Zero-Drift, Rail-to-Rail I/O CMOS Operational Amplifiers

1 FEATURES

- **Qualified for Automotive Applications**
- **AEC-Q100 Qualified with the Grade 1**
- **Low Offset Voltage: ±10μV (TYP)**
- **Input Offset Drift: ±0.05μV/°C**
- **High Gain Bandwidth Product: 4.3MHz**
- **Rail-to-Rail Input and Output**
- **High Gain, CMRR, PSRR: 120dB**
- **High Slew Rate: 2.5V/μs**
- **Low Noise: 0.93μVp-p (0.1Hz~10Hz)**
- **Low Power Consumption: 650μA/op amp**
- **Overload Recovery Time: 1μs**
- **Low Supply Voltage: +2.7V to +5.5V**
- **No External Capacitors Required**
- **Extended Temperature: -40°C to +125°C**

2 APPLICATIONS

- **Automotive Applications:**
  - **– ADAS**
  - **– Body Electronics and Lighting**
  - **– Current Sensing**
  - **– Battery Management Systems**
- **Temperature Sensors**
- **Medical/Industrial Instrumentation**
- **Pressure Sensors**
- **Battery-Powered Instrumentation**

3 DESCRIPTIONS

The RS8551-Q1, RS8552-Q1 series of CMOS operational amplifiers use auto-zero techniques to simultaneously provide very low offset voltage (100μV max) and near-zero drift over time and temperature. This family of amplifiers has ultralow noise, offset and power.

This miniature, high-precision operational amplifiers offset high input impedance and rail-to-rail input and rail-to-rail output swing. With high gain-bandwidth product of 4.3MHz and slew rate of 2.5V/μs.

Single or dual supplies as low as +2.7V (±1.35V) and up to +5.5V (±2.75V) may be used.

The RS8551-Q1/RS8552-Q1 are specified for the extended industrial and automotive temperature range (-40°C to 125°C). The RS8551-Q1 single amplifier is available in 5-lead SOT23, The RS8552-Q1 dual amplifier is available in 8-lead SOP and 8-lead MSOP narrow surface mount packages.

Device Information (1)

PART NUMBER	PACKAGE	BODY SIZE (NOM)
RS8551-Q1	SOT23-5	2.92mm×1.62mm
RS8552-Q1	SOP8	4.90mm×3.90mm
	MSOP8	3.00mm×3.00mm

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

Table of Contents

4 REVISION HISTORY

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

Version	Change Date	Change Item
A.1	2023/03/13	Initial version completed
A.1.1	2024/03/07	Modify packaging naming
A.2	2025/02/27	1. Update MSL note on Page 4 in RevA.1.1 2. Update PACKAGE note 3. Delete relevant information of RS8554-Q1

5 PACKAGE/ORDERING INFORMATION (1)

Orderable Device	Package Type	Pin	Channel	Lead finish/Ball material (2)	MSL Peak Temp (3)	Op Temp (°C)	Device Marking (4)	Package Qty
RS8551XF-Q1	SOT23-5	5	1	NIPDAUAG	MSL1-260°-Unlimited	-40°C ~ 125°C	8551	Tape and Reel, 3000
RS8552XK-Q1	SOP8	8	2	NIPDAUAG	MSL1-260°-Unlimited	-40°C ~125°C	RS8552	Tape and Reel, 4000
RS8552XM-Q1	MSOP8	8	2	NIPDAUAG	MSL1-260°-Unlimited	-40°C ~125°C	RS8552	Tape and Reel, 4000

NOTE:

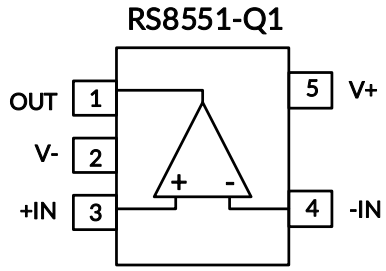
(1) This information is the most current data available for the designated devices. This data is subject to change without notice and revision of this document. For browser-based versions of this data sheet, refer to the right-hand navigation.

(2) Lead finish/Ball material. Orderable Devices may have multiple material finish options. Finish options are separated by a vertical ruled line. Lead finish/Ball material values may wrap to two lines if the finish value exceeds the maximum column width.

(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) 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.

6 PIN CONFIGURATION AND FUNCTIONS

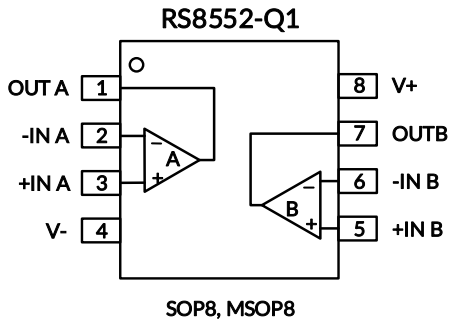


SOT23-5

PIN DESCRIPTION

NAME	PIN	I/O (1)	DESCRIPTION
	RS8551-Q1		
	SOT23-5		
-IN	4	I	Negative (inverting) input
+IN	3	I	Positive (noninverting) input
OUT	1	O	Output
V-	2	-	Negative (lowest) power supply
V+	5	-	Positive (highest) power supply

(1) I = Input, O = Output.



SOP8, MSOP8

PIN DESCRIPTION

NAME	PIN	I/O (1)	DESCRIPTION
	SOP8/MSOP8		
-INA	2	I	Inverting input, channel A
+INA	3	I	Noninverting input, channel A
-INB	6	I	Inverting input, channel B
+INB	5	I	Noninverting input, channel B
OUTA	1	O	Output, channel A
OUTB	7	O	Output, channel B
V-	4	-	Negative (lowest) power supply
V+	8	-	Positive (highest) power supply

(1) I = Input, O = Output.

7 SPECIFICATIONS

7.1 Absolute Maximum Ratings

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

			MIN	MAX	UNIT
Voltage	Supply, V_S=(V+) - (V-)			7	V
	Signal input pin (2)		(V-)-0.5	(V+) +0.5	
	Signal output pin (3)		(V-)-0.5	(V+) +0.5	
Current	Signal input pin (2)		-10	10	mA
	Signal output pin (3)		-55	55	mA
	Output short-circuits (4)		Continuous		
θ_{JA}	Package thermal impedance (5)	SOT23-5		230	°C/W
		SOP8		110	
		MSOP8		170	
Temperature	Operating range, T_A		-40	125	°C
	Junction, T_J (6)		-40	150	
	Storage, T_{stg}		-65	150	

(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) Input terminals are diode-clamped to the power-supply rails. Input signals that can swing more than 0.5V beyond the supply rails should be current-limited to 10mA or less.
(3) Output terminals are diode-clamped to the power-supply rails. Output signals that can swing more than 0.5V beyond the supply rails should be current-limited to ±55mA or less.
(4) Short-circuit to ground, one amplifier per package.
(5) The package thermal impedance is calculated in accordance with JESD-51.
(6) 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), per AEC Q100-002 (1)	±2000	V
		Charged-Device Model (CDM), per AEC Q100-011	±500	
		Latch-Up (LU), per AEC Q100-004	±100	mA

(1) AEC Q100-002 indicates that HBM stressing shall be in accordance with the ANSI/ESDA/JEDEC JS-001 specification.

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 Recommended Operating Conditions

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

		MIN	NOM	MAX	UNIT
Supply voltage, V_S= (V+) - (V-)	Single-supply	2.7		5.5	V
	Dual-supply	±1.35		±2.75	

7.4 Electrical Characteristics

Boldface limits apply over the specified temperature range, Full [9] = -40°C to +125°C.
(At T_A= +25°C, V_S=5V, R_L= 10kΩ connected to V_S/2, and V_{OUT}= V_S/2, unless otherwise noted.) [1]

PARAMETER	SYMBOL	CONDITION	T_J	RS855X-Q1			UNIT
				MIN[2]	TYP[3]	MAX[2]	
OFFSET VOLTAGE							
Input Offset Voltage	V_{OS}	V_{CM}= V_S/2	25°C	-50	±10	50	μV
			Full	-100		100	
Input Offset Voltage Average Drift	V_{OS} Tc		Full		±0.05		μV/°C
Power-Supply Rejection Ratio	PSRR	V_S= +2.7V to +5.5V V_{CM}<V_S-2V	25°C	105	120		dB
			Full	90			
Channel Separation, dc			25°C		0.13		μV/V
INPUT BIAS CURRENT							
Input Bias Current [4] [5]	I_B	V_{CM} = V_S/2	25°C		±50		pA
Input Offset Current [5]	I_{OS}	V_{CM} = V_S/2	25°C		±10		pA
NOISE PERFORMANCE							
Input Voltage Noise	e_np-p	f= 0.1Hz to 10Hz	25°C		0.93		μVpp
Input Voltage Noise Density [5]	e_n	f= 1KHz	25°C		45		nV/$\sqrt{\text{Hz}}$
INPUT VOLTAGE RANGE							
Common-Mode Voltage Range	V_{CM}		Full	(V-)-0.1		(V+)+0.1	V
Common-Mode Rejection Ratio	CMRR	(V-)-0.1V<V_{CM}<(V+)+0.1V	25°C	105	120		dB
			Full	100			
INPUT CAPACITANCE							
Differential			25°C		1		pF
Common-Mode			25°C		25		pF
DYNAMIC PERFORMANCE							
Slew Rate [8]	SR	G= +1	25°C		2.5		V/μs
Gain-Bandwidth Product	GBW		25°C		4.3		MHz
Overload Recovery Time	t_{OR}		25°C		1		μs
OUTPUT CHARACTERISTICS							
Open-Loop Voltage Gain	A_{OL}	R_L= 10KΩ V_O= 0.3V to 4.7V	25°C	105	120		dB
			Full	105			
Voltage Output Swing From Rail	V_{OH}	R_L=10 KΩ to GND	25°C		8	20	mV
			Full			30	
	V_{OL}	R_L=10 KΩ to V+	25°C		8	20	mV
			Full			30	
Short-Circuit Current [6] [7]	I_{SC}		25°C	±30	±48		mA
			Full	±25			
POWER SUPPLY							
Operating Voltage Range	V_S		25°C	2.7		5.5	V
Quiescent Current Per Amplifier	I_Q	V_S=5V	25°C		0.65	1.05	mA
			Full			1.1	

NOTE:
(1) Electrical table values apply only for factory testing conditions at the temperature indicated. Factory testing conditions result in very limited self-heating of the device.
(2) Limits are 100% production tested at 25°C. Limits over the operating temperature range are ensured through correlations using statistical quality control (SQC) method.
(3) 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.
(4) Positive current corresponds to current flowing into the device.
(5) This parameter is ensured by design and/or characterization and is not tested in production.
(6) 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) Short circuit test is a momentary test.
(8) Number specified is the slower of positive and negative slew rates.
(9) Specified by characterization only.

7.5 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.

At T_A= +25°C, V_S= 5V, R_L= 10kΩ connected to V_S/2, V_{OUT} = V_S/2, unless otherwise noted.

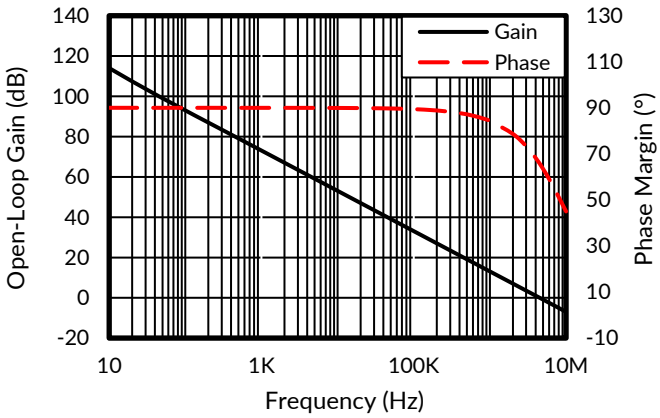


Figure 1. Open-Loop Gain and Phase vs Frequency

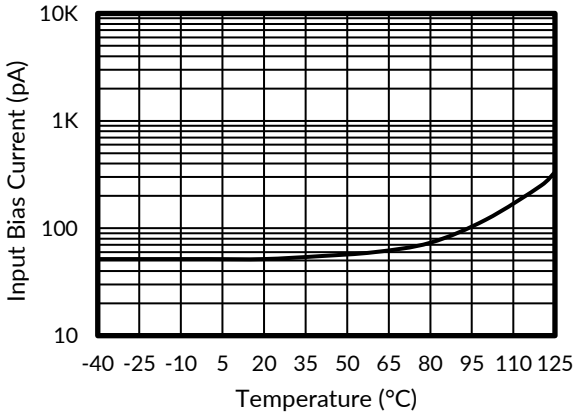


Figure 2. Input Bias Current vs Temperature

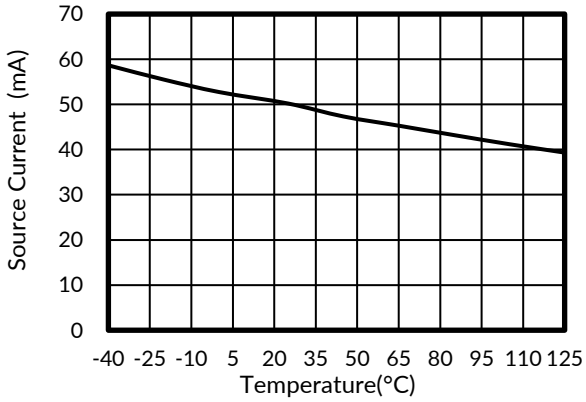


Figure 3. Source Current vs Temperature

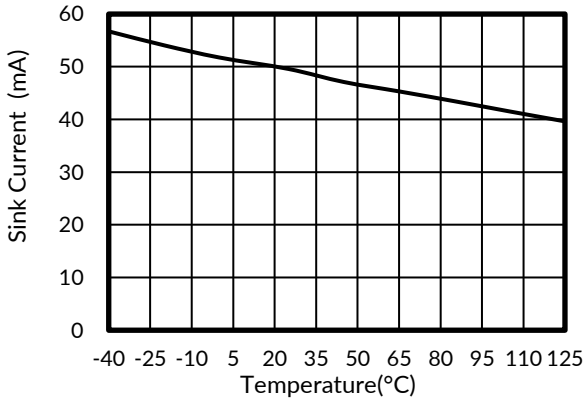


Figure 4. Sink Current vs Temperature

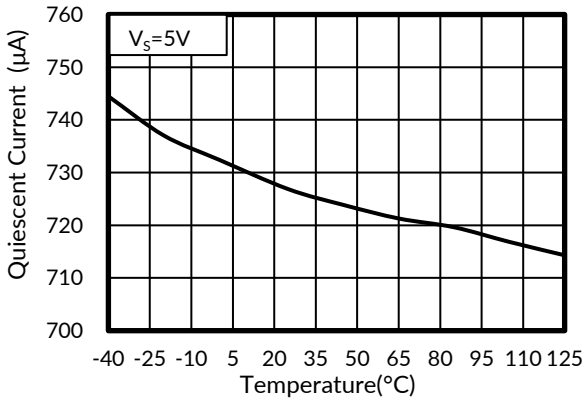


Figure 5. Quiescent Current vs Temperature

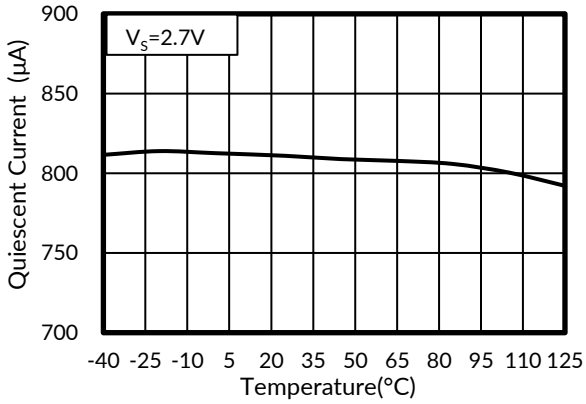


Figure 6. Quiescent Current vs Temperature

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.

At T_A= +25°C, V_S= 5V, R_L= 10kΩ connected to V_S/2, V_{OUT} = V_S/2, unless otherwise noted.

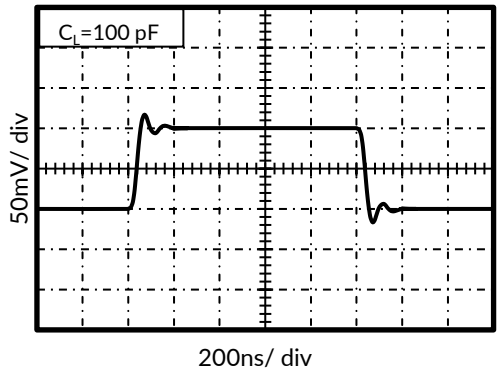


Figure 7. Small-Signal Step Response

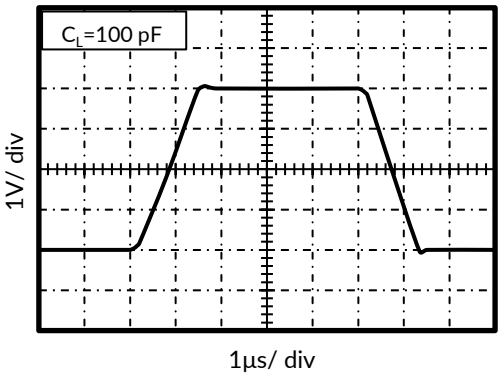


Figure 8. Large-Signal Step Response

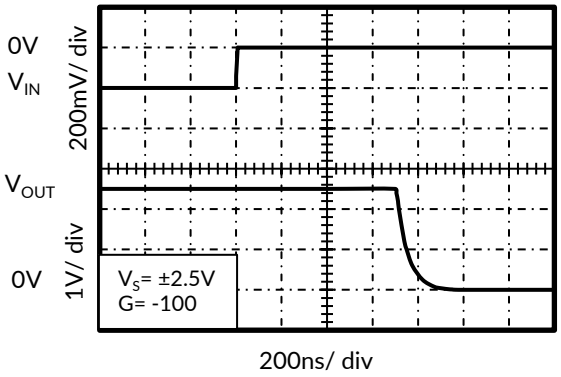


Figure 9. Positive Overvoltage Recovery

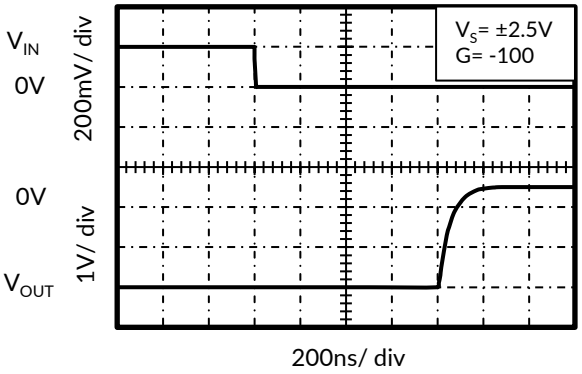


Figure 10. Negative Overvoltage Recovery

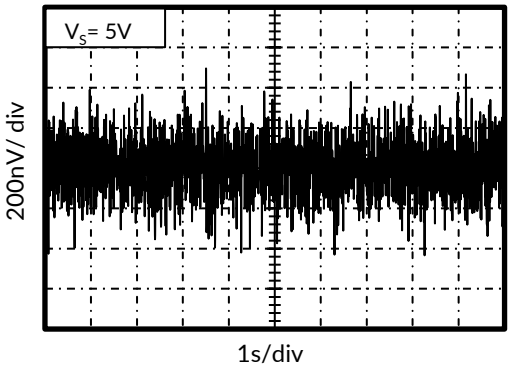


Figure 11. 0.1Hz to 10Hz Noise

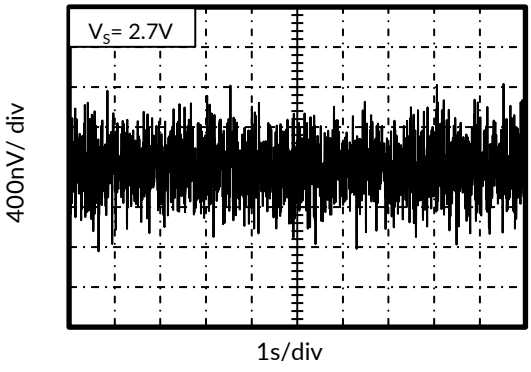


Figure 12. 0.1Hz to 10Hz Noise

8 DETAILED DESCRIPTION

8.1 Overview

The RS8551-Q1, RS8552-Q1 series op amps are unity-gain stable and free from unexpected output phase reversal. They use auto-zeroing techniques to provide low offset voltage and very low drift over time and temperature.

Good layout practice mandates use of a 0.1μF capacitor placed closely across the supply pins.

For lowest offset voltage and precision performance, circuit layout and mechanical conditions should be optimized. Avoid temperature gradients that create thermoelectric (Seebeck) effects in thermocouple junctions formed from connecting dissimilar conductors. These thermally-generated potentials can be made to cancel by assuring that they are equal on both input terminals.

- Use low thermoelectric-coefficient connections (avoid dissimilar metals).
- Thermally isolate components from power supplies or other heat-sources.
- Shield op amp and input circuitry from air currents, such as cooling fans.

Following these guidelines will reduce the likelihood of junctions being at different temperatures, which can cause thermoelectric voltages of 0.1μV/°C or higher, depending on materials used.

8.2 Operating Voltage

The RS8551-Q1, RS8552-Q1 series op amps operate over a power-supply range of +2.7V to +5.5V (±1.35V to ±2.75V). Supply voltages higher than 7V (absolute maximum) can permanently damage the amplifier. Parameters that vary over supply voltage or temperature are shown in the Typical Characteristics section of this data sheet.

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 Note

Typical Applications

9.2 Bidirectional Current-Sensing

This single-supply, low-side, bidirectional current-sensing solution detects load currents from -1A to 1A. The single-ended output spans from 110mV to 3.19V. This design uses the RS8551-Q1, RS8552-Q1 because of its low offset voltage and rail-to-rail input and output. One of the amplifiers is configured as a difference amplifier and the other provides the reference voltage.

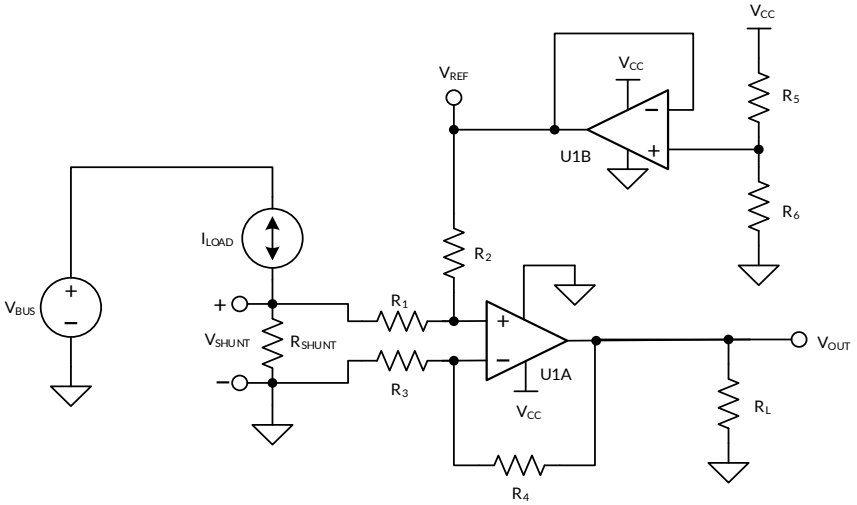


Figure 13. Bidirectional Current-Sensing Schematic

9.3 Design Requirements

This solution has the following requirements:

- Supply voltage: 3.3V
- Input: -1 A to 1 A
- Output: 1.65V ±1.54V (110mV to 3.19V)

9.4 Detailed Design Procedure

The load current, I_{LOAD}, flows through the shunt resistor (R_{SHUNT}) to develop the shunt voltage, V_{SHUNT}. The shunt voltage is then amplified by the difference amplifier, which consists of U1A and R_1 through R_4. The gain of the difference amplifier is set by the ratio of R_4 to R_3. To minimize errors, set R_2= R_4 and R_1= R_3. The reference voltage, V_{REF}, is supplied by buffering a resistor divider using U1B. The transfer function is given by Equation 1.

$V_{OUT}=V_{SHUNT}\times Gain_{Diff\_Amp}+V_{REF}$

Where

$V_{SHUNT}=I_{LOAD}\times R_{SHUNT}$

$$Gain_{Diff\_Amp}=\frac{R_4}{R_3}$$

$$V_{REF}=V_{CC}\times\left(\frac{R_6}{R_5+R_6}\right) \quad (1)$$

There are two types of errors in this design: offset and gain. Gain errors are introduced by the tolerance of the shunt resistor and the ratios of R_4 to R_3 and, similarly, R_2 to R_1. Offset errors are introduced by the voltage divider

(R_5 and R_6) and how closely the ratio of R_4/R_3 matches R_2/R_1. The latter value impacts the CMRR of the difference amplifier, which ultimately translates to an offset error. Because this is a low-side measurement, the value of V_{SHUNT} is the ground potential for the system load. Therefore, it is important to place a maximum value on V_{SHUNT}. In this design, the maximum value for V_{SHUNT} is set to 100 mV. Equation 2 calculates the maximum value of the shunt resistor given a maximum shunt voltage of 100 mV and maximum load current of 1 A.

$$R_{SHUNT(Max)} = \frac{V_{SHUNT(Max)}}{I_{LOAD(Max)}} = \frac{100\ mV}{1\ A} = 100\ m\Omega \quad (2)$$

The tolerance of R_{SHUNT} is directly proportional to cost. For this design, a shunt resistor with a tolerance of 0.5% was selected. If greater accuracy is required, select a 0.1% resistor or better.

The load current is bidirectional; therefore, the shunt voltage range is −100 mV to 100 mV. This voltage is divided down by R_1 and R_2 before reaching the operational amplifier, U1A. Take care to ensure that the voltage present at the noninverting node of U1A is within the common-mode range of the device. Therefore, it is important to use an operational amplifier, such as the RS8551-Q1, RS8552-Q1 that has a common-mode range that extends below the negative supply voltage. Finally, to minimize offset error, note that the RS8551-Q1, RS8552-Q1 has a typical offset voltage of ±3μV (±20μV maximum). Given a symmetric load current of -1A to 1A, the voltage divider resistors (R_5 and R_6) must be equal. To be consistent with the shunt resistor, a tolerance of 0.5% was selected. To minimize power consumption, 10kΩ resistors were used. To set the gain of the difference amplifier, the common-mode range and output swing of the RS8551-Q1, RS8552-Q1 must be considered. Equation 3 and Equation 4 depict the typical common-mode range and maximum output swing, respectively of the RS8551-Q1, RS8552-Q1 given a 3.3V supply.

$-100mV < V_{CM} < 3.4V$ (3)

$100mV < V_{OUT} < 3.2V$ (4)

The gain of the difference amplifier can now be calculated as shown in Equation 5.

$$Gain_{Diff\_Amp} = \frac{V_{OUT\_Max} - V_{OUT\_Min}}{R_{SHUNT} \times (I_{MAX} - I_{MIN})} = \frac{3.2\ V - 100\ mV}{100\ m\Omega \times [1\ A - (-1A)]} = 15.5\ \frac{V}{V} \quad (5)$$

The resistor value selected for R_1 and R_3 was 1kΩ. 15.4kΩ was selected for R_2 and R_4 because it is the nearest standard value. Therefore, the ideal gain of the difference amplifier is 15.4 V/V.

The gain error of the circuit primarily depends on R_1 through R_4. As a result of this dependence, 0.1% resistors were selected. This configuration reduces the likelihood that the design requires a two-point calibration. A simple one-point calibration, if desired, removes the offset errors introduced by the 0.5% resistors.

9.5 Application Curve

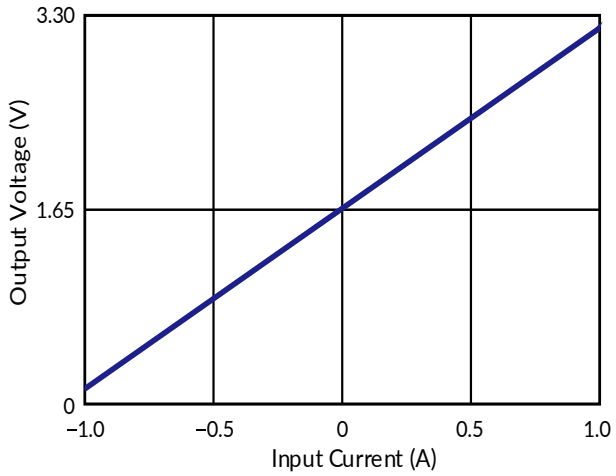


Figure 14. Bidirectional Current-Sensing Circuit Performance: Output Voltage vs Input Current

10 LAYOUTS

10.1 Layout Guidelines

Attention to good layout practices is always recommended. Keep traces short. When possible, use a PCB ground plane with surface-mount components placed as close to the device pins as possible. Place a 0.1μF capacitor closely across the supply pins.

These guidelines should be applied throughout the analog circuit to improve performance and provide benefits such as reducing the EMI susceptibility.

10.2 Layout Example

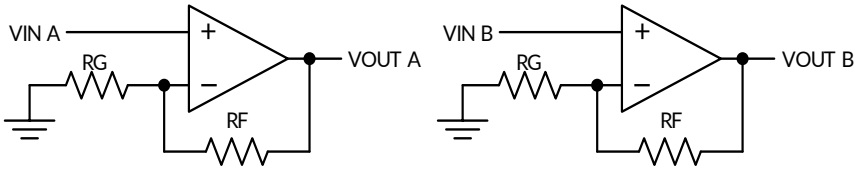


Figure 15. Schematic Representation

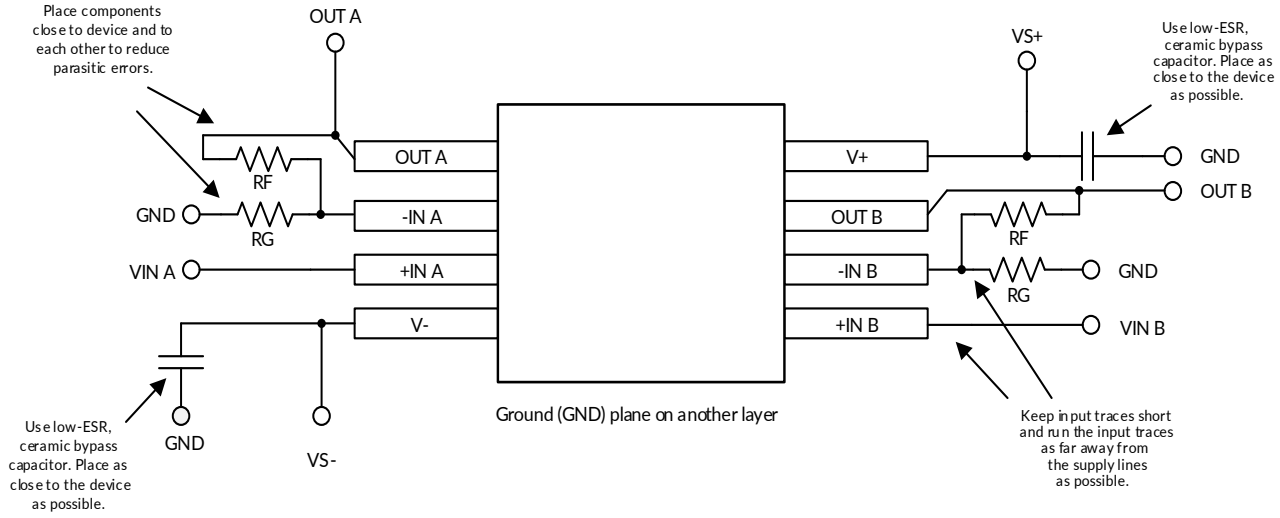
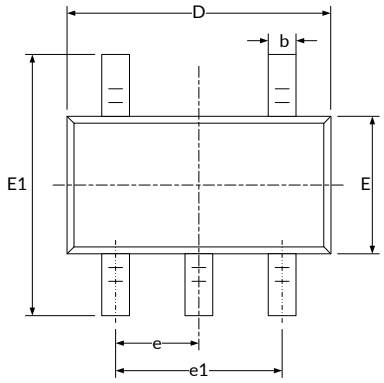


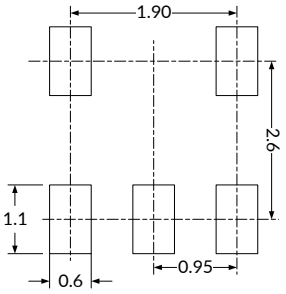
Figure 16. Layout Example

NOTE: Layout Recommendations have been shown for dual op-amp only, follow similar precautions for Single and four.

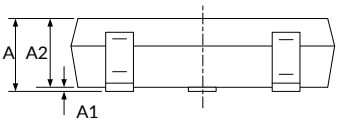
11 PACKAGE OUTLINE DIMENSIONS

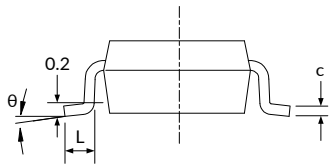
SOT23-5 (3)





RECOMMENDED LAND PATTERN (Unit: mm)



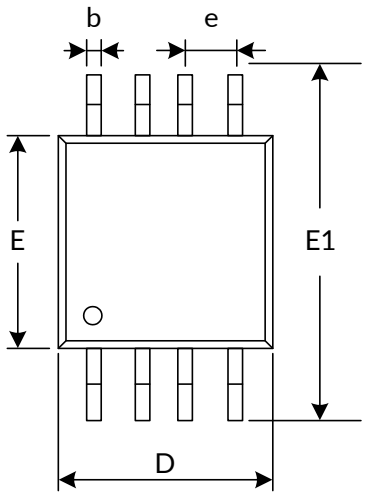


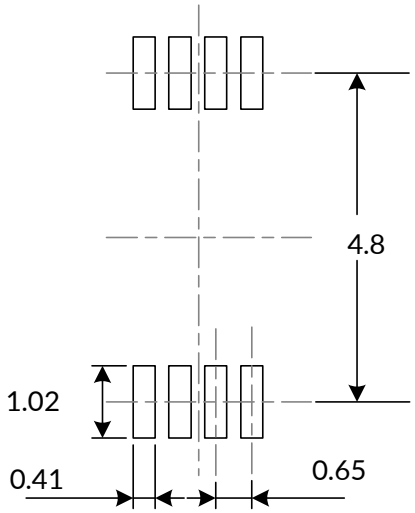
Symbol	Dimensions In Millimeters		Dimensions In Inches	
	Min	Max	Min	Max
A (1)		1.250		0.049
A1	0.000	0.150	0.000	0.006
A2	1.000	1.200	0.039	0.047
b	0.360	0.500	0.014	0.020
c	0.100	0.200	0.004	0.008
D (1)	2.826	3.026	0.111	0.119
E (1)	1.526	1.726	0.060	0.068
E1	2.600	3.000	0.102	0.118
e	0.950(BSC) (2)		0.037(BSC) (2)	
e1	1.800	2.000	0.071	0.079
L	0.350	0.600	0.014	0.024
θ	0°	8°	0°	8°

NOTE:

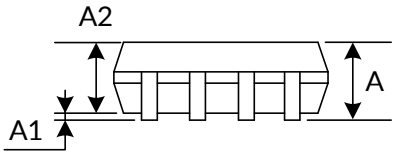
1. Plastic or metal protrusions of 0.15mm maximum per side are not included.
2. BSC (Basic Spacing between Centers), "Basic" spacing is nominal.
3. This drawing is subject to change without notice.

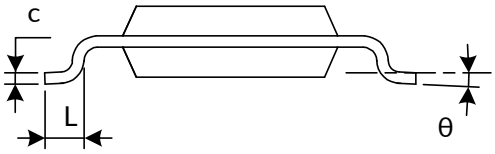
MSOP8 (3)





RECOMMENDED LAND PATTERN (Unit: mm)



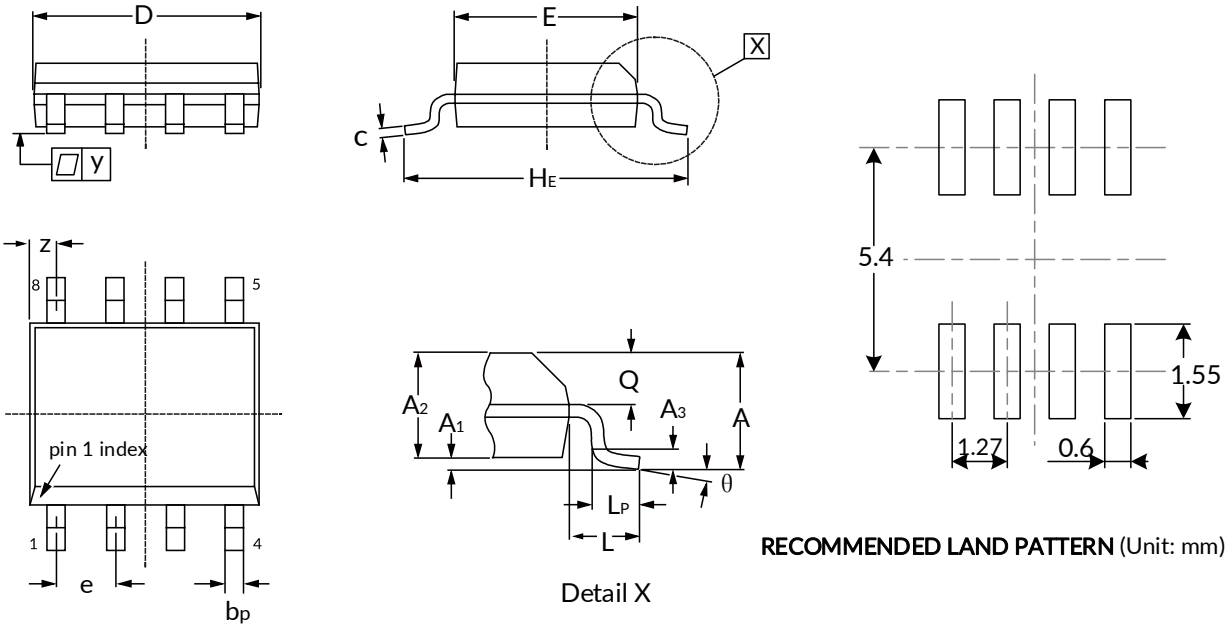


Symbol	Dimensions In Millimeters		Dimensions In Inches	
	Min	Max	Min	Max
A (1)	0.820	1.100	0.032	0.043
A1	0.020	0.150	0.001	0.006
A2	0.750	0.950	0.030	0.037
b	0.250	0.380	0.010	0.015
c	0.090	0.230	0.004	0.009
D (1)	2.900	3.100	0.114	0.122
e	0.650(BSC) (2)		0.026(BSC) (2)	
E (1)	2.900	3.100	0.114	0.122
E1	4.750	5.050	0.187	0.199
L	0.400	0.800	0.016	0.031
θ	0°	6°	0°	6°

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.

SOP8 (2)



RECOMMENDED LAND PATTERN (Unit: mm)

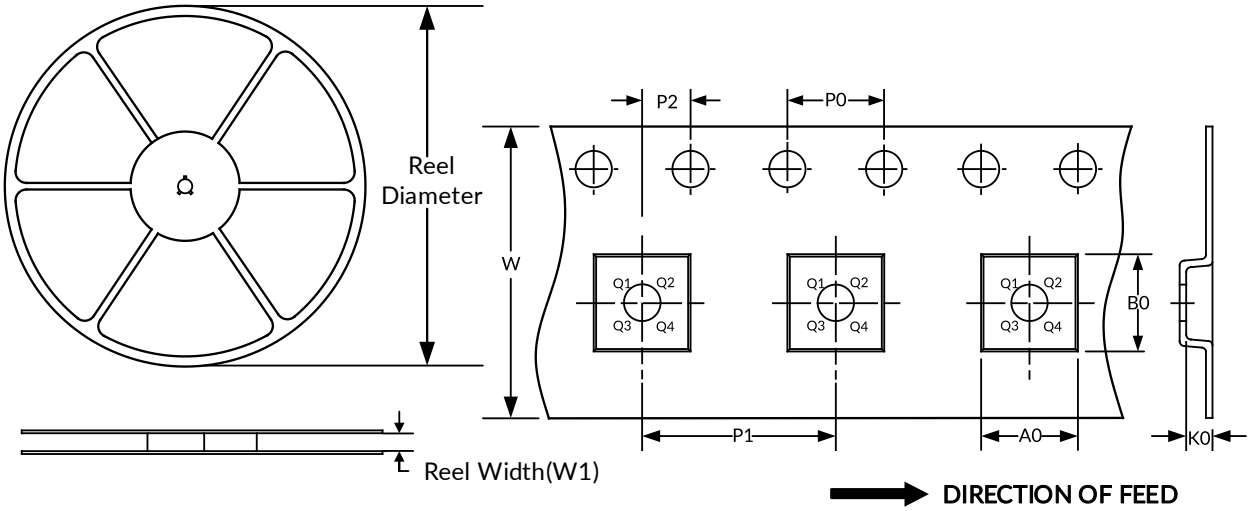
Symbol	Dimensions In Millimeters		Dimensions In Inches	
	Min	Max	Min	Max
A (1)		1.750		0.069
A_1	0.100	0.250	0.004	0.010
A_2	1.250	1.450	0.049	0.057
A_3	0.25		0.010	
b_p	0.360	0.490	0.014	0.019
c	0.190	0.250	0.007	0.010
D (1)	4.800	5.000	0.190	0.200
E (1)	3.800	4.000	0.150	0.160
H_E	5.800	6.200	0.228	0.244
e	1.270		0.050	
L	1.05		0.041	
L_P	0.400	1.000	0.016	0.039
Q	0.600	0.700	0.024	0.028
Z	0.300	0.700	0.012	0.028
y	0.1		0.004	
θ	0°	8°	0°	8°

NOTE:
1. Plastic or metal protrusions of 0.15mm maximum per side are not included.
2. This drawing is subject to change without notice.

12 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
SOT23-5	7”	9.5	3.20	3.20	1.40	4.0	4.0	2.0	8.0	Q3
MSOP8	13”	12.4	5.20	3.30	1.50	4.0	8.0	2.0	12.0	Q1
SOP8	13”	12.4	6.40	5.40	2.10	4.0	8.0	2.0	12.0	Q1

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

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