



LM124-LM224-LM324

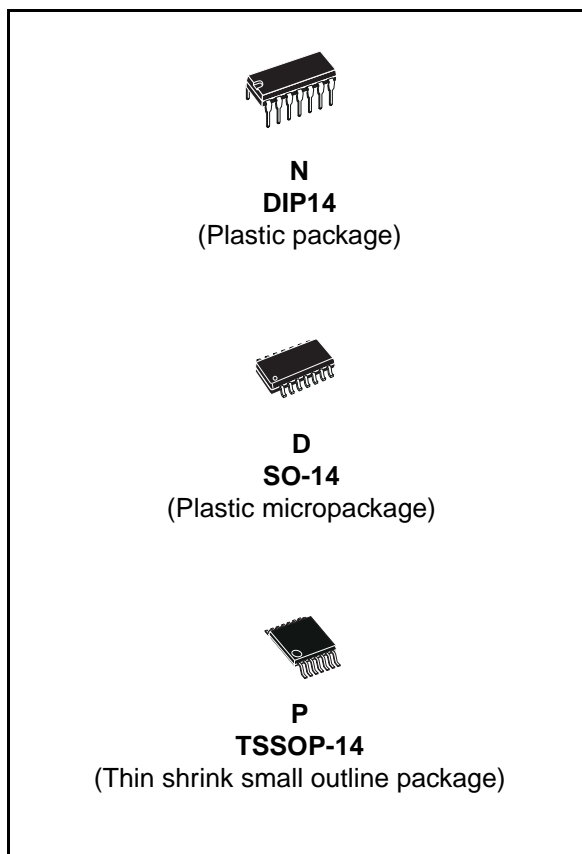
Low power quad operational amplifiers

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 μ A
- Low input bias current: 20 nA
- Low input offset voltage: 5 mV max. (For more accurate applications, use the equivalent parts LM124A-LM224A-LM324A which feature 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 | Packing |
|-------------|-------------------|--|---------------------|
| LM124N | -55°C, +125°C | DIP | Tube |
| LM124D/DT | | SO | Tube or tape & reel |
| LM224N | -40°C, +105°C | DIP | Tube |
| LM224D/DT | | SO | Tube or tape & reel |
| LM224PT | | TSSOP (Thin shrink outline package) | Tape & reel |
| LM324N | 0°C, +70°C | DIP | Tube |
| LM324D/DT | | SO | Tube or tape & reel |
| LM324PT | | TSSOP (Thin shrink outline package) | Tape & reel |

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1 Pin & schematic diagram

Figure 1. Pin connections (top view)

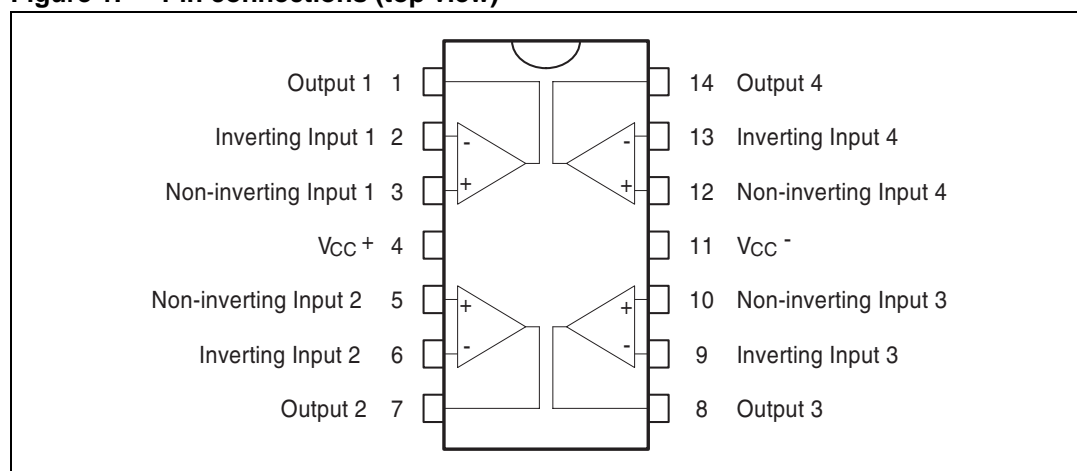
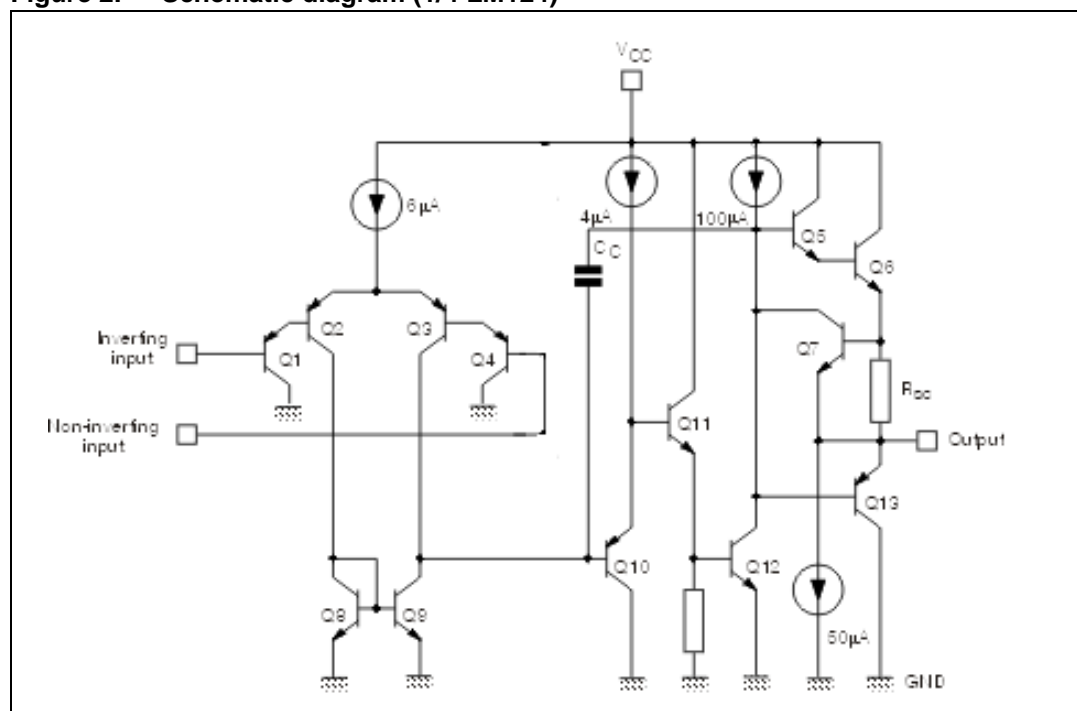


Figure 2. Schematic diagram (1/4 LM124)



2 Absolute maximum ratings

Table 1. Absolute maximum ratings

| Symbol | Parameter | LM124 | LM224 | LM324 | Unit |
|-------------------|---|------------------|-------------|------------|------|
| V _{CC} | Supply voltage | ±16 or 32 | | | V |
| V _i | Input voltage | 32 | | | V |
| V _{id} | Differential input voltage ⁽¹⁾ | 32 | | | V |
| P _{tot} | Power dissipation N suffix D suffix | 500 | 500 400 | 500 400 | mW |
| | Output short-circuit duration ⁽²⁾ | Infinite | | | |
| I _{in} | Input current ⁽³⁾ | 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 |
| T _j | Maximum junction temperature | 150 | | | °C |
| R _{thja} | Thermal resistance junction to ambient ⁽⁴⁾ 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 ⁽⁵⁾ | 250 | | | V |
| | MM: machine model ⁽⁶⁾ | 150 | | | |
| | CDM: charged device model | 1500 | | | |

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 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 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 is restored for input voltages above -0.3 V.
4. 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).
5. Human body model, 100 pF discharged through a 1.5 k Ω resistor into pin of device.
6. 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 < 5 Ω), into pin-to-pin of device.

3 Electrical characteristics

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

| Symbol | Parameter | Min. | Typ. | Max. | Unit |
|---------------------|--|----------|------------|--------------------------------|------|
| V_{io} | Input offset voltage ⁽¹⁾ $T_{\text{amb}} = +25^\circ\text{ C}$ LM124-LM224 LM324 | | 2 | 5 7 | mV |
| | $T_{\text{min}} \leq T_{\text{amb}} \leq T_{\text{max}}$ LM124-LM224 LM324 | | | 7 9 | |
| I_{io} | Input offset current $T_{\text{amb}} = +25^\circ\text{ C}$ $T_{\text{min}} \leq T_{\text{amb}} \leq T_{\text{max}}$ | | 2 | 30 100 | nA |
| I_{ib} | Input bias current ⁽²⁾ $T_{\text{amb}} = +25^\circ\text{ C}$ $T_{\text{min}} \leq T_{\text{amb}} \leq T_{\text{max}}$ | | 20 | 150 300 | nA |
| A_{vd} | Large signal voltage gain $V_{CC}^+ = +15\text{ V}$, $R_L = 2\text{ k}\Omega$, $V_o = 1.4\text{ V}$ to 11.4 V $T_{\text{amb}} = +25^\circ\text{ C}$ $T_{\text{min}} \leq T_{\text{amb}} \leq T_{\text{max}}$ | 50 25 | 100 | | V/mV |
| SVR | Supply voltage rejection ratio ($R_s \leq 10\text{ k}\Omega$) $V_{CC}^+ = 5\text{ V}$ to 30 V $T_{\text{amb}} = +25^\circ\text{ C}$ $T_{\text{min}} \leq T_{\text{amb}} \leq T_{\text{max}}$ | 65 65 | 110 | | dB |
| I_{CC} | Supply current, all Amp, no load $T_{\text{amb}} = +25^\circ\text{ C}$ $V_{CC} = +5\text{ V}$ $V_{CC} = +30\text{ V}$ | | 0.7 1.5 | 1.2 3 | mA |
| | $T_{\text{min}} \leq T_{\text{amb}} \leq T_{\text{max}}$ $V_{CC} = +5\text{ V}$ $V_{CC} = +30\text{ V}$ | | 0.8 1.5 | 1.2 3 | |
| V_{icm} | Input common mode voltage range $V_{CC} = +30\text{ V}$ ⁽³⁾ $T_{\text{amb}} = +25^\circ\text{ C}$ $T_{\text{min}} \leq T_{\text{amb}} \leq T_{\text{max}}$ | 0 0 | | $V_{CC} - 1.5$ $V_{CC} - 2$ | V |
| CMR | Common mode rejection ratio ($R_s \leq 10\text{ k}\Omega$) $T_{\text{amb}} = +25^\circ\text{ C}$ $T_{\text{min}} \leq T_{\text{amb}} \leq T_{\text{max}}$ | 70 60 | 80 | | dB |
| I_{source} | Output current source ($V_{id} = +1\text{ V}$) $V_{CC} = +15\text{ V}$, $V_o = +2\text{ V}$ | 20 | 40 | 70 | mA |

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

| Symbol | Parameter | Min. | Typ. | Max. | Unit |
|-------------------|---|----------------------|--------------|----------|--------------------------------------|
| I_{sink} | Output sink current ($V_{\text{id}} = -1\text{ V}$) | | | | |
| | $V_{CC} = +15\text{ V}$, $V_o = +2\text{ V}$ $V_{CC} = +15\text{ V}$, $V_o = +0.2\text{ V}$ | 10 12 | 20 50 | | mA μA |
| V_{OH} | High level output voltage $V_{CC} = +30\text{ V}$ $T_{\text{amb}} = +25^\circ\text{C}$, $R_L = 2\text{ k}\Omega$ $T_{\text{min}} \leq T_{\text{amb}} \leq T_{\text{max}}$ $T_{\text{amb}} = +25^\circ\text{C}$, $R_L = 10\text{ k}\Omega$ $T_{\text{min}} \leq T_{\text{amb}} \leq T_{\text{max}}$ | 26 26 27 27 | 27 28 | | V |
| | $V_{CC} = +5\text{ V}$, $R_L = 2\text{ k}\Omega$ $T_{\text{amb}} = +25^\circ\text{C}$ $T_{\text{min}} \leq T_{\text{amb}} \leq T_{\text{max}}$ | 3.5 3 | | | |
| V_{OL} | Low level output voltage ($R_L = 10\text{ k}\Omega$) $T_{\text{amb}} = +25^\circ\text{C}$ $T_{\text{min}} \leq T_{\text{amb}} \leq T_{\text{max}}$ | | 5 | 20 20 | mV |
| SR | Slew rate $V_{CC} = 15\text{ V}$, $V_i = 0.5\text{ to }3\text{ V}$, $R_L = 2\text{ k}\Omega$, $C_L = 100\text{ pF}$, unity gain | | 0.4 | | V/μs |
| GBP | Gain bandwidth product $V_{CC} = 30\text{ V}$, $f = 100\text{ kHz}$, $V_{\text{in}} = 10\text{ mV}$, $R_L = 2\text{ k}\Omega$, $C_L = 100\text{ pF}$ | | 1.3 | | MHz |
| THD | Total harmonic distortion $f = 1\text{ kHz}$, $A_v = 20\text{ dB}$, $R_L = 2\text{ k}\Omega$, $V_o = 2\text{ V}_{\text{pp}}$, $C_L = 100\text{ pF}$, $V_{CC} = 30\text{ V}$ | | 0.015 | | % |
| e_n | Equivalent input noise voltage $f = 1\text{ kHz}$, $R_s = 100\text{ }\Omega$, $V_{CC} = 30\text{ V}$ | | 40 | | $\frac{\text{nV}}{\sqrt{\text{Hz}}}$ |
| DV_{io} | Input offset voltage drift | | 7 | 30 | $\mu\text{V}/^\circ\text{C}$ |
| DI_{io} | Input offset current drift | | 10 | 200 | $\text{pA}/^\circ\text{C}$ |
| V_{o1}/V_{o2} | Channel separation ⁽⁴⁾ $1\text{ kHz} \leq f \leq 20\text{ kHz}$ | | 120 | | dB |

- $V_o = 1.4\text{ V}$, $R_s = 0\text{ }\Omega$, $5\text{ V} < V_{CC}^+ < 30\text{ V}$, $0 < V_{\text{ic}} < V_{CC}^+ - 1.5\text{ V}$
- 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 change in the load 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. V. The upper end of the common-mode voltage range is $V_{CC}^+ - 1.5\text{ V}$, but either or both inputs can go to +32 V without damage.
- Due to the proximity of external components, ensure that stray capacitance between these external parts does not cause coupling. Typically, this can be detected because this type of capacitance increases at higher frequencies.

Figure 3. Input bias current vs. ambient temperature

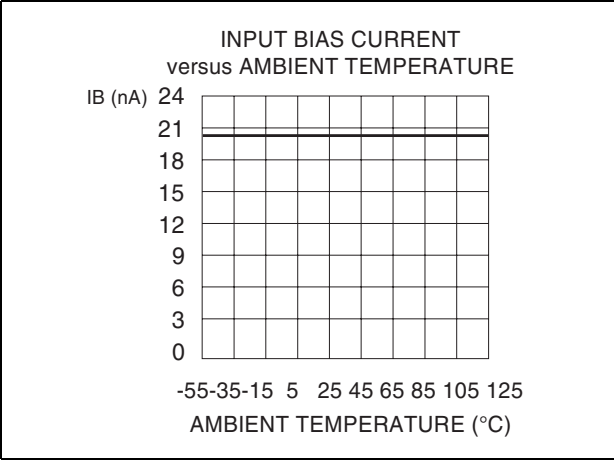


Figure 4. Current limiting

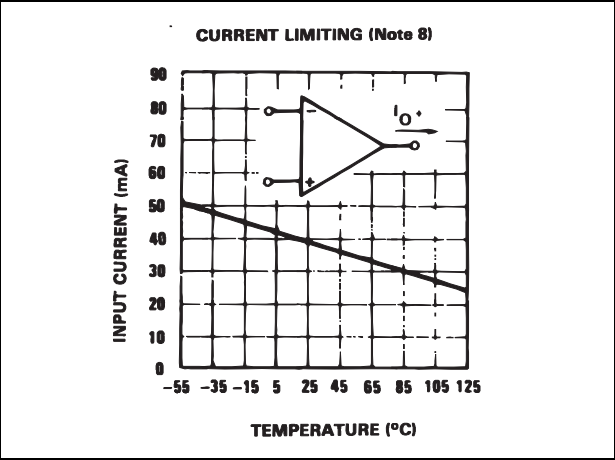


Figure 5. Input voltage range

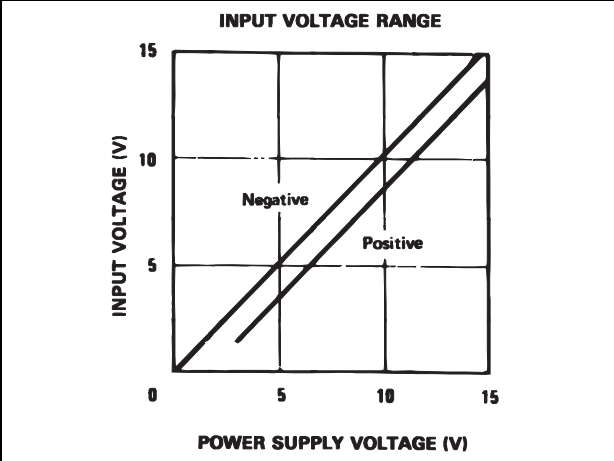


Figure 6. Supply current

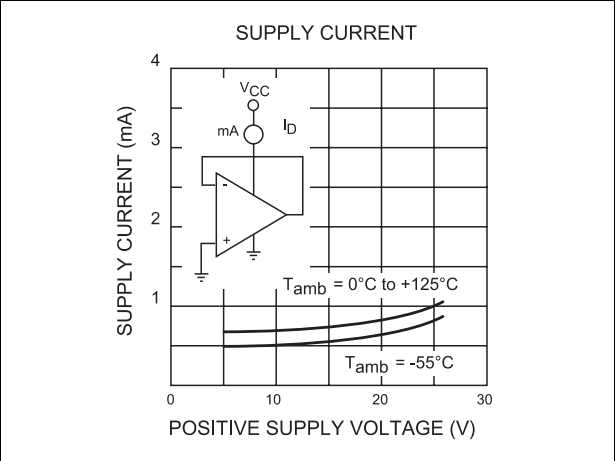


Figure 7. Gain bandwidth product

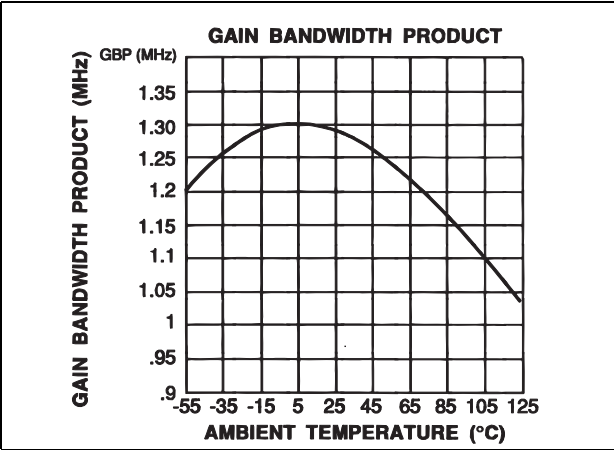
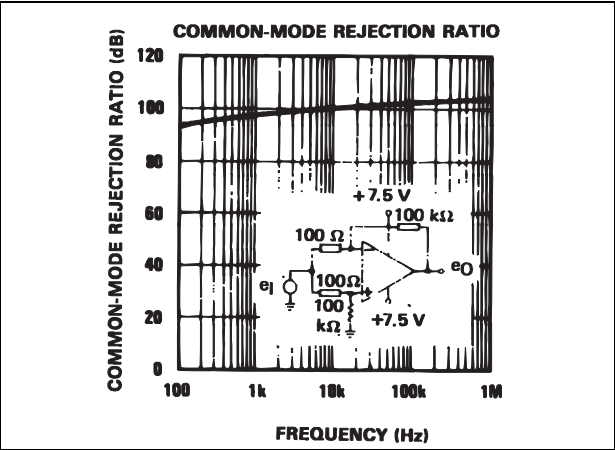


Figure 8. Common mode rejection ratio



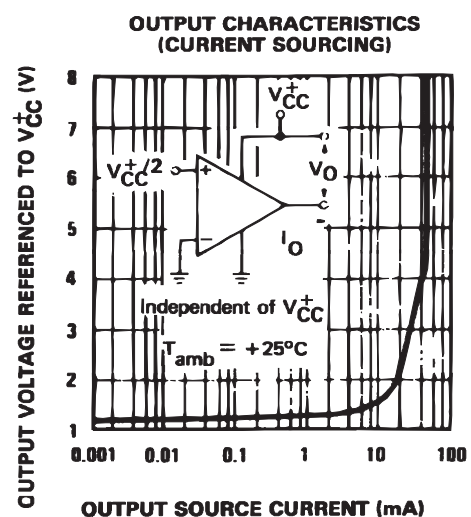
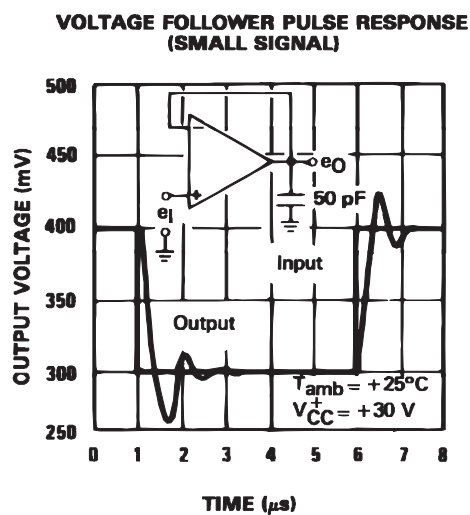
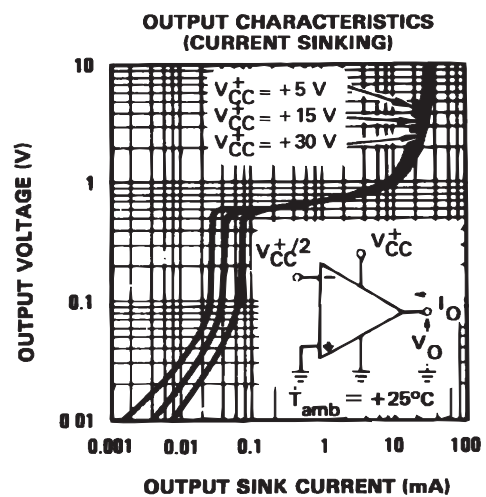
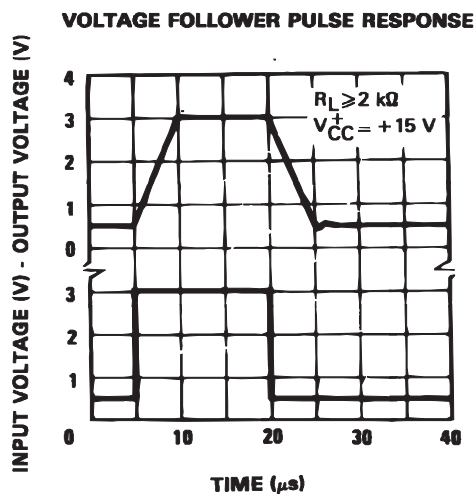
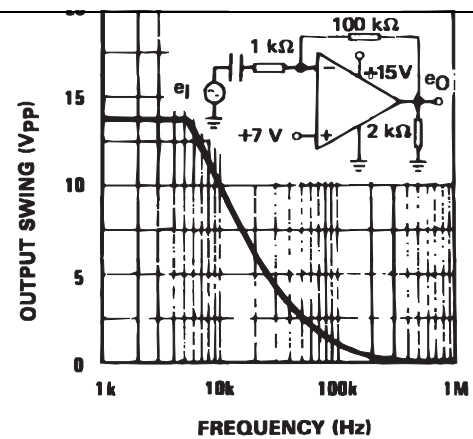
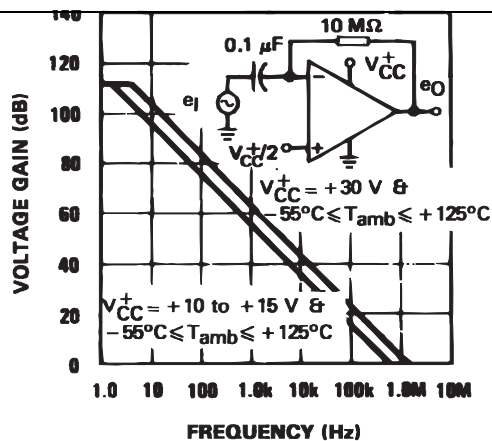


Figure 9. Input current

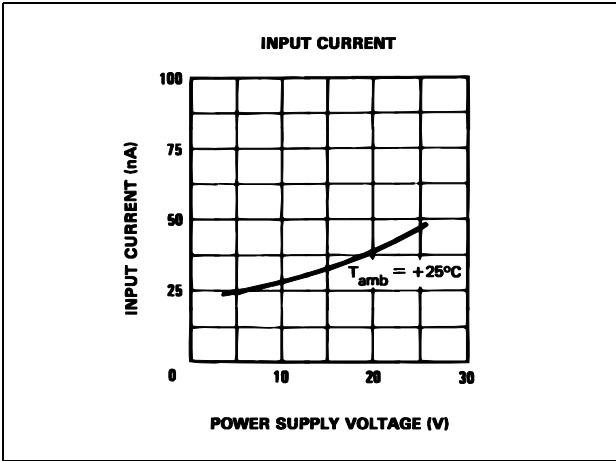


Figure 10. Large signal voltage gain

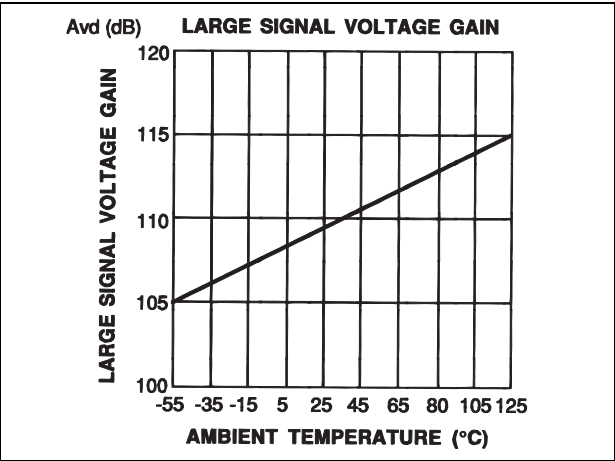


Figure 11. Power supply & common mode rejection ratio

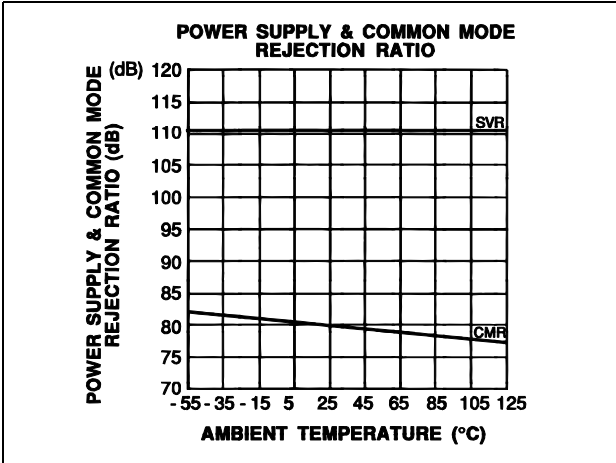
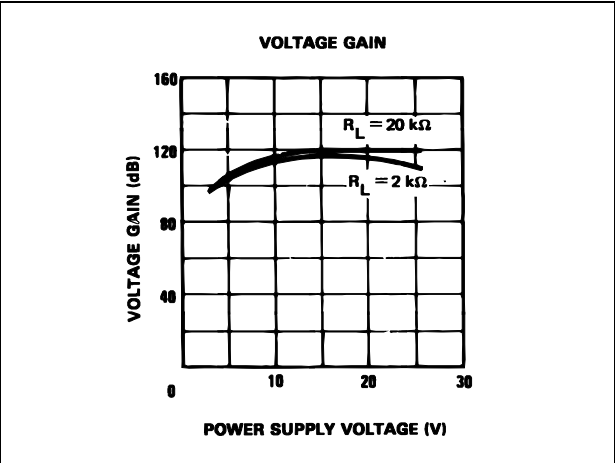


Figure 12. Voltage gain



4 Typical single-supply applications

Figure 13. AC coupled inverting amplifier

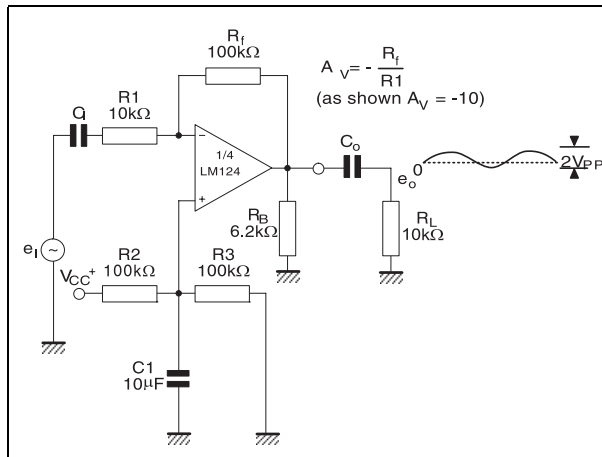


Figure 14. High input Z adjustable gain DC instrumentation amplifier

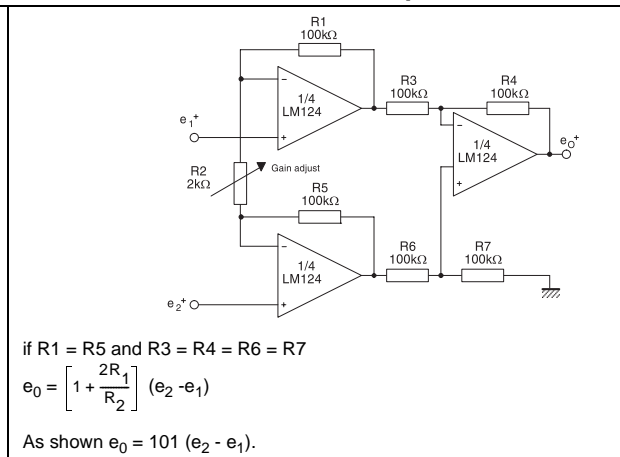


Figure 15. AC coupled non inverting amplifier

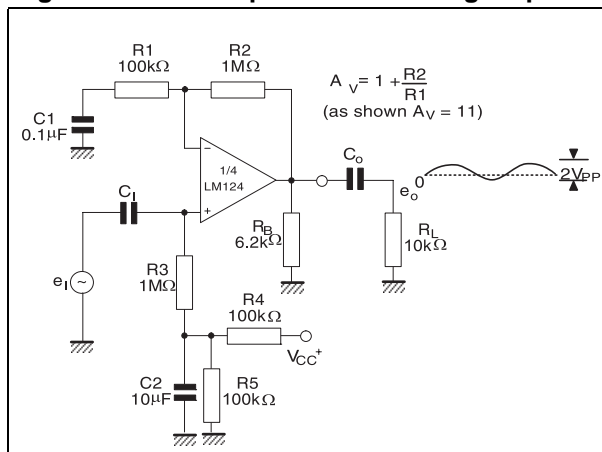


Figure 16. DC summing amplifier

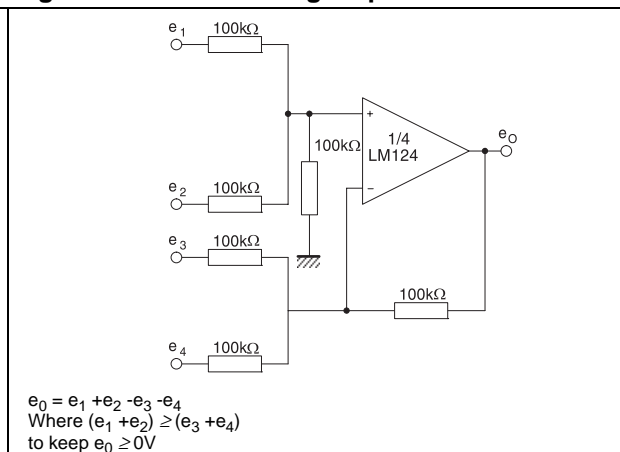


Figure 17. Non-inverting DC gain

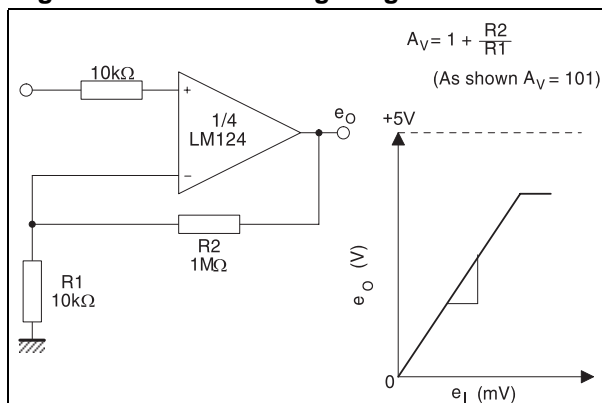


Figure 18. Low drift peak detector

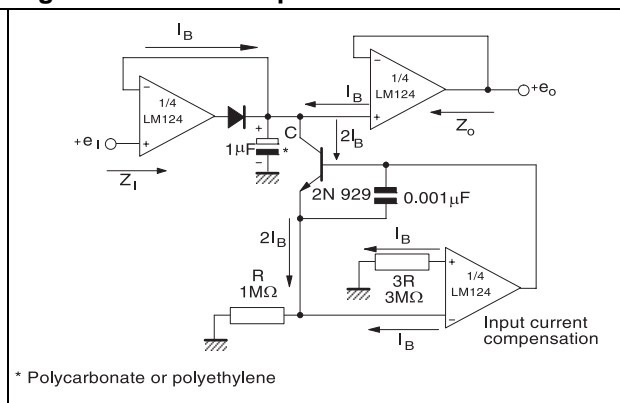


Figure 19. Active bandpass filter

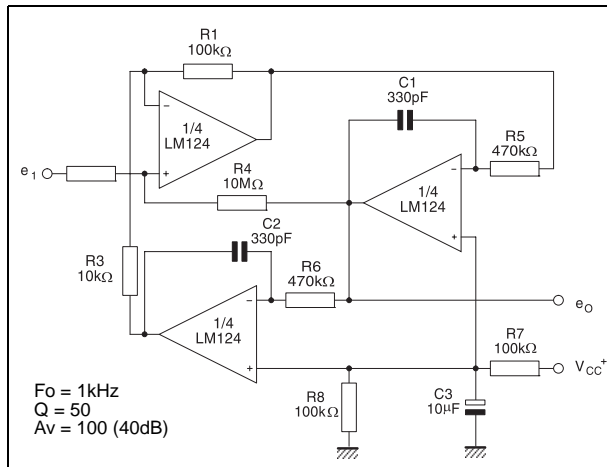


Figure 20. High input Z, DC differential amplifier

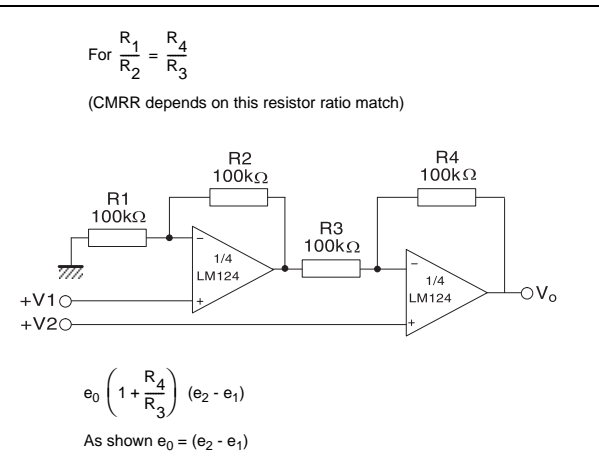
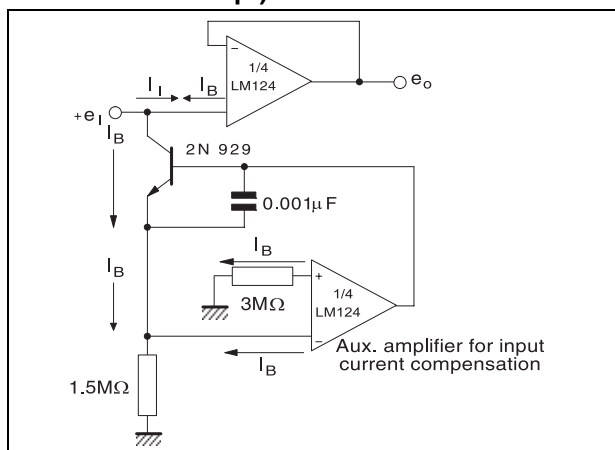


Figure 21. Using symmetrical amplifiers to reduce input current (general concept)



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
```

```

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 | μA |
| V_{icm} | | -15 to +13.5 | V |
| V_{OH} | $R_L = 2\text{ k}\Omega$ ($V_{CC}^+ = 15V$) | +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/ μs |

6 Package information

In order to meet environmental requirements, STMicroelectronics offers these devices in ECOPACK® 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.

6.1 DIP14 package

| Ref. | Dimensions | | | | | |
|------|-------------|-------|------|--------|-------|-------|
| | Millimeters | | | Inches | | |
| | 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 |

The diagrams illustrate the physical dimensions of the DIP14 package. The side view shows the package height (L), pin height (a1), pin spacing (B), pin width (b), pin pitch (e), and lead length (Z). The top view shows the package width (D), lead spacing (E), and lead width (b1). The bottom view shows the pin numbering: 14 on the left, 8 on the right, 1 on the bottom left, and 7 on the bottom right.

6.2 SO-14 package

| Ref. | Dimensions | | | | | |
|------|-------------|------|-------|--------|-------|-------|
| | Millimeters | | | Inches | | |
| | 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 |
| c | 0.19 | | 0.25 | 0.007 | | 0.010 |
| c1 | 45° (typ.) | | | | | |
| D | 8.55 | | 8.75 | 0.336 | | 0.344 |
| H | 5.8 | | 6.2 | 0.228 | | 0.244 |
| e | | 1.27 | | | 0.050 | |
| E | 3.8 | | 4.0 | 0.149 | | 0.157 |
| L | 0.5 | | 0.127 | 0.019 | | 0.050 |
| k | 8° (max.) | | | | | |

6.3 TSSOP14 package

| Ref. | Dimensions | | | | | |
|------|-------------|----------|------|--------|------------|--------|
| | Millimeters | | | Inches | | |
| | Min. | Typ. | Max. | Min. | Typ. | Max. |
| A | | | 1.2 | | | 0.047 |
| A1 | 0.05 | 0.010 | 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° |
| L1 | 0.45 | 0.60 | 0.75 | 0.018 | 0.024 | 0.030 |

PIN 1 IDENTIFICATION

7 Revision history

| Date | Revision | Changes |
|-------------|----------|--|
| 1-Oct.-2003 | 1 | First release. |
| 2-Jan-2005 | 2 | Modifications on AMR Table 1 on page 4 (explanation of V_{id} and V_i limits). |
| 1-Jun-2005 | 3 | ESD protection inserted in Table 1 on page 4 . |
| 2-Jan-2006 | 4 | T_j and R_{thjc} parameters added in Table 1. on page 4 . |
| 4-Oct-2006 | 5 | Editorial update. Table 3 moved to Section 5: Macromodels on page 12 . |

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