Single Power Supply, Rail-to-Rail Input and Output, High-Precision Operational Amplifier

PRODUCT DESCRIPTION

The MS8551/8552/8554 is a rail-to-rail input and output, high-precision operational amplifier. It has ultra-low input offset voltage and bias current. The single power supply ranges from 1.8V to 5V.

Rail-to-rail input and output enables the MS8551/8552/8554 to easily amplify the sensor signal of high-level and low-level. All features make it ideal for medical device, strain gauge amplifier and sensors, such as temperature, position and pressure sensors. And it can also be used in other applications which need high-precision, long-term stability and operate in 1.8V to 5V power supply.

The MS8551/8552/8554 can be applicable to industrial temperature range from -40°C to +125°C.

FEATURES

- Low Offset Voltage: 1μV (TYP)
- Rail-to-Rail Input and Output
- Single Power Supply: 1.8V to 5.5V
- Voltage Gain: 145dB (TYP) (5V Operating Voltage)
- Power Supply Rejection Ratio: 120dB (TYP)
- Common-mode Rejection Ratio: 120dB (TYP)
- Ultra-low Input Bias Current: 10pA
- Low Operating Current: 800μA Each Channel (TYP)
- Overload Recovery Time: 50μs (5V Operating Voltage)
- No Need for Additional External Capacitor

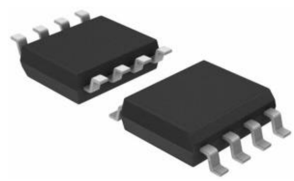
PRODUCT SPECIFICATION

Part Number	Package	Marking
MS8551S	SOT23-5	8551S
MS8551	SOP8	MS8551
MS8552	SOP8	MS8552
MS8552M	MSOP8	MS8552M
MS8554	SOP14	MS8554

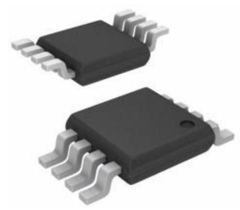
PRODUCT GRADE

Grade	Offset Voltage (μV)	Condition
A	0-2	5V Power Supply
B	2-6	5V Power Supply
C	6-24	5V Power Supply

SOT23-5



SOP8



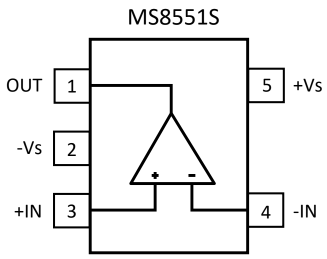
MSOP8

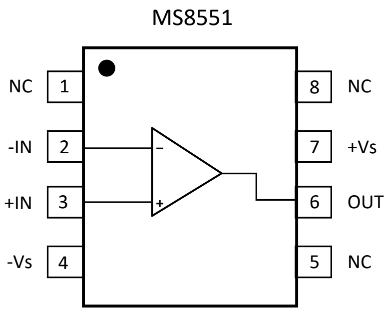
SOP14

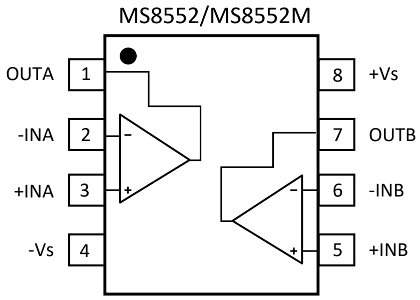
APPLICATIONS

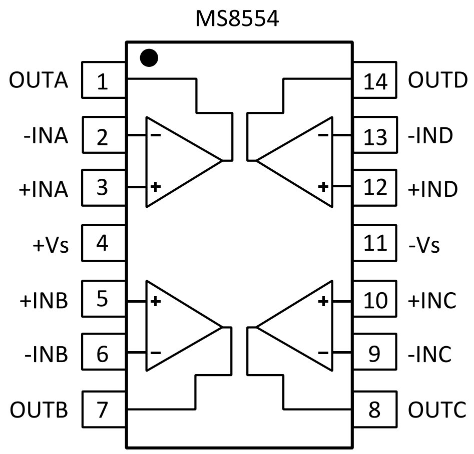
- Temperature Measurement
- Pressure Sensor
- High-precision Current Sense
- Electronic Weigh
- Strain Gauge Amplifier
- Medical Device
- Thermocouple Amplifier
- Handheld Test Device

PIN CONFIGURATION









PIN DESCRIPTION

Pin	Name	Type	Description
MS8551S			
1	OUT	O	Channel Output
2	-Vs	-	Negative Power Supply
3	+IN	I	Positive Input
4	-IN	I	Negative Input
5	+Vs	-	Positive Power Supply
MS8551			
1	NC	-	Not Connection
2	-IN	I	Negative Input
3	+IN	I	Positive Input
4	-Vs	-	Negative Power Supply
5	NC	-	Not Connection
6	OUT	O	Channel Output
7	+Vs	-	Positive Power Supply
8	NC	-	Not Connection
MS8552/MS8552M			
1	OUTA	O	Channel A Output
2	-INA	I	Negative Input (Channel A)
3	+INA	I	Positive Input (Channel A)
4	-Vs	-	Negative Power Supply
5	+INB	I	Positive Input (Channel B)
6	-INB	I	Negative Input (Channel B)
7	OUTB	O	Channel B Output
8	+Vs	-	Positive Power Supply
MS8554			
1	OUTA	O	Channel A Output
2	-INA	I	Negative Input (Channel A)
3	+INA	I	Positive Input (Channel A)
4	+Vs	-	Positive Power Supply
5	+INB	I	Positive Input (Channel B)
6	-INB	I	Negative Input (Channel B)
7	OUTB	O	Channel B Output
8	OUTC	O	Channel C Output
9	-INC	I	Negative Input (Channel C)
10	+INC	I	Positive Input (Channel C)
11	-Vs	-	Negative Power Supply
12	+IND	I	Positive Input (Channel D)
13	-IND	I	Negative Input (Channel D)
14	OUTD	O	Channel D Output

ABSOLUTE MAXIMUM RATINGS

Any exceeding absolute maximum rating application causes permanent damage to device. Because long-time absolute operation state affects device reliability. Absolute ratings just conclude from a series of extreme tests. It doesn't represent chip can operate normally in these extreme conditions.

Parameter	Symbol	Ratings	Unit
Power Supply	Vs	6	V
Input Voltage		GND ~ (+Vs) +0.3	V
Differential Input Voltage		-5 ~ 5 (or power supply, based on less value)	V
Junction Temperature		-65 ~ 150	°C
Operating Temperature	TA	-40 ~ 125	°C
Storage Temperature	Tstg	-65 ~ 150	°C
Lead Temperature (Soldering, 60s)		300	°C
ESD (HBM)		3000	V

ELECTRICAL CHARACTERISTICS (5V)

Unless otherwise noted, V_S=+5V, VCM=+2.5V, V_O=+2.5V, T_A=25°C.

Parameter	Symbol	Condition	Min	Typ	Max	Unit
Input Characteristics						
Input Offset Voltage	V_{OS}			1	5	µV
		-40°C ≤ T_A ≤ +125°C			10	
Input Bias Current	I_B			10	50	pA
		-40°C ≤ T_A ≤ +125°C			4	nA
Input Offset Current	I_{OS}	-40°C ≤ T_A ≤ +125°C		150	400	pA
Input Voltage			0		5	V
Common-mode Rejection Ratio	CMRR	VCM = 0V to 5V	100	120		dB
		-40°C ≤ T_A ≤ +125°C	95	110		
Large-signal Gain	A_{VO}	RL= 10kΩ, Vo= 0.3V to 4.7V	125	145		dB
		-40°C ≤ T_A ≤ +125°C	120	135		
Input Offset Voltage Drift	$\Delta V_{OS}/\Delta T_A$	-40°C ≤ T_A ≤ +125°C		0.04	0.05	µV/°C
Output Characteristics						
Output High Voltage	V_{OH}	RL = 100kΩ to GND	4.99	4.998		V
		-40°C ≤ T_A ≤ +125°C	4.99	4.997		
		RL = 10kΩ to GND	4.95	4.98		V
		-40°C ≤ T_A ≤ +125°C	4.95	4.975		
Output Low Voltage	V_{OL}	RL = 100kΩ to +Vs		3	12	mV
		-40°C ≤ T_A ≤ +125°C		5	12	
		RL = 10kΩ to +Vs		10	30	mV
		-40°C ≤ T_A ≤ +125°C		15	30	
Short-circuit Current	I_{SC}		40	70		mA
		-40°C ≤ T_A ≤ +125°C		75		
Power Supply						
Power Supply Rejection Ratio	PSRR	Vs =1.8V to 5.5V, -40°C ≤ T_A ≤ +125°C	110	120		dB
Quiescent Current/Amplifier	I_Q	Vo = 0		850	975	µA
		-40°C ≤ T_A ≤ +125°C		1000	1075	

Parameter	Symbol	Condition	Min	Typ	Max	Unit
Dynamic Characteristics						
Gain Bandwidth Product	GBP	Av = +100		3		MHz
Slew Rate	SR	Av = +1, RL = 10kΩ		0.4		V/μs
Overload Recovery Time				0.05		ms
Noise Characteristics						
Voltage Noise	$e_{n\ P\text{-}P}$	0.1Hz to 10Hz		1.0		$\mu V_{p\text{-}p}$
Voltage Noise Density	e_n	f = 1kHz		42		$nV/\sqrt{Hz}$
Current Noise Density	i_n	f = 10Hz		2		$fA/\sqrt{Hz}$

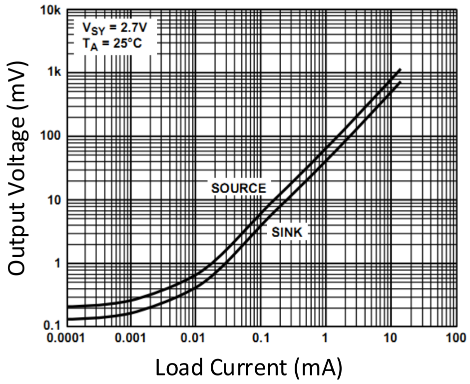
ELECTRICAL CHARACTERISTICS (2.7V)

Unless otherwise noted, Vs=+2.7V, VCM=+1.35V, Vo=+1.35V, TA=25°C.

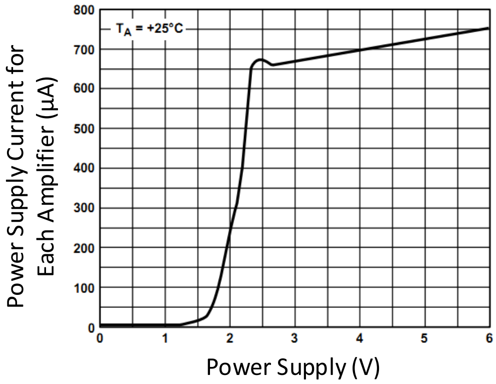
Parameter	Symbol	Condition	Min	Typ	Max	Unit
Input Characteristics						
Input Offset Voltage	V_{OS}			1	5	µV
		-40°C ≤ T_A ≤ +125°C			10	
Input Bias Current	I_B			10	50	pA
		-40°C ≤ T_A ≤ +125°C			4	nA
Input Offset Current	I_{OS}	-40°C ≤ T_A ≤ +125°C		150	400	pA
Input Voltage			0		2.7	V
Common-mode Rejection Ratio	CMRR	VCM = 0V to 5V	115	120		dB
		-40°C ≤ T_A ≤ +125°C	110	120		
Large-signal Gain	A_{VO}	RL= 10kΩ, Vo= 0.3V to 2.4V	110	130		dB
		-40°C ≤ T_A ≤ +125°C	105	130		
Input Offset Voltage Drift	$\Delta V_{OS}/\Delta T_A$	-40°C ≤ T_A ≤ +125°C		0.04	0.05	µV/°C
Output Characteristics						
Output High Voltage	V_{OH}	RL = 100kΩ to GND	2.685	2.697		V
		-40°C ≤ T_A ≤ +125°C	2.685	2.696		
		RL = 10kΩ to GND	2.67	2.68		V
		-40°C ≤ T_A ≤ +125°C	2.67	2.675		
Output Low Voltage	V_{OL}	RL = 100kΩ to +Vs		1	10	mV
		-40°C ≤ T_A ≤ +125°C		2	10	
		RL = 10kΩ to +Vs		10	20	mV
		-40°C ≤ T_A ≤ +125°C		15	20	
Short-circuit Current	I_{SC}		20	25		mA
		-40°C ≤ T_A ≤ +125°C		20		
Power Supply						
Power Supply Rejection Ratio	PSRR	Vs =1.8V to 5.5V, -40°C ≤ T_A ≤ +125°C	110	120		dB
Quiescent Current/Amplifier	I_Q	Vo = 0		750	900	µA
		-40°C ≤ T_A ≤ +125°C		950	1000	

Parameter	Symbol	Condition	Min	Typ	Max	Unit
Dynamic Characteristics						
Gain Bandwidth Product	GBP	Av = +100		2		MHz
Slew Rate	SR	Av = +1, RL = 10kΩ		0.4		V/μs
Overload Recovery Time				0.05		ms
Noise Characteristics						
Voltage Noise	$e_{n\ P\text{-}P}$	0.1Hz to 10Hz		1.6		$\mu V_{p\text{-}p}$
Voltage Noise Density	e_n	f = 1kHz		75		$nV/\sqrt{Hz}$
Current Noise Density	i_n	f = 10Hz		2		$fA/\sqrt{Hz}$

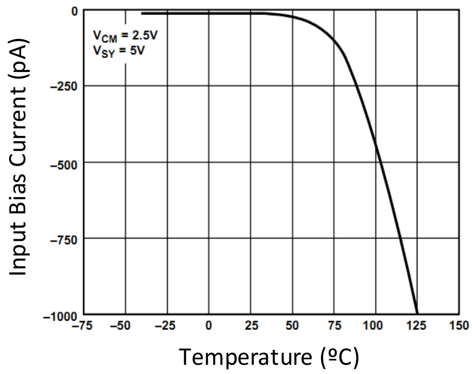
TYPICAL CHARACTERISTIC CURVES



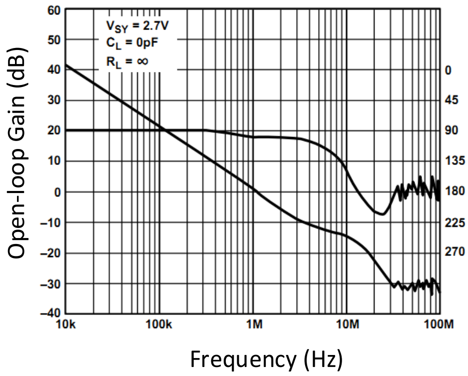
Output Voltage VS. Load Current at 2.7V



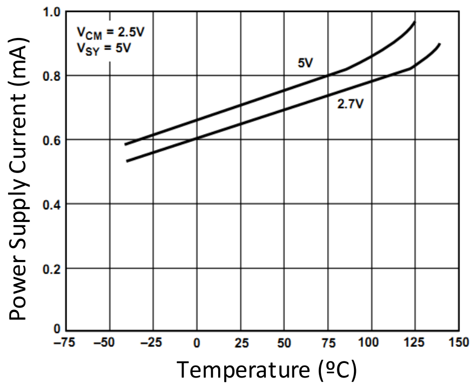
Power Supply Current for Each Amplifier VS. Power Supply



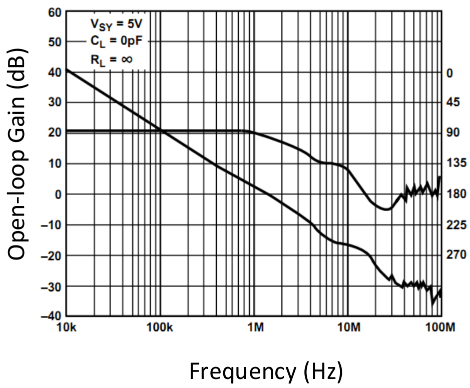
Input Bias Current VS. Temperature



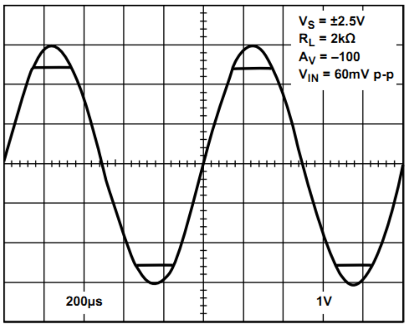
Open-loop Gain VS. Frequency at 2.7V



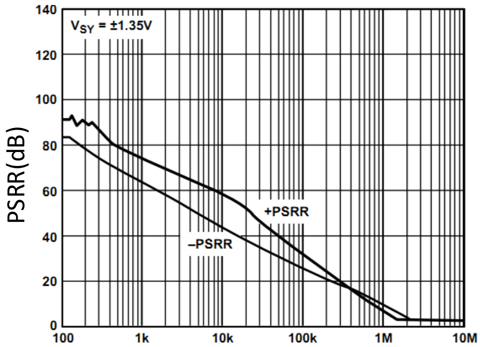
Power Supply Current VS. Temperature



Open-loop Gain VS. Frequency at 5V

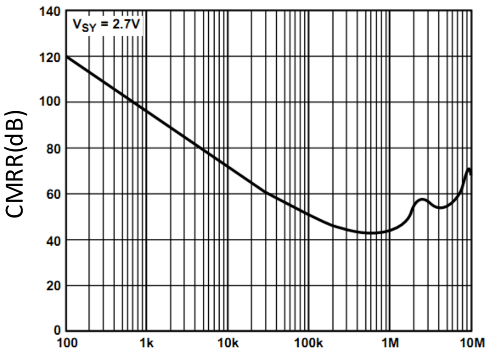


No Phase Reversal



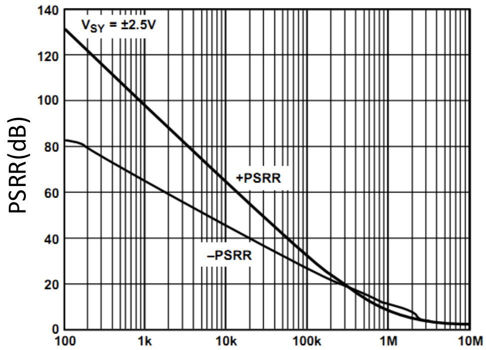
Frequency (Hz)

PSRR VS. Frequency at ±1.35V



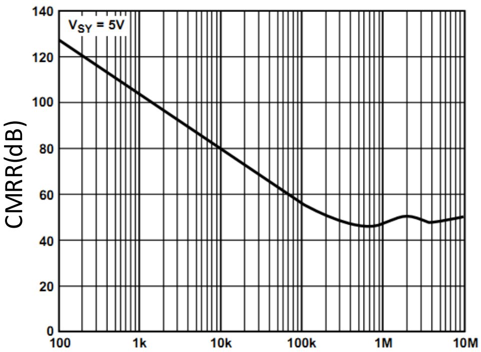
Frequency (Hz)

CMRR VS. Frequency at 2.7V



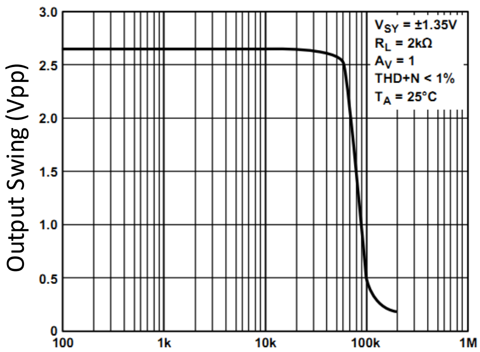
Frequency (Hz)

PSRR VS. Frequency at ±2.5V



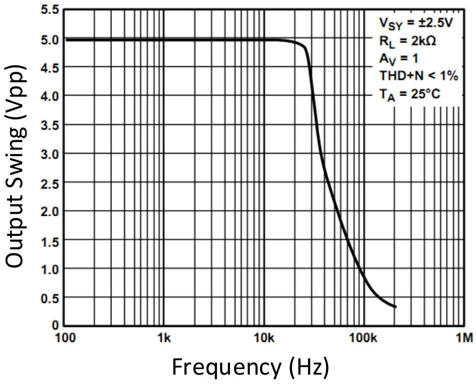
Frequency (Hz)

CMRR VS. Frequency at 5V

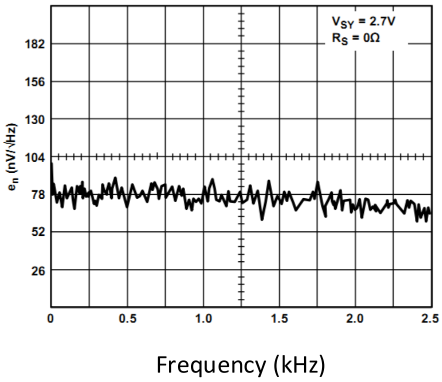


Frequency (Hz)

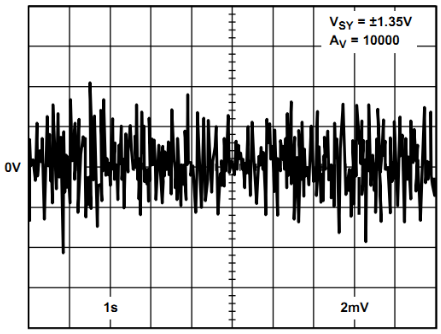
Maximum Output Swing VS. Frequency at 2.7V



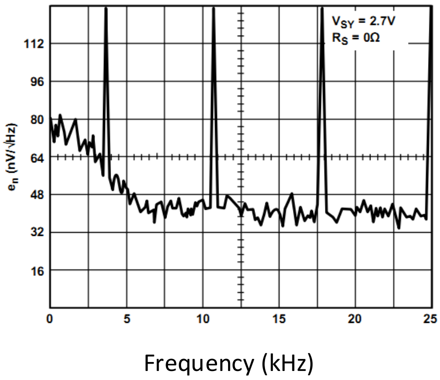
Maximum Output Swing VS. Frequency at 5V



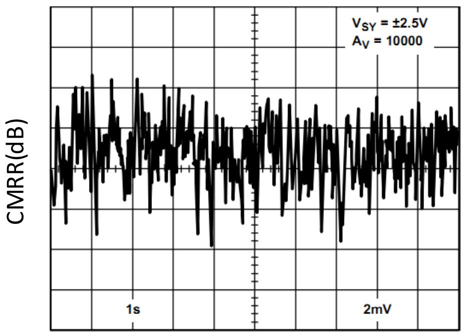
0Hz to 2.5kHz Voltage Noise Density at 2.7V



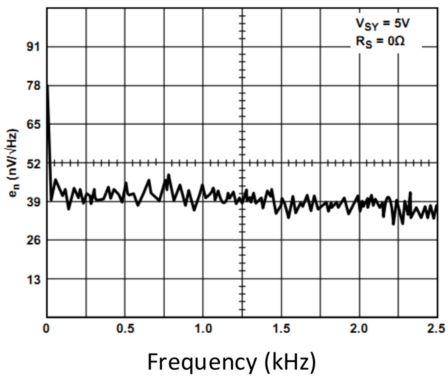
0.1Hz to 10Hz Noise at 2.7V



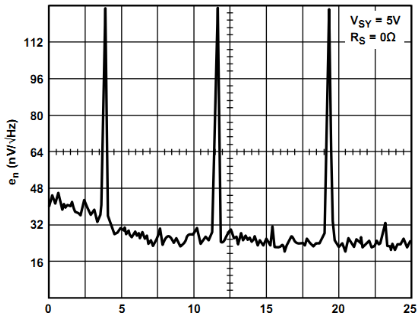
0Hz to 2.5kHz Voltage Noise Density at 2.7V



0.1Hz to 10Hz Noise at 5V

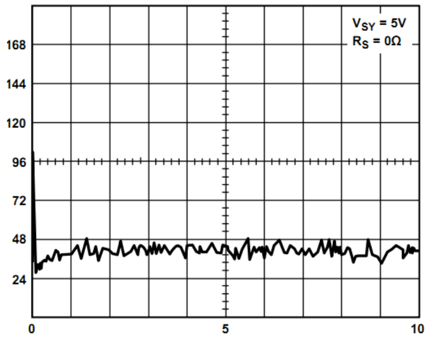


0Hz to 2.5kHz Voltage Noise Density at 5V



Frequency (kHz)

0Hz to 2.5kHz Voltage Noise Density at 5V



Frequency (Hz)

0Hz to 10Hz Voltage Noise Density at 5V

TYPICAL APPLICATIONS

5V High-precision Strain Gauge Circuit

The ultra-low input offset voltage makes the MS8551/8552/8554 ideal for high-precision and high-gain applications, such as electronic weigh or strain gauge. The figure 1 shows the measurement system for a strain gauge with single power supply and high precision.

REF192 provides a 2.5V high-precision reference voltage for amplifier A2. A2 increases the reference voltage to 4.0V for the top of the strain gauge resistor bridge. Q1 provides the current for the 350Ω bridge network. A1 is usually used to amplify the full-scale output voltage of the bridge, equaling to 2×(R1+R2)/RB. RB is the load resistance of the bridge network.

Output voltage is changed from 0V with no strain to 4.0V with full strain using the values in Figure 1.

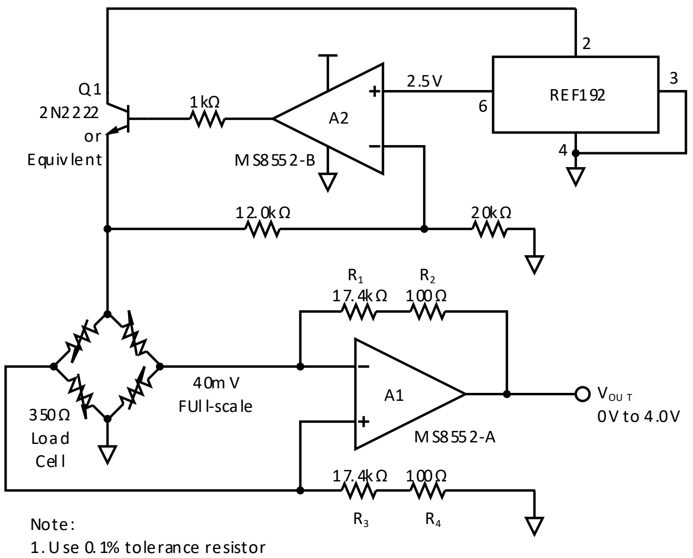


Figure 1. 5V High-precision Strain Gauge Circuit

3V Instrumentation Amplifier

The MS855X is ideal selection for single power supply instrumentation amplifier due to the features of high CMRR, high open-loop gain and low to 3V operating voltage. The CMRR is more than 120dB and it is the function of the error value of external resistor. In Figure 2, the gain of the differential amplifier is:

$$V_{OUT} = V1\left(\frac{R_4}{R_3+R_4}\right)\left(1+\frac{R_1}{R_2}\right) - V2\left(\frac{R_2}{R_1}\right)$$

In the ideal differential amplifier, the resistor ratio is set as follows:

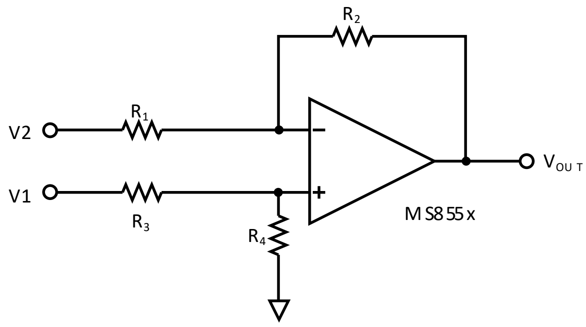
$$A_V = \frac{R_4}{R_3} = \frac{R_2}{R_1}$$

System output voltage is set as follows:

$$V_{OUT} = A_V(V1 - V2)$$

Because of finite component tolerances, the ratio of four resistors is not exactly equal. Any mismatch would affect system CMRR. Refer to Figure 2, CMRR is as follows:

$$CMRR = \frac{R_1R_4 + 2R_2R_4 + R_2R_3}{2R_1R_4 - 2R_2R_3}$$

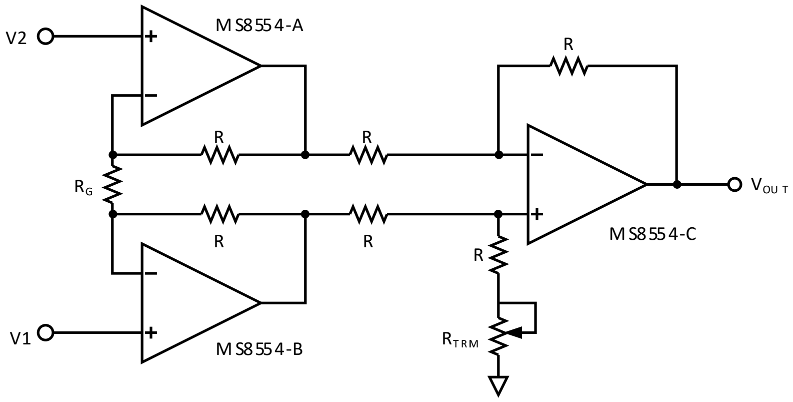


$$IF\ \frac{R_4}{R_3}=\frac{R_2}{R_1},\ THEN\ V_{OUT}=\frac{R_2}{R_1}\times(V1-V2)$$

Figure 2. Differential Amplifier Circuit with the MS855x

The three-amplifier instrumentation amplifier circuit is shown in Figure 3. If four resistances are same, the output voltage of differential amplifier is unity gain. If the resistor tolerance is δ, the worst-case CMRR of instrumentation amplifier is: $CMRR_{MIN}=1/2\delta$。

If using 1% tolerance resistor, the worst-case system CMRR is 0.02 or 34dB. Therefore, high-precision resistors and an additional trimming resistor are used in Figure 3. Thus, very high CMRR is achieved. The value of trimming resistor should equal to the value of R multiplied by tolerance. For example, using 10kΩ resistor with 1% tolerance needs to be in series with a 100Ω trimming resistor.



$$V_{OUT}=1+\frac{2R}{R_G}(V1-V2)$$

Figure 3. Discrete Instrumentation Amplifier Circuit

High-precision Thermocouple Amplifier

Figure 4 shows K-type thermocouple amplifier circuit using cold junction compensation. Even if use 5V power supply, the MS855x can also provide enough accuracy for under 0.02°C resolution from 0°C to 500°C. D1 is used as a temperature measurement device to correct the cold junction error of the thermocouple, so D1 should be placed as close as possible to the two terminating junctions. When the thermocouple measurement terminal is immersed in 0°C ice water, R_6 should be adjusted until the system output is at 0V.

Using the values in Figure 4, the ratio of output voltage and temperature is 10mV/°C. If in order to get wider range of temperature measurement, R8 can be decreased to 62kΩ. This generates 5mV/°C change on the output terminal, and the allowable measurement range is increased to 1000°C.

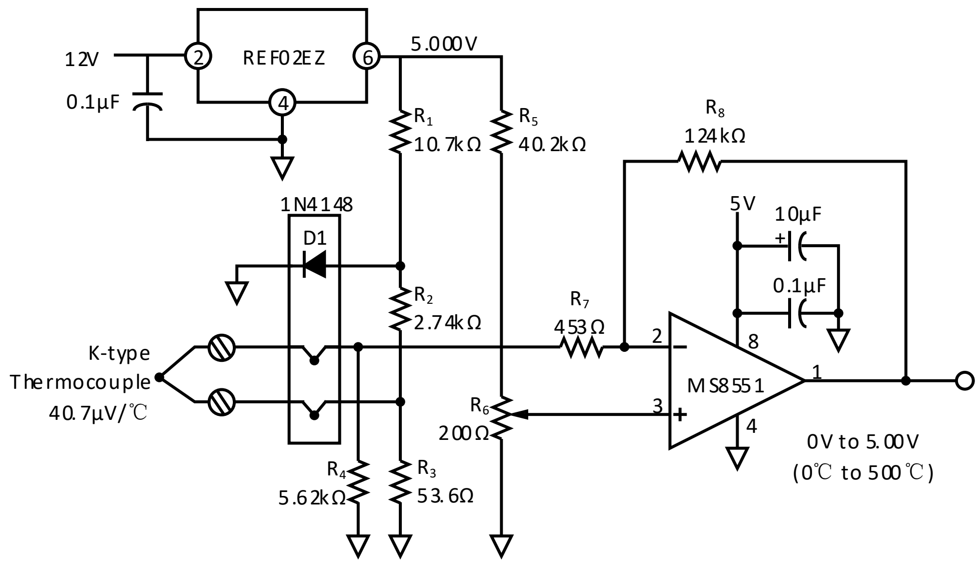


Figure 4. High-precision K-type Thermocouple Amplifier with Cold Junction Compensation

High-precision Current Meter

The MS8551/8552/8554 is ideal amplifier for high-precision current measurement, due to the features of low input bias current and ultra-low offset voltage at single power supply. Its rail-to-rail input can monitor the current source and current sink, which can be completed just by a MS8552.

Figure 5 shows the circuit for monitoring the current source. In this circuit, the input common-mode voltage of the amplifier is near the positive power supply. The rail-to-rail input provides a precise amplification even though common-mode voltage is near the power supply. CMOS input structure doesn't draw any input bias current, thus ensuring the minimum measurement.

0.1Ω resistor would generate a voltage drop on the negative terminal of the MS8551/8552/8554. The output of the amplifier is normal only when one voltage drop is on the negative terminal. And there is a current flowing through R1 and R2. The monitor output is as follows:

$$MonitorOutput = R_2 \times \left(\frac{R_{SENSE}}{R_1}\right) \times I_L$$

If use the component values shown in Figure 5, the transmission ratio of monitor output voltage is 2.5V/A.

Figure 6 shows the circuit for monitoring the current sink. In this circuit, the input common-mode voltage is near ground. Similarly, the current flowing through a 0.1Ω resistor generates a voltage drop. The output voltage is as follows:

$$V_{OUT} = (V+) - \left(\frac{R_2}{R_1} \times R_{SENSE} \times I_L\right)$$

If use the component values shown in Figure 6, the transmission ratio of output voltage is -2.5V/A.

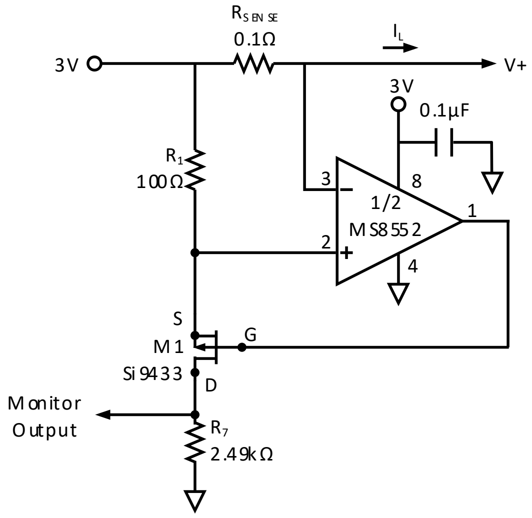


Figure 5. Current Source Monitor Circuit

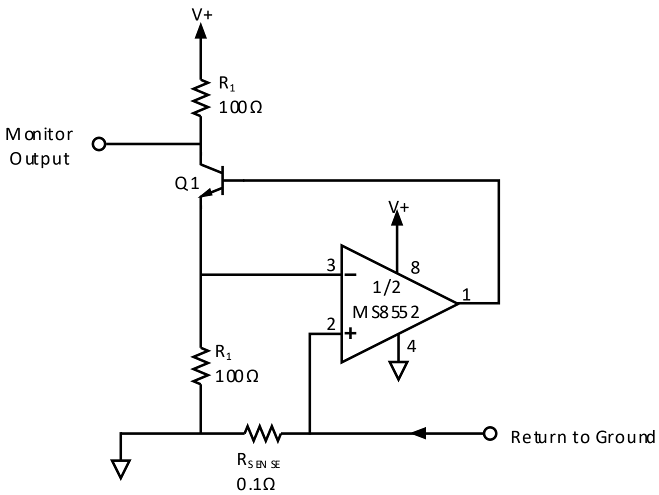


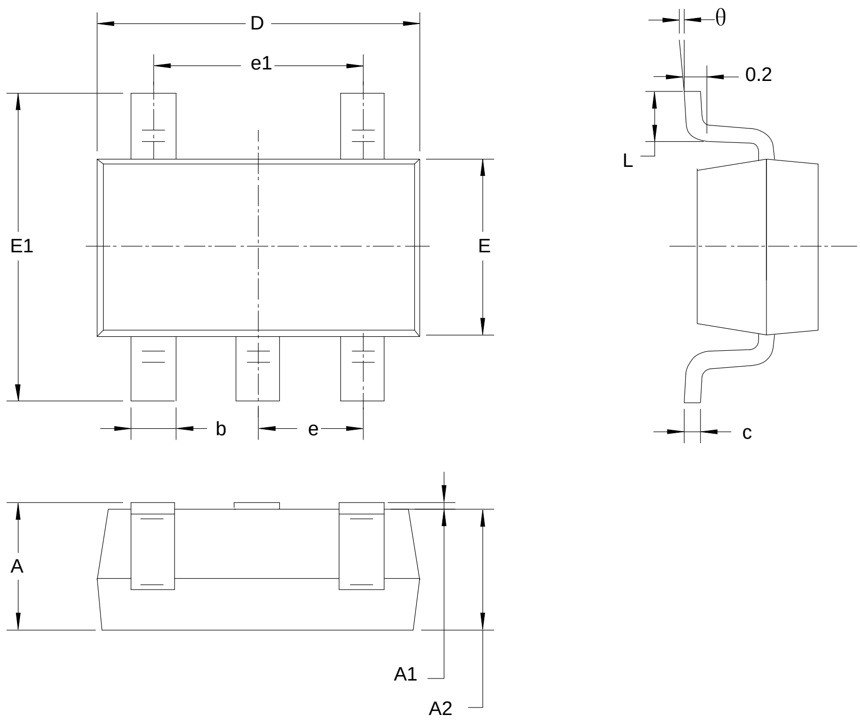
Figure 6. Current Sink Monitor Circuit

High-precision Voltage Comparator

The MS8551/8552/8554 can operate in open-loop condition and is used as a high-precision voltage comparator. The offset voltage is less than 50µV in this condition. The slight increase of offset voltage is because automatic correction structure can remain low offset only in closed-loop (there is one negative feedback). Due to 50mV overdrive voltage, there have delay time of 15µs on the rising edge and 8µs on the falling edge. Ensure the differential input voltage doesn’t exceed the overdrive voltage.

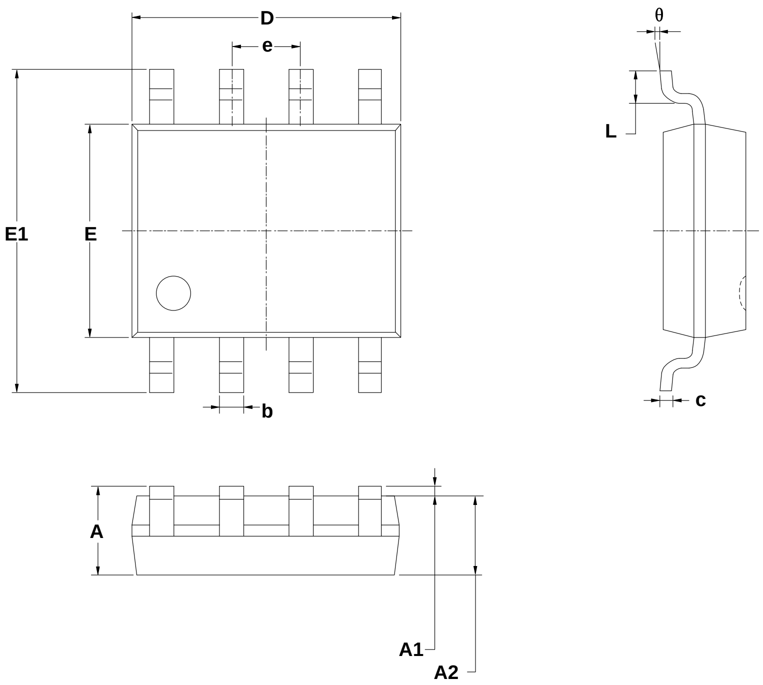
PACKAGE OUTLINE DIMENSIONS

SOT23-5



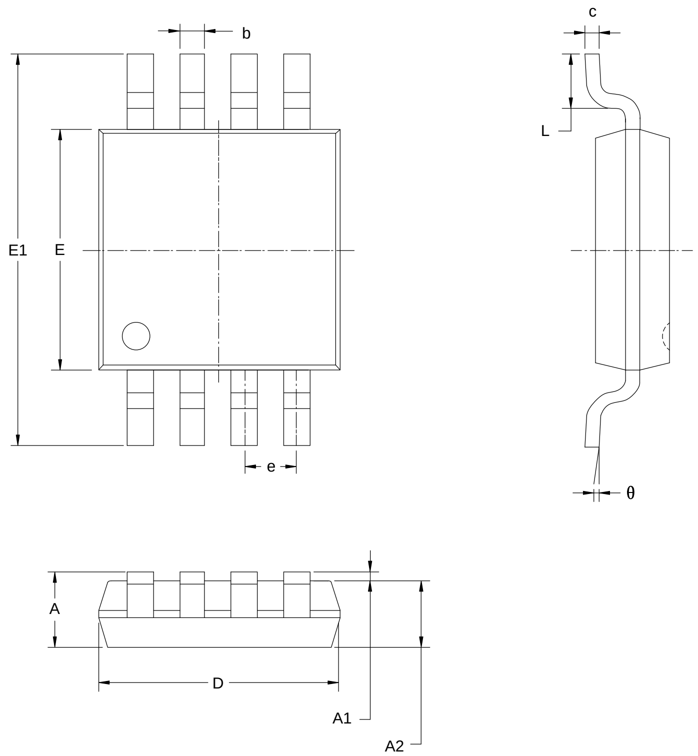
Symbol	Dimensions in Millimeters		Dimensions in Inches	
	Min	Max	Min	Max
A	1.050	1.250	0.041	0.049
A1	0.000	0.100	0.000	0.004
A2	1.050	1.150	0.041	0.045
b	0.300	0.500	0.012	0.020
c	0.100	0.200	0.004	0.008
D	2.820	3.020	0.111	0.119
E	1.500	1.700	0.059	0.067
E1	2.650	2.950	0.104	0.116
e	0.950 BSC		0.037 BSC	
e1	1.900 BSC		0.075 BSC	
L	0.300	0.600	0.012	0.024
θ	0^{o}	8^{o}	0^{o}	8^{o}

SOP8



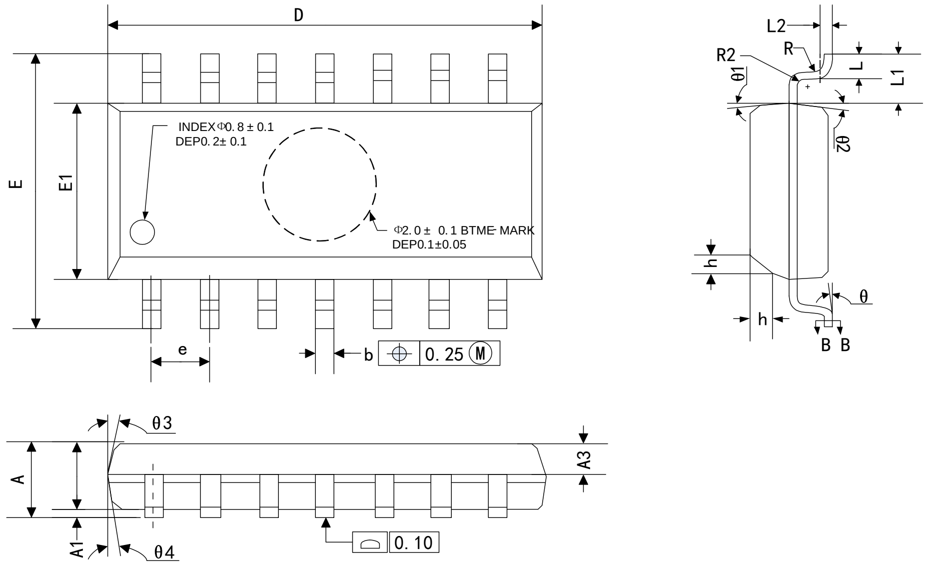
Symbol	Dimensions in Millimeters		Dimensions in Inches	
	Min	Max	Min	Max
A	1.350	1.750	0.053	0.069
A1	0.100	0.250	0.004	0.010
A2	1.350	1.550	0.053	0.061
b	0.330	0.510	0.013	0.020
c	0.170	0.250	0.006	0.010
D	4.700	5.100	0.185	0.200
E	3.800	4.000	0.150	0.157
E1	5.800	6.200	0.228	0.244
e	1.27 BSC		0.050 BSC	
L	0.400	1.270	0.016	0.050
θ	0 °	8 °	0 °	8 °

MSOP8



Symbol	Dimensions in Millimeters		Dimensions in Inches	
	Min	Max	Min	Max
A	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	2.900	3.100	0.114	0.122
E	2.900	3.100	0.114	0.122
E1	4.750	5.050	0.187	0.199
e	0.650BSC		0.026BSC	
L	0.400	0.800	0.016	0.031
θ	0º	6º	0º	6º

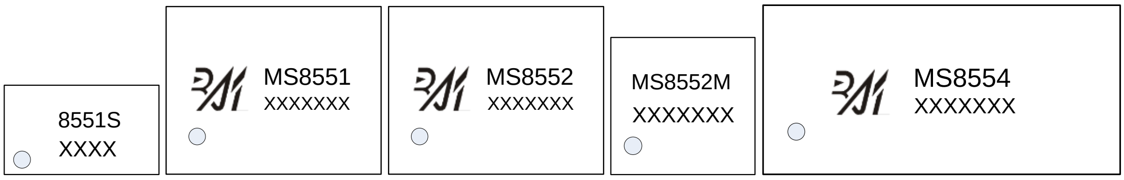
SOP14



Symbol	Dimensions in Millimeters		
	Min	Typ	Max
A	1.35		1.75
A1	0.10		0.25
A2	1.25		1.65
A3	0.55		0.75
D	8.53		8.73
E	5.80		6.20
E1	3.80		4.00
e	1.27 BSC		
L	0.45		0.80
L1	1.04 REF		
L2	0.25 BSC		
R	0.07		
R1	0.07		
h	0.30		0.50
θ	0°		8°
θ1	6°	8°	10°
θ2	6°	8°	10°
θ3	5°	7°	9°
θ4	5°	7°	9°

MARKING and PACKAGING SPECIFICATIONS

1. Marking Drawing Description



Product Name: 8551S, MS8551, MS8552, MS8552M, MS8554

Product Code: XXXX, XXXXXXX

2. Marking Drawing Demand

Laser printing, contents in the middle, font type Arial.

3. Packaging Specifications

Device	Package	Piece/Reel	Reel/Box	Piece /Box	Box/Carton	Piece/Carton
MS8551S	SOT23-5	3000	10	30000	4	120000
MS8551	SOP8	2500	1	2500	8	20000
MS8552	SOP8	4000	1	4000	8	32000
MS8552M	MSOP8	3000	1	3000	8	24000
MS8554	SOP14	2500	1	2500	8	20000

STATEMENT

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- The process of improving product is endless. And our company would sincerely provide more excellent product for customer.

MOS CIRCUIT OPERATION PRECAUTIONS

Static electricity can be generated in many places. The following precautions can be taken to effectively prevent the damage of MOS circuit caused by electrostatic discharge:

1. The operator shall ground through the anti-static wristband.
2. The equipment shell must be grounded.
3. The tools used in the assembly process must be grounded.
4. Must use conductor packaging or anti-static materials packaging or transportation.

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