



# LM124, LM224, LM324

## Low power quad operational amplifiers

### Features

- Wide gain bandwidth: 1.3 MHz
- Input common-mode voltage range includes ground
- Large voltage gain: 100 dB
- Very low supply current per amplifier: 375  $\mu$ A
- Low input bias current: 20 nA
- Low input offset voltage: 5 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

### Description

The LM124, LM224 and LM324 consist of four independent, high gain, internally frequency-compensated operational amplifiers. 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.



**N**  
**DIP14**  
(Plastic package)



**D**  
**SO-14**  
(Plastic micropackage)



**P**  
**TSSOP-14**  
(Thin shrink small outline package)



**Q**  
**QFN16 3x3**  
(Plastic micropackage)

# 1 Pin and schematic diagram

Figure 1. Pin connections (top view)

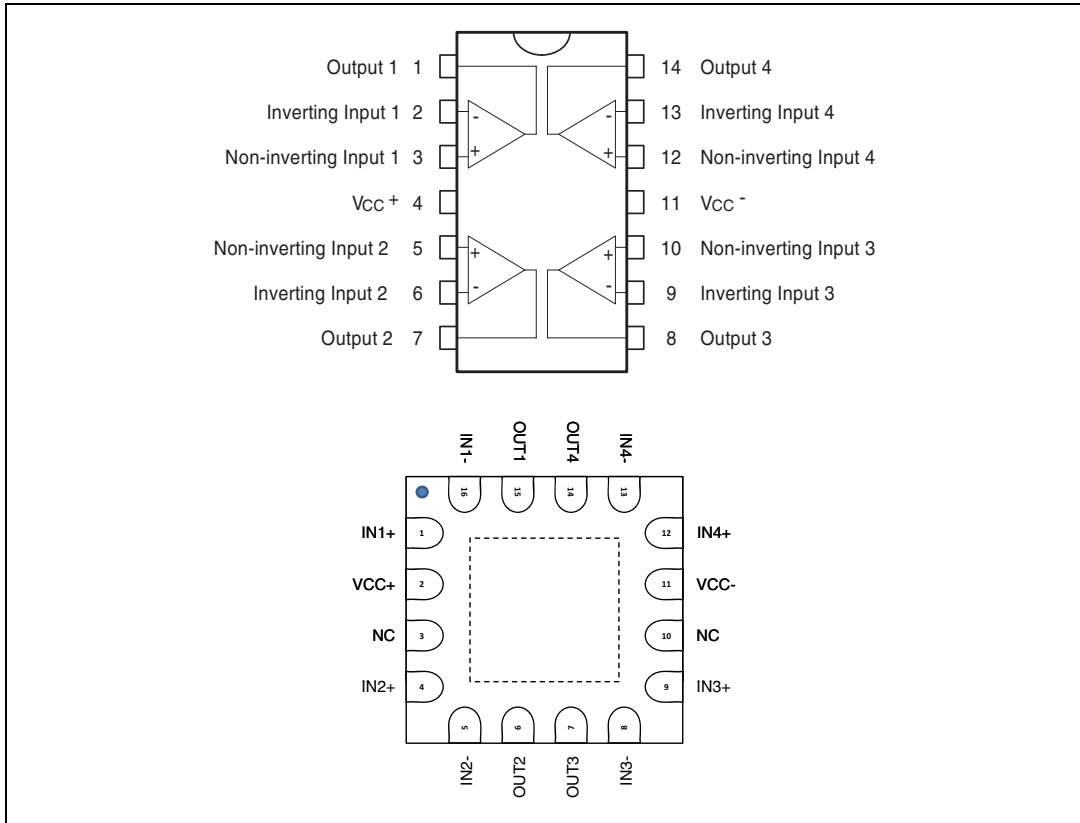
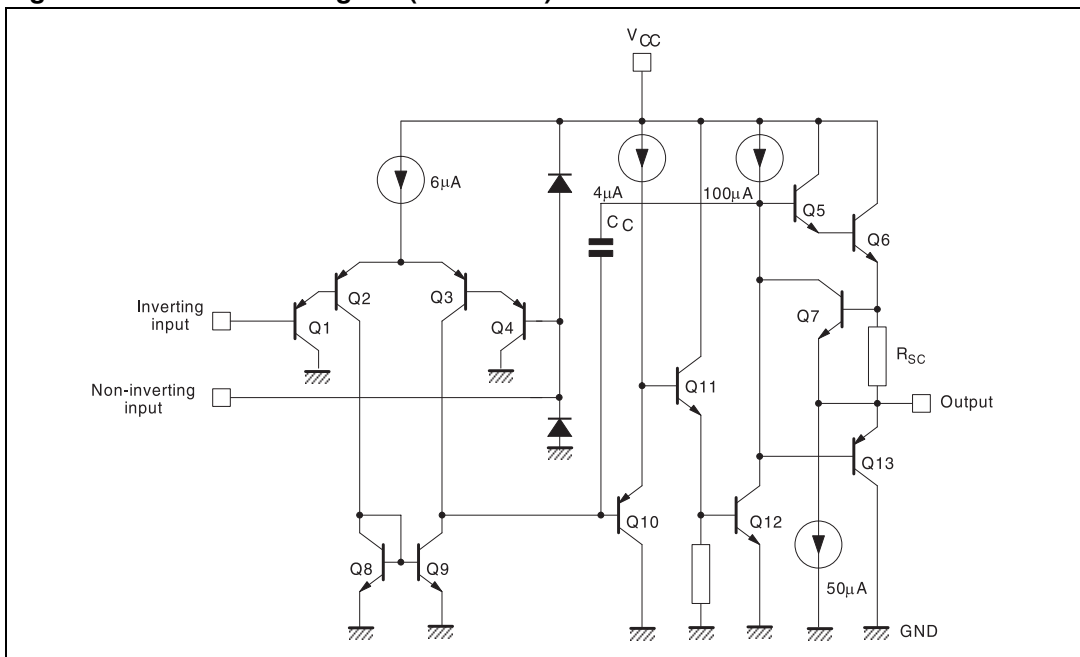


Figure 2. Schematic diagram (1/4 LM124)



## 2 Absolute maximum ratings

**Table 1. Absolute maximum ratings**

| Symbol     | Parameter  | LM124   | LM224       | LM324    | Unit |
|------------|--|---|-------------|----------|------|
| $V_{CC}$   | Supply voltage   | ±16 or 32   |             |          | V    |
| $V_{in}$   | Input voltage <sup>(1)</sup>   | -0.3 to 32  |             |          | V    |
| $V_{id}$   | Differential input voltage <sup>(2)</sup>  | 32  |             |          | V    |
|            | Output short-circuit duration <sup>(3)</sup>   | Infinite  |             |          |      |
| $I_{in}$   | Input current <sup>(4)</sup> : $V_{in}$ driven negative<br>Input current <sup>(5)</sup> : $V_{in}$ driven positive above AMR value | 5 mA in DC or 50 mA in AC (duty cycle = 10%, T=1s)<br>0.4 |             |          | mA   |
| $T_{oper}$ | Operating free-air temperature range   | -55 to +125   | -40 to +105 | 0 to +70 | °C   |
| $T_{stg}$  | Storage temperature range  | -65 to +150   |             |          | °C   |
| $T_j$      | Maximum junction temperature   | 150   |             |          | °C   |
| $R_{thja}$ | Thermal resistance junction to ambient <sup>(6)</sup><br>SO14<br>TSSOP14<br>DIP14<br>QFN16 3x3                                     | 103<br>100<br>83<br>45                                    |             |          | °C/W |
| $R_{thjc}$ | Thermal resistance junction to case<br>SO14<br>TSSOP14<br>DIP14<br>QFN16   | 31<br>32<br>33<br>14                                      |             |          | °C/W |
| ESD        | HBM: human body model <sup>(7)</sup>   | 250   |             |          | V    |
|            | MM: machine model <sup>(8)</sup>   | 150   |             |          |      |
|            | CDM: charged device model <sup>(9)</sup>   | 1500  |             |          |      |

1. Either or both input voltages must not exceed the magnitude of  $V_{CC}^+$  or  $V_{CC}^-$ . All voltage values, except differential voltages are with respect to ground terminal.
2. Differential voltages are the non-inverting input terminal with respect to the inverting input terminal.
3. 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.
4. 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 input diode clamp. In addition to this diode action, there is 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 is restored for input voltages above -0.3 V.
5. The junction base/substrate of the input PNP transistor polarized in reverse must be protected by a resistor in series with the inputs to limit the input current to 400  $\mu$ A max ( $R = (V_{in} - 32 \text{ V})/400 \mu\text{A}$ ).
6. 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, a two-layer board).
7. Human body model, 100 pF discharged through a 1.5 k $\Omega$  resistor into pin of device.
8. Machine model ESD: a 200 pF capacitor is charged to the specified voltage, then discharged directly into the IC with no external series resistor (internal resistor < 5  $\Omega$ ), into pin-to-pin of device.
9. Charged device model: all pins plus package are charged together to the specified voltage and then discharged directly to ground.

### 3 Electrical characteristics

**Table 2.**  $V_{CC}^+ = +5\text{ V}$ ,  $V_{CC}^- = \text{ground}$ ,  $V_o = 1.4\text{ V}$ ,  $T_{\text{amb}} = +25^\circ\text{ C}$  (unless otherwise specified)

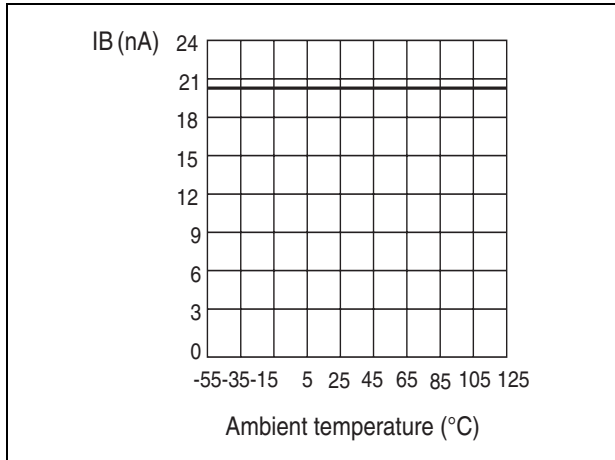
| Symbol              | Parameter   | Min.     | Typ.       | Max.                           | Unit |
|---------------------|---|----------|------------|--------------------------------|------|
| $V_{io}$            | Input offset voltage <sup>(1)</sup><br>$T_{\text{amb}} = +25^\circ\text{ C}$<br>LM124-LM224<br>LM324  |          | 2          | 5<br>7                         | mV   |
|                     | $T_{\text{min}} \leq T_{\text{amb}} \leq T_{\text{max}}$<br>LM124-LM224<br>LM324  |          |            | 7<br>9                         |      |
| $I_{io}$            | Input offset current<br>$T_{\text{amb}} = +25^\circ\text{ C}$<br>$T_{\text{min}} \leq T_{\text{amb}} \leq T_{\text{max}}$   |          | 2          | 30<br>100                      | nA   |
| $I_{ib}$            | Input bias current <sup>(2)</sup><br>$T_{\text{amb}} = +25^\circ\text{ C}$<br>$T_{\text{min}} \leq T_{\text{amb}} \leq T_{\text{max}}$  |          | 20         | 150<br>300                     | nA   |
| $A_{vd}$            | Large signal voltage gain<br>$V_{CC}^+ = +15\text{ V}$ , $R_L = 2\text{ k}\Omega$ , $V_o = 1.4\text{ V to } 11.4\text{ V}$<br>$T_{\text{amb}} = +25^\circ\text{ C}$<br>$T_{\text{min}} \leq T_{\text{amb}} \leq T_{\text{max}}$ | 50<br>25 | 100        |                                | V/mV |
| SVR                 | Supply voltage rejection ratio ( $R_s \leq 10\text{ k}\Omega$ )<br>$V_{CC}^+ = 5\text{ V to } 30\text{ V}$<br>$T_{\text{amb}} = +25^\circ\text{ C}$<br>$T_{\text{min}} \leq T_{\text{amb}} \leq T_{\text{max}}$                 | 65<br>65 | 110        |                                | dB   |
| $I_{CC}$            | Supply current, all Amp, no load<br>$T_{\text{amb}} = +25^\circ\text{ C}$<br>$V_{CC} = +5\text{ V}$<br>$V_{CC} = +30\text{ V}$  |          | 0.7<br>1.5 | 1.2<br>3                       | mA   |
|                     | $T_{\text{min}} \leq T_{\text{amb}} \leq T_{\text{max}}$<br>$V_{CC} = +5\text{ V}$<br>$V_{CC} = +30\text{ V}$   |          | 0.8<br>1.5 | 1.2<br>3                       |      |
| $V_{icm}$           | Input common mode voltage range<br>$V_{CC} = +30\text{ V}$ <sup>(3)</sup><br>$T_{\text{amb}} = +25^\circ\text{ C}$<br>$T_{\text{min}} \leq T_{\text{amb}} \leq T_{\text{max}}$  | 0<br>0   |            | $V_{CC} - 1.5$<br>$V_{CC} - 2$ | V    |
| CMR                 | Common mode rejection ratio ( $R_s \leq 10\text{ k}\Omega$ )<br>$T_{\text{amb}} = +25^\circ\text{ C}$<br>$T_{\text{min}} \leq T_{\text{amb}} \leq T_{\text{max}}$   | 70<br>60 | 80         |                                | dB   |
| $I_{\text{source}}$ | Output current source ( $V_{id} = +1\text{ V}$ )<br>$V_{CC} = +15\text{ V}$ , $V_o = +2\text{ V}$   | 20       | 40         | 70                             | mA   |

**Table 2.**  $V_{CC}^+ = +5\text{ V}$ ,  $V_{CC}^- = \text{ground}$ ,  $V_o = 1.4\text{ V}$ ,  $T_{\text{amb}} = +25^\circ\text{ C}$  (unless otherwise specified) (continued)

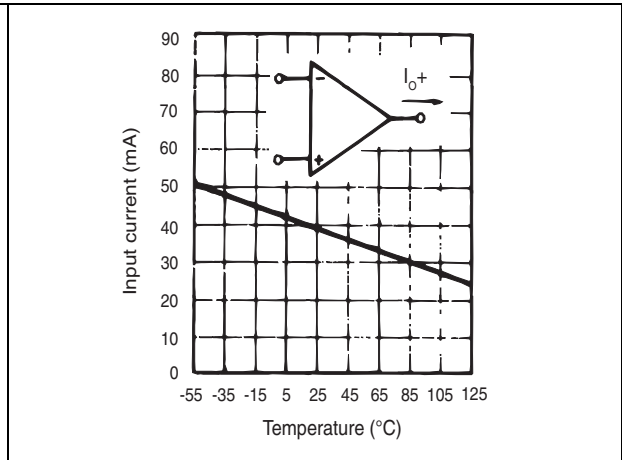
| Symbol                        | Parameter   | Min.                 | Typ.     | Max.     | Unit                                 |
|-------------------------------|---|----------------------|----------|----------|--------------------------------------|
| $I_{\text{sink}}$             | Output sink current ( $V_{\text{id}} = -1\text{ V}$ )   |                      |          |          |                                      |
|                               | $V_{CC} = +15\text{ V}$ , $V_o = +2\text{ V}$<br>$V_{CC} = +15\text{ V}$ , $V_o = +0.2\text{ V}$  | 10<br>12             | 20<br>50 |          | mA<br>$\mu\text{A}$                  |
| $V_{\text{OH}}$               | High level output voltage<br>$V_{CC} = +30\text{ V}$<br>$T_{\text{amb}} = +25^\circ\text{ C}$ , $R_L = 2\text{ k}\Omega$<br>$T_{\text{min}} \leq T_{\text{amb}} \leq T_{\text{max}}$<br>$T_{\text{amb}} = +25^\circ\text{ C}$ , $R_L = 10\text{ k}\Omega$<br>$T_{\text{min}} \leq T_{\text{amb}} \leq T_{\text{max}}$ | 26<br>26<br>27<br>27 | 27<br>28 |          | V                                    |
|                               | $V_{CC} = +5\text{ V}$ , $R_L = 2\text{ k}\Omega$<br>$T_{\text{amb}} = +25^\circ\text{ C}$<br>$T_{\text{min}} \leq T_{\text{amb}} \leq T_{\text{max}}$  | 3.5<br>3             |          |          |                                      |
| $V_{\text{OL}}$               | Low level output voltage ( $R_L = 10\text{ k}\Omega$ )<br>$T_{\text{amb}} = +25^\circ\text{ C}$<br>$T_{\text{min}} \leq T_{\text{amb}} \leq T_{\text{max}}$   |                      | 5        | 20<br>20 | mV                                   |
| SR                            | Slew rate<br>$V_{CC} = 15\text{ V}$ , $V_i = 0.5\text{ to }3\text{ V}$ , $R_L = 2\text{ k}\Omega$ , $C_L = 100\text{ pF}$ ,<br>unity gain   |                      | 0.4      |          | V/ $\mu\text{s}$                     |
| GBP                           | Gain bandwidth product<br>$V_{CC} = 30\text{ V}$ , $f = 100\text{ kHz}$ , $V_{\text{in}} = 10\text{ mV}$ , $R_L = 2\text{ k}\Omega$ ,<br>$C_L = 100\text{ pF}$  |                      | 1.3      |          | MHz                                  |
| THD                           | Total harmonic distortion<br>$f = 1\text{ kHz}$ , $A_v = 20\text{ dB}$ , $R_L = 2\text{ k}\Omega$ , $V_o = 2\text{ V}_{\text{pp}}$ ,<br>$C_L = 100\text{ pF}$ , $V_{CC} = 30\text{ V}$  |                      | 0.015    |          | %                                    |
| $e_n$                         | Equivalent input noise voltage<br>$f = 1\text{ kHz}$ , $R_s = 100\ \Omega$ , $V_{CC} = 30\text{ V}$   |                      | 40       |          | $\frac{\text{nV}}{\sqrt{\text{Hz}}}$ |
| $DV_{\text{io}}$              | Input offset voltage drift  |                      | 7        | 30       | $\mu\text{V}/^\circ\text{C}$         |
| $DI_{\text{io}}$              | Input offset current drift  |                      | 10       | 200      | $\text{pA}/^\circ\text{C}$           |
| $V_{\text{o1}}/V_{\text{o2}}$ | Channel separation <sup>(4)</sup><br>$1\text{ kHz} \leq f \leq 20\text{ kHz}$   |                      | 120      |          | dB                                   |

- $V_o = 1.4\text{ V}$ ,  $R_s = 0\ \Omega$ ,  $5\text{ V} < V_{CC}^+ < 30\text{ V}$ ,  $0 < V_{\text{ic}} < V_{CC}^+ - 1.5\text{ V}$ .
- 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 change in the load 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. 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 V without damage.
- Due to the proximity of the external components, ensure that stray capacitance between these external parts does not cause coupling. Coupling can be detected because this type of capacitance increases at higher frequencies.

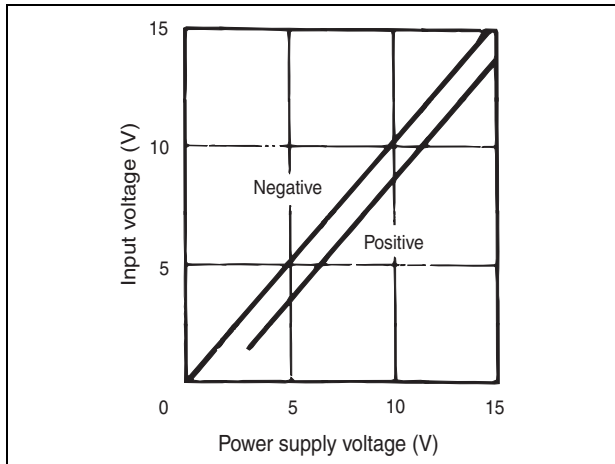
**Figure 3. Input bias current vs. ambient temperature**



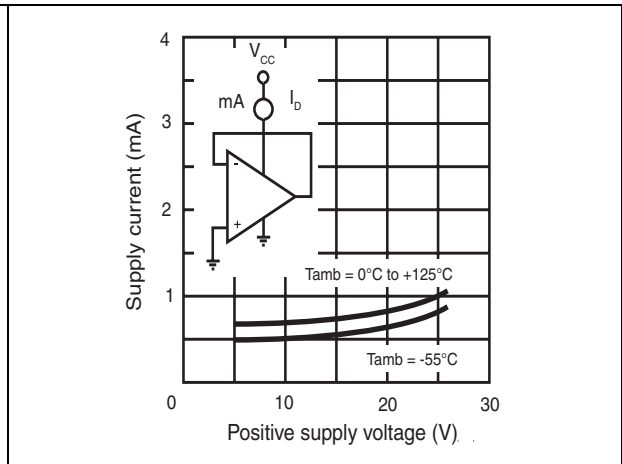
**Figure 4. Current limiting**



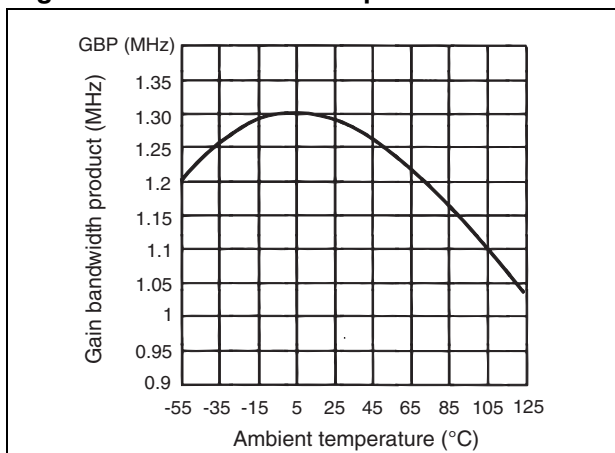
**Figure 5. Input voltage range**



**Figure 6. Supply current**



**Figure 7. Gain bandwidth product**



**Figure 8. Common mode rejection ratio**

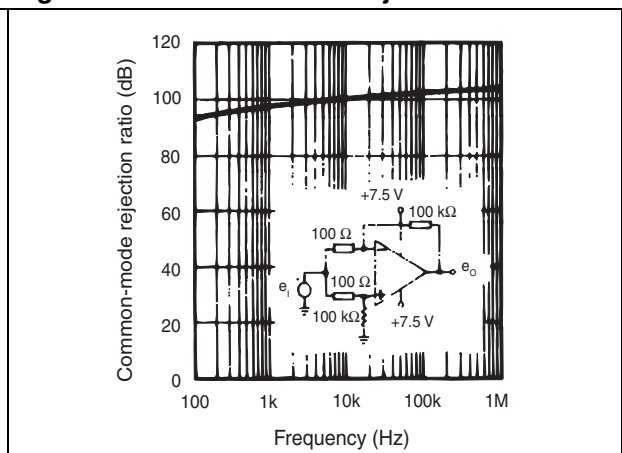


Figure 9. Open loop frequency response

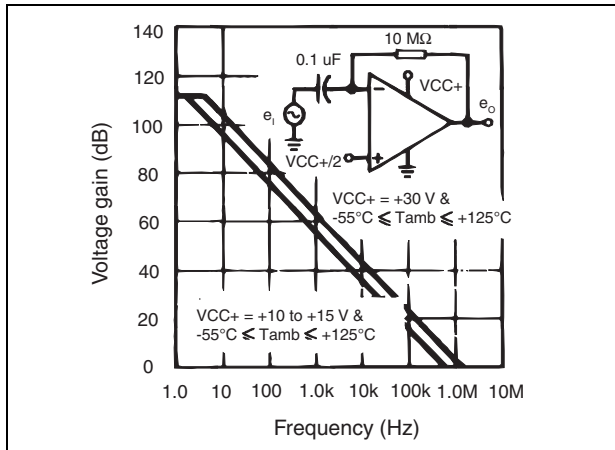


Figure 10. Large signal frequency response

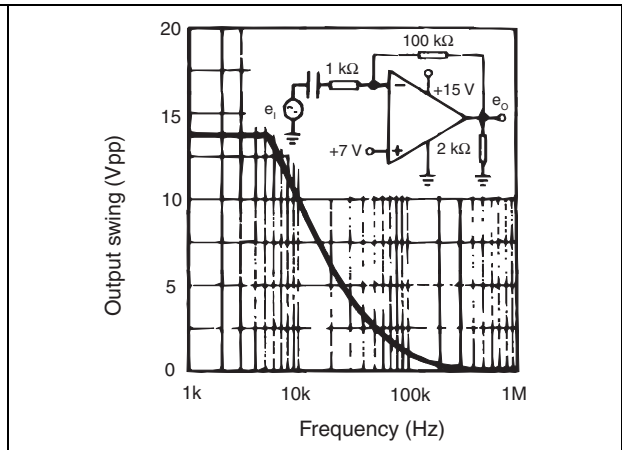


Figure 11. Voltage follower pulse response

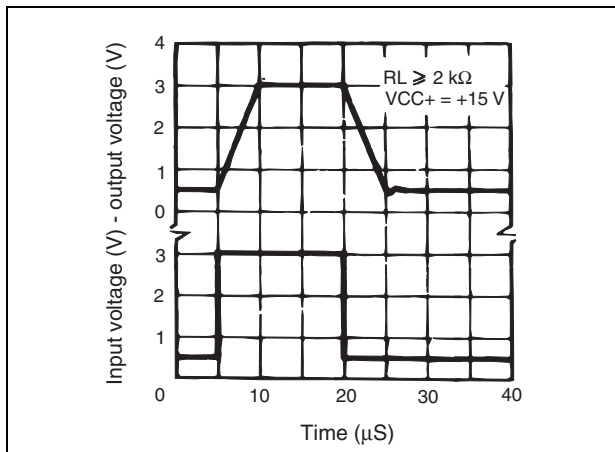


Figure 12. Output characteristics (current sinking)

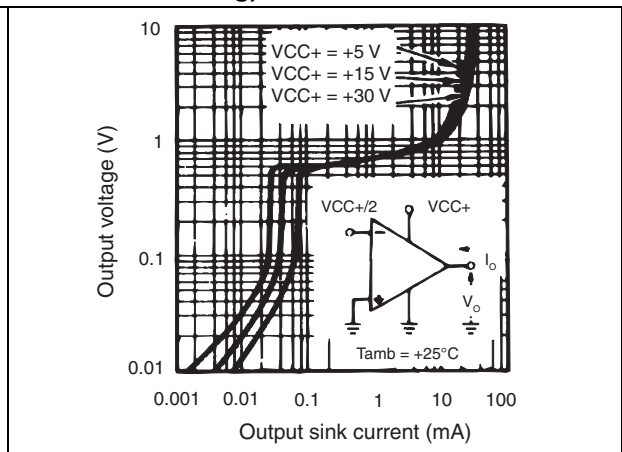


Figure 13. Voltage follower pulse response (small signal)

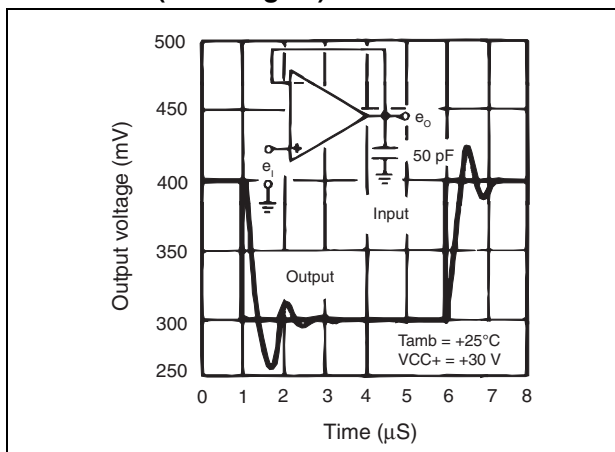


Figure 14. Output characteristics (current sourcing)

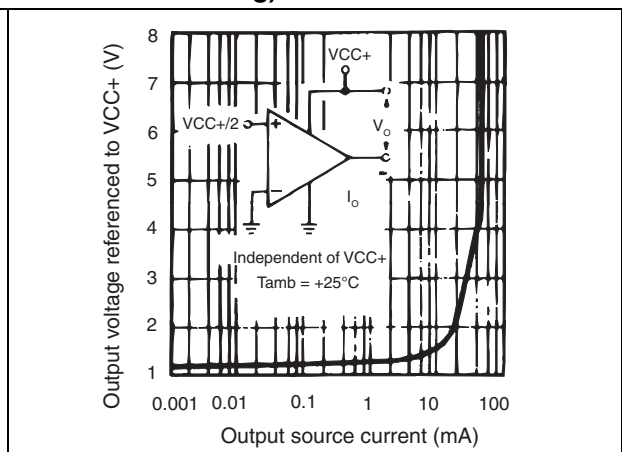


Figure 15. Input current

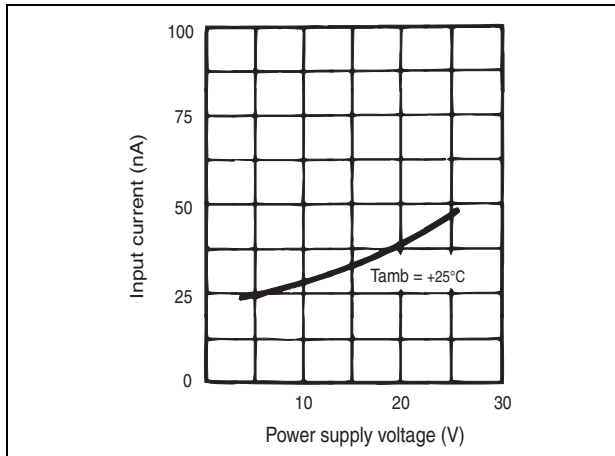


Figure 16. Large signal voltage gain

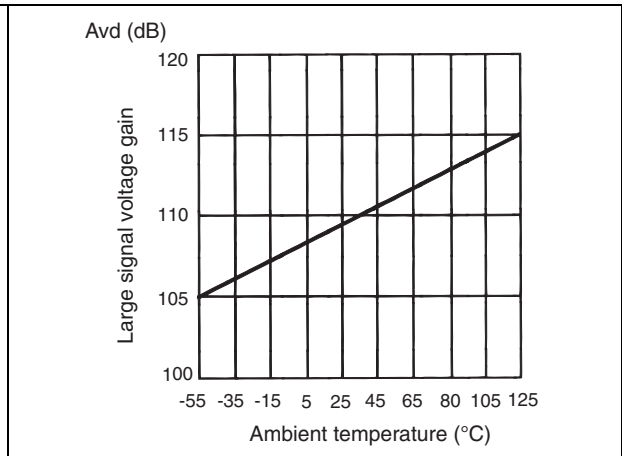


Figure 17. Power supply and common mode rejection ratio

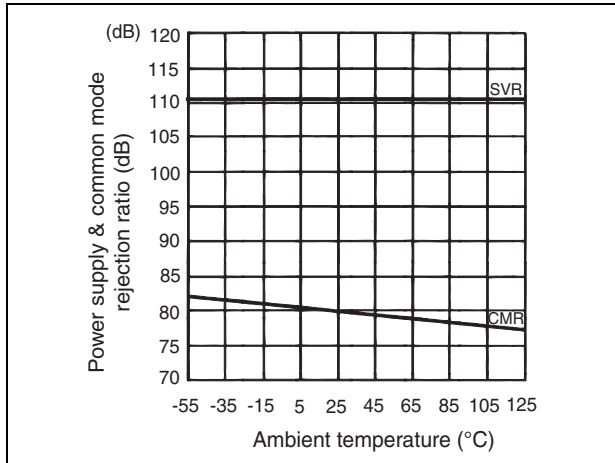
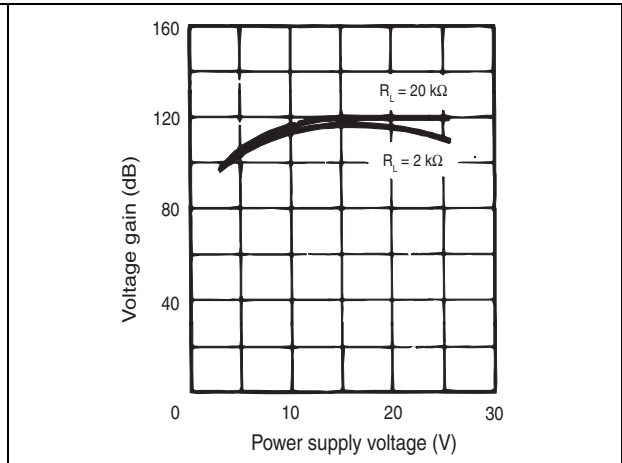


Figure 18. Voltage gain





# 4 Typical single-supply applications

Figure 19. AC coupled inverting amplifier

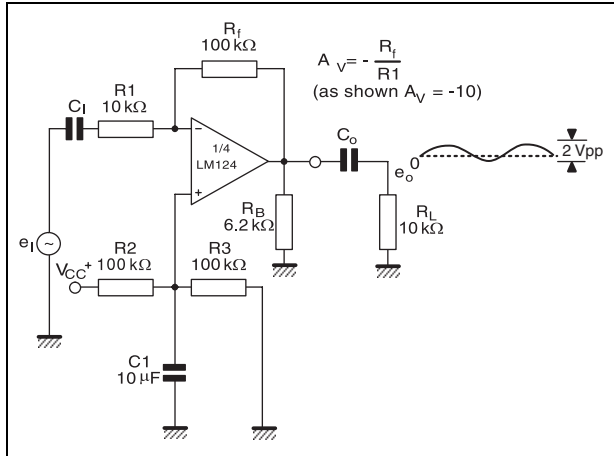


Figure 20. High input Z adjustable gain DC instrumentation amplifier

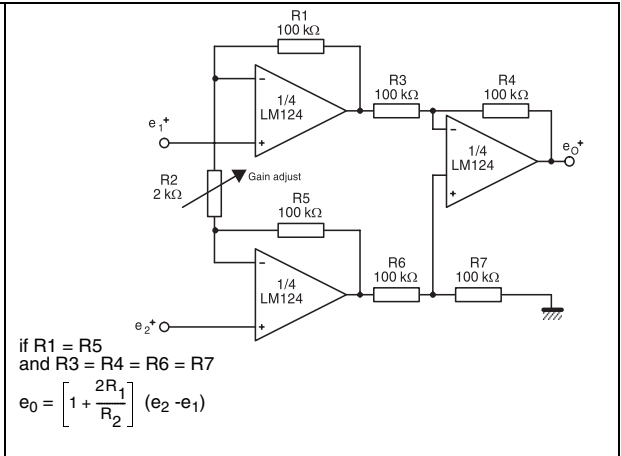


Figure 21. AC coupled non inverting amplifier

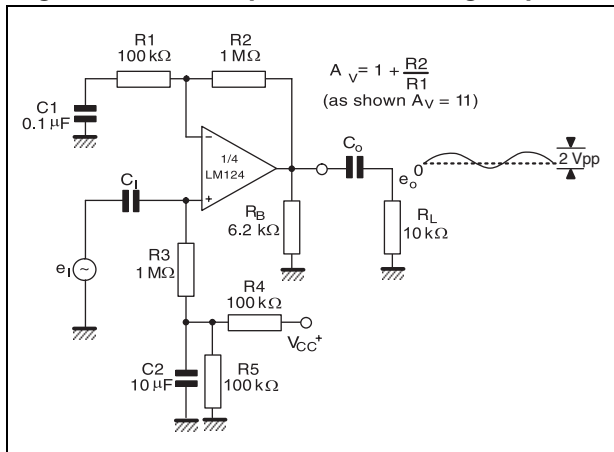


Figure 22. DC summing amplifier

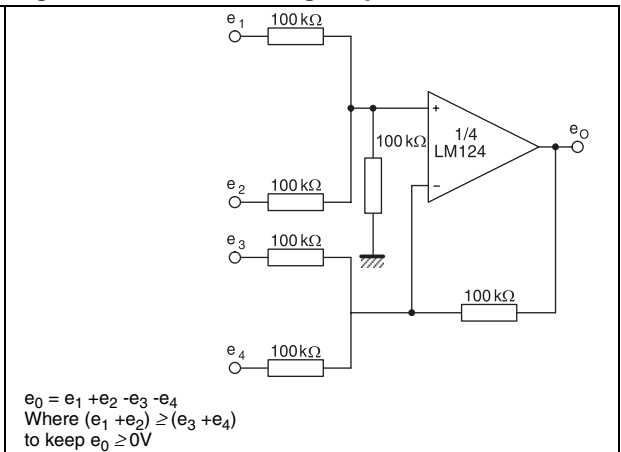


Figure 23. Non-inverting DC gain

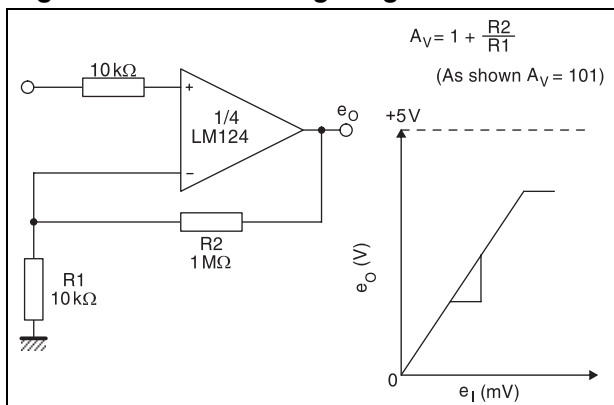


Figure 24. Low drift peak detector

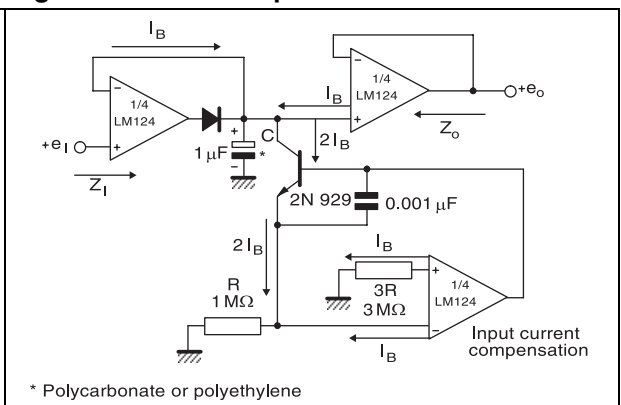


Figure 25. Active bandpass filter

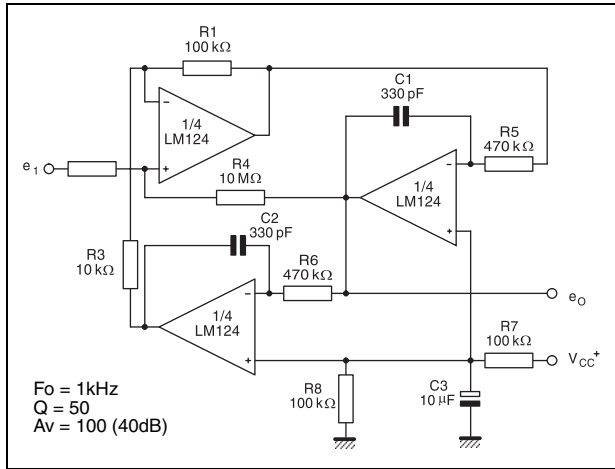


Figure 26. High input Z, DC differential amplifier

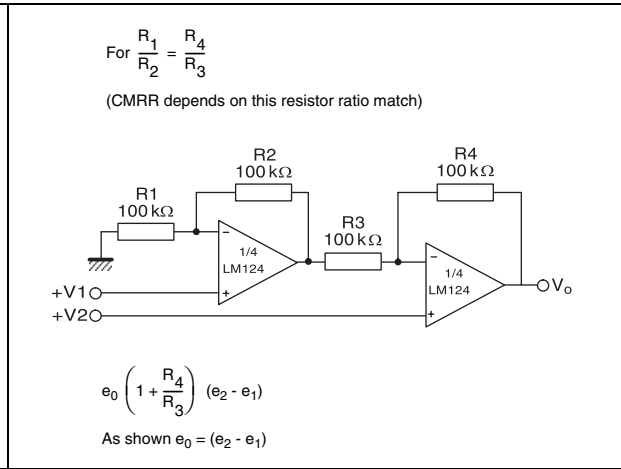
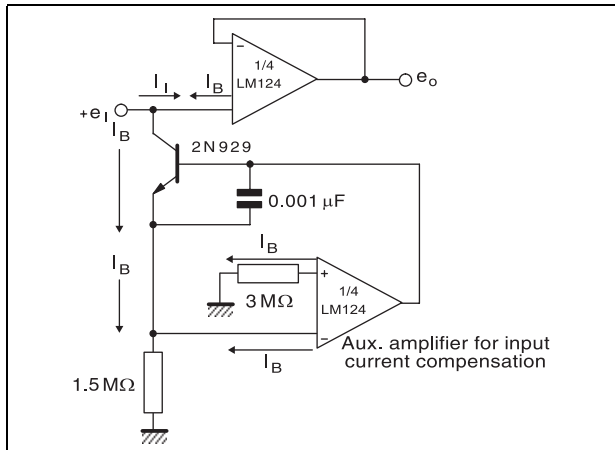


Figure 27. Using symmetrical amplifiers to reduce input current (general concept)



## 5 Package information

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

### 5.1 DIP14 package information

Figure 28. DIP14 package mechanical drawing

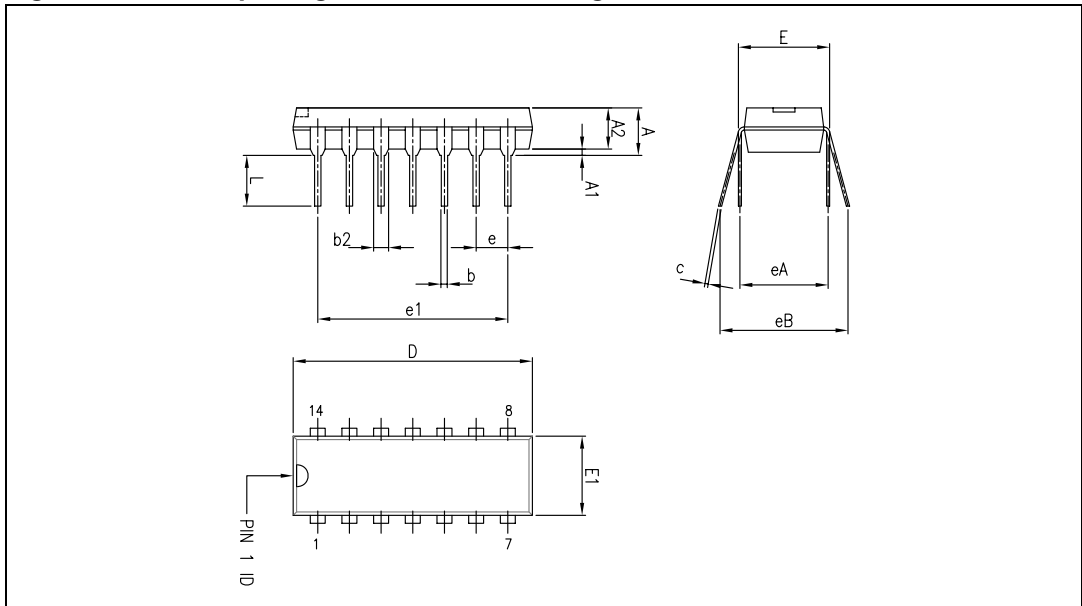


Table 3. DIP14 package mechanical data

| Ref. | Dimensions  |       |       |        |       |       |
|------|-------------|-------|-------|--------|-------|-------|
|      | Millimeters |       |       | Inches |       |       |
|      | Min.        | Typ.  | Max.  | Min.   | Typ.  | Max.  |
| A    |             |       | 5.33  |        |       | 0.21  |
| A1   | 0.38        |       |       | 0.015  |       |       |
| A2   | 2.92        | 3.30  | 4.95  | 0.11   | 0.13  | 0.19  |
| b    | 0.36        | 0.46  | 0.56  | 0.014  | 0.018 | 0.022 |
| b2   | 1.14        | 1.52  | 1.78  | 0.04   | 0.06  | 0.07  |
| c    | 0.20        | 0.25  | 0.36  | 0.007  | 0.009 | 0.01  |
| D    | 18.67       | 19.05 | 19.69 | 0.73   | 0.75  | 0.77  |
| E    | 7.62        | 7.87  | 8.26  | 0.30   | 0.31  | 0.32  |
| E1   | 6.10        | 6.35  | 7.11  | 0.24   | 0.25  | 0.28  |
| e    |             | 2.54  |       |        | 0.10  |       |
| e1   |             | 15.24 |       |        | 0.60  |       |
| eA   |             | 7.62  |       |        | 0.30  |       |
| eB   |             |       | 10.92 |        |       | 0.43  |
| L    | 2.92        | 3.30  | 3.81  | 0.11   | 0.13  | 0.15  |

## 5.2 SO-14 package information

Figure 29. SO-14 package mechanical drawing

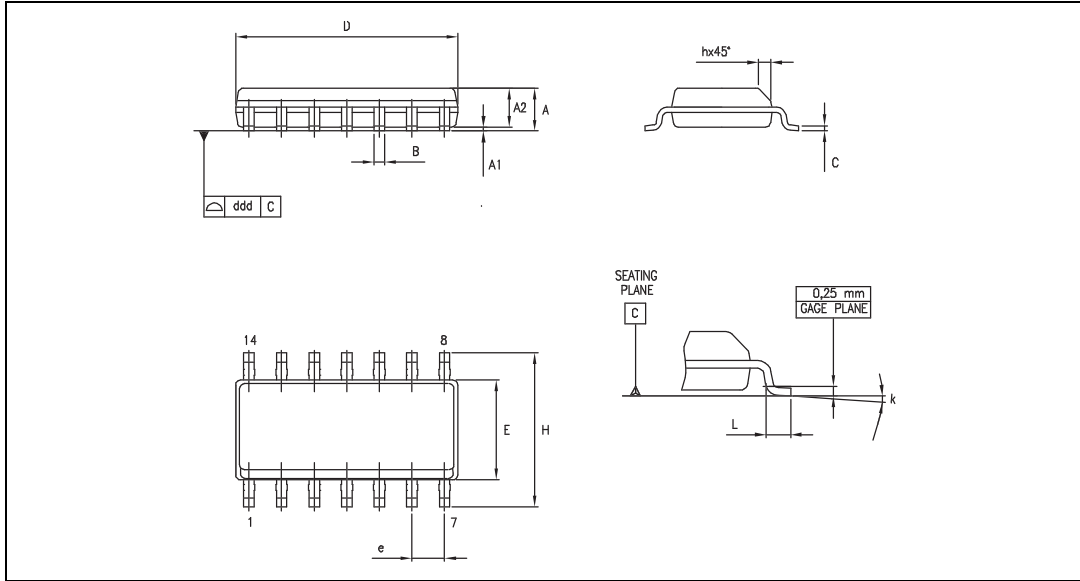


Table 4. SO-14 package mechanical data

| Dimensions |             |      |      |        |      |       |
|------------|-------------|------|------|--------|------|-------|
| Ref.       | Millimeters |      |      | Inches |      |       |
|            | Min.        | Typ. | Max. | Min.   | Typ. | Max.  |
| 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 |

### 5.3 QFN16 3x3 package mechanical data

Figure 30. QFN16 3x3 package mechanical drawing

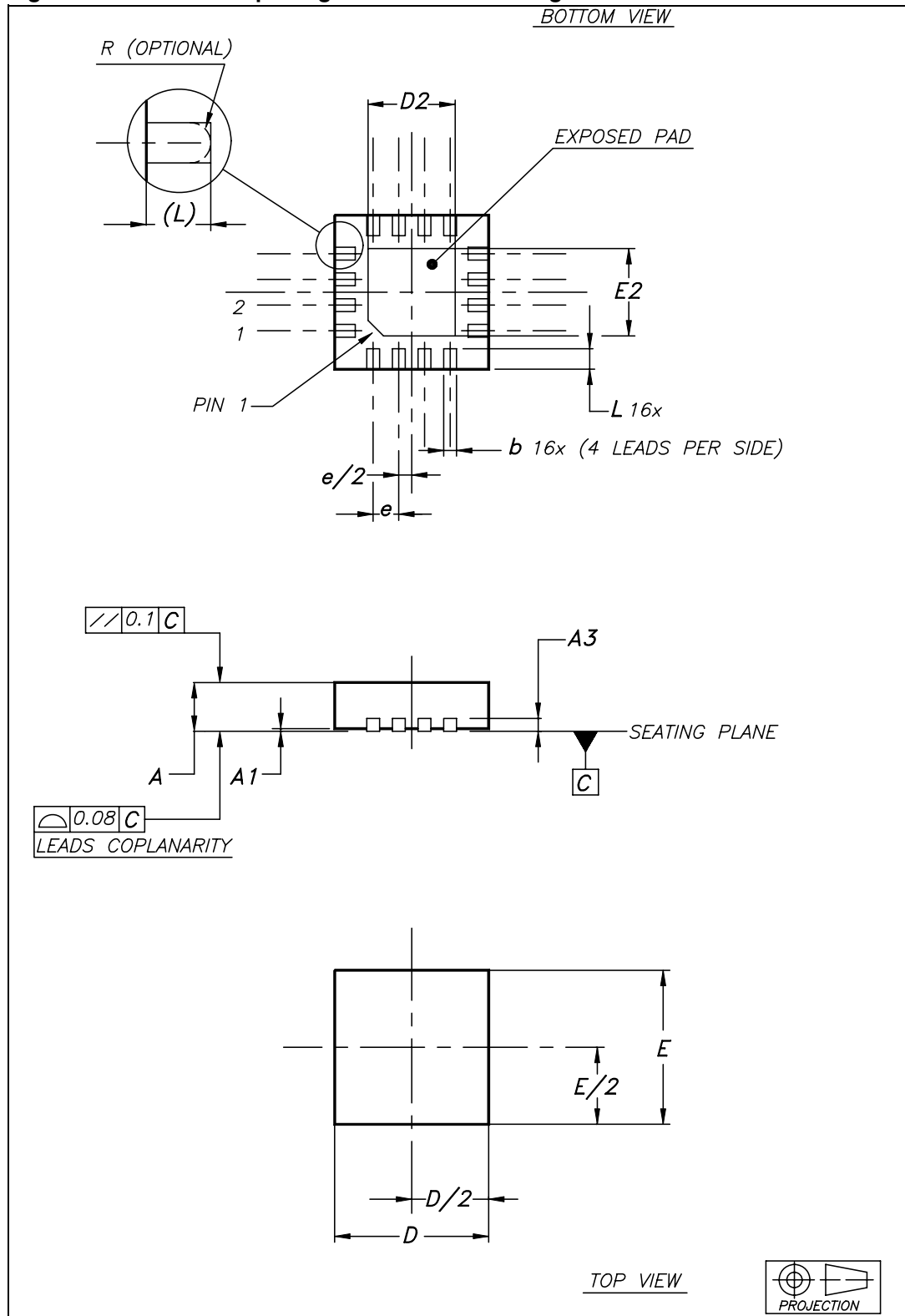
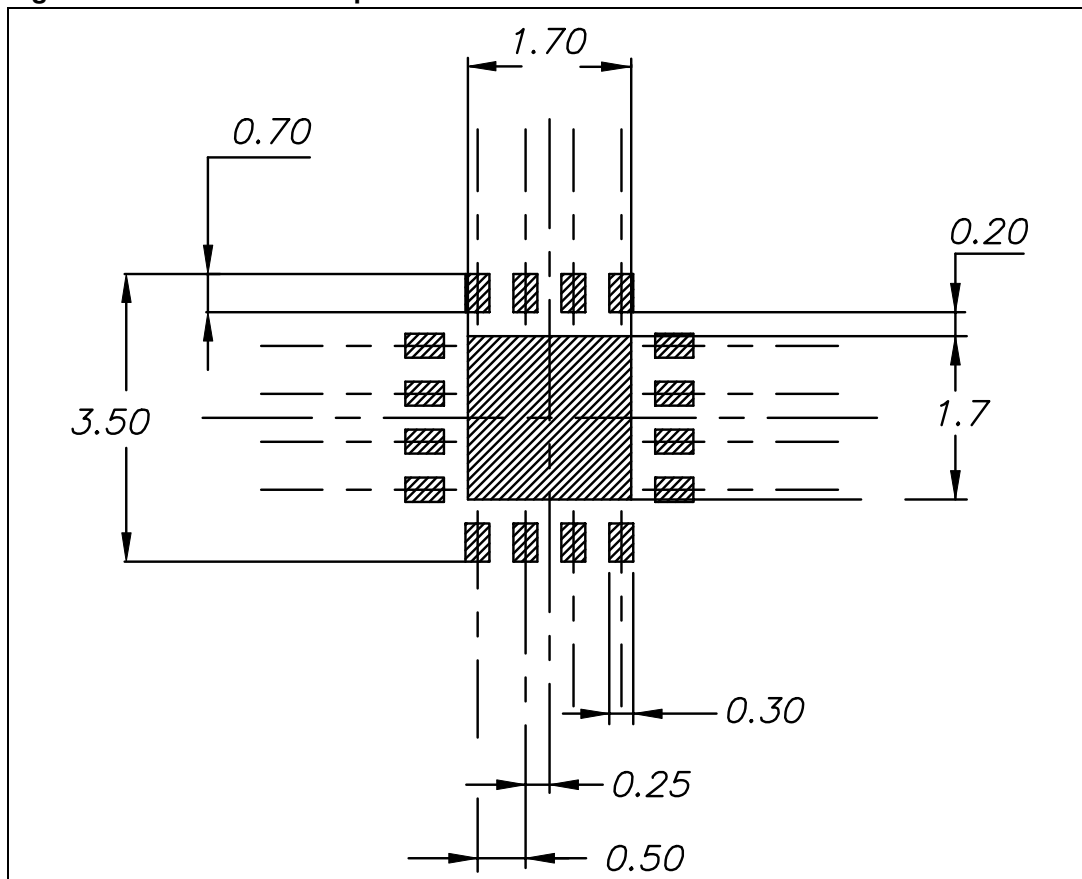


Table 5. QFN16 3x3 mm package mechanical data (pitch 0.5 mm)

| 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 31. QFN16 3x3 footprint recommendation



### 5.4 TSSOP14 package information

Figure 32. TSSOP14 package mechanical drawing

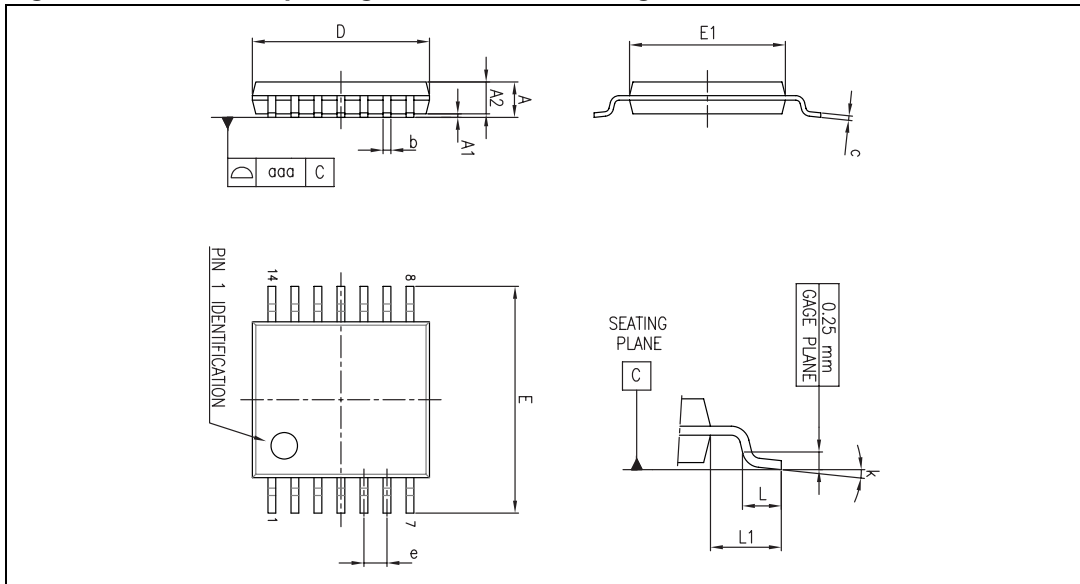


Figure 33. TSSOP14 package mechanical data

| 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 Ordering information

**Table 6. Order codes**

| Part number | Temperature range | Package   | Packing             | Marking |
|-------------|-------------------|-----------|---------------------|---------|
| LM124N      | -55°C, +125°C     | DIP14     | Tube                | LM124N  |
| LM124D/DT   |                   | SO-14     | Tube or tape & reel | 124     |
| LM224N      | -40°C, +105°C     | DIP14     | Tube                | LM224N  |
| LM224D/DT   |                   | SO-14     | Tube or tape & reel | 224     |
| LM224PT     |                   | TSSOP14   | Tape & reel         | 224     |
| LM224QT     |                   | QFN16 3x3 | Tape & reel         | K425    |
| LM324N      | 0°C, +70°C        | DIP14     | Tube                | LM324N  |
| LM324D/DT   |                   | SO-14     | Tube or tape & reel | 324     |
| LM324PT     |                   | TSSOP14   | Tape & reel         | 324     |
| LM324QT     |                   | QFN16 3x3 | Tape & reel         | K427    |

## 7 Revision history

**Table 7. Document revision history**

| Date         | Revision | Changes   |
|--------------|----------|---|
| 01-Oct.-2003 | 1        | First release.  |
| 02-Jan-2005  | 2        | Modifications on AMR <a href="#">Table 1 on page 3</a> (explanation of $V_{id}$ and $V_i$ limits).  |
| 01-Jun-2005  | 3        | ESD protection inserted in <a href="#">Table 1 on page 3</a> .  |
| 02-Jan-2006  | 4        | $T_j$ and $R_{thjc}$ parameters added in <a href="#">Table 1. on page 3</a> .   |
| 04-Oct-2006  | 5        | Editorial update. <a href="#">Table 3</a> moved to <a href="#">Section 5: Macromodels on page 11</a> .  |
| 11-Jan-2010  | 6        | Added AMR values for input current in <a href="#">Table 1 on page 3</a> .   |
| 30-Jun-2011  | 7        | Added pin connections for QFN16 package in <a href="#">Figure 1 on page 2</a> .<br>Added thermal information for QFN16 package in <a href="#">Table 1 on page 3</a> .<br>Added QFN16 package information in <a href="#">Chapter 5</a> .<br>Added order codes for QFN16 package in <a href="#">Table 6: Order codes</a> .<br>Removed Spice model - refer to <a href="http://www.st.com">www.st.com</a> for latest model available. |

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