

# LM124, LM124A, LM224, LM224A LM324, LM324A, LM324Y, LM2902, LM2902Q QUADRUPLE OPERATIONAL AMPLIFIERS

SLOS066E—SEPTEMBER 1975—REVISED FEBRUARY 1997

- **Wide Range of Supply Voltages:**  
Single Supply . . . 3 V to 30 V (LM2902 and LM2902Q 3 V to 26 V), or Dual Supplies
- **Low Supply Current Drain Independent of Supply Voltage . . . 0.8 mA Typ**
- **Common-Mode Input Voltage Range Includes Ground Allowing Direct Sensing Near Ground**
- **Low Input Bias and Offset Parameters:**  
Input Offset Voltage . . . 3 mV Typ  
A Versions . . . 2 mV Typ  
Input Offset Current . . . 2 nA Typ  
Input Bias Current . . . 20 nA Typ  
A Versions . . . 15 nA Typ
- **Differential Input Voltage Range Equal to Maximum-Rated Supply Voltage . . . 32 V (26 V for LM2902 and LM2902Q)**
- **Open-Loop Differential Voltage Amplification . . . 100 V/mV Typ**
- **Internal Frequency Compensation**

## description

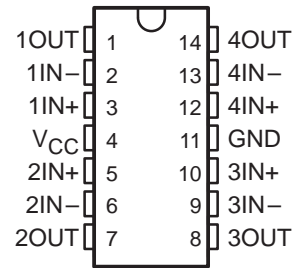
These devices consist of four independent high-gain frequency-compensated operational amplifiers that are designed specifically to operate from a single supply over a wide range of voltages. Operation from split supplies is also possible when the difference between the two supplies is 3 V to 30 V (for the LM2902 and LM2902Q, 3 V to 26 V) and  $V_{CC}$  is at least 1.5 V more positive than the input common-mode voltage. The low supply current drain is independent of the magnitude of the supply voltage.

Applications include transducer amplifiers, dc amplification blocks, and all the conventional operational amplifier circuits that now can be more easily implemented in single-supply-voltage systems. For example, the LM124 can be operated directly from the standard 5-V supply that is used in digital systems and easily provides the required interface electronics without requiring additional  $\pm 15$ -V supplies.

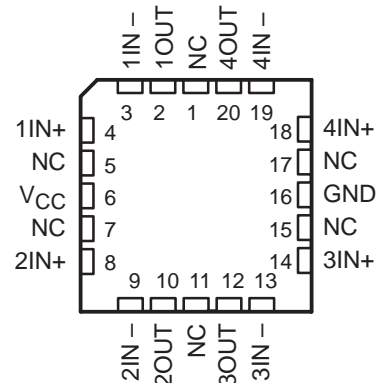
The LM2902Q is manufactured to demanding automotive requirements.

The LM124 and LM124A are characterized for operation over the full military temperature range of  $-55^{\circ}\text{C}$  to  $125^{\circ}\text{C}$ . The LM224 and LM224A are characterized for operation from  $-25^{\circ}\text{C}$  to  $85^{\circ}\text{C}$ . The LM324 and LM324A are characterized for operation from  $0^{\circ}\text{C}$  to  $70^{\circ}\text{C}$ . The LM2902 and LM2902Q are characterized for operation from  $-40^{\circ}\text{C}$  to  $125^{\circ}\text{C}$ .

LM124, LM124A . . . J OR W PACKAGE  
ALL OTHERS . . . D, DB, N OR PW PACKAGE  
(TOP VIEW)

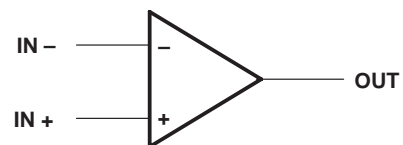


LM124, LM124A . . . FK PACKAGE  
(TOP VIEW)



NC – No internal connection

## symbol (each amplifier)



# LM124, LM124A, LM224, LM224A LM324, LM324A, LM324Y, LM2902, LM2902Q QUADRUPLE OPERATIONAL AMPLIFIERS

SLOS066E—SEPTEMBER 1975—REVISED FEBRUARY 1997

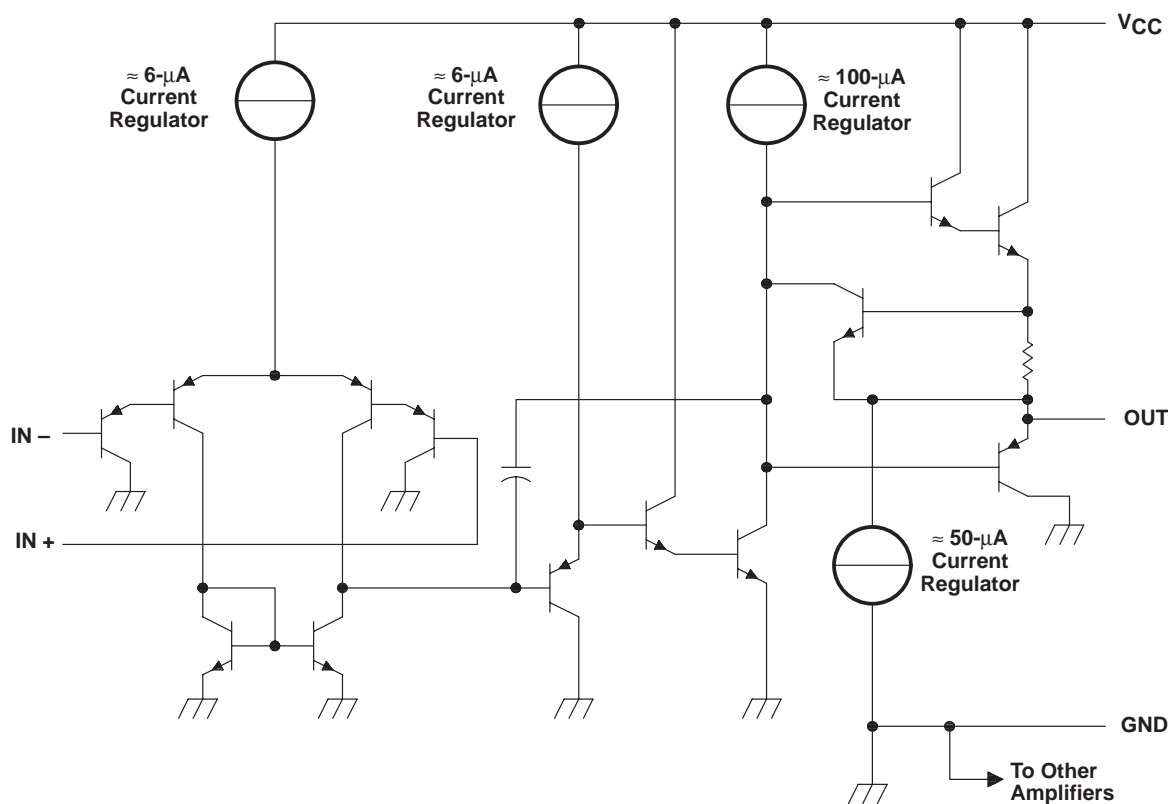
## AVAILABLE OPTIONS

| T <sub>A</sub>    | V <sub>I</sub> Omax<br>AT 25°C | PACKAGED DEVICES         |                                   |                         |                       |                       |                |                     | CHIP<br>FORM<br>(Y) |
|-------------------|--------------------------------|--------------------------|-----------------------------------|-------------------------|-----------------------|-----------------------|----------------|---------------------|---------------------|
|                   |                                | SMALL<br>OUTLINE<br>(D)† | VERY<br>SMALL<br>OUTLINE<br>(DB)‡ | CHIP<br>CARRIER<br>(FK) | CERAMIC<br>DIP<br>(J) | PLASTIC<br>DIP<br>(N) | TSSOP<br>(PW)‡ | FLAT<br>PACK<br>(W) |                     |
| 0°C to<br>70°C    | 7 mV                           | LM324D                   | LM324DBLE                         | —                       | —                     | LM324N                | LM324PWLE      | —                   | LM324Y              |
|                   | 3 mV                           | LM324AD                  | —                                 | —                       | —                     | LM324AN               | LM324APWLE     | —                   |                     |
| -25°C to<br>85°C  | 5 mV                           | LM224D                   | —                                 | —                       | —                     | LM224N                | —              | —                   | —                   |
|                   | 3 mV                           | LM224AD                  | —                                 | —                       | —                     | LM224AN               | —              | —                   |                     |
| -40°C to<br>125°C | 7 mV                           | LM2902D                  | LM2902DBLE                        | —                       | —                     | LM2902N               | LM2902PWLE     | —                   | —                   |
|                   |                                | LM2902QD                 | —                                 | —                       | —                     | LM2902QN              | —              | —                   |                     |
| -55°C to<br>125°C | 5 mV                           | —                        | —                                 | LM124FK                 | LM124J                | —                     | —              | LM124W              | —                   |
|                   | 2 mV                           | —                        | —                                 | LM124AFK                | LM124AJ               | —                     | —              | —                   |                     |

† The D package is available taped and reeled. Add the suffix R to the device type (e.g., LM324DR).

‡ The DB and PW packages are only available left-end taped and reeled.

## schematic (each amplifier)



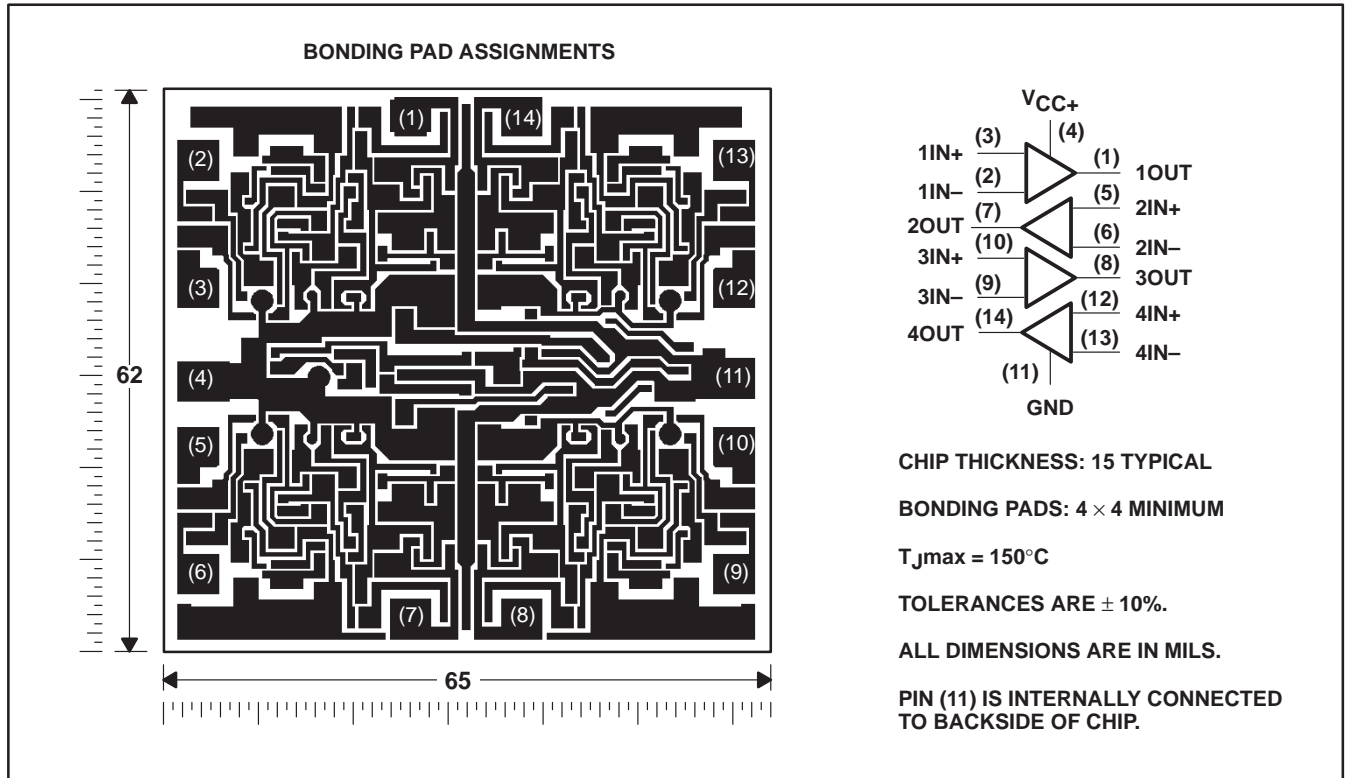
| COMPONENT COUNT<br>(total device) |    |
|-----------------------------------|----|
| Epi-FET                           | 1  |
| Transistors                       | 95 |
| Diodes                            | 4  |
| Resistors                         | 11 |
| Capacitors                        | 4  |

LM124, LM124A, LM224, LM224A  
 LM324, LM324A, LM324Y, LM2902, LM2902Q  
**QUADRUPLE OPERATIONAL AMPLIFIERS**

SLOS066E—SEPTEMBER 1975—REVISED FEBRUARY 1997

**LM324Y chip information**

This chip, when properly assembled, displays characteristics similar to the LM324. Thermal compression or ultrasonic bonding may be used on the doped-aluminum bonding pads. Chips may be mounted with conductive epoxy or a gold-silicon preform.



**LM124, LM124A, LM224, LM224A  
LM324, LM324A, LM324Y, LM2902, LM2902Q  
QUADRUPLE OPERATIONAL AMPLIFIERS**

SLOS066E– SEPTEMBER 1975 – REVISED FEBRUARY 1997

**absolute maximum ratings over operating free-air temperature range (unless otherwise noted)†**

|  |                 | LM124, LM124A<br>LM224, LM224A<br>LM324, LM324A | LM2902,<br>LM2902Q | UNIT |    |
|--|-----------------|---|--------------------|------|----|
| Supply voltage, $V_{CC}$ (see Note 1)  |                 | 32  | 26                 | V    |    |
| Differential input voltage, $V_{ID}$ (see Note 2)  |                 | $\pm 32$  | $\pm 26$           | V    |    |
| Input voltage, $V_I$ (either input)  |                 | -0.3 to 32                                      | -0.3 to 26         | V    |    |
| Duration of output short circuit (one amplifier) to ground at (or below) $T_A = 25^\circ\text{C}$ , $V_{CC} \leq 15\text{ V}$ (see Note 3) |                 | unlimited                                       | unlimited          |      |    |
| Continuous total dissipation   |                 | See Dissipation Rating Table                    |                    |      |    |
| Operating free-air temperature range, $T_A$  | LM124, LM124A   | -55 to 125                                      |                    | °C   |    |
|  | LM224, LM224A   | -25 to 85                                       |                    |      |    |
|  | LM324, LM324A   | 0 to 70   |                    |      |    |
|  | LM2902, LM2902Q |   | -40 to 125         |      |    |
| Storage temperature range  |                 | -65 to 150                                      | -65 to 150         | °C   |    |
| Case temperature for 60 seconds  |                 | FK package                                      | 260                | °C   |    |
| Lead temperature 1,6 mm (1/16 inch) from case for 60 seconds   |                 | J or W package                                  | 300                | 300  | °C |
| Lead temperature 1,6 mm (1/16 inch) from case for 10 seconds   |                 | D, DB, N, or PW package                         | 260                | 260  | °C |

† Stresses beyond those listed under “absolute maximum ratings” may cause permanent damage to the device. These are stress ratings only, and functional operation of the device at these or any other conditions beyond those indicated under “recommended operating conditions” is not implied. Exposure to absolute-maximum-rated conditions for extended periods may affect device reliability.

- NOTES: 1. All voltage values (except differential voltages and  $V_{CC}$  specified for the measurement of  $I_{OS}$ ) are with respect to the network GND.  
2. Differential voltages are at  $IN+$  with respect to  $IN-$ .  
3. Short circuits from outputs to  $V_{CC}$  can cause excessive heating and eventual destruction.

**DISSIPATION RATING TABLE**

| PACKAGE        | $T_A \leq 25^\circ\text{C}$<br>POWER RATING | DERATING<br>FACTOR | DERATE<br>ABOVE $T_A$ | $T_A = 70^\circ\text{C}$<br>POWER RATING | $T_A = 85^\circ\text{C}$<br>POWER RATING | $T_A = 125^\circ\text{C}$<br>POWER RATING |
|----------------|---|--------------------|-----------------------|--|--|---|
| D              | 900 mW                                      | 7.6 mW/°C          | 32°C                  | 611 mW                                   | 497 mW                                   | N/A                                       |
| DB             | 775 mW                                      | 6.2 mW/°C          | 25°C                  | 496 mW                                   | 403 mW                                   | N/A                                       |
| FK             | 900 mW                                      | 11.0 mW/°C         | 68°C                  | 878 mW                                   | 713 mW                                   | 273 mW                                    |
| J (LM124_)     | 900 mW                                      | 11.0 mW/°C         | 68°C                  | 878 mW                                   | 713 mW                                   | 273 mW                                    |
| J (all others) | 900 mW                                      | 8.2 mW/°C          | 40°C                  | 654 mW                                   | 531 mW                                   | N/A                                       |
| N              | 900 mW                                      | 9.2 mW/°C          | 52°C                  | 734 mW                                   | 596 mW                                   | N/A                                       |
| PW             | 700 mW                                      | 5.6 mW/°C          | 25°C                  | 448 mW                                   | 364 mW                                   | N/A                                       |
| W              | 900 mW                                      | 8.0 mW/°C          | 37°C                  | 636 mW                                   | 516 mW                                   | 196 mW                                    |



electrical characteristics at specified free-air temperature,  $V_{CC} = 5\text{ V}$  (unless otherwise noted)

| PARAMETER       | TEST CONDITIONS†   | $T_A$ ‡   | LM124, LM224 |                     |          | LM324               |      |          | LM2902, LM2902Q     |      |          | UNIT     |    |
|-----------------|--|---|--------------|---------------------|----------|---------------------|------|----------|---------------------|------|----------|----------|----|
|                 |  |   | MIN          | TYP§                | MAX      | MIN                 | TYP§ | MAX      | MIN                 | TYP§ | MAX      |          |    |
| $V_{IO}$        | Input offset voltage   | $V_{CC} = 5\text{ V to MAX}$ ,<br>$V_{IC} = V_{ICRmin}$ , $V_O = 1.4\text{ V}$              | 25°C         | 3                   | 5        |                     | 3    | 7        |                     | 3    | 7        | mV       |    |
|                 |  |   | Full range   |                     | 7        |                     |      | 9        |                     |      | 10       |          |    |
| $I_{IO}$        | Input offset current   | $V_O = 1.4\text{ V}$  | 25°C         | 2                   | 30       |                     | 2    | 50       |                     | 2    | 50       | nA       |    |
|                 |  |   | Full range   |                     | 100      |                     |      | 150      |                     |      | 300      |          |    |
| $I_{IB}$        | Input bias current   | $V_O = 1.4\text{ V}$  | 25°C         | -20                 | -150     |                     | -20  | -250     |                     | -20  | -250     | nA       |    |
|                 |  |   | Full range   |                     | -300     |                     |      | -500     |                     |      | -500     |          |    |
| $V_{ICR}$       | Common-mode input voltage range                                  | $V_{CC} = 5\text{ V to MAX}$  | 25°C         | 0 to $V_{CC} - 1.5$ |          | 0 to $V_{CC} - 1.5$ |      |          | 0 to $V_{CC} - 1.5$ |      |          | V        |    |
|                 |  |   | Full range   | 0 to $V_{CC} - 2$   |          | 0 to $V_{CC} - 2$   |      |          | 0 to $V_{CC} - 2$   |      |          |          |    |
| $V_{OH}$        | High-level output voltage  | $R_L = 2\text{ k}\Omega$  | 25°C         | $V_{CC} - 1.5$      |          | $V_{CC} - 1.5$      |      |          |                     |      |          | V        |    |
|                 |  |   | 25°C         |                     |          |                     |      |          | $V_{CC} - 1.5$      |      |          |          |    |
|                 |  |   | Full range   | 26                  |          | 26                  |      |          | 22                  |      |          |          |    |
|                 |  |   | Full range   | 27                  | 28       | 27                  | 28   |          | 23                  | 24   |          |          |    |
| $V_{OL}$        | Low-level output voltage   | $R_L \leq 10\text{ k}\Omega$  | Full range   |                     | 5        | 20                  |      | 5        | 20                  |      | 5        | 20       | mV |
|                 |  |   |              |                     |          |                     |      |          |                     |      |          |          |    |
| $A_{VD}$        | Large-signal differential voltage amplification                  | $V_{CC} = 15\text{ V}$ , $V_O = 1\text{ V to }11\text{ V}$ ,<br>$R_L \geq 2\text{ k}\Omega$ | 25°C         | 50                  | 100      |                     | 25   | 100      |                     |      | 100      | V/mV     |    |
|                 |  |   | Full range   | 25                  |          |                     | 15   |          |                     | 15   |          |          |    |
| CMRR            | Common-mode rejection ratio                                      | $V_{IC} = V_{ICRmin}$   | 25°C         | 70                  | 80       |                     | 65   | 80       |                     | 50   | 80       | dB       |    |
| $k_{SVR}$       | Supply-voltage rejection ratio ( $\Delta V_{CC}/\Delta V_{IO}$ ) |   | 25°C         | 65                  | 100      |                     | 65   | 100      |                     | 50   | 100      | dB       |    |
| $V_{O1}/V_{O2}$ | Crosstalk attenuation  | $f = 1\text{ kHz to }20\text{ kHz}$   | 25°C         |                     | 120      |                     |      | 120      |                     |      | 120      | dB       |    |
| $I_O$           | Output current   | $V_{CC} = 15\text{ V}$ ,<br>$V_O = 0$   | 25°C         | -20                 | -30      | -60                 | -20  | -30      | -60                 | -20  | -30      | -60      | mA |
|                 |  |   | Full range   | -10                 |          |                     | -10  |          |                     | -10  |          |          |    |
|                 |  |   | 25°C         | 10                  | 20       |                     | 10   | 20       |                     | 10   | 20       |          |    |
|                 |  |   | Full range   | 5                   |          |                     | 5    |          |                     | 5    |          |          |    |
| $I_{OS}$        | Short-circuit output current                                     | $V_{CC}$ at 5 V,<br>GND at -5 V   | 25°C         |                     | $\pm 40$ | $\pm 60$            |      | $\pm 40$ | $\pm 60$            |      | $\pm 40$ | $\pm 60$ | mA |
|                 |  |   |              |                     |          |                     |      |          |                     |      |          |          |    |
| $I_{CC}$        | Supply current (four amplifiers)                                 | $V_O = 2.5\text{ V}$ ,<br>$V_{CC} = \text{MAX}$ ,<br>$V_O = 0.5 V_{CC}$ , No load           | Full range   |                     | 0.7      | 1.2                 |      | 0.7      | 1.2                 |      | 0.7      | 1.2      | mA |
|                 |  |   | Full range   |                     | 1.4      | 3                   |      | 1.4      | 3                   |      | 1.4      | 3        |    |

† All characteristics are measured under open-loop conditions with zero common-mode input voltage unless otherwise specified. MAX  $V_{CC}$  for testing purposes is 26 V for LM2902 and LM2902Q, 30 V for the others.

‡ Full range is -55°C to 125°C for LM124, -25°C to 85°C for LM224, 0°C to 70°C for LM324, and -40°C to 125°C for LM2902 and LM2902Q.

§ All typical values are at  $T_A = 25^\circ\text{C}$ .

electrical characteristics at specified free-air temperature,  $V_{CC} = 5\text{ V}$  (unless otherwise noted)

| PARAMETER  | TEST CONDITIONS†  | $T_A$ ‡    | LM124A            |          |          | LM224A            |          |          | LM324A            |          |          | UNIT |
|--|---|------------|-------------------|----------|----------|-------------------|----------|----------|-------------------|----------|----------|------|
|  |   |            | MIN               | TYP§     | MAX      | MIN               | TYP§     | MAX      | MIN               | TYP§     | MAX      |      |
| $V_{IO}$ Input offset voltage  | $V_{CC} = 5\text{ V to }30\text{ V}$ ,<br>$V_{IC} = V_{ICRmin}$ , $V_O = 1.4\text{ V}$      | 25°C       |                   |          | 2        |                   | 2        | 3        |                   | 2        | 3        | mV   |
|  |   | Full range |                   |          | 4        |                   | 4        |          |                   | 5        |          |      |
| $I_{IO}$ Input offset current  | $V_O = 1.4\text{ V}$  | 25°C       |                   |          | 10       |                   | 2        |          | 15                | 2        | 30       | nA   |
|  |   | Full range |                   |          | 30       |                   | 30       |          |                   | 75       |          |      |
| $I_{IB}$ Input bias current  | $V_O = 1.4\text{ V}$  | 25°C       |                   |          | -50      |                   | -15      | -80      |                   | -15      | -100     | nA   |
|  |   | Full range |                   |          | -100     |                   | -100     |          |                   | -200     |          |      |
| $V_{ICR}$ Common-mode input voltage range                                  | $V_{CC} = 30\text{ V}$  | 25°C       | 0 to $V_{CC}-1.5$ |          |          | 0 to $V_{CC}-1.5$ |          |          | 0 to $V_{CC}-1.5$ |          |          | V    |
|  |   | Full range | 0 to $V_{CC}-2$   |          |          | 0 to $V_{CC}-2$   |          |          | 0 to $V_{CC}-2$   |          |          |      |
| $V_{OH}$ High-level output voltage   | $R_L = 2\text{ k}\Omega$  | 25°C       | $V_{CC}-1.5$      |          |          | $V_{CC}-1.5$      |          |          | $V_{CC}-1.5$      |          |          | V    |
|  | $V_{CC} = 30\text{ V}$ , $R_L = 2\text{ k}\Omega$   | Full range | 26                |          |          | 26                |          |          | 26                |          |          |      |
|  | $V_{CC} = 30\text{ V}$ , $R_L \geq 10\text{ k}\Omega$                                       | Full range | 27                |          |          | 27                | 28       |          | 27                | 28       |          |      |
| $V_{OL}$ Low-level output voltage  | $R_L \leq 10\text{ k}\Omega$  | Full range |                   |          | 20       |                   | 5        | 20       |                   | 5        | 20       | mV   |
| $A_{VD}$ Large-signal differential voltage amplification                   | $V_{CC} = 15\text{ V}$ , $V_O = 1\text{ V to }11\text{ V}$ ,<br>$R_L \geq 2\text{ k}\Omega$ | Full range | 25                |          |          | 25                |          |          | 15                |          |          | V/mV |
| CMRR Common-mode rejection ratio   | $V_{IC} = V_{ICRmin}$   | 25°C       | 70                |          |          | 70                | 80       |          | 65                | 80       |          | dB   |
| $k_{SVR}$ Supply-voltage rejection ratio ( $\Delta V_{CC}/\Delta V_{IO}$ ) |   | 25°C       | 65                |          |          | 65                | 100      |          | 65                | 100      |          | dB   |
| $V_{O1}/V_{O2}$ Crosstalk attenuation                                      | $f = 1\text{ kHz to }20\text{ kHz}$   | 25°C       |                   | 120      |          |                   | 120      |          |                   | 120      |          | dB   |
| $I_O$ Output current   | $V_{CC} = 15\text{ V}$ , $V_{ID} = 1\text{ V}$ ,<br>$V_O = 0$                               | 25°C       | -20               |          |          | -20               | -30      | -60      | -20               | -30      | -60      | mA   |
|  |   | Full range | -10               |          |          | -10               |          |          | -10               |          |          |      |
|  | $V_{CC} = 15\text{ V}$ , $V_{ID} = -1\text{ V}$ ,<br>$V_O = 15\text{ V}$                    | 25°C       | 10                |          |          | 10                | 20       |          | 10                | 20       |          |      |
|  |   | Full range | 5                 |          |          | 5                 |          |          | 5                 |          |          |      |
| $I_{OS}$ Short-circuit output current                                      | $V_{CC}$ at 5 V, $V_O = 0$ ,<br>GND at -5 V   | 25°C       |                   | $\pm 40$ | $\pm 60$ |                   | $\pm 40$ | $\pm 60$ |                   | $\pm 40$ | $\pm 60$ | mA   |
|  |   | Full range |                   | 0.7      | 1.2      |                   | 0.7      | 1.2      |                   | 0.7      | 1.2      |      |
| $I_{CC}$ Supply current (four amplifiers)                                  | $V_O = 2.5\text{ V}$ , No load<br>$V_{CC} = 30\text{ V}$ , $V_O = 15\text{ V}$ ,<br>No load | Full range |                   | 0.7      | 1.2      |                   | 0.7      | 1.2      |                   | 0.7      | 1.2      | mA   |
|  |   | Full range |                   | 1.4      | 3        |                   | 1.4      | 3        |                   | 1.4      | 3        |      |

† All characteristics are measured under open-loop conditions with zero common-mode input voltage unless otherwise specified.

‡ Full range is -55°C to 125°C for LM124A, -25°C to 85°C for LM224A, and 0°C to 70°C for LM324A.

§ All typical values are at  $T_A = 25^\circ\text{C}$ .

LM124, LM124A, LM224, LM224A  
LM324, LM324A, LM324Y, LM2902, LM2902Q  
QUADRUPLE OPERATIONAL AMPLIFIERS

SLOS066E – SEPTEMBER 1975 – REVISED FEBRUARY 1997

electrical characteristics,  $V_{CC} = 5\text{ V}$ ,  $T_A = 25^\circ\text{C}$  (unless otherwise noted)

| PARAMETER  | TEST CONDITIONST   | LM324Y            |          |          | UNIT |
|--|--|-------------------|----------|----------|------|
|  |  | MIN               | TYP      | MAX      |      |
| $V_{IO}$ Input offset voltage  | $V_{CC} = 5\text{ V to MAX}, V_{IC} = V_{ICRmin}, V_O = 1.4\text{ V}$              |                   | 3        | 7        | mV   |
| $I_{IO}$ Input offset current  |  |                   | 2        | 50       | nA   |
| $I_{IB}$ Input bias current  |  |                   | -20      | -250     | nA   |
| $V_{ICR}$ Common-mode input voltage range  | $V_{CC} = 5\text{ V to MAX}$   | 0 to $V_{CC}-1.5$ |          |          | V    |
| $V_{OH}$ High-level output voltage   | $R_L = 10\text{ k}\Omega$  | $V_{CC}-1.5$      |          |          | V    |
| $V_{OL}$ Low-level output voltage  | $R_L \leq 10\text{ k}\Omega$   |                   | 5        | 20       | mV   |
| $A_{VD}$ Large-signal differential voltage amplification                         | $V_{CC} = 15\text{ V}, V_O = 1\text{ V to }11\text{ V}, R_L \geq 2\text{ k}\Omega$ | 15                | 100      |          | V/mV |
| CMRR Common-mode rejection ratio   | $V_{IC} = V_{ICRmin}$  | 65                | 80       |          | dB   |
| $k_{SVR}$ Supply-voltage rejection ratio ( $\Delta V_{CC} \pm / \Delta V_{IO}$ ) |  | 65                | 100      |          | dB   |
| $I_O$ Output current   | $V_{CC} = 15\text{ V}, V_{ID} = 1\text{ V}, V_O = 0$                               | -20               | -30      | -60      | mA   |
|  | $V_{CC} = 15\text{ V}, V_{ID} = -1\text{ V}, V_O = 15\text{ V}$                    | 10                | 20       |          |      |
|  | $V_{ID} = 1\text{ V}, V_O = 200\text{ mV}$   | 12                | 30       |          |      |
| $I_{OS}$ Short-circuit output current  | $V_{CC}$ at 5 V, GND at -5 V, $V_O = 0$  |                   | $\pm 40$ | $\pm 60$ | mA   |
| $I_{CC}$ Supply current (four amplifiers)  | $V_O = 2.5 V_{CC},$ No load  |                   | 0.7      | 1.2      | mA   |
|  | $V_{CC} = \text{MAX}, V_O = 0.5 V_{CC},$ No load                                   |                   | 1.1      | 3        |      |

† All characteristics are measured under open-loop conditions with zero common-mode input voltage unless otherwise specified. MAX  $V_{CC}$  for testing purposes is 30 V.





## IMPORTANT NOTICE

Texas Instruments and its subsidiaries (TI) reserve the right to make changes to their products or to discontinue any product or service without notice, and advise customers to obtain the latest version of relevant information to verify, before placing orders, that information being relied on is current and complete. All products are sold subject to the terms and conditions of sale supplied at the time of order acknowledgement, including those pertaining to warranty, patent infringement, and limitation of liability.

TI warrants performance of its semiconductor products to the specifications applicable at the time of sale in accordance with TI's standard warranty. Testing and other quality control techniques are utilized to the extent TI deems necessary to support this warranty. Specific testing of all parameters of each device is not necessarily performed, except those mandated by government requirements.

CERTAIN APPLICATIONS USING SEMICONDUCTOR PRODUCTS MAY INVOLVE POTENTIAL RISKS OF DEATH, PERSONAL INJURY, OR SEVERE PROPERTY OR ENVIRONMENTAL DAMAGE ("CRITICAL APPLICATIONS"). TI SEMICONDUCTOR PRODUCTS ARE NOT DESIGNED, AUTHORIZED, OR WARRANTED TO BE SUITABLE FOR USE IN LIFE-SUPPORT DEVICES OR SYSTEMS OR OTHER CRITICAL APPLICATIONS. INCLUSION OF TI PRODUCTS IN SUCH APPLICATIONS IS UNDERSTOOD TO BE FULLY AT THE CUSTOMER'S RISK.

In order to minimize risks associated with the customer's applications, adequate design and operating safeguards must be provided by the customer to minimize inherent or procedural hazards.

TI assumes no liability for applications assistance or customer product design. TI does not warrant or represent that any license, either express or implied, is granted under any patent right, copyright, mask work right, or other intellectual property right of TI covering or relating to any combination, machine, or process in which such semiconductor products or services might be or are used. TI's publication of information regarding any third party's products or services does not constitute TI's approval, warranty or endorsement thereof.