

## 3.3MHz, Rail-to-Rail I/O CMOS Operational Amplifier

### Features

- **Low Offset Voltage:** 1.2mV (typ)
- **High Gain:** 105dB (typ)
- **High Gain Bandwidth Product:** 3.3MHz
- **Rail-to-rail Input/Output**
- **Low I<sub>B</sub>:** 10pA (typ)
- **Low supply voltage:** +2.7 V to +5.5 V
- **Low Power Consumption:** 260µA at 5 V (per amplifier)
- **Extended Temperature :** -40°C to +125°C

### Applications

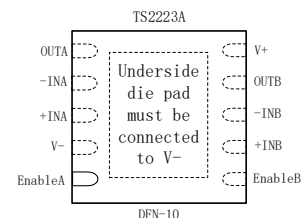
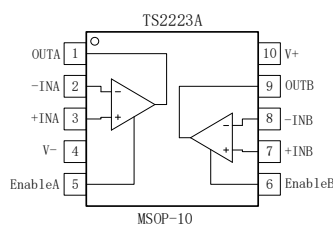
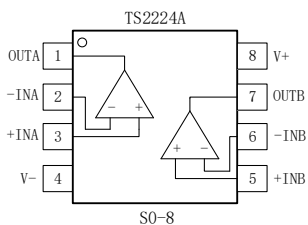
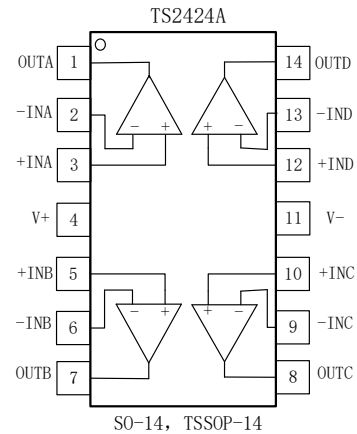
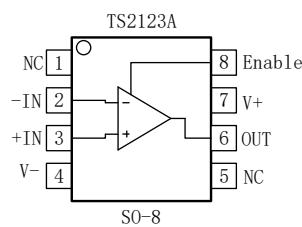
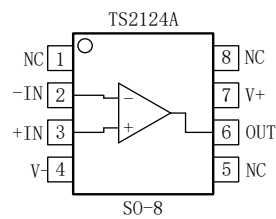
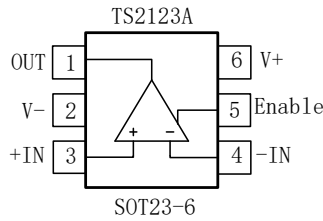
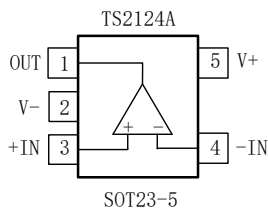
- **Signal Conditioning**
- **Current Sensor Amplifier**
- **Battery-Powered Applications**
- **Portable Devices**
- **Active Filtering**
- **Weight Scale Sensor**
- **Medical/Industrial Instrumentation**
- **Power Converter/Inverter**

### Product Description

The TS2123A/TS2124A families of products are low noise, low voltage and low power operational amplifiers with a gain-bandwidth product of 3.3MHz and slew rate of 2V/µs. The maximum input offset voltage is only 5mV and the input common mode range extends beyond the supply rails.

TS2123A/TS2124A families of operational amplifiers are specified at the full temperature range of -40°C to +125°C under single or dual power supplies of 2.7V to 5.5V, however these products will operate under an extended supply range from 2.7V to 5.5V at a reduced temperatures range.

The TS2123A and TS2223A have a power-down feature that reduces the supply current to 1µA.



## ORDERING INFORMATION

| Model   | Part Number     | Eco Plan | Package  | AMP | Shutdown | Container, Pack Qty |
|---------|-----------------|----------|----------|-----|----------|---------------------|
| TS2124A | TS2124ASOT235R  | Rohs     | SOT23-5  | 1   | NO       | Reel,3000           |
| TS2124A | TS2124ASO8R     | Rohs     | SO-8     | 1   | NO       | Reel,2500           |
| TS2123A | TS2123ASOT236R  | Rohs     | SOT23-6  | 1   | YES      | Reel,3000           |
| TS2123A | TS2123ASO8R     | Rohs     | SO-8     | 1   | YES      | Reel,2500           |
| TS2223A | TS2223AMSOP10R  | Rohs     | MSOP-10  | 2   | YES      | Reel,2500           |
| TS2224A | TS2224ASO8R     | Rohs     | SO-8     | 2   | NO       | Reel,2500           |
| TS2424A | TS2424ASO14R    | Rohs     | SO-14    | 4   | NO       | Reel,2500           |
| TS2424A | TS2424ATSSOP14R | Rohs     | TSSOP-14 | 4   | NO       | Reel,2500           |
| TS2223A | TS2223ADFN10R   | Rohs     | DFN-10   | 2   | YES      | Reel,2500           |

## ABSOLUTE MAXIMUM RATINGS

| Parameter                         | Min      | Max      | Unit |
|-----------------------------------|----------|----------|------|
| Supply Voltage                    |          | 7        | V    |
| Signal Input Terminal voltage     | (V-)-0.5 | (V+)+0.5 | V    |
| Operating Temperature             | -50      | 150      | °C   |
| Junction Temperature              |          | 150      | °C   |
| Storage Temperature Range         | -65      | 150      | °C   |
| Lead Temperature (Soldering, 10s) |          | 260      | °C   |
| ESD HBM                           |          | ±3000    | V    |
| ESD MM                            |          | ±400     | V    |
| ESC CDM                           |          | ±1000    | V    |

## ESD CAUTION



ESD (electrostatic discharge) sensitive device  
Charged devices and circuit boards can discharge without detection. Although this product features patented or proprietary protection circuitry, damage may occur on devices subjects to high energy ESD. Therefore, proper ESD precautions should be taken to avoid performance degradation or loss of functionality.

**ELECTRICAL CHARACTERISTICS:  $V_S = +2.7V$  to  $+5.5V$**

**Boldface** limits apply over the specified temperature range,  $T_A = -40^{\circ}C$  to  $+125^{\circ}C$ .

At  $T_A = +25^{\circ}C$ ,  $R_L = 10k\Omega$  connected to  $V_S/2$ , and  $V_{OUT} = V_S/2$ , unless otherwise noted.

| Symbol                        | Parameter   | Operating Conditions  | Min                         | Typ             | Max               | Unit              |
|-------------------------------|---|---|-----------------------------|-----------------|-------------------|-------------------|
| $V_S$                         | Power Supply Voltage  |   | <b>2.7</b>                  |                 | <b>5.5</b>        | V                 |
| $V_{IN +/-}$                  | Input Voltage Range   |   | (V-)-0.2                    |                 | (V+)+0.2          | V                 |
| $I_S$                         | Supply Current(per amplifier)   | $I_O=0$   |                             | 260             | 335               | $\mu A$           |
| PSRR                          | Power Supply Rejection Ratio<br>$T_A = -40^{\circ}C$ to $+125^{\circ}C$   | $V_S = 2.7$ to $V_S = 5.5V$ ,<br>$V_{CM} < (V+) - 2V$   |                             | 25              | 125<br><b>150</b> | $\mu V/V$         |
| <b>Input Characteristics</b>  |   |   |                             |                 |                   |                   |
| $V_{OS}$                      | Input Offset Voltage  |   |                             | 1.2             | 3.5               | mV                |
| $dV_{OS}/dT$                  | <b>Average Drift</b>  | $V_S=5.5V$  |                             | <b>2</b>        |                   | $\mu V/^{\circ}C$ |
| $I_B$                         | Input Bias Current  |   |                             | 1               |                   | pA                |
| $I_{OS}$                      | Input Offset Current  |   |                             | 1               |                   | pA                |
| CMRR                          | Common Mode Rejection Ratio<br>$T_A = -40^{\circ}C$ to $+125^{\circ}C$    | (V-)-0.2V < $V_{CM}$ < (V+)-2V  | 76                          | 88              |                   | dB                |
|                               | $T_A = -40^{\circ}C$ to $+125^{\circ}C$                                   | <b>(V-)-0.2V &lt; <math>V_{CM}</math> &lt; (V+)-2V</b><br>$V_S = 5.5V$ , (V-) - 0.2V < $V_{CM}$ < (V+) + 0.2V | <b>63</b><br>64             | <b>82</b><br>76 |                   | <b>dB</b><br>dB   |
|                               | $T_A = -40^{\circ}C$ to $+125^{\circ}C$                                   | <b><math>V_S = 5.5V</math>, (V-) - 0.2V &lt; <math>V_{CM}</math> &lt; (V+) + 0.2V</b>                         | <b>60</b>                   |                 |                   | <b>dB</b>         |
| AOL                           | Open-Loop Gain<br>$T_A = -40^{\circ}C$ to $+125^{\circ}C$                 | $V_S=5V$ $R_L=5K\Omega$<br>(V-)-0.125V < $V_{out}$ < (V+)-0.125V  | 99                          | 106             |                   | dB                |
|                               | Open-Loop Gain<br>$T_A = -40^{\circ}C$ to $+125^{\circ}C$                 | $V_S=5V$ $R_L=100k\Omega$<br>(V-)-25mV < $V_{out}$ < (V+)-25mV  | <b>84</b><br>103            | 107             |                   | <b>dB</b><br>dB   |
|                               |   |   | <b>96</b>                   |                 |                   | <b>dB</b>         |
| <b>Output Characteristics</b> |   |   |                             |                 |                   |                   |
| $V_{OUT}$                     | Output Voltage Swing From Rail<br>$T_A = -40^{\circ}C$ to $+125^{\circ}C$ | $R_L=100K\Omega$  |                             | 18              | 25                | mV                |
|                               | Output Voltage Swing From Rail<br>$T_A = -40^{\circ}C$ to $+125^{\circ}C$ | <b><math>R_L=100K\Omega</math></b><br>$R_L=5K\Omega$  |                             | 100             | 125               | <b>mV</b><br>mV   |
|                               |   | <b><math>R_L=5K\Omega</math></b>  |                             |                 | <b>125</b>        | <b>mV</b>         |
| $I_{OUT}$                     | Output Current  |   | See typical characteristics |                 |                   |                   |
| $R_{OUT}$                     | Open-Loop Output Impedance  | $f = 1MHz$ , $I_O = 0mA$  |                             | 40              |                   | $\Omega$          |
| <b>Dynamic Performance</b>    |   |   |                             |                 |                   |                   |
| GBW                           | Gain Bandwidth Product  |   |                             | 3.5             |                   | MHz               |
| $t_s$                         | Settling Time to 0.1%   | $V_{OUT}=2V$ step; $C_L=100p$<br>$G=+1$   |                             | 1.5             |                   | $\mu s$           |
|                               | Settling Time to 0.01%  | $V_{OUT}=2V$ step; $C_L=100p$<br>$G=+1$   |                             | 2               |                   | $\mu s$           |
| SR                            | Overload recovery time  | $V_{in} * Gain > V_S$   |                             | 0.3             |                   | $\mu s$           |
|                               | Slew Rate   | $G=+1$  |                             | 2.25            |                   | V/ $\mu s$        |
| THD                           | Total Harmonic Distortion+ Noise  | $V_S=5V$ , $V_O=3V_{pp}$ , $G=+1$ ,<br>$f=1kHz$   |                             | TBD             |                   | %                 |

**ELECTRICAL CHARACTERISTICS:  $V_S = +2.7V$  to  $+5.5V$**

**Boldface** limits apply over the specified temperature range,  $T_A = -40^{\circ}C$  to  $+125^{\circ}C$ .

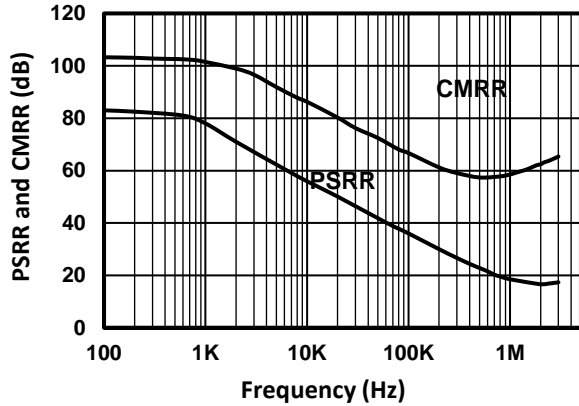
At  $T_A = +25^{\circ}C$ ,  $R_L = 10k\Omega$  connected to  $V_S/2$ , and  $V_{OUT} = V_S/2$ , unless otherwise noted.

| Symbol                   | Parameter                                       | Operating Conditions | Min | Type      | Max  | Unit                           |
|--------------------------|---|----------------------|-----|-----------|------|--------------------------------|
| <b>Noise Performance</b> |   |                      |     |           |      |                                |
| $V_{noise}$              | Input Voltage Noise                             | $f=0.1Hz$ to $10Hz$  |     | 2.5       |      | $\mu V_{pp}$                   |
| $e_n$                    | Input Voltage Noise Density                     | $f=10kHz$            |     | 15        |      | $nV/\sqrt{Hz}$                 |
| $i_n$                    | Input Current Noise Density                     | $f=10kHz$            |     | 4         |      | $fA/\sqrt{Hz}$                 |
| <b>Temperature Range</b> |   |                      |     |           |      |                                |
| $\theta_{JA}$            | Specified Range                                 |                      | -40 |           | +125 | $^{\circ}C$                    |
|                          | Operating Range                                 |                      | -55 |           | +150 | $^{\circ}C$                    |
|                          | Storage Range                                   |                      | -65 |           | +150 | $^{\circ}C$                    |
|                          | Thermal Resistance<br>SOT23-5, SOT23-6, SOT23-8 |                      |     | 200       |      | $^{\circ}C/W$                  |
|                          | MSOP-10, SO-8                                   |                      |     | 150       |      | $^{\circ}C/W$                  |
|                          | SO-14, TSSOP-14<br>DFN-10                       |                      |     | 100<br>56 |      | $^{\circ}C/W$<br>$^{\circ}C/W$ |

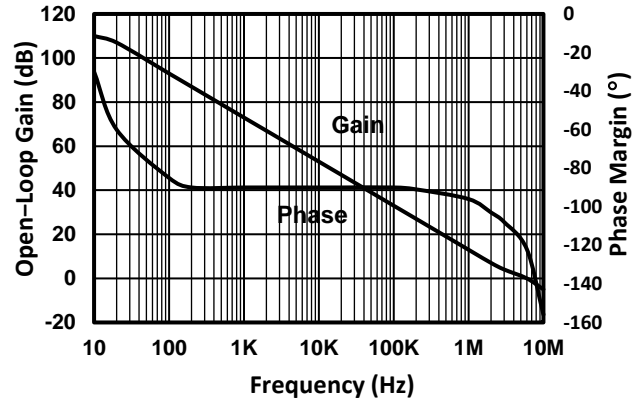
**TYPICAL CHARACTERISTICS**

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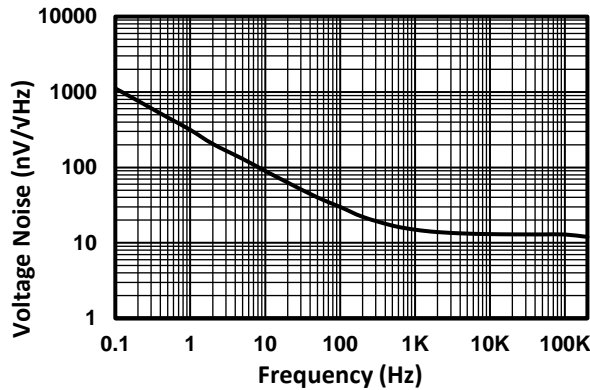
**POWER-SUPPLY AND COMMON-MODE REJECTION RATIO vs FREQUENCY**



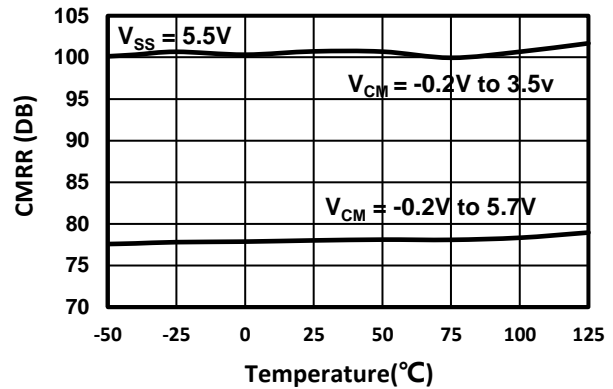
**OPEN-LOOP GAIN AND PHASE vs FREQUENCY**



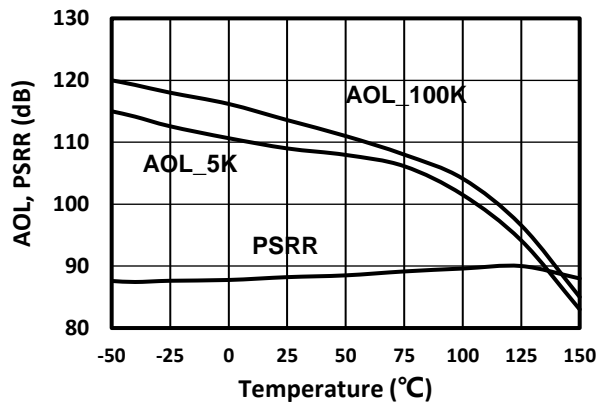
**INPUT VOLTAGE NOISE SPECTRAL DENSITY vs FREQUENCY**



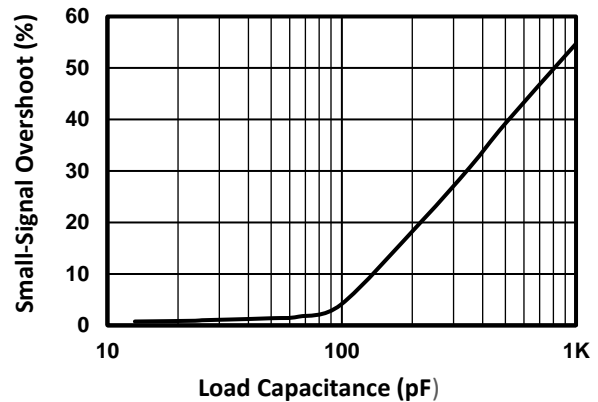
**COMMON-MODE REJECTION RATION vs TEMPERATURE**



**OPEN-LOOP GAIN AND POWER-SUPPLY REJECTION RATIO vs TEMPERATURE**



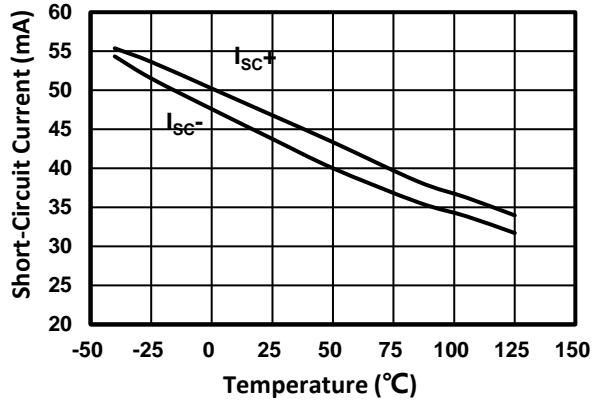
**SMALL-SIGNAL OVERSHOOT vs LOAD CAPACITANCE**



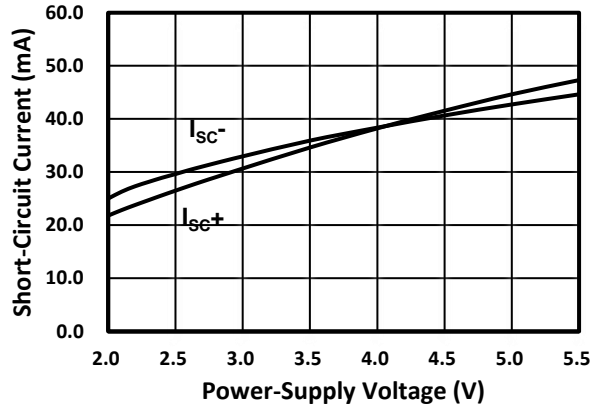
**TYPICAL CHARACTERISTICS**

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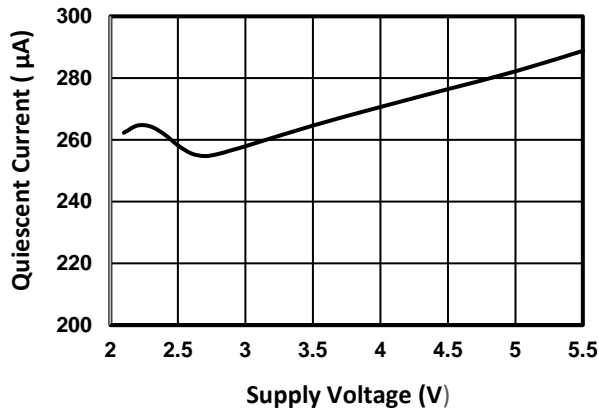
**SHORT-CIRCUIT CURRENT vs TEMPERATURE**



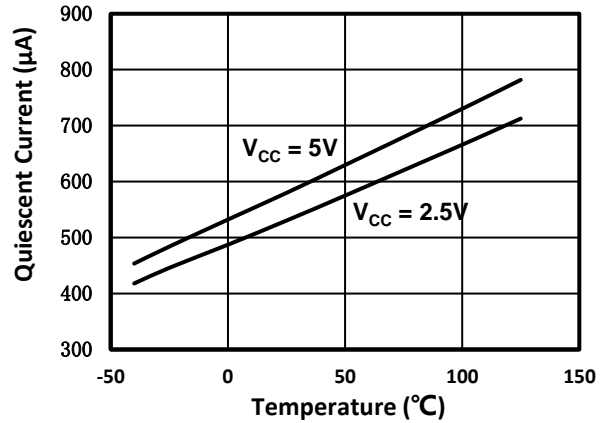
**CONTINUOUS SHORT-CIRCUIT CURRENT vs POWER-SUPPLY VOLTAGE**



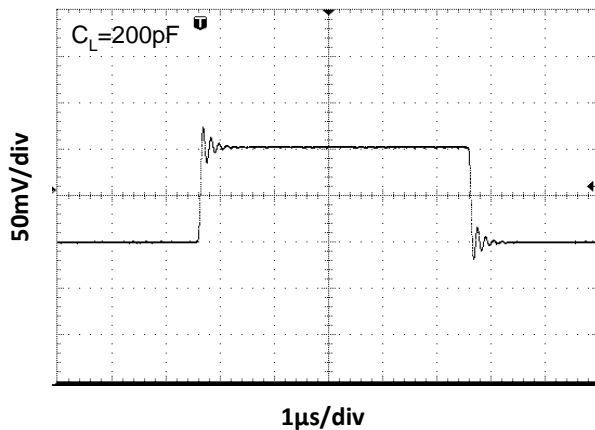
**QUIESCENT CURRENT vs SUPPLY VOLTAGE**



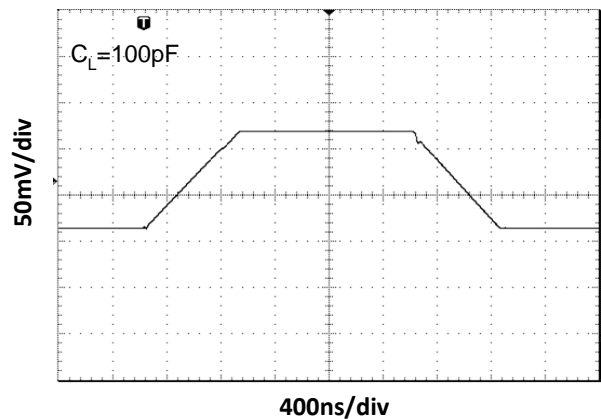
**QUIESCENT CURRENT vs TEMPERATURE**



**SMALL-SIGNAL STEP RESPONSE**

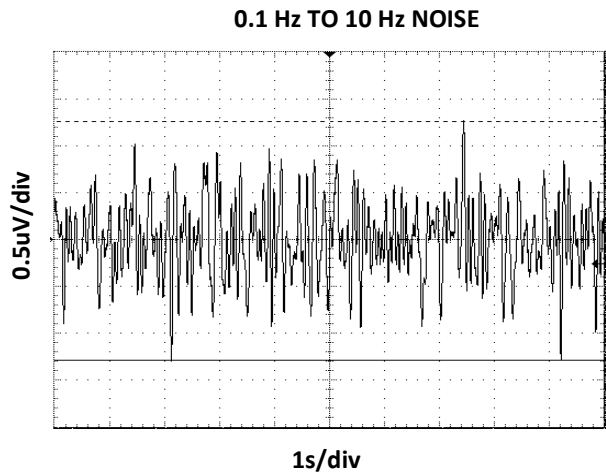
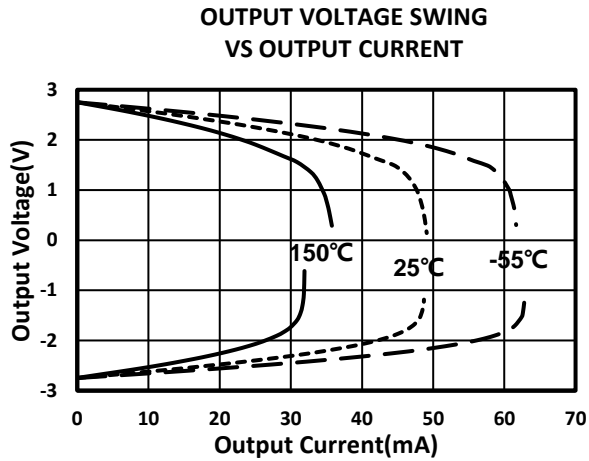
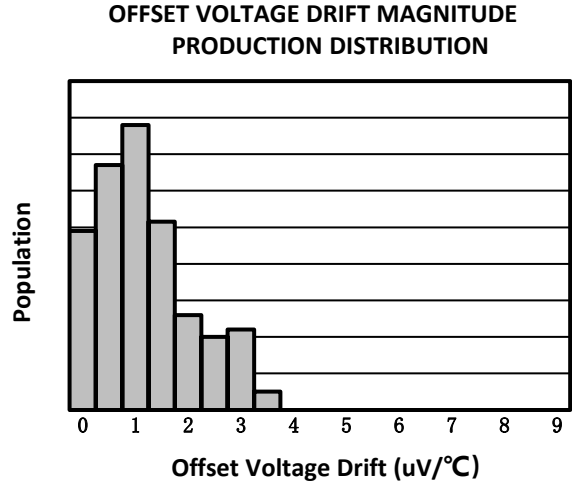
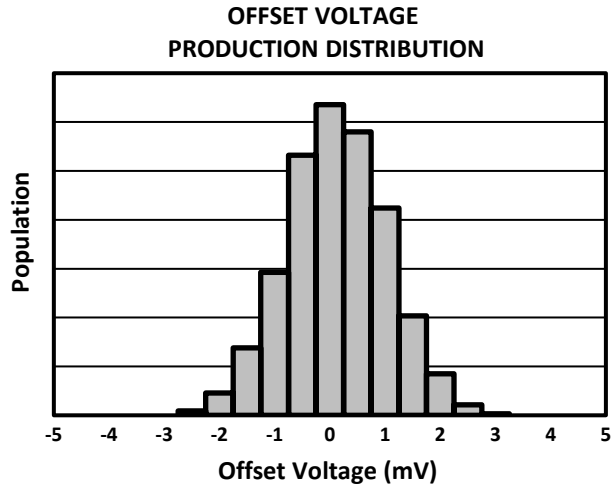


**LARGE-SIGNAL STEP RESPONSE**



**TYPICAL CHARACTERISTICS**

At  $T_A = +25^\circ\text{C}$ ,  $R_L = 10\text{k}\Omega$  connected to  $V_S/2$ , and  $V_{OUT} = V_S/2$ , unless otherwise noted.



## APPLICATION NOTES

The TS2123A and TS2124A families of op amps are suitable for a wide range of general-purpose applications. They provide Rail-to-rail input and output. Excellent ac performance makes them well-suited for audio and sensor applications. The input common-mode voltage range includes both rails, allowing the TS2123A and TS2124A families op amps to be used in bipolar and unipolar application.

Rail-to-rail input and output swing significantly increases dynamic range, especially in low-supply applications.

Power-supply pins should be bypassed with 0.1 $\mu$ F ceramic capacitors.

### POWER SUPPLY

The TS2123A and TS2124A families operate from a single +2.5V to +5.5V supply or dual  $\pm$ 1.25V to  $\pm$ 2.75V supplies. For single supply operation, bypass the power supply +VS with a 0.1 $\mu$ F capacitor which should be placed close to the +VS pin. For dual-supply operation, both the +VS and the -VS supplies should be bypassed to ground with separate 0.1 $\mu$ F ceramic capacitors. 2.2 $\mu$ F tantalum capacitor can be added for better performance.

The TS2123A and TS2124A families are ideal for battery-powered instrumentation and handheld devices because it can operate at the end of discharge voltage of most popular batteries.

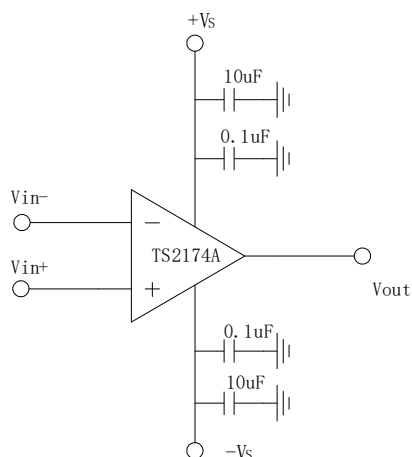


Figure1. Amplifier with Bypass Capacitors

### DRIVING CAPACITIVE LOADS

The TS2123A and TS2124A families can directly drive 1000pF in unity-gain without oscillation. The

unity-gain follower (buffer) is the most sensitive configuration to capacitive loading. Direct capacitive loading reduces the phase margin of amplifiers and this result in ringing or even oscillation. Applications that require greater capacitive driving capability should use an isolation resistor between the output and the capacitive load like the circuit in Figure2. The isolation resistor  $R_{ISO}$  and the load capacitor  $C_L$  form a zero to increase stability. The bigger the  $R_{ISO}$  resistor value, the more stable  $V_{OUT}$  will be. Note that this method results in a loss of gain accuracy because  $R_{ISO}$  forms a voltage divider with the  $R_{LOAD}$ .

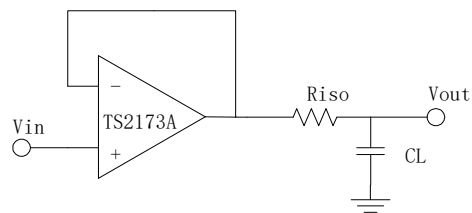


Figure 2. Indirectly Driving Heavy Capacitive Load

An improved circuit is shown in Figure 3. It provides DC accuracy as well as AC stability.  $R_f$  provides the DC accuracy by connecting the inverting signal with the output.  $C_f$  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 phase margin in the overall feedback loop.

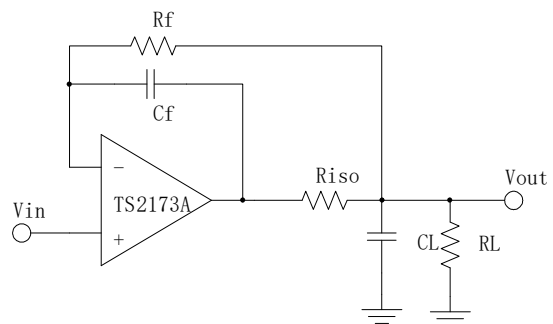


Figure 3. Indirectly Driving Heavy Capacitive Load with DC Accuracy

For non-buffer configuration, there are two other ways to increase the phase margin: (a) by increasing the amplifier's gain or (b) by placing a capacitor in parallel with the feedback resistor to counteract the parasitic capacitance associated with inverting node.



## TYPICAL APPLICATION

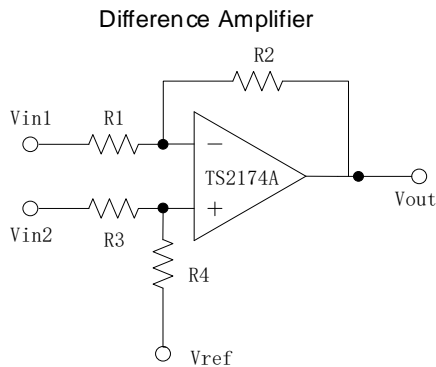


Figure 4. Differential Amplifier

The circuit shown in Figure 4 performs the difference function. If the resistor ratios are equal ( $R4/R3 = R2/R1$ ) then  $V_{out} = (V_{in2} - V_{in1}) \times R2/R1 + V_{ref}$ .

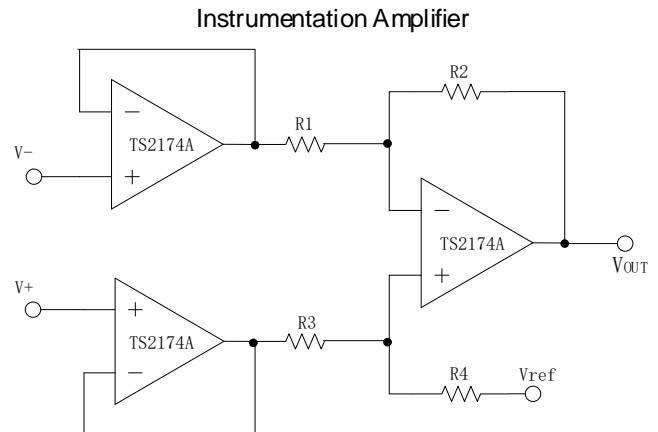


Figure 6. Instrumentation Amplifier

The circuit in Figure 6 performs the same function as that in Figure 4 but with the high input impedance.

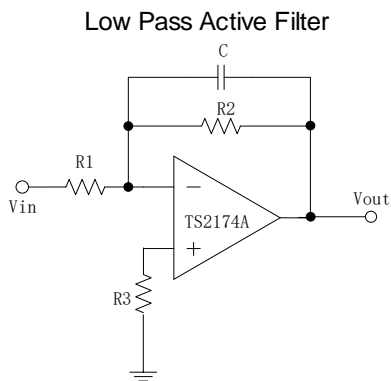
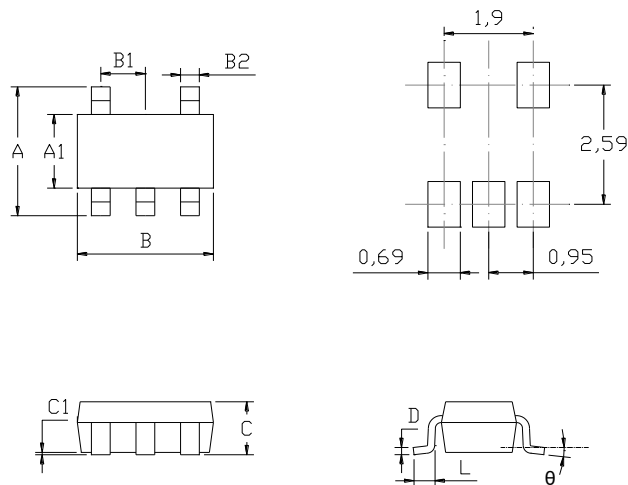


Figure 5. Low Pass Active Filter

The low pass filter shown in Figure 5 has a DC gain of  $(-R2 / R1)$  and the  $-3\text{dB}$  corner frequency is  $1/2\pi R2C$ . Make sure the filter is within the bandwidth of the amplifier. The Large values of feedback resistors can couple with parasitic capacitance and cause undesired effects such as ringing or oscillation in high-speed amplifiers. Keep resistors value as low as possible and consistent with output loading consideration.

## MECHANICAL DIMENSIONS

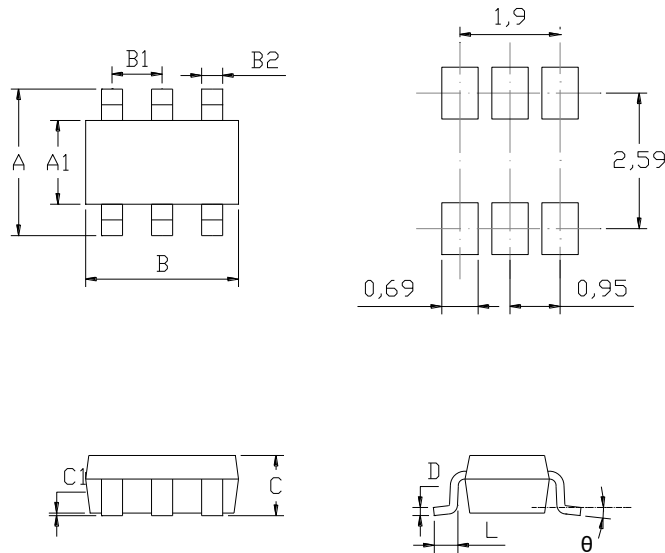
### SOT23-5 PACKAGE MECHANICAL DRAWING



### SOT23-5 PACKAGE MECHANICAL DATA

| symbol | dimensions  |         |        |           |
|--------|-------------|---------|--------|-----------|
|        | millimeters |         | inches |           |
|        | min         | max     | min    | max       |
| A      | 2.6         | 3       | 0.1024 | 0.1181    |
| A1     | 1.45        | 1.75    | 0.0571 | 0.0689    |
| B      | 2.75        | 3.05    | 0.1083 | 0.1201    |
| B1     | 0.95        |         | 0.0374 |           |
| B2     | 0.3         | 0.5     | 0.0118 | 0.0197    |
| C      |             | 1.45MAX |        | 0.0571MAX |
| C1     | 0           | 0.15    | 0.0000 | 0.0059    |
| L      | 0.3         | 0.5     | 0.0118 | 0.0197    |
| D      | 0.08        | 0.22    | 0.0031 | 0.0087    |
| θ      | 0°          | 8°      | 0°     | 8°        |

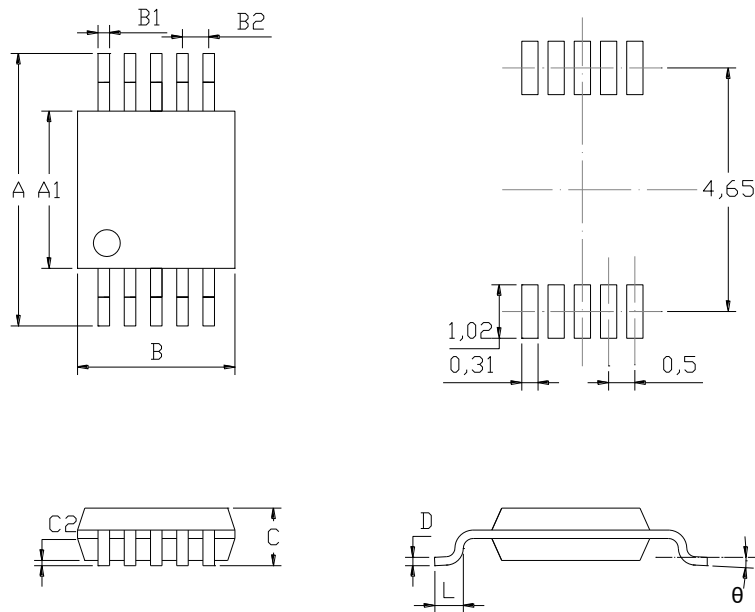
**SOT23-6 PACKAGE MECHANICAL DRAWING**



**SOT23-6 PACKAGE MECHANICAL DATA**

| symbol | dimensions  |         |        |            |
|--------|-------------|---------|--------|------------|
|        | millimeters |         | inches |            |
|        | min         | max     | min    | max        |
| A      | 2.6         | 3       | 0.1024 | 0.1181     |
| A1     | 1.45        | 1.75    | 0.0571 | 0.0689     |
| B      | 2.75        | 3.05    | 0.1083 | 0.1201     |
| B1     | 0.95        |         | 0.0374 |            |
| B2     | 0.3         | 0.5     | 0.0118 | 0.0197     |
| C      |             | 1.45MAX |        | 0.0571 MAX |
| C1     | 0           | 0.15    | 0.0000 | 0.0059     |
| L      | 0.3         | 0.5     | 0.0118 | 0.0197     |
| D      | 0.08        | 0.22    | 0.0031 | 0.0087     |
| θ      | 0°          | 8°      | 0°     | 8°         |

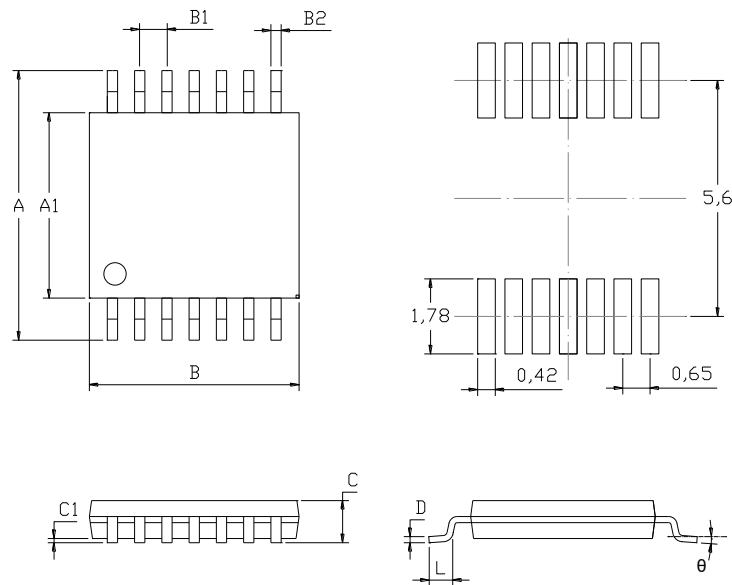
**MSOP-10 PACKAGE MECHANICAL DRAWING**



**MSOP-10 PACKAGE MECHANICAL DATA**

| symbol | dimensions  |         |        |        |
|--------|-------------|---------|--------|--------|
|        | millimeters |         | inches |        |
|        | min         | max     | min    | max    |
| A      | 4.75        | 5.05    | 0.1870 | 0.1988 |
| A1     | 2.9         | 3.1     | 0.1142 | 0.1220 |
| B      | 2.9         | 3.1     | 0.1142 | 0.1220 |
| B1     | 0.50        |         | 0.0197 |        |
| B2     | 0.17        | 0.27    | 0.0067 | 0.0106 |
| C      |             | 1.10MAX |        | 0.0433 |
| C1     | 0.05        | 0.15    | 0.0020 | 0.0059 |
| L      | 0.4         | 0.7     | 0.0157 | 0.0276 |
| D      | 0.13        | 0.23    | 0.0051 | 0.0091 |
| theta  | 0°          | 8°      | 0°     | 8°     |

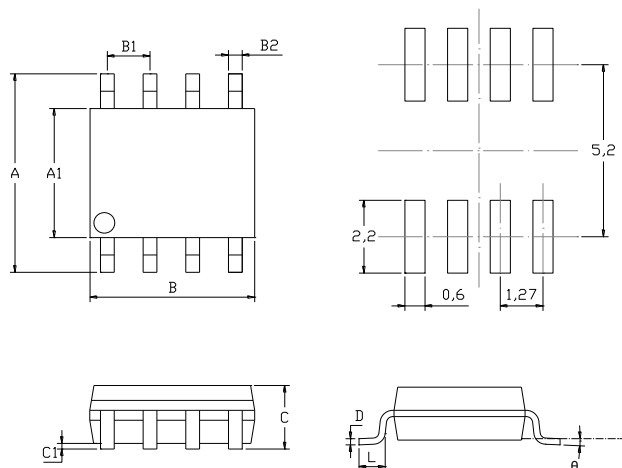
**TSSOP-14 PACKAGE MECHANICAL DRAWING**



**TSSOP-14 PACKAGE MECHANICAL DATA**

| symbol | dimensions  |         |        |           |
|--------|-------------|---------|--------|-----------|
|        | millimeters |         | inches |           |
|        | min         | max     | min    | max       |
| A      | 6.2         | 6.6     | 0.2441 | 0.2598    |
| A1     | 4.3         | 4.5     | 0.1693 | 0.1772    |
| B      | 4.9         | 5.1     | 0.1929 | 0.2008    |
| B1     | 0.65        |         | 0.0256 |           |
| B2     | 0.19        | 0.3     | 0.0075 | 0.0118    |
| C      |             | 1.20MAX |        | 0.0472MAX |
| C1     | 0.05        | 0.15    | 0.0020 | 0.0059    |
| L      | 0.5         | 0.75    | 0.0197 | 0.0295    |
| D      | 0.1         | 0.2     | 0.0039 | 0.0079    |
| θ      | 0°          | 8°      | 0°     | 8°        |

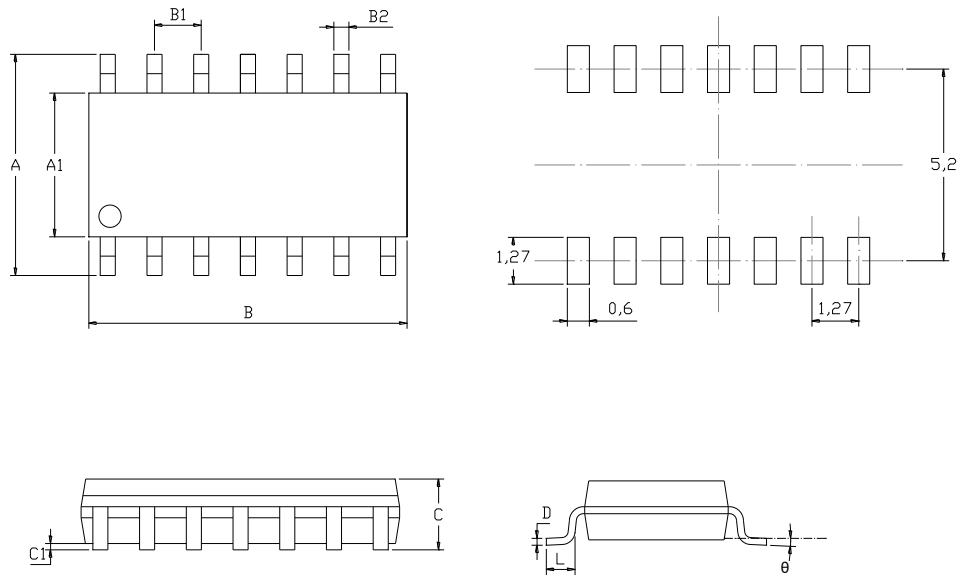
**SO-8 PACKAGE MECHANICAL DRAWING**



**SO-8 PACKAGE MECHANICAL DATA**

| symbol | dimensions  |         |        |           |
|--------|-------------|---------|--------|-----------|
|        | millimeters |         | inches |           |
|        | min         | max     | min    | max       |
| A      | 5.8         | 6.2     | 0.2283 | 0.2441    |
| A1     | 3.8         | 4       | 0.1496 | 0.1575    |
| B      | 4.8         | 5       | 0.1890 | 0.1969    |
| B1     | 1.27        |         | 0.0500 |           |
| B2     | 0.31        | 0.51    | 0.0122 | 0.0201    |
| C      |             | 1.75MAX |        | 0.0689MAX |
| C1     | 0.1         | 0.25    | 0.0039 | 0.0098    |
| L      | 0.4         | 1.27    | 0.0157 | 0.0500    |
| D      | 0.13        | 0.25    | 0.0051 | 0.0098    |
| θ      | 0°          | 8°      | 0°     | 8°        |

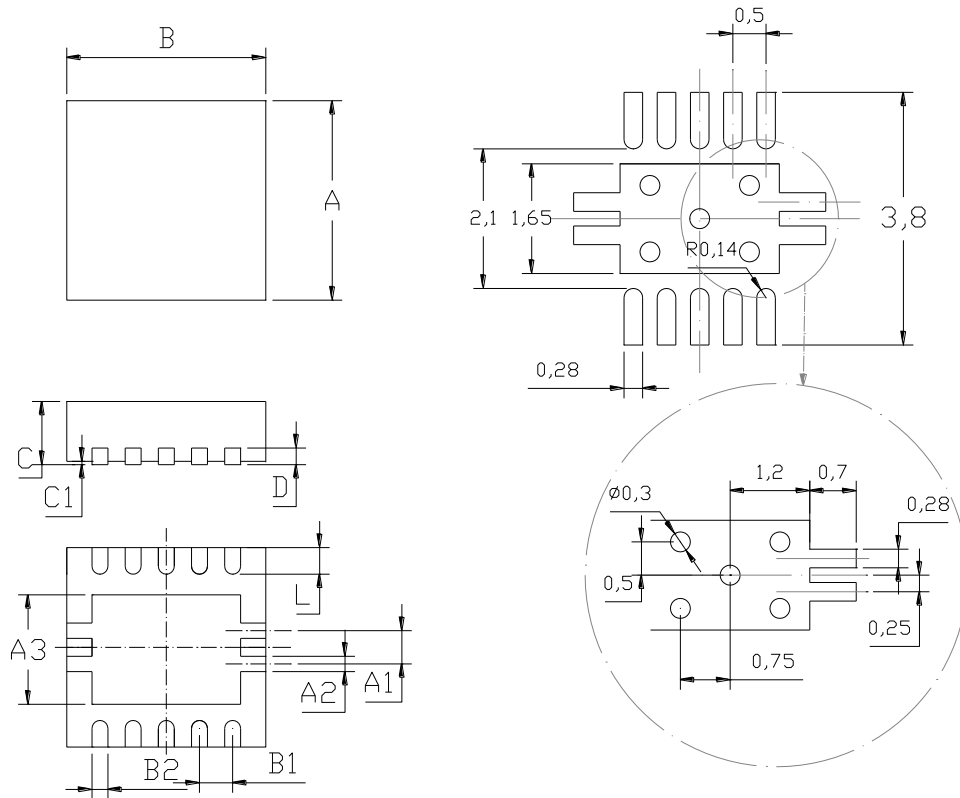
**SO-14 PACKAGE MECHANICAL DRAWING**



**SO-14 PACKAGE MECHANICAL DATA**

| symbol | dimensions  |         |        |        |
|--------|-------------|---------|--------|--------|
|        | millimeters |         | inches |        |
|        | min         | max     | min    | max    |
| A      | 6.2         | 5.8     | 0.2441 | 0.2283 |
| A1     | 3.8         | 4       | 0.1496 | 0.1575 |
| B      | 8.55        | 8.75    | 0.3366 | 0.3445 |
| B1     | 1.27        |         | 0.0500 |        |
| B2     | 0.31        | 0.51    | 0.0122 | 0.0201 |
| C      |             | 1.75MAX |        | 0.0689 |
| C1     | 0.1         | 0.25    | 0.0039 | 0.0098 |
| L      | 0.4         | 1.27    | 0.0157 | 0.0500 |
| D      | 0.13        | 0.25    | 0.0051 | 0.0098 |
| θ      | 0°          | 8°      | 0°     | 8°     |

**DFN-10 PACKAGE MECHANICAL DRAWING**



**DFN-10 PACKAGE MECHANICAL DATA**

| symbol | dimensions  |      |        |        |
|--------|-------------|------|--------|--------|
|        | millimeters |      | inches |        |
|        | min         | max  | min    | max    |
| A      | 2.9         | 3.1  | 0.1142 | 0.1220 |
| A1     | 0.5         |      | 0.0197 |        |
| A2     | 0.23        |      | 0.0091 |        |
| A3     | 1.55        | 1.75 | 0.0610 | 0.0689 |
| B      | 2.9         | 3.1  | 0.1142 | 0.1220 |
| B1     | 0.5         |      | 0.0197 |        |
| B2     | 0.18        | 0.3  | 0.0071 | 0.0118 |
| C      | 0.8         | 1    | 0.0315 | 0.0394 |
| C1     | 0           | 0.05 | 0.0000 | 0.0020 |
| L      | 0.3         | 0.5  | 0.0118 | 0.0197 |
| D      | 0.2         |      | 0.0079 |        |



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