

Bidirectional, Low-Power, Zero-Drift, Wide Dynamic Range, Precision Current-Sense Amplifier

1 FEATURES

- **Low Input Bias Currents: 1 nA (typ)**
(Enables Microamp Current Measurement)
- **Low Power:**
 - **Low Supply Voltage, V_S : 2.3 V to 5.5 V**
 - **Low Quiescent Current: 70 μ A at 25°C (typ)**
- **Accuracy:**
 - **Common-Mode Rejection Ratio: 120 dB (min)**
 - **Gain Error: $\pm 0.1\%$**
 - **Gain Drift: 15 ppm/°C (max)**
 - **Offset Voltage, V_{OS} : $\pm 30 \mu$ V (max)**
 - **Offset Drift: 0.5 μ V/°C (max)**
- **Wide Common-Mode Voltage: -6 V to +42 V**
- **Bidirectional Current Sensing Capability**
- **Gain Options:**
 - **RSA190A: 25 V/V**
 - **RSA190B: 50 V/V**
 - **RSA190C: 100 V/V**

2 APPLICATIONS

- Standard Notebook PC
- Smartphone
- Consumer Battery Charger
- Baseband Unit (BBU)
- Merchant Network and Server PSU
- Battery Test

3 DESCRIPTIONS

The RSA190 is a low-power, voltage-output, current-shunt monitor (also called a current-sense amplifier). This device is commonly used for overcurrent protection, precision current measurement for system optimization, or in closed-loop feedback circuits. The RSA190 can sense drops across shunts at common-mode voltages from -6 V to +42 V, independent of the supply voltage.

The low input bias current of the device permits the use of larger current-sense resistors, thus providing accurate current measurements in the microamp range. The low offset voltage of the zero-drift architecture extends the dynamic range of the current measurement. This feature allows for smaller sense resistors with lower power loss, while still providing accurate current measurements.

The RSA190 operates from a single 2.3 V to 5.5 V power supply, and draws a maximum of 80 μ A of supply current. Three fixed gain options are available: 25 V/V, 50 V/V or 100 V/V. The device is specified over the operating temperature range of -40°C to +125°C, and offered in SC70-6 packages.

Device Information (1)

PART NUMBER	PACKAGE	BODY SIZE(NOM)
RSA190	SC70-6	2.10mm×1.25mm

(1) For all available packages, see the orderable addendum at the end of the data sheet.

Typical Application

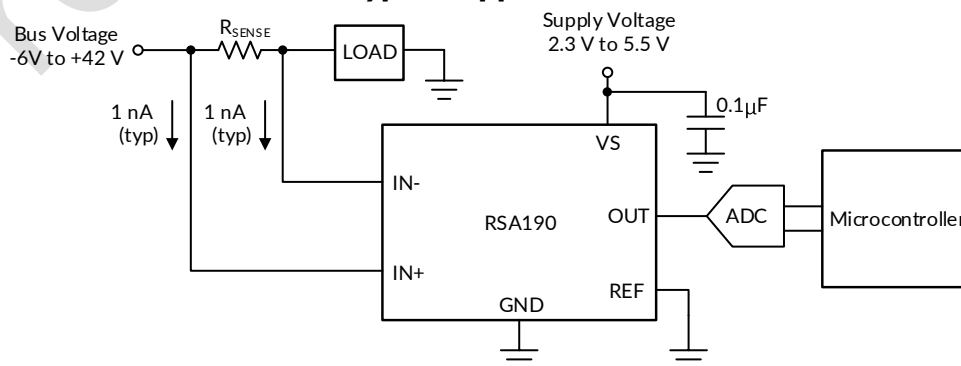


Table of Contents

1 FEATURES	1
2 APPLICATIONS	1
3 DESCRIPTIONS	1
4 REVISION HISTORY	3
5 PACKAGE/ORDERING INFORMATION ⁽¹⁾	4
6 PIN CONFIGURATION AND FUNCTIONS	5
7 SPECIFICATIONS	6
7.1 Absolute Maximum Ratings	6
7.2 ESD Ratings	6
7.3 Electrical Characteristics	7
7.4 Typical Characteristics	8
8 DETAILED DESCRIPTION	12
8.1 Overview	12
8.2 Functional Block Diagram	12
8.3 Feature Description	12
8.3.1 Precision Current Measurement	12
8.3.2 Low Input Bias Current	12
8.3.3 Low Quiescent Current	13
8.3.4 Bidirectional Current Monitoring	13
8.3.5 High-Side and Low-Side Current Sensing	13
8.3.6 High Common-Mode Rejection	14
8.3.7 Rail-to-Rail Output Swing	14
8.4 Device Functional Modes	14
8.4.1 Normal Operation	14
8.4.2 Unidirectional Mode	14
8.4.3 Bidirectional Mode	16
8.4.4 Input Differential Overload	16
9 APPLICATION AND IMPLEMENTATION	17
9.1 Application Information	17
9.1.1 Basic Connections	17
9.1.2 R _{SENSE} and Device Gain Selection	17
9.1.3 Signal Conditioning	18
9.1.4 Common-Mode Voltage Transients	19
9.2 Typical Applications	21
9.2.1 Design Requirements	21
9.2.2 Detailed Design Procedure	21
10 POWER SUPPLY RECOMMENDATIONS	22
11 LAYOUT	22
11.1 Layout Guidelines	22
11.2 Layout Example	22
12 PACKAGE OUTLINE DIMENSIONS	23
13 TAPE AND REEL INFORMATION	24

4 REVISION HISTORY

Note: Page numbers for previous revisions may differ from page numbers in the current version.

Version	Change Date	Change Item
A.0	2025/11/19	Preliminary version completed
A.0.1	2025/12/04	Update Typical Characteristics

Preliminary version

5 PACKAGE/ORDERING INFORMATION ⁽¹⁾

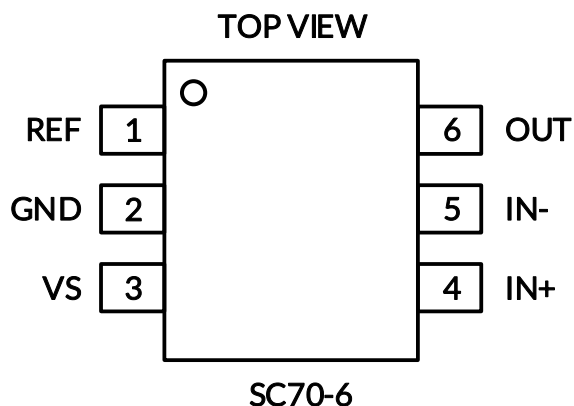
Orderable Device	Package Type	Pin	Channel	Op Temp(°C)	Device Marking ⁽²⁾	MSL ⁽³⁾	Package Qty
RSA190AXC6	SC70-6 ⁽⁴⁾	6	1	-40°C ~125°C	A190A	MSL1	Tape and Reel, 3000
RSA190BXC6	SC70-6 ⁽⁴⁾	6	1	-40°C ~125°C	A190B	MSL1	Tape and Reel, 3000
RSA190CXC6	SC70-6 ⁽⁴⁾	6	1	-40°C ~125°C	A190C	MSL1	Tape and Reel, 3000

NOTE:

- (1) This information is the most current data available for the designated devices. This data is subject to change without notice and revision of this document. For browser-based versions of this data sheet, refer to the right-hand navigation.
- (2) There may be additional marking, which relates to the lot trace code information (data code and vendor code), the logo or the environmental category on the device.
- (3) RUNIC classify the MSL level with using the common preconditioning setting in our assembly factory conforming to the JEDEC industrial standard J-STD-20F. Please align with RUNIC if your end application is quite critical to the preconditioning setting or if you have special requirement.
- (4) Equivalent to SOT363.

Preliminary version

6 PIN CONFIGURATION AND FUNCTIONS



PIN DESCRIPTION

NAME	PIN	TYPE	DESCRIPTION
	SC70-6		
GND	2	Analog	Ground
IN-	5	Analog input	Current-sense amplifier negative input. For high-side applications, connect to load side of sense resistor. For low-side applications, connect to ground side of sense resistor.
IN+	4	Analog input	Current-sense amplifier positive input. For high-side applications, connect to bus voltage side of sense resistor. For low-side applications, connect to load side of sense resistor.
OUT	6	Analog output	OUT pin. This pin provides an analog voltage output that is the gained up voltage difference from the IN+ to the IN- pins, and is offset by the voltage applied to the REF pin.
REF	1	Analog input	Reference input. Enables bidirectional current sensing with an externally applied voltage.
VS	3	Analog	Power supply, 2.3 V to 5.5 V

7 SPECIFICATIONS

7.1 Absolute Maximum Ratings

Over operating free-air temperature range (unless otherwise noted) ⁽¹⁾

PARAMETER	DESCRIPTION		MIN	MAX	UNITS
Voltage	Supply			6	V
	Analog inputs, V_{IN+} , V_{IN-} ⁽²⁾	Differential (V_{IN+}) - (V_{IN-})	-8	8	V
		Common-mode	-6	42	
	REF		GND - 0.3	$V_S + 0.3$	V
Output		GND - 0.3	$V_S + 0.3$	V	
Package thermal impedance, θ_{JA} ⁽³⁾		SC70-6		265	°C/W
Temperature	Operating free-air, T_A		-40	125	°C
	Junction, T_J ⁽⁴⁾			150	°C
	Storage, T_{stg}		-65	150	°C

(1) Stresses above these ratings may cause permanent damage. Exposure to absolute maximum conditions for extended periods may degrade device reliability. These are stress ratings only, and functional operation of the device at these or any other conditions beyond those specified is not implied.

(2) V_{IN+} and V_{IN-} are the voltages at the IN+ and IN- pins, respectively.

(3) The package thermal impedance is calculated in accordance with JESD-51.

(4) The maximum power dissipation is a function of $T_{J(MAX)}$, $R_{\theta JA}$, and T_A . The maximum allowable power dissipation at any ambient temperature is $P_D = (T_{J(MAX)} - T_A) / R_{\theta JA}$. All numbers apply for packages soldered directly onto a PCB.

7.2 ESD Ratings

The following ESD information is provided for handling of ESD-sensitive devices in an ESD protected area only.

			VALUE	UNIT
$V_{(ESD)}$	Electrostatic discharge	Human-Body Model (HBM)	TBD	V
		Charged-Device Model (CDM)	TBD	



ESD SENSITIVITY CAUTION

ESD damage can range from subtle performance degradation to complete device failure. Precision integrated circuits may be more susceptible to damage because very small parametric changes could cause the device not to meet its published specifications.

7.3 Electrical Characteristics

($V_S = 5V$, $V_{SENSE} = V_{IN+} - V_{IN-}$, $V_{CM} = 12V$, $V_{REF1} = V_{REF2} = V_S/2$ and $T_A = -40^\circ C$ to $+125^\circ C$, typical values are measured at $T_A = +25^\circ C$, unless otherwise noted.)

PARAMETER	SYMBOL	CONDITIONS	MIN ⁽¹⁾	TYP ⁽²⁾	MAX ⁽¹⁾	UNITS
INPUT						
Input Common-Mode Voltage	V_{CM}	$V_{IN+} = -6V$ to $42V$, $V_{SENSE} = 0mV$	-6		42	V
Common-Mode Rejection Ratio	CMRR	$V_{IN+} = -6V$ to $42V$, $V_{SENSE} = 0mV$, $T_A = -40^\circ C$ to $+125^\circ C$	120	140		dB
Offset Voltage, Input-Referred	V_{OS}	$V_{SENSE} = 0mV$, $T_A = +25^\circ C$		± 4.5	± 30	μV
Offset drift, RTI	dV_{OS}/dT	$V_{SENSE} = 0mV$, $T_A = -40^\circ C$ to $+125^\circ C$		0.2	0.5	$\mu V/^\circ C$
Power Supply Rejection Ratio	PSRR	$V_S = 2.3V$ to $5.5V$, $V_{SENSE} = 0mV$, $T_A = -40^\circ C$ to $+125^\circ C$		± 1.5	± 10	$\mu V/V$
Input Bias Current	I_B	I_{B+} , I_{B-} , $V_{SENSE} = 0mV$		1		nA
Reference Input Range			0		V_S	V
OUTPUT						
Gain	G	RSA190A		25		V/V
		RSA190B		50		
		RSA190C		100		
Gain Error		$GND + 100mV \leq V_{OUT} \leq V_S - 100mV$, $T_A = +25^\circ C$		± 0.035	± 0.1	%
		$T_A = -40^\circ C$ to $+125^\circ C$		± 7	± 15	ppm/ $^\circ C$
Nonlinearity Error		$GND + 100mV \leq V_{OUT} \leq V_S - 100mV$, $T_A = +25^\circ C$		± 0.09		%
Reference Voltage Rejection Ratio (Input-Referred)	RVRR	RSA190A, $T_A = -40^\circ C$ to $+125^\circ C$		± 3.3	± 15	$\mu V/V$
		RSA190B, $T_A = -40^\circ C$ to $+125^\circ C$		± 1.6	± 5	
		RSA190C, $T_A = -40^\circ C$ to $+125^\circ C$		TBD		
Maximum Capacitive Load		No sustained oscillation		1		nF
VOLTAGE OUTPUT						
Swing to V_S Power Supply Rail		$R_L = 10k\Omega$ to GND	$V_S - 0.02$	$V_S - 0.012$		V
Swing to GND		$R_L = 10k\Omega$ to GND, $V_{SENSE} = 0mV$, $V_{REF1} = V_{REF2} = 0V$		$V_{GND} + 10$	$V_{GND} + 15$	mV
FREQUENCY RESPONSE						
Bandwidth	BW	-3dB bandwidth	RSA190A		TBD	kHz
			RSA190B		83	
			RSA190C		TBD	
Settling Time	t_s	From current step to within 1% of final value		30		μs
Slew Rate	SR			0.7		V/ μs
NOISE (INPUT-REFERRED)						
Voltage Noise Density				120		nV/ \sqrt{Hz}
POWER SUPPLY						
Operating Voltage Range	V_S		2.3		5.5	V
Quiescent Current	I_Q	$V_{SENSE} = 0mV$, $T_A = +25^\circ C$		70	80	μA
		vs. temperature, $T_A = -40^\circ C$ to $+125^\circ C$			90	

NOTE:

- (1) Limits are 100% production tested at $25^\circ C$. Limits over the operating temperature range are ensured through correlations using statistical quality control (SQC) method.
- (2) Typical values represent the most likely parametric norm as determined at the time of characterization. Actual typical values may vary over time and will also depend on the application and configuration.

7.4 Typical Characteristics

NOTE: The graphs and tables provided following this note are a statistical summary based on a limited number of samples and are provided for informational purposes only.

$V_S = 5V$, $V_{SENSE} = V_{IN+} - V_{IN-}$, $V_{CM} = 12V$, $V_{REF1} = V_{REF2} = V_S/2$ (unless otherwise noted)

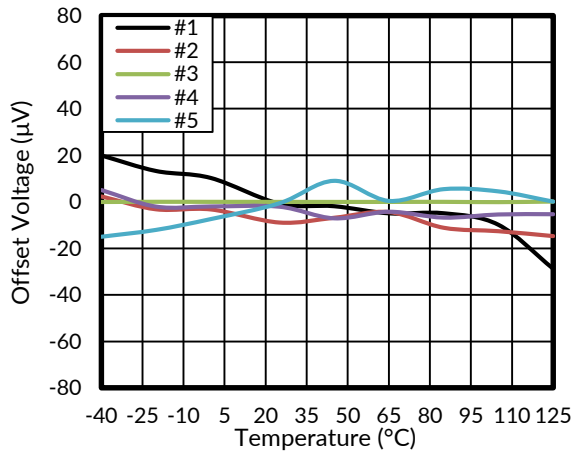


Figure 1. Offset Voltage vs Temperature

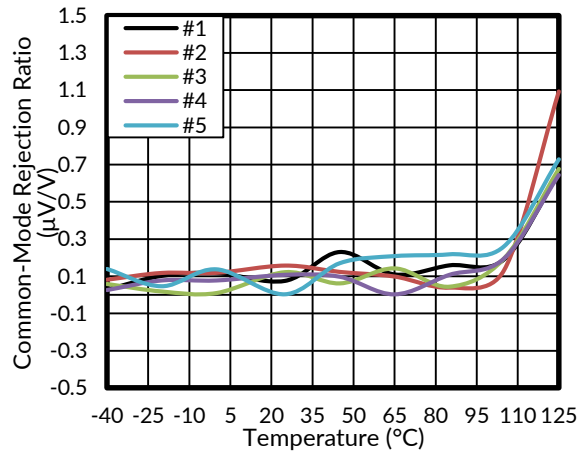


Figure 2. Common-Mode Rejection Ratio vs Temperature

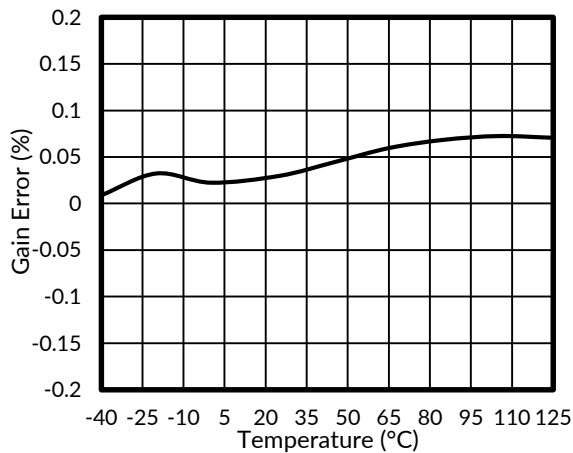


Figure 3. Gain Error vs Temperature

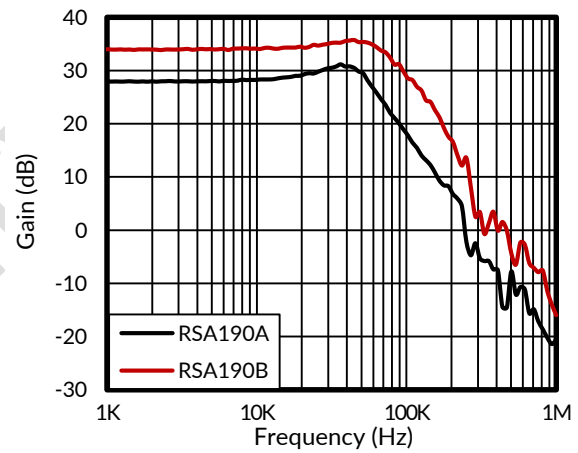


Figure 4. Gain vs Frequency

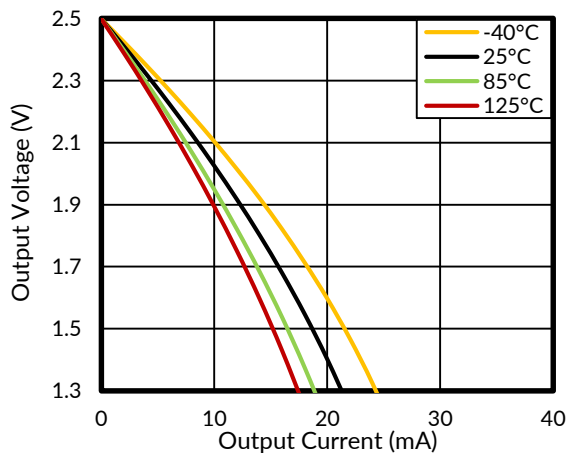


Figure 5. Output Voltage vs Output Current (I_{SOURCE})

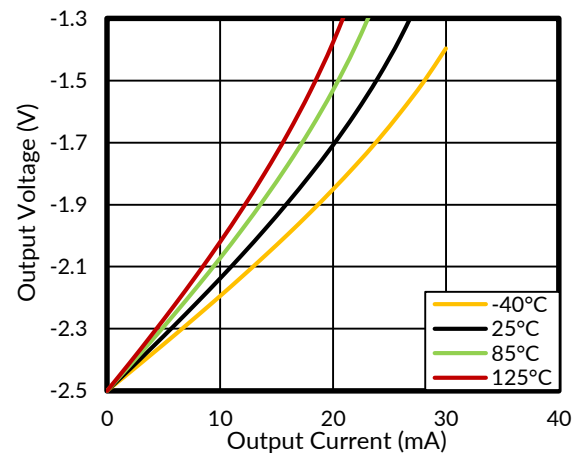


Figure 6. Output Voltage vs Output Current (I_{SINK})

Typical Characteristics

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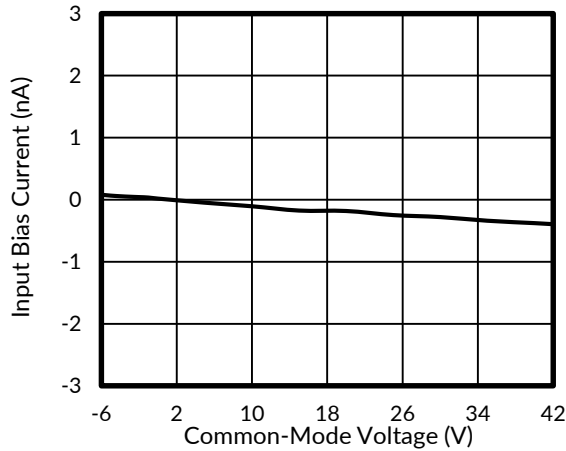


Figure 7. Input Bias Current vs Common Mode Voltage

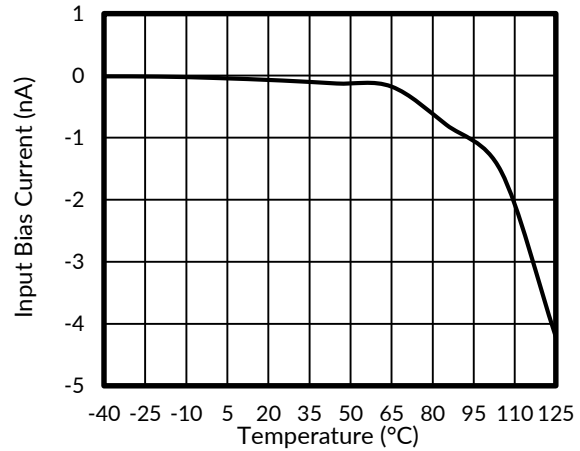


Figure 8. Input Bias Current vs Temperature

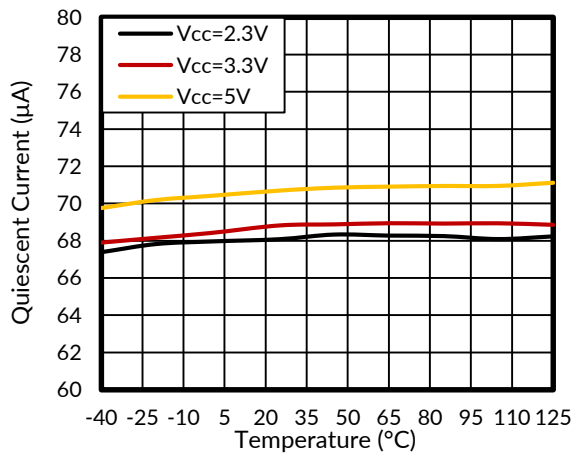


Figure 9. Quiescent Current vs Temperature

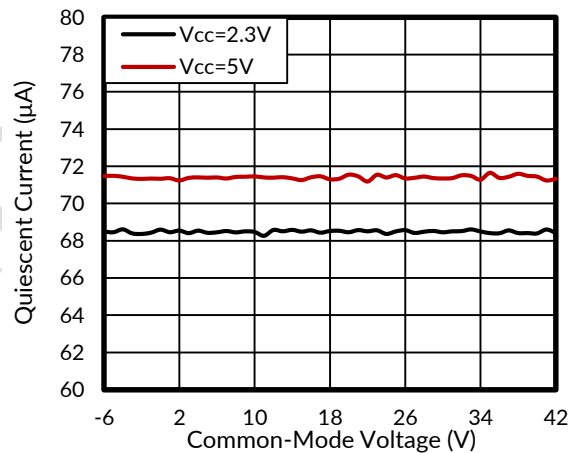


Figure 10. Quiescent Current vs Common Mode Voltage

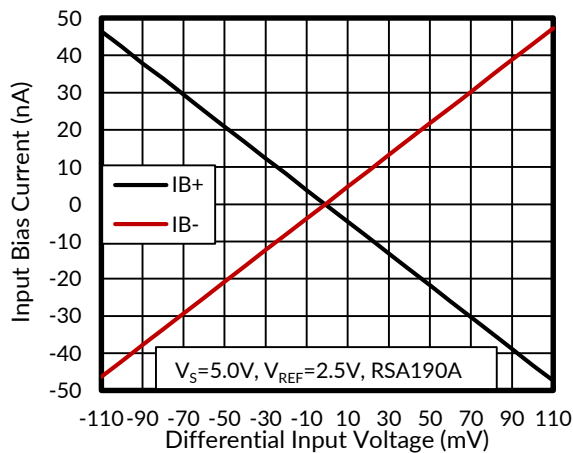


Figure 11. IB+ and IB- vs Differential Input Voltage

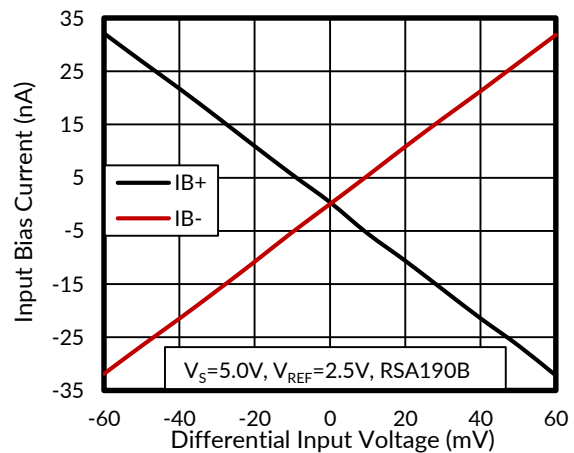


Figure 12. IB+ and IB- vs Differential Input Voltage

Typical Characteristics

NOTE: The graphs and tables provided following this note are a statistical summary based on a limited number of samples and are provided for informational purposes only.

$V_S = 5V$, $V_{SENSE} = V_{IN+} - V_{IN-}$, $V_{CM} = 12V$, $V_{REF1} = V_{REF2} = V_S/2$ (unless otherwise noted)

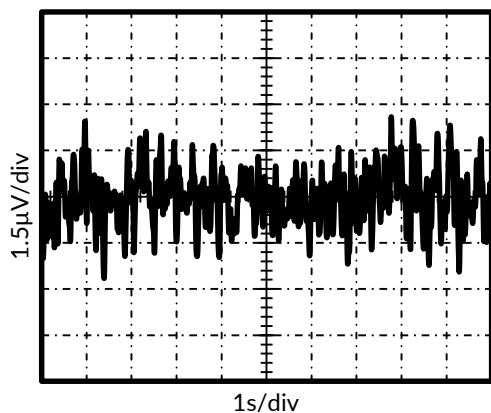


Figure 13. 0.1-Hz to 10-Hz Voltage Noise

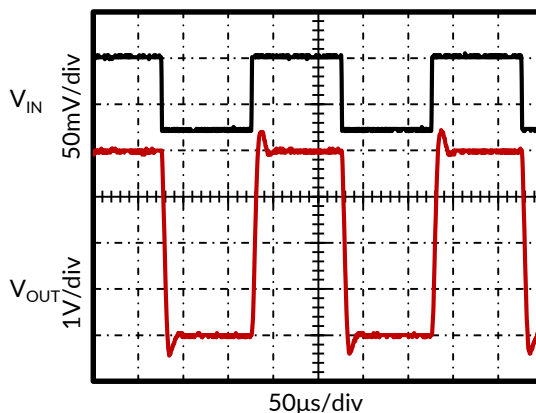


Figure 14. Large Single Step Response

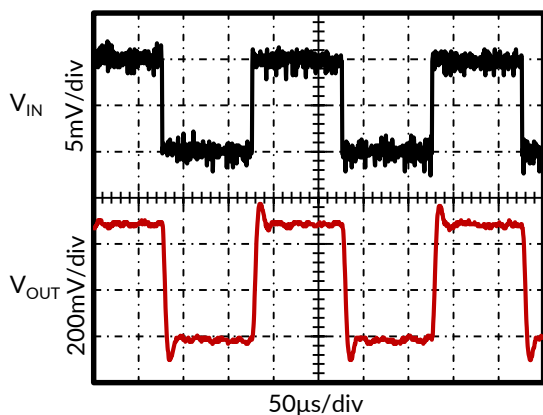


Figure 15. Small Single Step Response

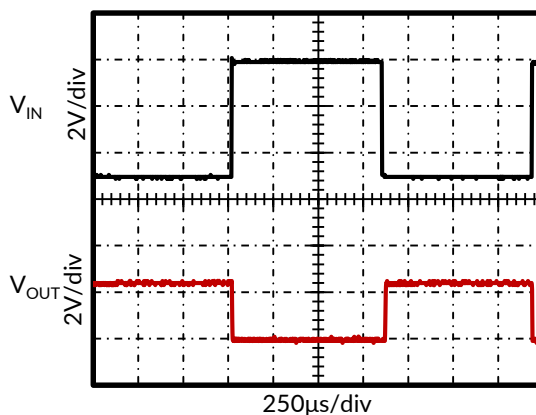


Figure 16. Inverting Differential Input Overload

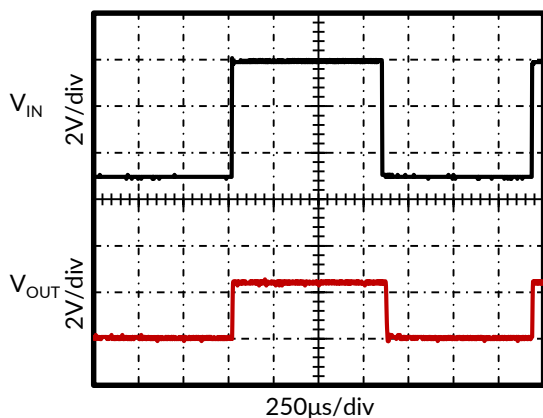


Figure 17. Noninverting Differential Input Overload

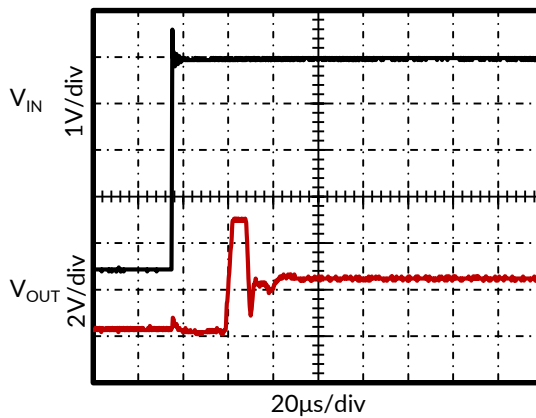


Figure 18. Start-Up Response

Typical Characteristics

NOTE: The graphs and tables provided following this note are a statistical summary based on a limited number of samples and are provided for informational purposes only.

$V_S = 5V$, $V_{SENSE} = V_{IN+} - V_{IN-}$, $V_{CM} = 12V$, $V_{REF1} = V_{REF2} = V_S/2$ (unless otherwise noted)

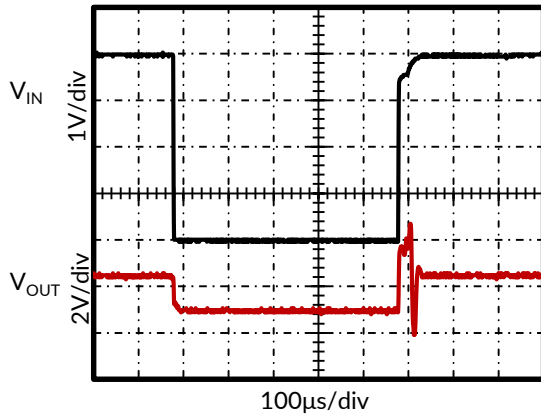


Figure 19. Brownout Recovery

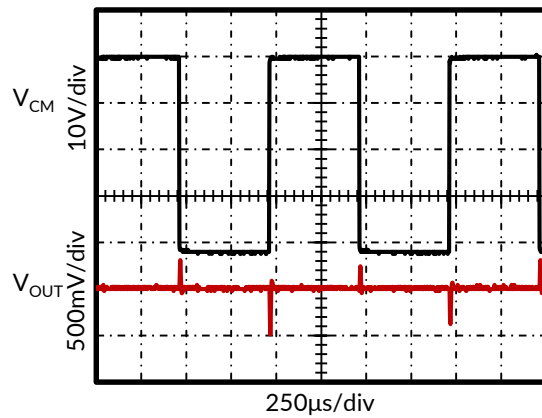


Figure 20. Common-Mode Voltage Transient Response

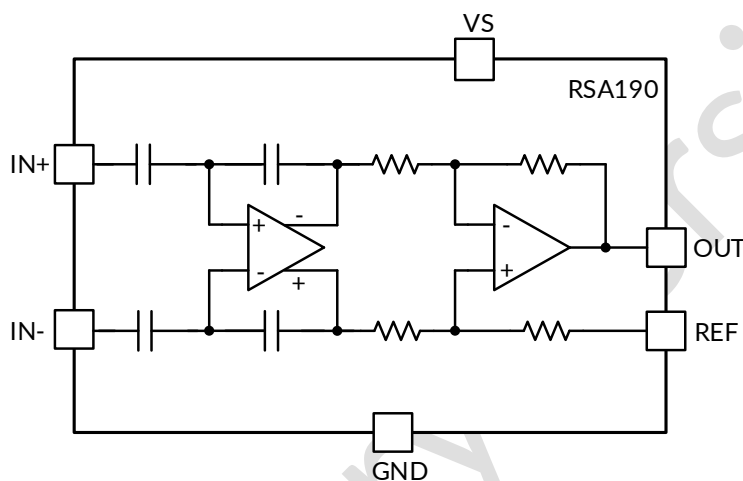
Preliminary V0

8 DETAILED DESCRIPTION

8.1 Overview

The RSA190 is a low bias current, low offset, 42V common-mode, current-sensing amplifier. The RSA190 is a specially designed, current-sensing amplifier that accurately measures voltages developed across current-sensing resistors on common-mode voltages that far exceed the supply voltage. Current is measured on input voltage rails as high as 42 V at V_{IN+} and V_{IN-} , with a supply voltage, V_S , as low as 2.3 V. The RSA190 is intended for use in both low-side and high-side current-sensing configurations where high accuracy and low current consumption are required.

8.2 Functional Block Diagram



8.3 Feature Description

8.3.1 Precision Current Measurement

The RSA190 allows for accurate current measurements over a wide dynamic range. The high accuracy of the device is attributable to the low gain error and offset specifications. The offset voltage of the RSA190 is less than 30 μV . In this case, the low offset improves the accuracy at light loads when V_{IN+} approaches V_{IN-} . Another advantage of low offset is the ability to use a lower-value shunt resistor that reduces the power loss in the current-sense circuit, and improves the power efficiency of the end application.

The maximum gain error of the RSA190 is specified 0.1% of the actual value, depending on the gain option. As the sensed voltage becomes much larger than the offset voltage, the gain error becomes the dominant source of error in the current-sense measurement. When the device monitors currents near the full-scale output range, the total measurement error approaches the value of the gain error.

8.3.2 Low Input Bias Current

The RSA190 is different from many current-sense amplifiers because this device offers very low input bias current. The low input bias current of the RSA190 has three primary benefits.

The first benefit is the reduction of the current consumed by the device in both the enabled and disabled states. Classical current-sense amplifier topologies typically consume tens of microamps of current at the inputs. For these amplifiers, the input current is the result of the resistor network that sets the gain and additional current to bias the input amplifier. To reduce the bias current to near zero, the RSA190 uses a capacitively coupled amplifier on the input stage, followed by a difference amplifier on the output stage.

The second benefit of low bias current is the ability to use input filters to reject high-frequency noise before the signal is amplified. In a traditional current-sense amplifier, the addition of input filters comes at the cost of

reduced accuracy. However, as a result of the low bias currents, input filters have little effect on the measurement accuracy of the RSA190.

The third benefit of low bias current is the ability to use a larger current-sense resistor. This ability allows the device to accurately monitor currents as low as 1 μA .

8.3.3 Low Quiescent Current

The device features low quiescent current (I_Q), while still providing sufficient small-signal bandwidth to be usable in most applications. The quiescent current of the RSA190 is only 70 μA (typ), while providing a small-signal bandwidth of 83 kHz in a gain of 50. The low I_Q and good bandwidth allow the device to be used in many portable electronic systems without excessive drain on the battery.

8.3.4 Bidirectional Current Monitoring

RSA190 devices can sense current flow through a sense resistor in both directions. The bidirectional current-sensing capability is achieved by applying a voltage at the REF pin to offset the output voltage. A positive differential voltage sensed at the inputs results in an output voltage that is greater than the applied reference voltage. Likewise, a negative differential voltage at the inputs results in output voltage that is less than the applied reference voltage. The output voltage of the current-sense amplifier is shown in Equation 1.

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

where

- I_{LOAD} is the load current to be monitored.
- R_{SENSE} is the current-sense resistor.
- GAIN is the gain option of the selected device.
- V_{REF} is the voltage applied to the REF pin.

(1)

8.3.5 High-Side and Low-Side Current Sensing

The RSA190 supports input common-mode voltages from -6 V to $+42\text{ V}$. Because of the internal topology, the common-mode range is not restricted by the power-supply voltage (V_S). The ability to operate with common-mode voltages greater or less than V_S allows the RSA190 to be used in high-side and low-side current-sensing applications, as shown in Figure 21.

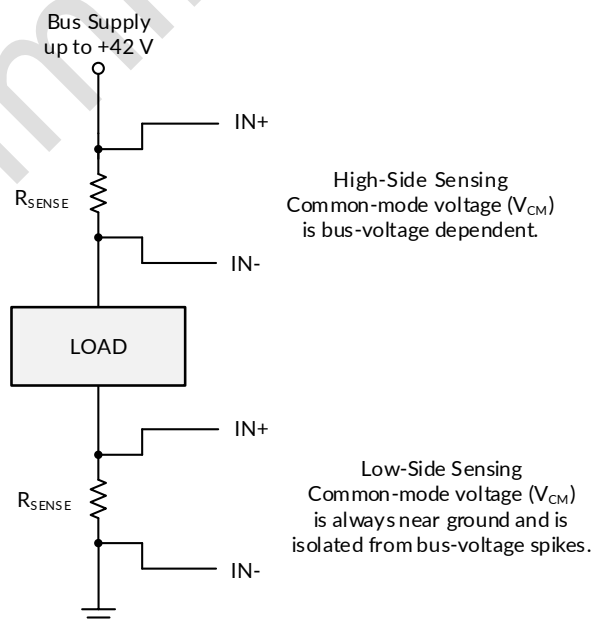


Figure 21. High-Side and Low-Side Sensing Connections

8.3.6 High Common-Mode Rejection

The RSA190 uses a capacitively coupled amplifier on the front end. Therefore, dc common-mode voltages are blocked from downstream circuits, resulting in very high common-mode rejection. Typically, the common-mode rejection of the RSA190 is approximately 140 dB. The ability to reject changes in the dc common-mode voltage allows the RSA190 to monitor both high- and low-voltage rail currents with very little change in the offset voltage.

8.3.7 Rail-to-Rail Output Swing

The RSA190 allows linear current-sensing operation with the output close to the supply rail and ground. The maximum specified output swing to the positive rail is $V_S - 0.02\text{ V}$, and the maximum specified output swing to GND is only $\text{GND} + 15\text{ mV}$. The close-to-rail output swing is useful to maximize the usable output range.

8.4 Device Functional Modes

8.4.1 Normal Operation

The RSA190 is in normal operation when the following conditions are met:

- The power-supply voltage (V_S) is between 2.3 V and 5.5 V.
- The common-mode voltage (V_{CM}) is within the specified range of -6 V to $+42\text{ V}$.
- The maximum differential input signal times the gain plus V_{REF} is less than the positive swing voltage.
- The minimum differential input signal times the gain plus V_{REF} is greater than the zero load swing to GND (see the Rail-to-Rail Output Swing section).

During normal operation, this device produces an output voltage that is the amplified representation of the difference voltage from $IN+$ to $IN-$ plus the voltage applied to the REF pin.

8.4.2 Unidirectional Mode

This device can be configured to monitor current flowing in one direction (unidirectional) or in both directions (bidirectional) depending on how the REF pin is connected. The most common case is unidirectional where the output is set to ground when no current is flowing by connecting the REF pin to ground, as shown in Figure 22. When the current flows from the bus supply to the load, the input voltage from $IN+$ to $IN-$ increases and causes the output voltage at the OUT pin to increase.

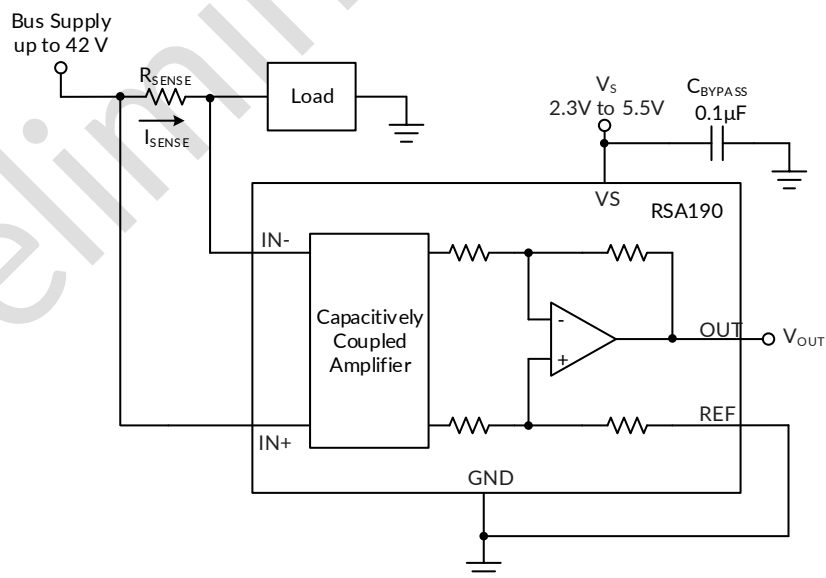


Figure 22. Typical Unidirectional Application

The linear range of the output stage is limited by how close the output voltage can approach ground under zero input conditions. The zero current output voltage of the RSA190 is very small and for most unidirectional applications the REF pin is simply grounded. However, if the measured current multiplied by the current sense

resistor and device gain is less than the zero current output voltage then bias the REF pin to a convenient value above the zero current output voltage to get the output into the linear range of the device. To limit common-mode rejection errors, buffer the reference voltage connected to the REF pin.

A less-frequently used output biasing method is to connect the REF pin to the power-supply voltage, V_s . This method results in the output voltage saturating at 40 mV less than the supply voltage when no differential input voltage is present. This method is similar to the output saturated low condition with no differential input voltage when the REF pin is connected to ground. The output voltage in this configuration only responds to currents that develop negative differential input voltage relative to the device $IN-$ pin. Under these conditions, when the negative differential input signal increases, the output voltage moves downward from the saturated supply voltage. The voltage applied to the REF pin must not exceed V_s .

Another use for the REF pin in unidirectional operation is to level shift the output voltage. Figure 23 shows an application where the device ground is set to a negative voltage so currents biased to negative supplies, as seen in optical networking cards, can be measured. The GND of the RSA190 can be set to negative voltages, as long as the inputs do not violate the common-mode range specification and the voltage difference between V_s and GND does not exceed 5.5 V. In this example, the output of the RSA190 is fed into a positive-biased ADC. By grounding the REF pin, the voltages at the output will be positive and not damage the ADC. To make sure the output voltage never goes negative, the supply sequencing must be the positive supply first, followed by the negative supply.

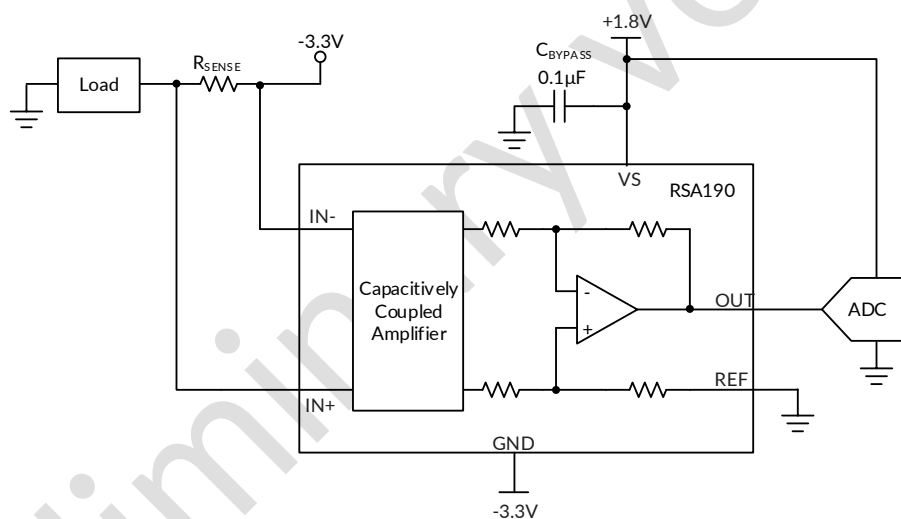


Figure 23. Using the REF Pin to Level-Shift Output Voltage

8.4.3 Bidirectional Mode

The RSA190 devices are bidirectional current-sense amplifiers capable of measuring currents through a resistive shunt in two directions. This bidirectional monitoring is common in applications that include charging and discharging operations where the current flowing through the resistor can change directions.

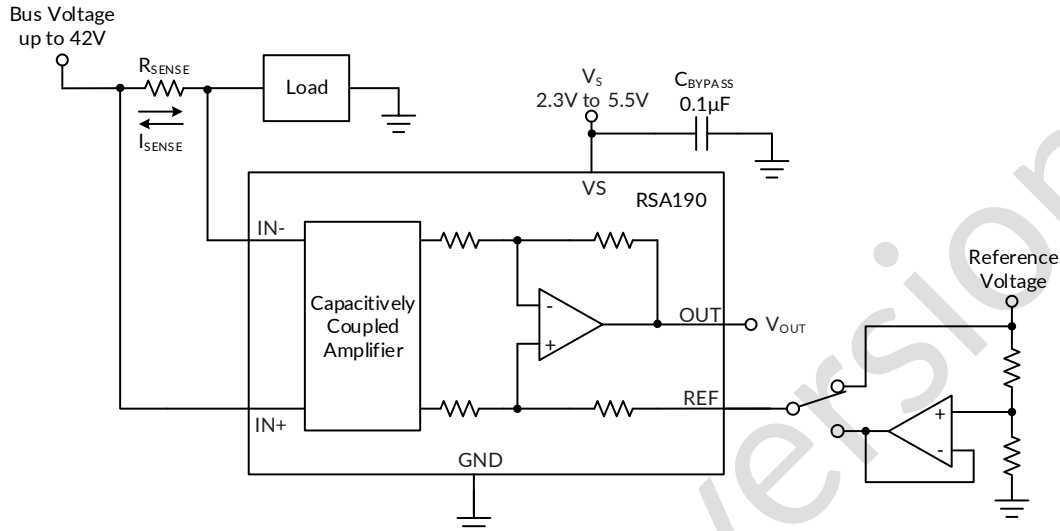


Figure 24. Bidirectional Application

The ability to measure this current flowing in both directions is achieved by applying a voltage to the REF pin, as shown in Figure 24. The voltage applied to REF (V_{REF}) sets the output state that corresponds to the zero-input level state. The output then responds by increasing above V_{REF} for positive differential signals (relative to the IN- pin) and responds by decreasing below V_{REF} for negative differential signals. This reference voltage applied to the REF pin can be set anywhere between 0 V to V_S . For bidirectional applications, V_{REF} is typically set at $V_S/2$ for equal signal range in both current directions. In some cases, V_{REF} is set at a voltage other than $V_S/2$; for example, when the bidirectional current and corresponding output signal do not need to be symmetrical.

8.4.4 Input Differential Overload

If the differential input voltage ($V_{IN+} - V_{IN-}$) times gain exceeds the voltage swing specification, the RSA190 drives its output as close as possible to the positive supply or ground, and does not provide accurate measurement of the differential input voltage. If this input overload occurs during normal circuit operation, then reduce the value of the shunt resistor or use a lower-gain version with the chosen sense resistor to avoid this mode of operation. If a differential overload occurs in a time-limited fault event, then the output of the RSA190 returns to the expected value approximately 80 μ s after the fault condition is removed.

9 APPLICATION AND IMPLEMENTATION

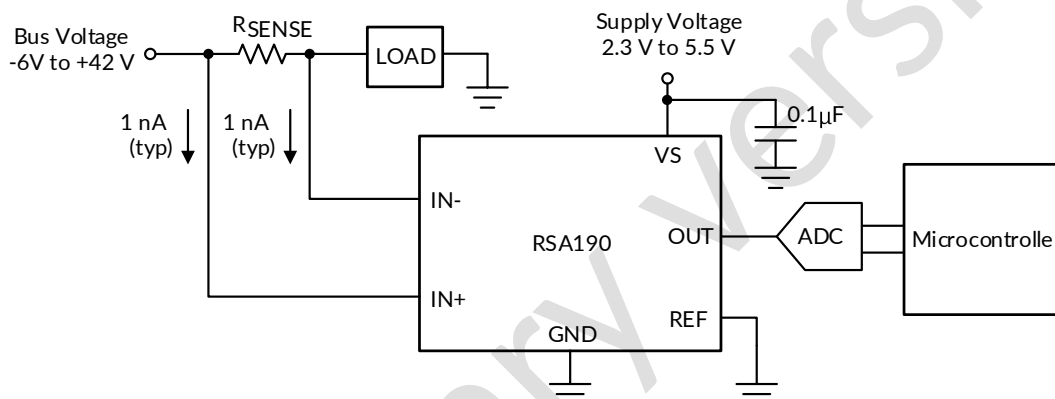
Information in the following applications sections is not part of the RUNIC component specification, and RUNIC does not warrant its accuracy or completeness. RUNIC's customers are responsible for determining suitability of components for their purposes. Customers should validate and test their design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

9.1 Application Information

The RSA190 amplifies the voltage developed across a current-sensing resistor as current flows through the resistor to the load or ground. The high common-mode rejection of the RSA190 make it usable over a wide range of voltage rails while still maintaining an accurate current measurement.

9.1.1 Basic Connections

Figure 25 shows the basic connections of the RSA190. Place the device as close as possible to the current sense resistor and connect the input pins (IN+ and IN-) to the current sense resistor through kelvin connections.



NOTE: To help eliminate ground offset errors between the device and the analog-to-digital converter (ADC), connect the REF pin to the ADC reference input. When driving SAR ADCs, filter or buffer the output of the RSA190 before connecting directly to the ADC.

Figure 25. Basic Connections for the RSA190

9.1.2 R_{SENSE} and Device Gain Selection

The accuracy of any current-sense amplifier is maximized by choosing the current-sense resistor to be as large as possible. A large sense resistor maximizes the differential input signal for a given amount of current flow and reduces the error contribution of the offset voltage. However, there are practical limits as to how large the current-sense resistor can be in a given application because of the resistor size and maximum allowable power dissipation. Equation 2 gives the maximum value for the current-sense resistor for a given power dissipation budget:

$$R_{SENSE} < \frac{PD_{MAX}}{I_{MAX}^2}$$

where:

- PD_{MAX} is the maximum allowable power dissipation in R_{SENSE}.
 - I_{MAX} is the maximum current that will flow through R_{SENSE}.
- (2)

An additional limitation on the size of the current-sense resistor and device gain is due to the power-supply voltage, V_S, and device swing-to-rail limitations. In order to make sure that the current-sense signal is properly passed to the output, both positive and negative output swing limitations must be examined. Equation 3 provides the maximum values of R_{SENSE} and GAIN to keep the device from exceeding the positive swing limitation.

$$I_{MAX} \times R_{SENSE} \times GAIN < V_{SP} - V_{REF}$$

where:

- I_{MAX} is the maximum current that will flow through R_{SENSE} .
 - $GAIN$ is the gain of the current-sense amplifier.
 - V_{SP} is the positive output swing as specified in the data sheet.
 - V_{REF} is the externally applied voltage on the REF pin.
- (3)

To avoid positive output swing limitations when selecting the value of R_{SENSE} , there is always a trade-off between the value of the sense resistor and the gain of the device under consideration. If the sense resistor selected for the maximum power dissipation is too large, then it is possible to select a lower-gain device in order to avoid positive swing limitations.

The negative swing limitation places a limit on how small the sense resistor value can be for a given application. Equation 4 provides the limit on the minimum value of the sense resistor.

$$I_{MIN} \times R_{SENSE} \times GAIN > V_{SN} - V_{REF}$$

where:

- I_{MIN} is the minimum current that will flow through R_{SENSE} .
 - $GAIN$ is the gain of the current-sense amplifier.
 - V_{SN} is the negative output swing of the device (see Rail-to-Rail Output Swing).
 - V_{REF} is the externally applied voltage on the REF pin.
- (4)

In addition to adjusting R_{SENSE} and the device gain, the voltage applied to the REF pin can be slightly increased above GND to avoid negative swing limitations.

9.1.3 Signal Conditioning

When performing accurate current measurements in noisy environments, the current-sensing signal is often filtered. The RSA190 features low input bias currents. Therefore, adding a differential mode filter to the input without sacrificing the current-sense accuracy is possible. Filtering at the input is advantageous because this action attenuates differential noise before the signal is amplified. Figure 26 provides an example of how to use a filter on the input pins of the device.

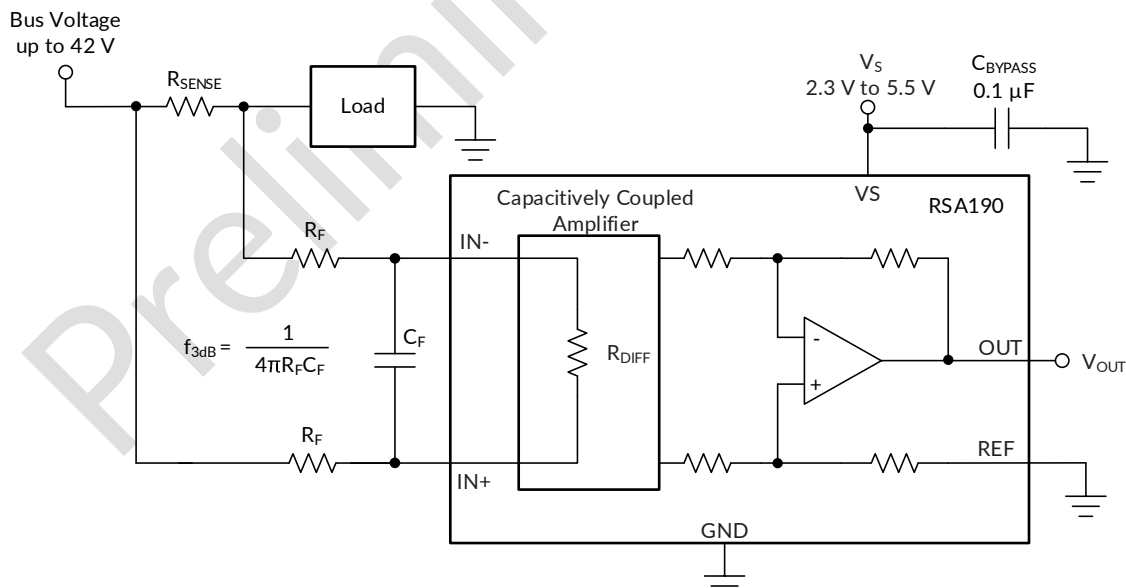


Figure 26. Filter at the Input Pins

The differential input impedance (R_{DIFF}) shown in Figure 26 limits the maximum value for R_F .

As the voltage drop across the sense resistor (V_{SENSE}) increases, the amount of voltage dropped across the input filter resistors (R_F) also increases. The increased voltage drop results in additional gain error. The error caused by these resistors is calculated by the resistor divider equation shown in Equation 5.

$$\text{Error (\%)} = \left(1 - \frac{R_{\text{DIFF}}}{R_{\text{SENSE}} + R_{\text{DIFF}} + (2 \times R_F)} \right) \times 100$$

where:

- R_{DIFF} is the differential input impedance.
- R_F is the added value of the series filter resistance. (5)

The input stage of the RSA190 uses a capacitive feedback amplifier topology in order to achieve high dc precision. As a result, periodic high-frequency shunt voltage (or current) transients of significant amplitude (10 mV or greater) and duration (hundreds of nanoseconds or greater) may be amplified by the RSA190, even though the transients are greater than the device bandwidth. Use a differential input filter in these applications to minimize disturbances at the RSA190 output.

The high input impedance and low bias current of the RSA190 provide flexibility in the input filter design without impacting the accuracy of current measurement. For example, set $R_F = 100 \Omega$ and $C_F = 22 \text{ nF}$ to achieve a low-pass filter corner frequency of 36.2 kHz. These filter values significantly attenuate most unwanted high-frequency signals at the input without severely impacting the current sensing bandwidth or precision. If a lower corner frequency is desired, increase the value of C_F .

Filtering the input filters out differential noise across the sense resistor. If high-frequency, common-mode noise is a concern, add an RC filter from the OUT pin to ground. The RC filter helps filter out both differential and common mode noise, as well as, internally generated noise from the device. The value for the resistance of the RC filter is limited by the impedance of the load. Any current drawn by the load manifests as an external voltage drop from the RSA190 OUT pin to the load input.

9.1.4 Common-Mode Voltage Transients

With a small amount of additional circuitry, the RSA190 can be used in circuits subject to transients that exceed the absolute maximum voltage ratings. The most simple way to protect the inputs from negative transients is to add resistors in series to the IN- and IN+ pins. Use resistors that are 1 k Ω or less, and limit the current in the ESD structures to less than 5 mA. For example, using 1 k Ω resistors in series with the RSA190 allows voltages as low as -5 V, while limiting the ESD current to less than 5 mA. If protection from high-voltage or more-negative, common-voltage transients is needed, use the circuits shown in Figure 27 and Figure 28. When implementing these circuits, use only Zener diodes or Zener-type transient absorbers (sometimes referred to as transzorbis); any other type of transient absorber has an unacceptable time delay. Start by adding a pair of resistors as a working impedance for the Zener diode, as shown in Figure 27. Keep these resistors as small as possible; most often, use around 100 Ω . Larger values can be used with an effect on gain that is discussed in the Signal Conditioning section. This circuit limits only short-term transients; therefore, many applications are satisfied with a 100 Ω resistor along with conventional Zener diodes of the lowest acceptable power rating. This combination uses the least amount of board space.

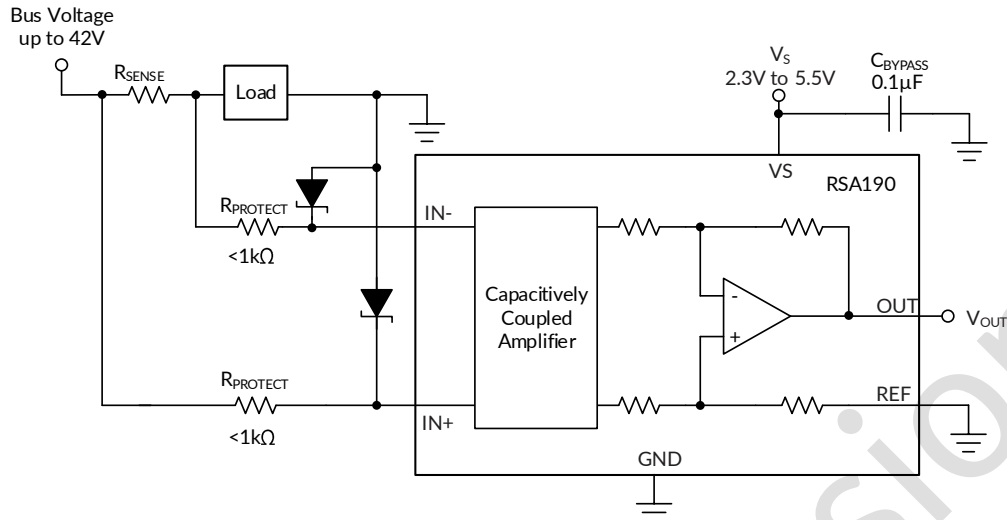


Figure 27. Transient Protection Using Dual Zener Diodes

In the event that low-power Zener diodes do not have sufficient transient absorption capability, a higher-power transzorb must be used. The most package-efficient solution involves using a single transzorb and back-to-back diodes between the device inputs, as shown in Figure 28. The most space-efficient solutions are dual, series-connected diodes.

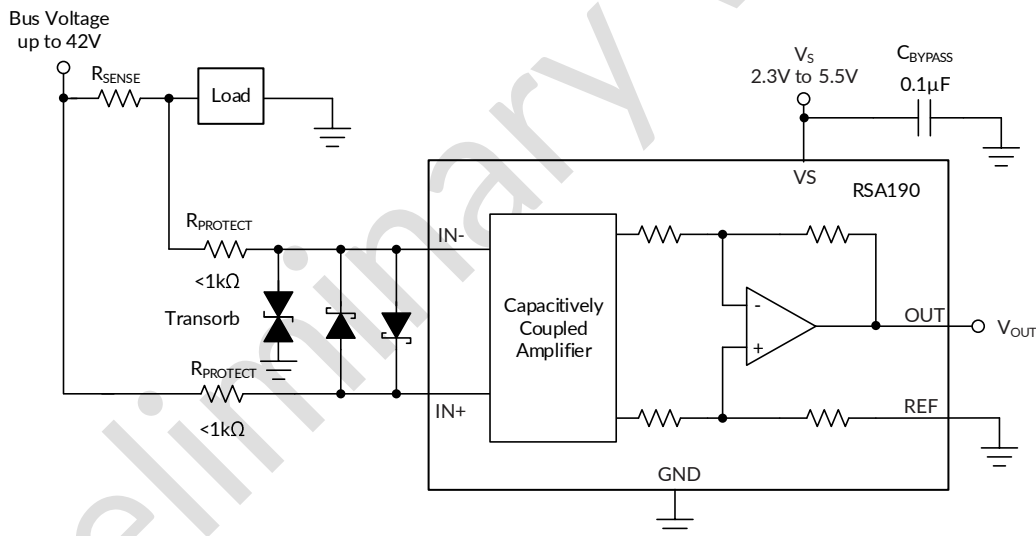


Figure 28. Transient Protection Using a Single Transzorb and Input Clamps

9.2 Typical Applications

The low input bias current of the RSA190 allows accurate monitoring of small-value currents. To accurately monitor currents in the microamp range, increase the value of the sense resistor to increase the sense voltage so that the error introduced by the offset voltage is small. The circuit configuration for monitoring low-value currents is shown in Figure 29. As a result of the differential input impedance of the RSA190, limit the value of R_{SENSE} to 1 k Ω or less for best accuracy.

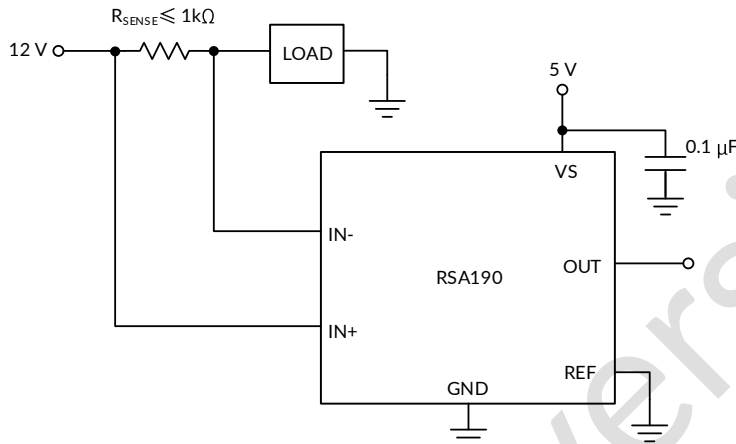


Figure 29. Microamp Current Measurement

9.2.1 Design Requirements

The design requirements for the circuit shown in Figure 29 are listed in Table 1.

Table 1. Design Parameters

DESIGN PARAMETER	EXAMPLE VALUE
Power-supply voltage (V_S)	5 V
Bus supply rail (V_{CM})	12 V
Minimum sense current (I_{MIN})	1 μ A
Maximum sense current (I_{MAX})	150 μ A
Device gain (GAIN)	25 V/V
Reference voltage (V_{REF})	0 V
Amplifier current in sleep or disabled state	<1 μ A

9.2.2 Detailed Design Procedure

The maximum value of the current-sense resistor is calculated based choice of gain, value of the maximum current the be sensed (I_{MAX}), and the power supply voltage (V_S). When operating at the maximum current, the output voltage must not exceed the positive output swing specification, V_{SP} . Using Equation 6, for the given design parameters the maximum value for R_{SENSE} is calculated to be 1.328 k Ω .

$$R_{SENSE} < \frac{V_{SP}}{I_{MAX} \times GAIN} \quad (6)$$

However, because this value exceeds the maximum recommended value for R_{SENSE} , a resistance value of 1 k Ω must be used. When operating at the minimum current value, I_{MIN} the output voltage must be greater than the swing to GND (V_{SN}), specification. For this example, the output voltage at the minimum current is calculated using Equation 7 to be 25 mV, which is greater than the value for V_{SN} .

$$V_{OUTMIN} = I_{MIN} \times R_{SENSE} \times GAIN \quad (7)$$

10 POWER SUPPLY RECOMMENDATIONS

The input circuitry of the RSA190 accurately measures beyond the power-supply voltage, V_s . For example, V_s can be 5 V, whereas the bus supply voltage at $IN+$ and $IN-$ can be as high as 42 V. However, the output voltage range of the OUT pin is limited by the voltage on the VS pin. The RSA190 also withstands the full differential input signal range up to 8 V at the $IN+$ and $IN-$ input pins, regardless of whether the device has power applied at the VS pin. There is no sequencing requirement for VS and V_{IN+} or V_{IN-} .

11 LAYOUT

11.1 Layout Guidelines

- 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 ohmic value of the current resistor, any additional high-current carrying impedance can cause significant measurement errors.
- Place the power-supply bypass capacitor as close as possible to the device power supply and ground pins. 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.
- When routing the connections from the current-sense resistor to the device, keep the trace lengths as short as possible. The input filter capacitor C_F should be placed as close as possible to the input pins of the device.

11.2 Layout Example

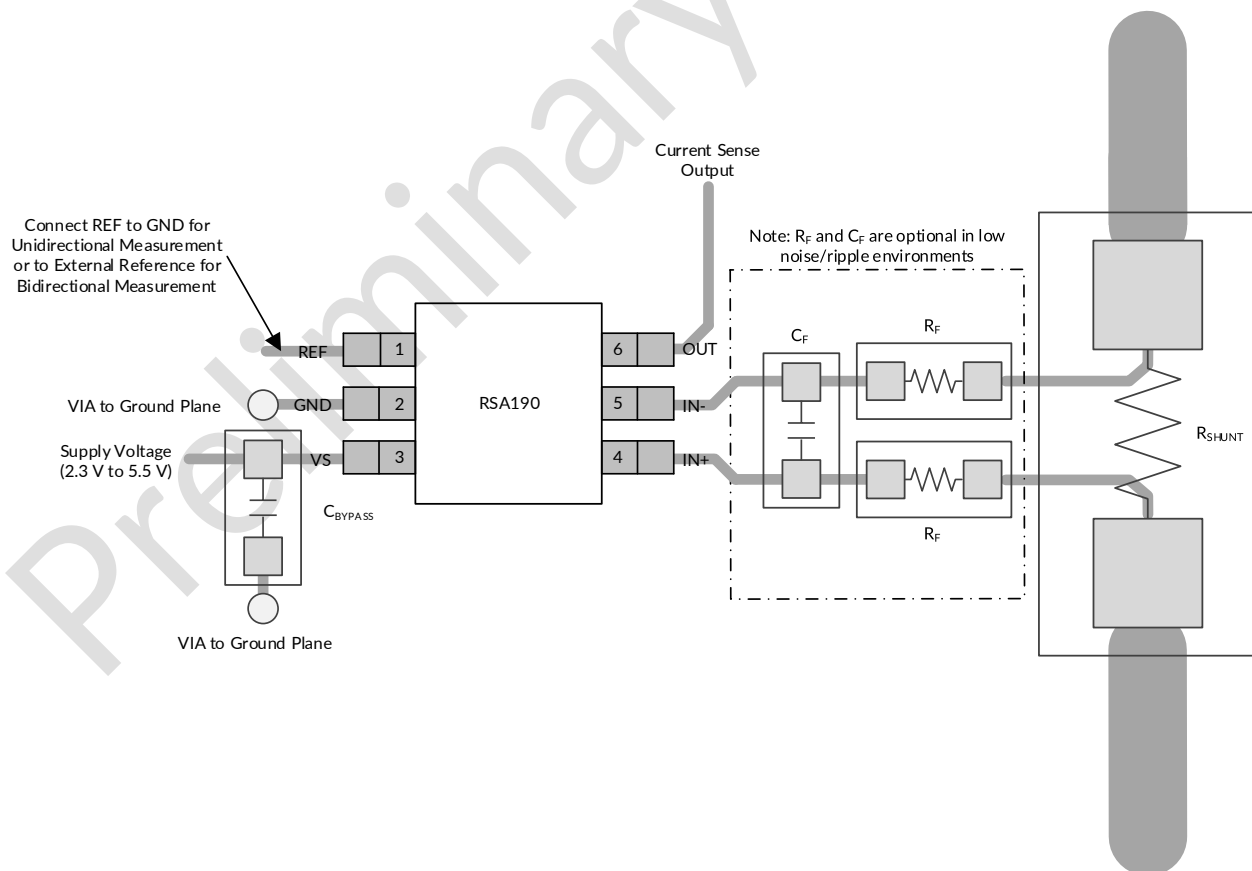
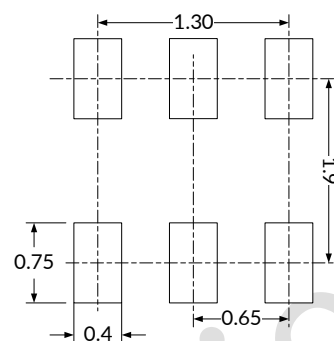
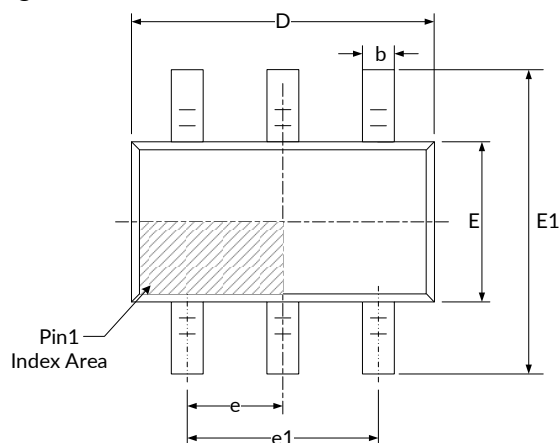
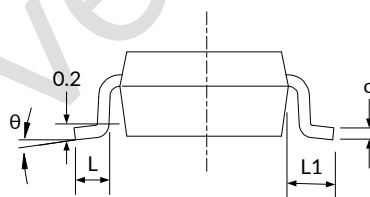
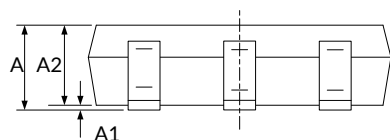


Figure 30. Recommended Layout

12 PACKAGE OUTLINE DIMENSIONS

SC70-6⁽³⁾

RECOMMENDED LAND PATTERN (Unit: mm)


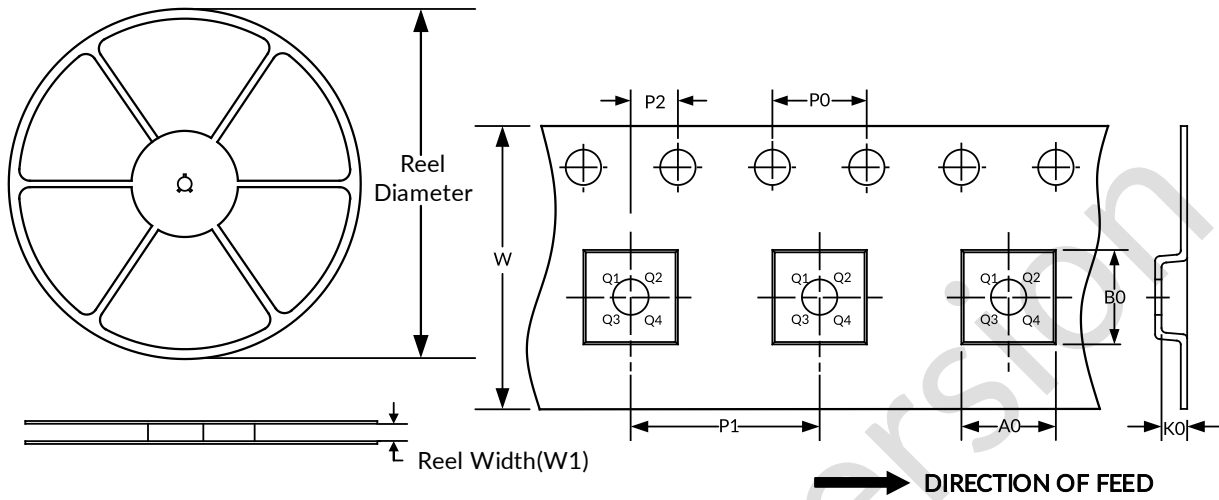
Symbol	Dimensions In Millimeters		Dimensions In Inches	
	Min	Max	Min	Max
A ⁽¹⁾	0.900	1.100	0.035	0.043
A1	0.000	0.100	0.000	0.004
A2	0.900	1.000	0.035	0.039
b	0.150	0.350	0.006	0.014
c	0.080	0.150	0.003	0.006
D ⁽¹⁾	2.000	2.200	0.079	0.087
E ⁽¹⁾	1.150	1.350	0.045	0.053
E1	2.150	2.450	0.085	0.096
e	0.650 (BSC) ⁽²⁾		0.026 (BSC) ⁽²⁾	
e1	1.300 (BSC) ⁽²⁾		0.051 (BSC) ⁽²⁾	
L	0.260	0.460	0.010	0.018
L1	0.525		0.021	
θ	0°	8°	0°	8°

NOTE:

1. Plastic or metal protrusions of 0.15mm maximum per side are not included.
2. BSC (Basic Spacing between Centers), "Basic" spacing is nominal.
3. This drawing is subject to change without notice.

13 TAPE AND REEL INFORMATION REEL DIMENSIONS

TAPE DIMENSION



NOTE: The picture is only for reference. Please make the object as the standard.

KEY PARAMETER LIST OF TAPE AND REEL

Package Type	Reel Diameter	Reel Width (mm)	A0 (mm)	B0 (mm)	K0 (mm)	P0 (mm)	P1 (mm)	P2 (mm)	W (mm)	Pin1 Quadrant
SC70-6	7"	9.5	2.40	2.50	1.20	4.0	4.0	2.0	8.0	Q3

NOTE:

1. All dimensions are nominal.
2. Plastic or metal protrusions of 0.15mm maximum per side are not included.

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Preliminary version