

## Low power quad operational amplifiers

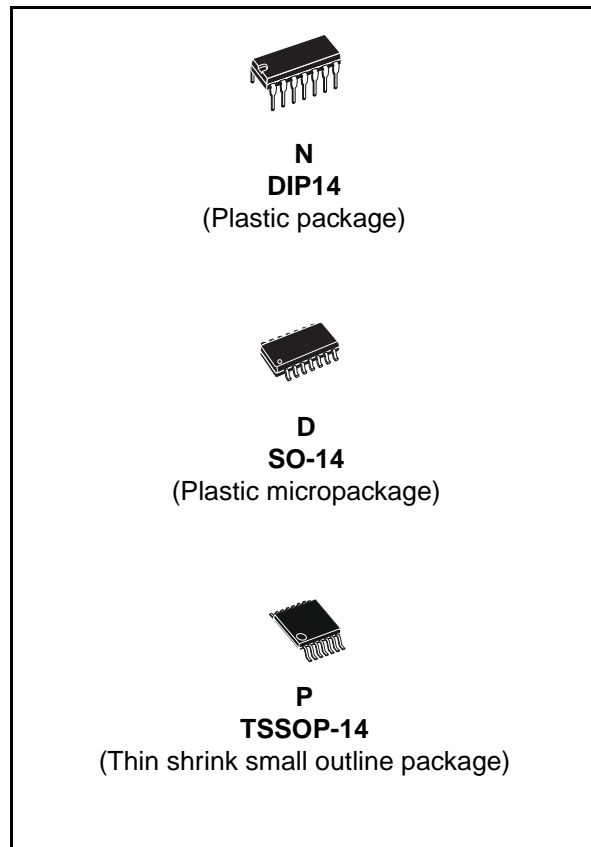
### Features

- Wide gain bandwidth: 1.3 MHz
- Input common-mode voltage range includes ground
- Large voltage gain: 100 dB
- Very low supply current/amplifier: 375  $\mu$ A
- Low input bias current: 20 nA
- Low input offset voltage: 3 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

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.



### 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

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# 1 Pin connections and schematic diagram

Figure 1. Pin connections (top view)

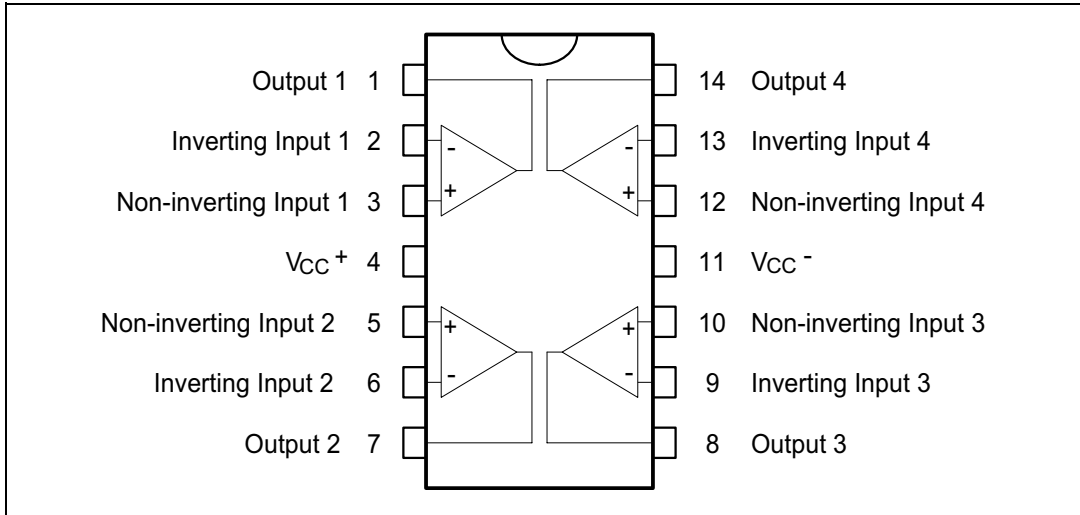
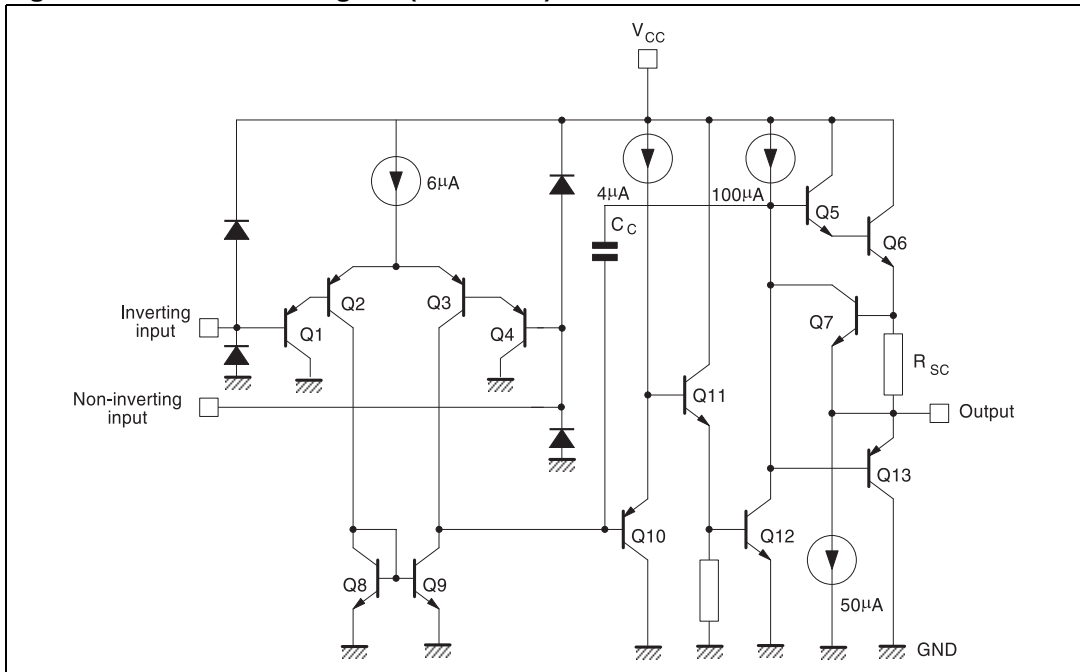


Figure 2. Schematic diagram (1/4 LM124)



## 2 Absolute maximum ratings

**Table 1. Absolute maximum ratings**

Symbol	Parameter	LM224A	LM324A	Unit
$V_{CC}$	Supply voltage	±16 or 32		V
$V_i$	Input voltage	-0.3 to $V_{CC} + 0.3$		V
$V_{id}$	Differential input voltage <sup>(1)</sup>	32		V
$P_{tot}$	Power dissipation:			
	N suffix D suffix	500 400	500 400	mW
	Output short-circuit duration <sup>(2)</sup>	Infinite		
$I_{in}$	Input current <sup>(3)</sup>	50		mA
$T_{oper}$	Operating free-air temperature range	-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>(4)</sup> :			
	SO14	103		°C/W
	TSSOP14	100		
DIP14	83			
$R_{thjc}$	Thermal resistance junction to case:			
	SO14	31		°C/W
	TSSOP14	32		
DIP14	33			
ESD	HBM: human body model <sup>(5)</sup>	700		V
	MM: machine model <sup>(6)</sup>	150		
	CDM: charged device model	1500		

- Neither of the input voltages must exceed the magnitude of  $V_{CC}^+$  or  $V_{CC}^-$ .
- 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.
- 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 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 during which an input is driven negative. This is not destructive and normal output will set up again for input voltage higher than -0.3 V.
- 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).
- Human body model, 100 pF discharged through a 1.5 kΩ resistor into pin of device.
- Machine model ESD, a 200 pF cap is charged to the specified voltage, then discharged directly into the IC with no external series resistor (internal resistor < 5Ω), into pin-to-pin of device.

### 3 Electrical characteristics

**Table 2.**  $V_{CC}^+ = +5V$ ,  $V_{CC}^- = \text{Ground}$ ,  $V_o = 1.4V$ ,  $T_{amb} = +25^\circ C$  (unless otherwise specified)

Symbol	Parameter	Min.	Typ.	Max.	Unit
$V_{io}$	Input offset voltage <sup>(1)</sup> : $T_{amb} = +25^\circ C$ $T_{min} \leq T_{amb} \leq T_{max}$		2	3 5	mV
$I_{io}$	Input offset current: $T_{amb} = +25^\circ C$ $T_{min} \leq T_{amb} \leq T_{max}$		2	20 40	nA
$I_{ib}$	Input bias current <sup>(2)</sup> : $T_{amb} = +25^\circ C$ $T_{min} \leq T_{amb} \leq T_{max}$		20	100 200	nA
$A_{vd}$	Large signal voltage gain: $V_{CC}^+ = +15 V$ , $R_L = 2 k\Omega$ , $V_o = 1.4 V$ to $11.4 V$ $T_{amb} = +25^\circ C$ $T_{min} \leq T_{amb} \leq T_{max}$	50 25	100		V/mV
SVR	Supply voltage rejection ratio ( $R_s \leq 10 k\Omega$ ): $V_{CC}^+ = 5 V$ to $30 V$ $T_{amb} = +25^\circ C$ $T_{min} \leq T_{amb} \leq T_{max}$	65 65	110		dB
$I_{CC}$	Supply current, all Amp, no load: – $T_{amb} = +25^\circ C$ $V_{CC} = +5V$ $V_{CC} = +30 V$ – $T_{min} \leq T_{amb} \leq T_{max}$ $V_{CC} = +5 V$ $V_{CC} = +30 V$		0.7 1.5	1.2 3	mA
$V_{icm}$	Input common mode voltage range: $V_{CC} = +30 V$ <sup>(3)</sup> $T_{amb} = +25^\circ C$ $T_{min} \leq T_{amb} \leq T_{max}$	0 0		$V_{CC} - 1.5$ $V_{CC} - 2$	V
CMR	Common mode rejection ratio ( $R_s \leq 10 k\Omega$ ): $T_{amb} = +25^\circ C$ $T_{min} \leq T_{amb} \leq T_{max}$	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
$I_{sink}$	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 $\mu A$

**Table 2.**  $V_{CC}^+ = +5V$ ,  $V_{CC}^- = \text{Ground}$ ,  $V_o = 1.4V$ ,  $T_{amb} = +25^\circ C$  (unless otherwise specified)

Symbol	Parameter	Min.	Typ.	Max.	Unit
$V_{OH}$	High level output voltage $V_{CC} = +30 V$ , $R_L = 2 k\Omega$ $T_{amb} = +25^\circ C$ $T_{min} \leq T_{amb} \leq T_{max}$	26 26	27		V
	$V_{CC} = +30 V$ , $R_L = 10 k\Omega$ $T_{amb} = +25^\circ C$ $T_{min} \leq T_{amb} \leq T_{max}$	27 27	28		V
	$V_{CC} = +5 V$ , $R_L = 2 k\Omega$ $T_{amb} = +25^\circ C$ $T_{min} \leq T_{amb} \leq T_{max}$	3.5 3			V
$V_{OL}$	Low level output voltage ( $R_L = 10k\Omega$ ): $T_{amb} = +25^\circ C$ $T_{min} \leq T_{amb} \leq T_{max}$		5	20 20	mV
SR	Slew rate: $V_{CC} = 15 V$ , $V_i = 0.5$ to $3 V$ , $R_L = 2 k\Omega$ , $C_L = 100 pF$ , unity gain		0.4		V/ $\mu s$
GBP	Gain bandwidth product: $V_{CC} = 30 V$ , $f = 100 kHz$ , $V_{in} = 10 mV$ , $R_L = 2 k\Omega$ , $C_L = 100pF$		1.3		MHz
THD	Total harmonic distortion: $f = 1kHz$ , $A_v = 20dB$ , $R_L = 2k\Omega$ , $V_o = 2V_{pp}$ , $C_L =$ $100pF$ , $V_{CC} = 30V$		0.015		%
$e_n$	Equivalent input noise voltage: $f = 1 kHz$ , $R_s = 100 \Omega$ , $V_{CC} = 30 V$		40		$\frac{nV}{\sqrt{Hz}}$
$DV_{io}$	Input offset voltage drift		7	30	$\mu V/^\circ C$
$DI_{io}$	Input offset current drift		10	200	$pA/^\circ C$
$V_{o1}/V_{o2}$	Channel separation <sup>(4)</sup> - $1kHz \leq f \leq 20 kHz$		120		dB

- $V_o = 1.4 V$ ,  $R_s = 0 \Omega$ ,  $5 V < V_{CC}^+ < 30 V$ ,  $0 < V_{ic} < V_{CC}^+ - 1.5 V$
- 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 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.
- 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.

Figure 3. Input bias current vs. ambient temperature

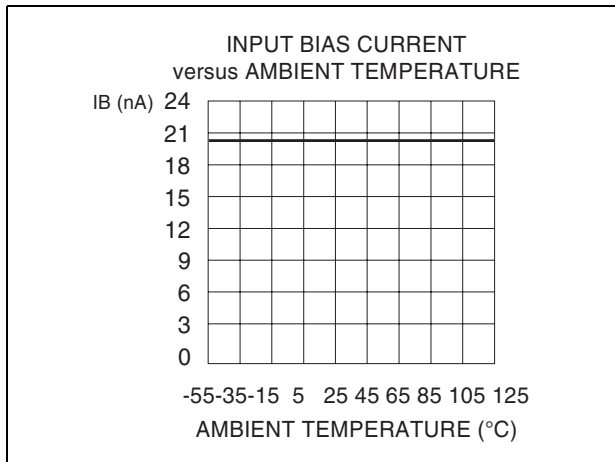


Figure 4. Current limiting

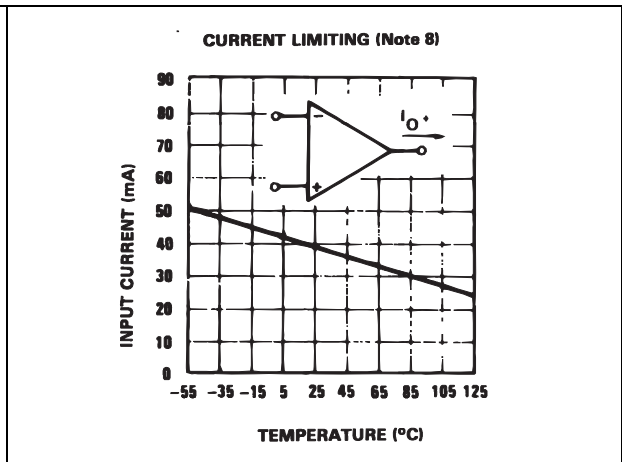


Figure 5. Input voltage range

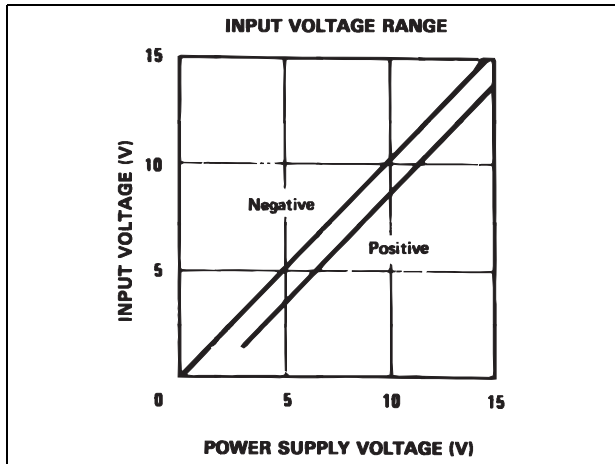


Figure 6. Supply current

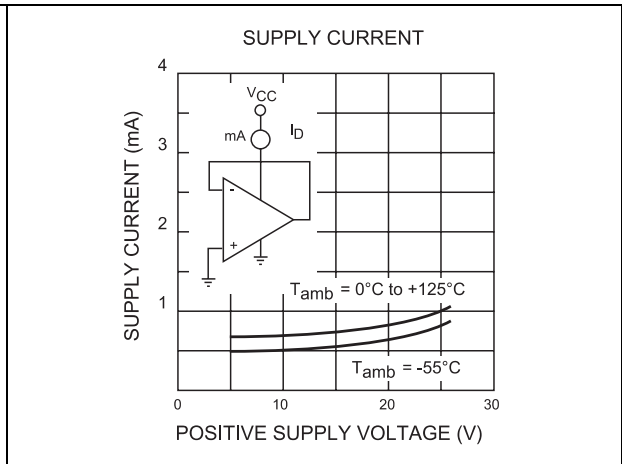


Figure 7. Gain bandwidth product

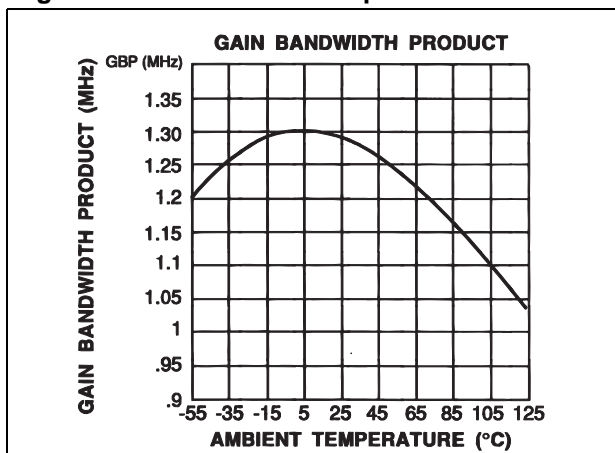


Figure 8. Common mode rejection ratio

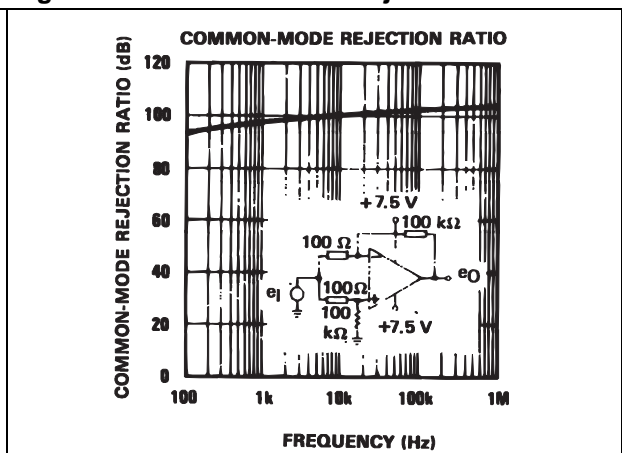


Figure 9. Input bias current vs. ambient temperature

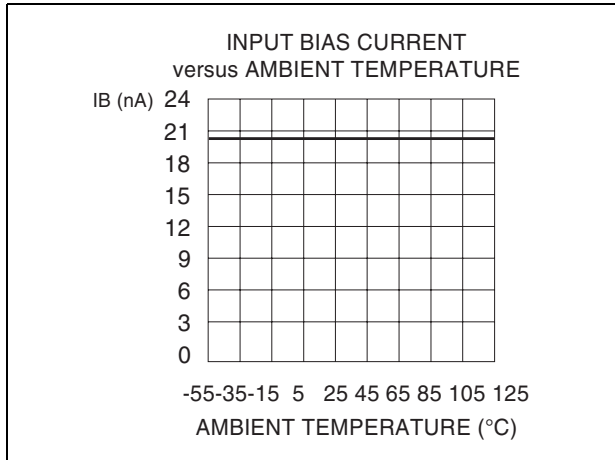


Figure 10. Current limiting

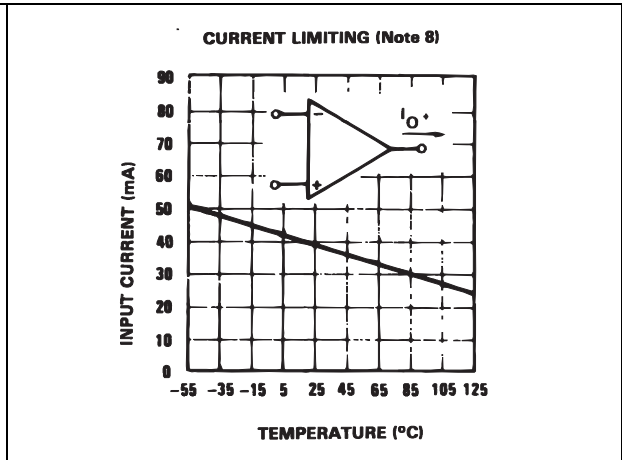


Figure 11. Input voltage range

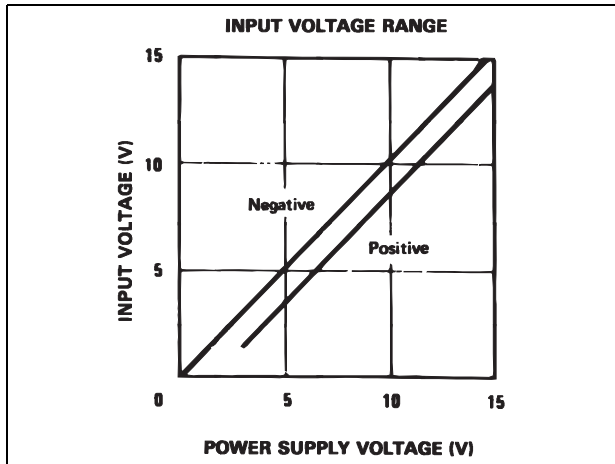


Figure 12. Supply current

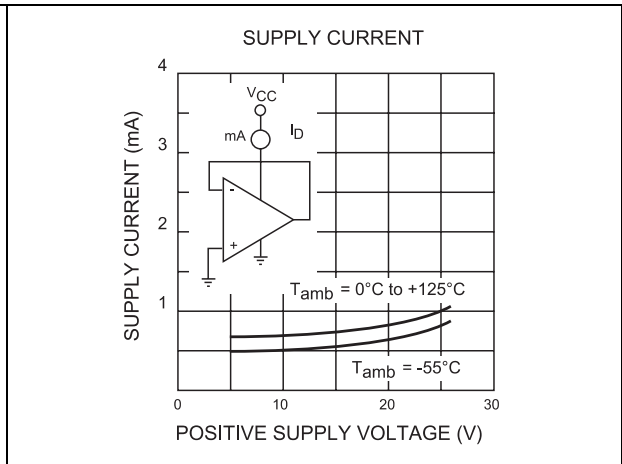


Figure 13. Gain bandwidth product

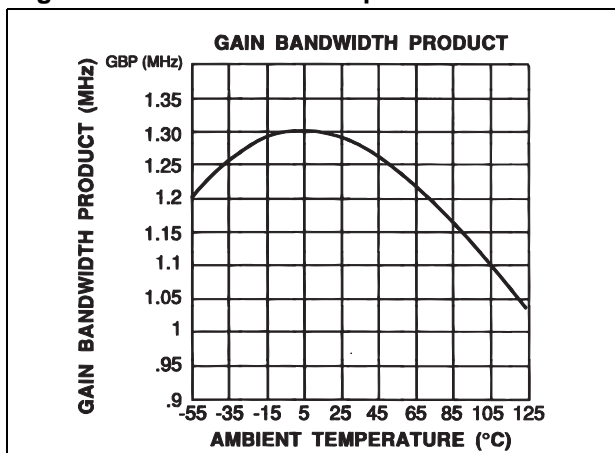


Figure 14. Common mode rejection ratio

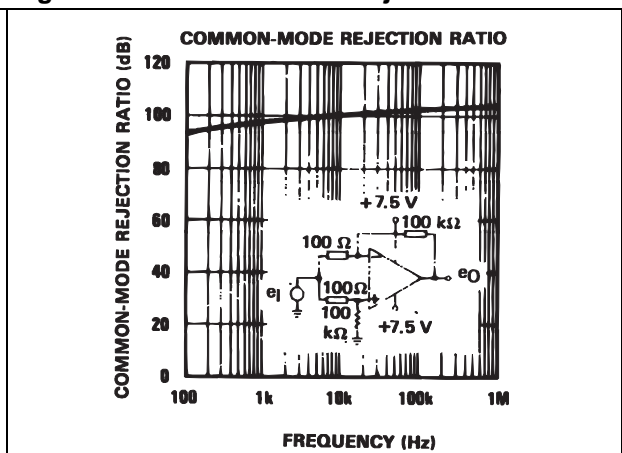




Figure 15. Electrical curves

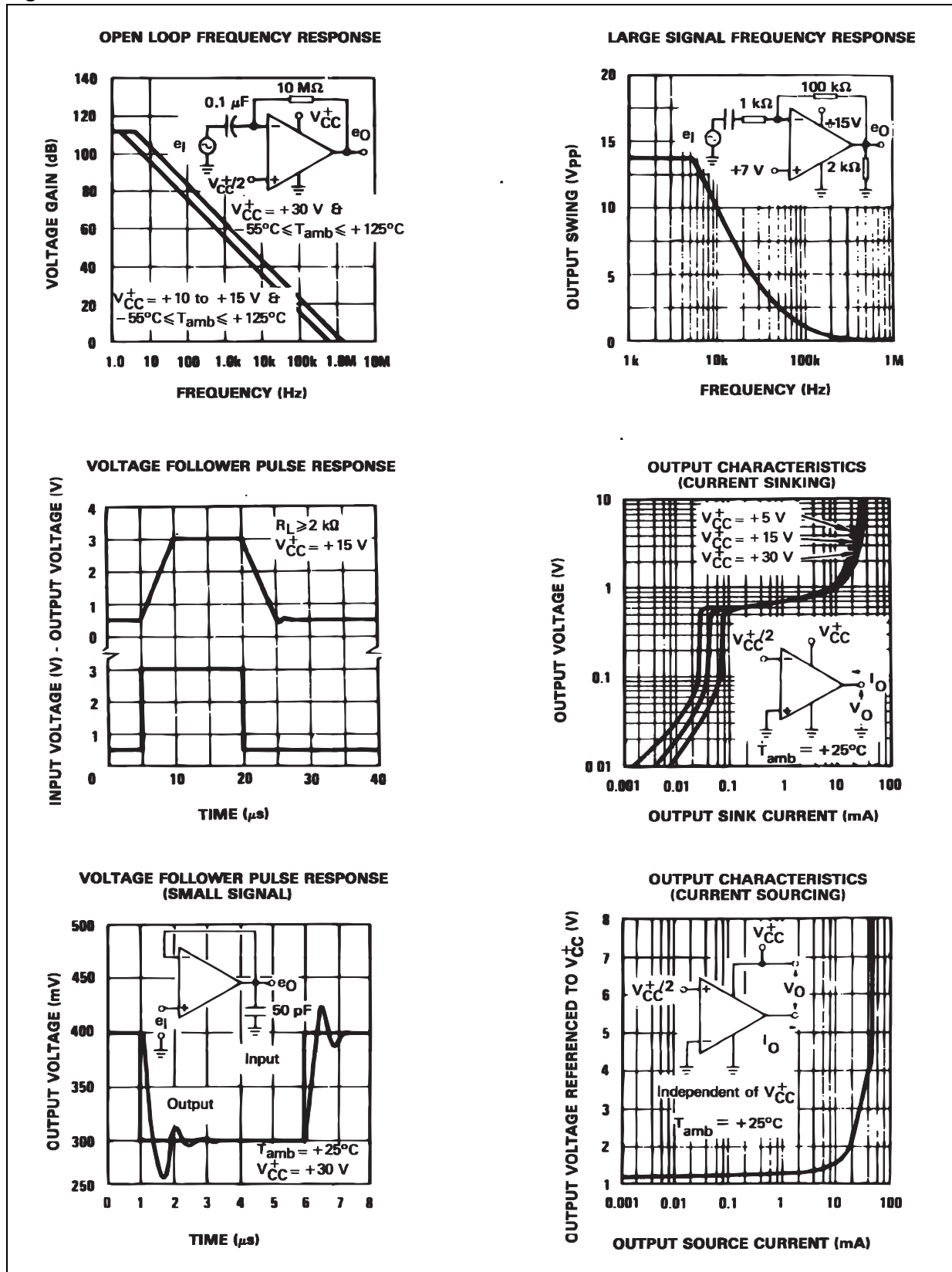


Figure 16. Input current

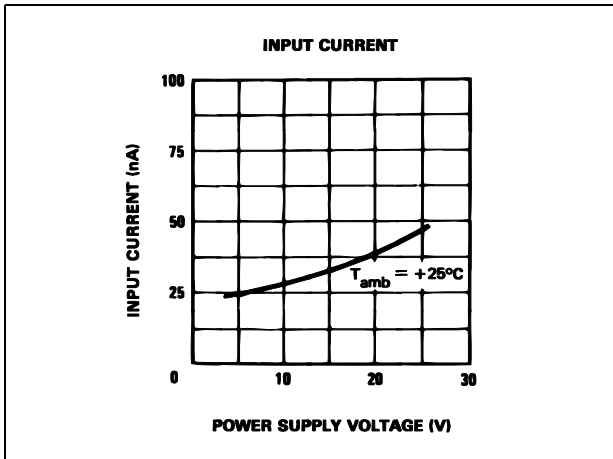


Figure 17. Large signal voltage gain

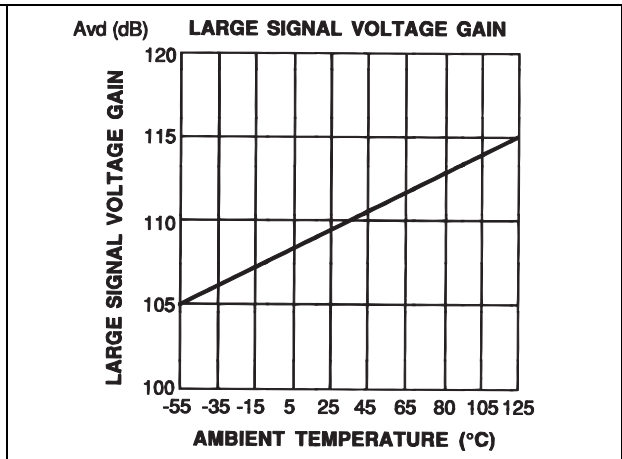


Figure 18. Power supply & common mode rejection ratio

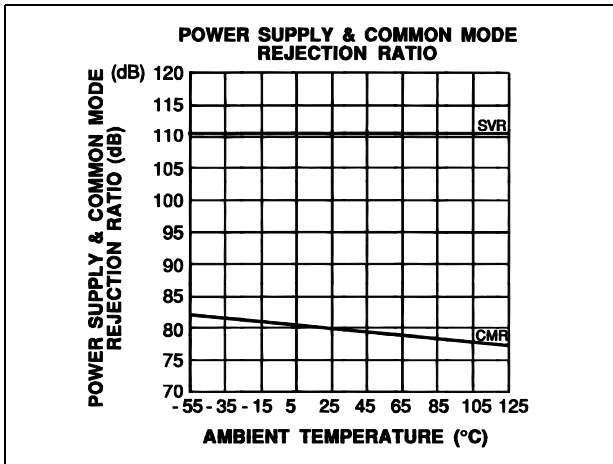
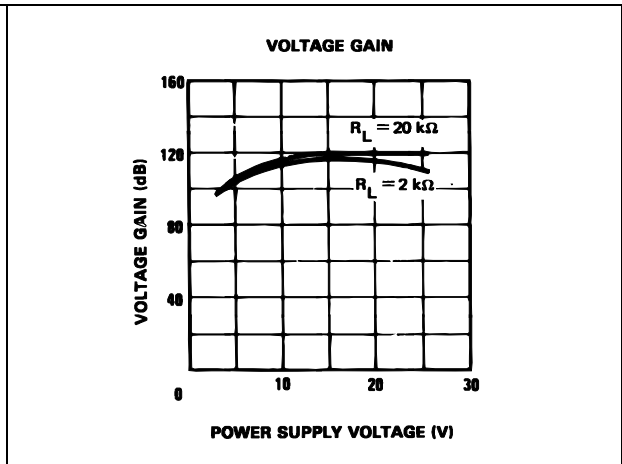


Figure 19. Voltage gain



# 4 Typical single-supply applications

Figure 20. AC coupled inverting amplifier

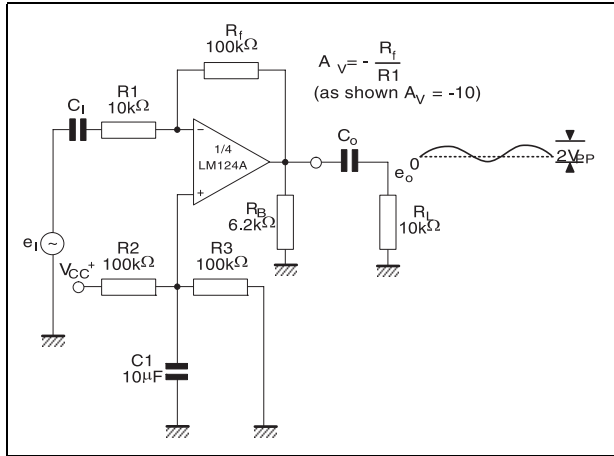


Figure 21. High input Z adjustable gain DC instrumentation amplifier

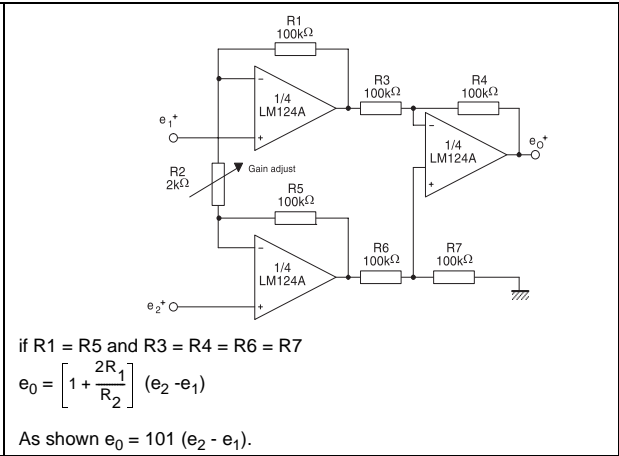


Figure 22. AC coupled non inverting amplifier

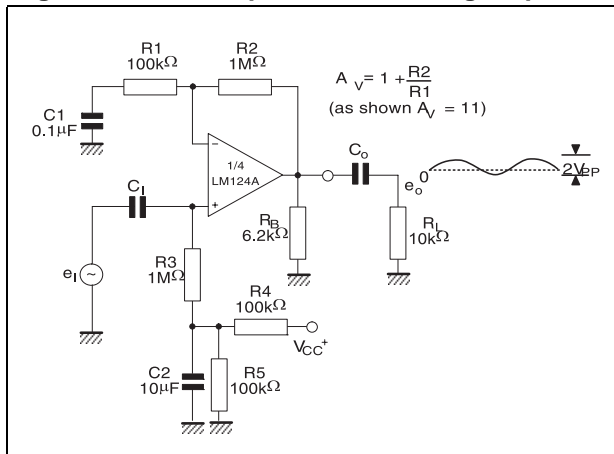


Figure 23. DC summing amplifier

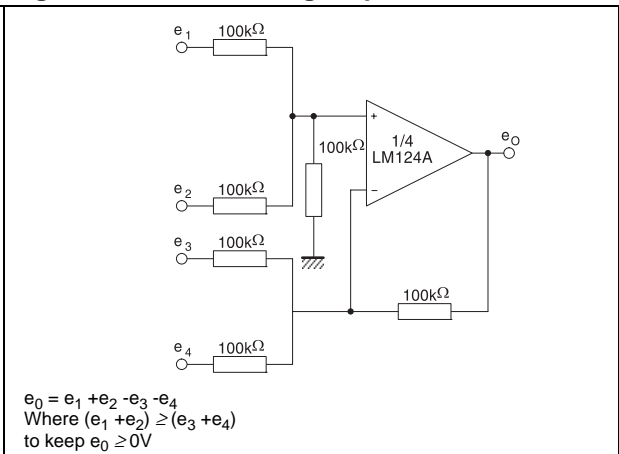


Figure 24. Non-inverting DC gain

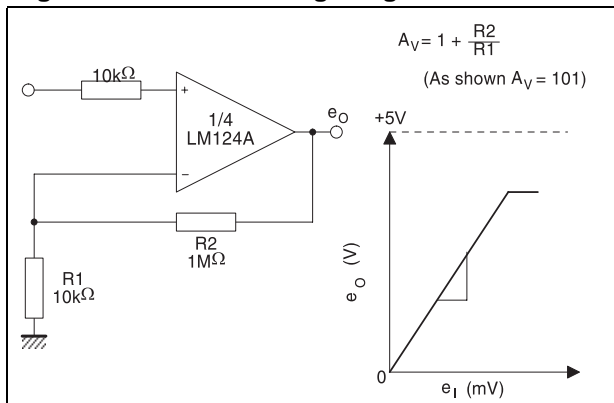


Figure 25. Low drift peak detector

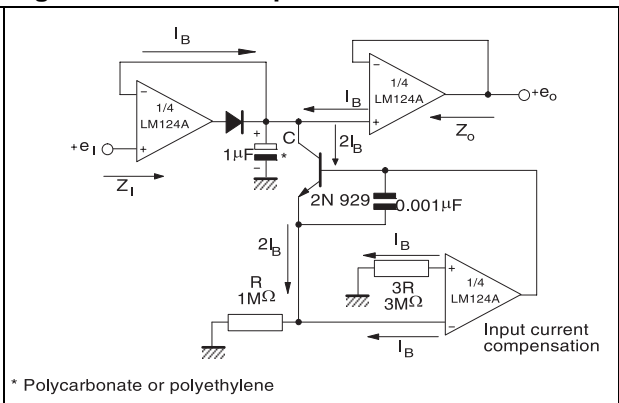


Figure 26. Active bandpass filter

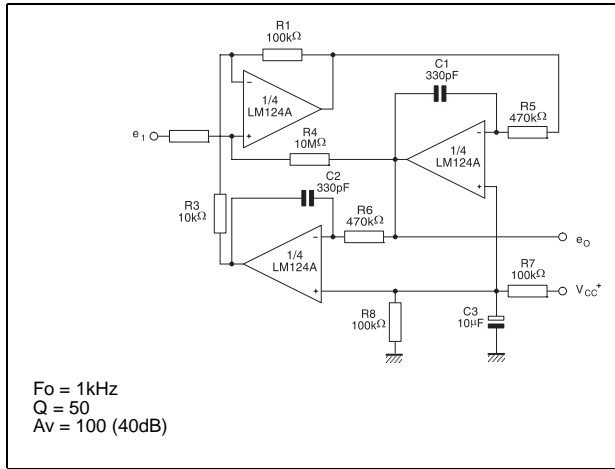


Figure 27. High input Z, DC differential amplifier

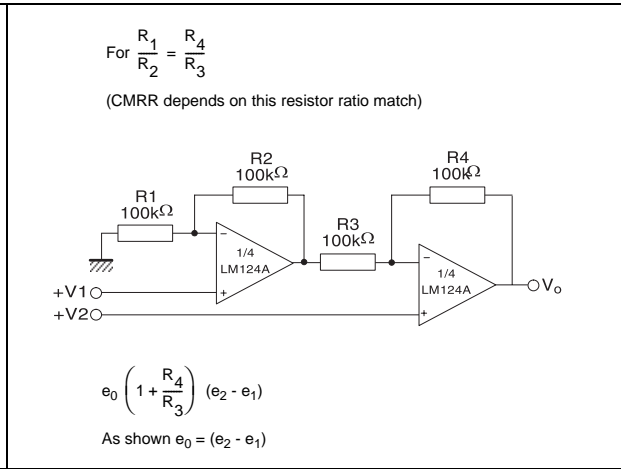
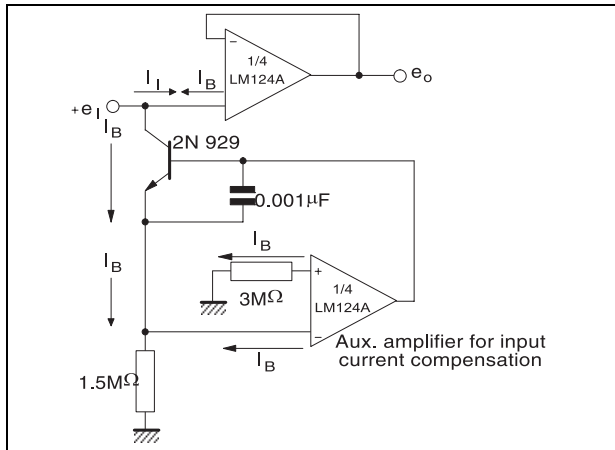


Figure 28. Using symmetrical amplifiers to reduce input current (general concept)



## 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** (i.e. 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 issued 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
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.**  $V_{CC}^+ = +15V$ ,  $V_{CC}^- = 0V$ ,  $T_{amb} = 25^\circ C$  (unless otherwise specified)

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

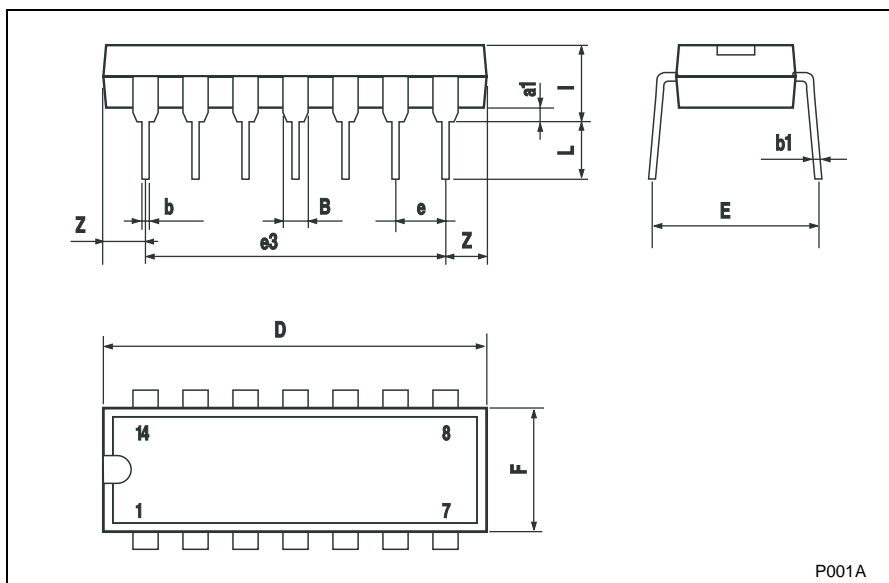
## 6 Package mechanical data

In order to meet environmental requirements, STMicroelectronics offers these devices in ECOPACK<sup>®</sup> packages. These packages have a Lead-free second level interconnect. The category of second level interconnect is marked on the package and on the inner box label, in compliance with JEDEC Standard JESD97. The maximum ratings related to soldering conditions are also marked on the inner box label. ECOPACK is an STMicroelectronics trademark. ECOPACK specifications are available at: [www.st.com](http://www.st.com).

### 6.1 DIP14 package

**Plastic DIP-14 MECHANICAL DATA**

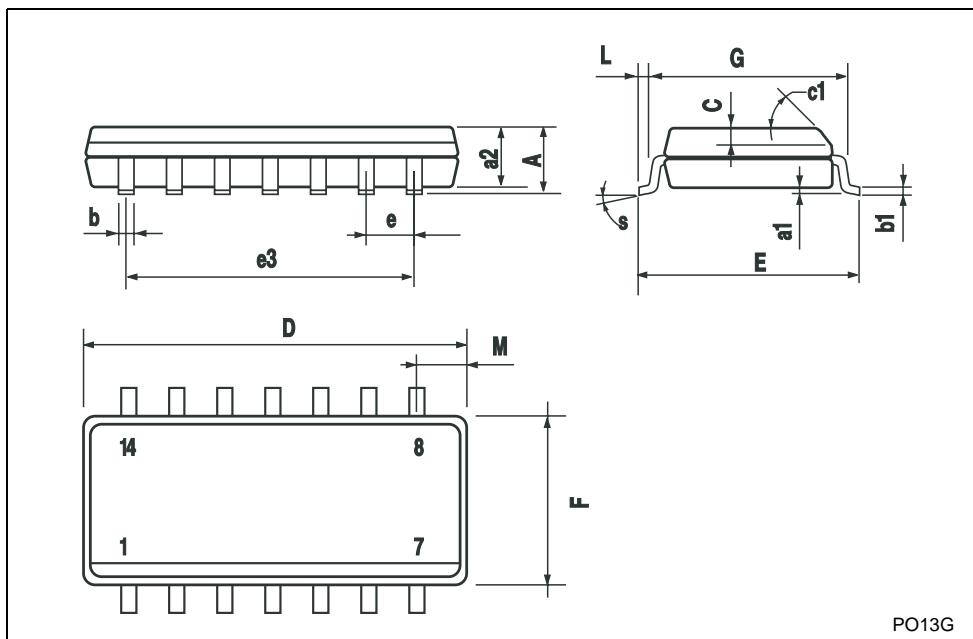
DIM.	mm.			inch		
	MIN.	TYP.	MAX.	MIN.	TYP.	MAX.
a1	0.51			0.020		
B	1.39		1.65	0.055		0.065
b		0.5			0.020	
b1		0.25			0.010	
D			20			0.787
E		8.5			0.335	
e		2.54			0.100	
e3		15.24			0.600	
F			7.1			0.280
l			5.1			0.201
L		3.3			0.130	
Z	1.27		2.54	0.050		0.100





## 6.2 SO-14 package

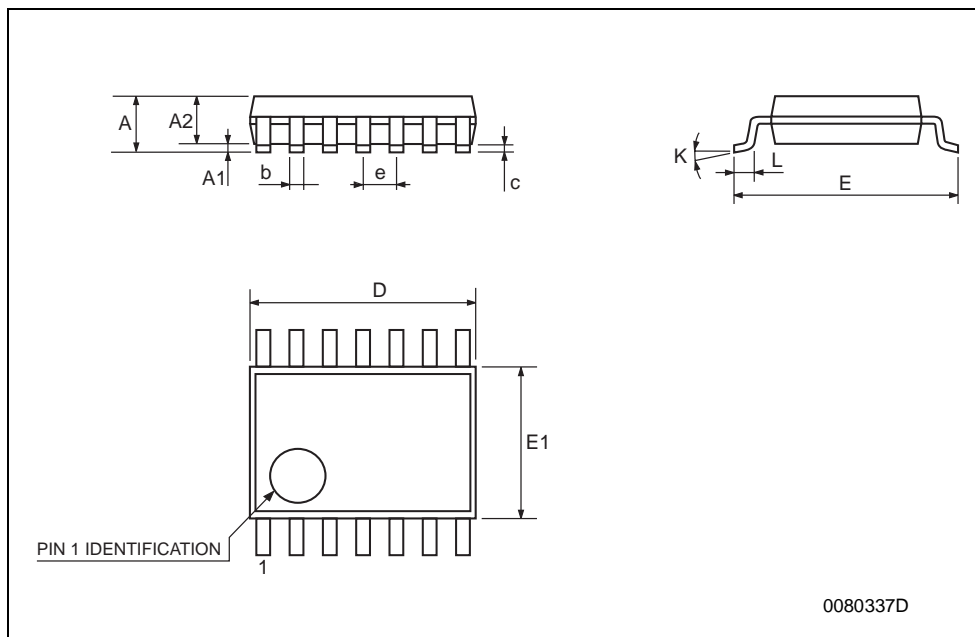
SO-14 MECHANICAL DATA						
DIM.	mm.			inch		
	MIN.	TYP.	MAX.	MIN.	TYP.	MAX.
A			1.75			0.068
a1	0.1		0.2	0.003		0.007
a2			1.65			0.064
b	0.35		0.46	0.013		0.018
b1	0.19		0.25	0.007		0.010
C		0.5			0.019	
c1	45° (typ.)					
D	8.55		8.75	0.336		0.344
E	5.8		6.2	0.228		0.244
e		1.27			0.050	
e3		7.62			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



## 7 Revision history

**Table 4. 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 <a href="#">Table 1 on page 4</a> . Updated macromodel.
1-Jun-2005	3	ESD protection inserted in <a href="#">Table 1 on page 4</a> .
25-Sep-2006	4	Editorial update.

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