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Jameco Part Number 23683MOT

# LM324, LM324A, LM224, LM2902, LM2902V

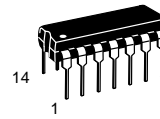
## Quad Low Power Operational Amplifiers

The LM324 series are low-cost, quad operational amplifiers with true differential inputs. They have several distinct advantages over standard operational amplifier types in single supply applications. The quad amplifier can operate at supply voltages as low as 3.0 V or as high as 32 V with quiescent currents about one-fifth of those associated with the MC1741 (on a per amplifier basis). The common mode input range includes the negative supply, thereby eliminating the necessity for external biasing components in many applications. The output voltage range also includes the negative power supply voltage.

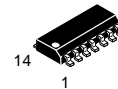
- Short Circuited Protected Outputs
- True Differential Input Stage
- Single Supply Operation: 3.0 V to 32 V
- Low Input Bias Currents: 100 nA Maximum (LM324A)
- Four Amplifiers Per Package
- Internally Compensated
- Common Mode Range Extends to Negative Supply
- Industry Standard Pinouts
- ESD Clamps on the Inputs Increase Ruggedness without Affecting Device Operation

### QUAD DIFFERENTIAL INPUT OPERATIONAL AMPLIFIERS

#### SEMICONDUCTOR TECHNICAL DATA



**N SUFFIX**  
PLASTIC PACKAGE  
CASE 646  
(LM224, LM324,  
LM2902 Only)



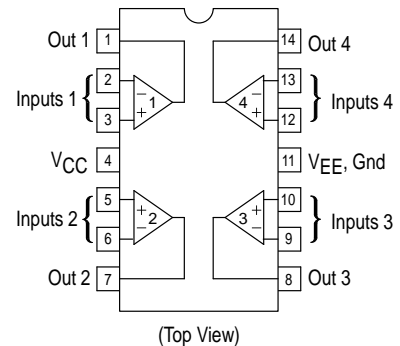
**D SUFFIX**  
PLASTIC PACKAGE  
CASE 751A  
(SO-14)

#### MAXIMUM RATINGS ( $T_A = +25^\circ\text{C}$ , unless otherwise noted.)

| Rating   | Symbol                       | LM224<br>LM324, LM324A | LM2902,<br>LM2902V         | Unit             |
|--|------------------------------|------------------------|----------------------------|------------------|
| Power Supply Voltages<br>Single Supply<br>Split Supplies | $V_{CC}$<br>$V_{CC}, V_{EE}$ | 32<br>$\pm 16$         | 26<br>$\pm 13$             | Vdc              |
| Input Differential<br>Voltage Range (See<br>Note 1)      | $V_{IDR}$                    | $\pm 32$               | $\pm 26$                   | Vdc              |
| Input Common Mode<br>Voltage Range                       | $V_{ICR}$                    | -0.3 to 32             | -0.3 to 26                 | Vdc              |
| Output Short Circuit<br>Duration                         | $t_{SC}$                     | Continuous             |                            |                  |
| Junction Temperature                                     | $T_J$                        | 150                    |                            | $^\circ\text{C}$ |
| Storage Temperature<br>Range                             | $T_{stg}$                    | -65 to +150            |                            | $^\circ\text{C}$ |
| Operating Ambient<br>Temperature Range                   | $T_A$                        | -25 to +85<br>0 to +70 | -40 to +105<br>-40 to +125 | $^\circ\text{C}$ |

**NOTE:** 1. Split Power Supplies.

#### PIN CONNECTIONS



#### ORDERING INFORMATION

| Device   | Operating<br>Temperature Range            | Package     |
|----------|---|-------------|
| LM2902D  | $T_A = -40^\circ$ to $+105^\circ\text{C}$ | SO-14       |
| LM2902N  |   | Plastic DIP |
| LM2902VD | $T_A = -40^\circ$ to $+125^\circ\text{C}$ | SO-14       |
| LM2902VN |   | Plastic DIP |
| LM224D   | $T_A = -25^\circ$ to $+85^\circ\text{C}$  | SO-14       |
| LM224N   |   | Plastic DIP |
| LM324AD  | $T_A = 0^\circ$ to $+70^\circ\text{C}$    | SO-14       |
| LM324AN  |   | Plastic DIP |
| LM324D   |   | SO-14       |
| LM324N   |   | Plastic DIP |

# LM324, LM324A, LM224, LM2902, LM2902V

**ELECTRICAL CHARACTERISTICS** ( $V_{CC} = 5.0\text{ V}$ ,  $V_{EE} = \text{Gnd}$ ,  $T_A = 25^\circ\text{C}$ , unless otherwise noted.)

| Characteristics  | Symbol                   | LM224           |                |             | LM324A          |                |             | LM324           |                |             | LM2902          |                |             | LM2902V         |                |             | Unit                         |
|--|--------------------------|-----------------|----------------|-------------|-----------------|----------------|-------------|-----------------|----------------|-------------|-----------------|----------------|-------------|-----------------|----------------|-------------|------------------------------|
|  |                          | Min             | Typ            | Max         | Min             | Typ            | Max         | Min             | Typ            | Max         | Min             | Typ            | Max         | Min             | Typ            | Max         |                              |
| Input Offset Voltage<br>$V_{CC} = 5.0\text{ V}$ to $30\text{ V}$<br>( $26\text{ V}$ for LM2902,<br>V), $V_{ICR} = 0\text{ V}$ to<br>$V_{CC} - 1.7\text{ V}$ , $V_O =$<br>$1.4\text{ V}$ , $R_S = 0\ \Omega$<br>$T_A = 25^\circ\text{C}$<br>$T_A = T_{\text{high}}^{(1)}$<br>$T_A = T_{\text{low}}^{(1)}$   | $V_{IO}$                 | -               | 2.0            | 5.0         | -               | 2.0            | 3.0         | -               | 2.0            | 7.0         | -               | 2.0            | 7.0         | -               | 2.0            | 7.0         | mV                           |
| Average Temperature<br>Coefficient of Input<br>Offset Voltage<br>$T_A = T_{\text{high}}$ to $T_{\text{low}}^{(1)}$   | $\Delta V_{IO}/\Delta T$ | -               | 7.0            | -           | -               | 7.0            | 30          | -               | 7.0            | -           | -               | 7.0            | -           | -               | 7.0            | -           | $\mu\text{V}/^\circ\text{C}$ |
| Input Offset Current<br>$T_A = T_{\text{high}}$ to $T_{\text{low}}^{(1)}$  | $I_{IO}$                 | -               | 3.0            | 30          | -               | 5.0            | 30          | -               | 5.0            | 50          | -               | 5.0            | 50          | -               | 5.0            | 50          | nA                           |
| Average Temperature<br>Coefficient of Input<br>Offset Current<br>$T_A = T_{\text{high}}$ to $T_{\text{low}}^{(1)}$   | $\Delta I_{IO}/\Delta T$ | -               | 10             | -           | -               | 10             | 300         | -               | 10             | -           | -               | 10             | -           | -               | 10             | -           | $\text{pA}/^\circ\text{C}$   |
| Input Bias Current<br>$T_A = T_{\text{high}}$ to $T_{\text{low}}^{(1)}$  | $I_{IB}$                 | -               | -90            | -150        | -               | -45            | -100        | -               | -90            | -250        | -               | -90            | -250        | -               | -90            | -250        | nA                           |
| Input Common Mode<br>Voltage Range <sup>(2)</sup><br>$V_{CC} = 30\text{ V}$ ( $26\text{ V}$ for<br>LM2902, V)<br>$V_{CC} = 30\text{ V}$ ( $26\text{ V}$ for<br>LM2902, V),<br>$T_A = T_{\text{high}}$ to $T_{\text{low}}$  | $V_{ICR}$                | 0               | -              | 28.3        | 0               | -              | 28.3        | 0               | -              | 28.3        | 0               | -              | 24.3        | 0               | -              | 24.3        | V                            |
| Differential Input<br>Voltage Range  | $V_{IDR}$                | -               | -              | $V_{CC}$    | -               | -              | $V_{CC}$    | -               | -              | $V_{CC}$    | -               | -              | $V_{CC}$    | -               | -              | $V_{CC}$    | V                            |
| Large Signal Open<br>Loop Voltage Gain<br>$R_L = 2.0\text{ k}\Omega$ , $V_{CC} =$<br>$15\text{ V}$ , for Large $V_O$<br>Swing, $T_A = T_{\text{high}}$<br>to $T_{\text{low}}^{(1)}$  | $A_{VOL}$                | 50<br>25        | 100<br>-       | -<br>-      | 25<br>15        | 100<br>-       | -<br>-      | 25<br>15        | 100<br>-       | -<br>-      | 25<br>15        | 100<br>-       | -<br>-      | 25<br>15        | 100<br>-       | -<br>-      | V/mV                         |
| Channel Separation<br>$10\text{ kHz} \leq f \leq 20\text{ kHz}$ ,<br>Input Referenced  | CS                       | -               | -120           | -           | -               | -120           | -           | -               | -120           | -           | -               | -120           | -           | -               | -120           | -           | dB                           |
| Common Mode<br>Rejection, $R_S \leq 10\text{ k}\Omega$   | CMR                      | 70              | 85             | -           | 65              | 70             | -           | 65              | 70             | -           | 50              | 70             | -           | 50              | 70             | -           | dB                           |
| Power Supply<br>Rejection  | PSR                      | 65              | 100            | -           | 65              | 100            | -           | 65              | 100            | -           | 50              | 100            | -           | 50              | 100            | -           | dB                           |
| Output Voltage—High<br>Limit ( $T_A = T_{\text{high}}$ to<br>$T_{\text{low}}^{(1)}$ )<br>$V_{CC} = 5.0\text{ V}$ , $R_L =$<br>$2.0\text{ k}\Omega$ , $T_A = 25^\circ\text{C}$<br>$V_{CC} = 30\text{ V}$ ( $26\text{ V}$ for<br>LM2902, V),<br>$R_L = 2.0\text{ k}\Omega$<br>$V_{CC} = 30\text{ V}$ ( $26\text{ V}$ for<br>LM2902, V),<br>$R_L = 10\text{ k}\Omega$ | $V_{OH}$                 | 3.3<br>26<br>27 | 3.5<br>-<br>28 | -<br>-<br>- | 3.3<br>26<br>27 | 3.5<br>-<br>28 | -<br>-<br>- | 3.3<br>26<br>27 | 3.5<br>-<br>28 | -<br>-<br>- | 3.3<br>22<br>23 | 3.5<br>-<br>24 | -<br>-<br>- | 3.3<br>22<br>23 | 3.5<br>-<br>24 | -<br>-<br>- | V                            |

**NOTES:** 1.  $T_{\text{low}} = -25^\circ\text{C}$  for LM224  
 $= 0^\circ\text{C}$  for LM324, A  
 $= -40^\circ\text{C}$  for LM2902  
 $= -40^\circ\text{C}$  for LM2902V  
 $T_{\text{high}} = +85^\circ\text{C}$  for LM224  
 $= +70^\circ\text{C}$  for LM324, A  
 $= +105^\circ\text{C}$  for LM2902  
 $= +125^\circ\text{C}$  for LM2902V

2. The input common mode voltage or either input signal voltage should not be allowed to go negative by more than 0.3 V. The upper end of the common mode voltage range is  $V_{CC} - 1.7\text{ V}$ .

# LM324, LM324A, LM224, LM2902, LM2902V

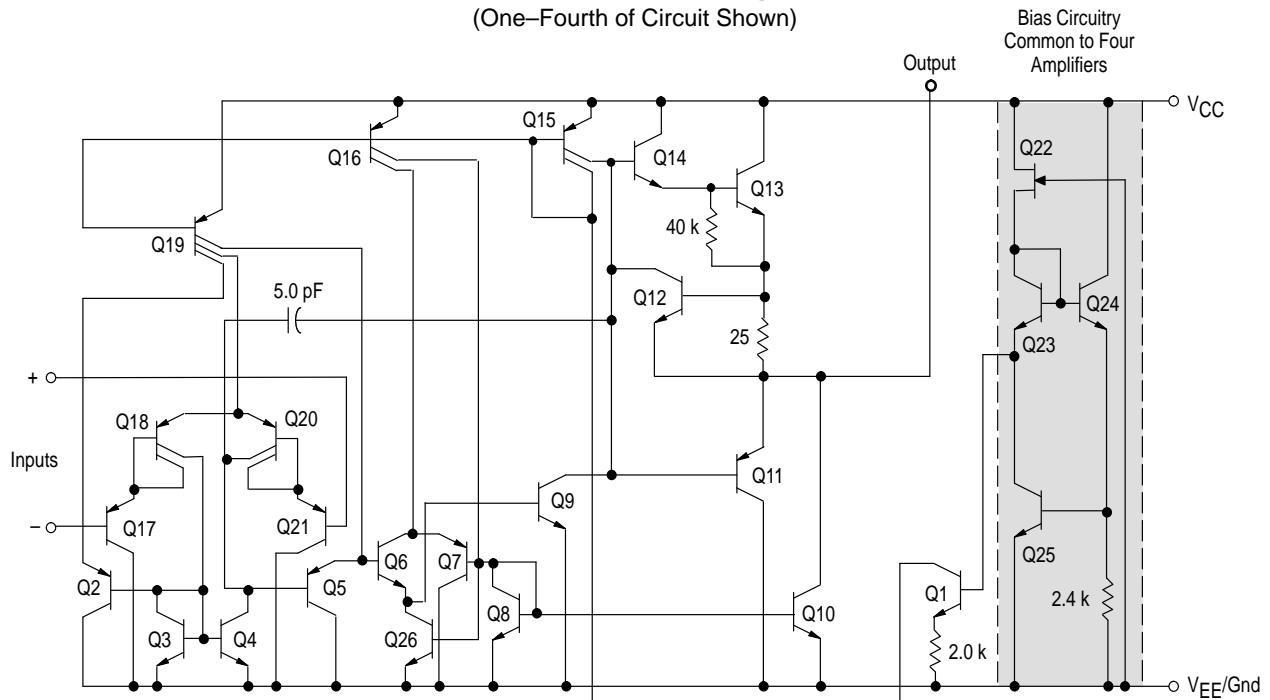
**ELECTRICAL CHARACTERISTICS** ( $V_{CC} = 5.0\text{ V}$ ,  $V_{EE} = \text{Gnd}$ ,  $T_A = 25^\circ\text{C}$ , unless otherwise noted.)

| Characteristics  | Symbol   | LM224 |     |     | LM324A |     |     | LM324 |     |     | LM2902 |     |     | LM2902V |     |     | Unit |
|--|----------|-------|-----|-----|--------|-----|-----|-------|-----|-----|--------|-----|-----|---------|-----|-----|------|
|  |          | Min   | Typ | Max | Min    | Typ | Max | Min   | Typ | Max | Min    | Typ | Max | Min     | Typ | Max |      |
| Output Voltage – Low Limit, $V_{CC} = 5.0\text{ V}$ , $R_L = 10\text{ k}\Omega$ , $T_A = T_{\text{high}}$ to $T_{\text{low}}^{(1)}$  | $V_{OL}$ | –     | 5.0 | 20  | –      | 5.0 | 20  | –     | 5.0 | 20  | –      | 5.0 | 100 | –       | 5.0 | 100 | mV   |
| Output Source Current ( $V_{ID} = +1.0\text{ V}$ , $V_{CC} = 15\text{ V}$ )<br>$T_A = 25^\circ\text{C}$<br>$T_A = T_{\text{high}}$ to $T_{\text{low}}^{(1)}$   | $I_{O+}$ | 20    | 40  | –   | 20     | 40  | –   | 20    | 40  | –   | 20     | 40  | –   | 20      | 40  | –   | mA   |
| Output Sink Current ( $V_{ID} = -1.0\text{ V}$ , $V_{CC} = 15\text{ V}$ ) $T_A = 25^\circ\text{C}$<br>$T_A = T_{\text{high}}$ to $T_{\text{low}}^{(1)}$<br>( $V_{ID} = -1.0\text{ V}$ , $V_O = 200\text{ mV}$ , $T_A = 25^\circ\text{C}$ ) | $I_{O-}$ | 10    | 20  | –   | 10     | 20  | –   | 10    | 20  | –   | 10     | 20  | –   | 10      | 20  | –   | mA   |
| Output Short Circuit to Ground <sup>(3)</sup>  | $I_{SC}$ | –     | 40  | 60  | –      | 40  | 60  | –     | 40  | 60  | –      | 40  | 60  | –       | 40  | 60  | mA   |
| Power Supply Current ( $T_A = T_{\text{high}}$ to $T_{\text{low}}^{(1)}$ )<br>$V_{CC} = 30\text{ V}$ (26 V for LM2902, V),<br>$V_O = 0\text{ V}$ , $R_L = \infty$<br>$V_{CC} = 5.0\text{ V}$ ,<br>$V_O = 0\text{ V}$ , $R_L = \infty$      | $I_{CC}$ | –     | –   | 3.0 | –      | 1.4 | 3.0 | –     | –   | 3.0 | –      | –   | 3.0 | –       | –   | 3.0 | mA   |
|  |          | –     | –   | 1.2 | –      | 0.7 | 1.2 | –     | –   | 1.2 | –      | –   | 1.2 | –       | –   | 1.2 | mA   |

**NOTES:** 1.  $T_{\text{low}} = -25^\circ\text{C}$  for LM224  
 $T_{\text{low}} = 0^\circ\text{C}$  for LM324, A  
 $T_{\text{low}} = -40^\circ\text{C}$  for LM2902  
 $T_{\text{low}} = -40^\circ\text{C}$  for LM2902V  
 $T_{\text{high}} = +85^\circ\text{C}$  for LM224  
 $T_{\text{high}} = +70^\circ\text{C}$  for LM324, A  
 $T_{\text{high}} = +105^\circ\text{C}$  for LM2902  
 $T_{\text{high}} = +125^\circ\text{C}$  for LM2902V

2. The input common mode voltage or either input signal voltage should not be allowed to go negative by more than 0.3 V. The upper end of the common mode voltage range is  $V_{CC} - 1.7\text{ V}$ .

**Representative Circuit Diagram**  
(One-Fourth of Circuit Shown)

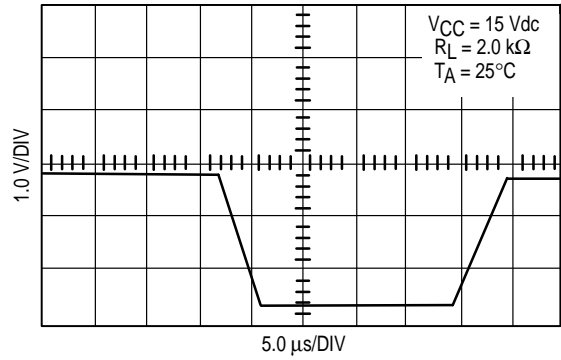


# LM324, LM324A, LM224, LM2902, LM2902V

## CIRCUIT DESCRIPTION

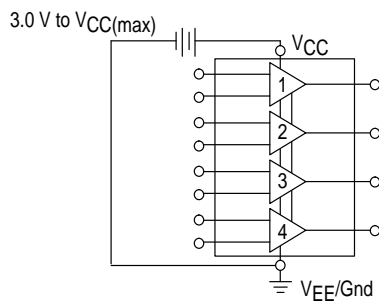
The LM324 series is made using four internally compensated, two-stage operational amplifiers. The first stage of each consists of differential input devices Q20 and Q18 with input buffer transistors Q21 and Q17 and the differential to single ended converter Q3 and Q4. The first stage performs not only the first stage gain function but also performs the level shifting and transconductance reduction functions. By reducing the transconductance, a smaller compensation capacitor (only 5.0 pF) can be employed, thus saving chip area. The transconductance reduction is accomplished by splitting the collectors of Q20 and Q18. Another feature of this input stage is that the input common mode range can include the negative supply or ground, in single supply operation, without saturating either the input devices or the differential to single-ended converter. The second stage consists of a standard current source load amplifier stage.

### Large Signal Voltage Follower Response

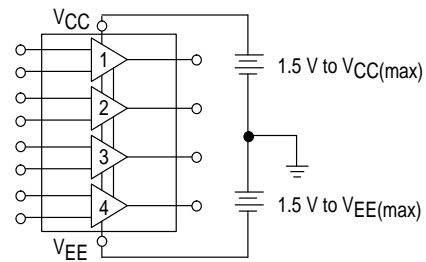


Each amplifier is biased from an internal-voltage regulator which has a low temperature coefficient thus giving each amplifier good temperature characteristics as well as excellent power supply rejection.

### Single Supply

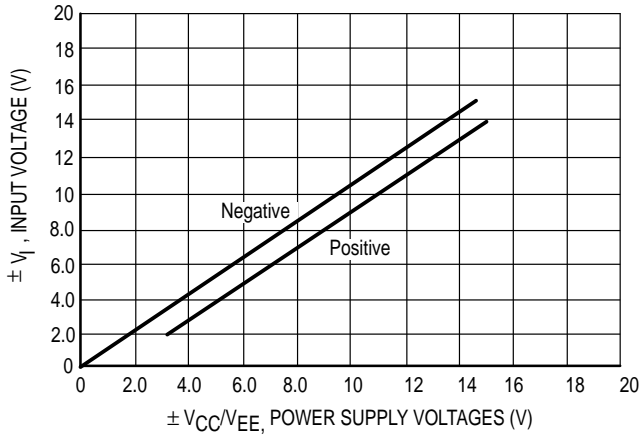


### Split Supplies

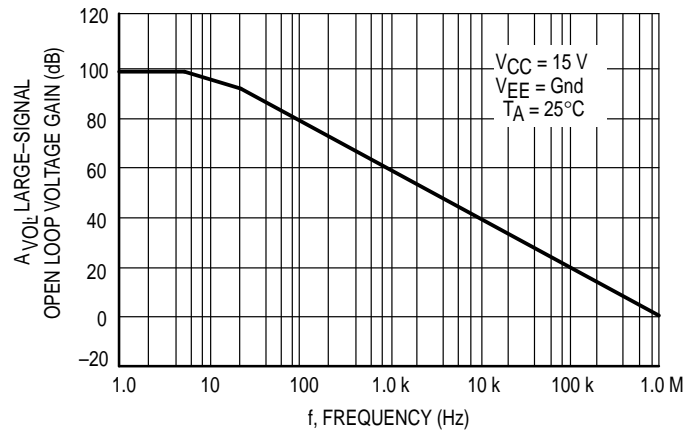


# LM324, LM324A, LM224, LM2902, LM2902V

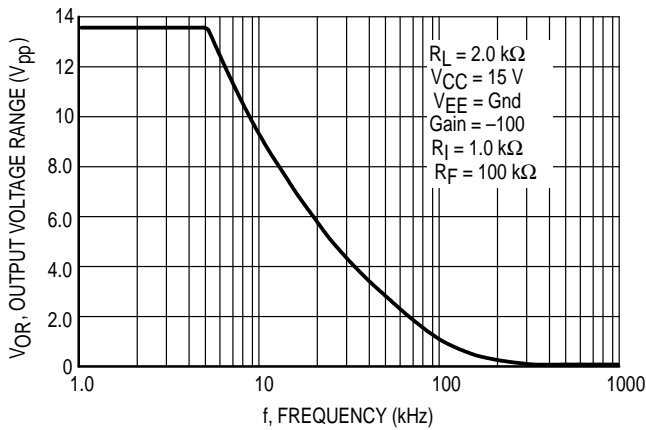
**Figure 1. Input Voltage Range**



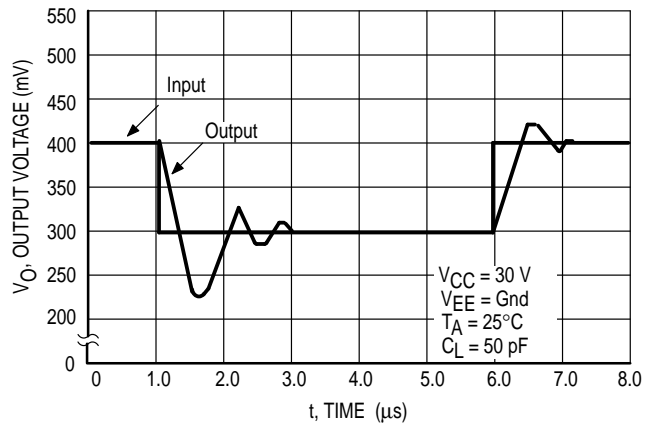
**Figure 2. Open Loop Frequency**



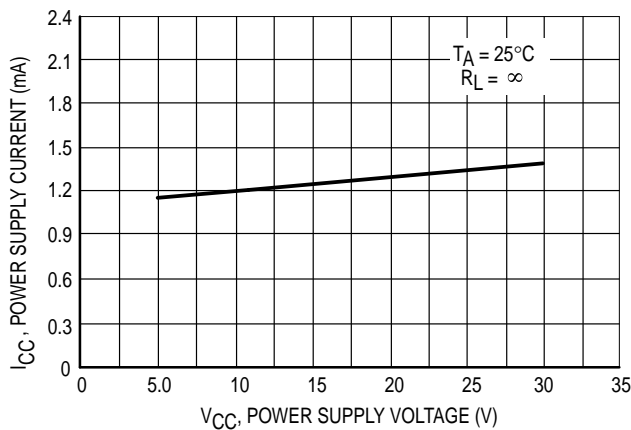
**Figure 3. Large-Signal Frequency Response**



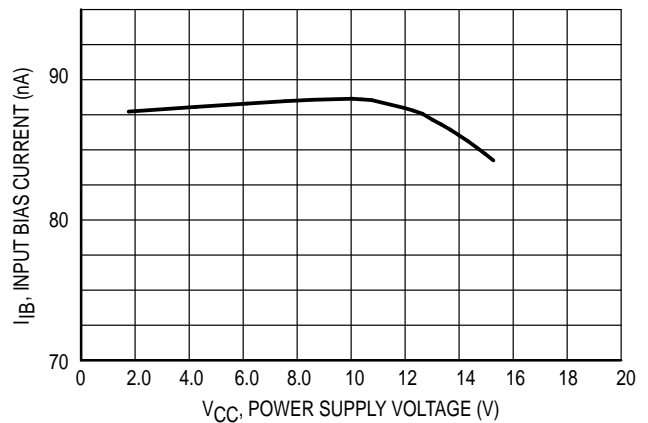
**Figure 4. Small-Signal Voltage Follower Pulse Response (Noninverting)**



**Figure 5. Power Supply Current versus Power Supply Voltage**



**Figure 6. Input Bias Current versus Power Supply Voltage**



# LM324, LM324A, LM224, LM2902, LM2902V

Figure 7. Voltage Reference

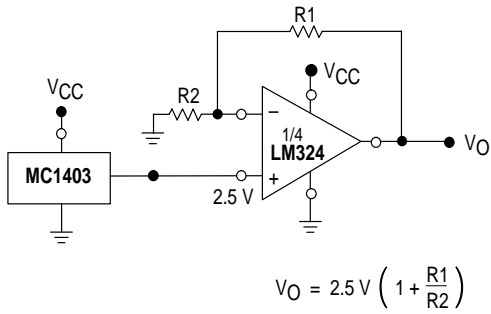


Figure 8. Wien Bridge Oscillator

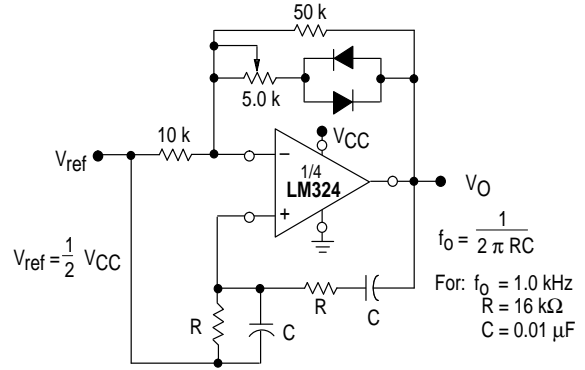


Figure 9. High Impedance Differential Amplifier

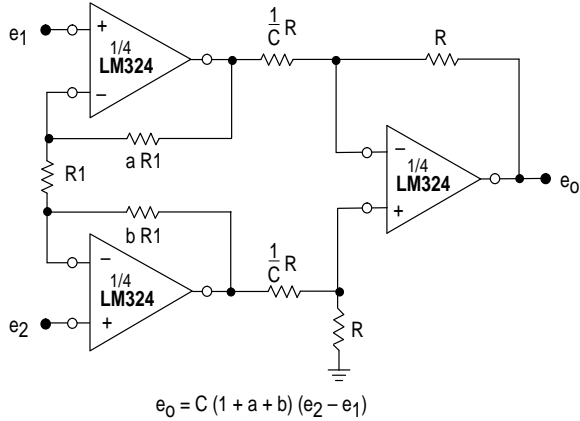


Figure 10. Comparator with Hysteresis

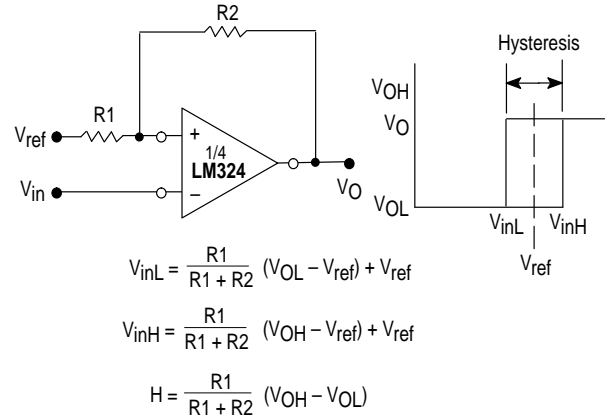
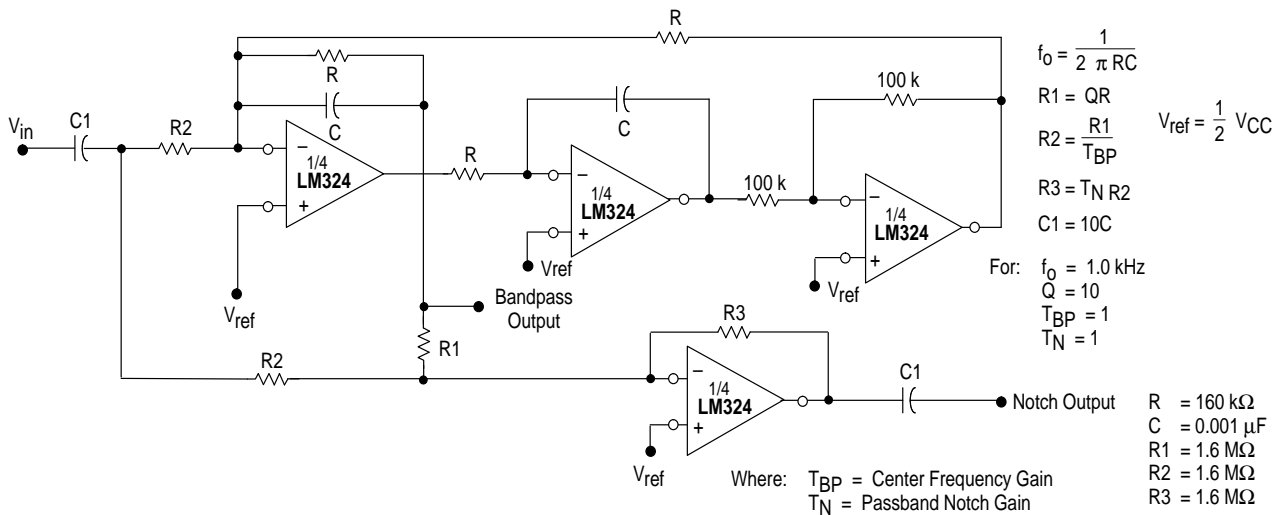


Figure 11. Bi-Quad Filter



# LM324, LM324A, LM224, LM2902, LM2902V

Figure 12. Function Generator

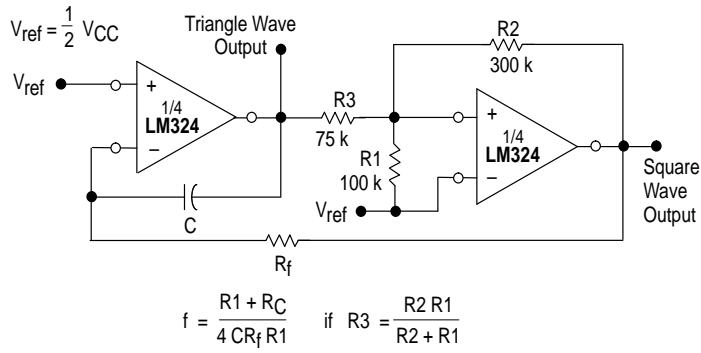
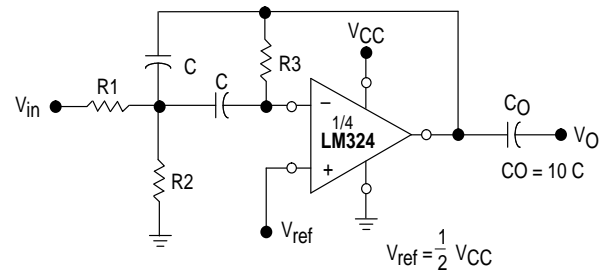


Figure 13. Multiple Feedback Bandpass Filter



Given:  $f_0$  = center frequency  
 $A(f_0)$  = gain at center frequency

Choose value  $f_0, C$

Then:  $R3 = \frac{Q}{\pi f_0 C}$

$R1 = \frac{R3}{2 A(f_0)}$

$R2 = \frac{R1 R3}{4Q^2 R1 - R3}$

For less than 10% error from operational amplifier,  $\frac{Q_0 f_0}{BW} < 0.1$

where  $f_0$  and BW are expressed in Hz.

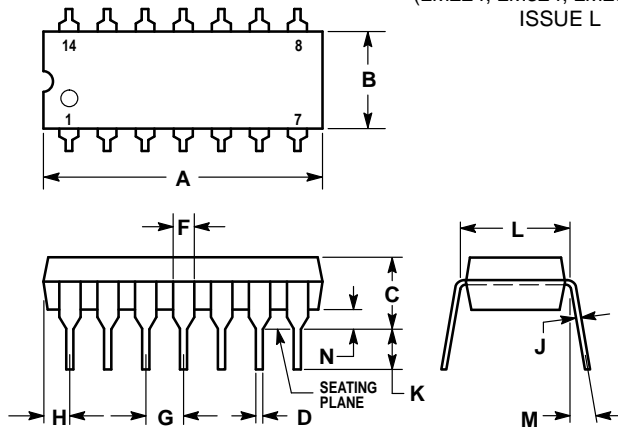
If source impedance varies, filter may be preceded with voltage follower buffer to stabilize filter parameters.



# LM324, LM324A, LM224, LM2902, LM2902V

## OUTLINE DIMENSIONS

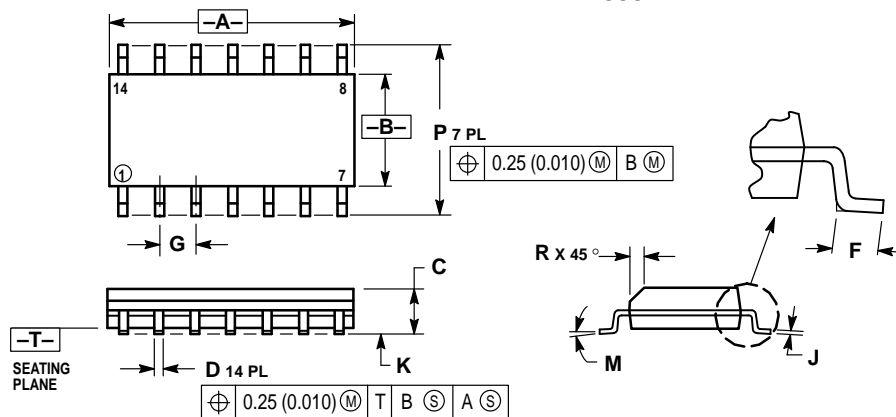
**N SUFFIX**  
**PLASTIC PACKAGE**  
**CASE 646-06**  
**(LM224, LM324, LM2902 Only)**  
**ISSUE L**



- NOTES:
- LEADS WITHIN 0.13 (0.005) RADIUS OF TRUE POSITION AT SEATING PLANE AT MAXIMUM MATERIAL CONDITION.
  - DIMENSION L TO CENTER OF LEADS WHEN FORMED PARALLEL.
  - DIMENSION B DOES NOT INCLUDE MOLD FLASH.
  - ROUNDED CORNERS OPTIONAL.

| DIM | INCHES    |       | MILLIMETERS |       |
|-----|-----------|-------|-------------|-------|
|     | MIN       | MAX   | MIN         | MAX   |
| A   | 0.715     | 0.770 | 18.16       | 19.56 |
| B   | 0.240     | 0.260 | 6.10        | 6.60  |
| C   | 0.145     | 0.185 | 3.69        | 4.69  |
| D   | 0.015     | 0.021 | 0.38        | 0.53  |
| F   | 0.040     | 0.070 | 1.02        | 1.78  |
| G   | 0.100 BSC |       | 2.54 BSC    |       |
| H   | 0.052     | 0.095 | 1.32        | 2.41  |
| J   | 0.008     | 0.015 | 0.20        | 0.38  |
| K   | 0.115     | 0.135 | 2.92        | 3.43  |
| L   | 0.300 BSC |       | 7.62 BSC    |       |
| M   | 0°        | 10°   | 0°          | 10°   |
| N   | 0.015     | 0.039 | 0.39        | 1.01  |

**D SUFFIX**  
**PLASTIC PACKAGE**  
**CASE 751A-03**  
**(SO-14)**  
**ISSUE F**



- NOTES:
- DIMENSIONING AND TOLERANCING PER ANSI Y14.5M, 1982.
  - CONTROLLING DIMENSION: MILLIMETER.
  - DIMENSIONS A AND B DO NOT INCLUDE MOLD PROTRUSION.
  - MAXIMUM MOLD PROTRUSION 0.15 (0.006) PER SIDE.
  - DIMENSION D DOES NOT INCLUDE DAMBAR PROTRUSION. ALLOWABLE DAMBAR PROTRUSION SHALL BE 0.127 (0.005) TOTAL IN EXCESS OF THE D DIMENSION AT MAXIMUM MATERIAL CONDITION.

| DIM | MILLIMETERS |      | INCHES    |       |
|-----|-------------|------|-----------|-------|
|     | MIN         | MAX  | MIN       | MAX   |
| A   | 8.55        | 8.75 | 0.337     | 0.344 |
| B   | 3.80        | 4.00 | 0.150     | 0.157 |
| C   | 1.35        | 1.75 | 0.054     | 0.068 |
| D   | 0.35        | 0.49 | 0.014     | 0.019 |
| F   | 0.40        | 1.25 | 0.016     | 0.049 |
| G   | 1.27 BSC    |      | 0.050 BSC |       |
| J   | 0.19        | 0.25 | 0.008     | 0.009 |
| K   | 0.10        | 0.25 | 0.004     | 0.009 |
| M   | 0°          | 7°   | 0°        | 7°    |
| P   | 5.80        | 6.20 | 0.228     | 0.244 |
| R   | 0.25        | 0.50 | 0.010     | 0.019 |

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