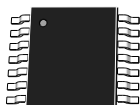


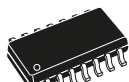
## Low-power quad operational amplifiers



QFN16 3x3



TSSOP14



SO14

### Features

- Wide gain bandwidth: 1.3 MHz
- Input common mode voltage range includes ground
- Large voltage gain: 100 dB
- Very low supply current/amplifier: 375  $\mu$ A
- Low input bias current: 20 nA
- Low input voltage: 3 mV max.
- Low input offset current: 2 nA
- Wide power supply range:
  - Single supply: 3 V to 30 V
  - Dual supplies:  $\pm 1.5$  V to  $\pm 15$  V

### Related products

- See [TSB572](#) and [TSB611](#), 36 V newer technology devices, which have enhanced accuracy and ESD rating, reduced power consumption, and automotive grade qualification
- See [LM2902](#) and [LM2902W](#) for automotive grade applications

### Description

The [LM124](#), [LM224x](#) and [LM324x](#) consist of four independent, high gain operational amplifiers with frequency compensation implemented internally. They operate from a single power supply over a wide range of voltages.

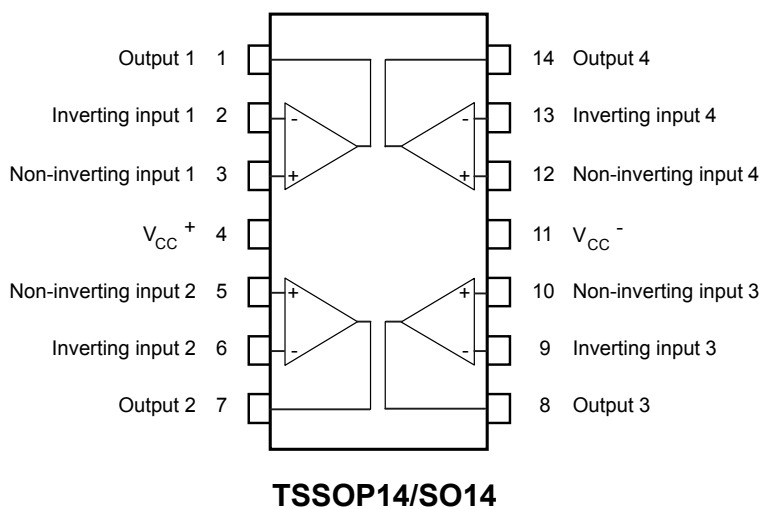
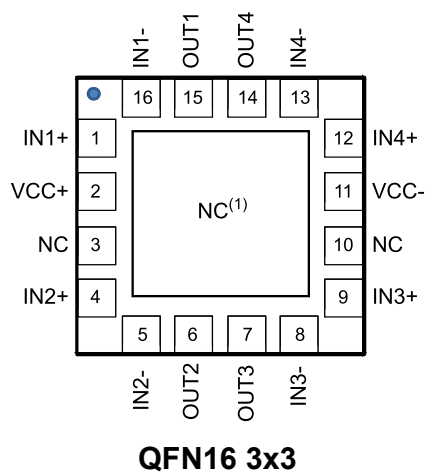
Operation from split power supplies is also possible and the low-power supply current drain is independent of the magnitude of the power supply voltage.

| Product status link                   |                                                         |
|---------------------------------------|---------------------------------------------------------|
| <a href="#">LM124, LM224x, LM324x</a> |                                                         |
| Product reference                     | Part numbers                                            |
| LM124 <sup>(1)</sup>                  | LM124                                                   |
| LM224x                                | LM224, LM224A <sup>(2)</sup> ,<br>LM224W <sup>(3)</sup> |
| LM324x                                | LM324, LM324A,<br>LM324W <sup>(3)</sup>                 |

1. Prefixes: LM1, LM2, and LM3 refer to temperature range
2. Suffix A refers to enhanced  $V_{io}$  performance
3. Suffix W refers to enhanced ESD ratings.

## 1 Pin connections and schematic diagram

Figure 1. Pin connections (top view)



1. The exposed pads of the QFN16 3x3 can be connected to VCC- or left floating

The circuit diagram illustrates a two-stage CMOS operational amplifier. The first stage is a differential pair consisting of NMOS transistors Q1 and Q2, and PMOS transistors Q3 and Q4. The inputs are labeled 'Inverting input' and 'Non-inverting input'. The differential pair is biased by a 6  $\mu\text{A}$  current source. The second stage is a common-source amplifier using NMOS transistor Q10 and PMOS transistor Q11. The output of the first stage is connected to the gate of Q10. The second stage is biased by a 4  $\mu\text{A}$  current source and a compensation capacitor  $C_C$ . The final output stage is a Wilson current source, which is a three-transistor circuit (Q5, Q6, Q7) that provides a high output impedance. It is biased by a 100  $\mu\text{A}$  current source. The output of the Wilson current source is connected to the output node, which is also connected to a load resistor  $R_{sc}$  and a 50  $\mu\text{A}$  current source. The output is labeled 'Output'. The circuit is powered by  $V_{CC}$  and GND.

## 2 Absolute maximum ratings and operating conditions

**Table 1. Absolute maximum ratings**

| Symbol     | Parameter                                             |                     | Value                    | Unit                 |
|------------|-------------------------------------------------------|---------------------|--------------------------|----------------------|
| $V_{CC}$   | Supply voltage                                        |                     | $\pm 16$ or 32           | V                    |
| $V_i$      | Input voltage<br>LM224A, LM324A, LM224W, LM324W       |                     | $-0.3$ to $V_{CC} + 0.3$ |                      |
|            | Input voltage<br>LM124, LM224, LM324                  |                     | $-0.3$ to 32             |                      |
| $V_{id}$   | Differential input voltage <sup>(1)</sup>             |                     | 32                       |                      |
| $P_{tot}$  | Power dissipation: D suffix                           |                     | 400                      | mW                   |
|            | Output short-circuit duration <sup>(2)</sup>          |                     | Infinite                 |                      |
| $I_{in}$   | Input current <sup>(3)</sup>                          |                     | 50                       | mA                   |
| $T_{stg}$  | Storage temperature range                             |                     | $-65$ to $150$           | $^{\circ}\text{C}$   |
| $T_j$      | Maximum junction temperature                          |                     | 150                      |                      |
| $R_{thja}$ | Thermal resistance junction to ambient <sup>(4)</sup> | QFN16 3x3           | 45                       | $^{\circ}\text{C/W}$ |
|            |                                                       | TSSOP14             | 100                      |                      |
|            |                                                       | SO14                | 103                      |                      |
| $R_{thjc}$ | Thermal resistance junction to case                   | QFN16 3x3           | 14                       |                      |
|            |                                                       | TSSOP14             | 32                       |                      |
|            |                                                       | SO14                | 31                       |                      |
| ESD        | HBM: human body model <sup>(5)</sup>                  | LM224A, LM324A      | 800                      | V                    |
|            |                                                       | LM224W, LM324W      | 700                      |                      |
|            |                                                       | LM124, LM224, LM324 | 250                      |                      |
|            | MM: machine model <sup>(6)</sup>                      |                     | 100                      |                      |
|            | CDM: charged device model                             |                     | 1500                     |                      |

- Neither of the input voltages must exceed the magnitude of ( $V_{CC}^{+}$ ) or ( $V_{CC}^{-}$ ).
- Short-circuits from the output to  $V_{CC}$  can cause excessive heating if  $V_{CC} > 15$  V. The maximum output current is approximately 40 mA independent of the magnitude of  $V_{CC}$ . Destructive dissipation can result from simultaneous short-circuits on all amplifiers.
- This input current only exists when the voltage at any of the input leads is driven negative. It is due to the collector-base junction of the input PNP transistor becoming forward biased and thereby acting as an input diode clamp. In addition to this diode action, there is also an NPN parasitic action on the IC chip. This transistor action can cause the output voltages of the op amps to go to the  $V_{CC}$  voltage level (or to ground for a large overdrive) for the time during which an input is driven negative. This is not destructive and normal output starts up again for input voltages higher than  $-0.3$  V.
- Short-circuits can cause excessive heating. Destructive dissipation can result from simultaneous short-circuits on all amplifiers. These are typical values given for a single layer board (except for TSSOP which is a two-layer board).
- Human body model: 100 pF discharged through a 1.5 k $\Omega$  resistor between two pins of the device, done for all couples of pin combinations with other pins floating.
- Machine model: a 200 pF cap is charged to the specified voltage, then discharged directly between two pins of the device with no external series resistor (internal resistor < 5  $\Omega$ ), done for all couples of pin combinations with other pins floating.

**Table 2. Operating conditions**

| Symbol     | Parameter                                                                 |               | Value                 | Unit               |
|------------|---------------------------------------------------------------------------|---------------|-----------------------|--------------------|
| $V_{CC}$   | Supply voltage                                                            | Single supply | 3 to 30               | V                  |
|            |                                                                           | Dual supply   | $\pm 1.5$ to $\pm 15$ |                    |
| $V_{ICM}$  | Common-mode input voltage range<br>$T_{amb} = 25\text{ }^{\circ}\text{C}$ |               | 0 to $V_{CC} - 1.5$   |                    |
|            | Common-mode input voltage range<br>$T_{min.} \leq T_{amb} \leq T_{max.}$  |               | 0 to $V_{CC} - 2$     |                    |
| $T_{Oper}$ | Operating temperature range                                               | LM124         | -55 to 125            | $^{\circ}\text{C}$ |
|            |                                                                           | LM224         | -40 to 105            |                    |
|            |                                                                           | LM324         | 0 to 70               |                    |

### 3 Electrical characteristics

**Table 3.**  $V_{CC+} = 5\text{ V}$ ,  $V_{CC-} = \text{ground}$ ,  $V_O = 1.4\text{ V}$ ,  $T_{\text{amb}} = 25\text{ }^{\circ}\text{C}$  (unless otherwise specified)

| Symbol                                                     | Parameter                                                                                                      |                                                                                 |       | Min. | Typ. | Max. | Unit |
|------------------------------------------------------------|----------------------------------------------------------------------------------------------------------------|---------------------------------------------------------------------------------|-------|------|------|------|------|
| V <sub>io</sub><br>LM224A,<br>LM324A,<br>LM224W,<br>LM324W |                                                                                                                | T <sub>amb</sub> = 25 °C                                                        |       |      | 2    | 3    |      |
|                                                            |                                                                                                                | T <sub>min</sub> ≤ T <sub>amb</sub> ≤ T <sub>max</sub>                          |       |      |      | 5    |      |
| V <sub>io</sub><br>LM124,<br>LM224,<br>LM324               | Input offset voltage <sup>(1)</sup>                                                                            | T <sub>amb</sub> = 25 °C                                                        | LM124 |      | 2    | 5    | mV   |
|                                                            |                                                                                                                |                                                                                 | LM224 |      |      |      |      |
|                                                            |                                                                                                                |                                                                                 | LM324 |      | 2    | 7    |      |
|                                                            |                                                                                                                | T <sub>min</sub> ≤ T <sub>amb</sub> ≤ T <sub>max</sub>                          | LM124 |      |      | 7    |      |
|                                                            |                                                                                                                |                                                                                 | LM224 |      |      |      |      |
|                                                            |                                                                                                                |                                                                                 | LM324 |      |      |      |      |
| I <sub>io</sub>                                            | Input offset current                                                                                           | T <sub>amb</sub> = 25 °C                                                        |       |      | 2    | 20   | nA   |
|                                                            |                                                                                                                | T <sub>min</sub> ≤ T <sub>amb</sub> ≤ T <sub>max</sub>                          |       |      |      | 40   |      |
| I <sub>ib</sub>                                            | Input bias current <sup>(2)</sup>                                                                              | T <sub>amb</sub> = 25 °C                                                        |       |      | 20   | 100  |      |
|                                                            |                                                                                                                | T <sub>min</sub> ≤ T <sub>amb</sub> ≤ T <sub>max</sub>                          |       |      |      | 200  |      |
| A <sub>vd</sub>                                            | Large signal voltage gain, V <sub>CC</sub> += 15 V,<br>R <sub>L</sub> = 2 kΩ, V <sub>o</sub> = 1.4 V to 11.4 V | T <sub>amb</sub> = 25 °C                                                        |       | 50   | 100  |      | V/mV |
|                                                            |                                                                                                                | T <sub>min</sub> ≤ T <sub>amb</sub> ≤ T <sub>max</sub>                          |       | 25   |      |      |      |
| SVR                                                        | Supply voltage rejection ratio,<br>R <sub>s</sub> ≤ 10 kΩ,<br>V <sub>CC</sub> += 5 V to 30 V                   | T <sub>amb</sub> = 25 °C                                                        |       | 65   | 110  |      | dB   |
|                                                            |                                                                                                                | T <sub>min</sub> ≤ T <sub>amb</sub> ≤ T <sub>max</sub>                          |       | 65   |      |      |      |
| I <sub>CC</sub>                                            | Supply current, all amps, no load                                                                              | T <sub>amb</sub> = 25 °C, V <sub>CC</sub> = 5V                                  |       |      | 0.7  | 1.2  | mA   |
|                                                            |                                                                                                                | T <sub>amb</sub> = 25 °C, V <sub>CC</sub> = 30 V                                |       |      | 1.5  | 3    |      |
|                                                            |                                                                                                                | T <sub>min</sub> ≤ T <sub>amb</sub> ≤ T <sub>max</sub> , V <sub>CC</sub> = 5 V  |       |      | 0.8  | 1.2  |      |
|                                                            |                                                                                                                | T <sub>min</sub> ≤ T <sub>amb</sub> ≤ T <sub>max</sub> , V <sub>CC</sub> = 30 V |       |      | 1.5  | 3    |      |
| V <sub>icm</sub>                                           | Input common mode voltage range <sup>(3)</sup>                                                                 | V <sub>CC</sub> = 30 V, T <sub>amb</sub> = 25 °C                                |       | 0    |      | 28.5 | V    |
|                                                            |                                                                                                                | V <sub>CC</sub> = 30 V, T <sub>min</sub> ≤ T <sub>amb</sub> ≤ T <sub>max</sub>  |       | 0    |      | 28   |      |
| CMR                                                        | Common mode rejection ratio,<br>R <sub>s</sub> ≤ 10 kΩ                                                         | T <sub>amb</sub> = 25 °C                                                        |       | 70   | 80   |      | dB   |
|                                                            |                                                                                                                | T <sub>min</sub> ≤ T <sub>amb</sub> ≤ T <sub>max</sub>                          |       | 60   |      |      |      |
| I <sub>source</sub>                                        | Output current source, V <sub>id</sub> = 1 V                                                                   | V <sub>CC</sub> = 15 V, V <sub>o</sub> = 2 V                                    |       | 20   | 40   | 70   | mA   |
| I <sub>sink</sub>                                          | Output sink current, V <sub>id</sub> = -1 V                                                                    | V <sub>CC</sub> = 15 V, V <sub>o</sub> = 2 V                                    |       | 10   | 20   |      |      |
|                                                            |                                                                                                                | V <sub>CC</sub> = 15 V, V <sub>o</sub> = 0.2 V                                  |       | 12   | 50   |      | μA   |

| Symbol          | Parameter                                                                     |                                                                                                                                                 |  | Min. | Typ.  | Max. | Unit                           |
|-----------------|-------------------------------------------------------------------------------|-------------------------------------------------------------------------------------------------------------------------------------------------|--|------|-------|------|--------------------------------|
| $V_{OH}$        | High level output voltage, $V_{CC} = 30\text{ V}$ , $R_L = 2\text{ k}\Omega$  | $T_{amb} = 25\text{ }^{\circ}\text{C}$                                                                                                          |  | 26   | 27    |      | V                              |
|                 |                                                                               | $T_{min} \leq T_{amb} \leq T_{max}$                                                                                                             |  | 26   |       |      |                                |
|                 | High level output voltage, $V_{CC} = 30\text{ V}$ , $R_L = 10\text{ k}\Omega$ | $T_{amb} = 25\text{ }^{\circ}\text{C}$                                                                                                          |  | 27   | 28    |      |                                |
|                 |                                                                               | $T_{min} \leq T_{amb} \leq T_{max}$                                                                                                             |  | 27   |       |      |                                |
|                 | High level output voltage, $V_{CC} = 5\text{ V}$ , $R_L = 2\text{ k}\Omega$   | $T_{amb} = 25\text{ }^{\circ}\text{C}$                                                                                                          |  | 3.5  |       |      |                                |
|                 |                                                                               | $T_{min} \leq T_{amb} \leq T_{max}$                                                                                                             |  | 3    |       |      |                                |
| $V_{OL}$        | Low level output voltage, $R_L = 10\text{ k}\Omega$                           | $T_{amb} = 25\text{ }^{\circ}\text{C}$                                                                                                          |  |      | 5     | 20   | mV                             |
|                 |                                                                               | $T_{min} \leq T_{amb} \leq T_{max}$                                                                                                             |  |      |       | 20   |                                |
| SR              | Slew rate                                                                     | $V_{CC} = 15\text{ V}$ , $V_i = 0.5\text{ to }3\text{ V}$ , $R_L = 2\text{ k}\Omega$ , $C_L = 100\text{ pF}$ , unity gain                       |  |      | 0.4   |      | V/ $\mu\text{s}$               |
| GBP             | Gain bandwidth product                                                        | $V_{CC} = 30\text{ V}$ , $f = 100\text{ kHz}$ , $V_{in} = 10\text{ mV}$ , $R_L = 2\text{ k}\Omega$ , $C_L = 100\text{ pF}$                      |  |      | 1.3   |      | MHz                            |
| THD             | Total harmonic distortion                                                     | $f = 1\text{ kHz}$ , $A_v = 20\text{ dB}$ , $R_L = 2\text{ k}\Omega$ , $V_o = 2\text{ V}_{pp}$ , $C_L = 100\text{ pF}$ , $V_{CC} = 30\text{ V}$ |  |      | 0.015 |      | %                              |
| $e_n$           | Equivalent input noise voltage                                                | $f = 1\text{ kHz}$ , $R_s = 100\text{ }\Omega$ , $V_{CC} = 30\text{ V}$                                                                         |  |      | 40    |      | nV/ $\sqrt{\text{Hz}}$         |
| $DV_{io}$       | Input offset voltage drift                                                    |                                                                                                                                                 |  |      | 7     | 30   | $\mu\text{V}/^{\circ}\text{C}$ |
| $DI_{io}$       | Input offset current drift                                                    |                                                                                                                                                 |  |      | 10    | 200  | pA/ $^{\circ}\text{C}$         |
| $V_{o1}/V_{o2}$ | Channel separation <sup>(4)</sup>                                             | $1\text{ kHz} \leq f \leq 20\text{ kHz}$                                                                                                        |  |      | 120   |      | kHz                            |

- $V_o = 1.4\text{ V}$ ,  $R_s = 0\text{ }\Omega$ ,  $5\text{ V} < V_{CC}^{+} < 30\text{ V}$ ,  $0 < V_{ic} < V_{CC}^{+} - 1.5\text{ V}$
- The direction of the input current is out of the IC. This current is essentially constant, independent of the state of the output so there is no load change on the input lines.
- The input common-mode voltage of either input signal voltage should not be allowed to go negative by more than  $0.3\text{ V}$ . The upper end of the common-mode voltage range is  $(V_{CC}^{+}) - 1.5\text{ V}$ , but either or both inputs can go to  $32\text{ V}$  without damage.
- Due to the proximity of external components, ensure that there is no coupling originating from stray capacitance between these external parts. Typically, this can be detected at higher frequencies because this type of capacitance increases.

## 4 Electrical characteristic curves

Figure 4. Input bias current vs. temperature

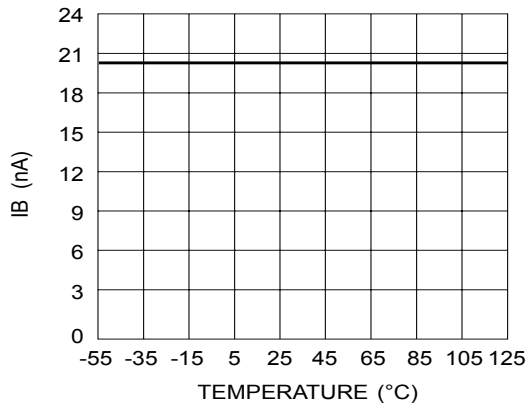


Figure 5. Output current limitation

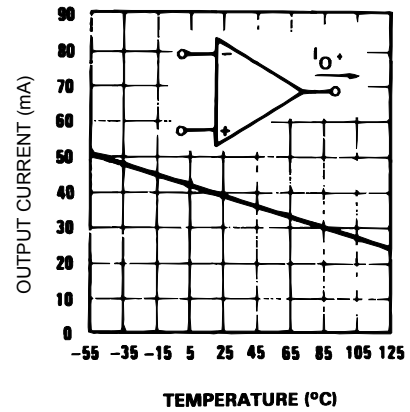


Figure 6. Input voltage range

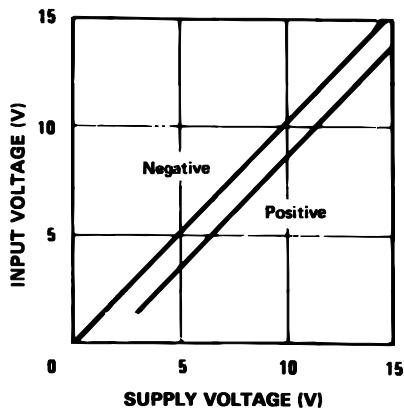


Figure 7. Supply current vs. supply voltage

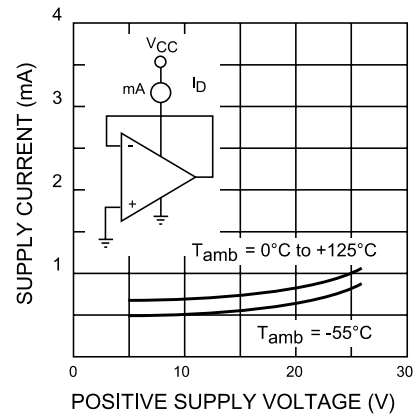


Figure 8. Gain bandwidth product vs. temperature

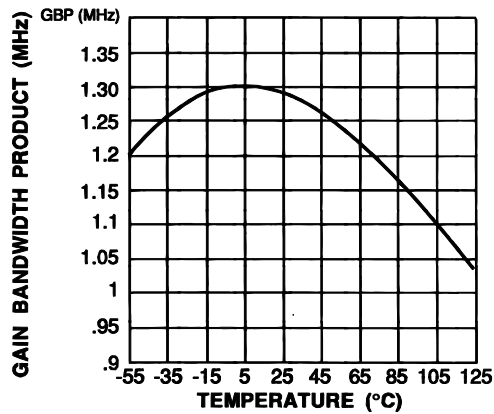


Figure 9. Common-mode rejection ratio

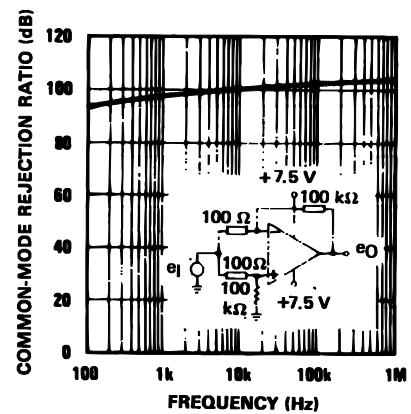




Figure 10. Open loop frequency response

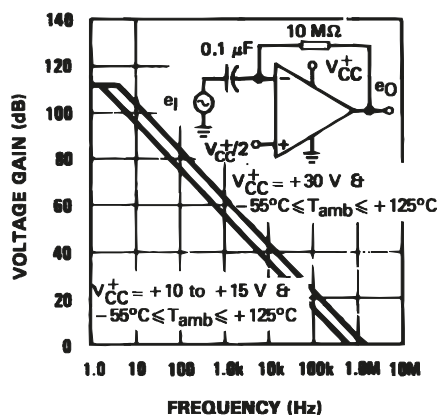


Figure 11. Large signal frequency response

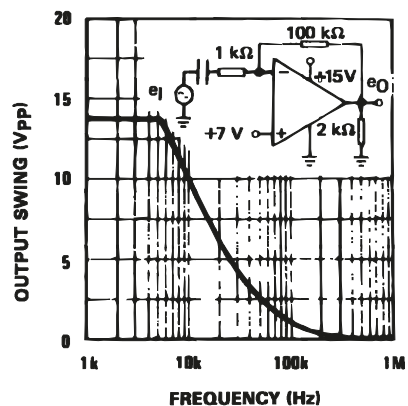


Figure 12. Voltage follower pulse response

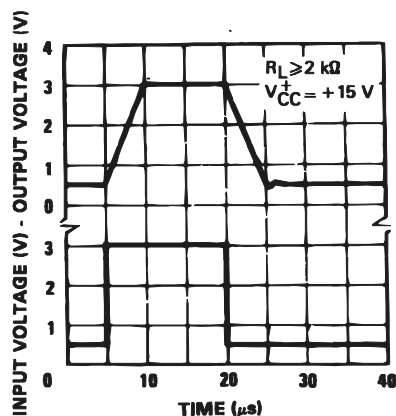


Figure 13. Output characteristics (current sinking)

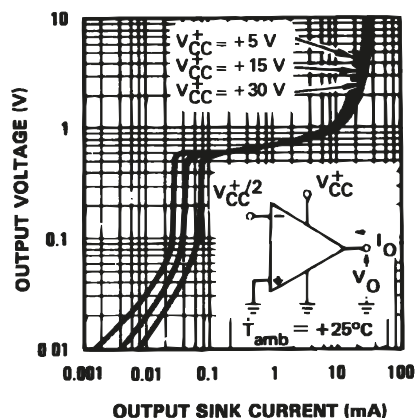


Figure 14. Voltage follower pulse response (small signal)

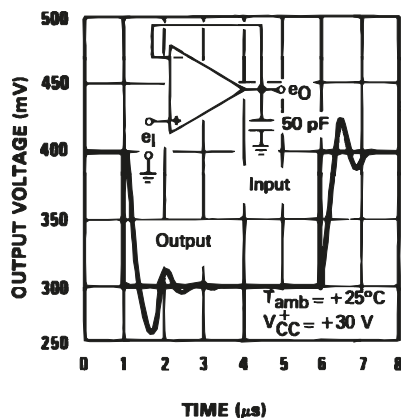


Figure 15. Output characteristics (current sourcing)

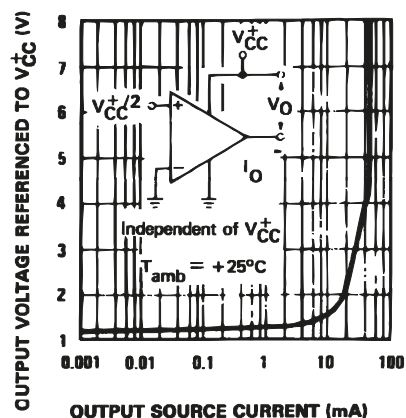


Figure 16. Input current vs. supply voltage

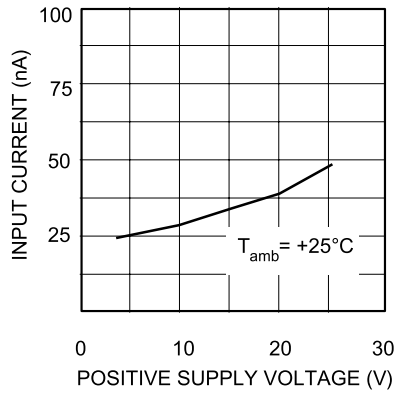


Figure 17. Large signal voltage gain vs. temperature

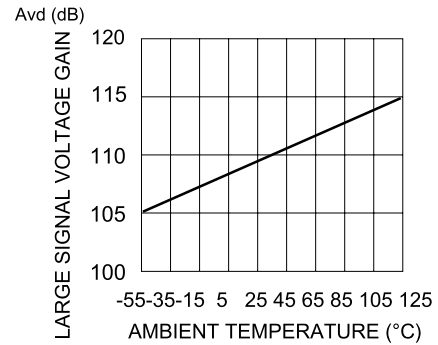


Figure 18. Power supply and common mode rejection ratio vs. temperature

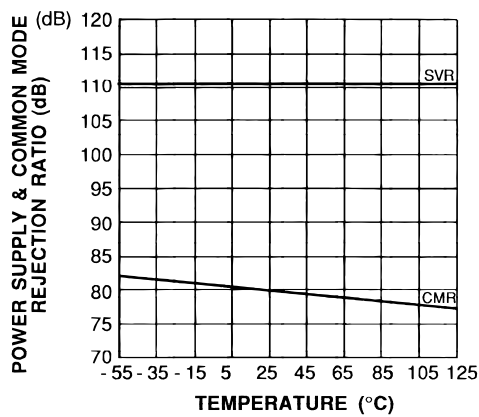
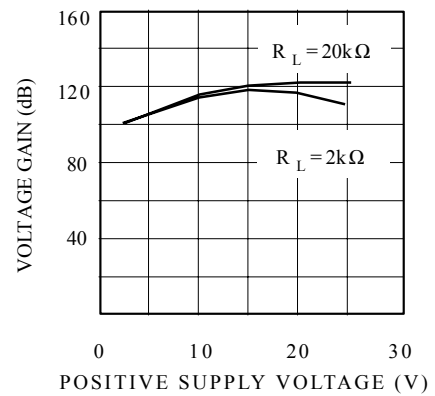


Figure 19. Voltage gain vs. supply voltage



## 5 Typical single-supply applications

Figure 20. AC coupled inverting amplifier

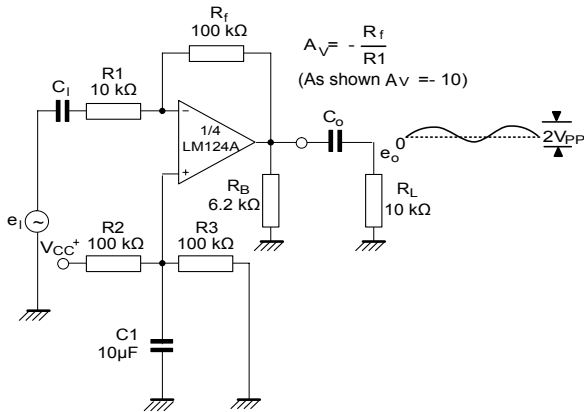


Figure 21. High input Z adjustable gain DC instrumentation amplifier

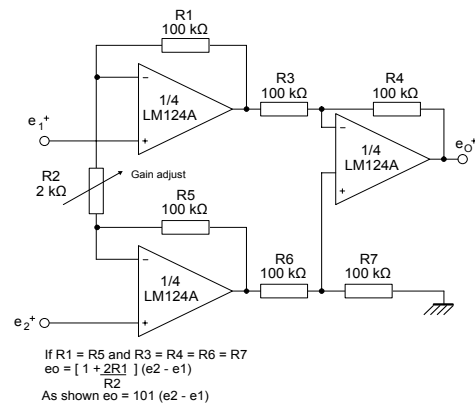


Figure 22. AC coupled non inverting amplifier

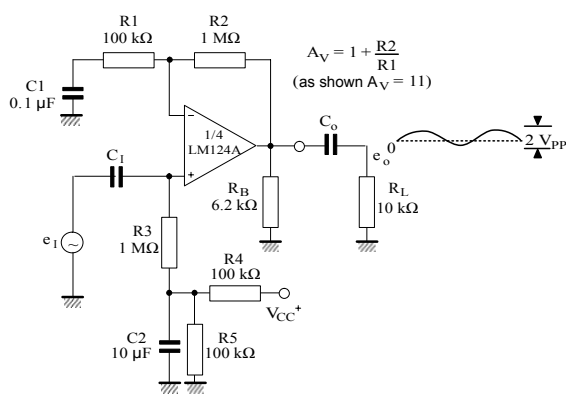


Figure 23. DC summing amplifier

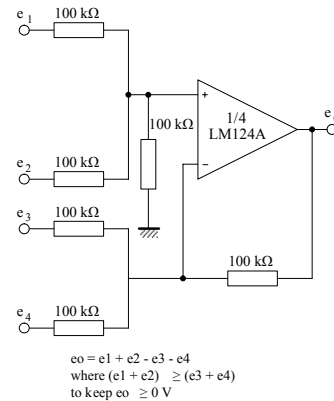


Figure 24. Non-inverting DC gain

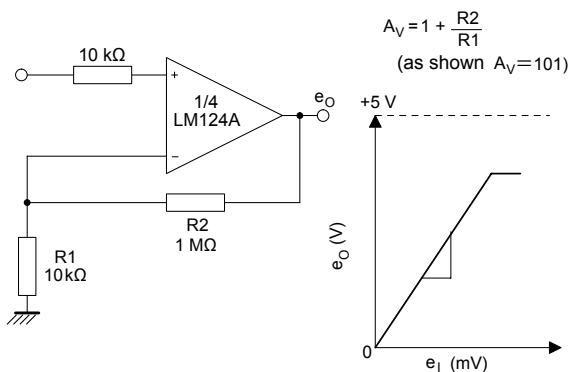
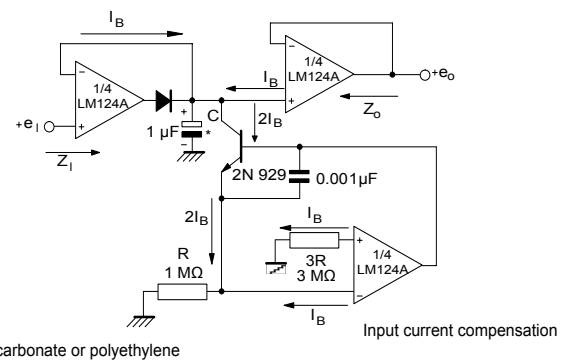
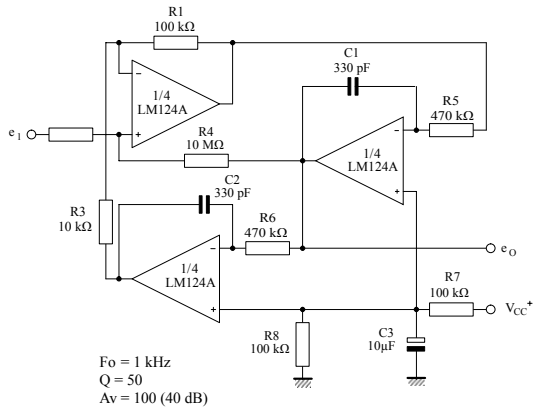


Figure 25. Low drift peak detector

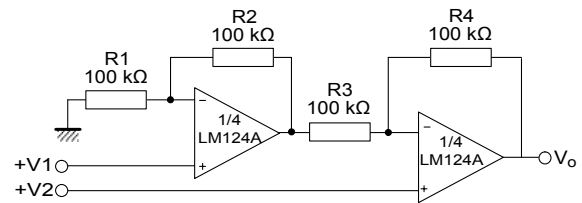


**Figure 26. Active bandpass filter**



**Figure 27. High input Z, DC differential amplifier**

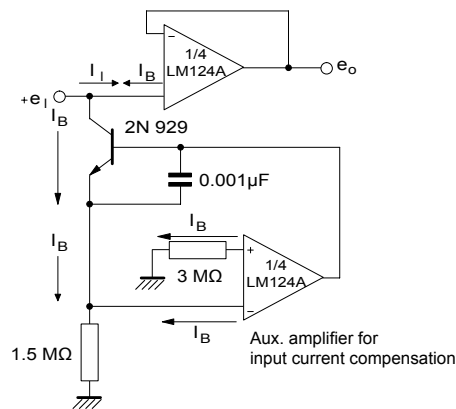
For  $\frac{R_1}{R_2} = \frac{R_4}{R_3}$  CMRR depends on the following resistor ration match



$$V_o = \left(1 + \frac{R_4}{R_3}\right) (V_2 - V_1)$$

As shown  $V_o = 2 * (V_2 - V_1)$

**Figure 28. Using symmetrical amplifiers to reduce input current (general concept)**



## 6 Package information

In order to meet environmental requirements, ST offers these devices in different grades of **ECOPACK** packages, depending on their level of environmental compliance. ECOPACK specifications, grade definitions and product status are available at: [www.st.com](http://www.st.com). ECOPACK is an ST trademark.

### 6.1 QFN16 3x3 package information

Figure 29. QFN16 3x3 package outline

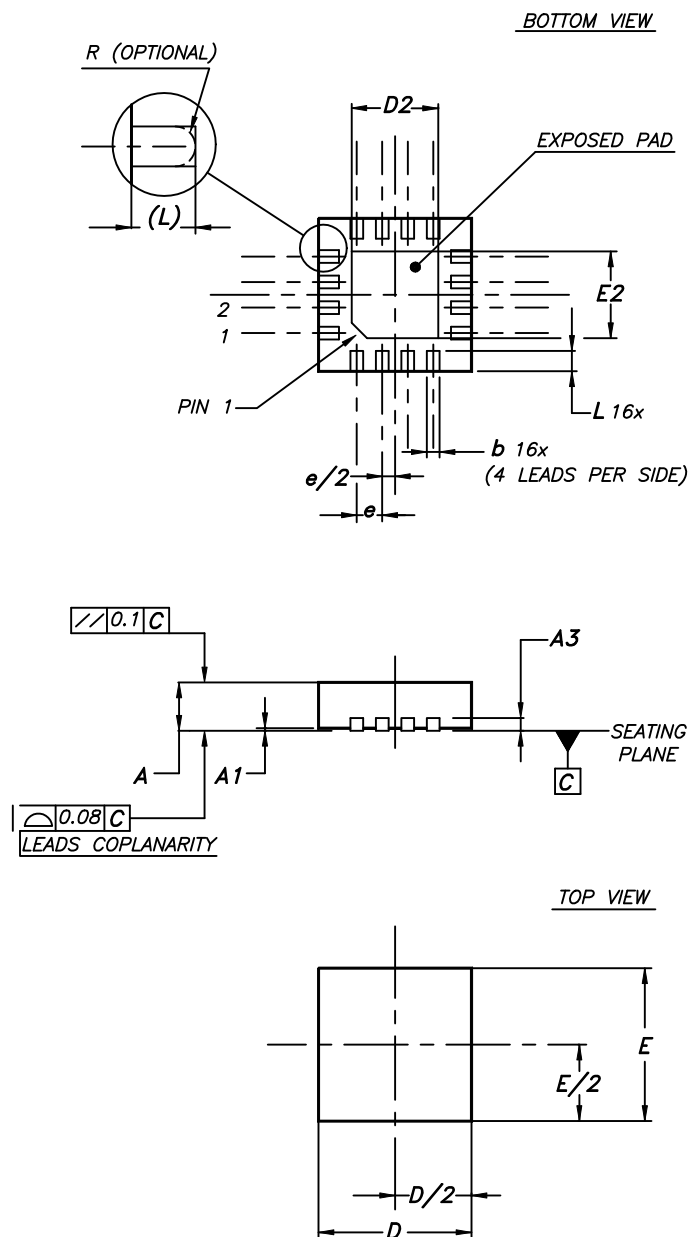
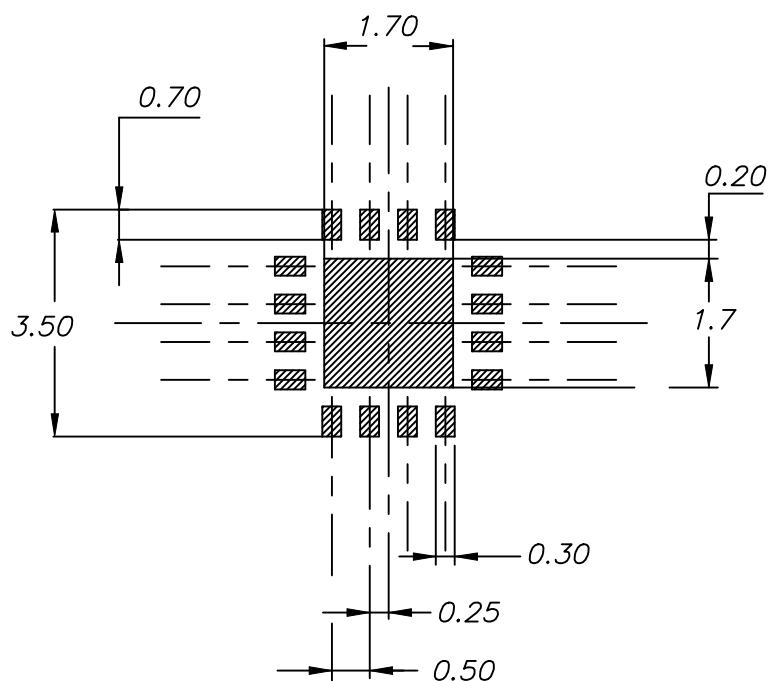


Table 4. QFN16 3x3 mechanical data

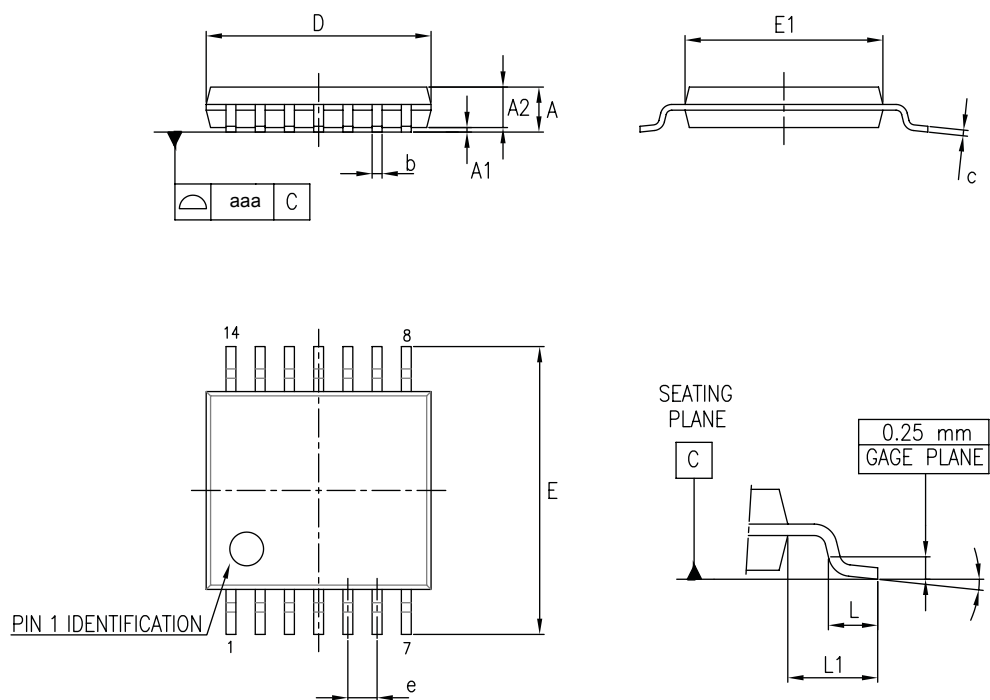
| Ref. | Dimensions  |      |      |        |       |       |
|------|-------------|------|------|--------|-------|-------|
|      | Millimeters |      |      | Inches |       |       |
|      | Min.        | Typ. | Max. | Min.   | Typ.  | Max.  |
| A    | 0.80        | 0.90 | 1.00 | 0.031  | 0.035 | 0.039 |
| A1   | 0           |      | 0.05 | 0      |       | 0.002 |
| A3   |             | 0.20 |      |        | 0.008 |       |
| b    | 0.18        |      | 0.30 | 0.007  |       | 0.012 |
| D    | 2.90        | 3.00 | 3.10 | 0.114  | 0.118 | 0.122 |
| D2   | 1.50        |      | 1.80 | 0.059  |       | 0.071 |
| E    | 2.90        | 3.00 | 3.10 | 0.114  | 0.118 | 0.122 |
| E2   | 1.50        |      | 1.80 | 0.059  |       | 0.071 |
| e    |             | 0.50 |      |        | 0.020 |       |
| L    | 0.30        |      | 0.50 | 0.012  |       | 0.020 |

Figure 30. QFN16 3x3 recommended footprint



## 6.2 TSSOP14 package information

**Figure 31. TSSOP14 package outline**

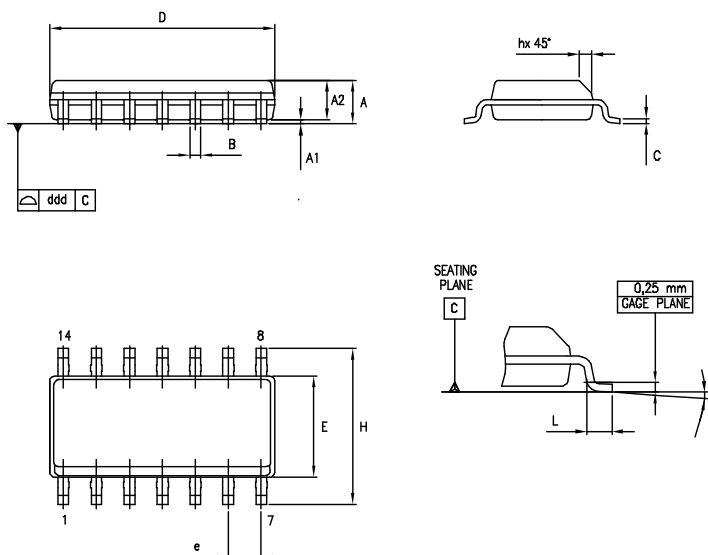


**Table 5. TSSOP14 package mechanical data**

| Ref. | Dimensions  |      |      |        |        |        |
|------|-------------|------|------|--------|--------|--------|
|      | Millimeters |      |      | Inches |        |        |
|      | Min.        | Typ. | Max. | Min.   | Typ.   | Max.   |
| A    |             |      | 1.20 |        |        | 0.047  |
| A1   | 0.05        |      | 0.15 | 0.002  | 0.004  | 0.006  |
| A2   | 0.80        | 1.00 | 1.05 | 0.031  | 0.039  | 0.041  |
| b    | 0.19        |      | 0.30 | 0.007  |        | 0.012  |
| c    | 0.09        |      | 0.20 | 0.004  |        | 0.0089 |
| D    | 4.90        | 5.00 | 5.10 | 0.193  | 0.197  | 0.201  |
| E    | 6.20        | 6.40 | 6.60 | 0.244  | 0.252  | 0.260  |
| E1   | 4.30        | 4.40 | 4.50 | 0.169  | 0.173  | 0.176  |
| e    |             | 0.65 |      |        | 0.0256 |        |
| L    | 0.45        | 0.60 | 0.75 | 0.018  | 0.024  | 0.030  |
| L1   |             | 1.00 |      |        | 0.039  |        |
| k    | 0°          |      | 8°   | 0°     |        | 8°     |
| aaa  |             |      | 0.10 |        |        | 0.004  |

## 6.3 SO14 package information

**Figure 32. SO14 package outline**



**Table 6. SO14 package mechanical data**

| Ref. | Dimensions  |      |      |        |      |       |
|------|-------------|------|------|--------|------|-------|
|      | Millimeters |      |      | Inches |      |       |
|      | Min.        | Typ. | Max. | Min.   | Typ. | Max.  |
|      |             |      | 1.75 |        |      | 0.069 |
| A    | 1.35        |      | 1.75 | 0.05   |      | 0.068 |
| A1   | 0.10        |      | 0.25 | 0.004  |      | 0.009 |
| A2   | 1.10        |      | 1.65 | 0.04   |      | 0.06  |
| B    | 0.33        |      | 0.51 | 0.01   |      | 0.02  |
| C    | 0.19        |      | 0.25 | 0.007  |      | 0.009 |
| D    | 8.55        |      | 8.75 | 0.33   |      | 0.34  |
| E    | 3.80        |      | 4.0  | 0.15   |      | 0.15  |
| e    |             | 1.27 |      |        | 0.05 |       |
| H    | 5.80        |      | 6.20 | 0.22   |      | 0.24  |
| h    | 0.25        |      | 0.50 | 0.009  |      | 0.02  |
| L    | 0.40        |      | 1.27 | 0.015  |      | 0.05  |
| k    | 8° (max.)   |      |      |        |      |       |
| ddd  |             |      | 0.10 |        |      | 0.004 |



## 7 Ordering information

**Table 7. Order codes**

| Order code | Temperature range | ESD (HBM, CDM) | V <sub>io</sub> max. @ 25 °C | Package   | Marking |
|------------|-------------------|----------------|------------------------------|-----------|---------|
| LM124DT    | -55 °C to 125 °C  | 250 V, 1.5 kV  | 5 mV                         | SO14      | 124     |
| LM224ADT   | -40 °C to 105 °C  | 800 V, 1.5 kV  | 3 mV                         |           | TSSOP14 |
| LM224APT   |                   |                |                              |           |         |
| LM224DT    |                   | 250 V, 1.5 kV  | 5 mV                         | SO14      | 224     |
| LM224PT    |                   |                |                              | TSSOP14   |         |
| LM224QT    |                   |                |                              | QFN16 3x3 | K425    |
| LM224WDT   |                   | 700 V, 1.5 kV  | 3 mV                         | SO14      | 224W    |
| LM324ADT   | 800 V, 1.5 kV     | TSSOP14        |                              |           | 324A    |
| LM324APT   |                   |                |                              |           |         |
| LM324AWDT  | 700 V, 1.5 kV     | SO14           |                              | 324AW     |         |
| LM324AWPT  |                   | TSSOP14        |                              |           |         |
| LM324WDT   |                   | SO14           |                              | 324W      |         |
| LM324WPT   |                   | TSSOP14        |                              |           |         |
| LM324DT    | 0 °C to 70 °C     | 250 V, 1.5 kV  | 5 mV                         | SO14      | 324     |
| LM324PT    |                   |                |                              | TSSOP14   |         |
| LM324QT    |                   |                |                              | QFN16 3x3 | K427    |

## Revision history

**Table 8. Document revision history**

| Date        | Revision | Changes                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 |
|-------------|----------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| 1-Mar-2001  | 1        | First release                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           |
| 1-Feb-2005  | 2        | Added explanation of $V_{id}$ and $V_i$ limits in Table 2 on page 4.<br>Updated macromodel.                                                                                                                                                                                                                                                                                                                                                                                                                             |
| 1-Jun-2005  | 3        | ESD protection inserted in Table 2 on page 4.                                                                                                                                                                                                                                                                                                                                                                                                                                                                           |
| 25-Sep-2006 | 4        | Editorial update.                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       |
| 22-Aug-2013 | 5        | Removed DIP package and all information pertaining to it<br>Table 1: Device summary: Removed order codes LM224AN, LM224AD, LM324AN, and LM324AD; updated packaging.<br>Table 2: Absolute maximum ratings: removed N suffix power dissipation data; updated footnotes 5 and 6.<br>Renamed Figure 3, Figure 4, Figure 6, Figure 7, Figure 16, Figure 17, Figure 18, and Figure 19.<br>Updated axes titles of Figure 4, Figure 5, Figure 7, and Figure 17.<br>Removed duplicate figures.<br>Removed Section 5: Macromodels |
| 06-Dec-2013 | 6        | Table 2: Absolute maximum ratings: updated ESD data for HBM and MM.                                                                                                                                                                                                                                                                                                                                                                                                                                                     |
| 10-Jun-2016 | 7        | LM124, LM224, LM324 and LM224W, LM324W datasheets merged with LM224A, LM324A datasheet. The following sections were reworked: Features, Description, Section 1: "Pin connections and schematic diagram", Section 2: "Absolute maximum ratings and operating conditions", and Section 3: "Electrical characteristics". The following sections were added: Related products and Section 7: "Ordering information". Packaged silhouettes, pin connections, and mechanical data were standardized and updated.              |
| 09-Sep-2019 | 8        | Updated cover page, Section 2 Absolute maximum ratings and operating conditions and Table 3. $V_{CC+} = 5\text{ V}$ , $V_{CC-} = \text{ground}$ , $V_o = 1.4\text{ V}$ , $T_{amb} = 25\text{ }^{\circ}\text{C}$ (unless otherwise specified).<br>Updated Figure 2. Schematic diagram (LM224A, LM324A, LM224W, LM324W, one channel) and Figure 3. Schematic diagram (LM124, LM224, LM324, one channel).                                                                                                                  |

## Contents

|          |                                                                |           |
|----------|----------------------------------------------------------------|-----------|
| <b>1</b> | <b>Pin connections and schematic diagram .....</b>             | <b>2</b>  |
| <b>2</b> | <b>Absolute maximum ratings and operating conditions .....</b> | <b>4</b>  |
| <b>3</b> | <b>Electrical characteristics.....</b>                         | <b>6</b>  |
| <b>4</b> | <b>Electrical characteristic curves .....</b>                  | <b>8</b>  |
| <b>5</b> | <b>Typical single-supply applications .....</b>                | <b>11</b> |
| <b>6</b> | <b>Package information.....</b>                                | <b>13</b> |
| 6.1      | QFN16 3x3 package information.....                             | 13        |
| 6.2      | TSSOP14 package information.....                               | 14        |
| 6.3      | SO14 package information.....                                  | 15        |
| <b>7</b> | <b>Ordering information .....</b>                              | <b>17</b> |
|          | <b>Revision history .....</b>                                  | <b>18</b> |

## List of tables

|                 |                                                                                                                                                                  |    |
|-----------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------|----|
| <b>Table 1.</b> | Absolute maximum ratings . . . . .                                                                                                                               | 4  |
| <b>Table 2.</b> | Operating conditions . . . . .                                                                                                                                   | 5  |
| <b>Table 3.</b> | $V_{CC+} = 5\text{ V}$ , $V_{CC-} = \text{ground}$ , $V_O = 1.4\text{ V}$ , $T_{\text{amb}} = 25\text{ }^{\circ}\text{C}$ (unless otherwise specified) . . . . . | 6  |
| <b>Table 4.</b> | QFN16 3x3 mechanical data . . . . .                                                                                                                              | 14 |
| <b>Table 5.</b> | TSSOP14 package mechanical data . . . . .                                                                                                                        | 15 |
| <b>Table 6.</b> | SO14 package mechanical data . . . . .                                                                                                                           | 16 |
| <b>Table 7.</b> | Order codes . . . . .                                                                                                                                            | 17 |
| <b>Table 8.</b> | Document revision history . . . . .                                                                                                                              | 18 |

## List of figures

|                   |                                                                                  |    |
|-------------------|----------------------------------------------------------------------------------|----|
| <b>Figure 1.</b>  | Pin connections (top view) . . . . .                                             | 2  |
| <b>Figure 2.</b>  | Schematic diagram (LM224A, LM324A, LM224W, LM324W, one channel) . . . . .        | 3  |
| <b>Figure 3.</b>  | Schematic diagram (LM124, LM224, LM324, one channel). . . . .                    | 3  |
| <b>Figure 4.</b>  | Input bias current vs. temperature . . . . .                                     | 8  |
| <b>Figure 5.</b>  | Output current limitation . . . . .                                              | 8  |
| <b>Figure 6.</b>  | Input voltage range . . . . .                                                    | 8  |
| <b>Figure 7.</b>  | Supply current vs. supply voltage . . . . .                                      | 8  |
| <b>Figure 8.</b>  | Gain bandwidth product vs. temperature . . . . .                                 | 8  |
| <b>Figure 9.</b>  | Common-mode rejection ratio . . . . .                                            | 8  |
| <b>Figure 10.</b> | Open loop frequency response . . . . .                                           | 9  |
| <b>Figure 11.</b> | Large signal frequency response . . . . .                                        | 9  |
| <b>Figure 12.</b> | Voltage follower pulse response . . . . .                                        | 9  |
| <b>Figure 13.</b> | Output characteristics (current sinking) . . . . .                               | 9  |
| <b>Figure 14.</b> | Voltage follower pulse response (small signal) . . . . .                         | 9  |
| <b>Figure 15.</b> | Output characteristics (current sourcing) . . . . .                              | 9  |
| <b>Figure 16.</b> | Input current vs. supply voltage. . . . .                                        | 10 |
| <b>Figure 17.</b> | Large signal voltage gain vs. temperature . . . . .                              | 10 |
| <b>Figure 18.</b> | Power supply and common mode rejection ratio vs. temperature . . . . .           | 10 |
| <b>Figure 19.</b> | Voltage gain vs. supply voltage . . . . .                                        | 10 |
| <b>Figure 20.</b> | AC coupled inverting amplifier . . . . .                                         | 11 |
| <b>Figure 21.</b> | High input Z adjustable gain DC instrumentation amplifier . . . . .              | 11 |
| <b>Figure 22.</b> | AC coupled non inverting amplifier . . . . .                                     | 11 |
| <b>Figure 23.</b> | DC summing amplifier . . . . .                                                   | 11 |
| <b>Figure 24.</b> | Non-inverting DC gain . . . . .                                                  | 11 |
| <b>Figure 25.</b> | Low drift peak detector . . . . .                                                | 11 |
| <b>Figure 26.</b> | Active bandpass filter . . . . .                                                 | 12 |
| <b>Figure 27.</b> | High input Z, DC differential amplifier. . . . .                                 | 12 |
| <b>Figure 28.</b> | Using symmetrical amplifiers to reduce input current (general concept) . . . . . | 12 |
| <b>Figure 29.</b> | QFN16 3x3 package outline . . . . .                                              | 13 |
| <b>Figure 30.</b> | QFN16 3x3 recommended footprint. . . . .                                         | 14 |
| <b>Figure 31.</b> | TSSOP14 package outline . . . . .                                                | 15 |
| <b>Figure 32.</b> | SO14 package outline . . . . .                                                   | 16 |

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