SA59131

-4V to 80V, High- and Low-Side, Bidirectional, Zero-Drift, Current-Sense Amplifier with Enhanced PWM Rejection

General Description

The SA59131 is fixed-gain, high-speed, high precision, high-side or low-side bidirectional current-sense amplifiers with a voltage output. It operates over a wide common-mode voltage range of –4V to 80V, independent of the supply voltage. The negative common-mode voltage allows the device to operate below ground. Enhanced PWM rejection makes the SA59131 suitable for current sensing and overcurrent protection in switching systems with large common-mode voltage transients (high ΔV/Δt) at the device's inputs, such as HEV/EV's DC/DC converters, motor controls, and battery management systems.

The SA59131 utilizes zero-drift architecture. Its low input offset voltage (V_{OS}) enables precise measurement of low-voltage drops. The devices operate from a single 2.7V to 5.5V power supply and draw 1.8mA (typ.) quiescent current. There fixed gains are available: 25 V/V, 50V/V and 100 V/V.

The device is available in TSSOP8 and SOP8 packages and is specified over operating temperature range of -40°C to 125°C. The devices are AEC−Q100 Grade 1 Qualified.

Features

- –4V to 80V Wide Common-Mode Operate Range
- Voltage-output, Current-sense Amplifier
- Enhanced PWM Rejection
- Excellent CMRR:
  - 132dB DC CMRR
  - 93dB AC CMRR at 50 kHz
- High Accuracy:
  - Gain Error: 0.15% (Max)
  - Gain Drift: 2.5ppm/°C (Max)
- Low Offset Voltage:
  - Offset Voltage: ±25μV (Max)
  - Offset Drift: 250nV/°C (Max)
- High Bandwidth: 500kHz
- Fixed Gain:
  - SA59131B: 25V/V
  - SA59131: 50V/V
  - SA59131D: 100V/V
- Quiescent Current: 2.4mA (Max)
- AEC-Q100 Grade 1 Qualified
- Package: TSSOP8/ SOP8
- MSL Rating: MSL1 (TSSOP8) / MSL3 (SOP8)

Applications

- Motor Controls
- Actuator Controls
- DC/DC Converters
- Battery Management Systems (BMS)
- eTurbo/ Charger

Typical Application and Block Diagram

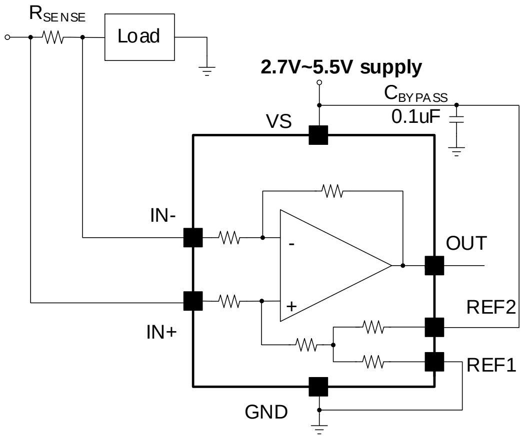


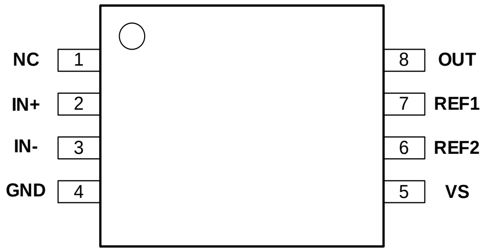
Figure 1. Typical Application Circuit

Ordering Information

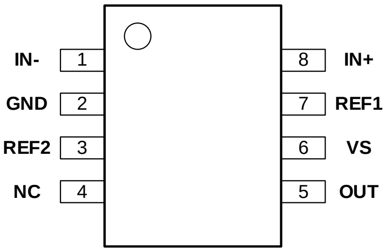
Ordering Part Number	Package Type	Top Mark	Gain
SA59131HMP	TSSOP8	**EBG*xyz***	**50V/V**
SA59131FAP	SOP8	**HAQ*xyz***	**50V/V**
SA59131BHMP	TSSOP8	**KMA*xyz***	**25V/V**
SA59131DHMP	TSSOP8	**KMD*xyz***	**100V/V**

x=year code, y=week code, z= lot number code.

Pinout (Top View)



(TSSOP8)



(SOP8)

Pin Name	Pin No.		Pin Description
	TSSOP8	SOP8	
NC	1	4	Reserved. Connect to ground.
IN+	2	8	Positive input of current-sense amplifier. Connect to the high-side of the current-sense resistor.
IN-	3	1	Negative input of current-sense amplifier. Connect to the low-side of the current-sense resistor.
GND	4	2	Ground.
VS	5	6	Power supply, 2.7 V to 5.5 V.
REF2	6	3	Reference 2 voltage. Connect to 0 V to VS.
REF1	7	7	Reference 1 voltage. Connect to 0 V to VS.
OUT	8	5	Output voltage.

Absolute Maximum Ratings

Parameter (Note 1)	Min	Max	Unit
VS	-0.3	6	V
IN+ - IN- (Differential)	-80	80	
IN+, IN- (Common mode)	-6	90	
OUT	GND-0.3	V_S+0.3V	
R_{EF1}, R_{EF2}, NC	GND-0.3	V_S+0.3V	
Operating free-air Temperature	-55	150	°C
Junction Temperature, Operating	-40	150	
Storage Temperature	-65	150	
ESD: HBM (Human Body Model)	± 2000		V
ESD: CDM (Charged Device Model)	± 1000		V

Thermal Information

Parameter (Note 2)	TSSOP8	SOP8	Unit
θ_{JA} Junction-to-Ambient Thermal Resistance	190	114	°C/W
θ_{JC} Junction-to-Case Thermal Resistance	38	37	
P_D Power Dissipation T_A = 25°C	0.53	0.88	W

Recommended Operating Conditions

Parameter (Note 3)	Min	Max	Unit
VS	2.7	5.5	V
Common mode, IN+, IN-	-4	80	
Operating free-air Temperature	-40	125	°C

Electrical Characteristics

T_A=–40°C to 125°C, V_S=5V, V_{SENSE}=V_{IN+}–V_{IN-}, V_{CM}=12V, and V_{REF1}=V_{REF2}=V_S/2, unless otherwise noted. (Note 4)

Parameter	Symbol	Conditions	Min	Typ	Max	Units
Input						
Common-Mode Input Voltage	V_{CM}		-4		80	V
Common-Mode Rejection Ratio	CMRR	V_{IN+}= -4V to 80V, V_{SENSE}=0mV	114	132		dB
		f = 50 kHz, T_A= 25°C (Note 5)		93		
Offset Voltage, Input-Referred	V_{OS}	V_{SENSE}=0mV, T_A= 25°C		±5	±25	µV
Offset Voltage Drift	dV_{OS}/dT	V_{SENSE}=0mV		±50	±250	nV/°C
Power-Supply Rejection Ratio	PSRR	V_S=2.7V to 5.5V, V_{SENSE}=0mV, SA59131B/D		±1	±6	µV/V
		V_S=2.7V to 5.5V, V_{SENSE}=0mV, SA59131		±1	±10	
Input Bias Current	I_B	I_{B+}, I_{B-}, V_{SENSE}=0mV, T_A= 25°C		85		µA
Reference Input Range			0		V_S	V
Output						
Gain	G	SA59131B		25		V/V
		SA59131		50		
		SA59131D		100		
Gain Error		V_{GND} + 50mV≤V_{OUT}≤V_S–200mV, T_A= 25°C		±0.02%	±0.15%	
Gain Error Drift				±0.5	±2.5	ppm/°C
Non-Linearity Error (Note 5)		V_{GND} + 10mV≤V_{OUT}≤V_S–200mV, T_A= 25°C		±0.01%		
Reference Divider Accuracy	RDA	$V_{OUT}=\lvert(V_{REF1}-V_{REF2})\rvert/2$ at V_{SENSE}=0mV		0.02%	0.12%	
Reference Voltage Rejection Ratio (Input-Referred)	RVRR	T_A= 25°C, SA59131B/D		5		µV/V
		T_A= 25°C, SA59131		2		
Maximum Capacitive Load (Note 5)		No sustained oscillation, T_A= 25°C		2.2		nF
Voltage Output						
Swing to V_S Power-Supply Rail		R_L=10kΩ to GND		V_S–0.025	V_S–0.1	V
Swing to GND		R_L=10kΩ to GND, V_{SENSE}=0mV V_{REF1}=V_{REF2}=0V		V_{GND}+1	V_{GND}+10	mV
Frequency Response (Note 5)						
Bandwidth	BW	–3-dB bandwidth, T_A= 25°C		500		kHz
		2% THD+N, T_A= 25°C		100		
Settling Time		output settles to 0.5% of final value, T_A= 25°C		7		µs
Slew Rate	SR	T_A= 25°C		2		V/µs
Noise (Input Referred) (Note 5)						
Voltage Noise Density		T_A= 25°C		40		nV/√Hz
Power Supply						
Operating Voltage Range	V_S		2.7		5.5	V
Quiescent Current	I_Q	V_{SENSE}=0mV, T_A= 25°C		1.8	2.4	mA
		I_Q vs temperature			2.6	
Temperature Range						
Specified 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 with natural convection at T_A = 25˚C on an 8.5cm×8.5cm one-layer Silergy Evaluation Board.

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

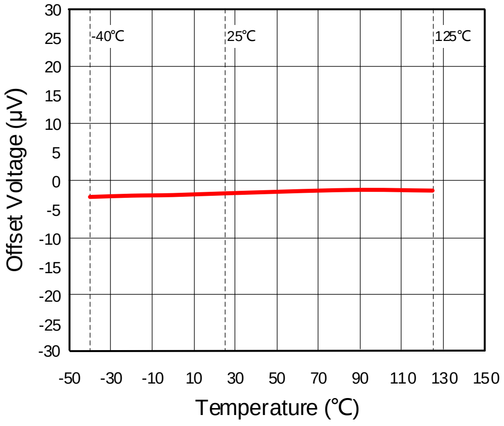
Note 4: Unless otherwise stated, limits are 100% production tested at $T_A \approx T_J$ = -40°C to 125°C. Limits over the operating temperature range (see recommended operating conditions) and relevant voltage range(s) are guaranteed by design, test, or statistical correlation.

Note 5: Guaranteed by design or statistical correlation and not production tested.

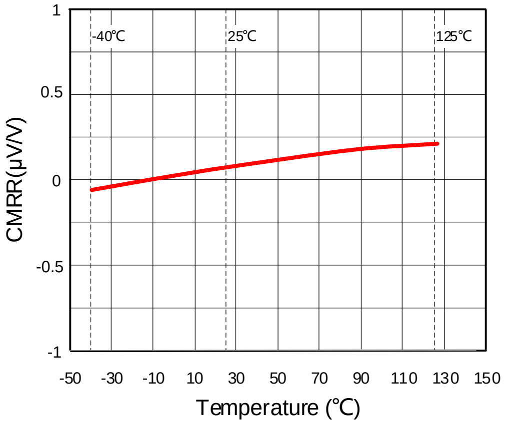
Typical Performance Characteristics

(T_A=25°C, V_S=5V, V_{SENSE}=V_{IN+}–V_{IN-}, V_{CM}=12V, and V_{REF1}=V_{REF2}=$V_{S/2}$, unless otherwise noted.)

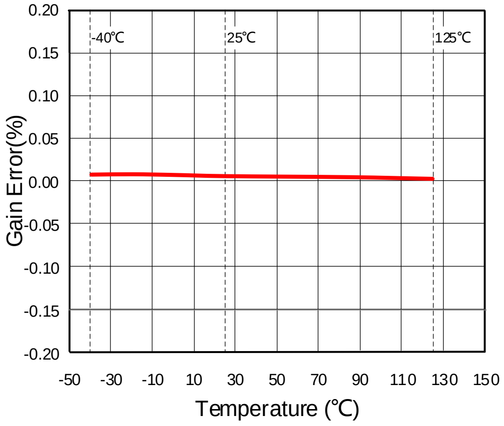
Input Offset Voltage vs. Temperature



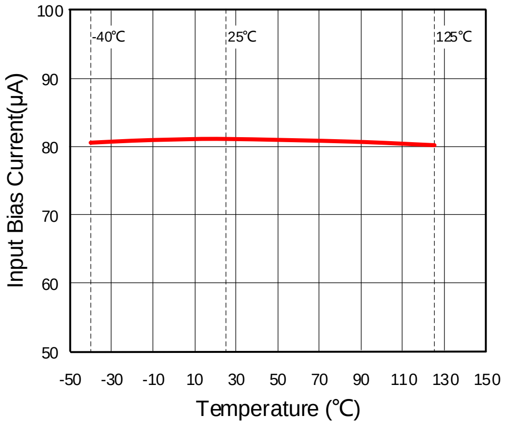
Common-Mode Rejection Ratio vs. Temperature



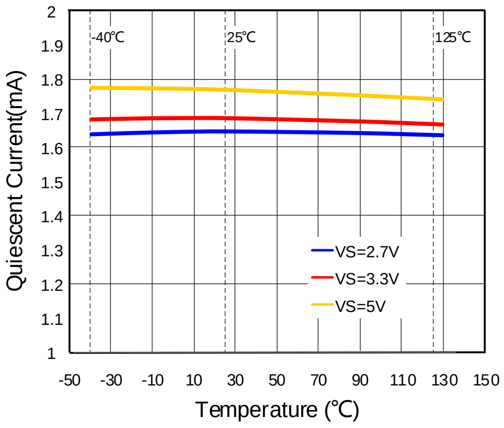
Gain Error vs. Temperature



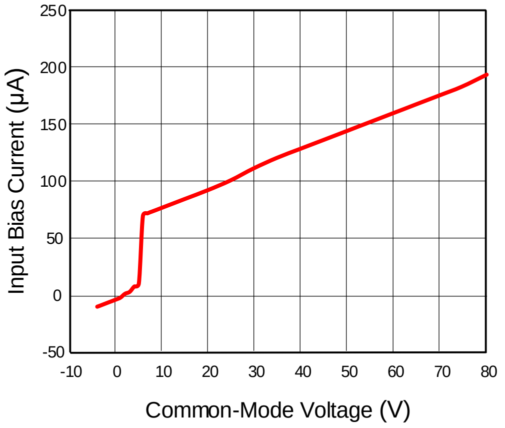
Input Bias Current vs. Temperature

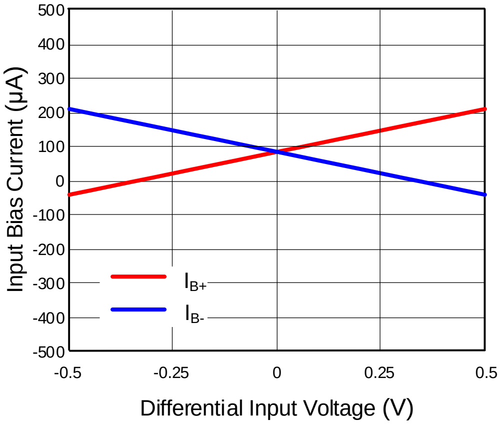


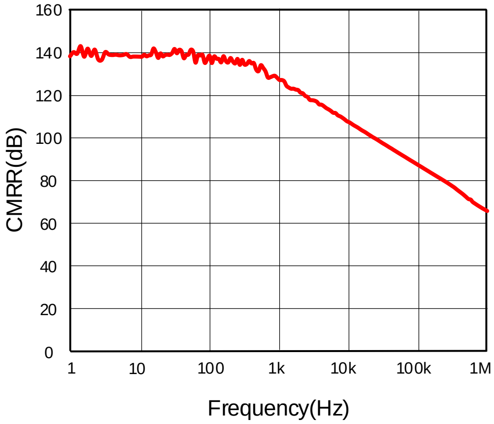
Quiescent Current vs. Temperature

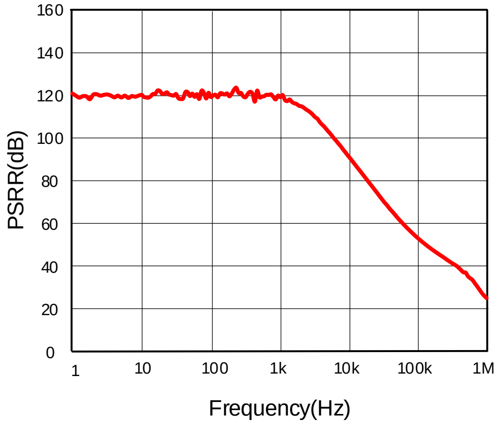


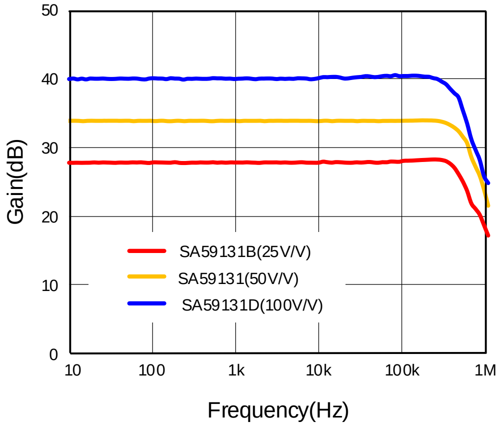
Input Bias Current vs. Common-Mode Voltage

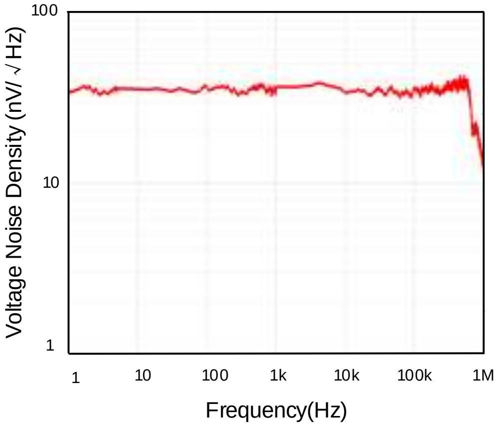


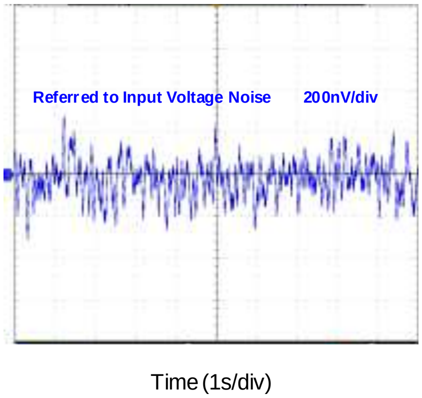

Input Bias Current vs. Differential Input Voltage


Common-Mode Rejection Ratio vs. Frequency

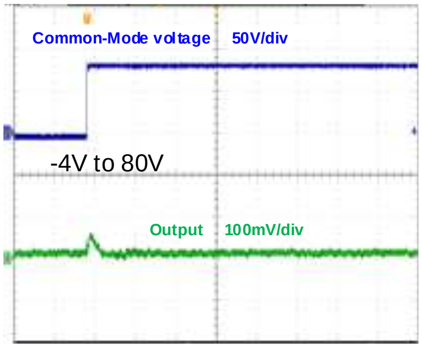

Power-Supply Rejection Ratio vs. Frequency


Gain vs. Frequency


Input Voltage Noise Spectral Density vs. Frequency

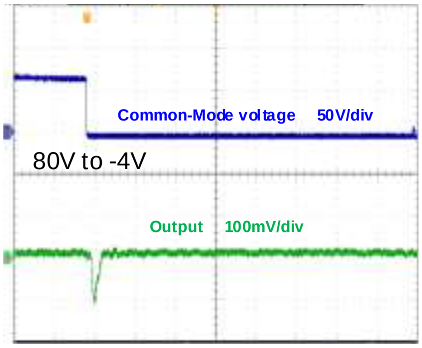

0.1Hz to 10Hz Voltage Noise

Common-Mode Voltage Transient Response



Time (8µs/div)

Common-Mode Voltage Transient Response



Time (8µs/div)

Application Information

The SA59131 is a zero-drift current-sense amplifier designed to sense current across a wide common-mode voltage range with an excellent common-mode rejection ratio (CMRR).

The device features enhanced pulse width modulation (PWM) rejection minimizing the impact of common-mode transients on the output signal, particularly in applications involving PWM signals.

Functional Block Diagram

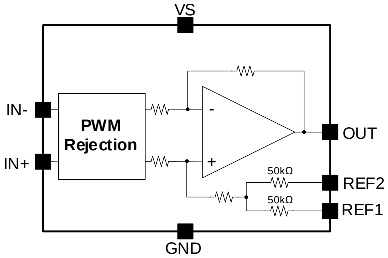


Figure 2. Functional Block Diagram

Enhanced PWM Rejection Operation

In applications heavily influenced by PWM signals, such as motor control or switching power supplies, large common-mode transients (ΔV/Δt) are of great importance. The SA59131 features enhanced PWM rejection, which improves the attenuation of large common-mode transients. Unlike traditional approaches that increase amplifier bandwidth to obtain higher common-mode transient rejection, the SA59131 offers a smaller size and a more flexible design. Its high common-mode rejection technique reduces large transients (ΔV/Δt) before they disrupt the system contributing to cost efficiency. Additionally, the combination of high AC CMRR and signal bandwidth minimizes output transients and ringing.

Unidirectional Operation and Reference Pin Configuration

For unidirectional operation, connect the two reference pins of the device to either the negative or positive rail. This configuration enables current measurement in one direction.

When using the SA59131 in unidirectional mode with ground as the reference, both reference inputs should be connected to ground, as shown in Figure 3. In this configuration, if the input is at 0V differential, the output will also be grounded, meaning that the input polarity must be positive to drive the amplifier output above ground.

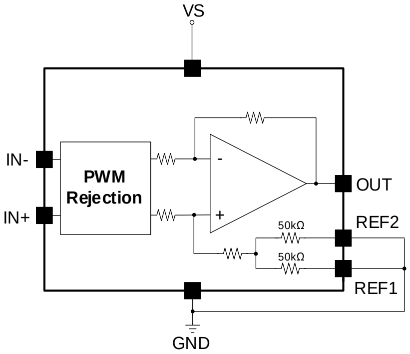


Figure 3. Ground Referenced Output

In unidirectional mode with VS as the reference, connect both reference pins to the positive supply, as shown in Figure 4. In this configuration, the input polarity must be negative to drive the amplifier output down.

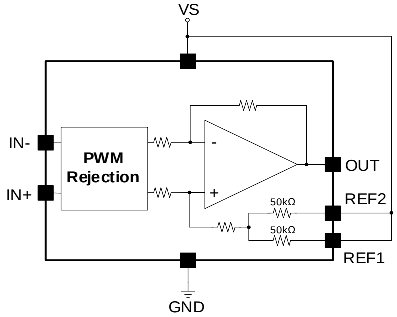


Figure 4. VS Referenced Output

Bidirectional Operation and Reference Pin Configuration

The SA59131 supports bidirectional current detection by configuring the voltages of the two reference pins, allowing the output signal to reference any voltage within the input limit of the reference pins. A typical configuration sets the reference inputs at half-scale to enable an equal measurement range in both directions. However, the design of the two reference pins provides more options for voltage configurations.

Connecting the two reference pins to an external reference voltage biases the output, as shown in Figure 5. In this case, the output will use this external reference voltage as the reference and fluctuate based on the differential input.

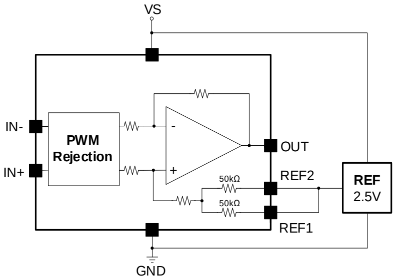


Figure 5. External Reference Output

Connecting one reference pin to VS and the other one to GND allows the internal voltage divider circuit to obtain the most common VS/2 reference, as shown in Figure 6.

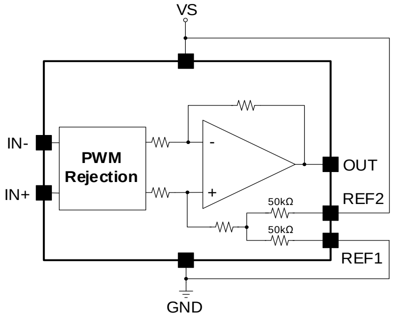


Figure 6. Mid-Supply Voltage Output

Similarly, connecting one REF pin to ground and the other REF pin to an external reference voltage creates a reference level at half of the external reference voltage, as shown in Figure 7.

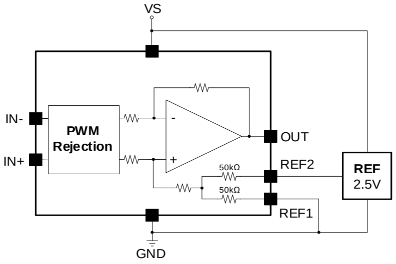


Figure 7. Mid-External Reference Output

The SA59131 can also achieve a custom reference voltage by selecting different external divider resistors, as shown in Figure 8. In this configuration, it should be noted that the output of the amplifier should be a two-ended differential signal. This approach accounts for the internal impedance of the reference pins, which can influence the external voltage division.

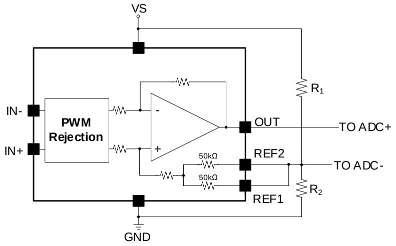


Figure 8. Setting the Reference Using a Resistor Divider

Selecting the Current-Sense Resistor (R_{SENSE})

The SA59131 senses the magnitude of the current by measuring the differential voltage across the sense resistor, so the range of the current-sense is determined by the current-sense resistor value.

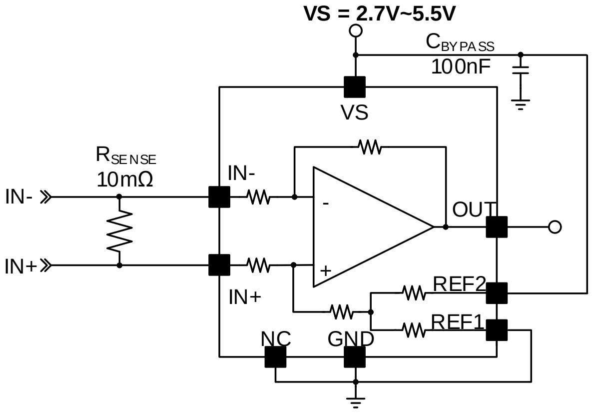
The optimal current-sense resistor is chosen based on the full-scale current to be measured and the gain of the selected device. Choosing the smallest current sense resistor maximizes the input range of the signal chain circuit, controlling the dynamic range of the input signal.

When selecting the current-sense resistor value, there is a trade-off between the accuracy of the current measurement and the maximum power dissipation of the current-sense resistor. A larger resistor increase the measured voltage signal, reduces the percentage of fixed errors in the measurement signal, and improves measurement accuracy. However, this also increases the power dissipation of the resistor, leading to temperature drift that can degrade the accuracy of the sensing resistor.

Based on these conditions, the measurement accuracy is inversely proportional to both the resistance value and the power dissipation due to the shunt resistor selection.

Because the SA59131 has a gain of 50V/V and a very low offset voltage, a lower-value current-sense resistor is recommended. This choice helps ensure high measurement accuracy while reducing power dissipation.

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

Layout Guidelines

For optimal performance, follow these PCB layout considerations:

- 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 significant measurement errors. The Kelvin connection ensures that only R_{SENSE} impedance is detected between the input pins.
- Minimize the loop formed by these connections.
- Place the bypass capacitor (0.1μF MLCC is recommended) as close as possible to the VS and GND pins.

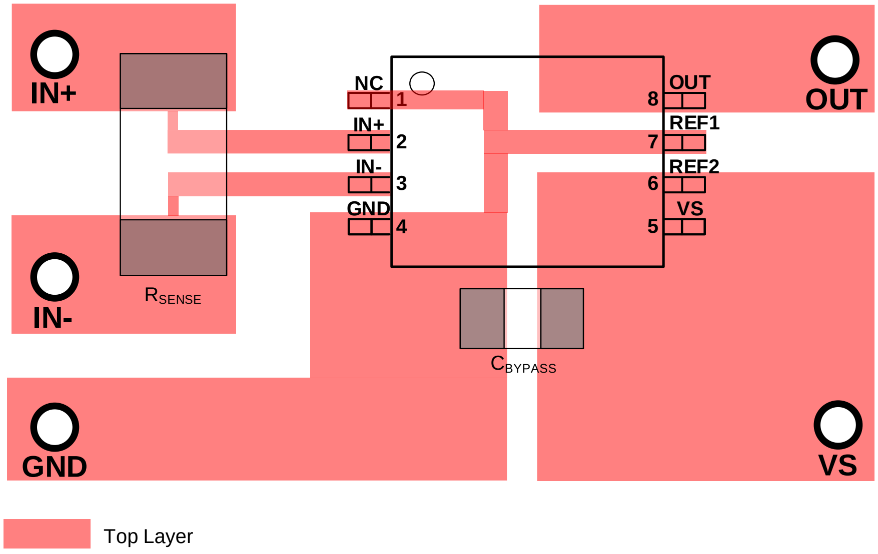


Figure 8. Recommended Layout (TSSOP8)

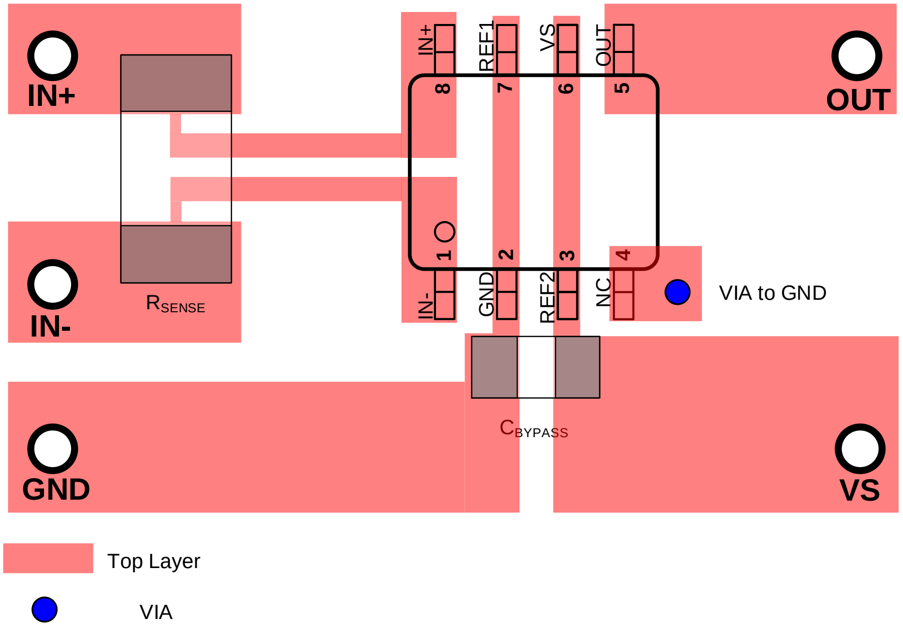
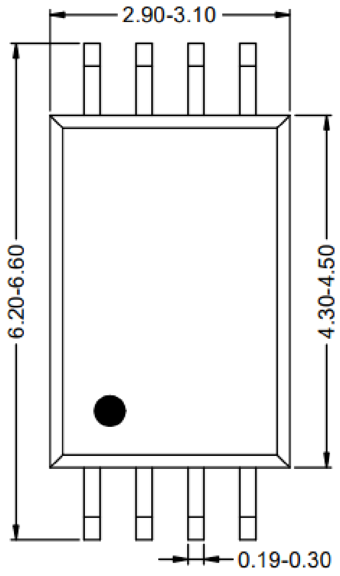
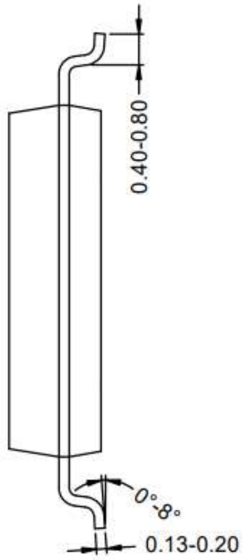


Figure 9. Recommended Layout (SOP8)

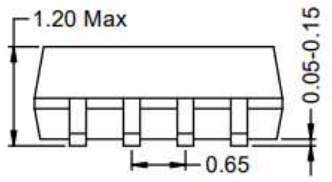
TSSOP8 Package Outline Drawing



Top View



Side View

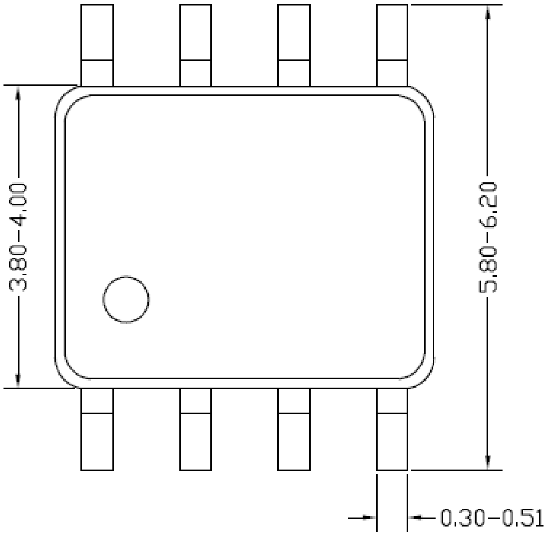


Front View

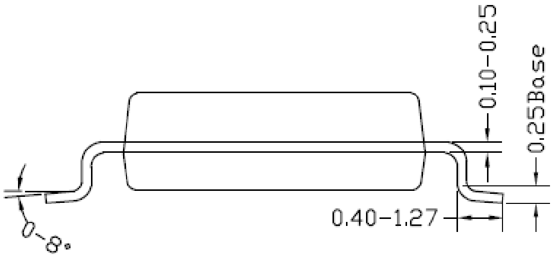
Recommended PCB Layout

Note: All dimensions are in millimeters and exclude mold flash and metal burr.

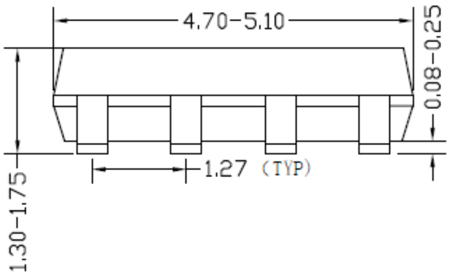
SOP8 Package Outline and PCB Layout Design



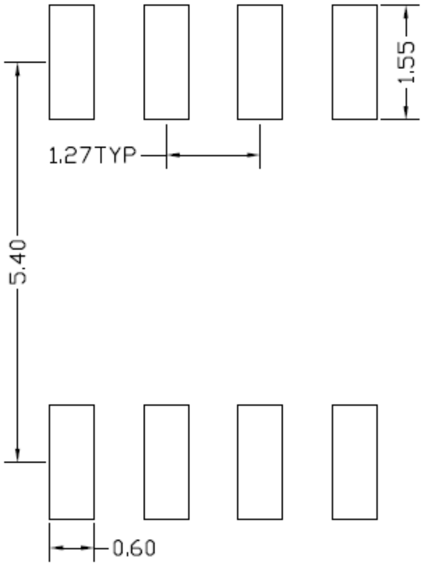
Top View



Side View



Front View

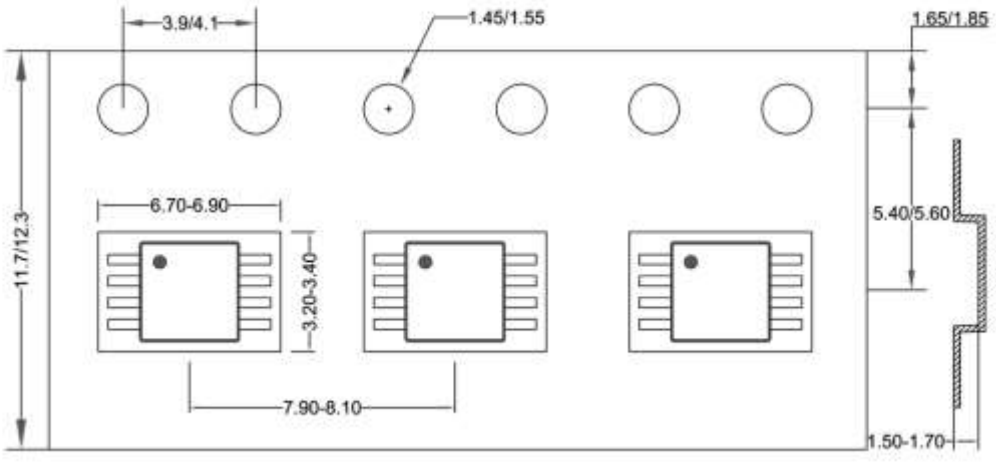


Recommended Pad Layout (Reference Only)

Note: All dimensions are in millimeters and exclude mold flash and metal burr.

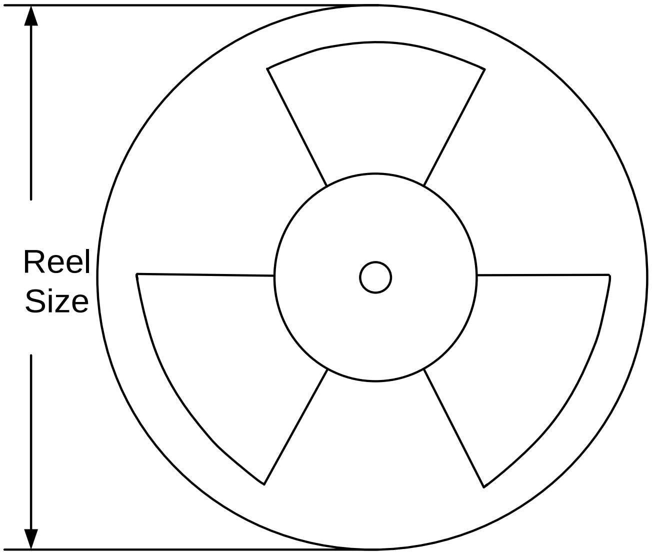
Tape and Reel Information

TSSOP8 Tape Dimensions and Pin 1 Orientation



Direction of feed →

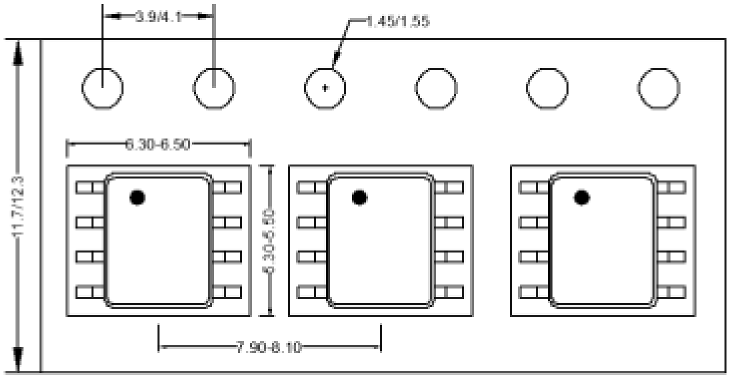
Reel Dimensions



Package types	Tape width (mm)	Pocket pitch(mm)	Reel size (Inch)	Trailer * length(mm)	Leader * length (mm)	Qty per reel
						(pcs)
TSSOP8	12	8	13"	400	400	3000

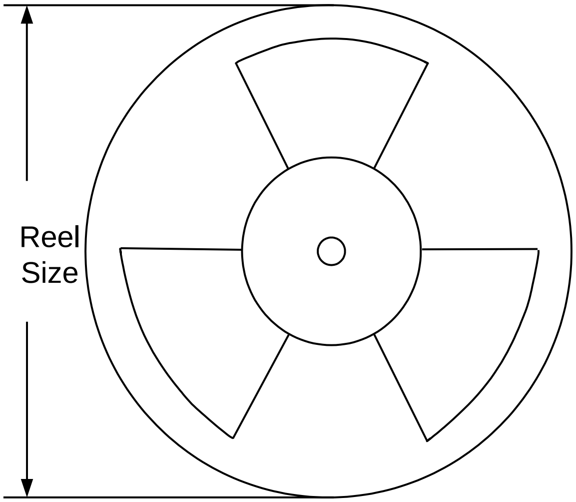
Tape and Reel Information

SOP8 Tape Dimensions and Pin 1 Orientation



Direction of feed →

Reel Dimensions



Package types	Tape width (mm)	Pocket pitch (mm)	Reel size (Inch)	Trailer length (mm)	Leader length (mm)	Qty per reel (pcs)
SOP8	12	8	13"	400	400	2500

Revision History

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

Date	**Revision**	**Change**
Oct. 15, 2025	Revision 1.0A	1.add SA59131BHMP and SA59131DHMP information 2.Gain vs. Frequency, the Frequency changes from 10Hz-10MHz to 10Hz-1MHz
Feb. 25, 2025	Revision 1.0	Initial Release

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