



# 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)

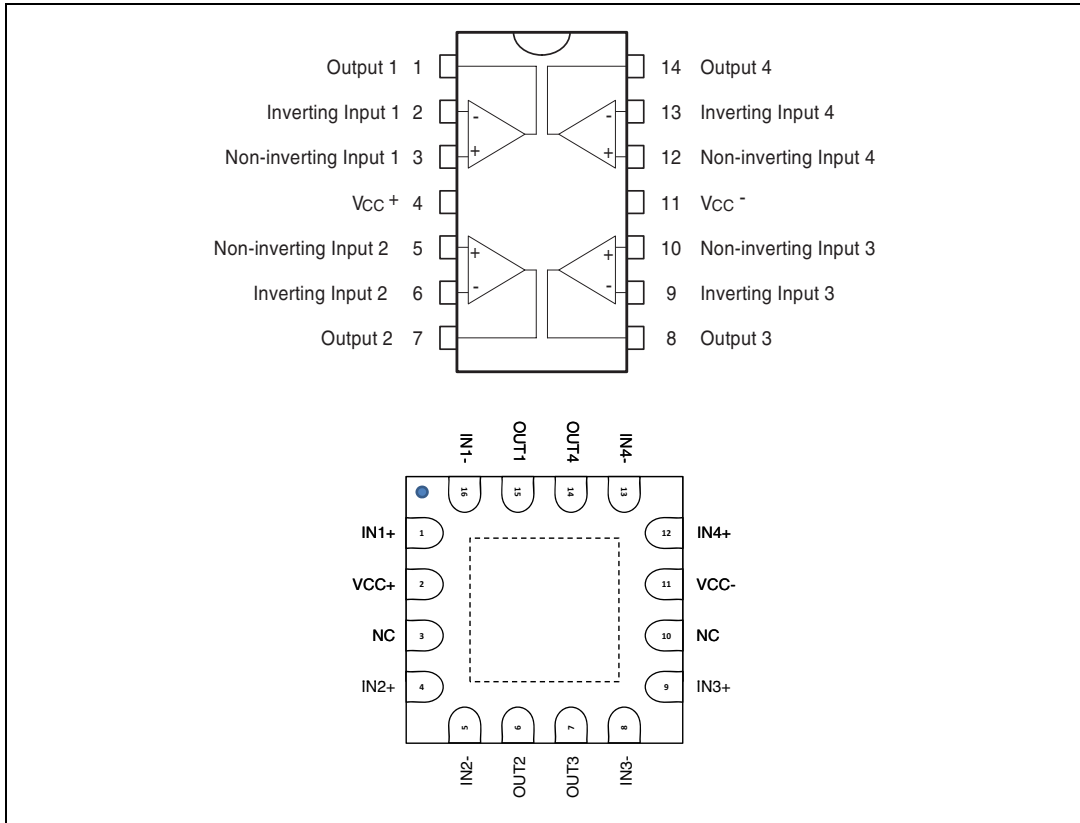
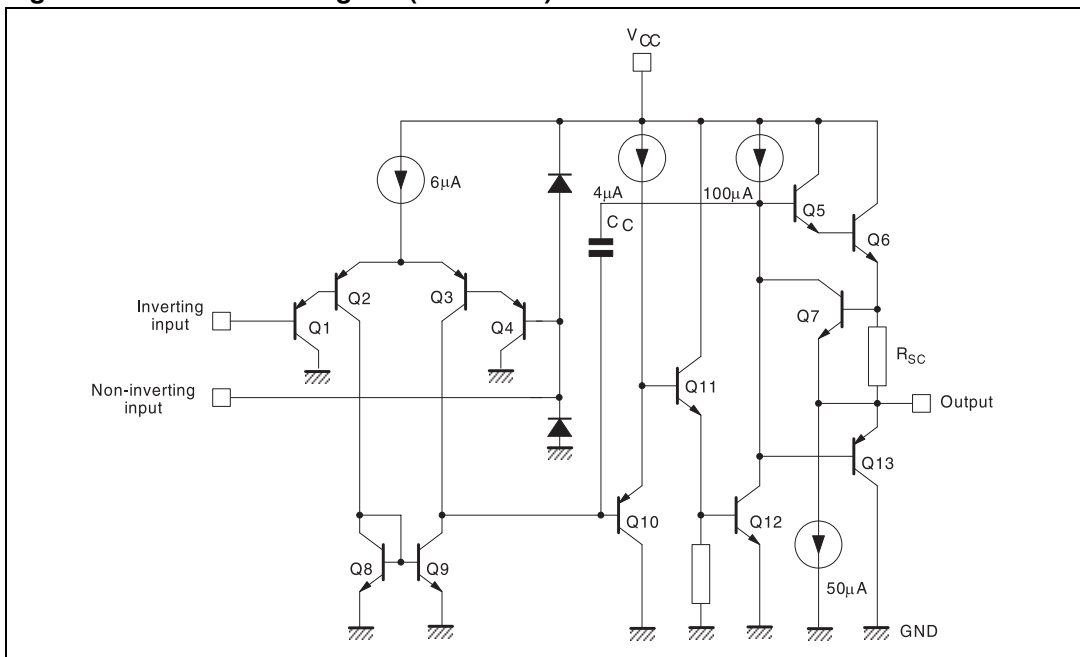


Figure 2. Schematic diagram (1/4 LM124)



## 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 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) 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> SO14 TSSOP14 DIP14 QFN16 3x3	103 100 83 45			°C/W
$R_{thjc}$	Thermal resistance junction to case SO14 TSSOP14 DIP14 QFN16	31 32 33 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)

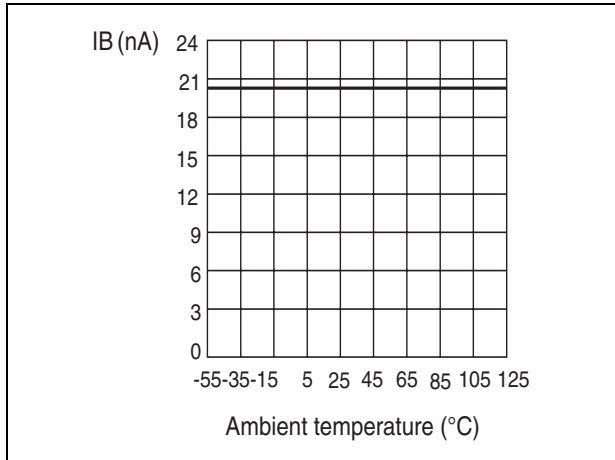
Symbol	Parameter	Min.	Typ.	Max.	Unit
$V_{io}$	Input offset voltage <sup>(1)</sup> $T_{\text{amb}} = +25^\circ\text{ C}$ LM124-LM224 LM324		2	5 7	mV
	$T_{\text{min}} \leq T_{\text{amb}} \leq T_{\text{max}}$ LM124-LM224 LM324			7 9	
$I_{io}$	Input offset current $T_{\text{amb}} = +25^\circ\text{ C}$ $T_{\text{min}}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

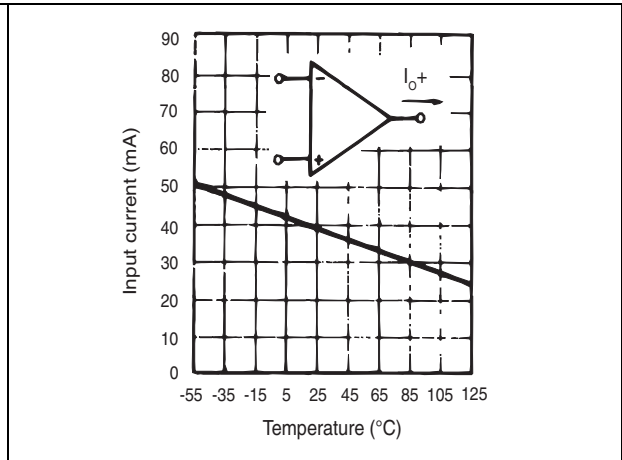
Symbol	Parameter	Min.	Typ.	Max.	Unit
$I_{\text{sink}}$	Output sink current ( $V_{\text{id}} = -1\text{ V}$ )				
	$V_{CC} = +15\text{ V}$ , $V_o = +2\text{ V}$ $V_{CC} = +15\text{ V}$ , $V_o = +0.2\text{ V}$	10 12	20 50		mA $\mu\text{A}$
$V_{\text{OH}}$	High level output voltage $V_{CC} = +30\text{ V}$ $T_{\text{amb}} = +25^\circ\text{ C}$ , $R_L = 2\text{ k}\Omega$ $T_{\text{min}} \leq T_{\text{amb}} \leq T_{\text{max}}$ $T_{\text{amb}} = +25^\circ\text{ C}$ , $R_L = 10\text{ k}\Omega$ $T_{\text{min}} \leq T_{\text{amb}} \leq T_{\text{max}}$	26 26 27 27	27 28		V
	$V_{CC} = +5\text{ V}$ , $R_L = 2\text{ k}\Omega$ $T_{\text{amb}} = +25^\circ\text{ C}$ $T_{\text{min}} \leq T_{\text{amb}} \leq T_{\text{max}}$	3.5 3			
$V_{\text{OL}}$	Low level output voltage ( $R_L = 10\text{ k}\Omega$ ) $T_{\text{amb}} = +25^\circ\text{ C}$ $T_{\text{min}} \leq T_{\text{amb}} \leq T_{\text{max}}$		5	20 20	mV
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 $V_{CC} = 30\text{ V}$ , $f = 100\text{ kHz}$ , $V_{\text{in}} = 10\text{ mV}$ , $R_L = 2\text{ k}\Omega$ , $C_L = 100\text{ pF}$		1.3		MHz
THD	Total harmonic distortion $f = 1\text{ kHz}$ , $A_v = 20\text{ dB}$ , $R_L = 2\text{ k}\Omega$ , $V_o = 2\text{ V}_{\text{pp}}$ , $C_L = 100\text{ pF}$ , $V_{CC} = 30\text{ V}$		0.015		%
$e_n$	Equivalent input noise voltage $f = 1\text{ kHz}$ , $R_s = 100\ \Omega$ , $V_{CC} = 30\text{ V}$		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> $1\text{ kHz} \leq f \leq 20\text{ kHz}$		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.

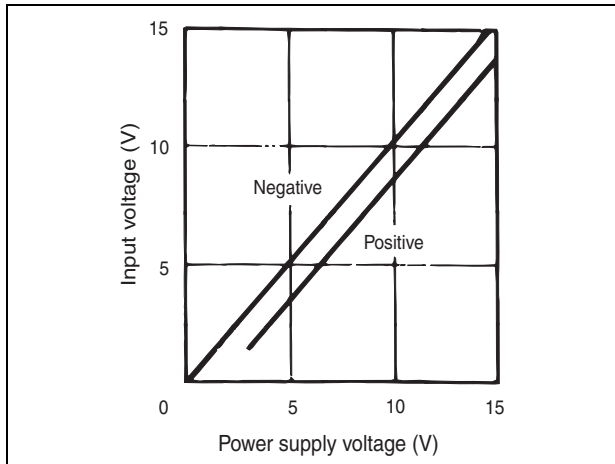
**Figure 3. Input bias current vs. ambient temperature**



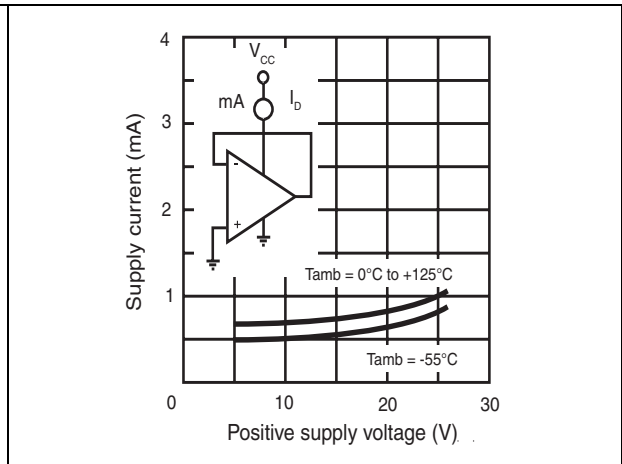
**Figure 4. Current limiting**



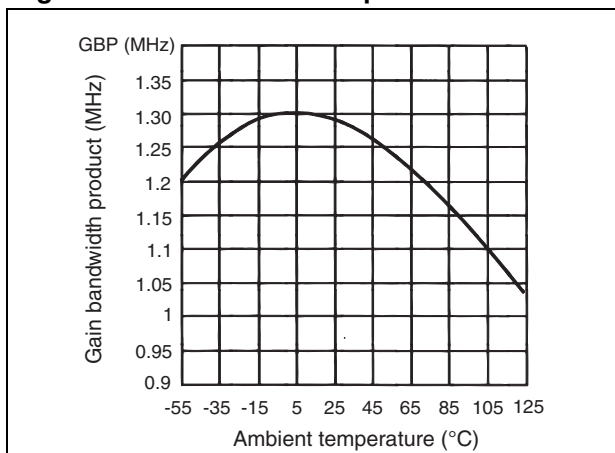
**Figure 5. Input voltage range**



**Figure 6. Supply current**



**Figure 7. Gain bandwidth product**



**Figure 8. Common mode rejection ratio**

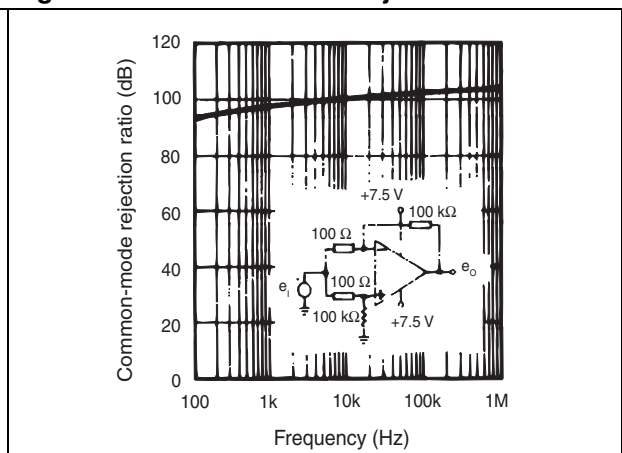


Figure 9. Open loop frequency response

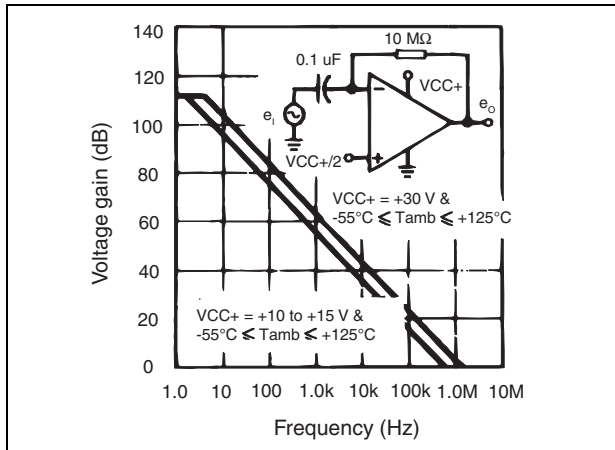


Figure 10. Large signal frequency response

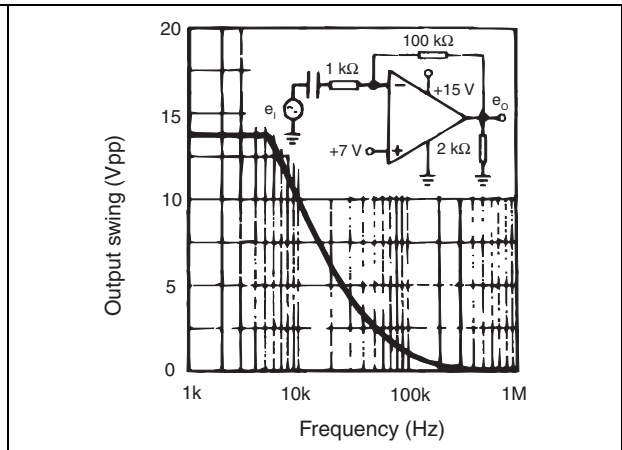


Figure 11. Voltage follower pulse response

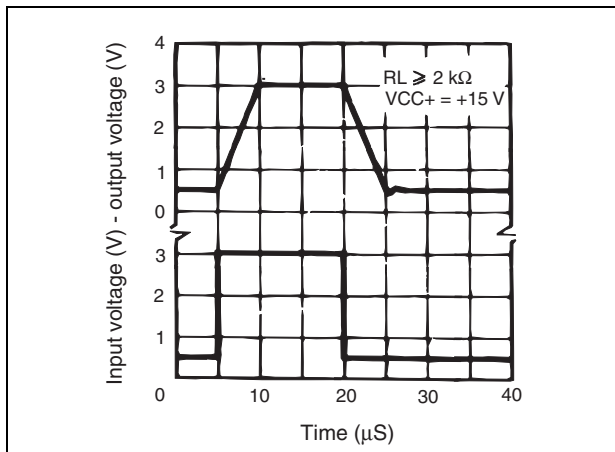


Figure 12. Output characteristics (current sinking)

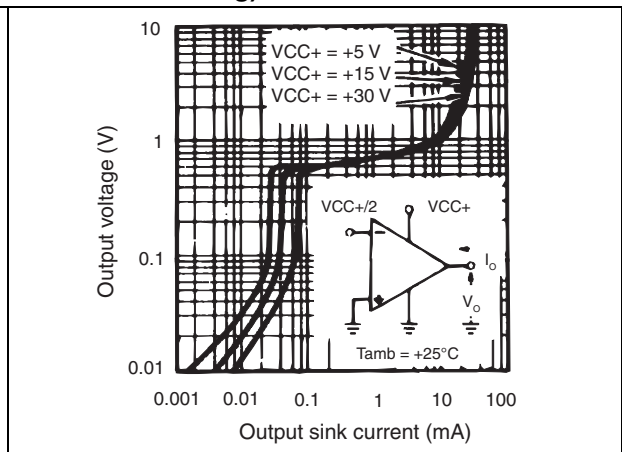


Figure 13. Voltage follower pulse response (small signal)

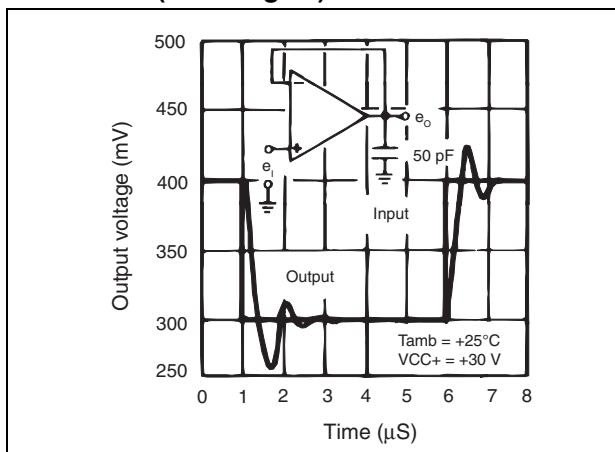


Figure 14. Output characteristics (current sourcing)

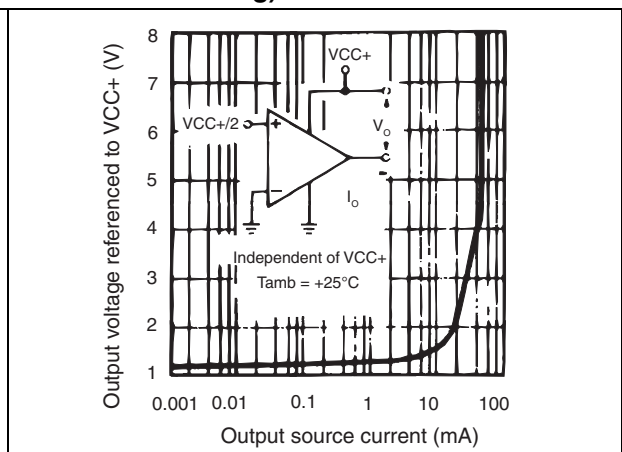


Figure 15. Input current

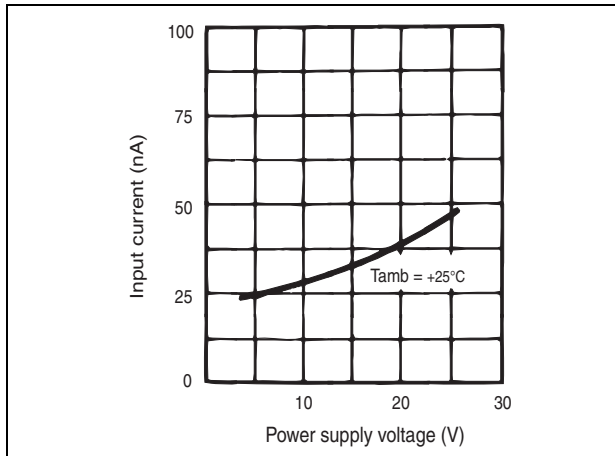


Figure 16. Large signal voltage gain

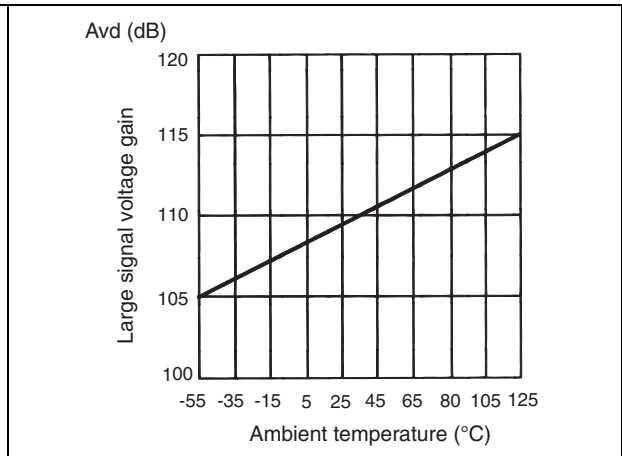


Figure 17. Power supply and common mode rejection ratio

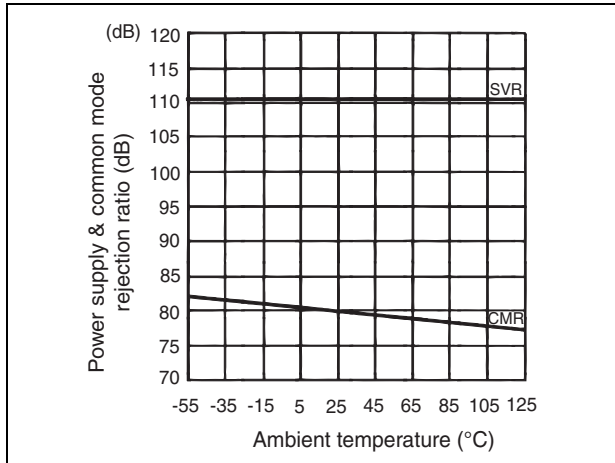
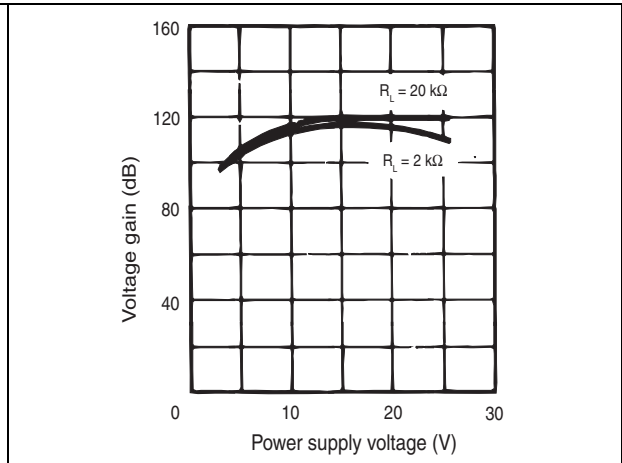


Figure 18. Voltage gain





# 4 Typical single-supply applications

Figure 19. AC coupled inverting amplifier

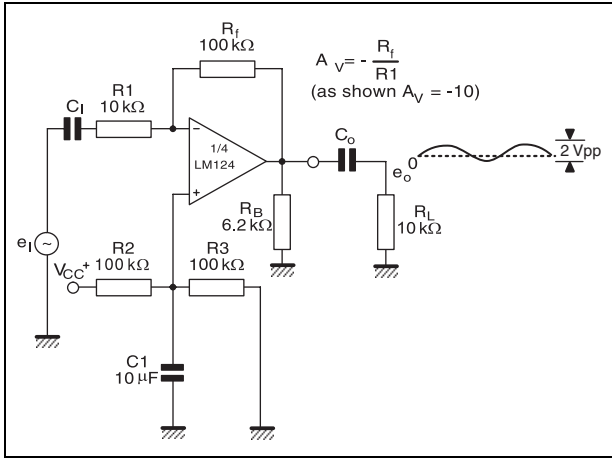


Figure 20. High input Z adjustable gain DC instrumentation amplifier

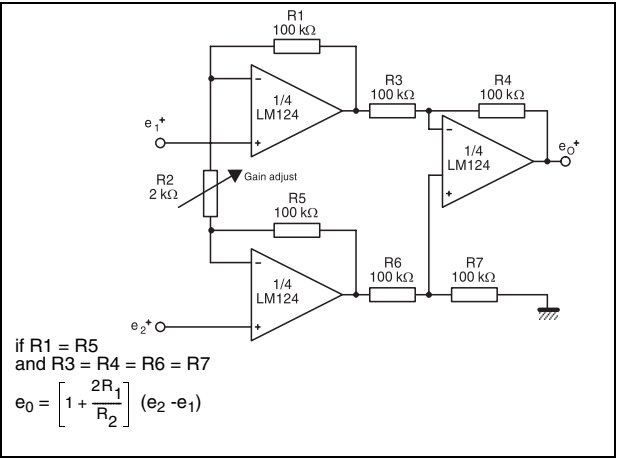


Figure 21. AC coupled non inverting amplifier

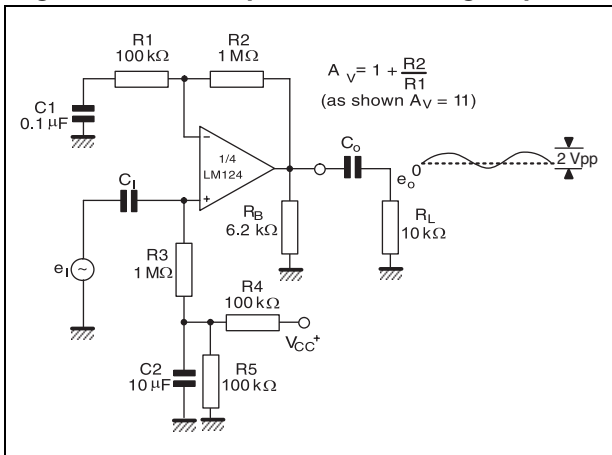


Figure 22. DC summing amplifier

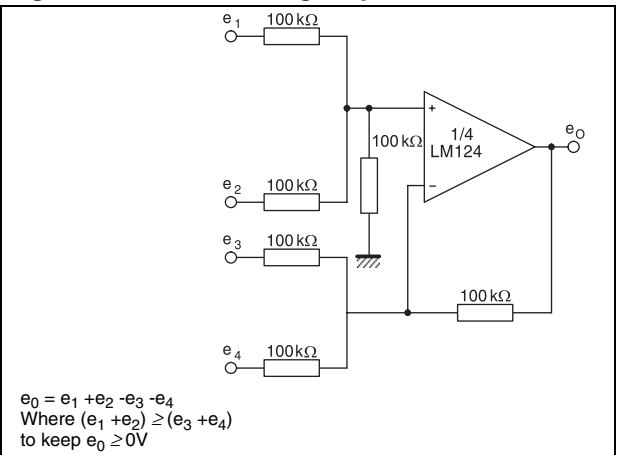


Figure 23. Non-inverting DC gain

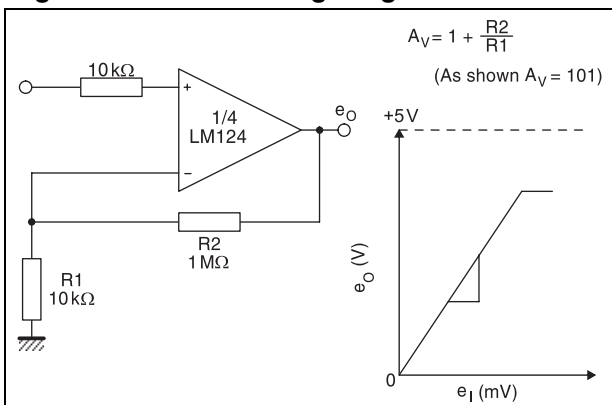


Figure 24. Low drift peak detector

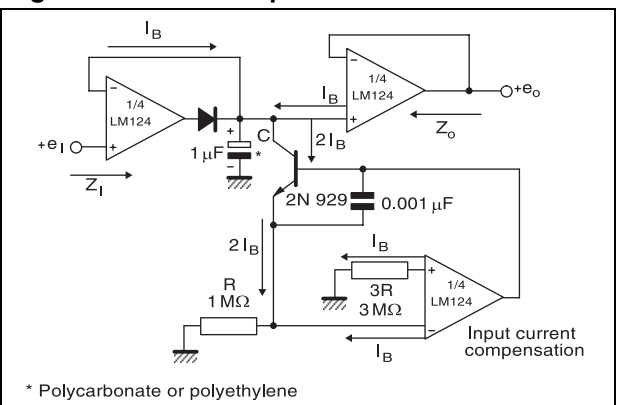


Figure 25. Active bandpass filter

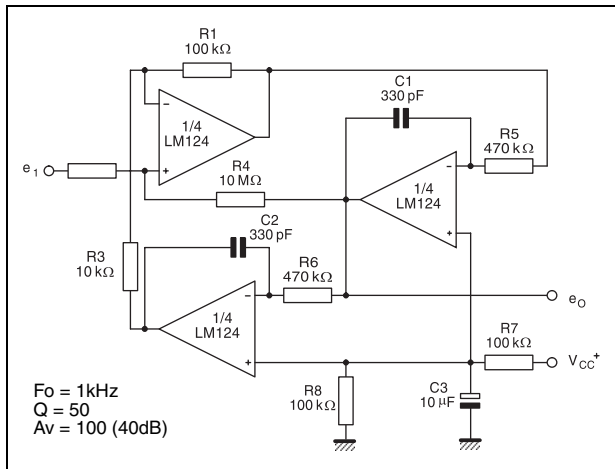


Figure 26. High input Z, DC differential amplifier

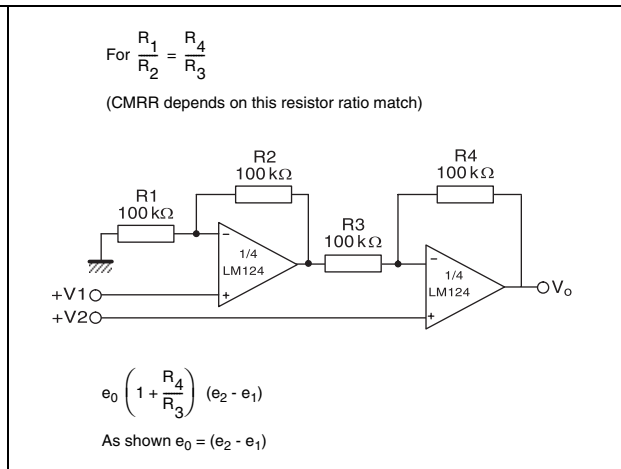
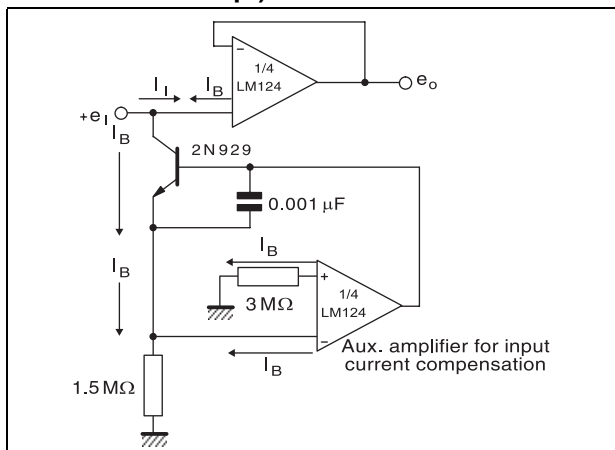


Figure 27. Using symmetrical amplifiers to reduce input current (general concept)



## 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

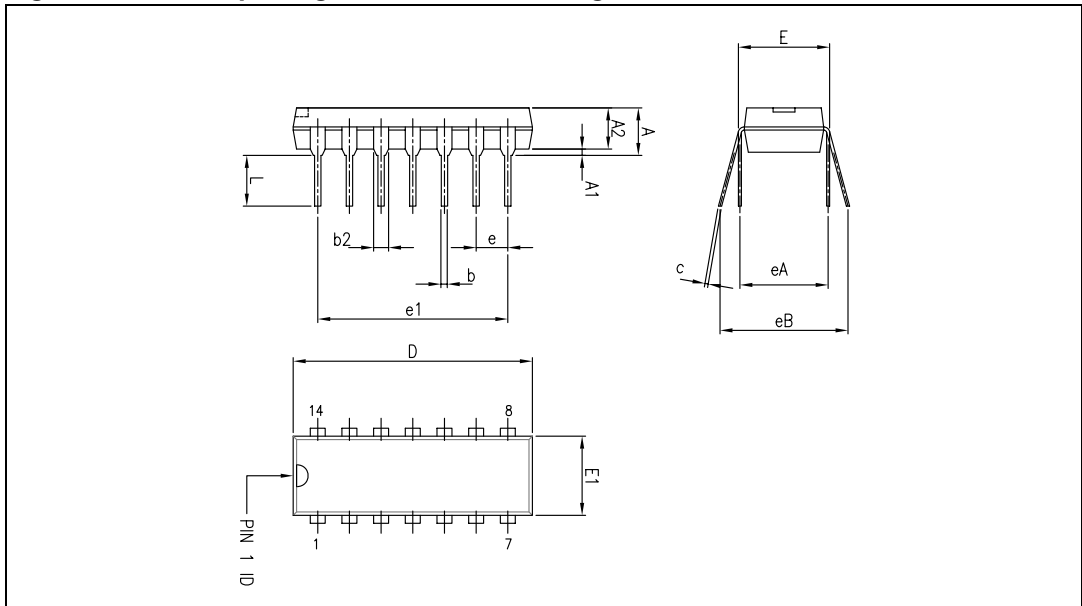


Table 3. DIP14 package mechanical data

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

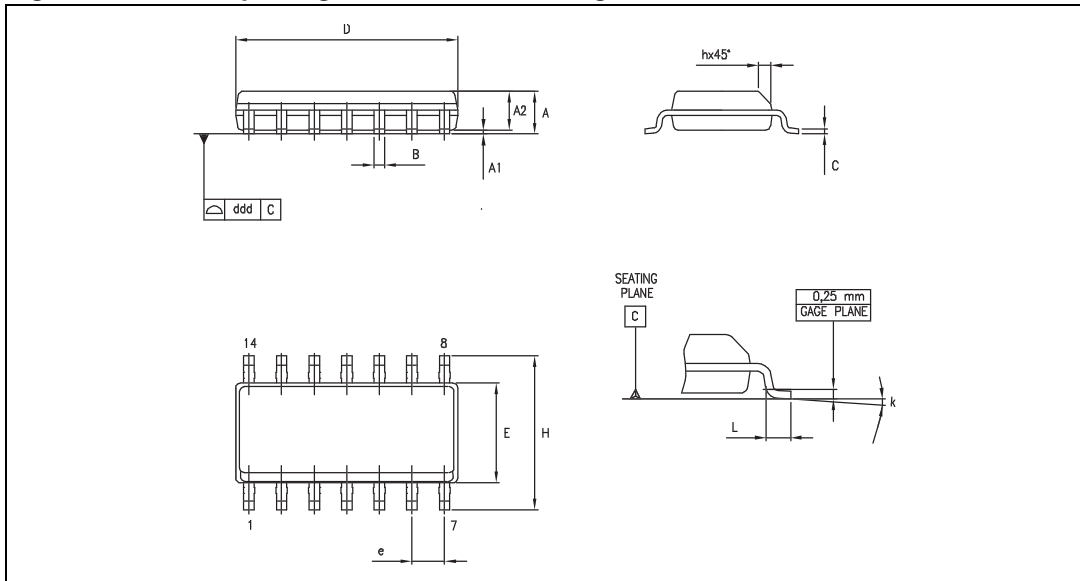
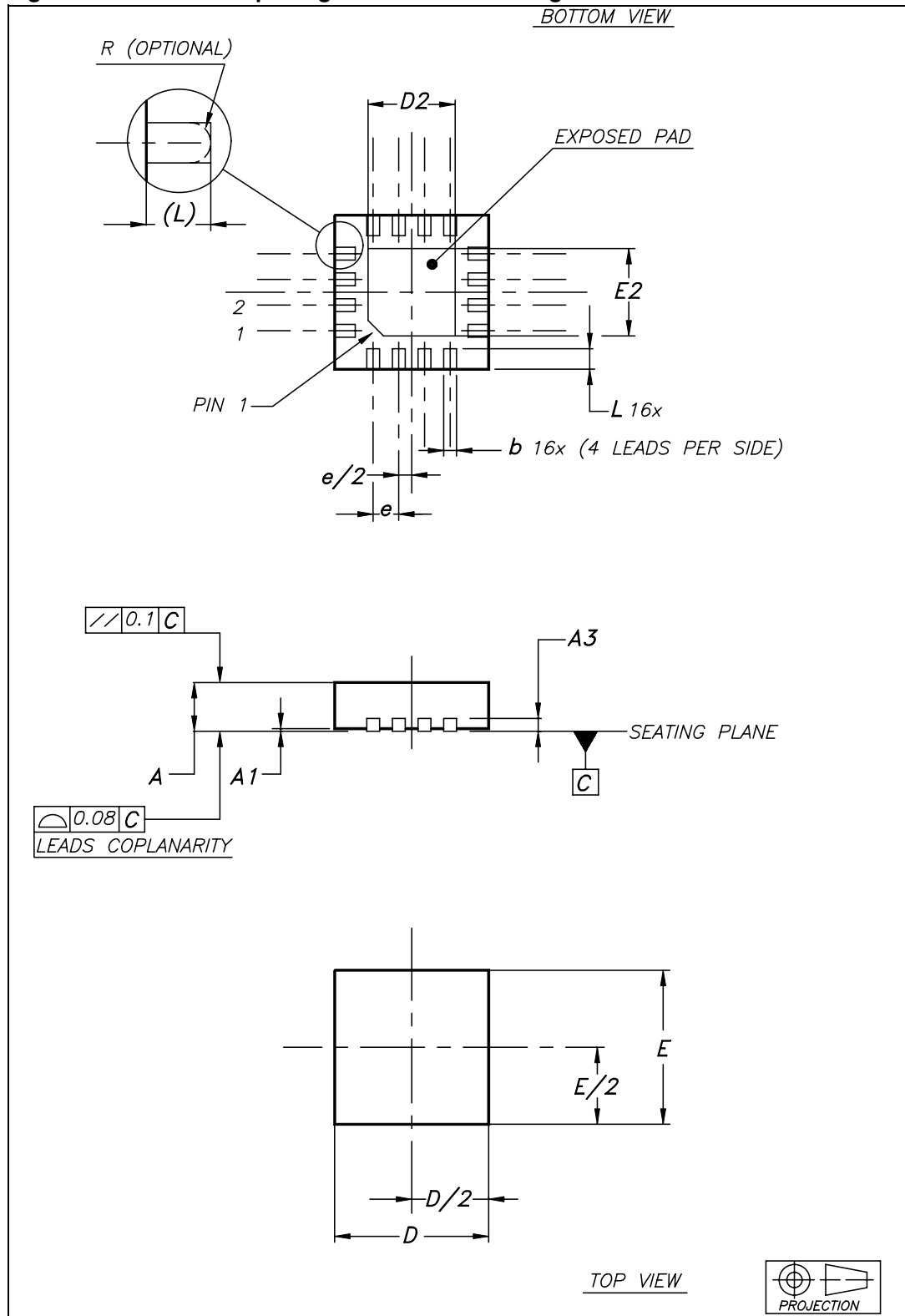


Table 4. SO-14 package mechanical data

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

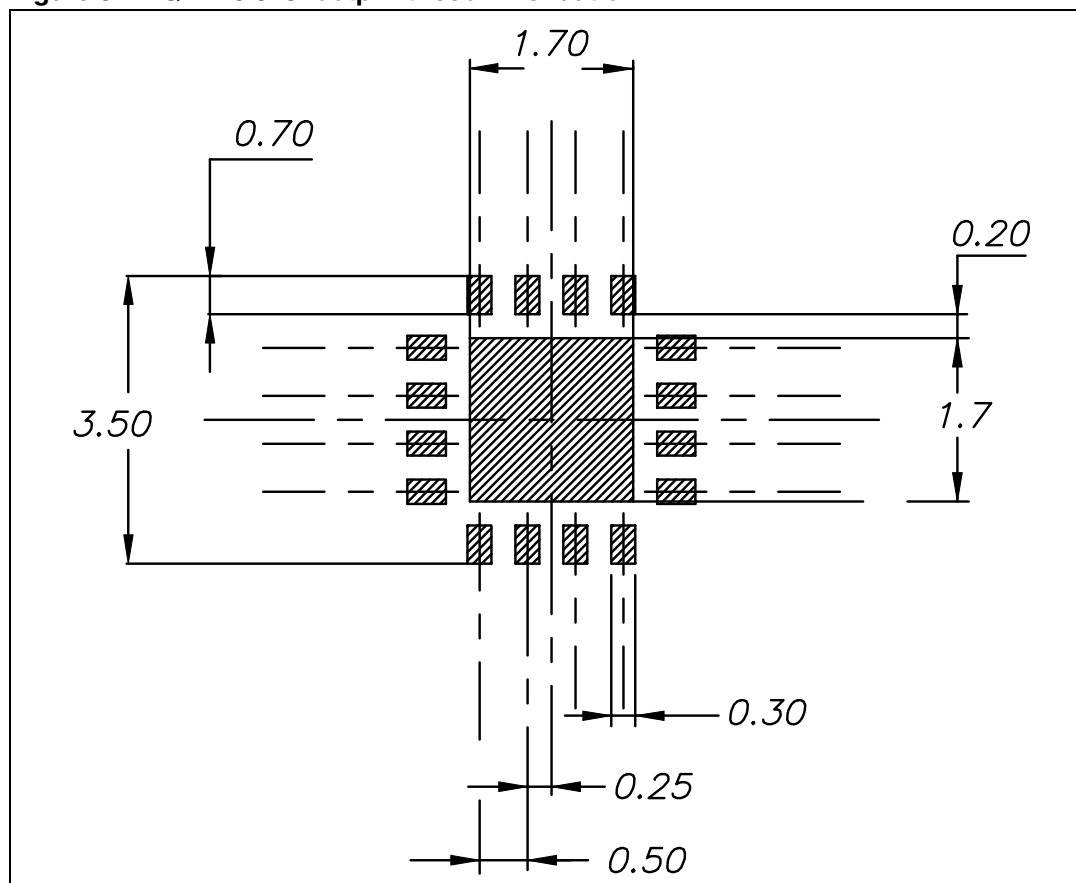
Figure 30. QFN16 3x3 package mechanical drawing



**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

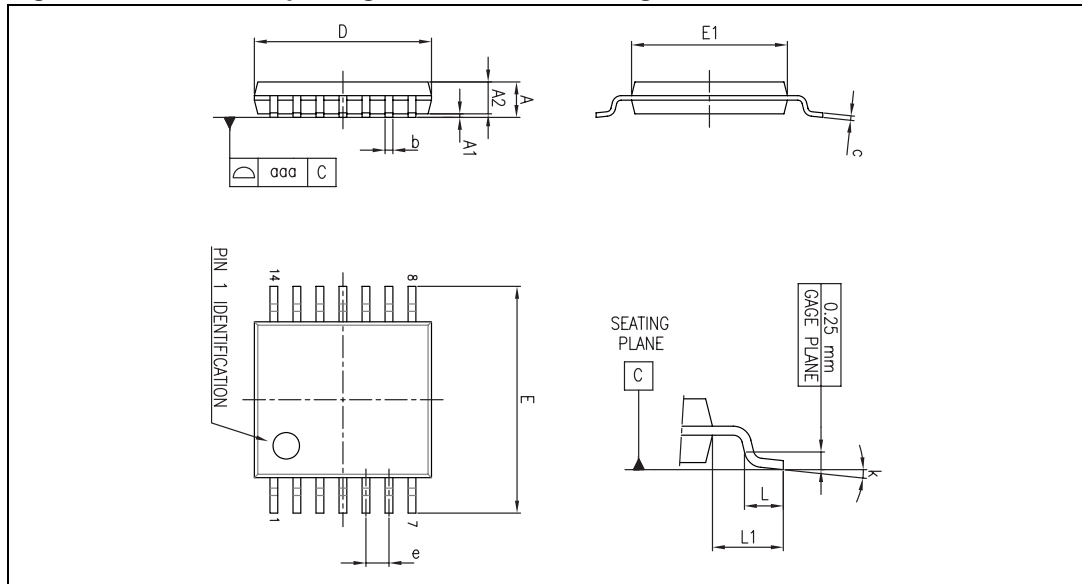


Figure 33. TSSOP14 package mechanical data

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> . Added thermal information for QFN16 package in <a href="#">Table 1 on page 3</a> . Added QFN16 package information in <a href="#">Chapter 5</a> . Added order codes for QFN16 package in <a href="#">Table 6: Order codes</a> . Removed Spice model - refer to <a href="http://www.st.com">www.st.com</a> for latest model available.

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