SQ52133E

-0.2V to +70V, Low Power, Bi-directional, High-precision Current Sense Amplifier with Ultra-low I_B

General Description

The SQ52133E is a 200V/V fixed Gain, low-power, high-precision, high-side or low-side current-sense amplifier with ultra-low input bias current, suitable for bidirectional or unidirectional current measurements. The common mode voltage range of the SQ52133E is from -0.2V to +70V, independent of the supply voltage.

The SQ52133E has an ultra-low input bias current (500pA typical). Compared with other current-sense amplifiers, this feature allows larger current-sense resistors to be used to enable current measurements in the micro-ampere range.

The supply voltage range of the SQ52133E is 1.8V to 5.5V and the device draws 62μA quiescent current. It is offered in a SOT363 package and is specified over the extended industrial temperature range of -40°C to 125°C.

Features

- Wide Common-mode Voltage Range, V_{CM}: –0.2V to +70V
- Low Input Bias Currents, I_B: 500pA (Typ.)
- Fixed Gain: 200V/V
- High-Accuracy:
  - Offset Voltage, V_{OS}: ±50μV (Max.)
  - Offset Drift: ±0.5μV/°C (Max.)
  - Gain Error: ±0.6% (Max.)
  - Gain Drift: ±15ppm/°C (Max.)
  - Common-mode Rejection Ratio: 134 dB (Min.)
- Low Supply Voltage, VCC: 1.8V to 5.5V
- Low Quiescent Current, IQ: 62μA (Typ.)
- Package: SOT363
- MSL Rating: MSL1

Applications

- Battery Management Systems (BMS)
- Servers
- Smartphones
- Notebook PCs
- Telecom equipment
- Power management

Typical Application

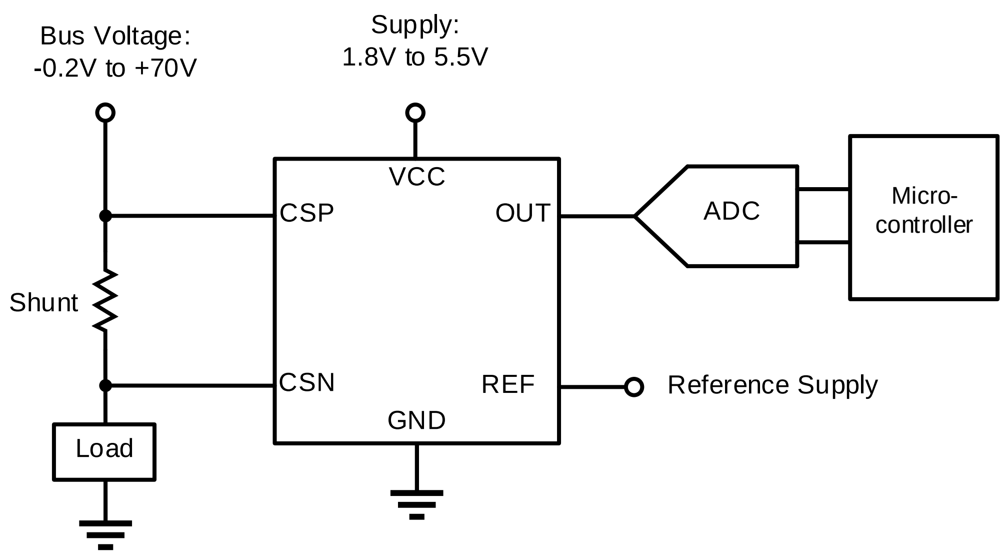


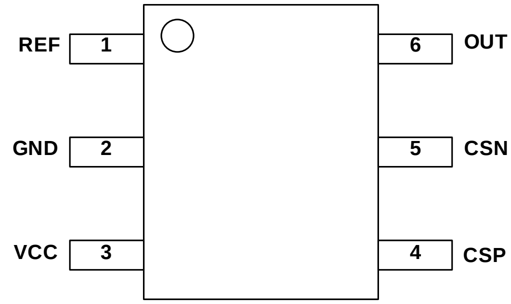
Figure 1. Simplified Application Circuit

Ordering Information

Ordering Part Number	Package Type	Top Mark
SQ52133EAHT	SOT363	**B**xyz①

*Note①： **x=year code, y=week code, z= lot number code.***

Pin out (Top View)



(SOT363)

Pin Description

Pin No	Pin Name	Pin Description
1	REF	Reference voltage input, 0V to VCC.
2	GND	Ground.
3	VCC	Power supply, 1.8 V to 5.5 V.
4	CSP	Connect to supply side of shunt resistor.
5	CSN	Connect to load side of shunt resistor.
6	OUT	Amplifier Output.

Block Diagram

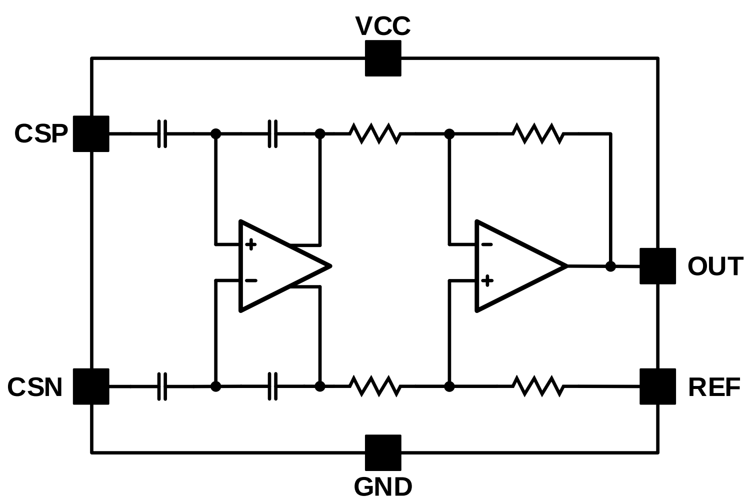


Figure 2. Block Diagram

Absolute Maximum Ratings

Parameter (Note 1)	Min	Max	Unit
VCC	-0.3	6	V
CSP-CSN (Differential)	-40	40	
CSP, CSN (Common-Mode)	GND-0.3	72	
Output	GND-0.3	VCC+0.3	
Input Current into Any Pin		5	mA
Operating Temperature	-40	125	°C
Storage Temperature Range	-65	150	
ESD: HBM (Human Body Model)	± 2500		V
ESD: CDM (Charged Device Model)	± 1000		V

Parameter (Note 2)	Max	Unit
θ_{JA} Junction-to-ambient Thermal Resistance	321	°C/W
θ_{JC} Junction-to-case Thermal Resistance	60	
P_D Power Dissipation T_A = 25°C	0.31	W

Recommended Operating Conditions

Parameter (Note 3)	Min	Max	Unit
Supply Voltage	1.8	5.5	V
Common-mode, CSP, CSN	GND-0.2	70	
Reference Voltage Range	GND	VCC	
Operating Free-air Temperature	-40	125	°C

Electrical Characteristics

T_A=25°C, V_{SENSE} = V_{CSP} – V_{CSN}, V_{CC} = 1.8 V to 5.0 V, V_{CM} = 12 V, V_{REF} = V_{CC} / 2, unless otherwise noted. (Note 4)

Parameter	Symbol	Conditions	Min	Typ	Max	Units
Input						
Common Mode Input Voltage	V_{CM}	T_A= -40°C to 125°C	-0.2		70	V
Common Mode Rejection Ratio, RTI (Note 5)	CMRR	V_{CC} = 1.8 V, V_{SENSE} = 0 mV, V_{CM} = -0.1 V to 70 V, T_A= -40°C to 125°C	134	140		dB
		V_{CC} = 5.5 V, V_{SENSE} = 0 mV, V_{CM} = -0.1 V to 70 V, T_A= -40°C to 125°C	128			
Offset Voltage, RTI	V_{OS}	V_{CC} = 1.8 V, V_{SENSE} = 0 mV		-0.5	±50	µV
Offset Voltage Drift	dV_{OS}/dT	V_{SENSE} = 0 mV, T_A= -40°C to 125°C		±0.05	±0.5	µV/°C
Power Supply Rejection Ratio, RTI	PSRR	V_{SENSE} = 0 mV, V_{CC} = 1.8 V to 5.5 V		-1	±10	µV/V
Input Bias Current	I_B	V_{SENSE} = 0 mV		0.5	3	nA
Input Offset Current	Ios	V_{SENSE} = 0 mV		±0.07		nA
Output						
Gain	G			200		V/V
Gain Error	E_G	V_{OUT} = 0.1 V to V_{CC} -0.1 V		±0.07	±0.6	%
		T_A=-40°C to 125°C		±2	±15	ppm/°C
Non-linearity Error (Note 6)		V_{OUT} = 0.1 V to V_{CC} -0.1 V		±0.01		%
Reference Voltage Rejection Ratio	RVRR	V_{REF} = 100 mV to V_{CC} -100 mV, T_A = -40°C to +125°C		±2	±5	µV/V
Maximum Capacitive Load (Note 6)		No sustained oscillation		1		nF
Voltage Output						
Swing to V_{CC} Power Supply Rail	VSP	V_{CC} = 1.8 V, R_L=10kΩ to GND, T_A = -40°C to 125°C		(V_{CC})–0.02	(V_{CC})–0.04	V
Swing to GND	VSN	V_{CC} = 1.8 V, R_L=10kΩ to GND, T_A = -40°C to 125°C, V_{SENSE} = -10 mV, V_{REF} = 0V		(V_{GND})+0.05	(V_{GND})+1	mV
Zero current output voltage	VZL	V_{CC} = 1.8 V, R_L=10kΩ to GND, T_A = -40°C to 125°C, V_{SENSE} = 0 mV, V_{REF} = 0mV		(V_{GND})+2	(V_{GND})+14	mV
Frequency Response (Note 6)						
Bandwidth	BW	C_{LOAD}=10pF		40		kHz
Slew Rate	SR	V_{CC} = 5.0 V, V_{OUT} = 0.5 V to 4.5 V		0.3		V/µs
Settling Time	t_S	From current step to within 1% of final value		30		µs
Noise, RTI (Note 6)						
Voltage Noise Density				75		nV/√Hz
Power Supply						
Supply Voltage	V_{CC}	T_A= -40°C to 125°C	1.8		5.5	V
Quiescent Current	I_Q	I_Q vs temperature, T_A= -40°C to 125°C		62	75	µA
Specified Temperature Range			-40		125	°C

Note 1: Stresses beyond the "Absolute Maximum Ratings" may cause permanent damage to the device. These are stress ratings only. Functional operation of the device at these or any other conditions beyond those indicated in the operational sections of the specification is not implied. Exposure to absolute maximum rating conditions for extended periods may affect device reliability.

Note 2: Package thermal resistance is measured in the natural convection at T_A=25°C on an 8.5cm×8.5cm size single-layer Silergy Evaluation Board.

Note 3: The device is not guaranteed to function outside its operating conditions.

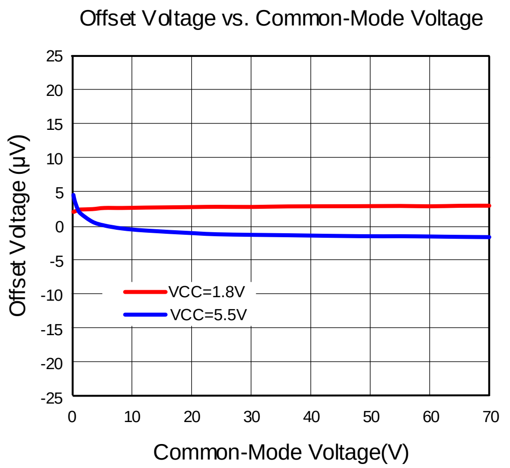
Note 4: Unless otherwise stated, limits are 100% production tested at $T_A \approx T_J$ = 25˚C. Limits over the operating temperature range (see recommended operating conditions) and relevant voltage range(s) are guaranteed by design, test, or statistical correlation.

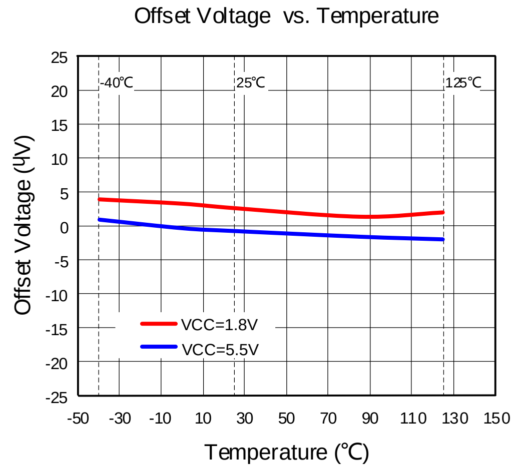
Note 5: RTI = Referred to Input.

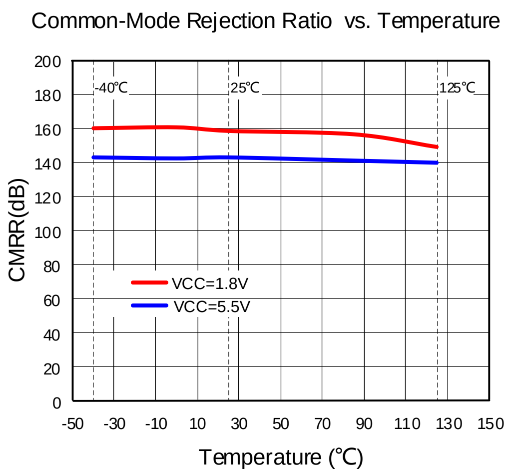
Note 6: Guaranteed by design or statistical correlation and not production tested.

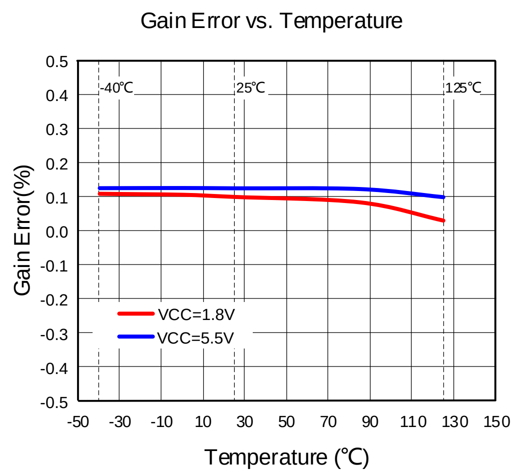
Typical Performance Characteristics

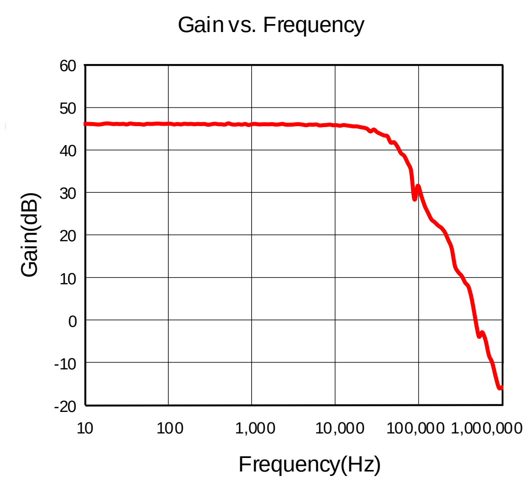
(T_A=25°C, V_{SENSE} = V_{CSP} – V_{CSN}, VCC = 5.0 V, V_{CM} = 12 V, V_{REF} = VCC / 2, unless otherwise noted.).

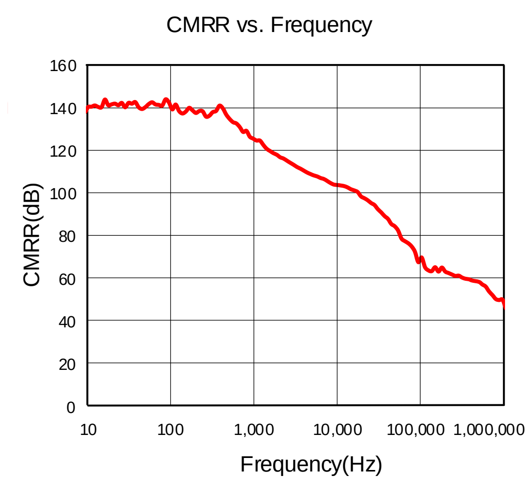


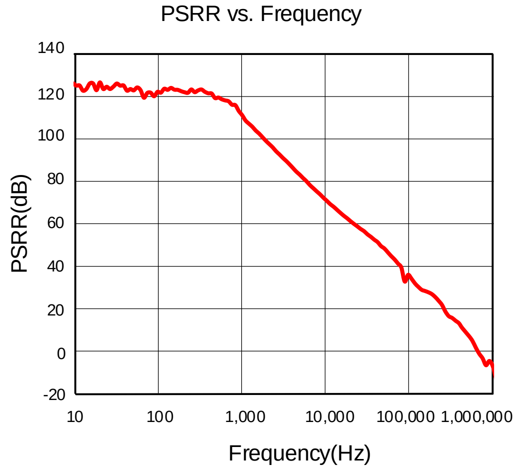


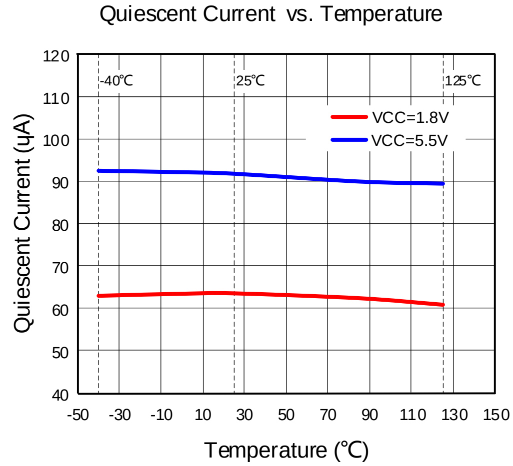


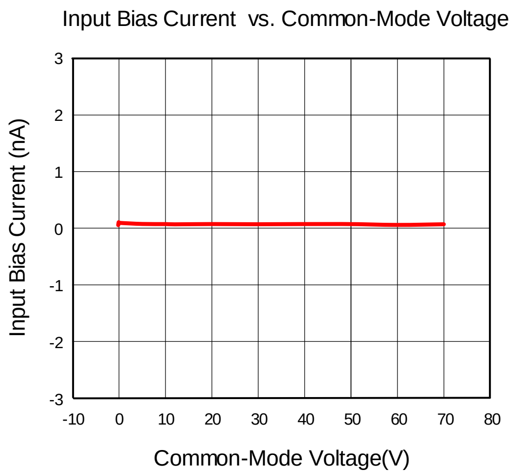


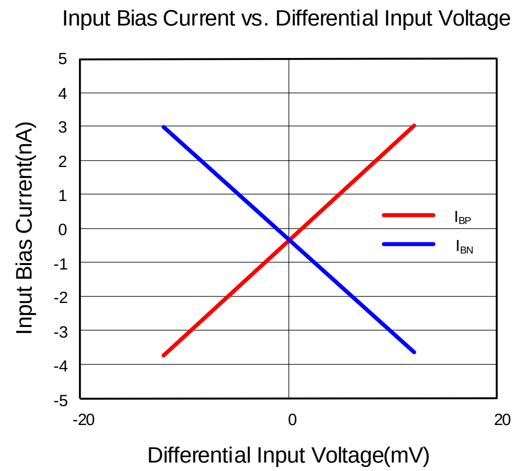


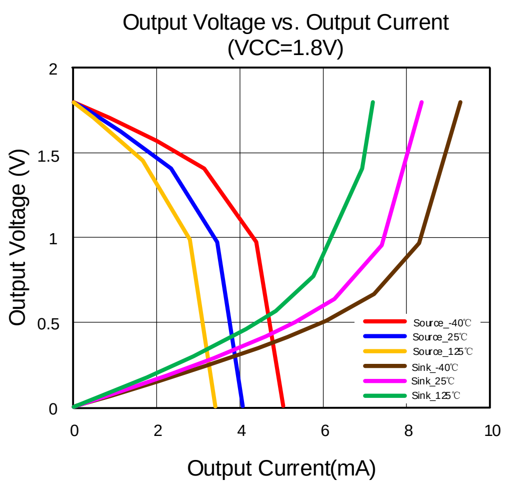


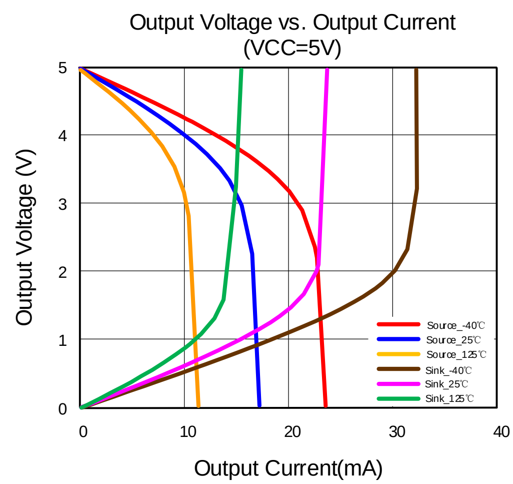

PSRR vs. Frequency
PSRR(dB)
140
120
100
80
60
40
20
0
-20
10
100
1,000
10,000
100,000
1,000,000
Frequency(Hz)


Quiescent Current vs. Temperature
Quiescent Current (μA)
-40℃
25℃
125℃
VCC=1.8V
VCC=5.5V
Temperature (℃)


Input Bias Current vs. Common-Mode Voltage
Input Bias Current (nA)
Common-Mode Voltage(V)


Input Bias Current vs. Differential Input Voltage
Input Bias Current(nA)
IBP
IBN
Differential Input Voltage(mV)


Output Voltage vs. Output Current
(VCC=1.8V)
Output Voltage (V)
Source_-40℃
Source_25℃
Source_125℃
Sink_-40℃
Sink_25℃
Sink_125℃
Output Current(mA)


Output Voltage vs. Output Current
(VCC=5V)
Output Voltage (V)
Source_-40℃
Source_25℃
Source_125℃
Sink_-40℃
Sink_25℃
Sink_125℃
Output Current(mA)

Application Information

The SQ52133E is an ultra-low input bias current, low-power, fixed gain current-sense amplifier that can sense current by amplifying the differential voltage across an external shunt resistor on common-mode voltages to create an output voltage. Its -0.2V to +70V wide common-mode range and high-precision enable it used in high-precision, high- and low-side applications.

Low Input Bias Current

The SQ52133E uses a capacitively coupled amplifier on the input stage, which results in an ultra-low input bias current, this feature can bring two benefits:

1. Low bias current allows larger current-sense resistors to be used to accurately measurements currents as low as 1 µA, and allows use input filters to improve the system signal-to-noise ratio (SNR).

2. Low bias current has the ability to be used at low-power applications. Classical current-sense amplifier typically consume tens or hundreds of micro-amps of bias current at the inputs, the loss of the amplifier is composed of this bias current and quiescent current, the ultra-low input bias current and low quiescent current of the SQ52133E make it suitable for low-power applications.

High-Side and Low-Side Current Sensing

The SQ52133E has -0.2V to +70V input common mode voltage range, which is independent of the supply voltage. This ability allows the current to be monitored during low-side conditions, while also enabling high-side current sensing above the supply voltage, as shown in the *Figure 3.*

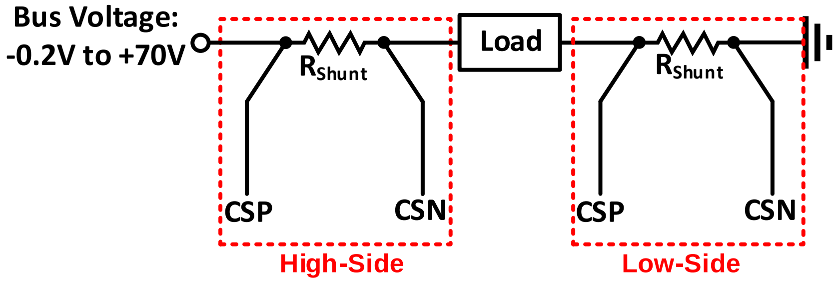


Figure 3. High-Side and Low-Side Current Sensing

REF Input

The SQ52133E will measure the voltage developed across a current-sense resistor when current passes through the device. The transfer function of SQ52133E is

$$OUT = 200 \times V_{SENSE} + V_{REF} \qquad (V_{SENSE} = V_{CSP} - V_{CSN})$$

This ability allows the SQ52133E applicable to unidirectional and bidirectional current sensing.

It should be noted that the linear output range of the SQ52133E is 2mV to VCC-0.04V, it means the output will saturate low condition with small input signal when the REF pin is connected to ground and output will saturate high condition with small input signal when the REF pin is connected to VCC. In order to achieve ideal linear amplification, it is necessary to ensure that the output voltage is between 2mV and VCC-0.04V.

For unidirectional current-sense application, the REF pin can be connected to ground directly as *Figure 4* shown. When the input signal increases, the output voltage will increase. When very low input currents need to be measured, the REF pin needs to be biased to a convenient value above 2 mV to bring the output into the linear range of the device.

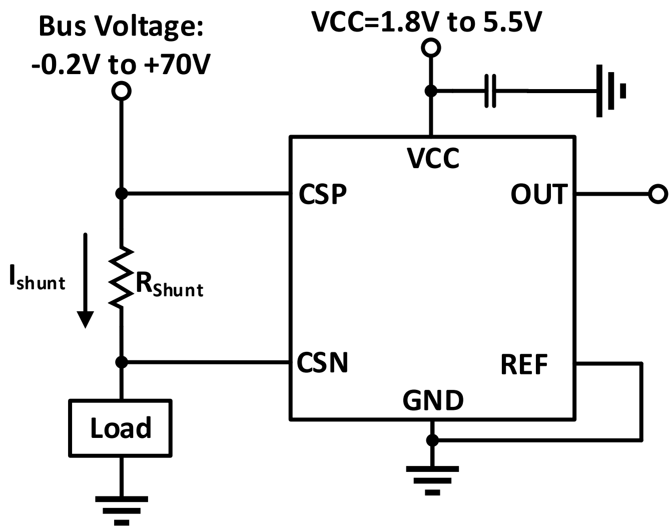


Figure 4. Unidirectional Current-sense Application

For bidirectional current-sense application, the REF pin can be connected to a reference voltage (for example 0.5×VCC) as *Figure 5* shown. The output rises above the reference voltage for positive differential input signals and falls below the reference voltage for negative differential input signals linearly.

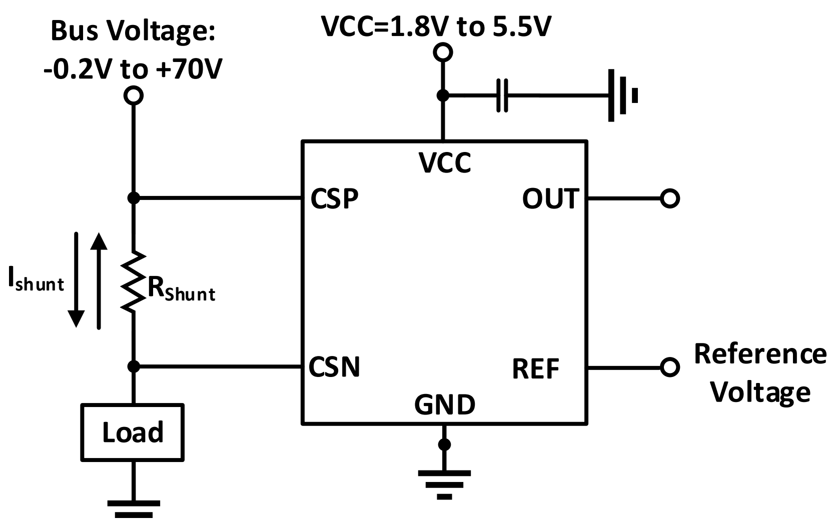


Figure 5. Bidirectional Current-sense Application

Like any differential amplifier, the common mode rejection ratio of the SQ52133E is affected by any impedance present at the REF input. This problem will not exist when the REF pin is connected directly to most reference or power supplies. When using a resistor divider from the power supply or a reference voltage, the REF pin must be buffered by an OP AMP as *Figure 6* shown.

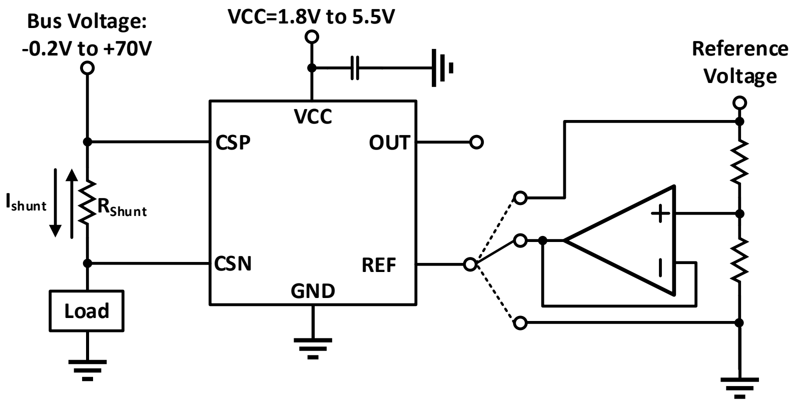


Figure 6. REF Pin Drive

In the system where using a differential input analog-to-digital converter (ADC) or using two separate single-ended input ADCs, the differential voltage of the OUT pin and the REF pin of the SQ52133E can be directly collected. This detection method can eliminate the influence of external impedance on the REF input, where the REF pin can be driven directly with a divider resistor without going through the buffer. As shown in *Figure 7.*

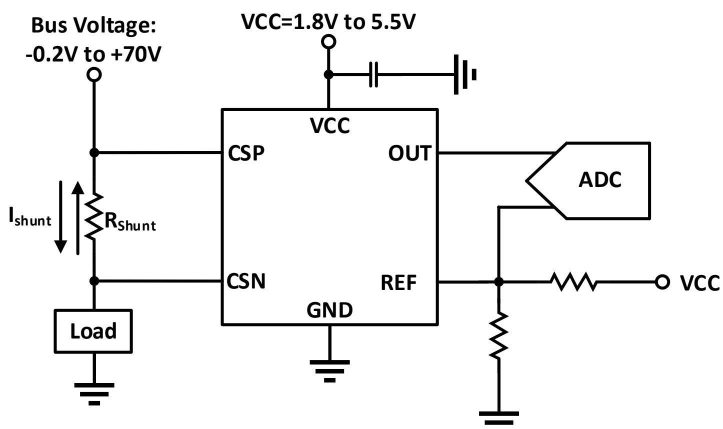


Figure 7. Sensing the SQ52133E to Cancel the Effects of Impedance on the REF Input

Input Filtering

To improve the de-glitch ability and the system SNR (Signal to Noise Ratio). It's recommended to place a RC filter at the inputs pins is as below shows.

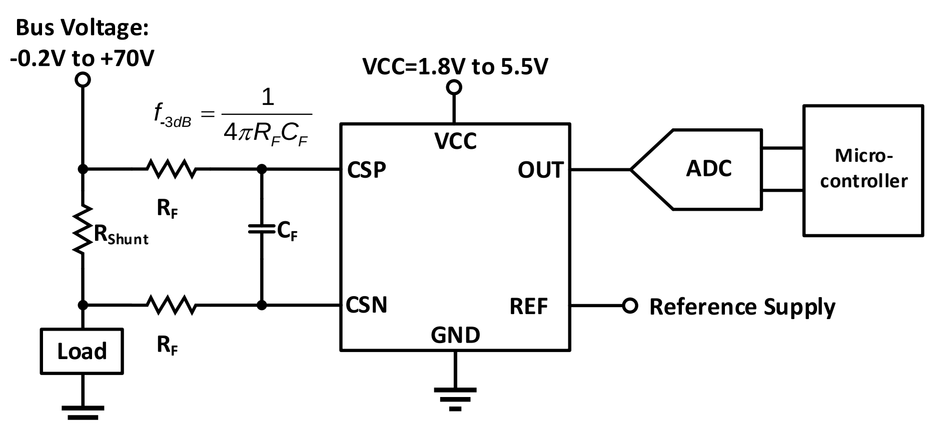


Figure 8. Filter at Input Pins

Selecting RSENSE

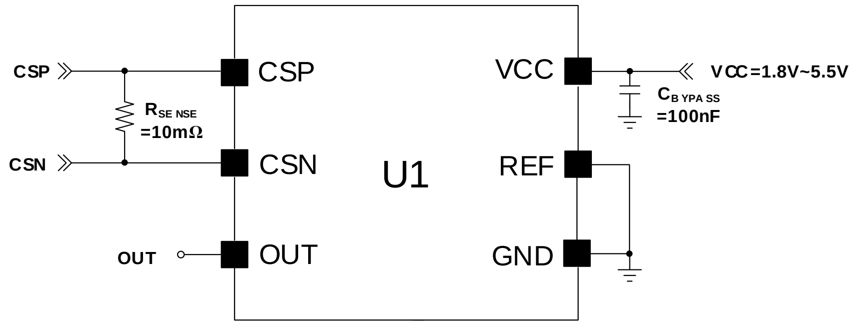
The value of the current sense resistor is influenced by the measured current, the range of the differential input voltage, the reference voltage V_{REF} and the power supply voltage. Additionally, the output swing also impact the resistor value. The presence of offset voltage, gain error, and other parameters in the current sense amplifier necessitates choosing the largest possible sense resistor to maximize the differential signal value, reduce detection errors, and enhance measurement accuracy. However, due to OUT voltage swing, the size of the resistor value will be subject to certain limitations.

A quick design table are shown as below:

Table.1 SQ52133E (200V/V)

Unidirectional Application (V_{REF}=0V)			**Bidirectional Application (V_{REF}=0.5×VCC)**		
I_{SENSE} range	Recommended R_{SENSE}		I_{SENSE} range	Recommended R_{SENSE}	
	VCC=5V	VCC=1.8V		VCC=5V	VCC=1.8V
0µA ~ 100µA	240Ω	85Ω	-100µA ~ 100µA	120Ω	43Ω
0mA ~ 10mA	2.4Ω	0.85Ω	-10mA ~ 10mA	1.2Ω	0.43Ω
0A ~ 1A	24mΩ	8.5mΩ	-1A ~ 1A	12mΩ	4.3mΩ
0A ~ 10A	2.4mΩ	0.85mΩ	-10A ~ 10A	1.2mΩ	0.43mΩ

Application Schematic



BOM List

Designator	Description	Part Number	MFR
C_{BYPASS}	100nF/50V/X7R, 0603	GCJ188R71H104KA12D	muRata
R_{SENSE}	10mΩ/1W, 2512, 1%	RL2512FK-070R01L	YAGEO

PCB Layout Guide

For optimal design, follow these PCB layout guidelines:

Use a Kelvin connection to connect the input pins to the current-sense resistor R_{SENSE}. Due to the low resistance values of R_{SENSE}, poor PCB routing often leads to additional parasitic resistance between input pins, resulting in additional errors. This connection method ensures that only R_{SENSE} impedance is detected between the input pins. Minimize the loop formed by these connections.

Place the bypass capacitor (a 0.1μF MLCC is recommended) as close as possible to the VCC and GND pins.

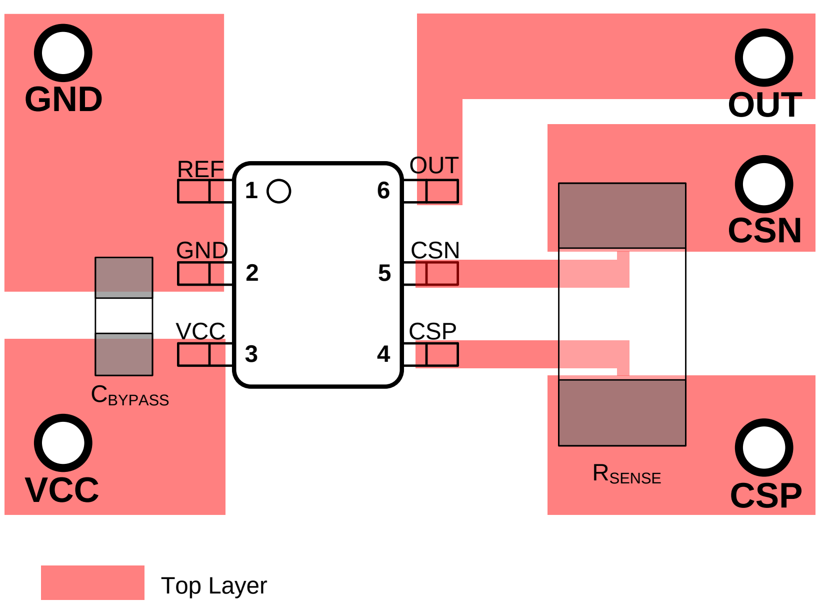
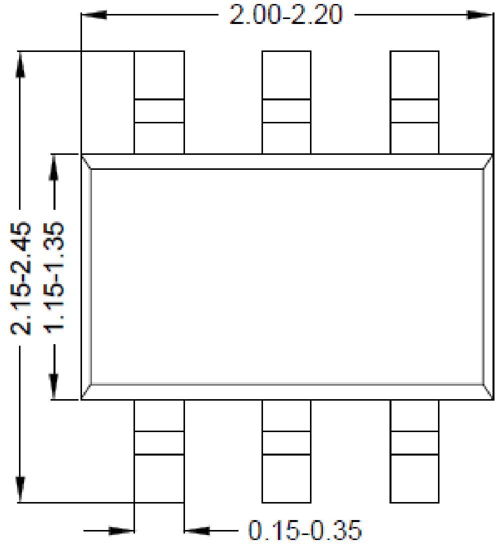
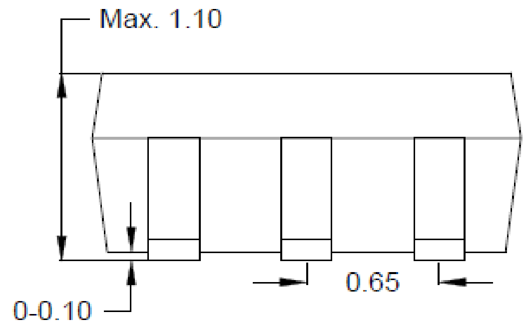


Figure 9. Recommended Layout

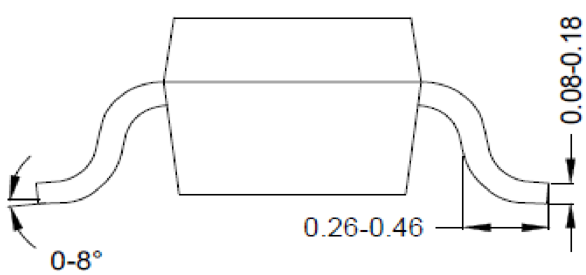
SOT363 Package Outline Drawing



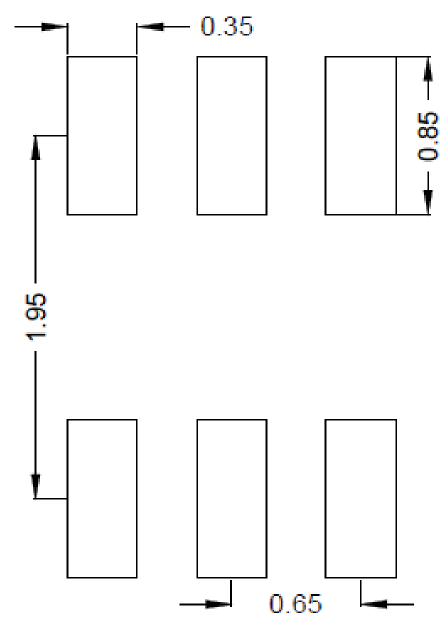
Top view



Side view A



Side view B



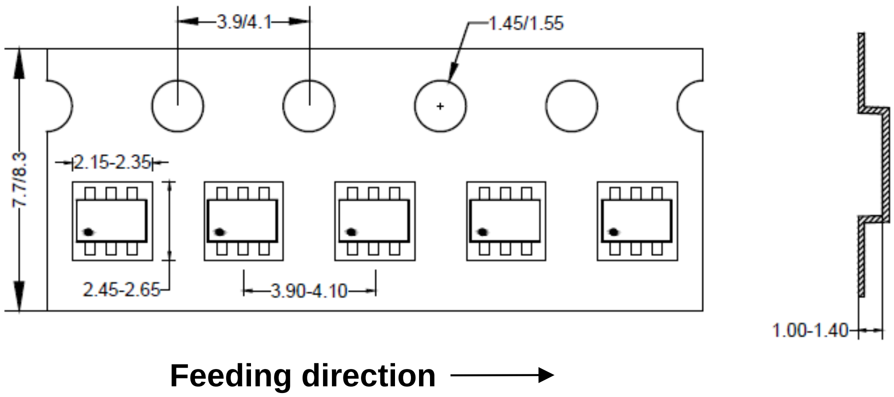
Recommended PCB layout
(Reference only)

Notes: All dimension in millimeter and exclude mold flash & metal burr.

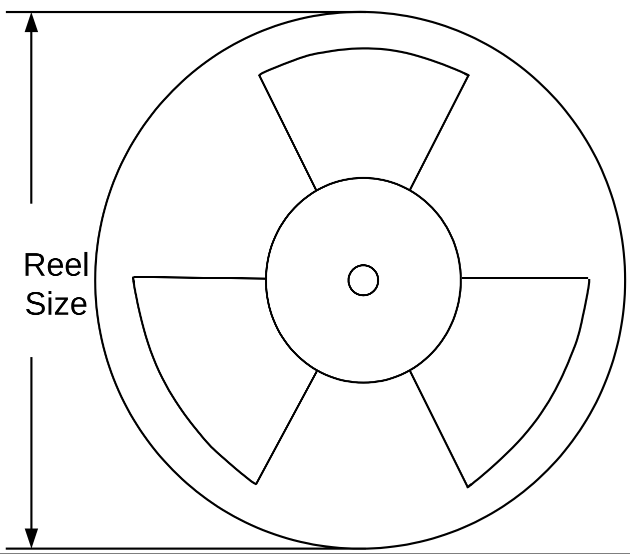
Tape and Reel Information

1. Tape Dimensions and Pin 1 Orientation

SOT363



2. Reel Dimensions



Package types	Tape width (mm)	Pocket pitch(mm)	Reel size (Inch)	Trailer length(mm)	Leader length (mm)	Qty per reel
SOT363	8	4	7"	280	160	3000

3. Others: NA

Revision History

The revision history provided is for informational purposes only and is believed to be accurate, however, not warranted. Please make sure that you have the latest revision.

Date	**Revision**	**Change**
September, 6, 2025	Revision 1.0	Initial Release.

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