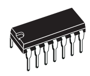
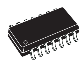
LM224A - LM324A

Low Power Quad Operational Amplifiers

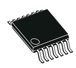
- **Wide gain bandwidth: 1.3MHz**
- **Large voltage gain: 100dB**
- **Very low supply current/ampli: 375µA**
- **Low input bias current: 20nA**
- **Low input offset voltage: 3mV max.**
- **Low input offset current: 2nA**
- **Wide power supply range:**
  Single supply: +3V to +30V
  Dual supplies: ±1.5V to ±15V
- **Input common-mode voltage range includes ground**
- **ESD internal protection: 2KV**



N
DIP14
(Plastic Package)



D
SO-14
(Plastic Micropackage)



P
TSSOP-14
(Thin Shrink Small Outline Package)

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.

All the pins are protected against electrostatic discharges up to 2KV (as a consequence, the input voltages must not exceed the magnitude of V_{CC}^{+} or V_{CC}^{-}.)

Order Codes

Part Number	Temperature Range	Package	Packaging
LM224AN	-40°C, +105°C	DIP	Tube
LM224AD/ADT		SO	Tube or Tape & Reel
LM224APT		TSSOP (Thin Shrink Outline Package)	Tape & Reel
LM324AN	0°C, +70°C	DIP	Tube
LM324AD/ADT		SO	Tube or Tape & Reel
LM324APT		TSSOP (Thin Shrink Outline Package)	Tape & Reel

1 Pin & Schematic Diagram

Figure 1: Pin connections (top view)

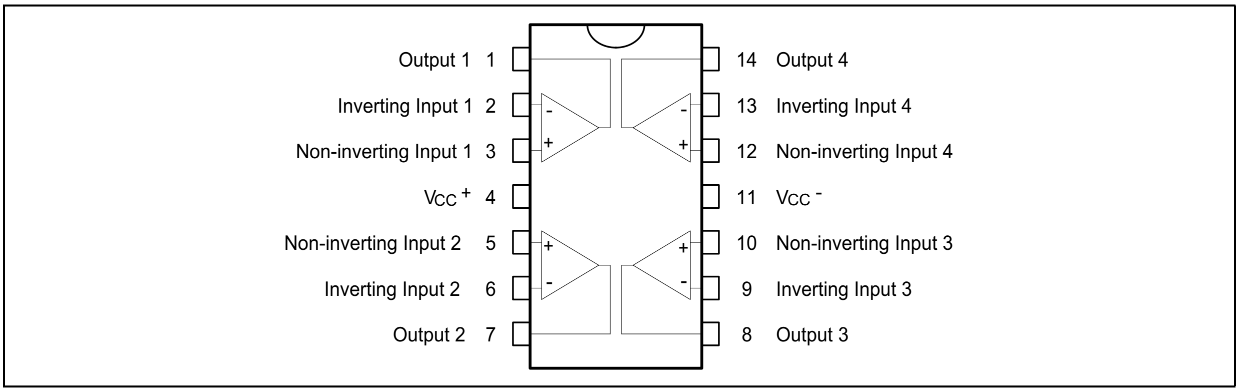
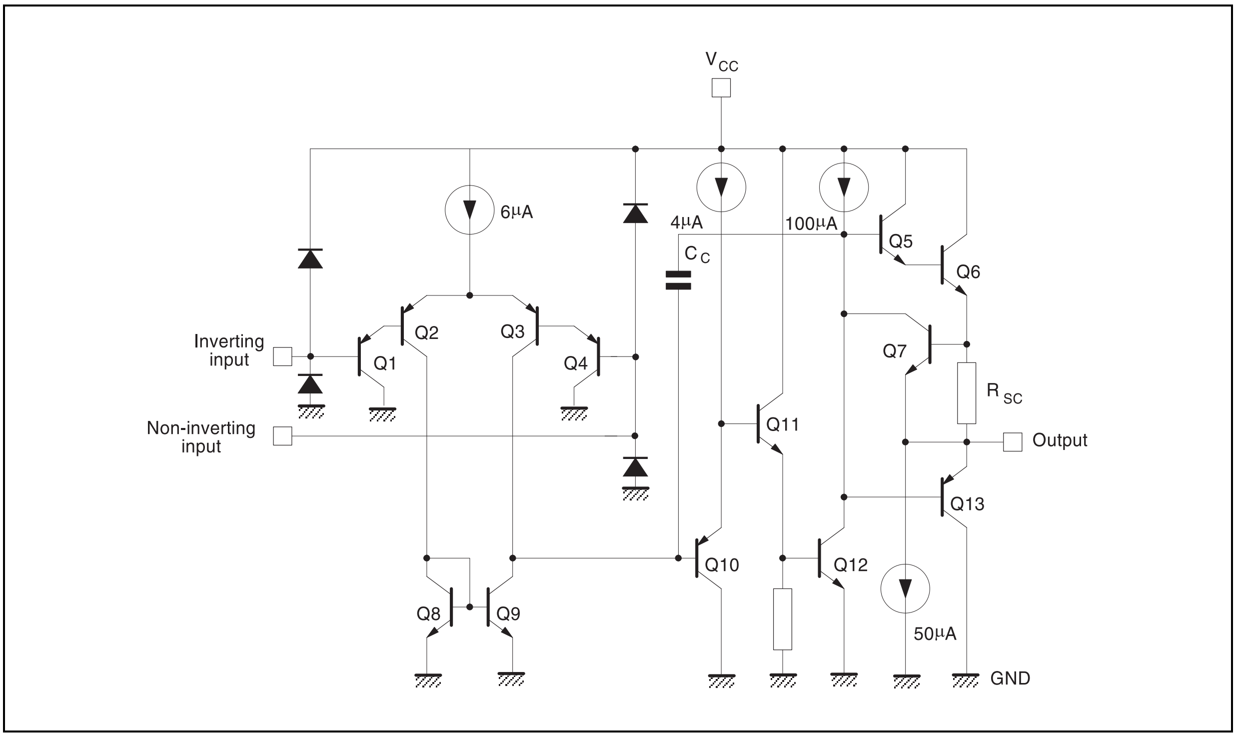


Figure 2: Schematic diagram (1/4 LM124A)



2 Absolute Maximum Ratings

Table 1: Key parameters and their absolute maximum ratings

Symbol	Parameter	LM124A	LM224A	LM324A	Unit
VCC	Supply voltage	±16 or 32			V
Vi	Input Voltage	-0.3 to Vcc + 0.3			V
V_{id}	Differential Input Voltage [1]	32			V
P_{tot}	Power DissipationN Suffix D Suffix	500	500 400	500 400	mW mW
	Output Short-circuit Duration [2]	Infinite			
I_{in}	Input Current [3]	50			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
R_{thja}	Thermal Resistance Junction to Ambient SO14 TSSOP14 DIP14	103 100 66			°C/W

1) Either or both input voltages must not exceed the magnitude of V_{CC}^+ or V_{CC}^-.

2) Short-circuits from the output to VCC can cause excessive heating if $V_{CC} > 15V$. The maximum output current is approximately 40mA independent of the magnitude of V_{CC}. Destructive dissipation can result from simultaneous short-circuit 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 input diodes clamps. In addition to this diode action, there is also 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 duration than an input is driven negative.
This is not destructive and normal output will set up again for input voltage higher than -0.3V.

3 Electrical Characteristics

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

Symbol	Parameter	Min.	Typ.	Max.	Unit
V_{io}	Input Offset Voltage - note [1] T_{amb} = +25°C $T_{min} \le T_{amb} \le T_{max}$		 2	 3 5	mV
I_{io}	Input Offset Current T_{amb} = +25°C $T_{min} \le T_{amb} \le T_{max}$		 2	 20 40	nA
I_{ib}	Input Bias Current - note [2] T_{amb} = +25°C $T_{min} \le T_{amb} \le T_{max}$		 20	 100 200	nA
A_{vd}	Large Signal Voltage Gain V_{CC}^+ = +15V, R_L = 2kΩ, V_o = 1.4V to 11.4V T_{amb} = +25°C $T_{min} \le T_{amb} \le T_{max}$	 50 25	 100		V/mV
SVR	Supply Voltage Rejection Ratio ($R_s \le$ 10kΩ) V_{CC}^+ = 5V to 30V 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} = +5V V_{CC} = +30V $T_{min} \le T_{amb} \le T_{max}$ V_{CC} = +5V V_{CC} = +30V		 0.7 1.5 0.8 1.5	 1.2 3 1.2 3	mA
V_{icm}	Input Common Mode Voltage Range V_{CC} = +30V - note [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 ($R_s \le$ 10kΩ) T_{amb} = +25°C $T_{min} \le T_{amb} \le T_{max}$	 70 60	 80		dB
I_{source}	Output Current Source (V_{id} = +1V) V_{CC} = +15V, V_o = +2V	 20	 40	 70	mA
I_{sink}	Output Sink Current (V_{id} = -1V) V_{CC} = +15V, V_o = +2V V_{CC} = +15V, V_o = +0.2V	 10 12	 20 50		 mA µA
V_{OH}	High Level Output Voltage V_{CC} = +30V T_{amb} = +25°C R_L = 2kΩ $T_{min} \le T_{amb} \le T_{max}$ T_{amb} = +25°C R_L = 10kΩ $T_{min} \le T_{amb} \le T_{max}$ V_{CC} = +5V, R_L = 2kΩ T_{amb} = +25°C $T_{min} \le T_{amb} \le T_{max}$	 26 26 27 27 3.5 3	 27 28		V

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

Symbol	Parameter	Min.	Typ.	Max.	Unit
VOL	Low Level Output Voltage (R_L = 10kΩ) T_{amb} = +25°C $T_{min} \leq T_{amb} \leq T_{max}$		5	20 20	mV
SR	Slew Rate V_{CC} = 15V, V_i = 0.5 to 3V, R_L = 2kΩ, C_L = 100pF, unity Gain		0.4		V/µs
GBP	Gain Bandwidth Product V_{CC} = 30V, f =100kHz,V_{in} = 10mV, R_L = 2kΩ, C_L = 100pF		1.3		MHz
THD	Total Harmonic Distortion f = 1kHz, A_v = 20dB, R_L = 2kΩ, V_o = $2V_{pp}$, C_L = 100pF, V_{CC} = 30V		0.015		%
e_n	Equivalent Input Noise Voltage f = 1kHz, R_s = 100Ω, V_{CC} = 30V		40		$\frac{nV}{\sqrt{Hz}}$
DV_{io}	Input Offset Voltage Drift		7	30	µV/°C
DI_{Iio}	Input Offset Current Drift		10	200	pA/°C
V_{o1}/V_{o2}	Channel Separation - note 4 $1kHz \leq f \leq 20kHZ$		120		dB

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

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 no loading change exists 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 0.3V. The upper end of the common-mode voltage range is V_{CC}^+ - 1.5V, but either or both inputs can go to +32V without damage.

4) Due to the proximity of external components insure that coupling is not originating via stray capacitance between these external parts. This typically can be detected as this type of capacitance increases at higher frequences.

Figure 3: Input bias current vs. ambient temperature

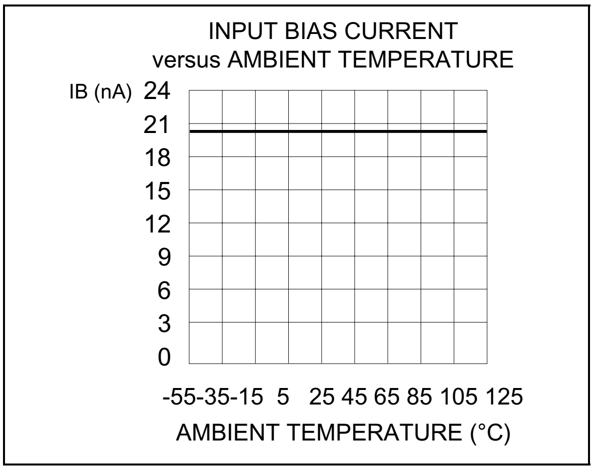


Figure 6: Current limiting

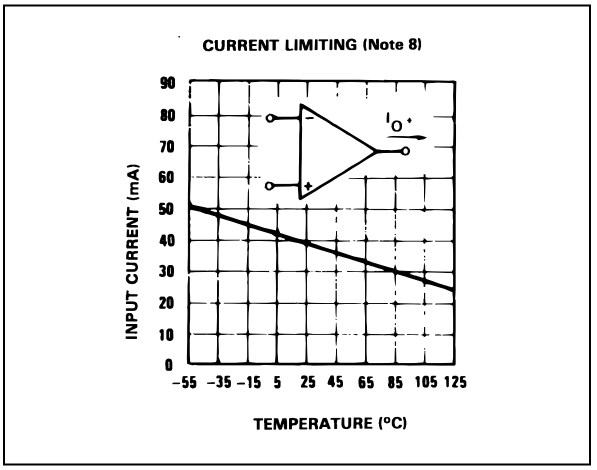


Figure 4: Input voltage range

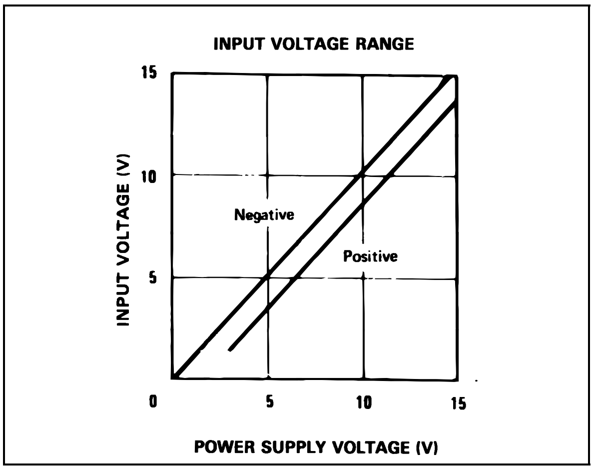


Figure 7: Supply current

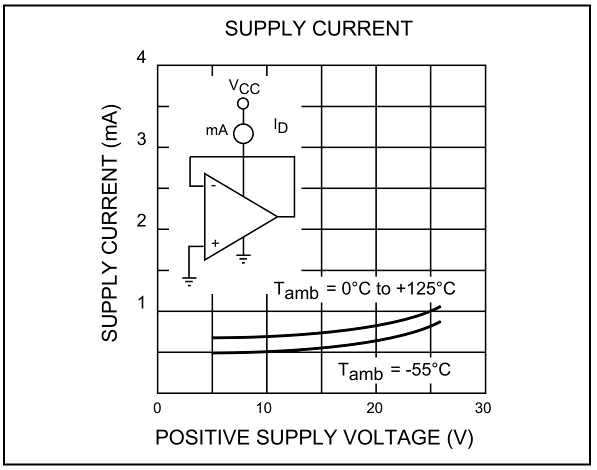


Figure 5: Gain bandwidth product

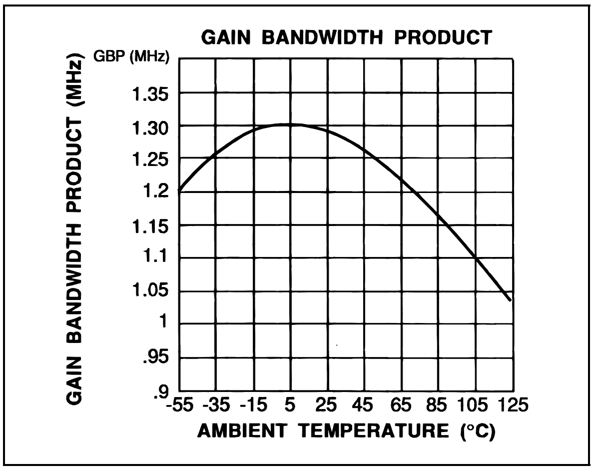


Figure 8: Common mode rejection ratio

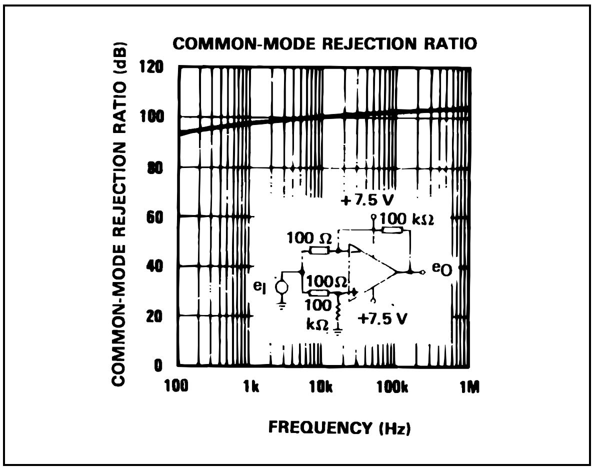


Figure 9: Electrical curves

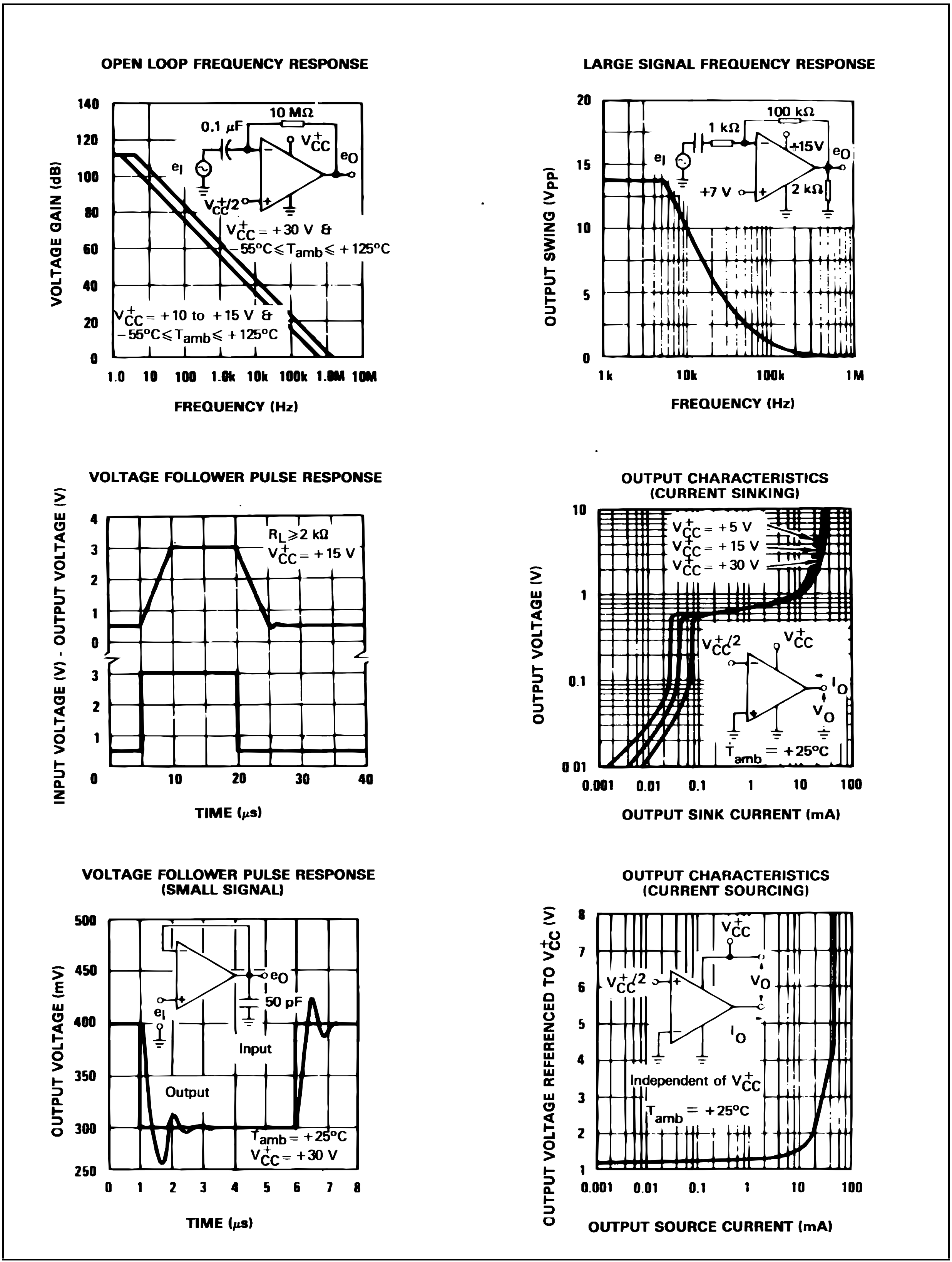


Figure 10: Input current

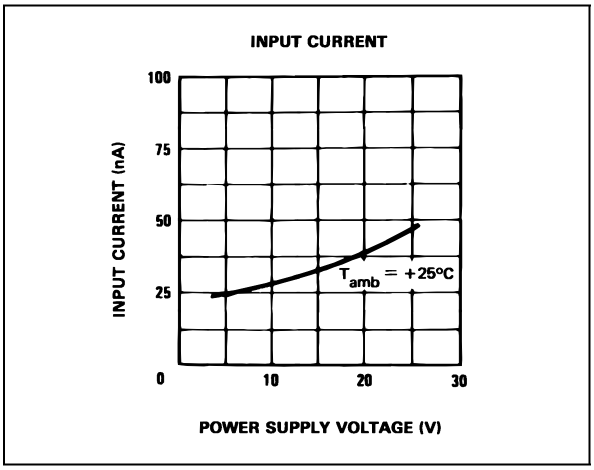


Figure 11: Power supply & common mode rejection ratio

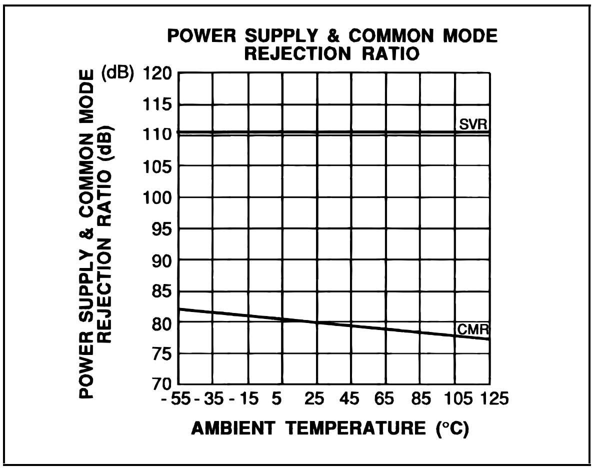


Figure 12: Voltage gain

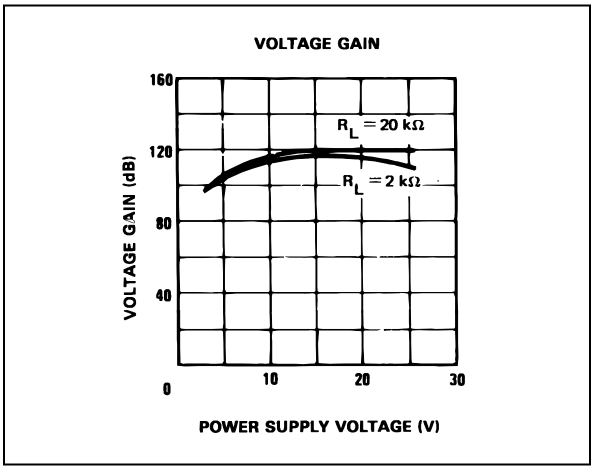
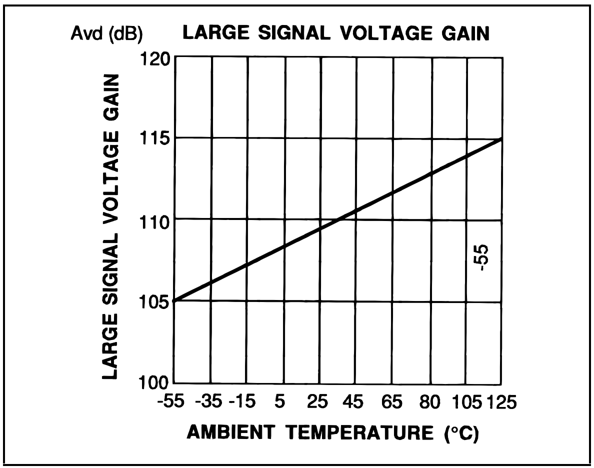


Figure 13: Large signal voltage gain



4 Typical Single - Supply Applications

Figure 14: AC coupled interting amplifier

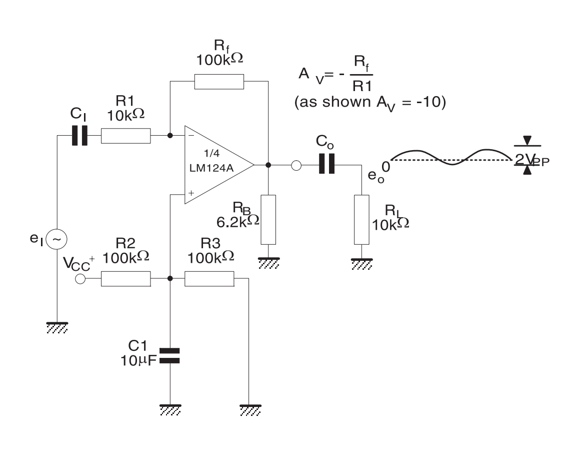


Figure 15: AC coupled non inverting amplifier

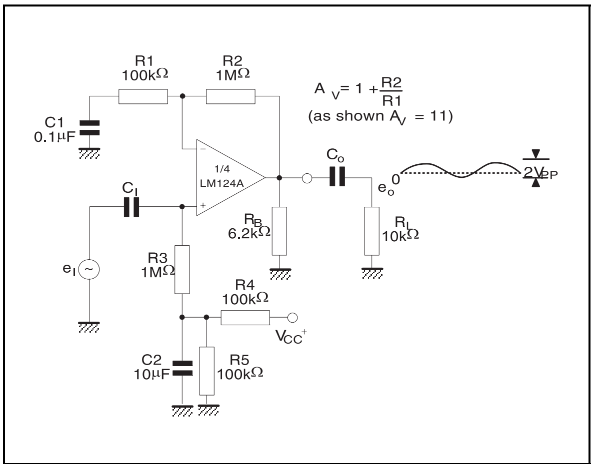


Figure 16: Non-inverting DC gain

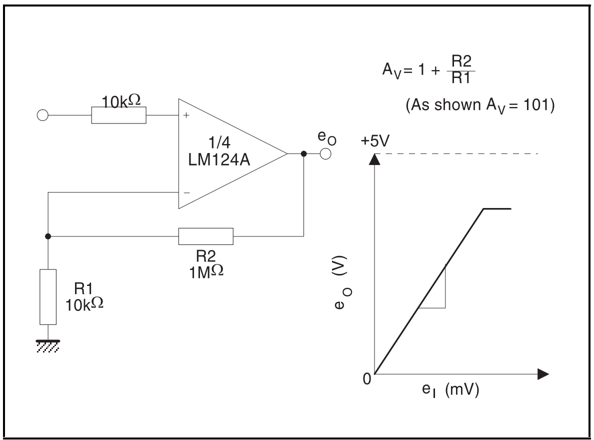
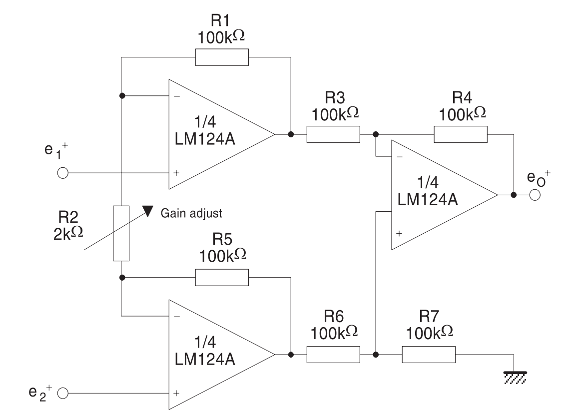


Figure 17: High input Z adjustable gain DC instrumentation amplifier

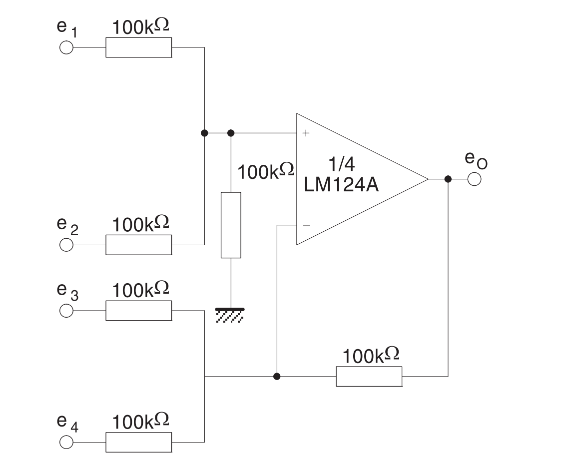


if R1 = R5 and R3 = R4 = R6 = R7

$$e_0 = \left[1 + \frac{2R_1}{R_2}\right](e_2 - e_1)$$

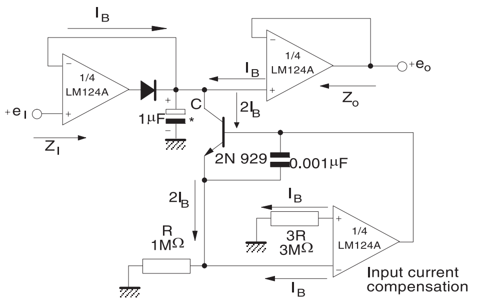
As shown $e_0 = 101\ (e_2 - e_1)$.

Figure 18: DC summing amplifier



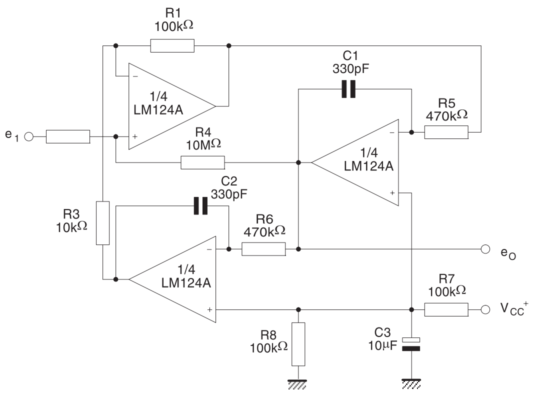
$e_0 = e_1 + e_2 - e_3 - e_4$
Where $(e_1 + e_2) \geq (e_3 + e_4)$
to keep $e_0 \geq 0V$

Figure 19: Low drift peak detector



* Polycarbonate or polyethylene

Figure 20: Activer bandpass filter



$F_o = 1kHz$

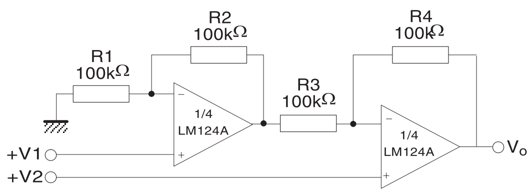
$Q = 50$

$A_v = 100$ (40dB)

Figure 21: High input Z, DC differential amplifier

For $\frac{R_1}{R_2} = \frac{R_4}{R_3}$

(CMRR depends on this resistor ratio match)



$e_0 \left(1 + \frac{R_4}{R_3}\right) (e_2 - e_1)$

As shown $e_0 = (e_2 - e_1)$

Figure 22: Using symetrical amplifiers to reduce input current (general concept)

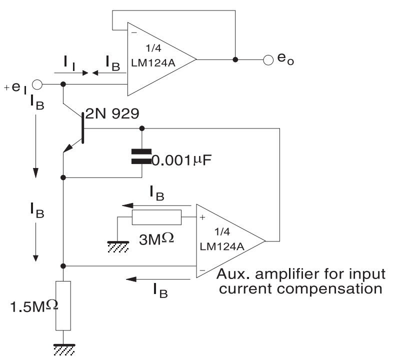


Table 3: V_{cc}^{+} = +15V, V_{cc}^{-} = 0V, T_{amb} = 25°C (unless otherwise specified)

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

5 Macromodel

Warning: ***Please consider following remarks 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 (i.e. temperature, supply voltage, etc.). Thus the macromodel is often not as exhaustive as the datasheet, its goal is to illustrate the main parameters of the product.
Data issued from macromodels used outside of its specified conditions (Vcc, Temperature, etc) or even worse: outside of the device operating conditions (Vcc, Vicm, etc) are not reliable in any way.

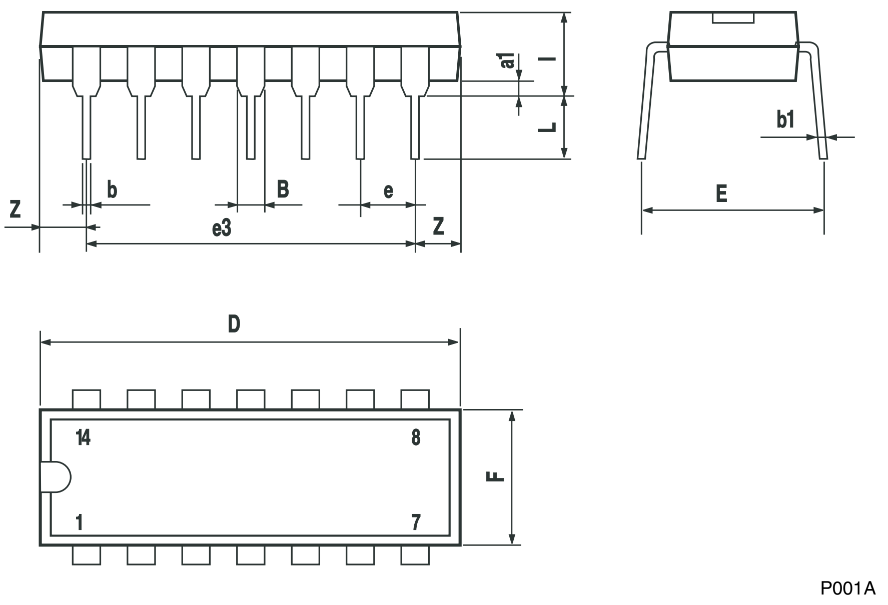
```
** Standard Linear Ics Macromodels, 1993.
** CONNECTIONS :
* 1 INVERTING INPUT
* 2 NON-INVERTING INPUT
* 3 OUTPUT
* 4 POSITIVE POWER SUPPLY
* 5 NEGATIVE POWER SUPPLY
.SUBCKT LM324 1 2 3 4 5
***************************
.MODEL MDTH D IS=1E-8 KF=3.104131E-15 CJO=10F
* INPUT STAGE
CIP 2 5 1.000000E-12
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
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
```

6 Package Mechanical Data

6.1 DIP14 Package

DIM.	mm.			inch		
	MIN.	TYP	MAX.	MIN.	TYP.	MAX.
a1	0.51			0.020		
B	1.39		1.65	0.055		0.065
b		0.5			0.020	
b1		0.25			0.010	
D			20			0.787
E		8.5			0.335	
e		2.54			0.100	
e3		15.24			0.600	
F			7.1			0.280
I			5.1			0.201
L		3.3			0.130	
Z	1.27		2.54	0.050		0.100

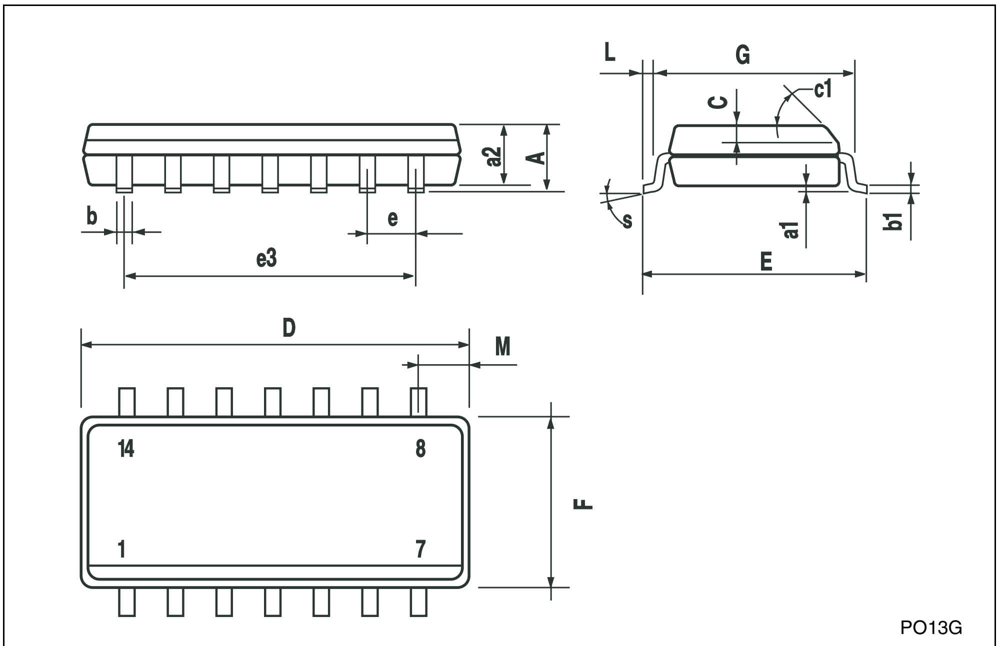
Plastic DIP-14 MECHANICAL DATA



6.2 SO-14 Package

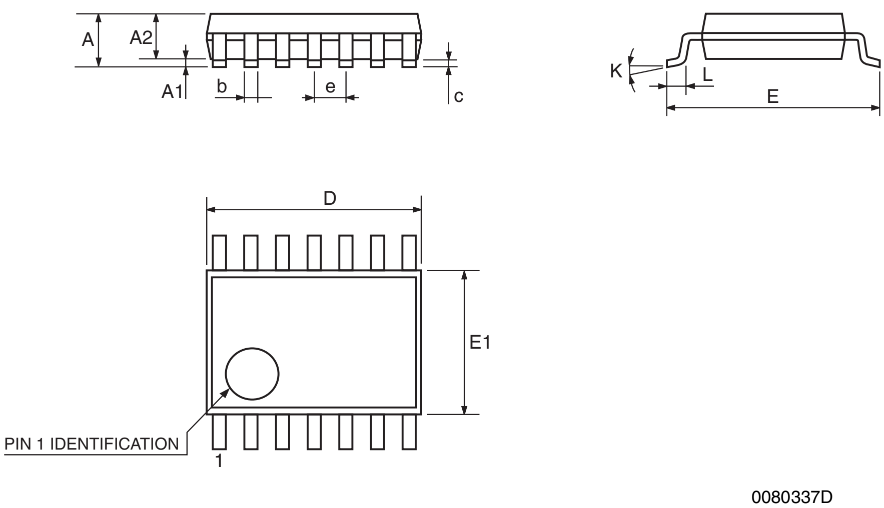
SO-14 MECHANICAL DATA

DIM.	mm.			inch		
	MIN.	TYP	MAX.	MIN.	TYP.	MAX.
A			1.75			0.068
a1	0.1		0.2	0.003		0.007
a2			1.65			0.064
b	0.35		0.46	0.013		0.018
b1	0.19		0.25	0.007		0.010
C		0.5			0.019	
c1	45° (typ.)					
D	8.55		8.75	0.336		0.344
E	5.8		6.2	0.228		0.244
e		1.27			0.050	
e3		7.62			0.300	
F	3.8		4.0	0.149		0.157
G	4.6		5.3	0.181		0.208
L	0.5		1.27	0.019		0.050
M			0.68			0.026
S	8° (max.)					



6.3 TSSOP14 Package

TSSOP14 MECHANICAL DATA						
DIM.	mm.			inch		
	MIN.	TYP	MAX.	MIN.	TYP.	MAX.
A			1.2			0.047
A1	0.05		0.15	0.002	0.004	0.006
A2	0.8	1	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	4.9	5	5.1	0.193	0.197	0.201
E	6.2	6.4	6.6	0.244	0.252	0.260
E1	4.3	4.4	4.48	0.169	0.173	0.176
e		0.65 BSC			0.0256 BSC	
K	0˚		8˚	0˚		8˚
L	0.45	0.60	0.75	0.018	0.024	0.030



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7 Summary of Changes

Date	Revision	Description of Changes
01 March 2001	1	First Release
01 Feb. 2005	2	- *Table 1 on page 3*: explanation of Vid and Vi limits - Macromodel updated