Zero-Drift, Bi-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
  - TPA192A1Q: 270 kHz
  - TPA192A2Q: 210 kHz
  - TPA192A3Q: 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
  - TPA192A1Q: 20 V/V
  - TPA192A2Q: 50 V/V
  - TPA192A3Q: 100 V/V
- Low Supply Current: 160 μA (Typ)
- Rail-to-Rail Output
- Package: SOT23-6
- 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 TPA192Q is a series of zero-drift, bi-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 TPA192Q 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 SOT23-6 package.

Typical Application Circuit

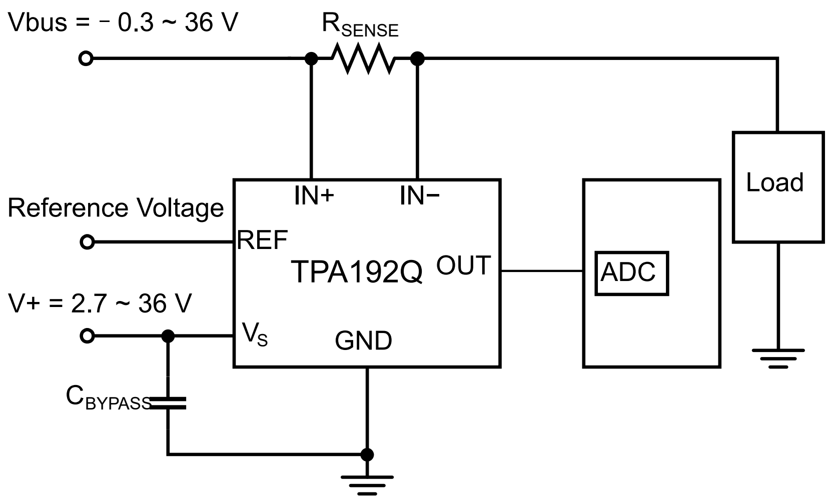


Table of Contents

Revision History

Date	Revision	Notes
2025-08	Rev.A.0	Initial version.
2025-12	Rev.A.1	The following updates are all about the new datasheet formats or typos, and the actual product remains unchanged. • Changed the Typical Bandwidth of TPA192A3Q from "150kHz" to "130kHz". • Added the Typical Performance Characteristics of TPA192A1Q and TPA192A3Q in the figures. • Changed the limit of Vos (VIN+ = 2.75 V) from ±150μV to ±500μV in the Electrical Characteristics: TPA192A1Q. • Changed the minimum value of CMRR from 90dB to 87dB and minimum value of PSRR from 97dB to 91dB in the Electrical Characteristics: TPA192A1Q. • Changed the Minimum Level of CDM from 1.5kV to 1kV.

Pin Configuration and Functions

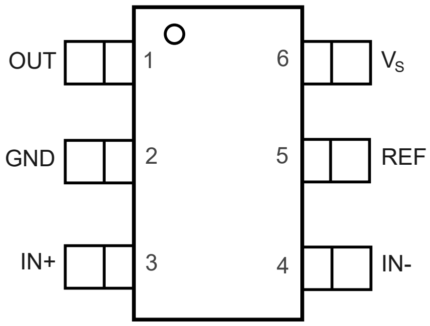


Table 1. Pin Functions: TPA192Q

Pin No.	Pin Name	I/O	Description
1	OUT	O	Output
2	GND		Ground
3	IN+	I	Non-inverting input
4	IN–	I	Inverting input
5	REF	I	Reference voltage
6	V_S	I	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
	REF Input	GND − 0.3	V_S + 0.3	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
SOT23-6	161	64	°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-}, V_{REF} = V_S / 2, 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, TPA192A1Q, TPA192A2Q, TPA192A3Q	−350	±100	350	µV
			V_{IN+} = 2.75 V, V_{SENSE} = 0 mV, TPA192A1Q	−500	±50	500	
			V_{IN+} = 2.75 V, V_{SENSE} = 0 mV, TPA192A2Q, TPA192A3Q	−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, TPA192A1Q	87	120		dB
			V_{IN+} = 0 V to 26 V, V_{SENSE} = 0 mV, T_A = −40°C to 125°C, TPA192A2Q, TPA192A3Q	90	120		dB
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, TPA192A1Q	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, TPA192A2Q, TPA192A3Q	97	128		dB
Output							
G	Gain	TPA192A1Q			20		V/V
		TPA192A2Q			50		
		TPA192A3Q			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 REF, T_A = −40°C to 125°C		0.1	0.15	V
V_{OL}	Output Swing from GND		R_L = 10 kΩ to REF, T_A = −40°C to 125°C		0.03	0.07	V
Frequency Response							
BW	Bandwidth	TPA192A1Q	C_{LOAD} = 10 pF		270		kHz
		TPA192A2Q			210		
		TPA192A3Q			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		nV/√Hz
Reference Input							
	Reference Input Range		V_S = 2.7 V to 5.5 V	0		V_S	V
			V_S = 5.5 V to 36 V	0		5.5	V

Typical Performance Characteristics

All test conditions: T_A = 25°C, V_S = 5 V, V_{IN+} = 12 V, V_{REF} = V_S / 2, unless otherwise noted.

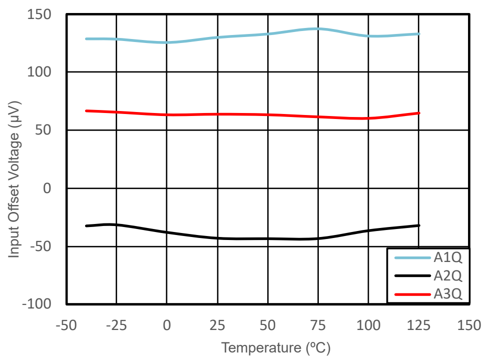


Figure 1. Offset Voltage vs. Temperature

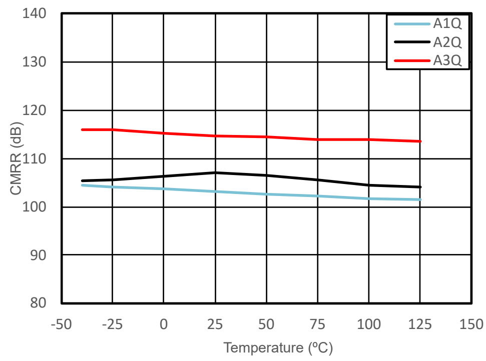


Figure 2. Common-Mode Rejection Ratio vs. Temperature

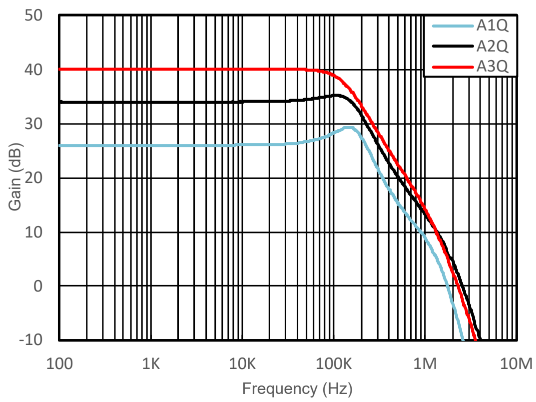


Figure 3. Gain vs. Frequency

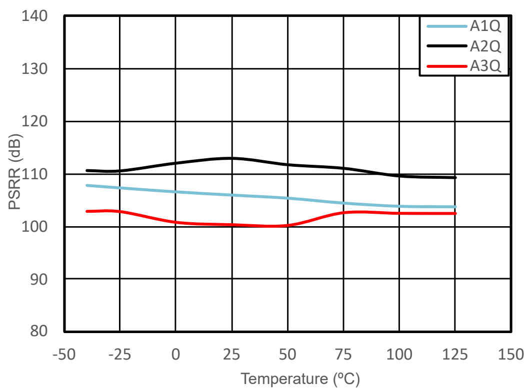


Figure 4. Power-Supply Rejection Ratio vs. Temperature

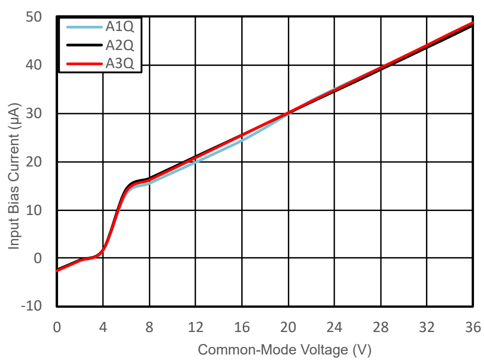


Figure 5. Input Bias Current vs. Common-Mode Voltage

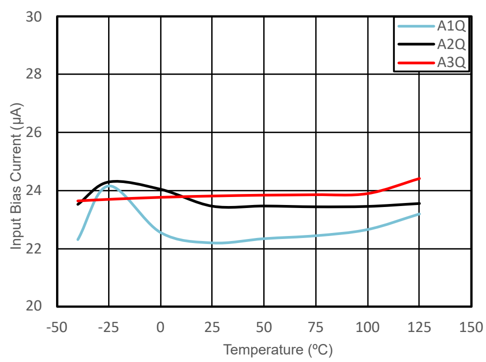


Figure 6. Input Bias Current vs. Temperature

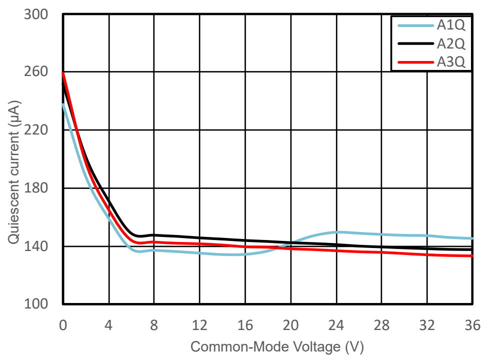


Figure 7. Quiescent Current vs. Common-Mode Voltage

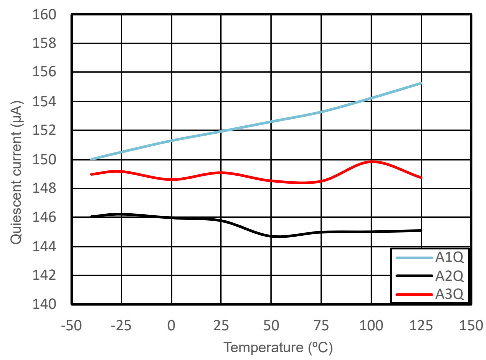


Figure 8. Quiescent Current vs. Temperature

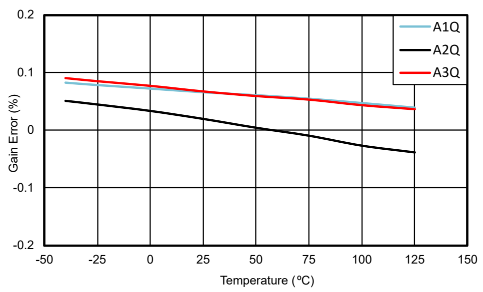


Figure 9. Gain Error vs. Temperature

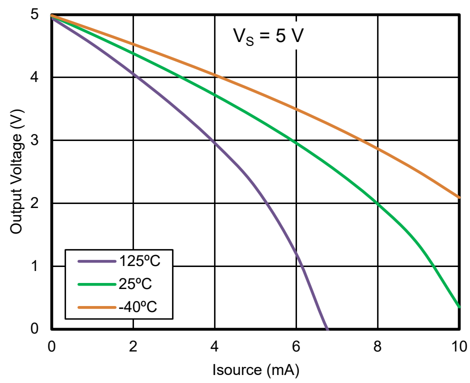


Figure 10. Output Voltage Swing vs. I_{source}

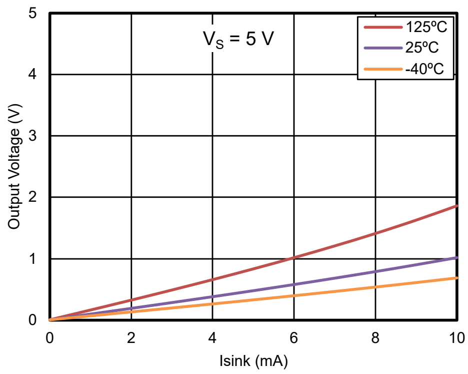


Figure 11. Output Voltage Swing vs. I_{sink}

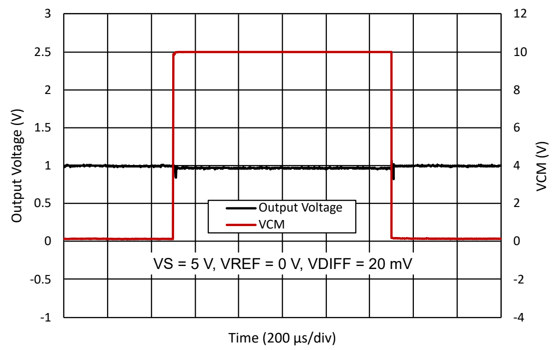


Figure 12. Common-Mode Voltage Transient Response

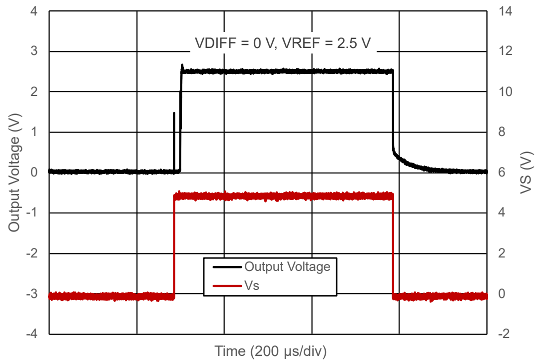


Figure 13. Start-up Response

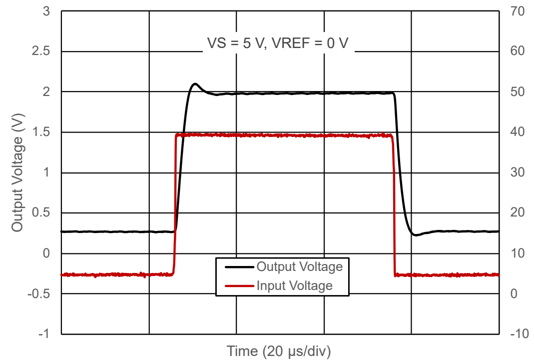


Figure 14. Step Response

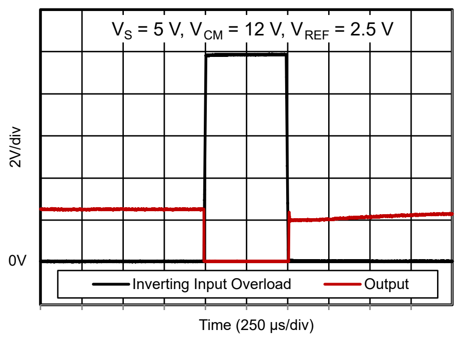


Figure 15. Inverting Differential Input Overload

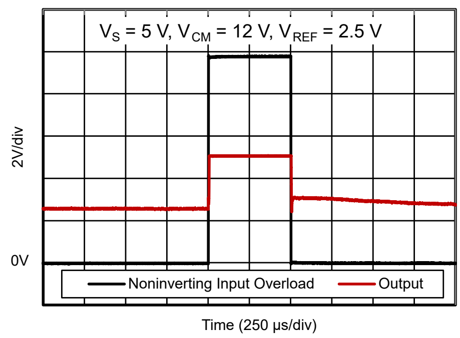


Figure 16. Noninverting Differential Input Overload

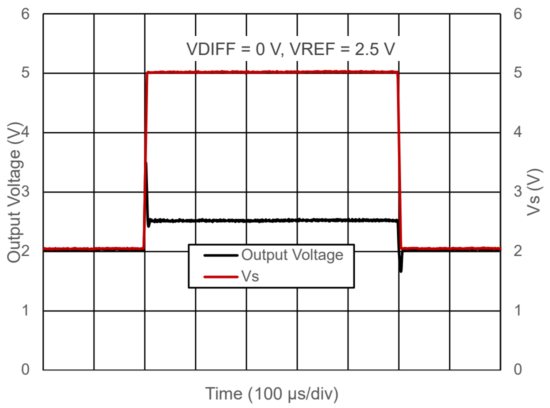


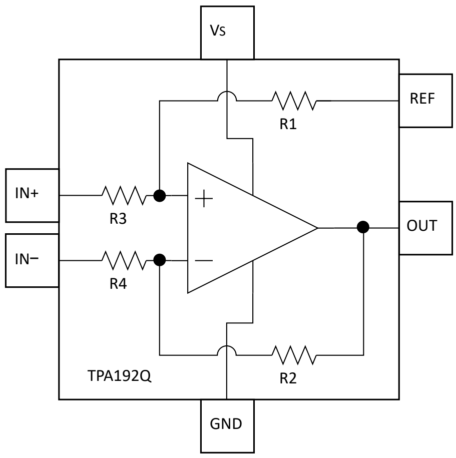
Figure 17. Brownout Recovery

Detailed Description

Overview

The TPA192Q series features a high-accuracy bidirectional, 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 TPA192Q can also be used as a low-side current sensing element.

Functional Block Diagram



PRODUCT	R1 and R2	R3 and R4
TPA192Q	1MΩ	1MΩ/GAIN

Figure 18. Functional Block Diagram

Feature Description

Wide-Input Common-Mode Voltage Range

Because of the internal topology, the TPA192Q 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 TPA192Q to be used in high-side and low-side current-sensing applications.

Reference Input, REF

The TPA192Q supports both unidirectional and bidirectional current-sensing operations. Connecting the reference input (REF) to ground configures the TPA192Q for unidirectional current sensing. For unidirectional current sensing, the output is referenced to ground, and the output voltage V_{OUT} is proportional to the positive voltage drop (V_{SENSE}) from IN+ to IN−. The TPA192Q operates as a bidirectional Current-Sense-Amplifier (CSA) by the application of a low source impedance reference voltage to REF above ground, typically V_S / 2. In the bidirectional current-sensing mode of operation, the output voltage V_{OUT} is referenced to V_{REF}.

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 TPA192Q 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 TPA192Q is independent of the supply voltage. It is a bidirectional, current-sense amplifier capable of measuring currents through a resistive shunt in two directions.

Typical Application

Figure 19 and Figure 20 show the typical application schematics of unidirectional and bidirectional applications.

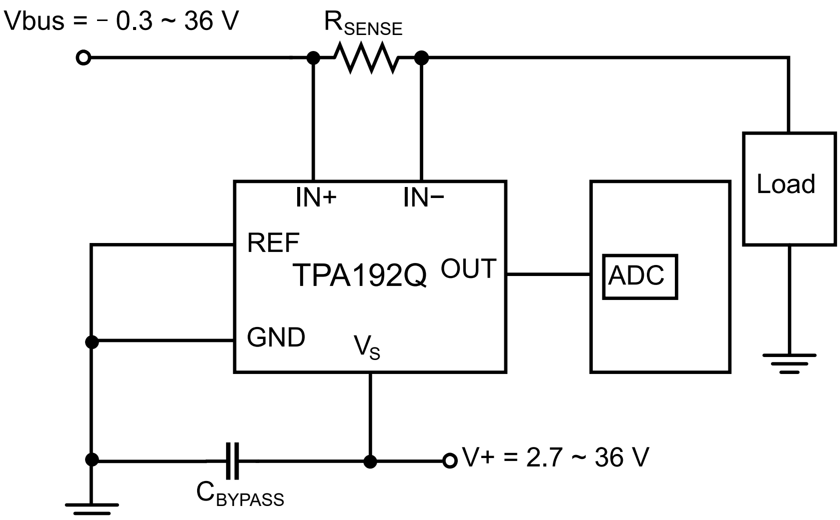


Figure 19. Unidirectional Application Schematic

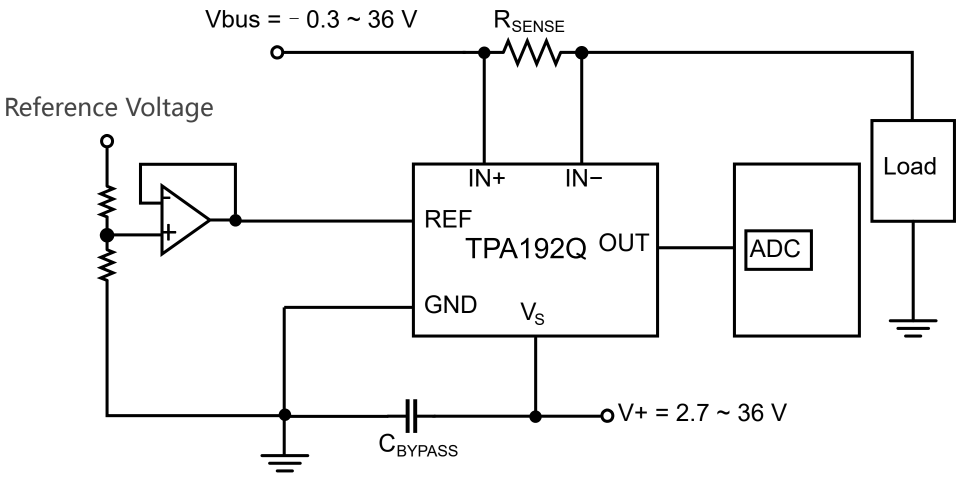


Figure 20. Bidirectional Application Schematic

Bidirectional and Unidirectional Operation

The TPA192Q series is capable of both unidirectional and bidirectional operations. For unidirectional current-sense applications, connect the REF input to GND. For bidirectional, connect REF to a reference. This sets bidirectional current sense with V_{OUT} = V_{REF} for V_{SENSE} = 0 mV. Positive V_{SENSE} causes OUT to swing toward the positive supply, while negative V_{SENSE} causes OUT to swing toward GND. This feature allows the output voltage to measure both charge and discharge currents. Use V_{REF} = V_S / 2 for the maximum dynamic range.

Battery-powered systems require a precise bidirectional current-sense amplifier to accurately monitor the charge and discharge currents of the battery. Measurements of OUT with respect to V_{REF} yield positive and negative voltages during charge and discharge cycles.

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 21 shows the location of external components as they appear on the PCB diagram.

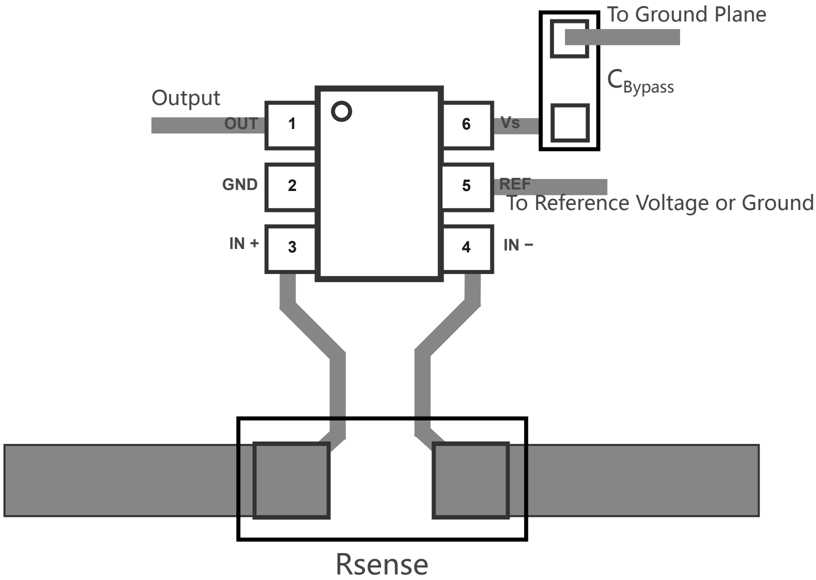
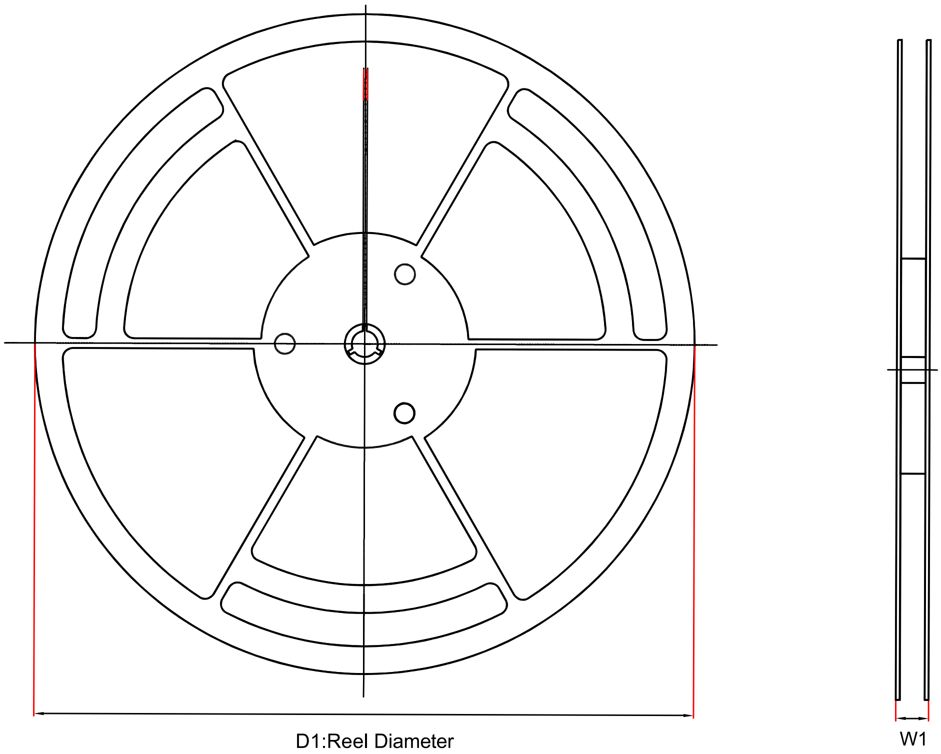
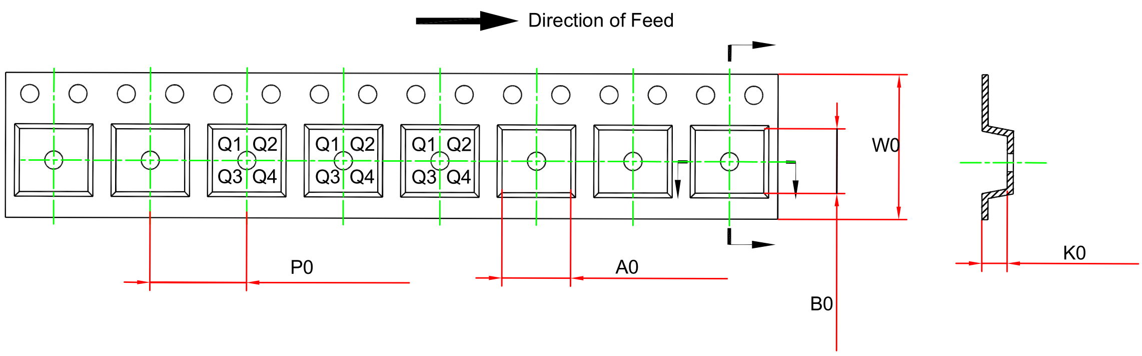


Figure 21. Recommended Layout

Tape and Reel Information





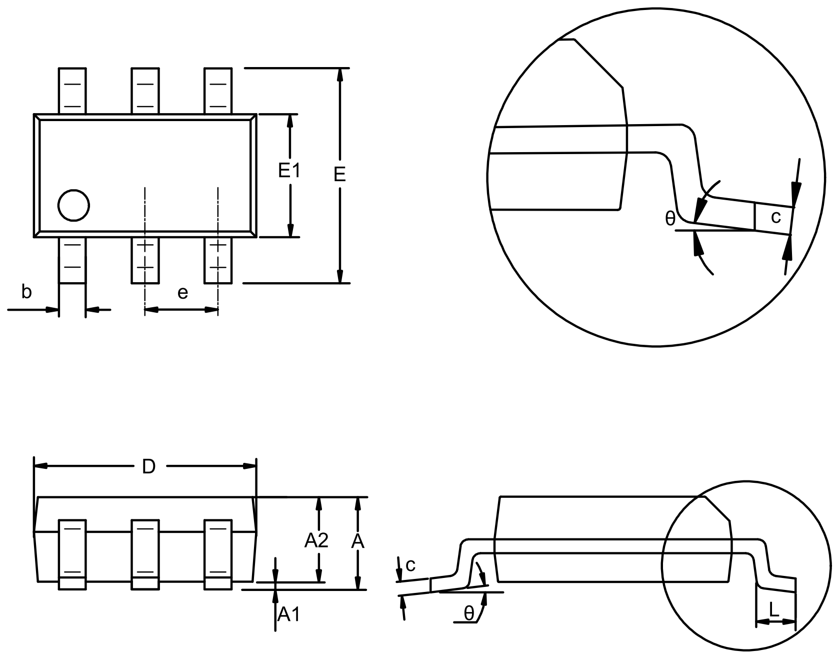
Order Number	Package	D1 (mm)	W1 (mm)	A0 (mm) (1)	B0 (mm) (1)	K0 (mm) (1)	P0 (mm)	W0 (mm)	Pin1 Quadrant
TPA192AxQ-S6TR-S	SOT23-6	180.0	12	3.3	3.2	1.4	4.0	8.0	Q3

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

Package Outline Dimensions

SOT23-6

Package Outline Dimensions S6T(SOT23-6-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.
3. Reference JEDEC MO-178.

Order Information

Order Number	Gain Option	Operating Temperature Range	Package	Marking Information	MSL	Transport Media, Quantity	Eco Plan
TPA192A1Q-S6TR-S (1)	20	−40 to 125°C	SOT23-6	A9I	1	Tape and Reel, 3000	Green
TPA192A2Q-S6TR-S	50	−40 to 125°C	SOT23-6	A9J	1	Tape and Reel, 3000	Green
TPA192A3Q-S6TR-S (1)	100	−40 to 125°C	SOT23-6	A9K	1	Tape and Reel, 3000	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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Performance Information. Performance tests or performance range contained in this document/material are either results of design simulation or actual tests conducted under designated testing environment. Any variation in testing environment or simulation environment, including but not limited to testing method, testing process or testing temperature, may affect actual performance of the product.

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