Datasheet

Low-power quad operational amplifiers





TSSOP14



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

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 LM124, LM224x, LM324x

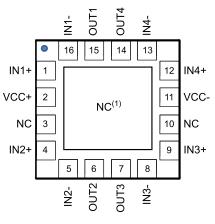
Product reference	Part numbers
LM124 ⁽¹⁾	LM124
LM224x	LM224, LM224A ⁽²⁾ , LM224W ⁽³⁾
LM324x	LM324, LM324A, LM324W ⁽³⁾

- 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.

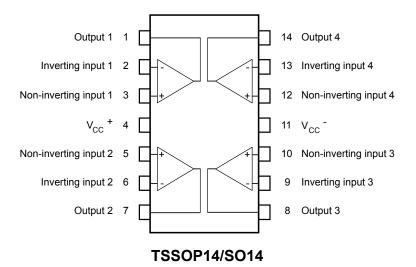


1 Pin connections and schematic diagram

Figure 1. Pin connections (top view)



QFN16 3x3



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

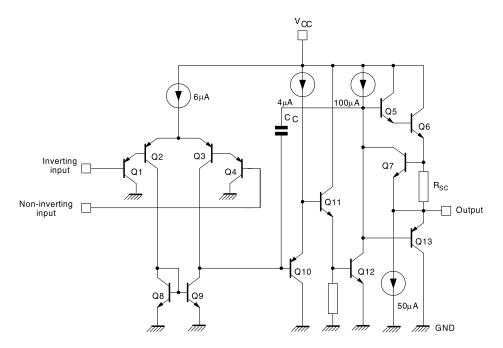
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6μΑ 4μΑ 100µA Q5 Cc Q6 Q2 Q3 Inverting input Q7 Q4 ${\rm R}_{\rm SC}$ 7111 Non-inverting input Q11 Output Q13 Q10 Q12 50µA ₩ GND

Figure 2. Schematic diagram (LM224A, LM324A, LM224W, LM324W, one channel)

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



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2 Absolute maximum ratings and operating conditions

Table 1. Absolute maximum ratings

Symbol	Parameter	Value	Unit	
V_{CC}	Supply voltage		±16 or 32	
	Input voltage		-0.3 to V _{CC} + 0.3	
V _i	LM224A, LM324A, LM224W, LM324W		0.0 10 10 10.0	V
٧١	Input voltage		-0.3 to 32	•
	LM124, LM224, LM324		-0.0 to 02	
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	
Tj	Maximum junction temperature	150	- "C	
		QFN16 3x3	45	
R_{thja}	Thermal resistance junction to ambient (4)	TSSOP14	100	
		SO14	103	°C/W
		QFN16 3x3	14	C/VV
R_{thjc}	Thermal resistance junction to case	TSSOP14	32	
		SO14	31	
		LM224A, LM324A	800	
	HBM: human body model (5)	LM224W, LM324W	700	
ESD		250	V	
	MM: machine model ⁽⁶⁾	100		
	CDM: charged device model		1500	

- 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.
- Short-circuits can cause excessive heating. Destructive dissipation can result from simultaneous shortcircuits 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 $k\Omega$ 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 Ω), done for all couples of pin
 combinations with other pins floating.

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Table 2. Operating conditions

Symbol	Parameter	Value	Unit	
V _{CC}	Supply voltage	Single supply	3 to 30	
VCC	Supply voltage	Dual supply	±1.5 to ±15	
View	Common-mode input voltage range Tamb= 25 °C	0 to V _{CC} - 1.5	V	
V _{ICM}	Common-mode input voltage range Tmin. ≤ Tamb ≤ Tmax.	0 to V _{CC} -2		
		LM124	-55 to 125	
T _{Oper}	Operating temperature range	LM224	-40 to 105	°C
		LM324	0 to 70	

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3 Electrical characteristics

Table 3. V_{CC} + = 5 V, V_{CC} - = ground, V_o = 1.4 V, T_{amb} = 25 °C (unless otherwise specified)

Symbol	Р	Min.	Тур.	Max.	Unit			
V _{io}		T _{amb} = 25 °C			2	3		
LM224A, LM324A, LM224W, LM324W		T _{min} ≤ T _{amb} ≤ T _{max}				5		
V _{io}	Input offset voltage (1)	T _{amb} = 25 °C	LM124 LM224		2	5	mV	
LM124,		dilib	LM324		2	7		
LM224,			LM124			_	-	
LM324		$T_{min} \le T_{amb} \le T_{max}$	LM224			7		
			LM324			9		
	Input offeet ourrent	T _{amb} = 25 °C			2	20		
l _{io}	Input offset current	$T_{min} \le T_{amb} \le T_{max}$				40	200	
I _{ib}	Input bias current (2)	T _{amb} = 25 °C			20	100	nA -	
		$T_{min} \le T_{amb} \le T_{max}$				200		
Λ .	Large signal voltage gain, V _{CC +} = 15 V,	T _{amb} = 25 °C		50	100		V/mV	
A_{vd}	$R_L = 2 k\Omega$, $V_0 = 1.4 V$ to 11.4 V	$T_{min} \le T_{amb} \le T_{max}$		25			V/mv	
	Supply voltage rejection ratio,	T _{amb} = 25 °C		65	110			
SVR	$R_S \le 10 \text{ k}\Omega$, $V_{CC} + 5 \text{ V to } 30 \text{ V}$	T _{min} ≤ T _{amb} ≤ T _{max}		65			dB	
		T_{amb} = 25 °C, V_{CC} = 5V			0.7	1.2		
	Complete surrent all areas and lead	T _{amb} = 25 °C, V _{CC} = 30 V			1.5	3		
I _{CC}	Supply current, all amps, no load	$T_{min} \le T_{amb} \le T_{max}, V_{CC} = 5 V$			0.8	1.2	mA	
		$T_{min} \le T_{amb} \le T_{max}, V_{CC} = 30 V$			1.5	3		
\/	(3)	V _{CC} = 30 V, T _{amb} = 25 °C		0		28.5		
V _{icm}	Input common mode voltage range (3)	V_{CC} = 30 V, $T_{min} \le T_{amb} \le T_{max}$		0		28	V	
CMD	Common mode rejection ratio,	T _{amb} = 25 °C		70	80		40	
CMR	$R_{s} \le 10 \text{ k}\Omega$	$T_{min} \le T_{amb} \le T_{max}$		60			dB	
I _{source}	Output current source, V _{id} = 1 V	V _{CC} = 15 V, V _o = 2 V		20	40	70	, and A	
1.	Output sink surrent V = 4 V	V _{CC} = 15 V, V _o = 2 V		10	20		mA	
I _{sink}	Output sink current, V _{id} = -1 V	V _{CC} = 15 V, V _o = 0.2 V		12	50		μA	

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Symbol		Min.	Тур.	Max.	Unit	
	High level output voltage, V _{CC} = 30 V,	T _{amb} = 25 °C	26	27		
	$R_L = 2 k\Omega$	$T_{min} \le T_{amb} \le T_{max}$	26			
Van	High level output voltage, V _{CC} = 30 V,	T _{amb} = 25 °C	27	28		V
V _{OH}	$R_L = 10 \text{ k}\Omega$	$T_{min} \le T_{amb} \le T_{max}$	27			V
	High level output voltage, V _{CC} = 5 V,	T _{amb} = 25 °C	3.5			
	$R_L = 2 k\Omega$	$T_{min} \le T_{amb} \le T_{max}$	3			
.,	Low level output voltage, $R_L = 10 \text{ k}\Omega$	T _{amb} = 25 °C		5	20	mV
V _{OL}		$T_{min} \le T_{amb} \le T_{max}$			20	IIIV
SR	Slew rate	V_{CC} = 15 V, V_i = 0.5 to 3 V, R_L = 2 k Ω , 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 k Ω , C_{L} =100 pF		1.3		MHz
THD	Total harmonic distortion	$f = 1kHz$, $A_V = 20 dB$, $R_L = 2 k\Omega$, $V_0 = 2 V_{pp}$, $C_L = 100 pF$, $V_{CC} = 30 V$		0.015		%
e _n	Equivalent input noise voltage	$f = 1 \text{ kHz}, R_s = 100 \Omega, V_{CC} = 30 \text{ V}$		40		nV/√Hz
DV _{io}	Input offset voltage drift			7	30	μV/°C
DI _{io}	Input offset current drift			10	200	pA/°C
V ₀₁ /V ₀₂	Channel separation (4)	1 kHz ≤ f ≤ 20 kHZ		120		kHz

^{1.} $V_0 = 1.4 \text{ V}$, $R_S = 0 \Omega$, 5 V < V_{CC} + < 30 V, 0 < V_{ic} < V_{CC} + - 1.5 V

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^{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.

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 24 21 18 15 (nA) 12 9 6 3 -55 -35 -15 5 25 45 65 85 105 125 TEMPERATURE (°C)

Figure 5. Output current limitation

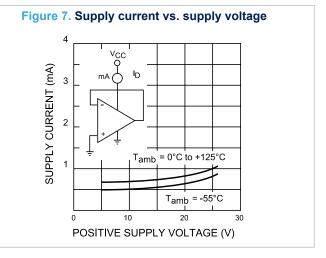
90
80
70
60
40
30
-55 -35 -15 5 25 45 65 85 105 125

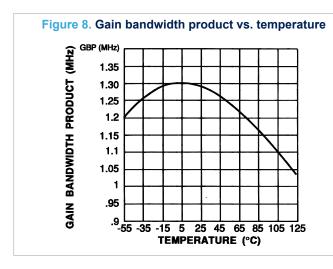
TEMPERATURE (°C)

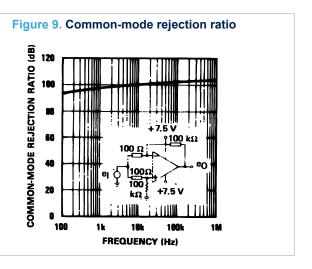
Figure 6. Input voltage range

Negative
Positive

Supply voltage (v)







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140 0.1 μF 120 VOLTAGE GAIN (dB) 100 +30 V & 55°C ≤ T_{amb} ≤ + 125°C 60

+10 to

10

55°C ≤ T_{amb} ≤ + 125°C

100 1.0k

FREQUENCY (Hz)

10k 100k 1.8M 10M

40

20

Figure 10. Open loop frequency response

100 kΩ 15 OUTPUT SWING (VPP) 10 5 14 100k FREQUENCY (Hz)

Figure 11. Large signal frequency response

Figure 12. Voltage follower pulse response

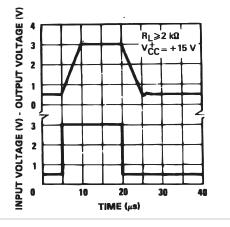


Figure 13. Output characteristics (current sinking)

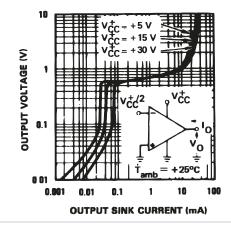


Figure 14. Voltage follower pulse response (small signal)

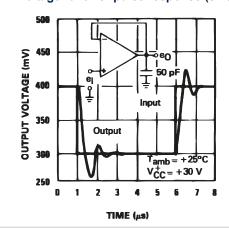
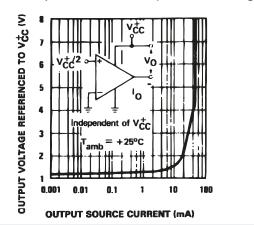


Figure 15. Output characteristics (current sourcing)



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Figure 16. Input current vs. supply voltage

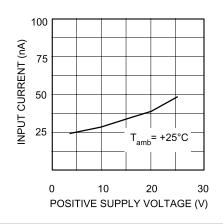


Figure 17. Large signal voltage gain vs. temperature

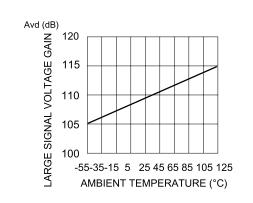


Figure 18. Power supply and common mode rejection ratio vs. temperature

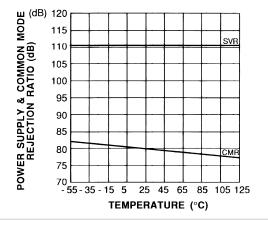
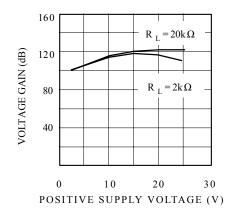


Figure 19. Voltage gain vs. supply voltage



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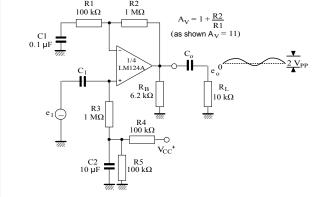
Typical single-supply applications 5

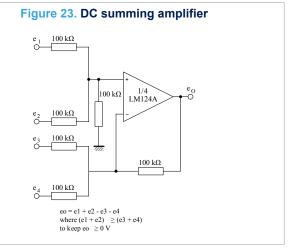
Figure 20. AC coupled inverting amplifier R_f 100 k Ω R1 10 kΩ (As shown Av =- 10) R_B 6.2 k Ω 10 kΩ R3 100 kΩ C1 10µF

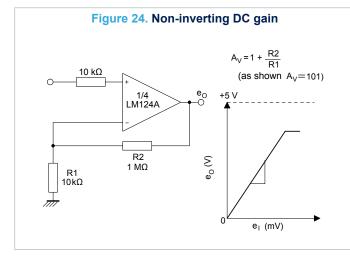
Figure 21. High input Z adjustable gain DC instrumentation amplifier R1 100 kΩ R4 100 kΩ 1/4 LM124A R5 100 kΩ R6 100 kΩ If R1 = R5 and R3 = R4 = R6 = R7 eo = [1 + <u>2R1</u>] (e2 - e1) R2 As shown eo = 101 (e2 - e1)

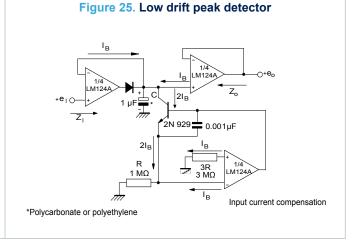
 $_{100\;k\Omega}^{R1}$

Figure 22. AC coupled non inverting amplifier









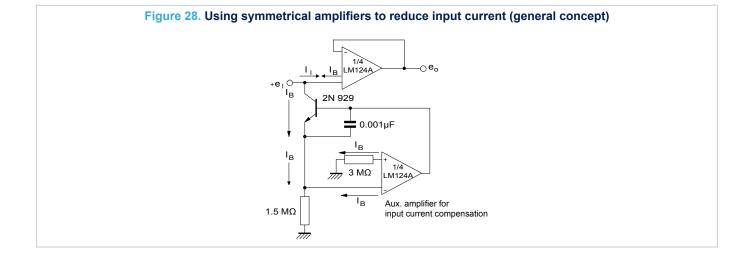
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Figure 26. Active bandpass filter $\begin{array}{c} R1 \\ 100 \, \mathrm{k}\Omega \\ \hline \\ 100 \, \mathrm{k}\Omega \\ \\$

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 $\frac{R_1^2}{100 \text{ k}\Omega} = \frac{R_4}{R_3} \text{ CMRR depends on the following resistor ration match}$ $\frac{R_1^2}{100 \text{ k}\Omega} = \frac{R_4}{100 \text{ k}\Omega} = \frac{R_4$



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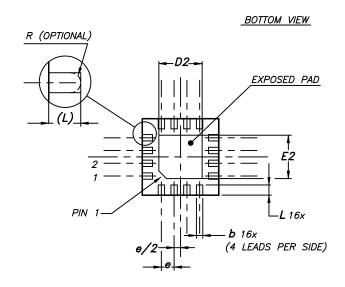


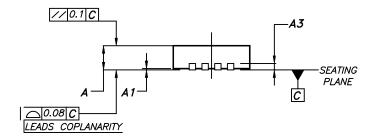
6 Package information

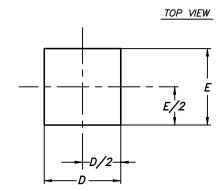
In order to meet environmental requirements, ST offers these devices in different grades of ECOPACK packages, depending on their level of environmental compliance. ECOPACK specifications, grade definitions and product status are available at: www.st.com. ECOPACK is an ST trademark.

6.1 QFN16 3x3 package information

Figure 29. QFN16 3x3 package outline







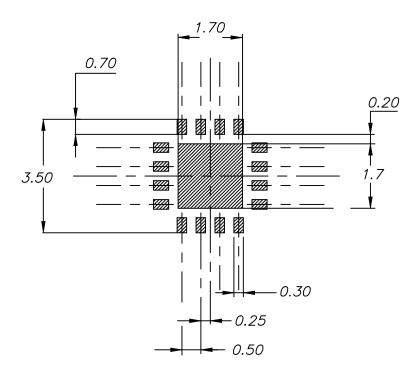
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Table 4. QFN16 3x3 mechanical data

	Dimensions							
Ref.		Millimeters		Inches				
	Min.	Тур.	Max.	Min.	Тур.	Max.		
А	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		
е		0.50			0.020			
L	0.30		0.50	0.012		0.020		

Figure 30. QFN16 3x3 recommended footprint



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6.2 TSSOP14 package information

Figure 31. TSSOP14 package outline

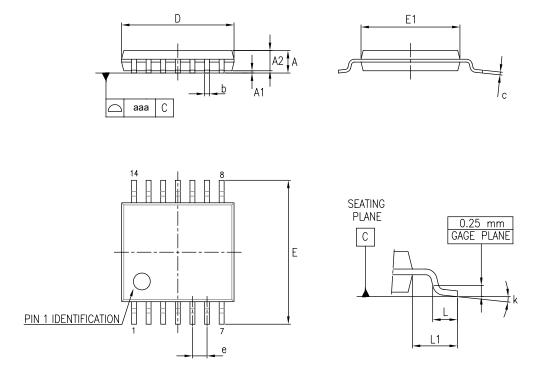


Table 5. TSSOP14 package mechanical data

	Dimensions							
Ref.		Millimeters		Inches				
	Min.	Тур.	Max.	Min.	Тур.	Max.		
А			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		
С	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		
е		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		

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6.3 SO14 package information

Figure 32. SO14 package outline

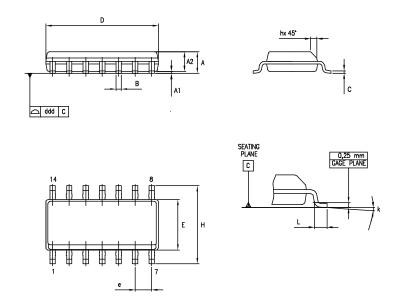


Table 6. SO14 package mechanical data

	Dimensions							
Ref.		Millimeters			Inches			
	Min.	Тур.	Max.	Min.	Тур.	Max.		
			1.75			0.069		
Α	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		
В	0.33		0.51	0.01		0.02		
С	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		
е		1.27			0.05			
Н	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		

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7 Ordering information

Table 7. Order codes

Order code	Temperature range	ESD (HBM, CDM)	V _{io} max. @ 25 °C	Package	Marking	
LM124DT	-55 °C to 125 °C	250 V, 1.5 kV	5 mV	SO14	124	
LM224ADT		800 V, 1.5 kV	3 mV	3014	224A	
LM224APT		000 V, 1.5 KV	31117	TSSOP14	224A	
LM224DT	-40 °C to 105 °C			SO14	224	
LM224PT	-40 C to 105 C	250 V, 1.5 kV	5 mV	TSSOP14	224	
LM224QT	-			QFN16 3x3	K425	
LM224WDT		700 V, 1.5 kV		SO14	224W	
LM324ADT		800 V, 1.5 kV			3014	324A
LM324APT				TSSOP14	324A	
LM324AWDT			3 mV	SO14	324AW	
LM324AWPT				TSSOP14	324AVV	
LM324WDT	0 °C to 70 °C	700 V, 1.5 kV		SO14	324W	
LM324WPT				TSSOP14	32400	
LM324DT				SO14	224	
LM324PT		250 V, 1.5 kV	5 mV	TSSOP14	324	
LM324QT				QFN16 3x3	K427	

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Revision history

Table 8. Document revision history

Date	Revision	Changes
1-Mar-2001	1	First release
4 F-1- 000F		Added explanation of V _{id} and V _i limits in Table 2 on page 4.
1-Feb-2005	2	Updated macromodel.
1-Jun-2005	3	ESD protection inserted in Table 2 on page 4.
25-Sep-2006	4	Editorial update.
		Removed DIP package and all information pertaining to it
		Table 1: Device summary: Removed order codes LM224AN, LM224AD, LM324AN, and LM324AD; updated packaging.
22-Aug-2013	5	Table 2: Absolute maximum ratings: removed N suffix power dissipation data; updated footnotes 5 and 6.
22 / lug 2010		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.
09-Sep-2019	8	Updated cover page, Section 2 Absolute maximum ratings and operating conditions and Table 3. V_{CC} = ground, V_{o} = 1.4 V, T_{amb} = 25 °C (unless otherwise specified). Updated Figure 2. Schematic diagram (LM224A, LM324A, LM224W, LM324W, one channel) and Figure 3. Schematic diagram (LM124, LM224, LM324, one channel).

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