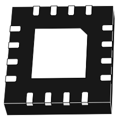
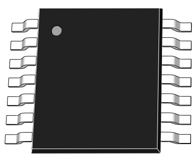
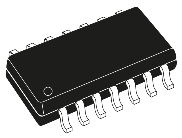
LM124, LM224x, LM324x

Low-power quad operational amplifiers

Datasheet - production data


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 µA
- 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: ±1.5 V to ±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

These circuits 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.

Table 1: Device summary

Product reference	Part numbers
LM124 (1)	LM124
LM224x	LM224, LM224A (2), LM224W (3)
LM324x	LM324, LM324A, LM324W

Notes:

(1)Prefixes LM1, LM2, and LM3 refer to temperature range.

(2)Suffix A refers to enhanced Vio performance

(3)Suffix W refers to enhanced ESD ratings

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2 Absolute maximum ratings and operating conditions 5
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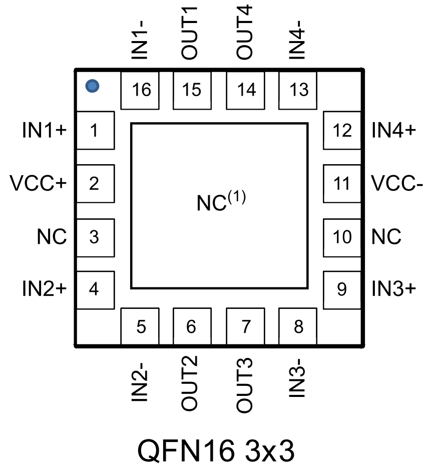
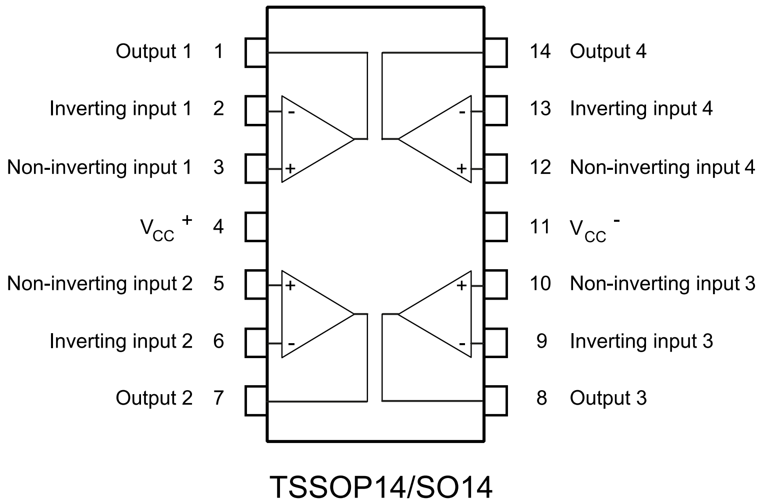
1 Pin connections and schematic diagram

Figure 1: Pin connections (top view)





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

Figure 2: Schematic diagram (LM224A, LM324A, LM324W, one channel)

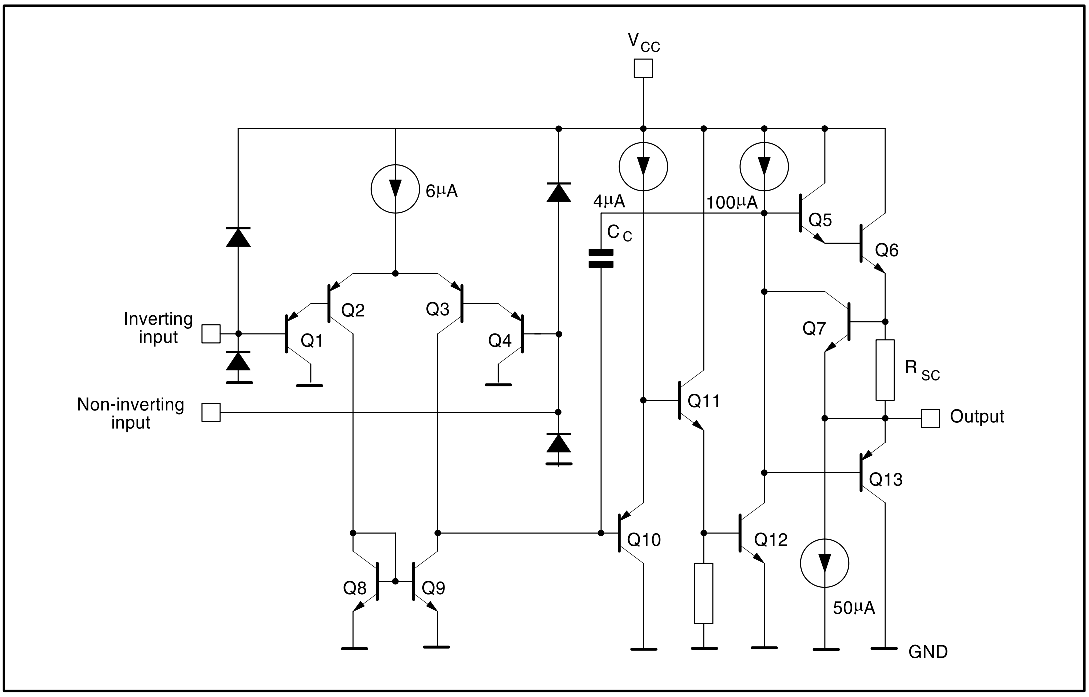
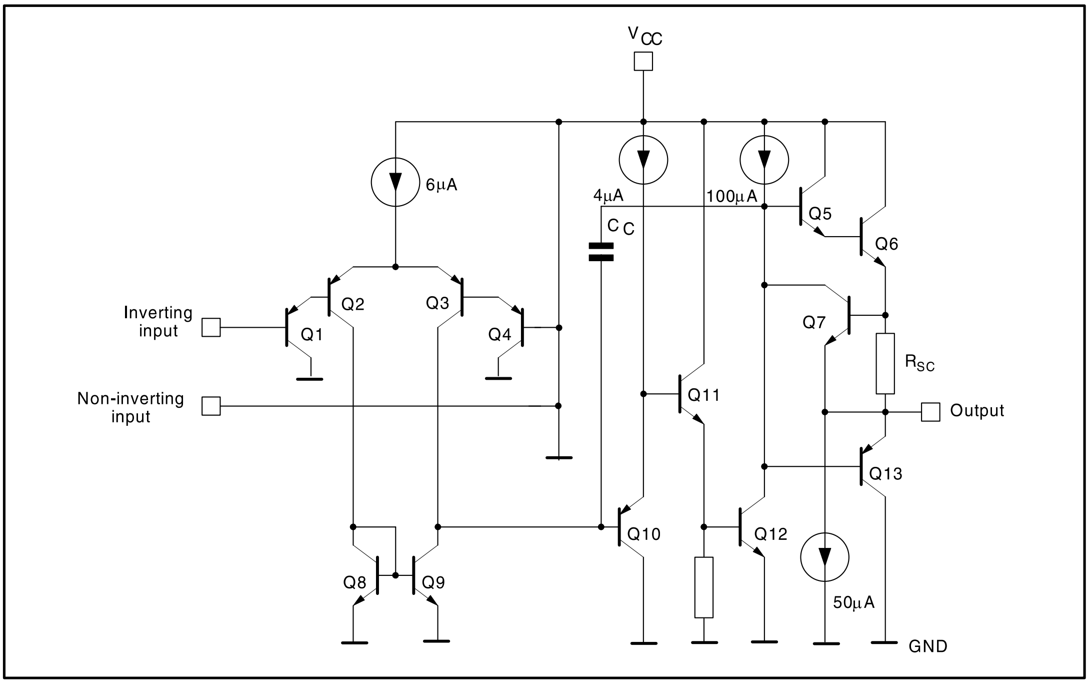


Figure 3: Schematic diagram (LM124, LM224, LM324, one channel)



2 Absolute maximum ratings and operating conditions

Table 2: Absolute maximum ratings

Symbol	Parameter		Value	Unit
V_{CC}	Supply voltage		±16 or 32	V
V_i	Input voltage		-0.3 to V_{CC} + 0.3	
V_{id}	Differential input voltage [(1)]		32	
P_{tot}	Power dissipation: D suffix		400	mW
	Output short-circuit duration [(2)]		Infinite	
I_{in}	Input current [(3)]		50	mA
T_{stg}	Storage temperature range		-65 to 150	°C
T_j	Maximum junction temperature		150	
R_{thja}	Thermal resistance junction to ambient [(4)]	QFN16 3x3	45	°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 [(5)]	LM224A, LM324A	800	V
		LM124W, LM324W	700	
		LM124, LM224, LM324	250	
	MM: machine model [(6)]		100	
	CDM: charged device model		1500	

Notes:

(1) Neither of the input voltages must exceed the magnitude of (V_{CC}^{+}) or (V_{CC}^{-}).

(2) 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.

(3) 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.

(4) 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).

(5) Human body model: 100 pF discharged through a 1.5 kΩ resistor between two pins of the device, done for all couples of pin combinations with other pins floating.

(6) 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 Ω), done for all couples of pin combinations with other pins floating.

Table 3: Operating conditions

Symbol	Parameter		Value	Unit
V_{CC}	Supply voltage	Single supply	3 to 30	V
		Dual supply	±1.5 to ±15	
V_{ICM}	Common-mode input voltage range		(V_{CC}^-) - 0.1 to (V_{CC}^+) - 1	
T_{Oper}	Operating temperature range	LM124	-55 to 125	°C
		LM224	-40 to 105	
		LM324	0 to 70	

3 Electrical characteristics

Table 4: VCC+ = 5 V, VCC- = Ground, Vo = 1.4 V, Tamb = 25 °C (unless otherwise specified)

Symbol	Parameter			Min.	Typ.	Max.	Unit
V_{io} LM224A, LM224W, LM324A, LM324W	Input offset voltage [1]	T_{amb} = 25 °C			2	3	mV
		$T_{min} \leq T_{amb} \leq T_{max}$				5	
V_{io} LM124, LM224, LM324		T_{amb} = 25 °C	LM124		2	5	
			LM224				
			LM324		2	7	
		$T_{min} \leq T_{amb} \leq T_{max}$	LM124			7	
			LM224				
			LM324			9	
I_{io}	Input offset current	T_{amb} = 25 °C			2	20	nA
		$T_{min} \leq T_{amb} \leq T_{max}$				40	
I_{ib}	Input bias current [2]	T_{amb} = 25 °C			20	100	
		$T_{min} \leq T_{amb} \leq T_{max}$				200	
A_{vd}	Large signal voltage gain, V_{CC}^+ = 15 V, R_L = 2 kΩ, V_o = 1.4 V to 11.4 V	T_{amb} = 25 °C		50	100		V/mV
		$T_{min} \leq T_{amb} \leq T_{max}$		25			
SVR	Supply voltage rejection ratio, $R_s \leq$ 10 kΩ, V_{CC}^+ = 5 V to 30 V	T_{amb} = 25 °C		65	110		dB
		$T_{min} \leq T_{amb} \leq T_{max}$		65			
I_{CC}	Supply current, all amps, no load	T_{amb} = 25 °C, V_{CC} = 5V			0.7	1.2	mA
		T_{amb} = 25 °C, V_{CC} = 30 V			1.5	3	
		$T_{min} \leq T_{amb} \leq T_{max}$, V_{CC} = 5 V			0.8	1.2	
		$T_{min} \leq T_{amb} \leq T_{max}$, V_{CC} = 30 V			1.5	3	
V_{icm}	Input common mode voltage range [3]	V_{CC} = 30 V, T_{amb} = 25 °C		0		28.5	V
		V_{CC} = 30 V, $T_{min} \leq T_{amb} \leq T_{max}$		0		28	
CMR	Common mode rejection ratio, $R_s \leq$ 10 kΩ	T_{amb} = 25 °C		70	80		dB
		$T_{min} \leq T_{amb} \leq T_{max}$		60			
I_{source}	Output current source, V_{id} = 1 V	V_{CC} = 15 V, V_o = 2 V		20	40	70	mA
I_{sink}	Output sink current, V_{id} = -1 V	V_{CC} = 15 V, V_o = 2 V		10	20		
		V_{CC} = 15 V, V_o = 0.2 V		12	50		µA
V_{OH}	High level output voltage, V_{CC} = 30 V, R_L = 2 kΩ	T_{amb} = 25 °C		26	27		V
		$T_{min} \leq T_{amb} \leq T_{max}$		26			
	High level output voltage, V_{CC} = 30 V, R_L = 10 kΩ	T_{amb} = 25 °C		27	28		
		$T_{min} \leq T_{amb} \leq T_{max}$		27			
	High level output voltage, V_{CC} = 5 V, R_L = 2 kΩ	T_{amb} = 25 °C		3.5			
		$T_{min} \leq T_{amb} \leq T_{max}$		3			

Symbol	Parameter		Min.	Typ.	Max.	Unit
V_{OL}	Low level output voltage, R_L = 10kΩ	T_{amb} = 25 °C		5	20	mV
		$T_{min} \leq T_{amb} \leq T_{max}$			20	
SR	Slew rate	V_{CC} = 15 V, V_i = 0.5 to 3 V, R_L = 2 kΩ, C_L = 100 pF, unity gain		0.4		V/µs
GBP	Gain bandwidth product	V_{CC} = 30 V, f = 100 kHz, V_{in} = 10 mV, R_L = 2 kΩ, C_L = 100 pF		1.3		MHz
THD	Total harmonic distortion	f = 1kHz, A_v = 20 dB, R_L = 2 kΩ, V_o = 2 V_{pp}, C_L = 100 pF, V_{CC} = 30 V		0.015		%
e_n	Equivalent input noise voltage	f = 1 kHz, R_s = 100 Ω, V_{CC} = 30 V		40		nV/√Hz
DV_{io}	Input offset voltage drift			7	30	µV/°C
DI_{io}	Input offset current drift			10	200	pA/°C
V_{o1}/V_{o2}	Channel separation (4)	1 kHz ≤ f ≤ 20 kHZ		120		kHz

Notes:

(1) V_o = 1.4 V, R_s = 0 Ω, 5 V < V_{CC}^+ < 30 V, 0 < V_{ic} < V_{CC}^+ - 1.5 V

(2) 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.

(3) The input common-mode voltage of either input signal voltage should not be allowed to go negative by more than 0.3 V. The upper end of the common-mode voltage range is (V_{CC}^+) - 1.5 V, but either or both inputs can go to 32 V without damage.

(4) 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

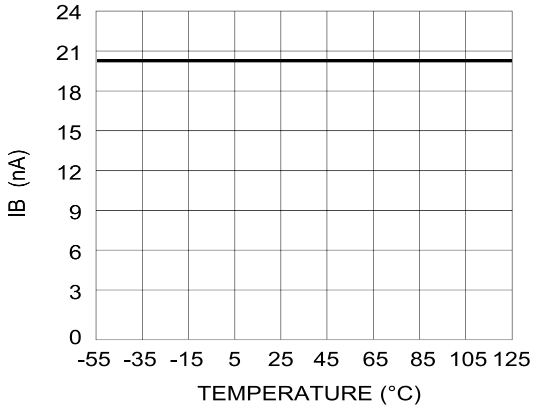


Figure 5: Output current limitation

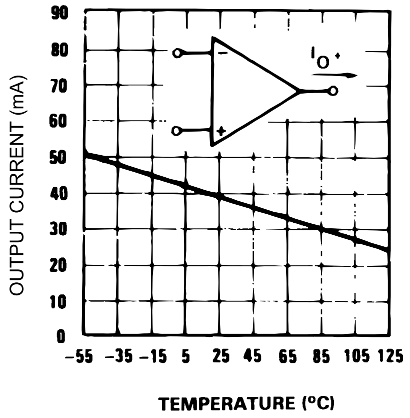


Figure 6: Input voltage range

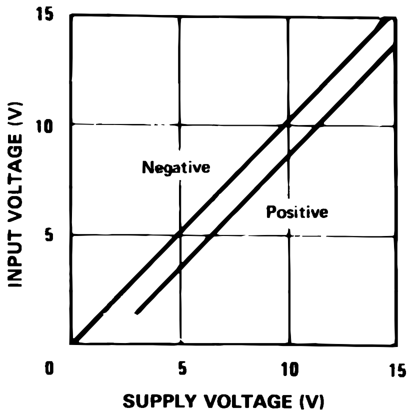


Figure 7: Supply current vs. supply voltage

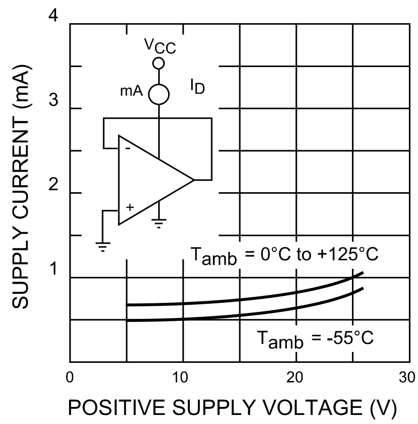


Figure 8: Gain bandwidth product vs. temperature

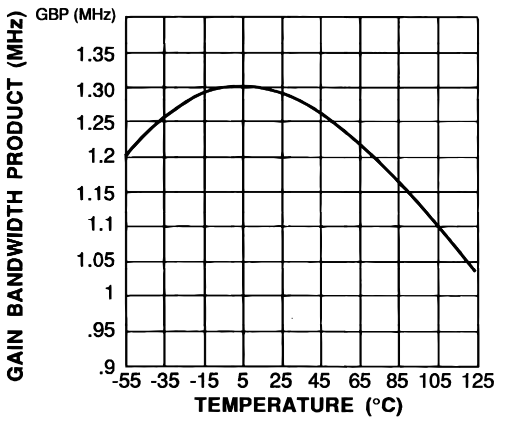


Figure 9: Common-mode rejection ratio

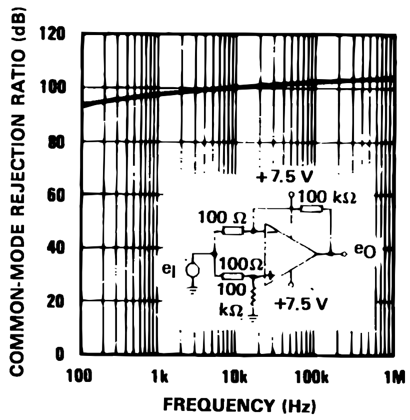


Figure 10: Open loop frequency response

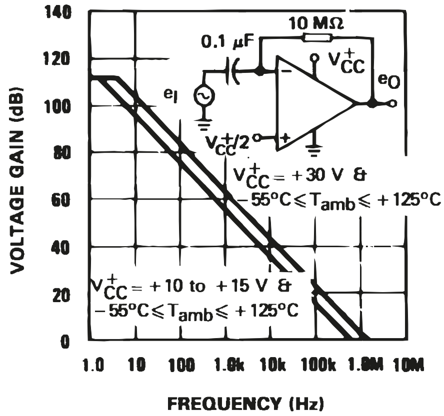


Figure 11: Large signal frequency response

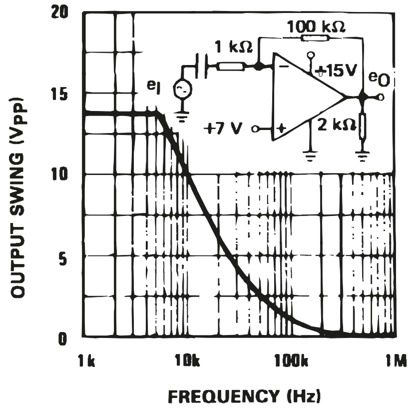


Figure 12: Voltage follower pulse response

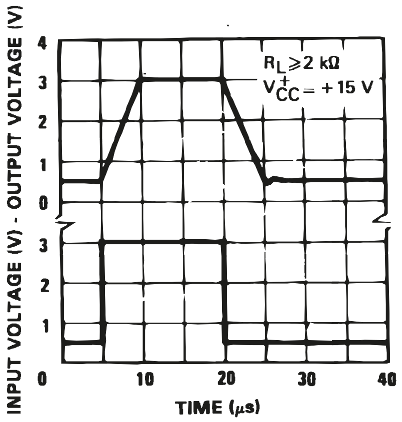


Figure 13: Output characteristics (current sinking)

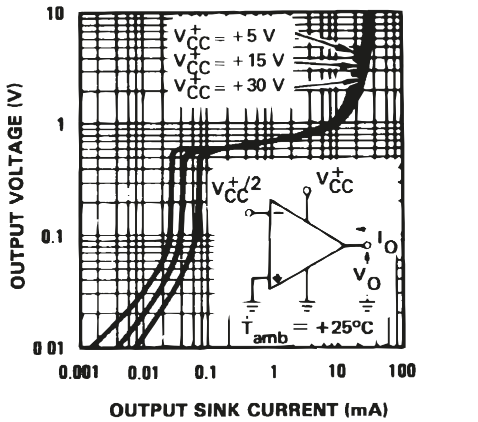


Figure 14: Voltage follower pulse response (small signal)

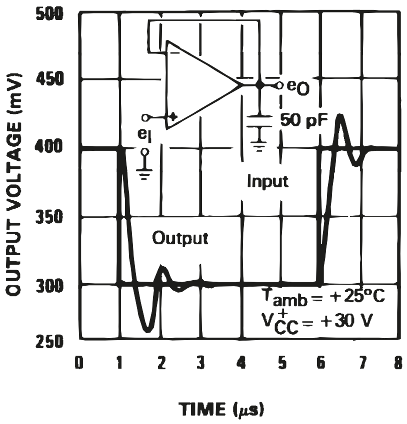


Figure 15: Output characteristics (current sourcing)

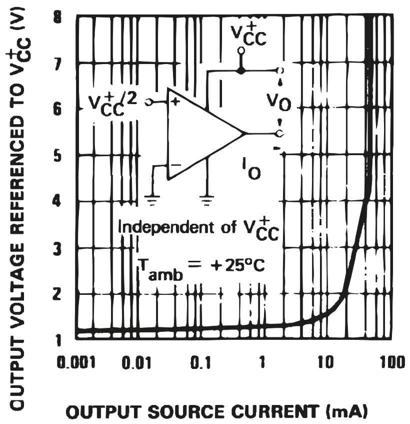


Figure 16: Input current vs. supply voltage

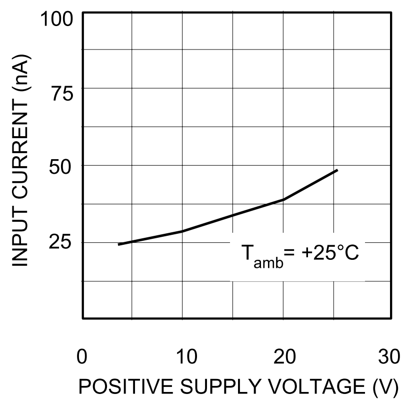


Figure 17: Large signal voltage gain vs. temperature

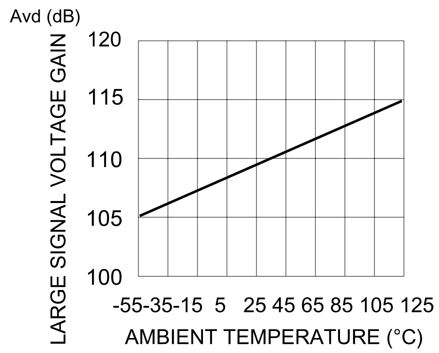


Figure 18: Power supply and common mode rejection ratio vs. temperature

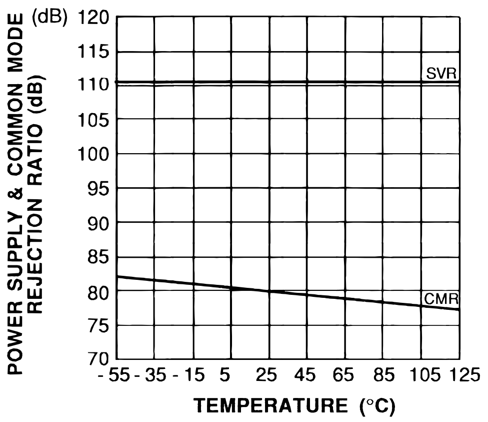
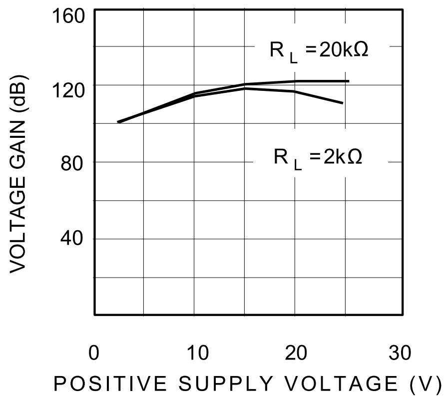


Figure 19: Voltage gain vs. supply voltage



5 Typical single-supply applications

Figure 20: AC coupled inverting amplifier

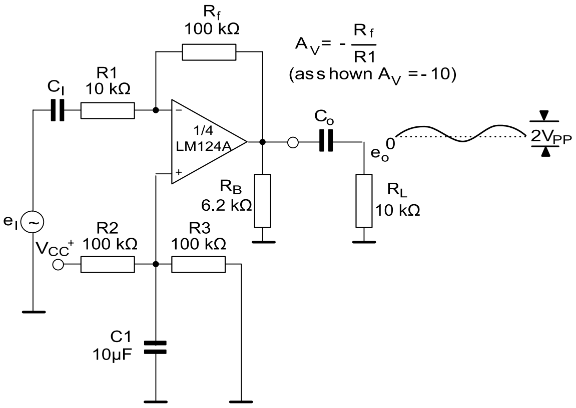


Figure 21: High input Z adjustable gain DC instrumentation amplifier

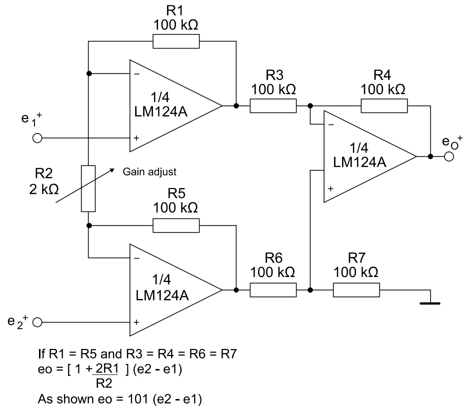


Figure 22: AC coupled non inverting amplifier

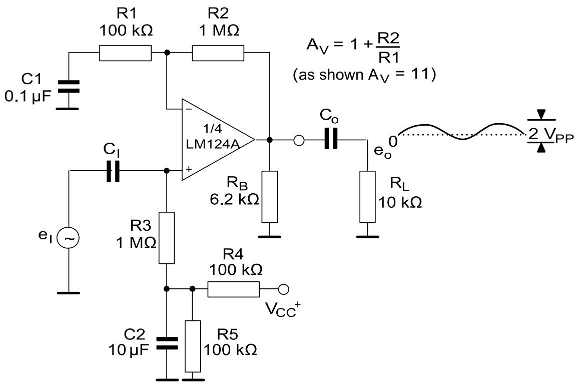


Figure 23: DC summing amplifier

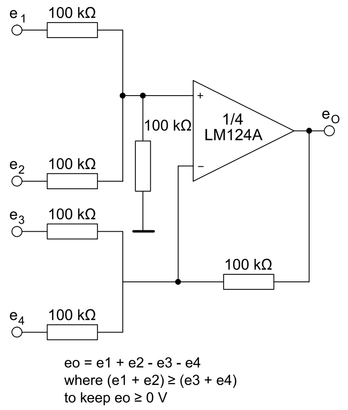


Figure 24: Non-inverting DC gain

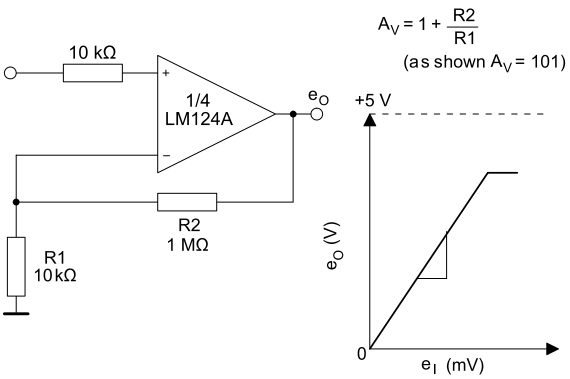


Figure 25: Low drift peak detector

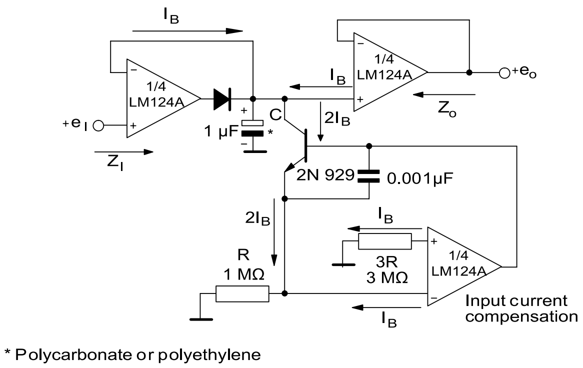


Figure 26: Active bandpass filter

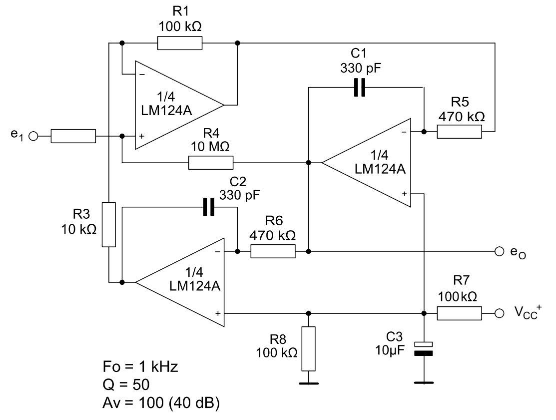


Figure 27: High input Z, DC differential amplifier

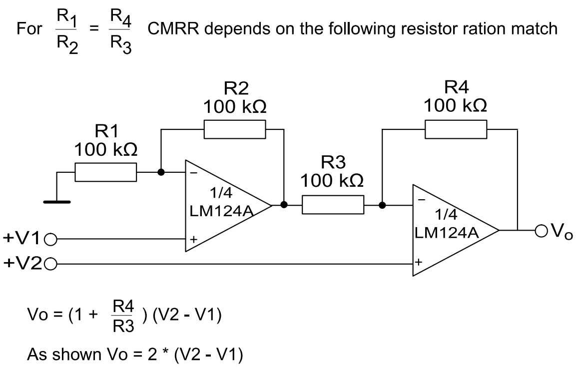
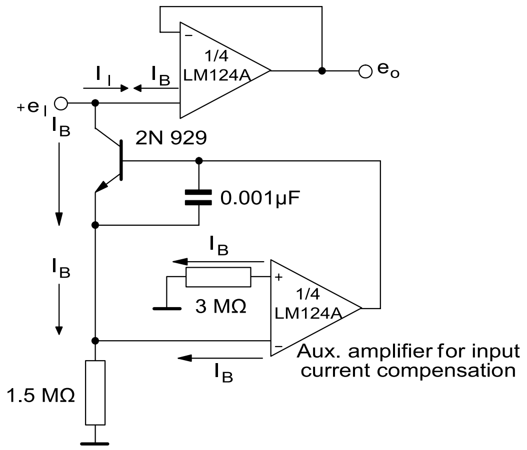


Figure 28: Using symmetrical amplifiers to reduce input current (general concept)



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***. ECOPACK® is an ST trademark.

6.1 QFN16 3x3 package information

Figure 29: QFN16 3x3 package outline

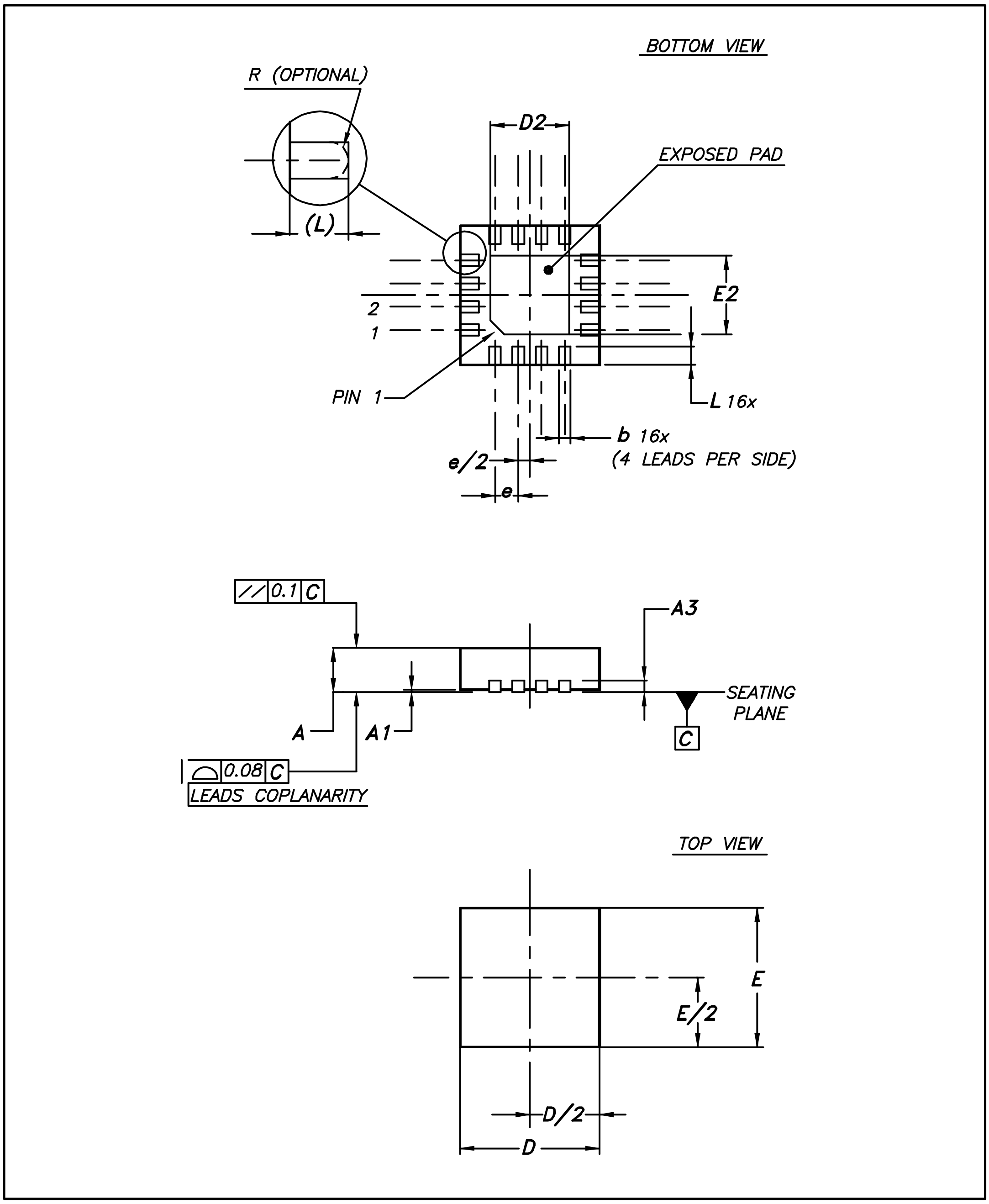
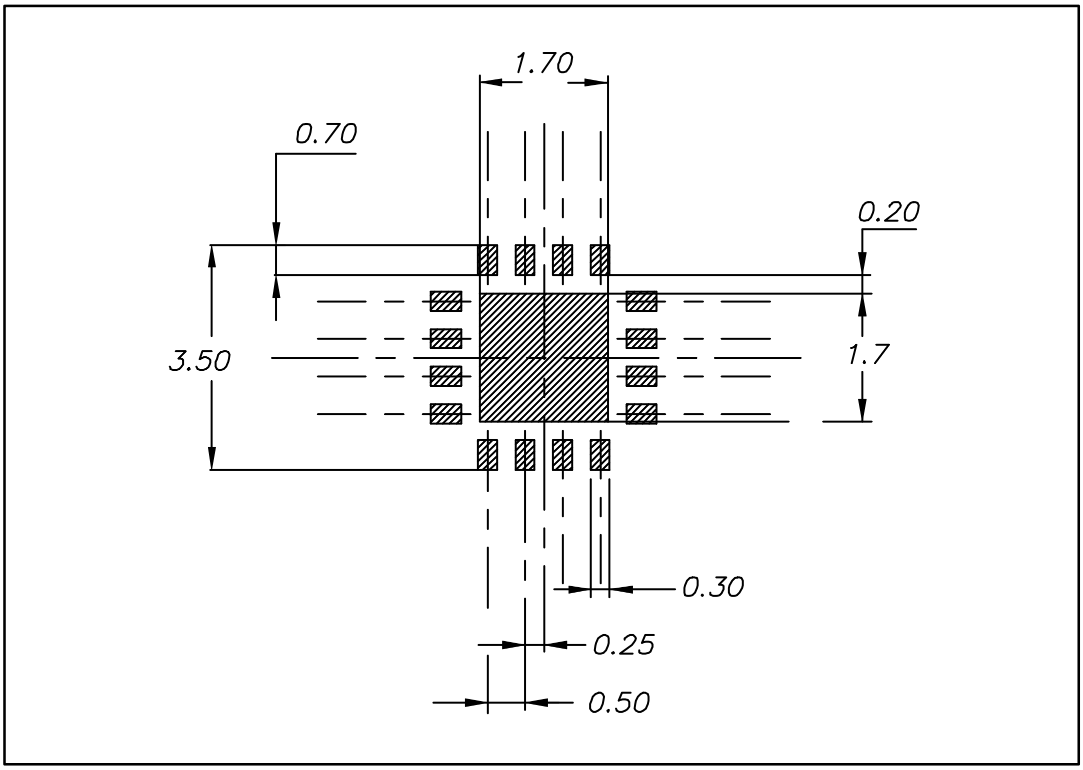


Table 5: QFN16 3x3 mechanical data

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

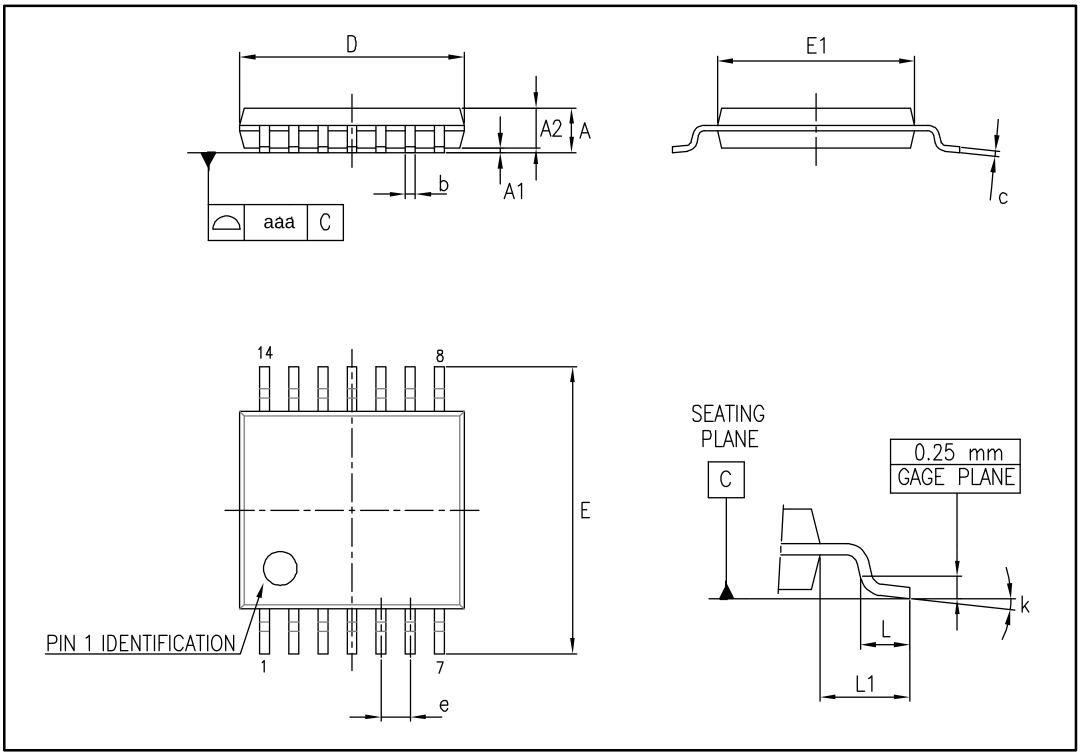


Table 6: TSSOP14 mechanical data

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

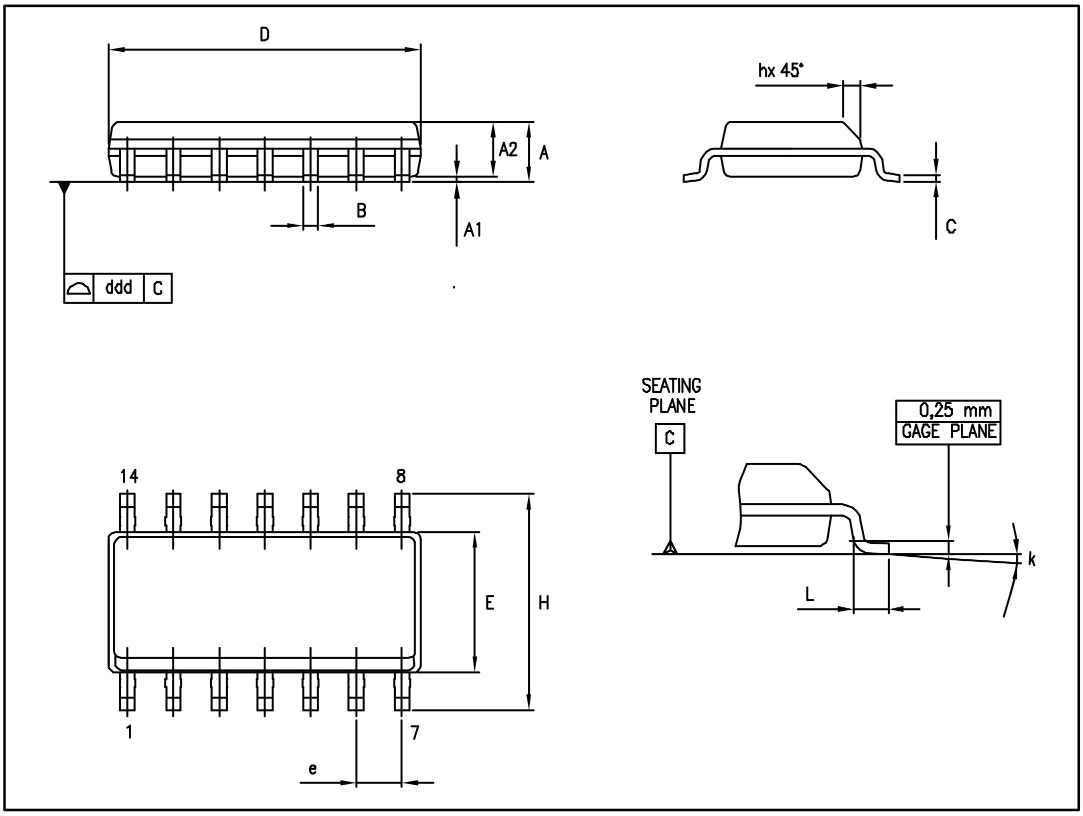


Table 7: SO14 mechanical data

Ref.	Dimensions					
	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

7 Ordering information

Table 8: Order codes

<table>
<tr><th>Order code</th><th>Temperature range</th><th>ESD (HBM, CDM)</th><th>V_{io} max @ 25 °C</th><th>Package</th><th>Marking</th></tr>
<tr><td>LM124DT</td><td>-55 °C to 125 °C</td><td>250 V, 1.5 kV</td><td>5 mV</td><td rowspan="2">SO14</td><td>124</td></tr>
<tr><td>LM224ADT</td><td rowspan="6">-40 °C to 105 °C</td><td rowspan="2">800 V, 1.5 kV</td><td rowspan="2">3 mV</td><td rowspan="2">224A</td></tr>
<tr><td>LM224APT</td><td>TSSOP14</td></tr>
<tr><td>LM224DT</td><td rowspan="3">250 V, 1.5 kV</td><td rowspan="3">5 mV</td><td>SO14</td><td rowspan="2">224</td></tr>
<tr><td>LM224PT</td><td>TSSOP14</td></tr>
<tr><td>LM224QT</td><td>QFN16 3x3</td><td>K425</td></tr>
<tr><td>LM224WDT</td><td>700 V, 1.5 kV</td><td rowspan="7">3 mV</td><td rowspan="2">SO14</td><td>224W</td></tr>
<tr><td>LM324ADT</td><td rowspan="9">0 °C to 70 °C</td><td rowspan="2">800 V, 1.5 kV</td><td rowspan="2">324A</td></tr>
<tr><td>LM324APT</td><td>TSSOP14</td></tr>
<tr><td>LM324AWDT</td><td rowspan="4">700 V, 1.5 kV</td><td>SO14</td><td rowspan="2">324AW</td></tr>
<tr><td>LM324AWPT</td><td>TSSOP14</td></tr>
<tr><td>LM324WDT</td><td>SO14</td><td rowspan="2">324W</td></tr>
<tr><td>LM324WPT</td><td>TSSOP14</td></tr>
<tr><td>LM324DT</td><td rowspan="3">250 V, 1.5 kV</td><td rowspan="3">5 mV</td><td>SO14</td><td rowspan="2">324</td></tr>
<tr><td>LM324PT</td><td>TSSOP14</td></tr>
<tr><td>LM324QT</td><td>QFN16 3x3</td><td>K427</td></tr>
</table>

8 Revision history

Table 9: 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. 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 Table 1: Device summary: Removed order codes LM224AN, LM224AD, LM324AN, and LM324AD; updated packaging. Table 2: Absolute maximum ratings: removed N suffix power dissipation data; updated footnotes 5 and 6. Renamed Figure 3, Figure 4, Figure 6, Figure 7, Figure 16, Figure 17, Figure 18, and Figure 19. Updated axes titles of Figure 4, Figure 5, Figure 7, and Figure 17. Removed duplicate figures. 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.

IMPORTANT NOTICE – PLEASE READ CAREFULLY