



# LM124 LM224 - LM324

## LOW POWER QUAD OPERATIONAL AMPLIFIERS

- WIDE GAIN BANDWIDTH : 1.3MHz
- INPUT COMMON-MODE VOLTAGE RANGE INCLUDES GROUND
- LARGE VOLTAGE GAIN : 100dB
- VERY LOW SUPPLY CURRENT/AMPLI : 375µA
- LOW INPUT BIAS CURRENT : 20nA
- LOW INPUT OFFSET VOLTAGE : 5mV max.  
(for more accurate applications, use the equivalent parts LM124A-LM224A-LM324A which feature 3mV max.)
- LOW INPUT OFFSET CURRENT : 2nA
- WIDE POWER SUPPLY RANGE :  
SINGLE SUPPLY : +3V TO +30V  
DUAL SUPPLIES : ±1.5V TO ±15V

### 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 CODE

| Part Number      | Temperature Range | Package |   |   |
|------------------|-------------------|---------|---|---|
|                  |                   | N       | D | P |
| LM124            | -55°C, +125°C     | •       | • | • |
| LM224            | -40°C, +105°C     | •       | • | • |
| LM324            | 0°C, +70°C        | •       | • | • |
| Example : LM224N |                   |         |   |   |

N = Dual in Line Package (DIP)

D = Small Outline Package (SO) - also available in Tape & Reel (DT)

P = Thin Shrink Small Outline Package (TSSOP) - only available in Tape & Reel (PT)



**N**  
**DIP14**  
(Plastic Package)

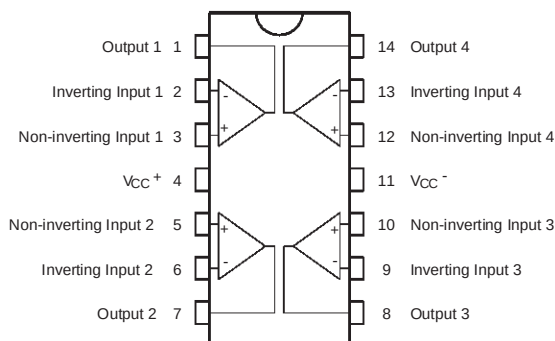


**D**  
**SO14**  
(Plastic Micropackage)

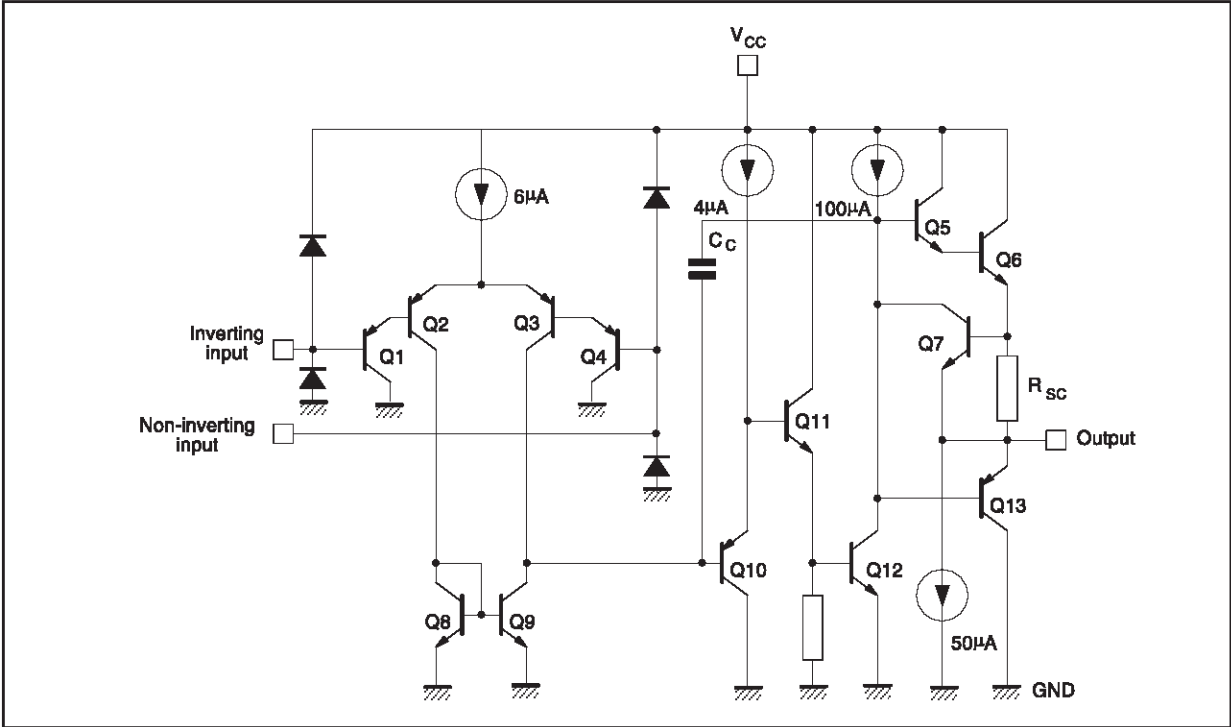


**P**  
**TSSOP14**  
(Thin Shrink Small Outline Package)

### PIN CONNECTIONS (top view)



SCHEMATIC DIAGRAM (1/4 LM124)



ABSOLUTE MAXIMUM RATINGS

| Symbol     | Parameter                                   | LM124          | LM224           | LM324    | Unit |
|------------|---------------------------------------------|----------------|-----------------|----------|------|
| $V_{CC}$   | Supply voltage                              | $\pm 16$ or 32 |                 |          | V    |
| $V_i$      | Input Voltage                               | -0.3 to +32    |                 |          | V    |
| $V_{id}$   | Differential Input Voltage <sup>1)</sup>    | +32            |                 |          | V    |
| $P_{tot}$  | Power Dissipation                           | 500            | N Suffix<br>500 | 500      | mW   |
|            |                                             |                | D Suffix<br>400 | 400      |      |
|            | Output Short-circuit Duration <sup>2)</sup> | Infinite       |                 |          |      |
| $I_{in}$   | Input Current <sup>3)</sup>                 | 50             | 50              | 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   |

1. Either or both input voltages must not exceed the magnitude of  $V_{CC}^+$  or  $V_{CC}^-$ .
2. Short-circuits from the output to  $V_{CC}$  can cause excessive heating if  $V_{CC} > 15V$ . 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.

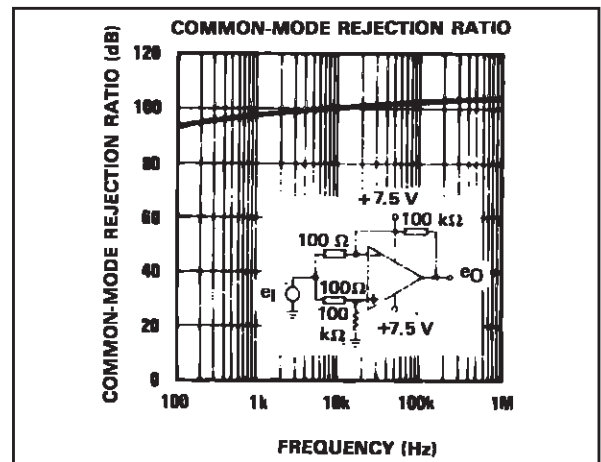
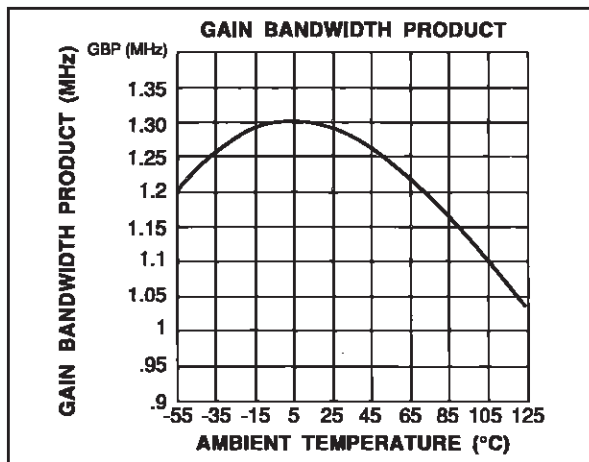
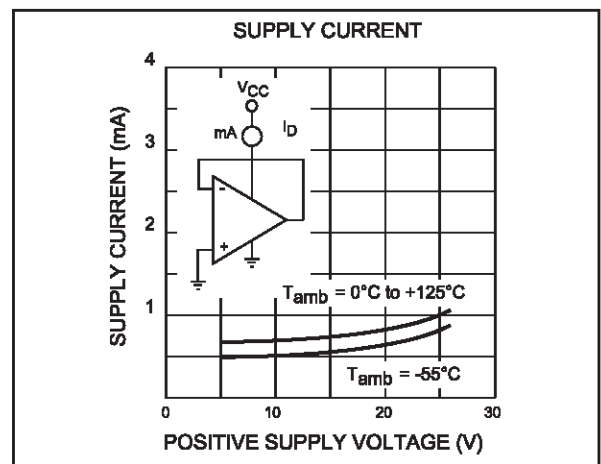
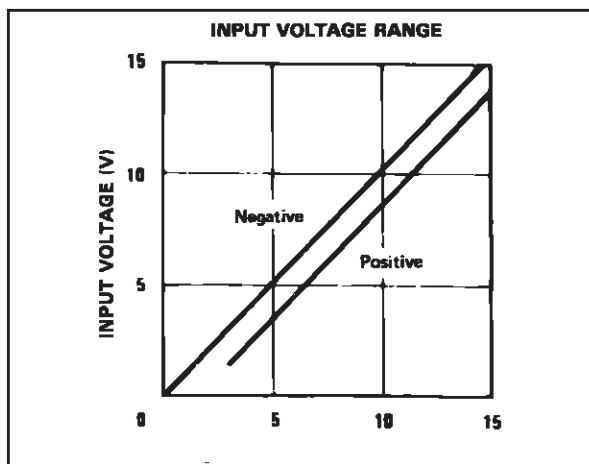
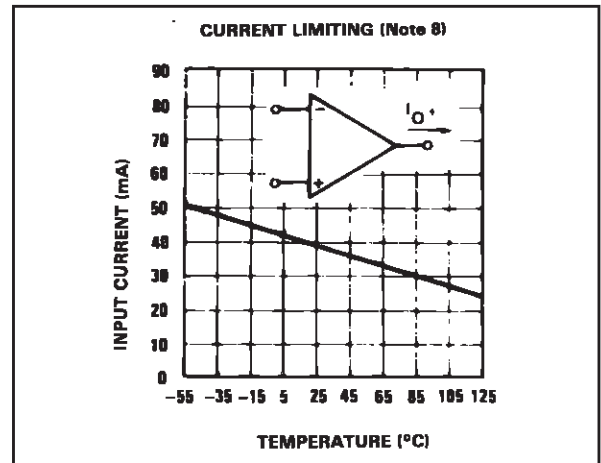
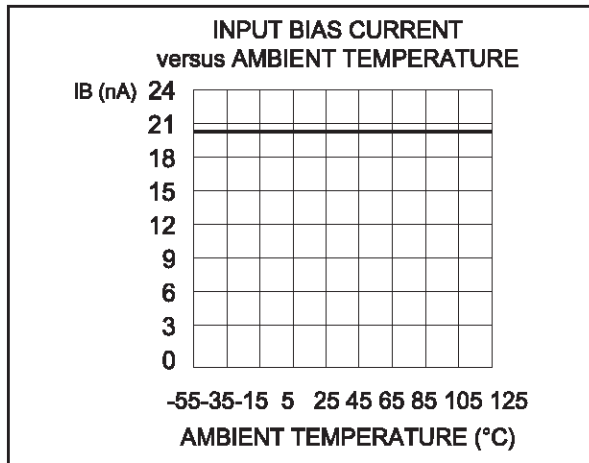
**ELECTRICAL CHARACTERISTICS**
 $V_{CC}^+ = +5V$ ,  $V_{CC}^- = \text{Ground}$ ,  $V_O = 1.4V$ ,  $T_{amb} = +25^\circ C$  (unless otherwise specified)

| Symbol       | Parameter                                                                                                                                                                                                                                                                                                    | Min.                             | Typ.                     | Max.                           | Unit          |
|--------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|----------------------------------|--------------------------|--------------------------------|---------------|
| $V_{io}$     | Input Offset Voltage - note <sup>1)</sup><br>$T_{amb} = +25^\circ C$<br>LM324<br>$T_{min} \leq T_{amb} \leq T_{max}$<br>LM324                                                                                                                                                                                |                                  | 2                        | 5<br>7<br>7<br>9               | mV            |
| $I_{io}$     | Input Offset Current<br>$T_{amb} = +25^\circ C$<br>$T_{min} \leq T_{amb} \leq T_{max}$                                                                                                                                                                                                                       |                                  | 2                        | 30<br>100                      | nA            |
| $I_{ib}$     | Input Bias Current - note <sup>2)</sup><br>$T_{amb} = +25^\circ C$<br>$T_{min} \leq T_{amb} \leq T_{max}$                                                                                                                                                                                                    |                                  | 20                       | 150<br>300                     | nA            |
| $A_{vd}$     | Large Signal Voltage Gain<br>$V_{CC}^+ = +15V$ , $R_L = 2k\Omega$ , $V_O = 1.4V$ to $11.4V$<br>$T_{amb} = +25^\circ C$<br>$T_{min} \leq T_{amb} \leq T_{max}$                                                                                                                                                | 50<br>25                         | 100                      |                                | V/mV          |
| SVR          | Supply Voltage Rejection Ratio ( $R_S \leq 10k\Omega$ )<br>$V_{CC}^+ = 5V$ to $30V$<br>$T_{amb} = +25^\circ C$<br>$T_{min} \leq T_{amb} \leq T_{max}$                                                                                                                                                        | 65<br>65                         | 110                      |                                | dB            |
| $I_{CC}$     | Supply Current, all Amp, no load<br>$T_{amb} = +25^\circ C$<br>$T_{min} \leq T_{amb} \leq T_{max}$<br>$V_{CC} = +5V$<br>$V_{CC} = +30V$<br>$V_{CC} = +5V$<br>$V_{CC} = +30V$                                                                                                                                 |                                  | 0.7<br>1.5<br>0.8<br>1.5 | 1.2<br>3<br>1.2<br>3           | mA            |
| $V_{icm}$    | Input Common Mode Voltage Range<br>$V_{CC} = +30V$ - note <sup>3)</sup><br>$T_{amb} = +25^\circ C$<br>$T_{min} \leq T_{amb} \leq T_{max}$                                                                                                                                                                    | 0<br>0                           |                          | $V_{CC} - 1.5$<br>$V_{CC} - 2$ | V             |
| CMR          | Common Mode Rejection Ratio ( $R_S \leq 10k\Omega$ )<br>$T_{amb} = +25^\circ C$<br>$T_{min} \leq T_{amb} \leq T_{max}$                                                                                                                                                                                       | 70<br>60                         | 80                       |                                | dB            |
| $I_{source}$ | Output Current Source ( $V_{id} = +1V$ )<br>$V_{CC} = +15V$ , $V_O = +2V$                                                                                                                                                                                                                                    | 20                               | 40                       | 70                             | mA            |
| $I_{sink}$   | Output Sink Current ( $V_{id} = -1V$ )<br>$V_{CC} = +15V$ , $V_O = +2V$<br>$V_{CC} = +15V$ , $V_O = +0.2V$                                                                                                                                                                                                   | 10<br>12                         | 20<br>50                 |                                | mA<br>$\mu A$ |
| $V_{OH}$     | High Level Output Voltage<br>$V_{CC} = +30V$<br>$T_{amb} = +25^\circ C$<br>$T_{min} \leq T_{amb} \leq T_{max}$<br>$T_{amb} = +25^\circ C$<br>$T_{min} \leq T_{amb} \leq T_{max}$<br>$V_{CC} = +5V$ , $R_L = 2k\Omega$<br>$T_{amb} = +25^\circ C$<br>$T_{min} \leq T_{amb} \leq T_{max}$<br>$R_L = 10k\Omega$ | 26<br>26<br>27<br>27<br>3.5<br>3 | 27<br>28                 |                                | V             |

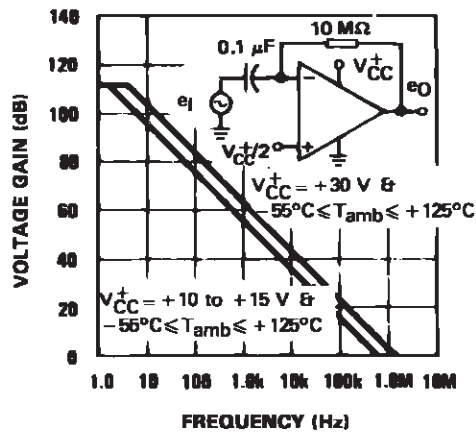
## LM124-LM224-LM324

| Symbol          | Parameter                                                                                                                    | Min. | Typ.  | Max.     | Unit                   |
|-----------------|------------------------------------------------------------------------------------------------------------------------------|------|-------|----------|------------------------|
| $V_{OL}$        | Low Level Output Voltage ( $R_L = 10k\Omega$ )<br>$T_{amb} = +25^\circ C$<br>$T_{min} \leq T_{amb} \leq T_{max}$             |      | 5     | 20<br>20 | mV                     |
| SR              | Slew Rate<br>$V_{CC} = 15V$ , $V_i = 0.5$ to $3V$ , $R_L = 2k\Omega$ , $C_L = 100pF$ , unity Gain                            |      | 0.4   |          | V/ $\mu s$             |
| GBP             | Gain Bandwidth Product<br>$V_{CC} = 30V$ , $f = 100kHz$ , $V_{in} = 10mV$ , $R_L = 2k\Omega$ , $C_L = 100pF$                 |      | 1.3   |          | MHz                    |
| THD             | Total Harmonic Distortion<br>$f = 1kHz$ , $A_v = 20dB$ , $R_L = 2k\Omega$ , $V_o = 2V_{pp}$ , $C_L = 100pF$ , $V_{CC} = 30V$ |      | 0.015 |          | %                      |
| $e_n$           | Equivalent Input Noise Voltage<br>$f = 1kHz$ , $R_s = 100\Omega$ , $V_{CC} = 30V$                                            |      | 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 - note <sup>4)</sup><br>$1kHz \leq f \leq 20kHz$                                                          |      | 120   |          | dB                     |

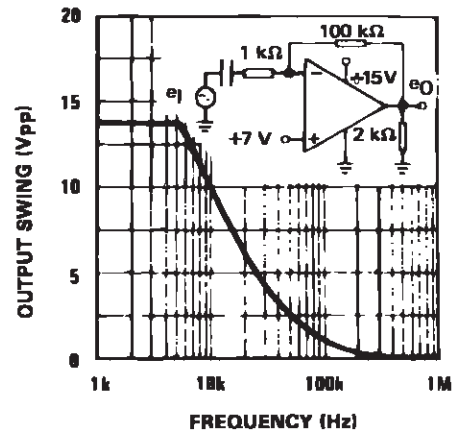
- $V_o = 1.4V$ ,  $R_s = 0\Omega$ ,  $5V < V_{CC}^+ < 30V$ ,  $0 < V_{ic} < V_{CC}^+ - 1.5V$
- The direction of the input current is out of the IC. This current is essentially constant, independent of the state of the output so no loading change exists on the input lines.
- The input common-mode voltage 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.
- 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 frequencies.



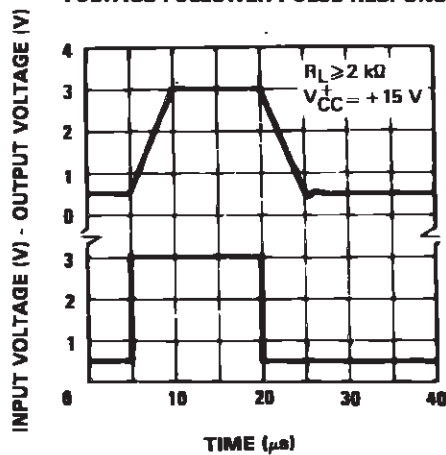
OPEN LOOP FREQUENCY RESPONSE



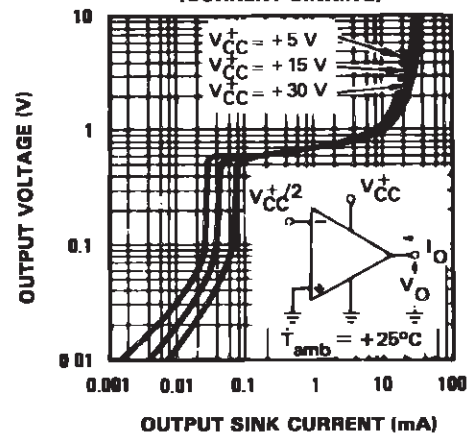
LARGE SIGNAL FREQUENCY RESPONSE



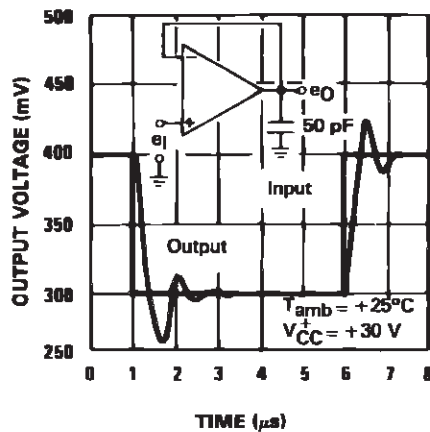
VOLTAGE FOLLOWER PULSE RESPONSE



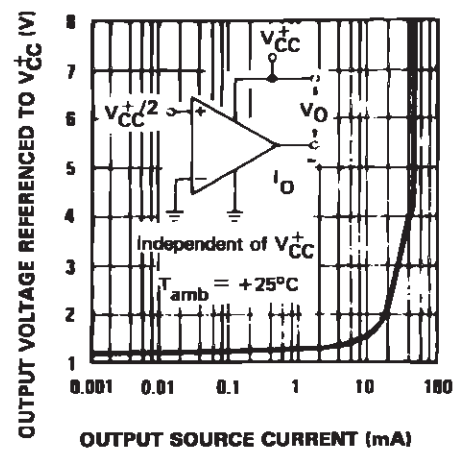
OUTPUT CHARACTERISTICS (CURRENT SINKING)

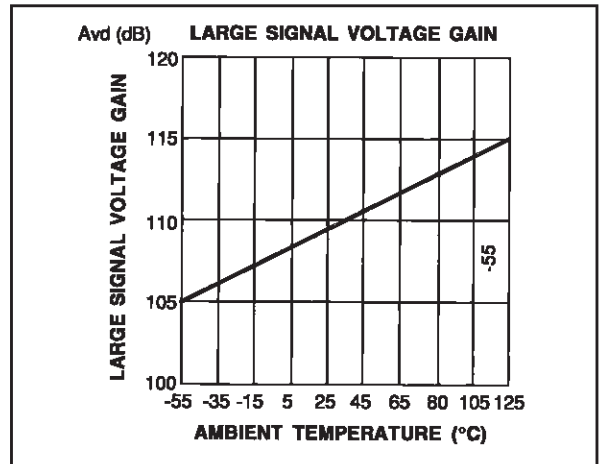
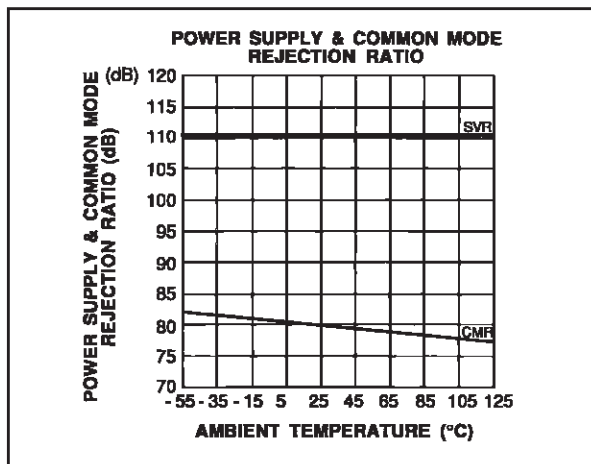
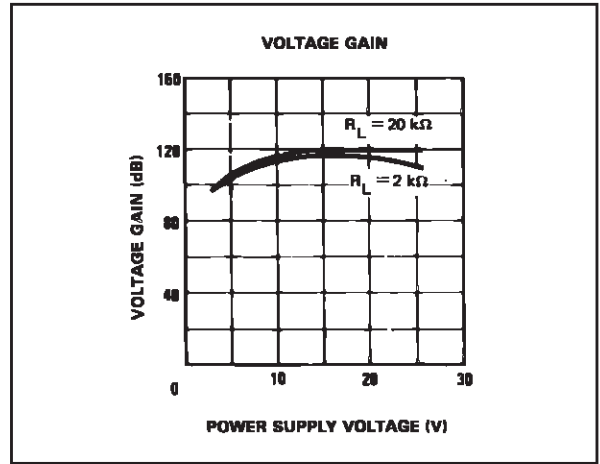
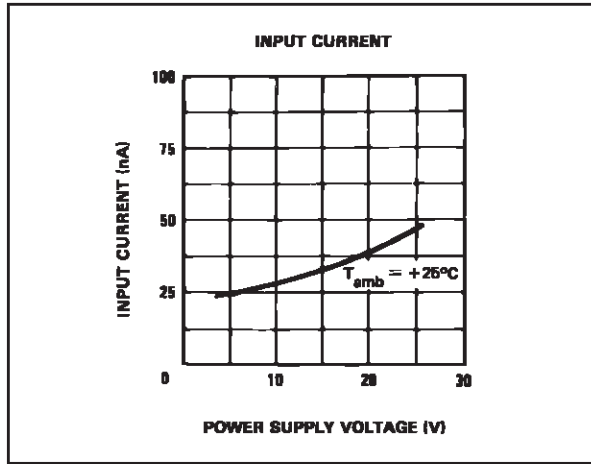


VOLTAGE FOLLOWER PULSE RESPONSE (SMALL SIGNAL)



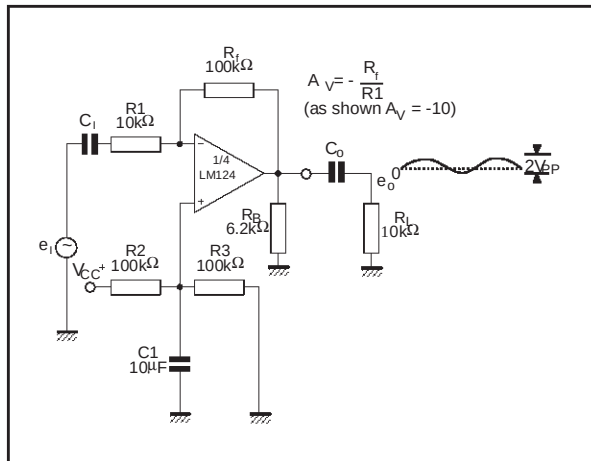
OUTPUT CHARACTERISTICS (CURRENT SOURCING)



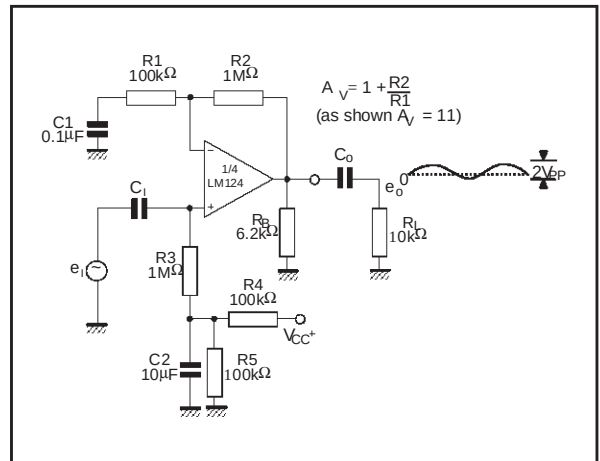


## TYPICAL SINGLE - SUPPLY APPLICATIONS

### AC COUPLED INVERTING AMPLIFIER

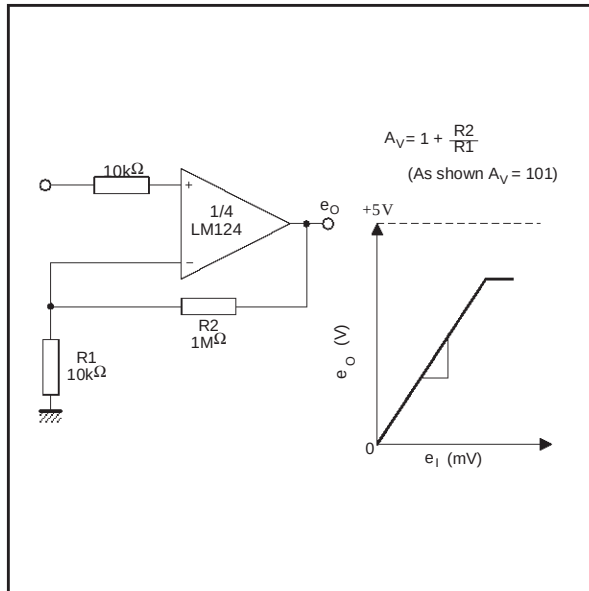


### AC COUPLED NON INVERTING AMPLIFIER

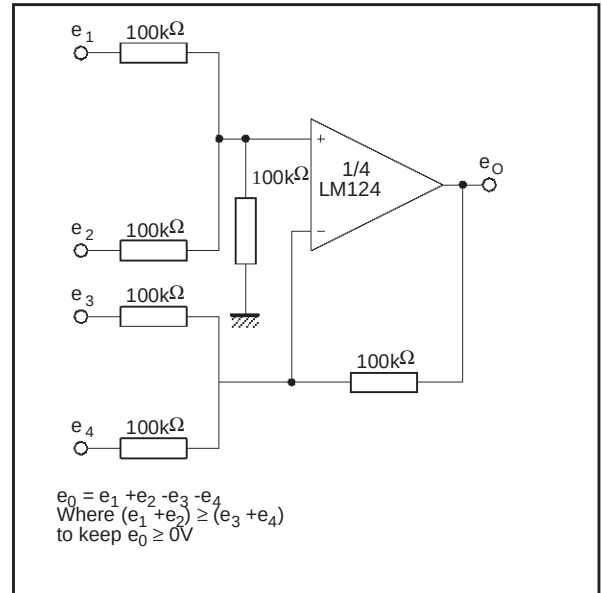


## TYPICAL SINGLE - SUPPLY APPLICATIONS

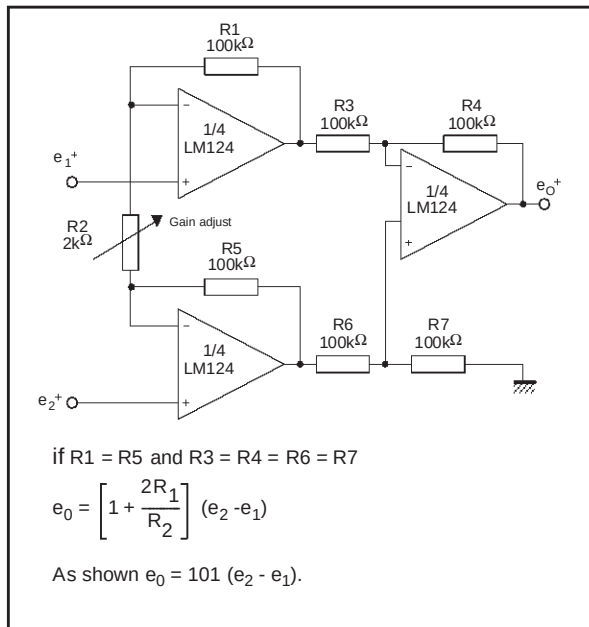
### NON-INVERTING DC GAIN



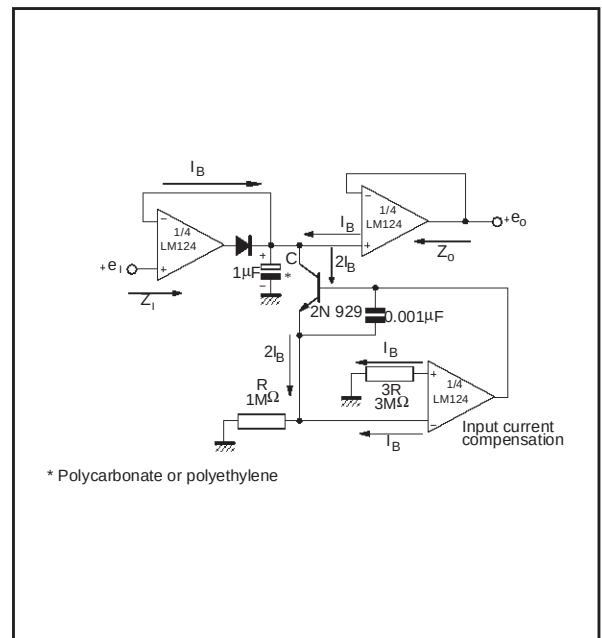
### DC SUMMING AMPLIFIER



### HIGH INPUT Z ADJUSTABLE GAIN DC INSTRUMENTATION AMPLIFIER



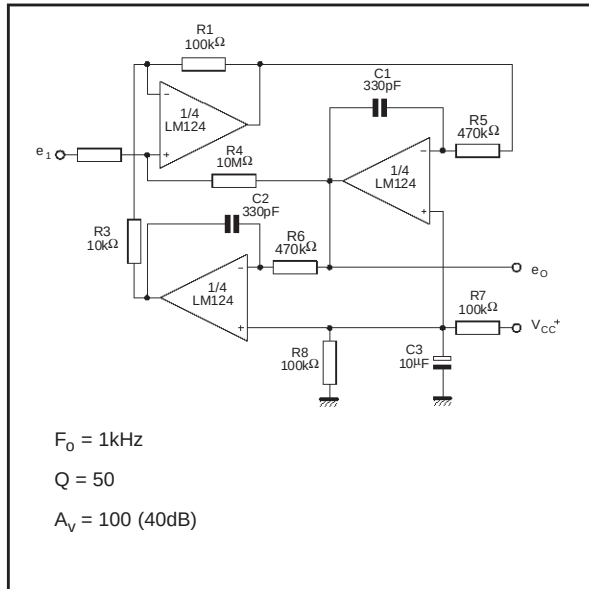
### LOW DRIFT PEAK DETECTOR



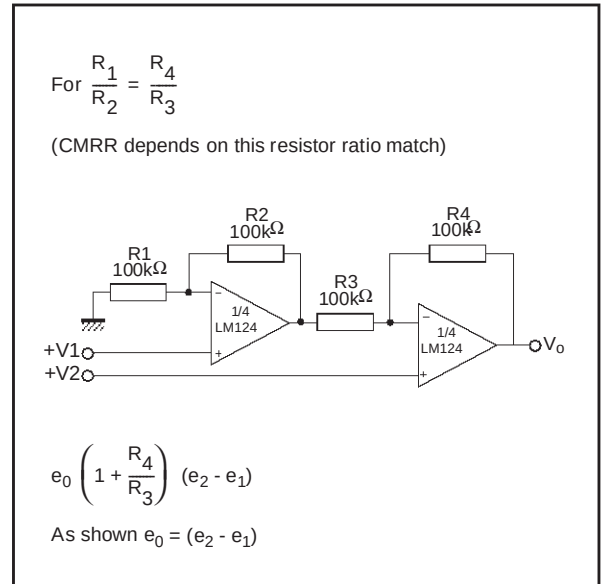


## TYPICAL SINGLE - SUPPLY APPLICATIONS

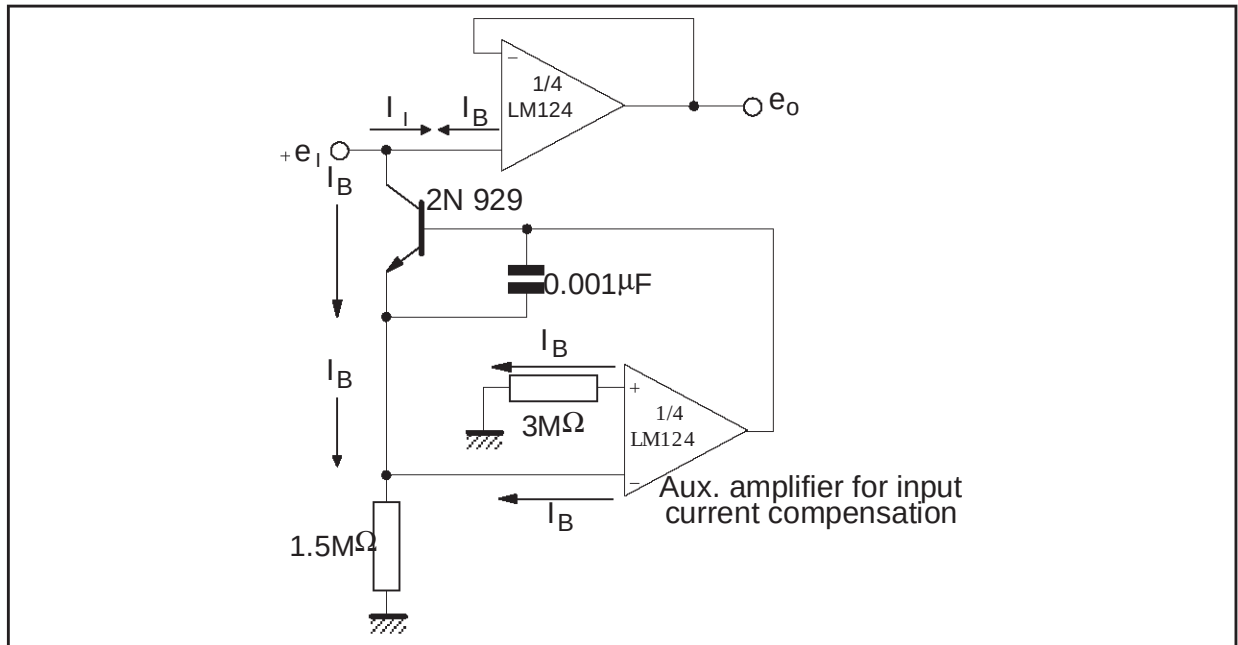
### ACTIVER BANDPASS FILTER



### HIGH INPUT Z, DC DIFFERENTIAL AMPLIFIER



### USING SYMETRICAL AMPLIFIERS TO REDUCE INPUT CURRENT (GENERAL CONCEPT)



## LM124-LM224-LM324

### MACROMODEL

\*\* Standard Linear lcs 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 (analog)

\*\*\*\*\*

.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

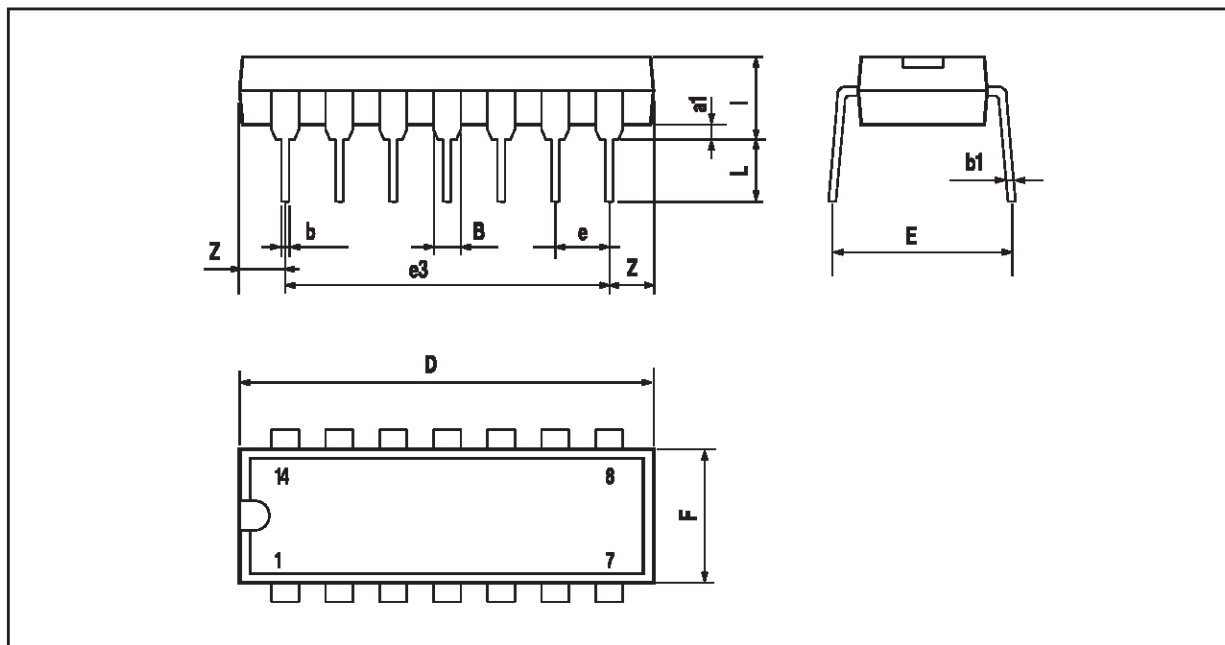
### ELECTRICAL CHARACTERISTICS

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

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

**PACKAGE MECHANICAL DATA**

14 PINS - PLASTIC DIP

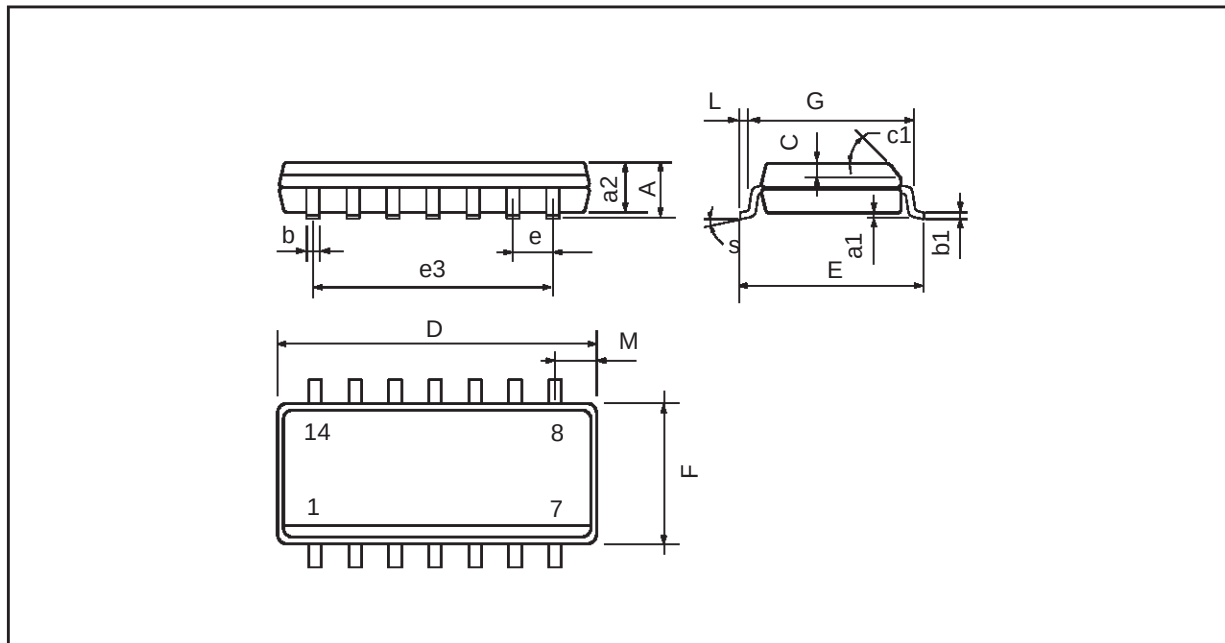


| Dimensions | Millimeters |       |      | Inches |       |       |
|------------|-------------|-------|------|--------|-------|-------|
|            | Min.        | Typ.  | Max. | Min.   | Typ.  | Max.  |
| $a_1$      | 0.51        |       |      | 0.020  |       |       |
| $B$        | 1.39        |       | 1.65 | 0.055  |       | 0.065 |
| $b$        |             | 0.5   |      |        | 0.020 |       |
| $b_1$      |             | 0.25  |      |        | 0.010 |       |
| $D$        |             |       | 20   |        |       | 0.787 |
| $E$        |             | 8.5   |      |        | 0.335 |       |
| $e$        |             | 2.54  |      |        | 0.100 |       |
| $e_3$      |             | 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 |

## LM124-LM224-LM324

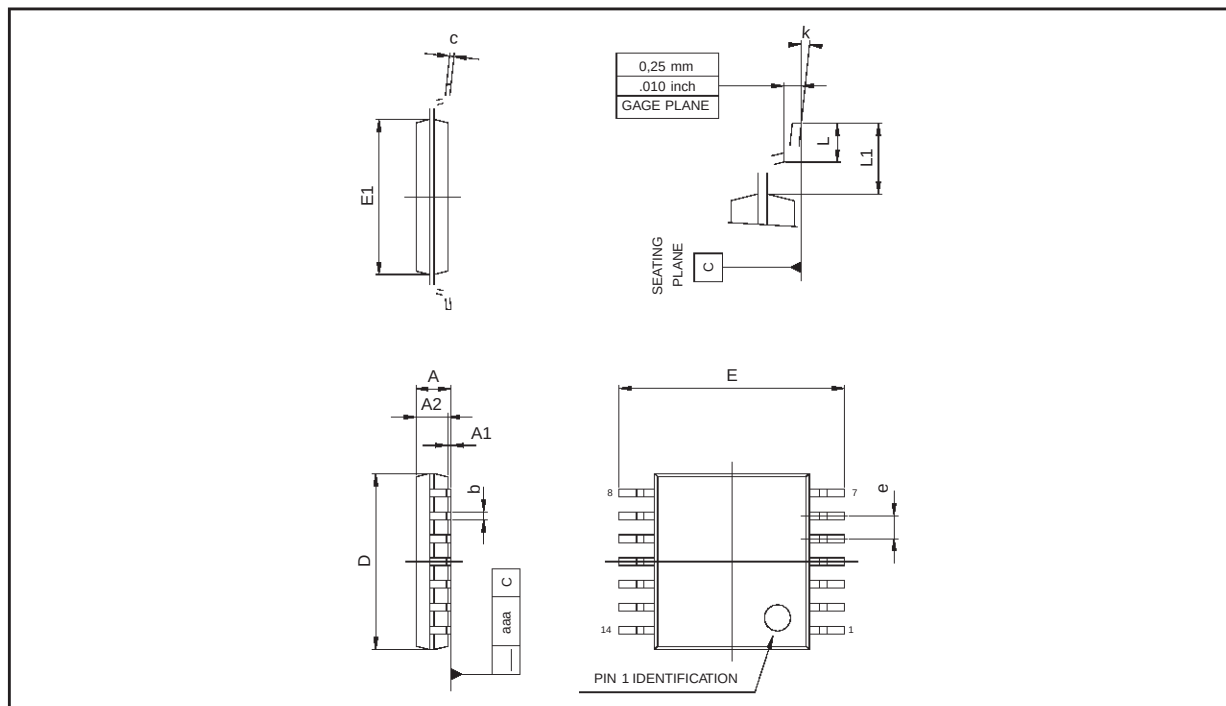
### PACKAGE MECHANICAL DATA

14 PINS - PLASTIC MICROPACKAGE (SO)



| Dimensions | Millimeters |      |      | Inches |       |       |
|------------|-------------|------|------|--------|-------|-------|
|            | Min.        | Typ. | Max. | Min.   | Typ.  | Max.  |
| A          |             |      | 1.75 |        |       | 0.069 |
| a1         | 0.1         |      | 0.2  | 0.004  |       | 0.008 |
| a2         |             |      | 1.6  |        |       | 0.063 |
| b          | 0.35        |      | 0.46 | 0.014  |       | 0.018 |
| b1         | 0.19        |      | 0.25 | 0.007  |       | 0.010 |
| C          |             | 0.5  |      |        | 0.020 |       |
| c1         | 45° (typ.)  |      |      |        |       |       |
| D (1)      | 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 (1)      | 3.8         |      | 4.0  | 0.150  |       | 0.157 |
| G          | 4.6         |      | 5.3  | 0.181  |       | 0.208 |
| L          | 0.5         |      | 1.27 | 0.020  |       | 0.050 |
| M          |             |      | 0.68 |        |       | 0.027 |
| S          | 8° (max.)   |      |      |        |       |       |

Note : (1) D and F do not include mold flash or protrusions - Mold flash or protrusions shall not exceed 0.15mm (.066 inc) ONLY FOR DATA BOOK.

**PACKAGE MECHANICAL DATA****14 PINS - THIN SHRINK SMALL OUTLINE PACKAGE (TSSOP)**

| Dimensions | Millimeters |       |       | Inches |       |       |
|------------|-------------|-------|-------|--------|-------|-------|
|            | Min.        | Typ.  | Max.  | Min.   | Typ.  | Max.  |
| A          |             |       | 1.20  |        |       | 0.05  |
| A1         | 0.05        |       | 0.15  | 0.01   |       | 0.006 |
| A2         | 0.80        | 1.00  | 1.05  | 0.031  | 0.039 | 0.041 |
| b          | 0.19        |       | 0.30  | 0.007  |       | 0.15  |
| c          | 0.09        |       | 0.20  | 0.003  |       | 0.012 |
| D          | 4.90        | 5.00  | 5.10  | 0.192  | 0.196 | 0.20  |
| E          |             | 6.40  |       |        | 0.252 |       |
| E1         | 4.30        | 4.40  | 4.50  | 0.169  | 0.173 | 0.177 |
| e          |             | 0.65  |       |        | 0.025 |       |
| k          | 0°          |       | 8°    | 0°     |       | 8°    |
| L          | 0.450       | 0.600 | 0.750 | 0.018  | 0.024 | 0.030 |
| L1         |             | 1.00  |       |        | 0.039 |       |
| aaa        |             |       | 0.100 |        |       | 0.004 |

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