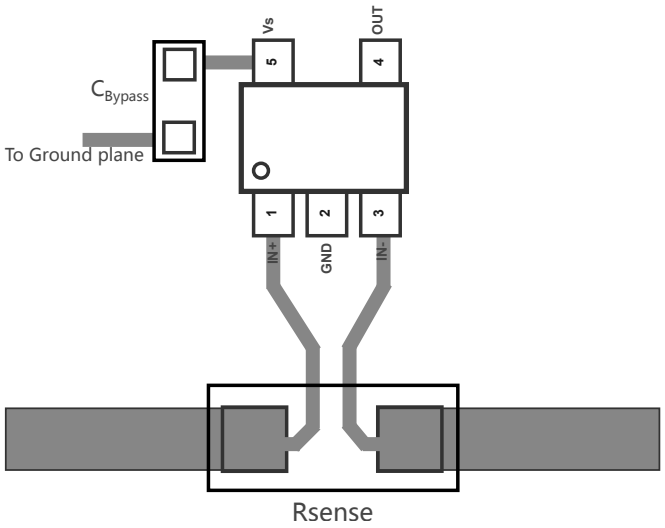
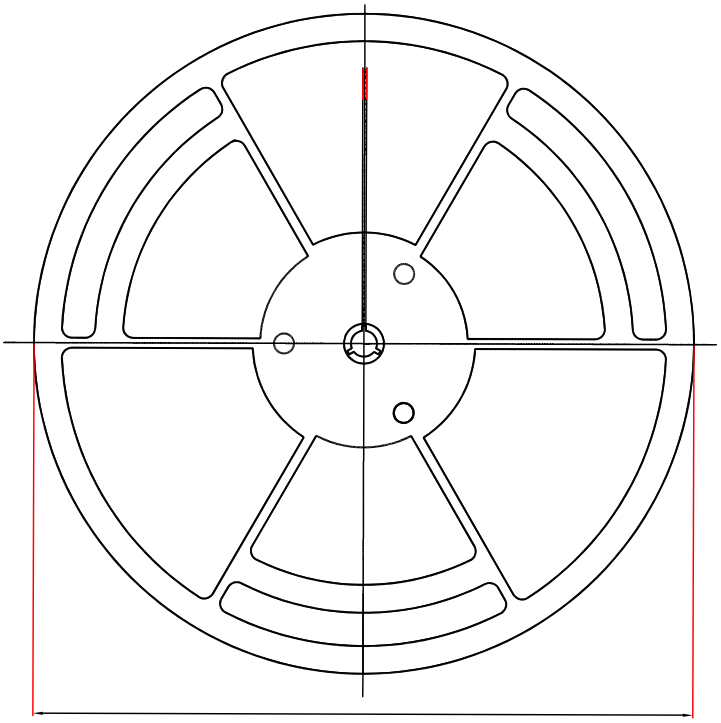
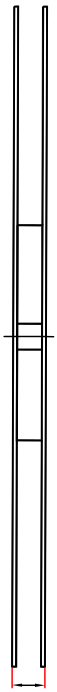
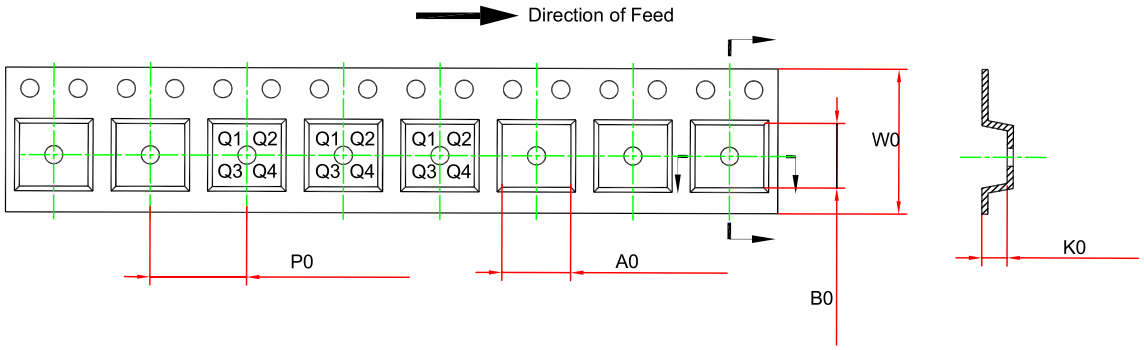


Figure 21. TPA198BxQ Recommended Layout

Tape and Reel Information







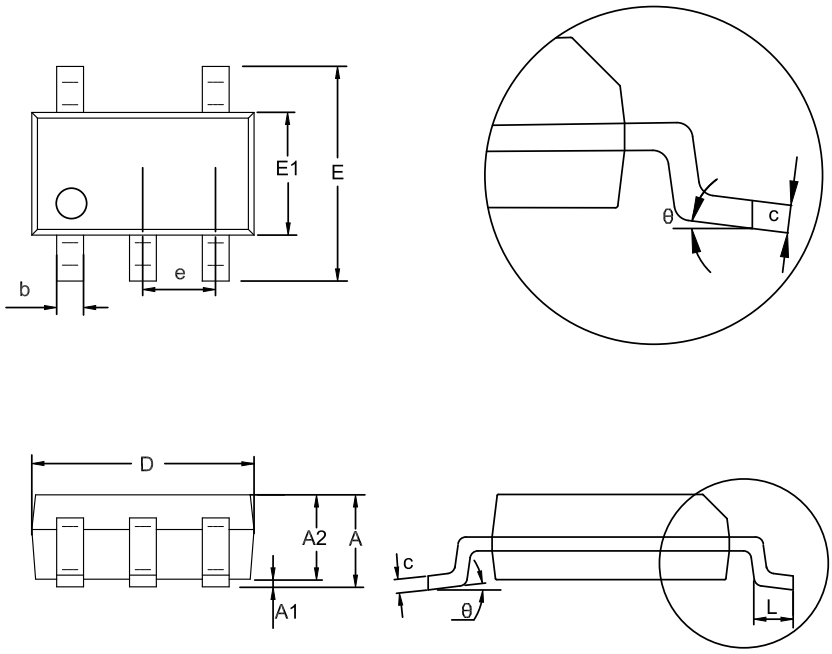
Order Number	Package	D1 (mm)	W1 (mm)	A0 (mm) (1)	B0 (mm) (1)	K0 (mm) (1)	P0 (mm)	W0 (mm)	Pin1 Quadrant
TPA198AxQ-S5TR-S	SOT23-5	180.0	12	3.3	3.25	1.4	4.0	8.0	Q3
TPA198BxQ-S5TR-S	SOT23-5	180.0	12	3.3	3.25	1.4	4.0	8.0	Q3

(1) The value is for reference only. Contact the 3PEAK factory for more information.

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 Option	Operating Temperature Range	Package	Marking Information	MSL	Transport Media, Quantity	Eco Plan
TPA198A1Q-S5TR-S	20	−40 to 125°C	SOT23-5	A9L	1	Tape and Reel, 3000	Green
TPA198A2Q-S5TR-S	50	−40 to 125°C	SOT23-5	A9M	1	Tape and Reel, 3000	Green
TPA198A3Q-S5TR-S (1)	100	−40 to 125°C	SOT23-5	A9N	1	Tape and Reel, 3000	Green
TPA198B1Q-S5TR-S (1)	20	−40 to 125°C	SOT23-5	A9O	1	Tape and Reel, 3000	Green
TPA198B2Q-S5TR-S (1)	50	−40 to 125°C	SOT23-5	A9P	1	Tape and Reel, 3000	Green
TPA198B3Q-S5TR-S(1)	100	−40 to 125°C	SOT23-5	A9Q	1	Tape and Reel, 3000	Green

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

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

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