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 µA
- 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: ±1.5 V to ±15 V

Description

These circuits 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)

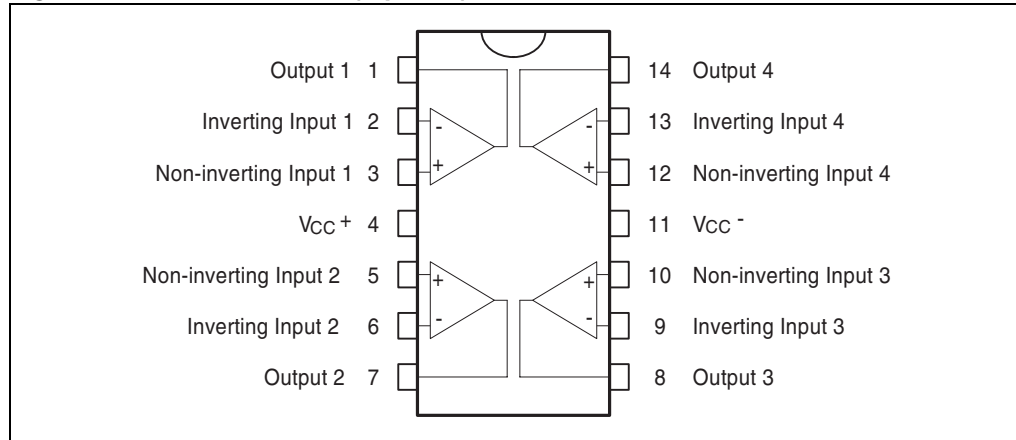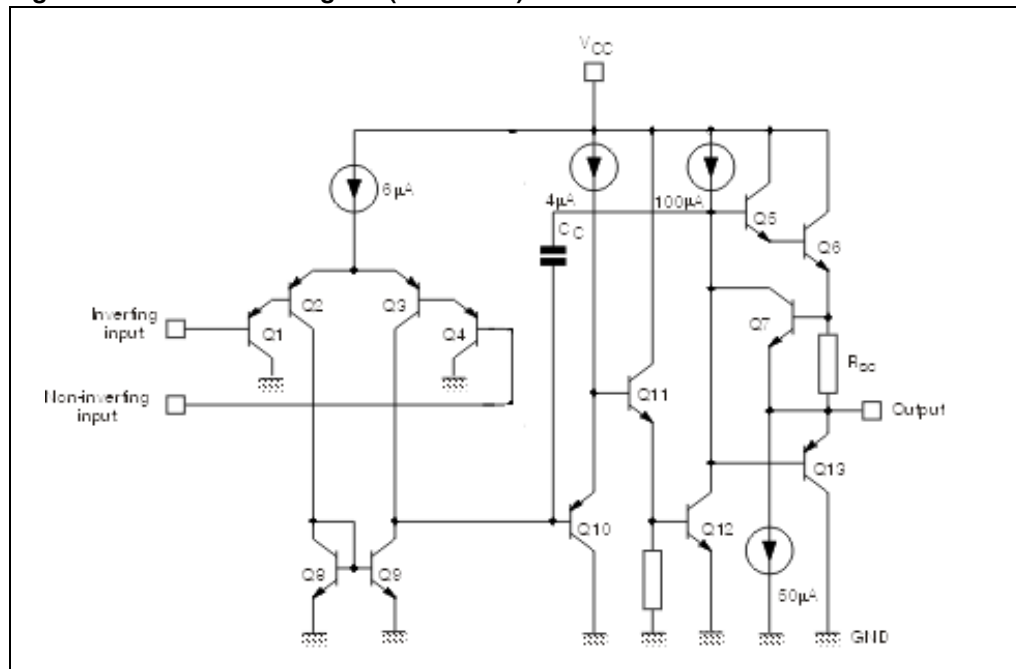# 1 Pin and schematic diagram

Figure 1.   Pin connections (top view)

Output 1	1	14 Output 4
Inverting Input 1	2	13 Inverting Input 4
Non-inverting Input 1	3	12 Non-inverting Input 4
V_{CC} +	4	11 V_{CC} -
Non-inverting Input 2	5	10 Non-inverting Input 3
Inverting Input 2	6	9 Inverting Input 3
Output 2	7	8 Output 3

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[1]	-0.3 to 32			V
V_{id}	Differential input voltage [2]	32			V
	Output short-circuit duration [3]	Infinite			
I_{in}	Input current [4]: V_{in} driven negative Input current [5]: 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[6] SO14 TSSOP14 DIP14	103 100 83			°C/W
R_{thjc}	Thermal resistance junction to case SO14 TSSOP14 DIP14	31 32 33			°C/W
ESD	HBM: human body model[7]	250			V
	MM: machine model[8]	150			
	CDM: charged device model[9]	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 µA max (R = (Vin - 32 V)/400 µA).

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 kΩ 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 Ω), 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 V, V_{CC}^-= ground, V_o = 1.4 V, T_{amb} = +25° C (unless otherwise specified)

Symbol	Parameter	Min.	Typ.	Max.	Unit

V_{io}	Input offset voltage [1]
	T_{amb} = +25° C
	  LM124-LM224
	  LM324
			2	5
				7
					mV

	$T_{min} \le T_{amb} \le T_{max}$
	  LM124-LM224
	  LM324
				7
				9	

I_{io}	Input offset current
	  T_{amb} = +25° C
	  $T_{min} \le T_{amb} \le T_{max}$
			2	30
				100
					nA

I_{ib}	Input bias current [2]
	  T_{amb} = +25° C
	  $T_{min} \le T_{amb} \le T_{max}$
			20	150
				300
					nA

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
	  $T_{min} \le T_{amb} \le T_{max}$
		50
		25
			100		V/mV

SVR	Supply voltage rejection ratio ($R_s \le$ 10 kΩ)
	V_{CC}^+ = 5 V to 30 V
	  T_{amb} = +25° C
	  $T_{min} \le T_{amb} \le T_{max}$
		65
		65
			110		dB

I_{CC}	Supply current, all Amp, no load
	T_{amb} = +25° C
	  V_{CC} = +5 V
	  V_{CC} = +30 V
			0.7
			1.5
				1.2
				3
					mA

	$T_{min} \le T_{amb} \le T_{max}$
	  V_{CC} = +5 V
	  V_{CC} = +30 V
			0.8
			1.5
				1.2
				3	

V_{icm}	Input common mode voltage range
	V_{CC} = +30 V [3]
	  T_{amb} = +25° C
	  $T_{min} \le T_{amb} \le T_{max}$
		0
		0
				V_{CC} -1.5
				V_{CC} -2
					V

CMR	Common mode rejection ratio ($R_s \le$ 10 kΩ)
	  T_{amb} = +25° C
	  $T_{min} \le T_{amb} \le T_{max}$
		70
		60
			80		dB

I_{source}	Output current source (V_{id} = +1 V) V_{CC} = +15 V, V_o = +2 V	20	40	70	mA

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

Symbol	Parameter	Min.	Typ.	Max.	Unit
I_{sink}	Output sink current (V_{id} = -1 V) V_{CC} = +15 V, V_o = +2 V V_{CC} = +15 V, V_o = +0.2 V	10 12	20 50		mA µA
V_{OH}	High level output voltage V_{CC} = +30 V T_{amb} = +25° C, R_L = 2 kΩ $T_{min} \leq T_{amb} \leq T_{max}$ T_{amb} = +25° C, R_L = 10 kΩ $T_{min} \leq T_{amb} \leq T_{max}$	26 26 27 27	27 28		V
	V_{CC} = +5 V, R_L = 2 kΩ T_{amb} = +25°C $T_{min} \leq T_{amb} \leq T_{max}$	3.5 3			
V_{OL}	Low level output voltage (R_L = 10 kΩ) T_{amb} = +25°C $T_{min} \leq T_{amb} \leq T_{max}$		5	20 20	mV
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 = 1 kHz, 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		$\frac{nV}{\sqrt{Hz}}$
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 $\leq$ f $\leq$ 20 kHZ		120		dB

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 change in the load 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. 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 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.

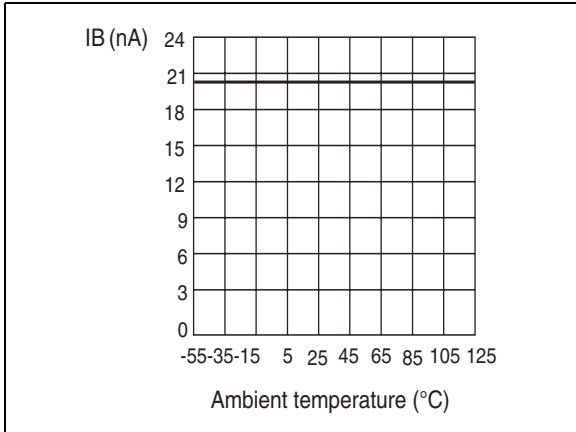**Figure 3.   Input bias current vs. ambient
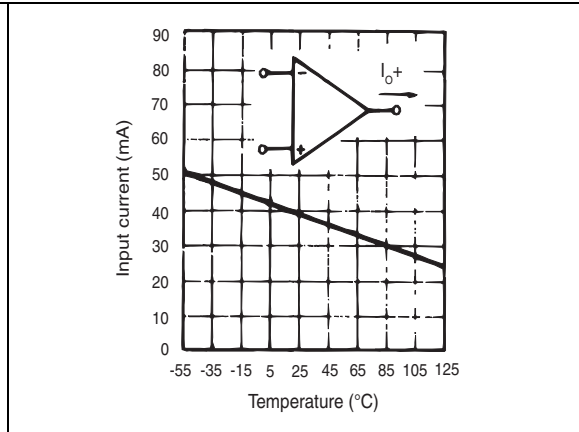temperature**

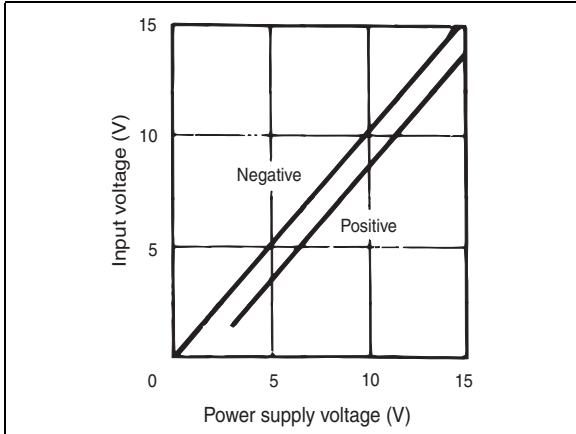**Figure 4.   Current limiting**

Figure 5.   Input voltage range

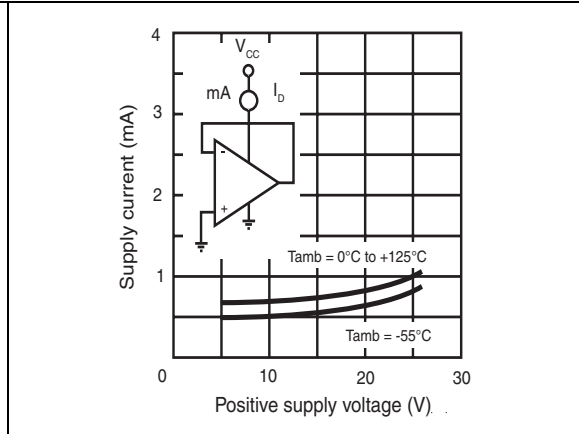
Figure 6.   Supply current

Figure 7.   Gain bandwidth product
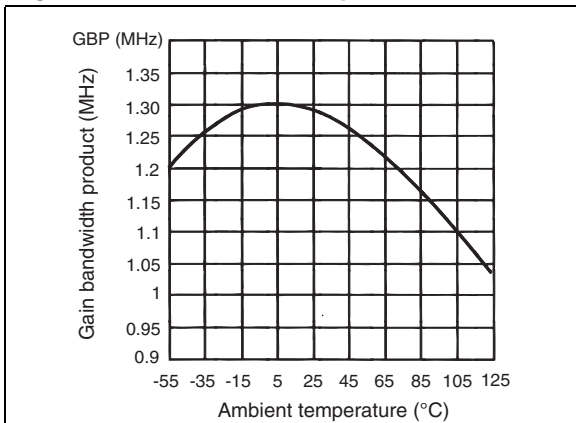

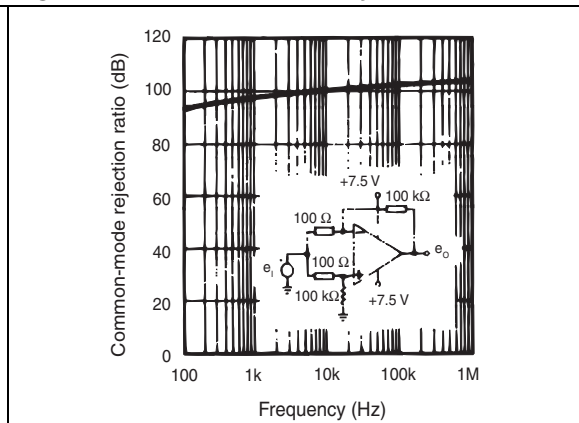**Figure 8.   Common mode rejection ratio**

Figure 9.   Open loop frequency response
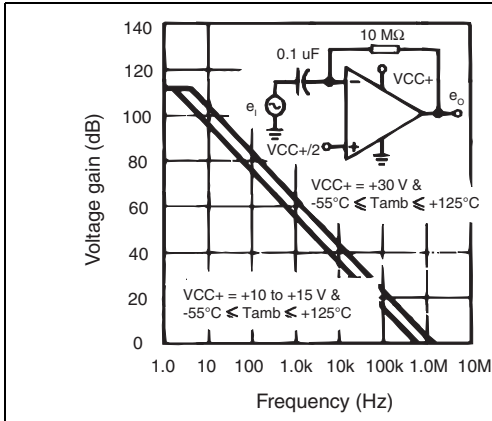

Figure 10.   Large signal frequency response
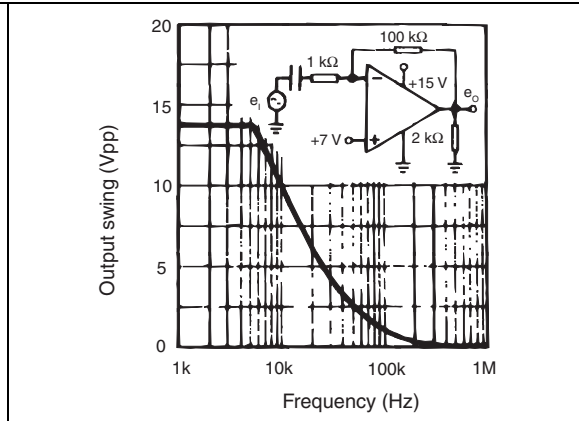

Figure 11.   Voltage follower pulse response
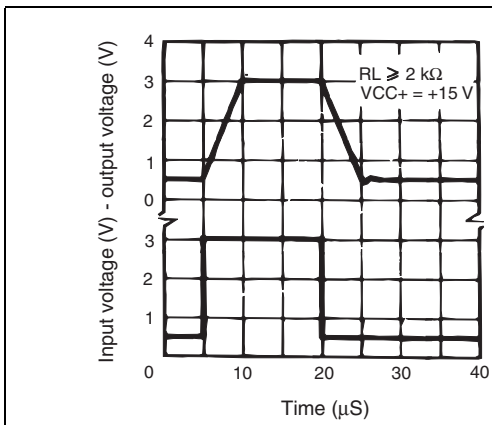

Figure 12.   Output characteristics (current sinking)
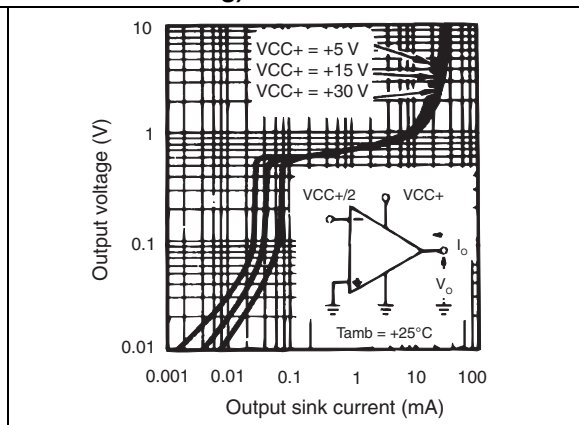

Figure 13.   Voltage follower pulse response (small signal)
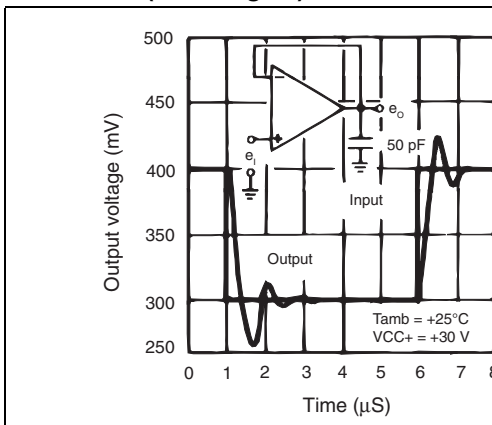

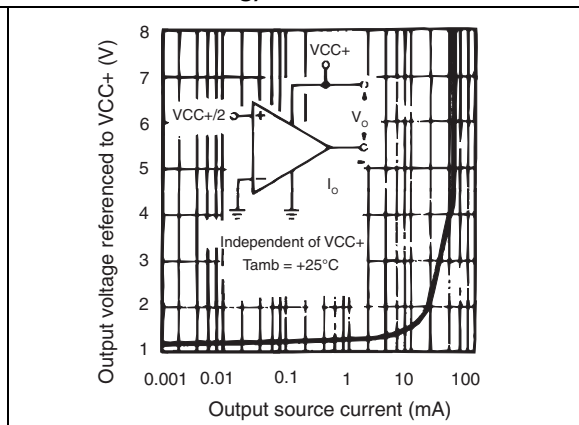**Figure 14.   Output characteristics (current sourcing)**
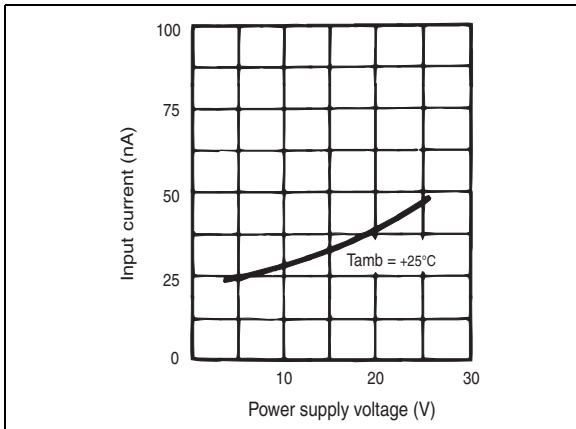
Figure 15. Input current

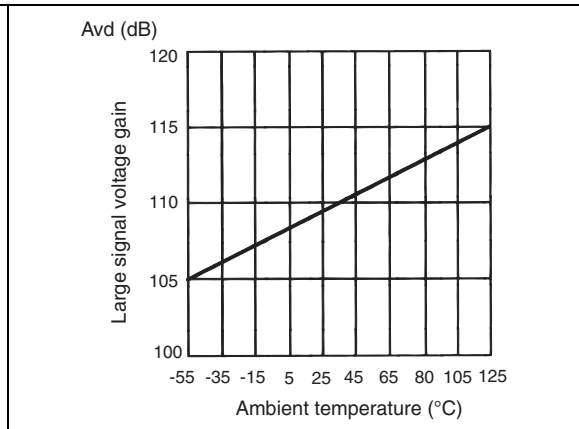**Figure 16. Large signal voltage gain**

Figure 17. Power supply and common mode rejection ratio
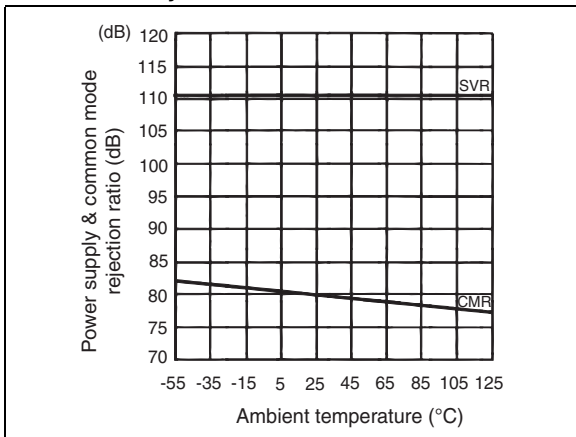
Figure 18. Voltage gain
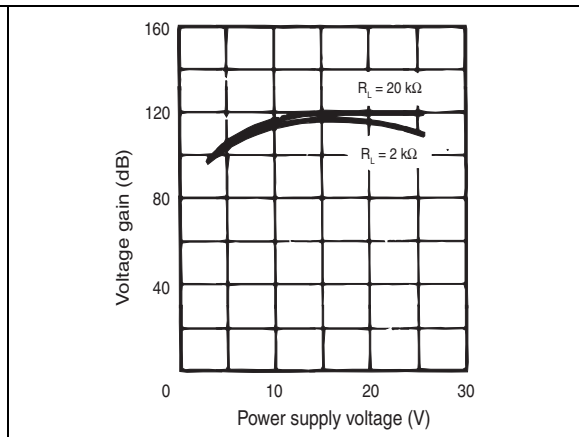
4　　Typical single-supply applications

Figure 19.　AC coupled inverting amplifier

$$A_V = -\frac{R_f}{R1}$$
(as shown $A_V = -10$)
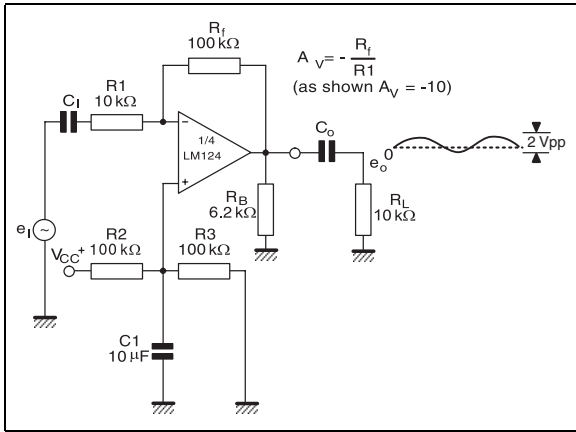
Figure 20.　High input Z adjustable gain DC instrumentation amplifier

if R1 = R5
and R3 = R4 = R6 = R7

$$e_0 = \left[1 + \frac{2R_1}{R_2}\right](e_2 - e_1)$$
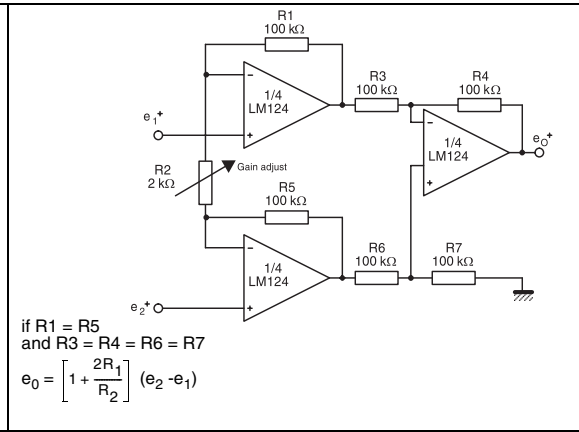
Figure 21.　AC coupled non inverting amplifier

$$A_V = 1 + \frac{R2}{R1}$$
(as shown $A_V = 11$)
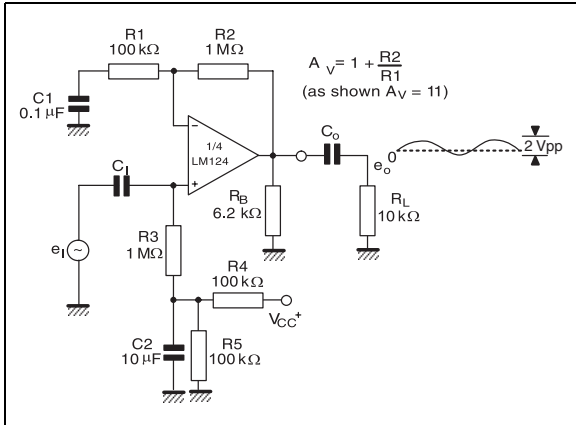
Figure 22.　DC summing amplifier

$e_0 = e_1 + e_2 - e_3 - e_4$
Where $(e_1 + e_2) \geq (e_3 + e_4)$
to keep $e_0 \geq 0V$
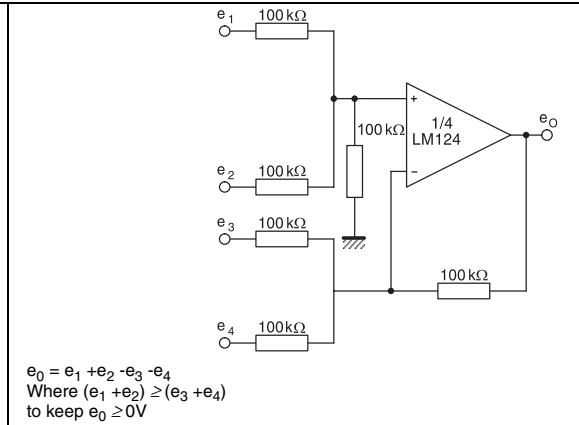
Figure 23.　Non-inverting DC gain

$$A_V = 1 + \frac{R2}{R1}$$
(As shown $A_V = 101$)
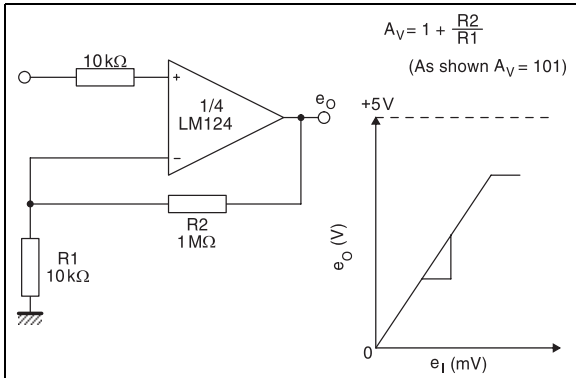
Figure 24.　Low drift peak detector

* Polycarbonate or polyethylene

Figure 25. Active bandpass filter

Figure 26. High input Z, DC differential amplifier
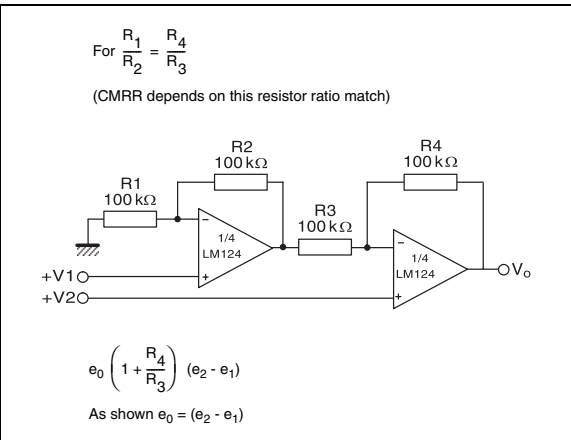
Figure 27. Using symmetrical amplifiers to reduce input current (general concept)
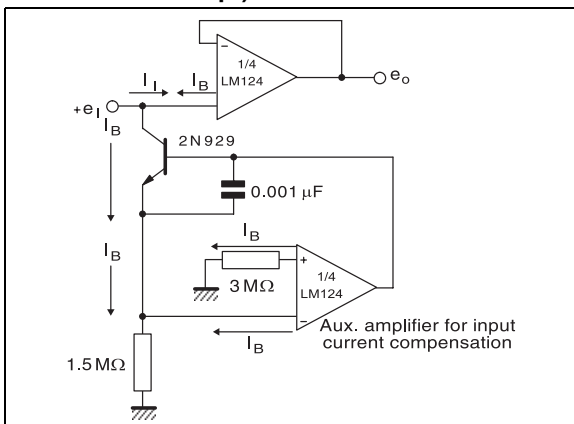
5   Macromodels

Note: *Please consider the following before using this macromodel:*

All models are a trade-off between accuracy and complexity (i.e. simulation time).

Macromodels are not a substitute to breadboarding; rather, they confirm the validity of a design approach and help to select surrounding component values.

A macromodel emulates the **nominal** *performance of a* **typical** *device within* **specified operating conditions** *(temperature, supply voltage, etc.). Thus the macromodel is often not as exhaustive as the datasheet, its purpose is to illustrate the main parameters of the product.*

Data derived from macromodels that is used outside of the specified conditions (V_{cc}, temperature, etc.) or even worse, outside of the device operating conditions (V_{cc}, V_{icm}, etc.) is not reliable in any way.

```
** Standard Linear Ics Macromodels, 1993.
** CONNECTIONS :
* 1 INVERTING INPUT
* 2 NON-INVERTING INPUT
* 3 OUTPUT
* 4 POSITIVE POWER SUPPLY
* 5 NEGATIVE POWER SUPPLY

.SUBCKT LM124 1 3 2 4 5
*****************************************************
.MODEL MDTH D IS=1E-8 KF=3.104131E-15 CJO=10F
* INPUT STAGE
CIP 2 5 1.000000E-12
CIN 1 5 1.000000E-12
EIP 10 5 2 5 1
EIN 16 5 1 5 1
RIP 10 11 2.600000E+01
RIN 15 16 2.600000E+01
RIS 11 15 2.003862E+02
DIP 11 12 MDTH 400E-12
DIN 15 14 MDTH 400E-12
VOFP 12 13 DC 0
VOFN 13 14 DC 0
IPOL 13 5 1.000000E-05
CPS 11 15 3.783376E-09
DINN 17 13 MDTH 400E-12
VIN 17 5 0.000000e+00
DINR 15 18 MDTH 400E-12
VIP 4 18 2.000000E+00
FCP 4 5 VOFP 3.400000E+01
FCN 5 4 VOFN 3.400000E+01
FIBP 2 5 VOFN 2.000000E-03
FIBN 5 1 VOFP 2.000000E-03
* AMPLIFYING STAGE
FIP 5 19 VOFP 3.600000E+02
FIN 5 19 VOFN 3.600000E+02
```
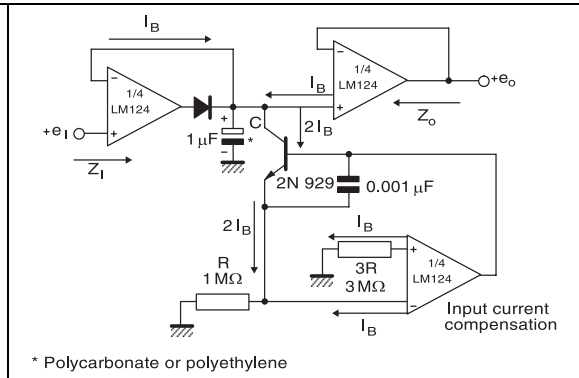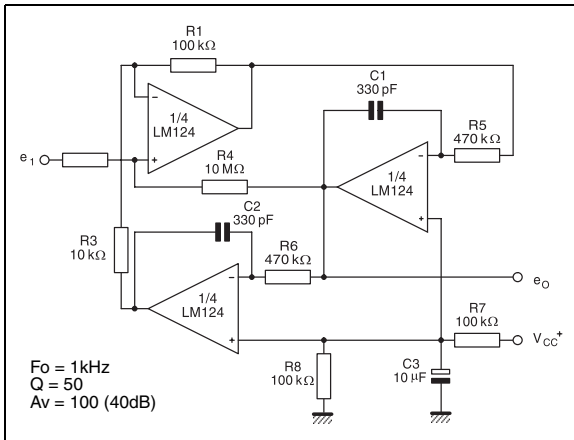
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RG1 19 5 3.652997E+06
RG2 19 4 3.652997E+06
CC 19 5 6.000000E-09
DOPM 19 22 MDTH 400E-12
DONM 21 19 MDTH 400E-12
HOPM 22 28 VOUT 7.500000E+03
VIPM 28 4 1.500000E+02
HONM 21 27 VOUT 7.500000E+03
VINM 5 27 1.500000E+02
EOUT 26 23 19 5 1
VOUT 23 5 0
ROUT 26 3 20
COUT 3 5 1.000000E-12
DOP 19 25 MDTH 400E-12
VOP 4 25 2.242230E+00
DON 24 19 MDTH 400E-12
VON 24 5 7.922301E-01
.ENDS
```

The values provided in *Table 3* are derived from this macromodel.

Table 3. V_{cc}^+ = +15 V, V_{cc}^- = 0 V, T_{amb} = 25°C (unless otherwise specified)

Symbol	Conditions	Value	Unit
V_{io}		0	mV
A_{vd}	R_L = 2 kΩ	100	V/mV
I_{cc}	No load, per amplifier	350	µA
V_{icm}		-15 to +13.5	V
V_{OH}	R_L = 2 kΩ (V_{CC}^+=15V)	+13.5	V
V_{OL}	R_L = 10 kΩ	5	mV
I_{os}	V_o = +2 V, V_{CC} = +15 V	+40	mA
GBP	R_L = 2 kΩ, C_L = 100 pF	1.3	MHz
SR	R_L = 2 kΩ, C_L = 100 pF	0.4	V/µs

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   DIP14 package information

Figure 28.   DIP14 package mechanical drawing
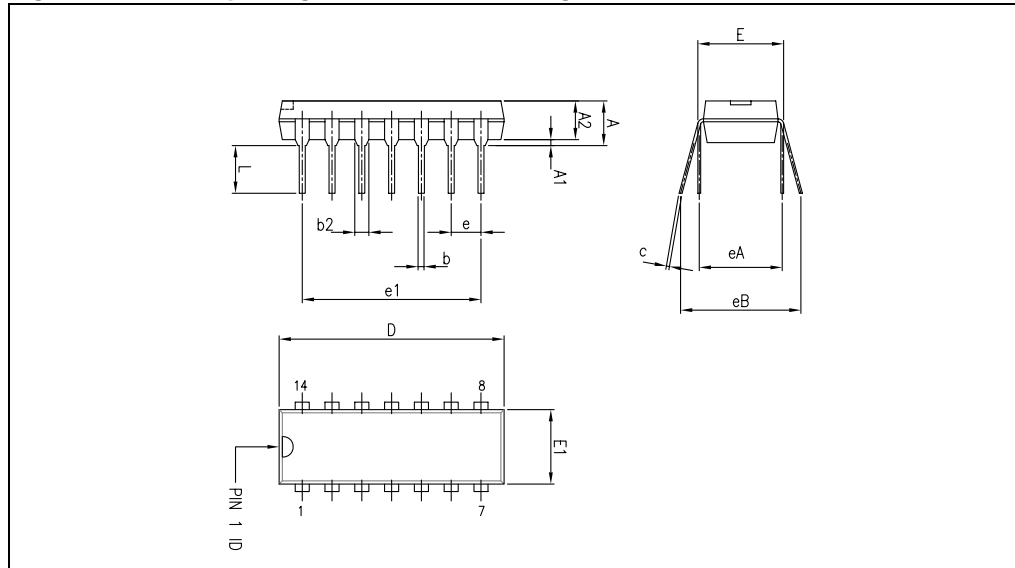
Table 4.   DIP14 package mechanical data

Ref.	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

6.2   SO-14 package information

Figure 29.   SO-14 package mechanical drawing
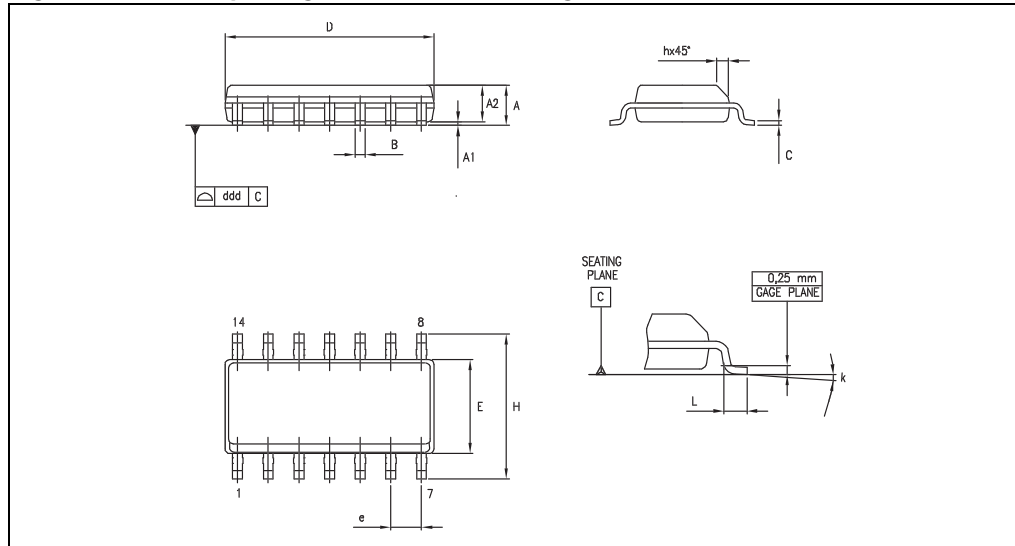
Table 5.   SO-14 package mechanical data

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

6.3   TSSOP14 package information

Figure 30.   TSSOP14 package mechanical drawing
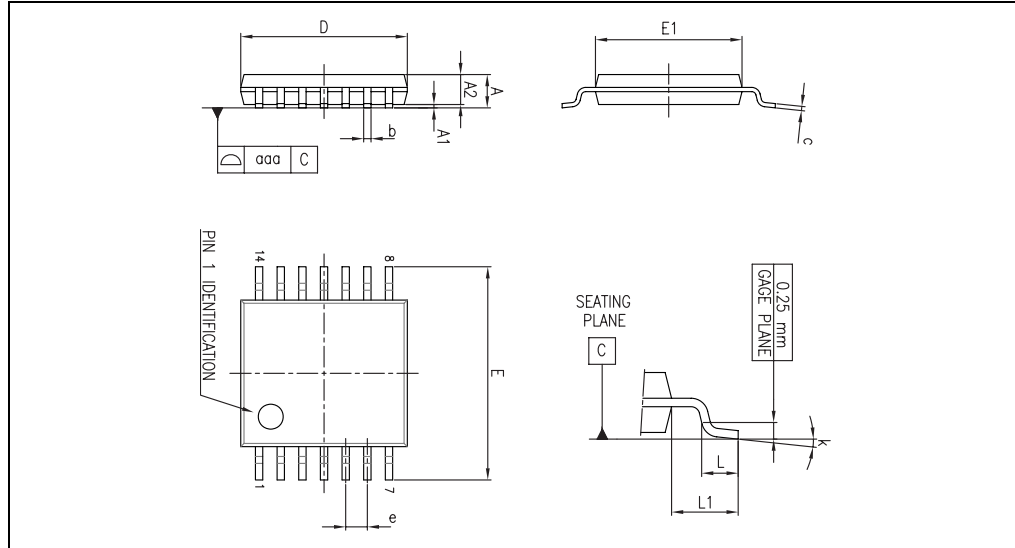
Figure 31.   TSSOP14 package mechanical data

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

7   Ordering information

Table 6.   Order codes

Part number	Temperature range	Package	Packing
LM124N	-55°C, +125°C	DIP14	Tube
LM124D/DT		SO-14	Tube or tape & reel
LM224N	-40°C, +105°C	DIP14	Tube
LM224D/DT		SO-14	Tube or tape & reel
LM224PT		TSSOP14 (Thin shrink outline package)	Tape & reel
LM324N	0°C, +70°C	DIP14	Tube
LM324D/DT		SO-14	Tube or tape & reel
LM324PT		TSSOP14 (Thin shrink outline package)	Tape & reel

8   Revision history

Table 7.   Document revision history

Date	Revision	Changes
01-Oct.-2003	1	First release.
02-Jan-2005	2	Modifications on AMR *Table 1 on page 3* (explanation of V_{id} and V_i limits).
01-Jun-2005	3	ESD protection inserted in *Table 1 on page 3*.
02-Jan-2006	4	T_j and R_{thjc} parameters added in *Table 1. on page 3*.
04-Oct-2006	5	Editorial update. *Table 3* moved to *Section 5: Macromodels on page 11*.
11-Jan-2010	6	Added AMR values for input current in *Table 1 on page 3*.

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