

General Description

The TPV324 is a single supply, low power CMOS dual operational amplifier; these amplifiers offer bandwidth of 1MHz, rail-to-rail inputs and outputs, and single-supply operation from 2.2V to 5.5V. The embedded anti-RF filter can significantly increase the RF immunity without extra components. Typical low quiescent supply current of 80 μ A in dual operational amplifiers within one chip and very low input bias current of 10pA make the devices an ideal choice for low offset, low power consumption and high impedance applications such as smoke detectors, photodiode amplifiers, and other sensors.

The TPV324 is available in SOP-14 and MSOP-14 packages. The extended temperature range of -40 °C to +125 °C over all supply voltages offers additional design flexibility.

Features

- Single-Supply Operation from +2.2V ~ +5.5V
- Rail-to-Rail Input / Output
- Gain-Bandwidth Product: 1MHz (Typ.)
- Low Input Bias Current: 10pA (Typ.)
- Low Offset Voltage: 5mV (Max.)
- Quiescent Current: 40 μ A per Amplifier (Typ.)
- Operating Temperature: -40°C ~ +125°C
- Available in SOP-14 and TSSOP-14 Packages

Applications

- Portable Equipment
- Mobile Communications
- Smoke Detector
- Medical Instrumentation
- Battery-Powered Instruments
- Sensor Interface
- Handheld Test Equipment

Ordering Information

Part Number	Package	QTY Per Reel	Reel Size
TPV324S14	SOP-14	2500	13"
TPV324M14	TSSOP-14	3000	13"

Pin Assignments

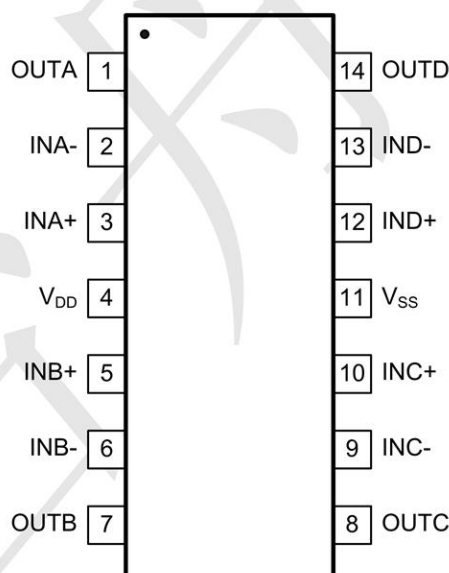


Figure 1. Pin Assignment Diagram (SOP14 and TSSOP14 Package)

Ordering Information

TPV324M14

Package Type
S14: SOP14
M14: TSOP14

TP= TECH PUBLIC

Electrical Characteristics

Absolute Maximum Ratings

Condition	Min	Max
Power Supply Voltage (VDD to Vss)	-0.5V	+7V
Analog Input Voltage (IN+ or IN-)	Vss-0.5V	VDD+0.5V
PDB Input Voltage	Vss-0.5V	+7V
Operating Temperature Range	-40°C	+125°C
Junction Temperature	+150°C	
Storage Temperature Range	-65°C	+150°C
Lead Temperature (soldering, 10sec)	+300°C	
Package Thermal Resistance (TA=+25°C)		
SOP14, θ_{JA}	90°C	
TSSOP14, θ_{JA}	100°C	

Note: Stress greater than those listed under Absolute Maximum Ratings may cause permanent damage to the device. This is a stress rating only and functional operation of the device at these or any other conditions outside those indicated in the operational sections of this specification are not implied. Exposure to absolute maximum rating conditions for extended periods may affect reliability.

Electrical Characteristics

($V_{DD} = +5V$, $V_{SS} = 0V$, $V_{CM} = 0V$, $V_{OUT} = V_{DD}/2$, $R_L = 100k\Omega$ tied to $V_{DD}/2$, $SHDNB = V_{DD}$, $T_A = -40^\circ C$ to $+125^\circ C$, unless otherwise noted. Typical values are at $T_A = +25^\circ C$.) (Notes 1)

Parameter	Symbol	Conditions	Min.	Typ.	Max.	Units
Supply-Voltage Range	V_{DD}	Guaranteed by the PSRR test	2.2	-	5.5	V
Quiescent Supply Current (per Amplifier)	I_Q	$V_{DD} = 5V$	30	40	60	μA
Input Offset Voltage	V_{OS}		-	0.5	± 5	mV
Input Offset Voltage Tempco	$\Delta V_{OS}/\Delta T$		-	2	-	$\mu V/^\circ C$
Input Bias Current	I_B	(Note 2)	-	10	-	pA
Input Offset Current	I_{OS}	(Note 2)	-	10	-	pA
Input Common-Mode Voltage Range	V_{CM}		-0.1	-	$V_{DD}+0.1$	V
Common-Mode Rejection Ratio	CMRR	$V_{DD}=5.5V$, $V_{SS}=0.1V$, $V_{CM} = V_{DD}/2$	55	65	-	dB
		$V_{SS} \leq V_{CM} \leq 5V$	60	80	-	dB
Power-Supply Rejection Ratio	PSRR	$V_{DD} = +2.5V$ to $+5.5V$	75	94	-	dB
Open-Loop Voltage Gain	A_V	$V_{DD}=5V$, $R_L=100k\Omega$, $0.05V \leq V_O \leq 4.95V$	100	110	-	dB
		$V_{DD}=5V$, $R_L=5k\Omega$, $0.05V \leq V_O \leq 4.95V$	70	80	-	dB
Output Voltage Swing	V_{OUT}	$ V_{IN+}-V_{IN-} \leq 10mV$, $V_{DD}-V_{OH}$	-	6	-	mV
		$R_L = 100k\Omega$ to $V_{DD}/2$, $V_{OL}-V_{SS}$	-	6	-	mV
		$ V_{IN+}-V_{IN-} \leq 10mV$, $V_{DD}-V_{OH}$	-	60	-	mV
		$R_L = 5k\Omega$ to $V_{DD}/2$, $V_{OL}-V_{SS}$	-	60	-	mV
Output Short-Circuit Current	I_{SC}	Sinking or Sourcing	-	± 20	-	mA
Gain Bandwidth Product	GBW	$A_V = +1V/V$	-	1	-	MHz
Slew Rate	SR	$A_V = +1V/V$	-	0.6	-	V/ μs
Settling Time	t_s	To 0.1%, $V_{OUT} = 2V$ step $A_V = +1V/V$	-	5	-	μs
Over Load Recovery Time		$V_{IN} \times \text{Gain} = V_S$	-	2	-	μs
Input Voltage Noise Density	e_n	$f = 10kHz$	-	20	-	nV/\sqrt{Hz}

Note 1: All devices are 100% production tested at $T_A = +25^\circ C$; all specifications over the automotive temperature range is guaranteed by design, not production tested.

Note 2: Parameter is guaranteed by design.

Application Information

Size

TPV324 series op amps are unity-gain stable and suitable for a wide range of general-purpose applications. The small footprints of the TPV324 series packages save space on printed circuit boards and enable the design of smaller electronic products.

Power Supply Bypassing and Board Layout

TPV324 series operates from a single 2.2V to 5.5V supply or dual $\pm 1.1V$ to $\pm 2.75V$ supplies. For best performance, a 0.1 μF ceramic capacitor should be placed close to the V_{DD} pin in single supply operation. For dual supply operation, both V_{DD} and V_{SS} supplies should be bypassed to ground with separate 0.1 μF ceramic capacitors.

Low Supply Current

The low supply current (typical 80 μA) of TPV324 series will help to maximize battery life. They are ideal for battery powered systems

Operating Voltage

TPV324 series operate under wide input supply voltage (2.2V to 5.5V). In addition, all temperature specifications apply from $-40^{\circ}C$ to $+125^{\circ}C$. Most behavior remains unchanged throughout the full operating voltage range. These guarantees ensure operation throughout the single Li-Ion battery lifetime

Rail-to-Rail Input

The input common-mode range of TPV324 series extends 100mV beyond the supply rails ($V_{SS}-0.1V$ to $V_{DD}+0.1V$). This is achieved by using complementary input stage. For normal operation, inputs should be limited to this range.

Rail-to-Rail Output

Rail-to-Rail output swing provides maximum possible dynamic range at the output. This is particularly important when operating in low supply voltages. The output voltage of TPV324 series can typically swing to less than 10mV from supply rail in light resistive loads ($>100k\Omega$), and 60mV of supply rail in moderate resistive loads (10k Ω).

Capacitive Load Tolerance

The TPV324 series can directly drive 250pF capacitive load in unity-gain without oscillation. Increasing the gain enhances the amplifier's ability to drive greater capacitive loads. In unity-gain configurations, the capacitive load drive can be improved by inserting an isolation resistor R_{ISO} in series with the capacitive load, as shown in **Figure 2**.

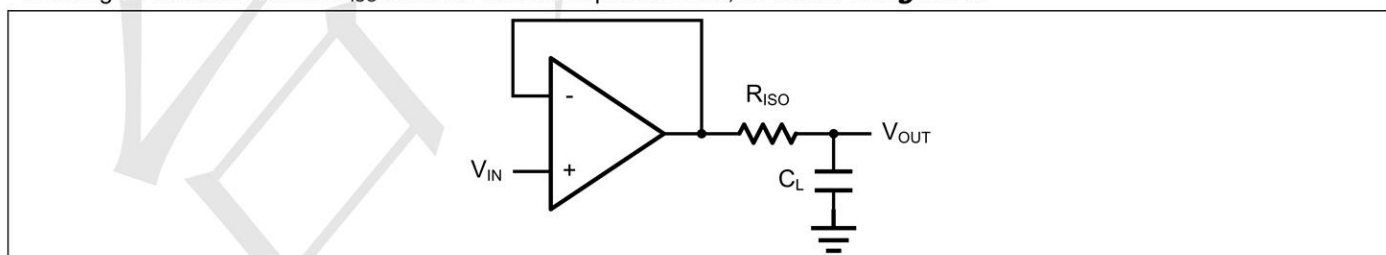


Figure 2. Indirectly Driving a Capacitive Load Using Isolation Resistor

The bigger the R_{ISO} resistor value, the more stable V_{OUT} will be. However, if there is a resistive load R_L in parallel with the capacitive load, a voltage divider (proportional to R_{ISO}/R_L) is formed, this will result in a gain error.

The circuit in **Figure 3** is an improvement to the one in **Figure 2**. R_F provides the DC accuracy by feed-forward the V_{IN} to R_L . C_F and R_{ISO} serve to counteract the loss of phase margin by feeding the high frequency component of the output signal back to the amplifier's inverting input, thereby preserving the phase margin in the overall feedback loop. Capacitive drive can be increased

by increasing the value of C_F . This in turn will slow down the pulse response.

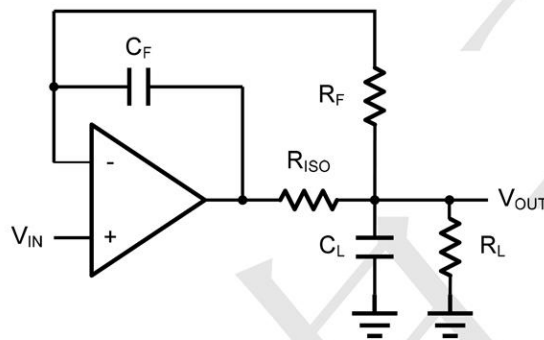


Figure 3. Indirectly Driving a Capacitive Load with DC Accuracy

5.8 Differential amplifier

The differential amplifier allows the subtraction of two input voltages or cancellation of a signal common to the two inputs. It is useful as a computational amplifier in making a differential to single-end conversion or in rejecting a common mode signal. **Figure 4** shows the differential amplifier using TPV324.

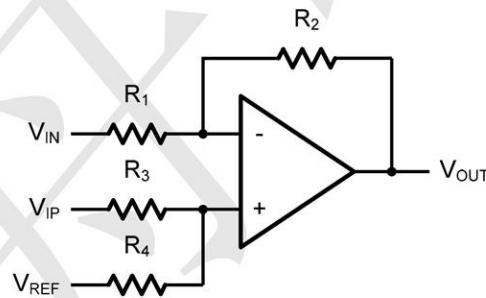


Figure 4. Differential Amplifier

$$V_{OUT} = \left(\frac{R_1 + R_2}{R_3 + R_4} \right) \frac{R_4}{R_1} V_{IN} - \frac{R_2}{R_1} V_{IP} + \left(\frac{R_1 + R_2}{R_3 + R_4} \right) \frac{R_3}{R_1} V_{REF}$$

If the resistor ratios are equal (i.e. $R_1 = R_3$ and $R_2 = R_4$), then

$$V_{OUT} = \frac{R_2}{R_1} (V_{IP} - V_{IN}) + V_{REF}$$

5.9 Instrumentation Amplifier

The input impedance of the previous differential amplifier is set by the resistors R_1 , R_2 , R_3 , and R_4 . To maintain the high input impedance, one can use a voltage follower in front of each input as shown in the following two instrumentation amplifiers.

5.10 Three-Op-Amp Instrumentation Amplifier

The dual TPV324 can be used to build a three-op-amp instrumentation amplifier as shown in **Figure 5**.

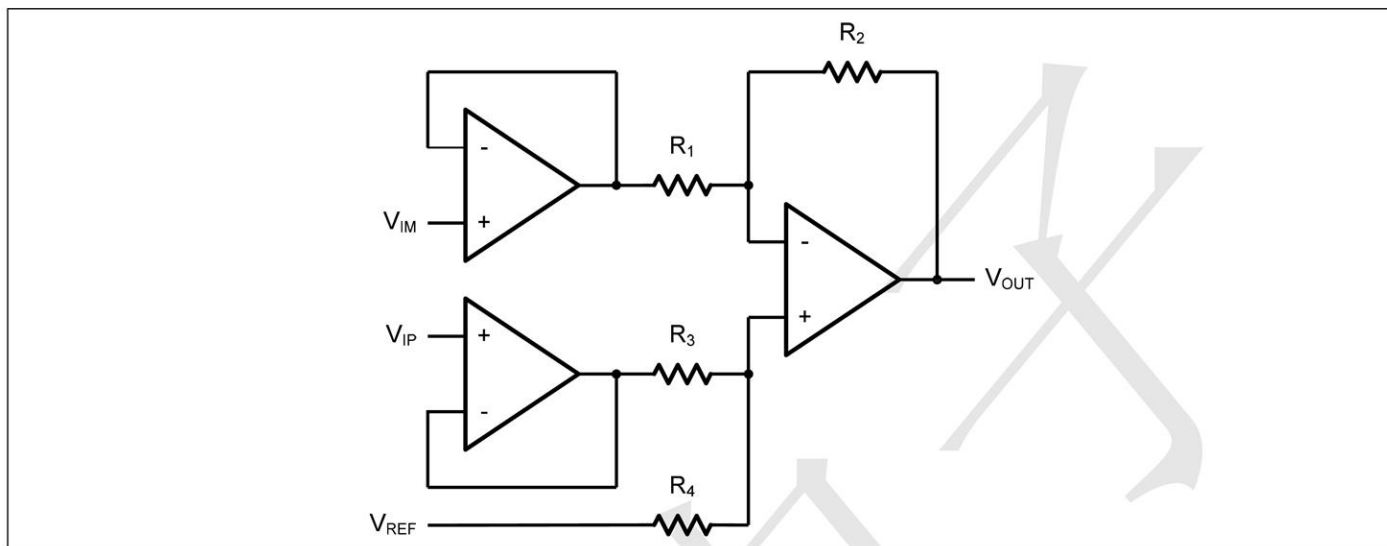


Figure 5. Three-Op-Amp Instrumentation Amplifier

The amplifier in **Figure 5** is a high input impedance differential amplifier with gain of R_2/R_1 . The two differential voltage followers assure the high input impedance of the amplifier.

$$V_o = \left(1 + \frac{R_4}{R_3}\right)(V_{IP} - V_{IN})$$

5.11 Two-Op-Amp Instrumentation Amplifier

TPV324 can also be used to make a high input impedance two-op-amp instrumentation amplifier as shown in **Figure 6**.

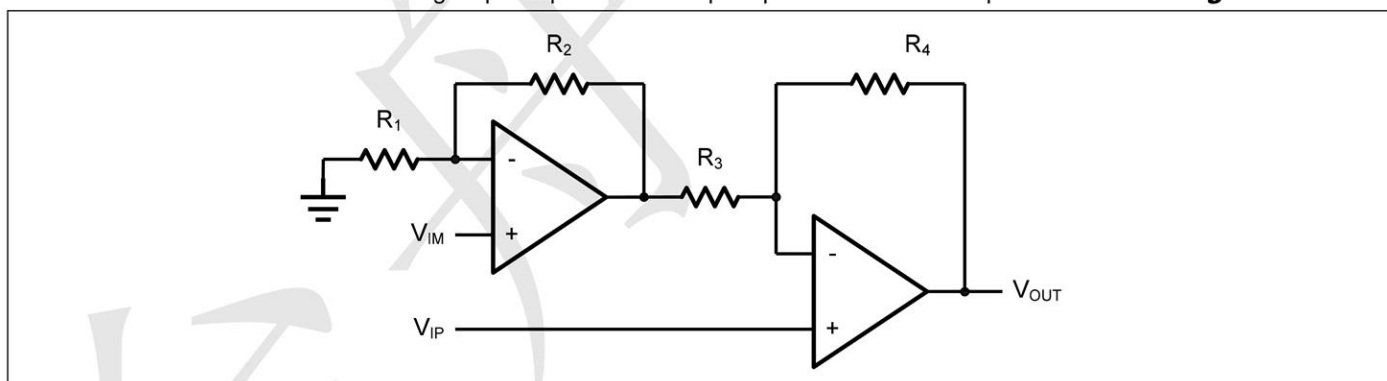


Figure 6. Two-Op-Amp Instrumentation Amplifier

Where $R_1=R_3$ and $R_2=R_4$. If all resistors are equal, then $V_o = 2(V_{IP} - V_{IN})$

5.12 Single-Supply Inverting Amplifier

The inverting amplifier is shown in Figure 6. The capacitor C_1 is used to block the DC signal going into the AC signal source V_{IN} . The value of R_1 and C_1 set the cut-off frequency to $f_c = 1/(2\pi R_1 C_1)$. The DC gain is defined by $V_{OUT} = -(R_2/R_1)V_{IN}$

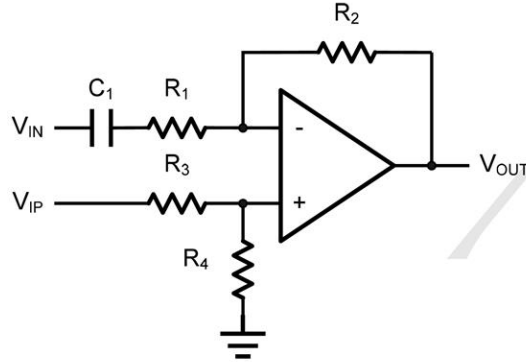


Figure 7. Single Supply Inverting Amplifier

5.13 Low Pass Active Filter

The low pass active filter is shown in **Figure 8**. The DC gain is defined by $-R_2/R_1$. The filter has a -20dB/decade roll-off after its corner frequency $f_c = 1/(2\pi R_3 C_1)$.

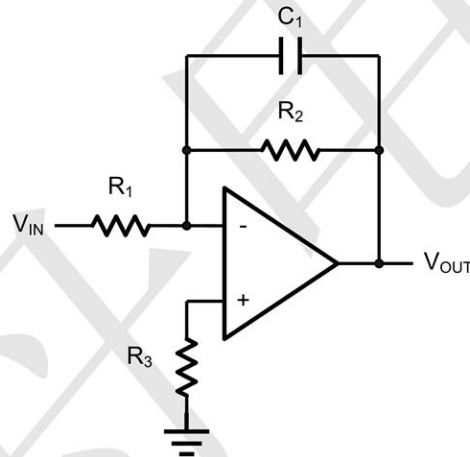


Figure 8. Low Pass Active Filter

5.14 Sallen-Key 2nd Order Active Low-Pass Filter

TPV324 can be used to form a 2nd order Sallen-Key active low-pass filter as shown in **Figure 9**. The transfer function from V_{IN} to V_{OUT} is given by

$$\frac{V_{OUT}}{V_{IN}}(S) = \frac{\frac{1}{C_1 C_2 R_1 R_2} A_{LP}}{S^2 + S \left(\frac{1}{C_1 R_1} + \frac{1}{C_1 R_2} + \frac{1}{C_2 R_2} \frac{A_{LP}}{C_2 R_2} \right) + \frac{1}{C_1 C_2 R_1 R_2}}$$

Where the DC gain is defined by $A_{LP} = 1 + R_3/R_4$, and the corner frequency is given by

$$\omega C = \sqrt{\frac{1}{C_1 C_2 R_1 R_2}}$$

The pole quality factor is given by

$$\frac{\omega C}{Q} = \frac{1}{C_1 R_1} + \frac{1}{C_1 R_2} + \frac{1}{C_2 R_2} - \frac{A_{LP}}{C_2 R_2}$$

Let $R_1=R_2=R$ and $C_1=C_2=C$, the corner frequency and the pole quality factor can be simplified as below

$$\omega_C = \frac{1}{CR}$$

And $Q=2-R_3/R_4$

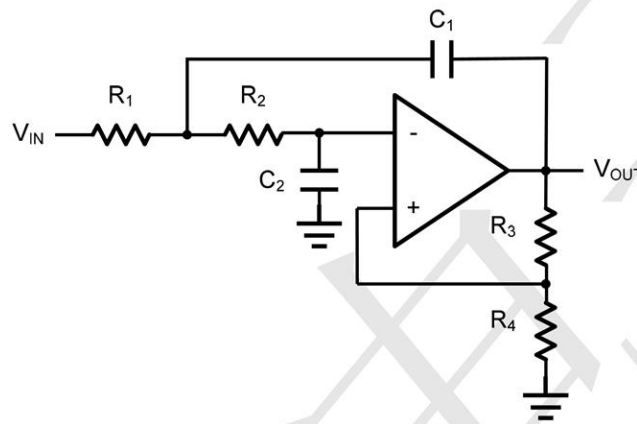


Figure 9. Sallen-Key 2nd Order Active Low-Pass Filter

5.15 Sallen-Key 2nd Order high-Pass Active Filter

The 2nd order Sallen-key high-pass filter can be built by simply interchanging those frequency selective components R_1 , R_2 , C_1 , and C_2 as shown in **Figure 10**.

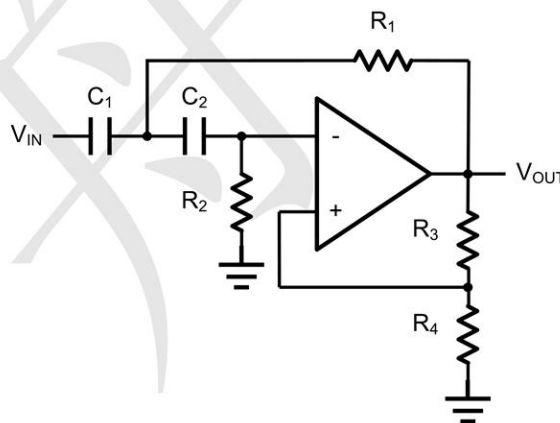


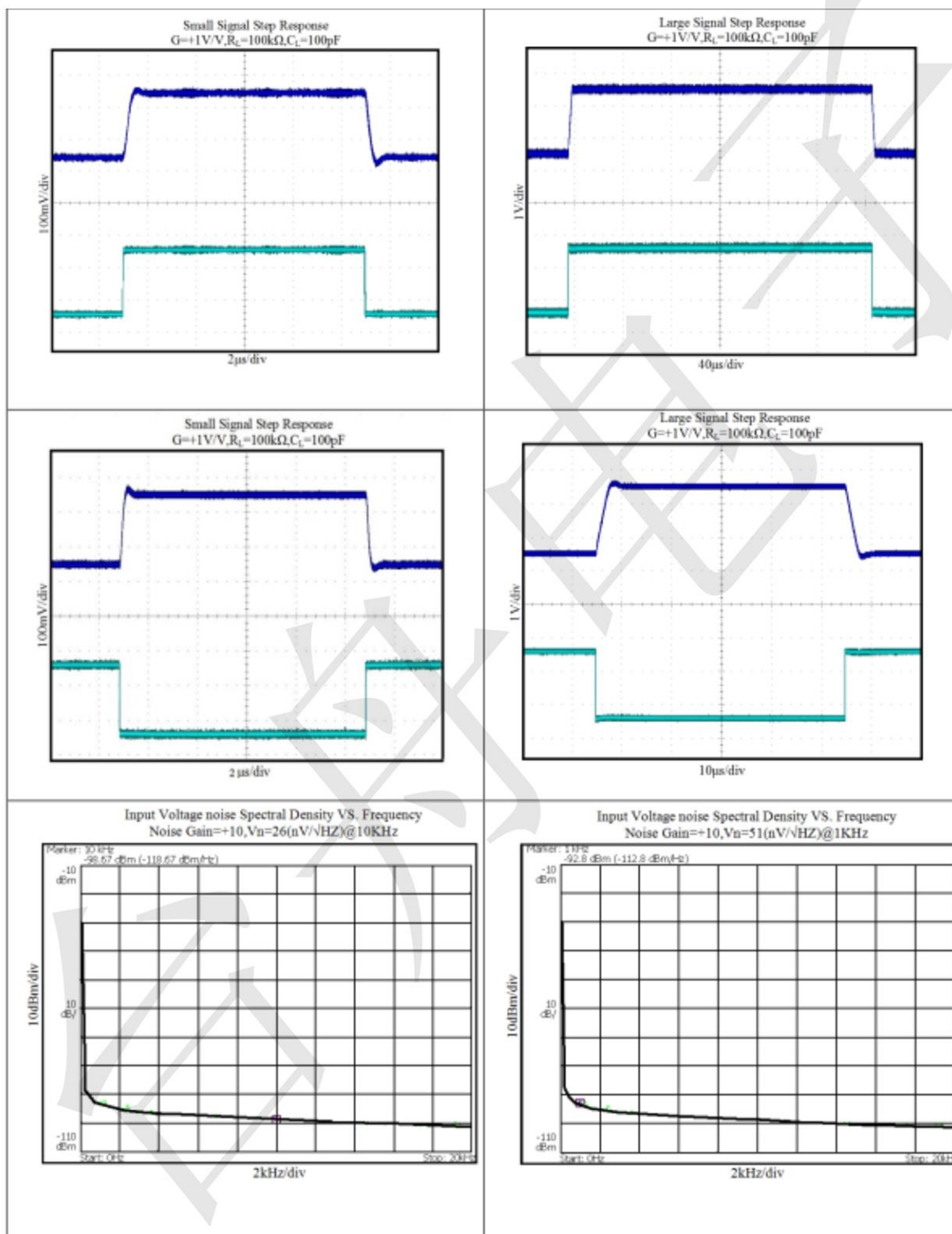
Figure 10. Sallen-Key 2nd Order Active High-Pass Filter

$$\frac{V_{OUT}}{V_{IN}}(S) = \frac{S^2 A_{HP}}{S^2 + S\left(\frac{1}{C_1 R_1} + \frac{1}{C_2 R_2} + \frac{1-A_{HP}}{C_1 R_1}\right) + \frac{1}{C_1 C_2 R_1 R_2}}$$

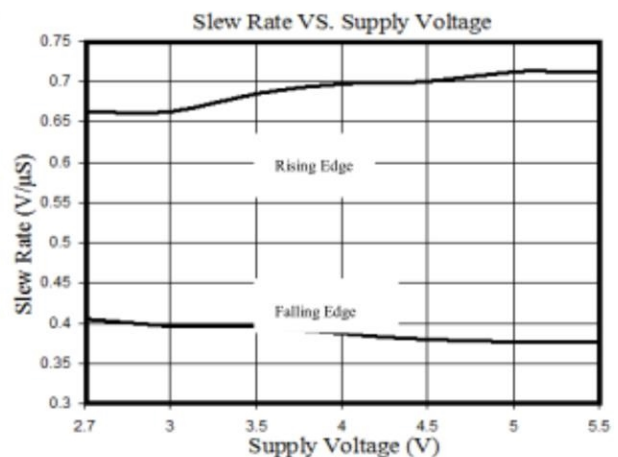
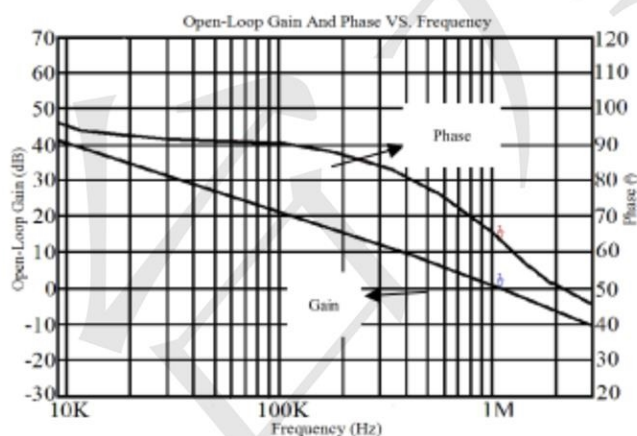
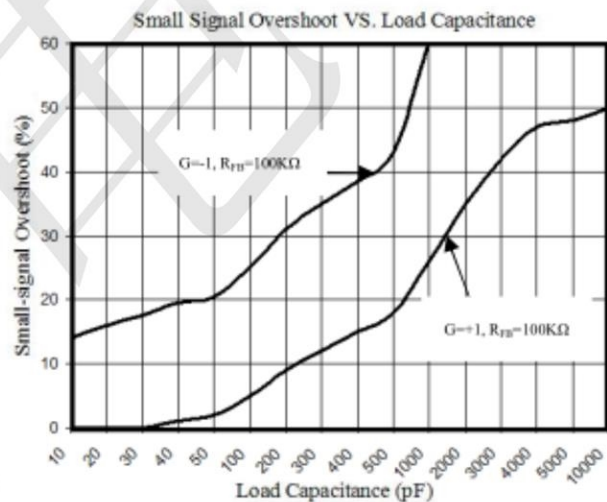
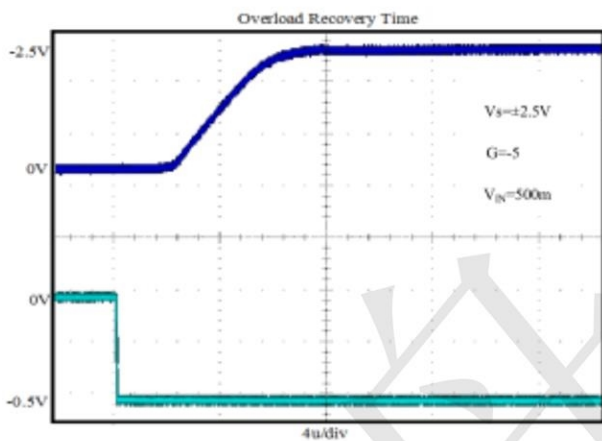
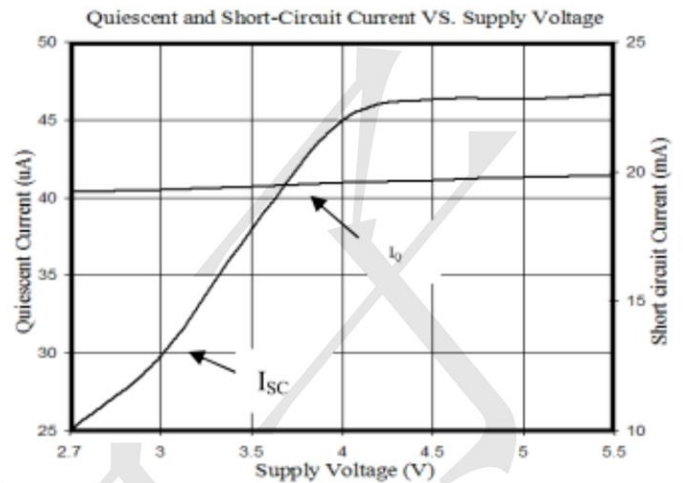
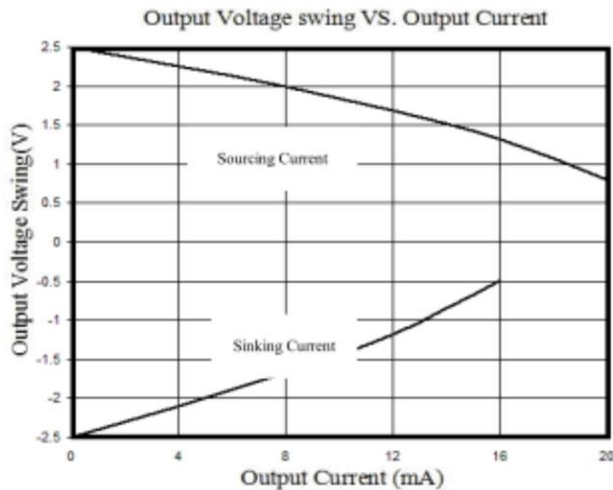
Where $A_{HP}=1+R_3/R_4$

Typical characteristics

At $T_A = +25^\circ\text{C}$, $R_L = 100\text{ k}\Omega$ connected to $V_S/2$ and $V_{OUT} = V_S/2$, unless otherwise noted.



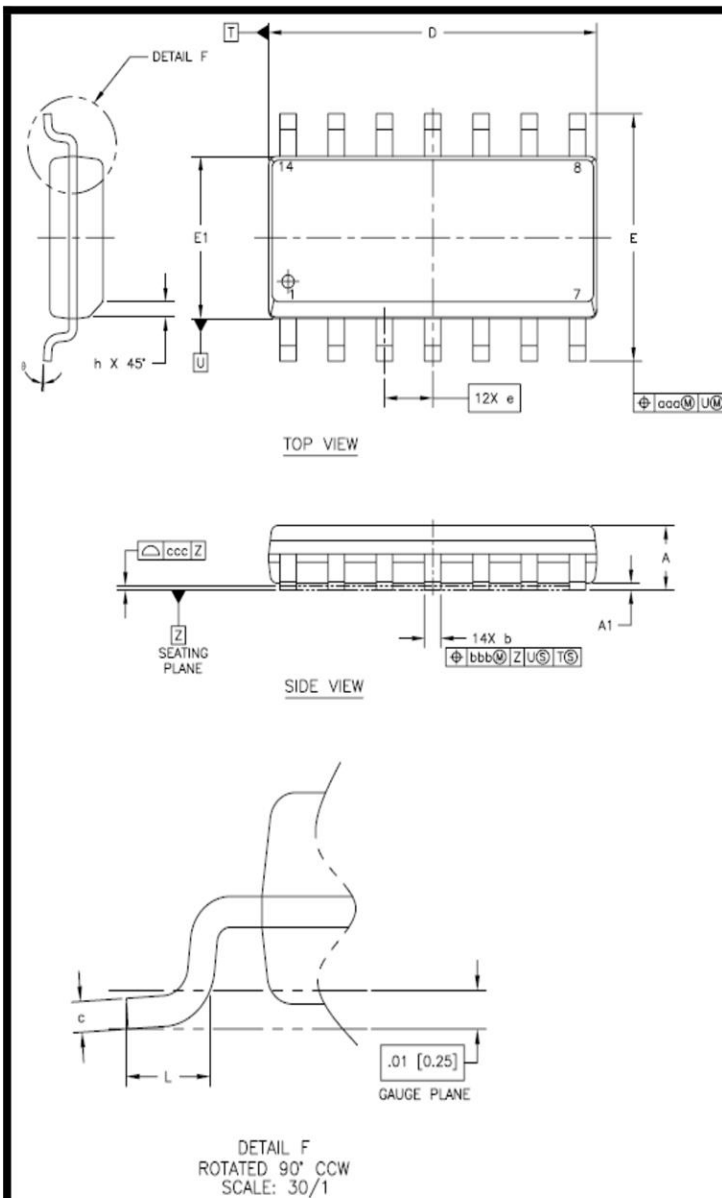
At $T_A = +25^\circ\text{C}$, $R_L = 100\text{ k}\Omega$ connected to $V_S/2$ and $V_{OUT} = V_S/2$, unless otherwise noted.



Package Information

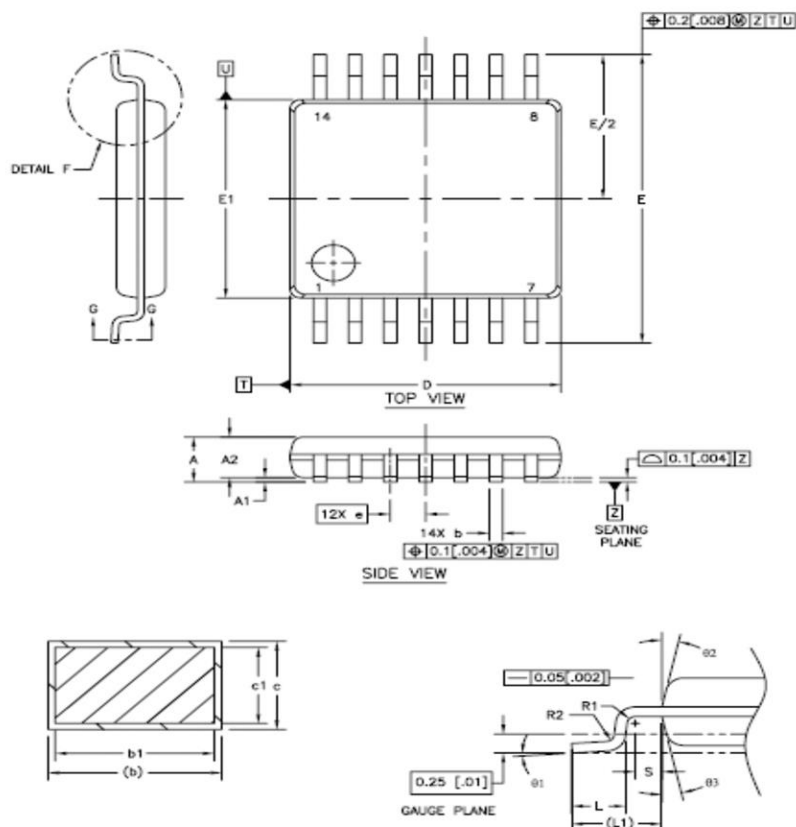
www.sot23.com.tw

SOP-14



DESCRIPTION	SYMBOL	INCH			MILLIMETER		
		MIN	NOM	MAX	MIN	NOM	MAX
TOTAL THICKNESS	A	.054	---	.068	1.35	---	1.75
STAND OFF	A1	.004	---	.009	0.10	---	0.25
LEAD WIDTH	b	.014	---	.019	0.35	---	0.49
L/F THICKNESS	c	.008	---	.009	0.19	---	0.25
BODY SIZE	D	.337	---	.344	8.55	---	8.75
	E1	.150	---	.157	3.80	---	4.00
	E	.228	---	.244	5.80	---	6.20
LEAD PITCH	e	.050 BSC			1.27 BSC		
	L	.016	---	.049	0.40	---	1.25
	h	.010	---	.019	0.25	---	0.50
	Ø	0°	---	7°	0°	---	7°
LEAD EDGE TOLERANCE	aaa	.010			0.25		
LEAD OFFSET	bbb	.010			0.25		
COPLANARITY	ccc	.004			0.10		

TSSOP-14



SECTION G-G
SCALE: 160/1

DETAIL F
ROTATED 90° CCW
SCALE: 20/1

DESCRIPTION	SYMBOL	MILLIMETER			INCH		
		MIN	NOM	MAX	MIN	NOM	MAX
TOTAL THICKNESS	A	---	---	1.1	---	---	.043
STAND OFF	A1	0.05	---	0.15	.002	---	.006
MOLD THICKNESS	A2	0.85	---	0.95	.033	---	.037
LEAD WIDTH (PLATING)	b	0.19	---	0.27	.007	---	.011
LEAD WIDTH	b1	0.19	---	0.25	.007	---	.010
L/F THICKNESS (PLATING)	c	0.13	---	0.18	.005	---	.007
L/F THICKNESS	c1	0.09	---	0.14	.004	---	.006
BODY SIZE	X	D	4.9	5	5.1	.193	.197
	Y	E1	4.3	4.4	4.5	.169	.173
		E	6.3	6.4	6.5	.248	.252
LEAD PITCH	e	0.65 BSC			.026 BSC		
	L	0.5	0.6	0.7	.020	.024	.028
FOOTPRINT	L1	1 REF			.039 REF		
	Ø1	Ø*			Ø*		
	Ø2	12° TYP			12° TYP		
	Ø3	12° TYP			12° TYP		
	R1	0.09	---	---	.004	---	---
	R2	0.09	---	---	.004	---	---
	S	0.2	---	---	.008	---	---

NOTES

1. DIMENSION D AND E1 DOES NOT INCLUDE MOLD PROTRUSION. ALLOWABLE MOLD PROTRUSION ON D IS 0.15mm(.006in) PER SIDE AND ON E1 IS 0.25mm(.010in) PER SIDE.
2. DIMENSION b DOES NOT INCLUDE DAM BAR PROTRUSION. ALLOWABLE DAM BAR PROTRUSION SHALL BE 0.13mm(.005in) TOTAL IN EXCESS OF THE b DIMENSION AT MAXIMUM MATERIAL CONDITION.