

LM124/LM224/LM324/LM2902 Low Power Quad Operational Amplifiers

Check for Samples: [LM124-N](#), [LM224-N](#), [LM2902-N](#), [LM324-N](#)

FEATURES

- Internally frequency compensated for unity gain
- Large DC voltage gain 100 dB
- Wide bandwidth (unity gain) 1 MHz
 - (temperature compensated)
- Wide power supply range:
 - Single supply 3V to 32V
 - or dual supplies $\pm 1.5V$ to $\pm 16V$
- Very low supply current drain (700 μA)—essentially independent of supply voltage
- Low input biasing current 45 nA
 - (temperature compensated)
- Low input offset voltage 2 mV
 - and offset current: 5 nA
- Input common-mode voltage range includes ground
- Differential input voltage range equal to the power supply voltage
- Large output voltage swing 0V to $V^+ - 1.5V$

DESCRIPTION

The LM124 series consists of four independent, high gain, internally frequency compensated operational amplifiers which were designed specifically to 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.

Application areas include transducer amplifiers, DC gain blocks and all the conventional op amp circuits which now can be more easily implemented in single power supply systems. For example, the LM124 series can be directly operated off of the standard +5V power supply voltage which is used in digital systems and will easily provide the required interface electronics without requiring the additional $\pm 15V$ power supplies.

UNIQUE CHARACTERISTICS

- In the linear mode the input common-mode voltage range includes ground and the output voltage can also swing to ground, even though operated from only a single power supply voltage
- The unity gain cross frequency is temperature compensated
- The input bias current is also temperature compensated

ADVANTAGES

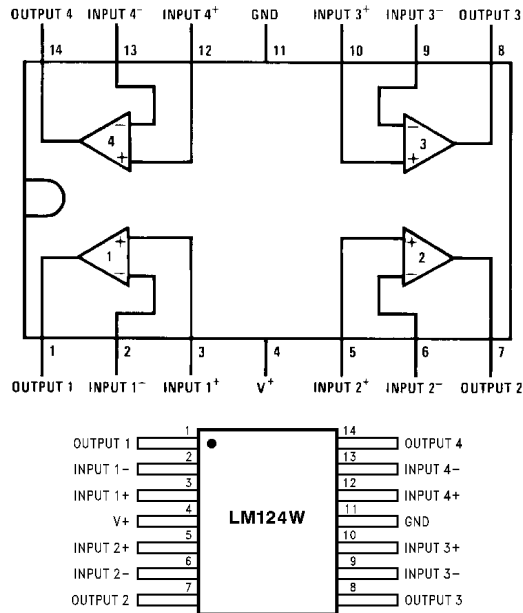
- Eliminates need for dual supplies
- Four internally compensated op amps in a single package
- Allows directly sensing near GND and V_{OUT} also goes to GND
- Compatible with all forms of logic
- Power drain suitable for battery operation



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CONNECTION DIAGRAM

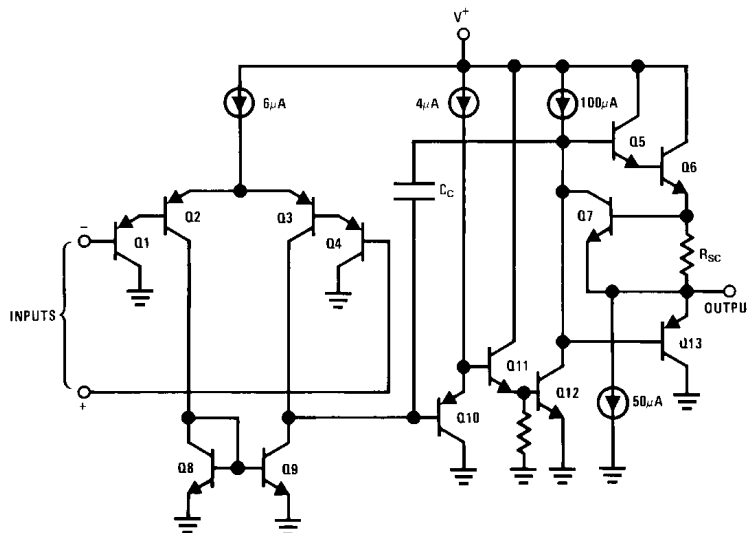


LM124A available per JM38510/11006
 LM124 available per JM38510/11005
 See STD Mil DWG 5962R99504 for Radiation Tolerant Device

Figure 1. Dual-In-Line Package Top View

SCHEMATIC DIAGRAM

(Each Amplifier)



These devices have limited built-in ESD protection. The leads should be shorted together or the device placed in conductive foam during storage or handling to prevent electrostatic damage to the MOS gates.

ABSOLUTE MAXIMUM RATINGS⁽¹⁾

| | LM124/LM224/LM324 | LM2902 |
|---|----------------------|-----------------|
| | LM124A/LM224A/LM324A | |
| Supply Voltage, V ⁺ | 32V | 26V |
| Differential Input Voltage | 32V | 26V |
| Input Voltage | -0.3V to +32V | -0.3V to +26V |
| Input Current | | |
| (V _{IN} < -0.3V) ⁽²⁾ | 50 mA | 50 mA |
| Power Dissipation ⁽³⁾ | | |
| Molded DIP | 1130 mW | 1130 mW |
| Cavity DIP | 1260 mW | 1260 mW |
| Small Outline Package | 800 mW | 800 mW |
| Output Short-Circuit to GND (One Amplifier) ⁽⁴⁾ | | |
| V ⁺ ≤ 15V and T _A = 25°C | Continuous | Continuous |
| Operating Temperature Range | | -40°C to +85°C |
| LM324/LM324A | 0°C to +70°C | |
| LM224/LM224A | -25°C to +85°C | |
| LM124/LM124A | -55°C to +125°C | |
| Storage Temperature Range | -65°C to +150°C | -65°C to +150°C |
| Lead Temperature (Soldering, 10 seconds) | 260°C | 260°C |
| Soldering Information | | |
| Dual-In-Line Package | | |
| Soldering (10 seconds) | 260°C | 260°C |
| Small Outline Package | | |
| Vapor Phase (60 seconds) | 215°C | 215°C |
| Infrared (15 seconds) | 220°C | 220°C |
| See AN-450 "Surface Mounting Methods and Their Effect on Product Reliability" for other methods of soldering surface mount devices. | | |
| ESD Tolerance ⁽⁵⁾ | 250V | 250V |

- (1) Refer to RETS124AX for LM124A military specifications and refer to RETS124X for LM124 military specifications.
- (2) This input current will only exist when the voltage at any of the input leads is driven negative. It is due to the collector-base junction of the input PNP transistors becoming forward biased and thereby acting as input diode clamps. In addition to this diode action, there is also lateral NPN parasitic transistor action on the IC chip. This transistor action can cause the output voltages of the op amps to go to the V⁺ voltage level (or to ground for a large overdrive) for the time duration that an input is driven negative. This is not destructive and normal output states will re-establish when the input voltage, which was negative, again returns to a value greater than -0.3V (at 25°C).
- (3) For operating at high temperatures, the LM324/LM324A/LM2902 must be derated based on a +125°C maximum junction temperature and a thermal resistance of 88°C/W which applies for the device soldered in a printed circuit board, operating in a still air ambient. The LM224/LM224A and LM124/LM124A can be derated based on a +150°C maximum junction temperature. The dissipation is the total of all four amplifiers—use external resistors, where possible, to allow the amplifier to saturate or to reduce the power which is dissipated in the integrated circuit.
- (4) Short circuits from the output to V⁺ can cause excessive heating and eventual destruction. When considering short circuits to ground, the maximum output current is approximately 40 mA independent of the magnitude of V⁺. At values of supply voltage in excess of +15V, continuous short-circuits can exceed the power dissipation ratings and cause eventual destruction. Destructive dissipation can result from simultaneous shorts on all amplifiers.
- (5) Human body model, 1.5 kΩ in series with 100 pF.

ELECTRICAL CHARACTERISTICS

V⁺ = +5.0V, ⁽¹⁾, unless otherwise stated

| Parameter | Conditions | LM124A | | | LM224A | | | LM324A | | | Units |
|------------------------------|---|--------|------|-------------------------|--------|------|-------------------------|--------|------|-------------------------|-----------------------|
| | | Min | Typ | Max | Min | Typ | Max | Min | Typ | Max | |
| Input Offset Voltage | ⁽²⁾ T _A = 25°C | | 1 | 2 | | 1 | 3 | | 2 | 3 | mV |
| Input Bias Current | I _{IN(+)} or I _{IN(-)} , V _{CM} = 0V, ⁽³⁾ T _A = 25°C | | 20 | 50 | | 40 | 80 | | 45 | 100 | nA |
| Input Offset Current | I _{IN(+)} or I _{IN(-)} , V _{CM} = 0V, T _A = 25°C | | 2 | 10 | | 2 | 15 | | 5 | 30 | nA |
| Input Common-Mode | V ⁺ = 30V, (LM2902, V ⁺ = 26V), T _A = 25°C | 0 | | V ⁺ -1 .5 | 0 | | V ⁺ -1 .5 | 0 | | V ⁺ -1 .5 | V |
| Voltage Range ⁽⁴⁾ | T _A = 25°C | | | | | | | | | | |
| Supply Current | Over Full Temperature Range R _L = ∞ On All Op Amps | | | | | | | | | | mA |
| | V ⁺ = 30V (LM2902 V ⁺ = 26V) | | 1.5 | 3 | | 1.5 | 3 | | 1.5 | 3 | |
| | V ⁺ = 5V | | 0.7 | 1.2 | | 0.7 | 1.2 | | 0.7 | 1.2 | |
| Large Signal | V ⁺ = 15V, R _L ≥ 2kΩ, T _A = 25°C | 50 | 100 | | 50 | 100 | | 25 | 100 | | V/m V |
| Voltage Gain | (V _O = 1V to 11V), T _A = 25°C | | | | | | | | | | |
| Common-Mode | DC, V _{CM} = 0V to V ⁺ - 1.5V, T _A = 25°C | 70 | 85 | | 70 | 85 | | 65 | 85 | | dB |
| Rejection Ratio | T _A = 25°C | | | | | | | | | | |
| Power Supply | V ⁺ = 5V to 30V | | | | | | | | | | |
| Rejection Ratio | (LM2902, V ⁺ = 5V to 26V), T _A = 25°C | 65 | 100 | | 65 | 100 | | 65 | 100 | | dB |
| Amplifier-to-Amplifier | f = 1 kHz to 20 kHz, T _A = 25°C | | -120 | | | -120 | | | -120 | | dB |
| Coupling ⁽⁵⁾ | (Input Referred) | | | | | | | | | | |
| Output Current | Source V _{IN⁺} = 1V, V _{IN⁻} = 0V, V ⁺ = 15V, V _O = 2V, T _A = 25°C | 20 | 40 | | 20 | 40 | | 20 | 40 | | mA |
| | Sink V _{IN⁻} = 1V, V _{IN⁺} = 0V, V ⁺ = 15V, V _O = 2V, T _A = 25°C | 10 | 20 | | 10 | 20 | | 10 | 20 | | |
| | V _{IN⁻} = 1V, V _{IN⁺} = 0V, V ⁺ = 15V, V _O = 200 mV, T _A = 25°C | 12 | 50 | | 12 | 50 | | 12 | 50 | | μA |
| Short Circuit to Ground | ⁽⁶⁾ V ⁺ = 15V, T _A = 25°C | | 40 | 60 | | 40 | 60 | | 40 | 60 | mA |
| Input Offset Voltage | ⁽²⁾ | | | 4 | | | 4 | | | 5 | mV |
| V _{OS} Drift | R _S = 0Ω | | 7 | 20 | | 7 | 20 | | 7 | 30 | μV/ ^o C |
| Input Offset Current | I _{IN(+)} - I _{IN(-)} , V _{CM} = 0V | | | 30 | | | 30 | | | 75 | nA |
| I _{OS} Drift | R _S = 0Ω | | 10 | 200 | | 10 | 200 | | 10 | 300 | pA/ ^o C |

- (1) These specifications are limited to -55°C ≤ T_A ≤ +125°C for the LM124/LM124A. With the LM224/LM224A, all temperature specifications are limited to -25°C ≤ T_A ≤ +85°C, the LM324/LM324A temperature specifications are limited to 0°C ≤ T_A ≤ +70°C, and the LM2902 specifications are limited to -40°C ≤ T_A ≤ +85°C.
- (2) V_O = 1.4V, R_S = 0Ω with V⁺ from 5V to 30V; and over the full input common-mode range (0V to V⁺ - 1.5V) for LM2902, V⁺ from 5V to 26V.
- (3) The direction of the input current is out of the IC due to the PNP input stage. This current is essentially constant, independent of the state of the output so no loading change exists on the input lines.
- (4) The input common-mode voltage of either input signal voltage should not be allowed to go negative by more than 0.3V (at 25°C). The upper end of the common-mode voltage range is V⁺ - 1.5V (at 25°C), but either or both inputs can go to +32V without damage (+26V for LM2902), independent of the magnitude of V⁺.
- (5) Due to 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.
- (6) Short circuits from the output to V⁺ can cause excessive heating and eventual destruction. When considering short circuits to ground, the maximum output current is approximately 40 mA independent of the magnitude of V⁺. At values of supply voltage in excess of +15V, continuous short-circuits can exceed the power dissipation ratings and cause eventual destruction. Destructive dissipation can result from simultaneous shorts on all amplifiers.

ELECTRICAL CHARACTERISTICS (continued)
 $V^+ = +5.0V$, ⁽¹⁾, unless otherwise stated

| Parameter | | Conditions | | LM124A | | | LM224A | | | LM324A | | | Unit s |
|------------------------------|----------|---|----------------------------------|--------|-----|-----------|--------|-----|-----------|--------|-----|-----------|-----------|
| | | | | Min | Typ | Max | Min | Typ | Max | Min | Typ | Max | |
| Input Bias Current | | $I_{IN(+)}$ or $I_{IN(-)}$ | | | 40 | 100 | | 40 | 100 | | 40 | 200 | nA |
| Input Common-Mode | | $V^+ = +30V$ | | 0 | | $V^+ - 2$ | 0 | | $V^+ - 2$ | 0 | | $V^+ - 2$ | V |
| Voltage Range ⁽⁴⁾ | | (LM2902, $V^+ = 26V$) | | | | | | | | | | | |
| Large Signal | | $V^+ = +15V$ (V_O Swing = 1V to 11V) | | | | | | | | | | | |
| Voltage Gain | | $R_L \geq 2\text{ k}\Omega$ | | 25 | | | 25 | | | 15 | | | V/m V |
| Output Voltage | V_{OH} | $V^+ = 30V$ | $R_L = 2\text{ k}\Omega$ | 26 | | | 26 | | | 26 | | | V |
| Swing | | (LM2902, $V^+ = 26V$) | $R_L = 10\text{ k}\Omega$ | 27 | 28 | | 27 | 28 | | 27 | 28 | | |
| | V_{OL} | $V^+ = 5V$, $R_L = 10\text{ k}\Omega$ | | | 5 | 20 | | 5 | 20 | | 5 | 20 | mV |
| Output Current | Source | $V_O = 2V$ | $V_{IN}^+ = +1V$, | 10 | 20 | | 10 | 20 | | 10 | 20 | | mA |
| | | | $V_{IN}^- = 0V$, $V^+ = 15V$ | | | | | | | | | | |
| | Sink | | $V_{IN}^- = +1V$, | 10 | 15 | | 5 | 8 | | 5 | 8 | | |
| | | | $V_{IN}^+ = 0V$, $V^+ = 15V$ | | | | | | | | | | |

ELECTRICAL CHARACTERISTICS

V⁺ = +5.0V, ⁽¹⁾, unless otherwise stated

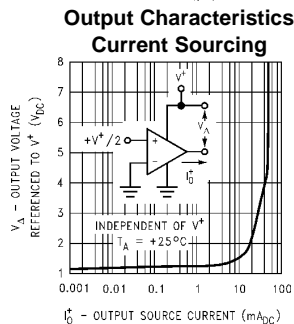
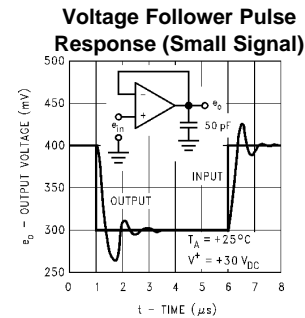
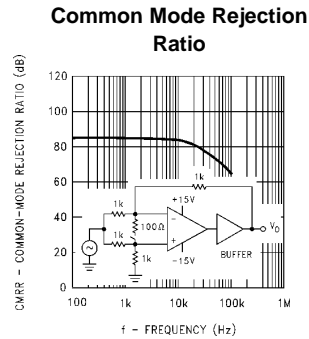
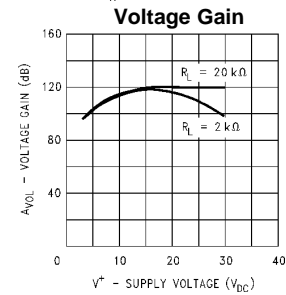
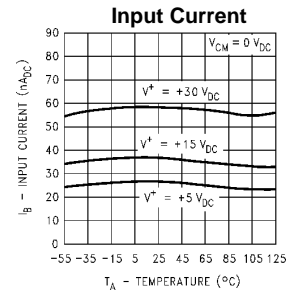
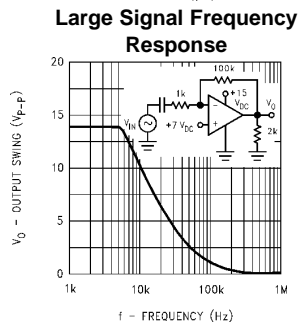
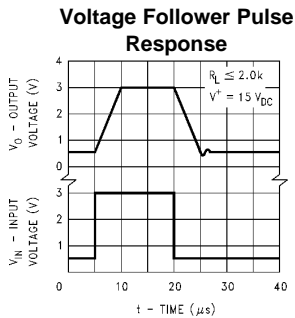
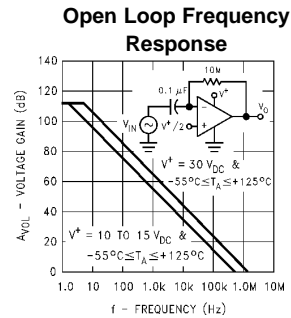
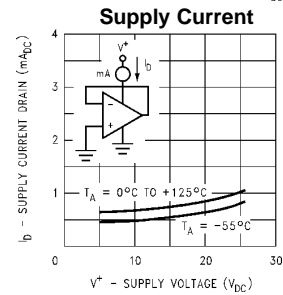
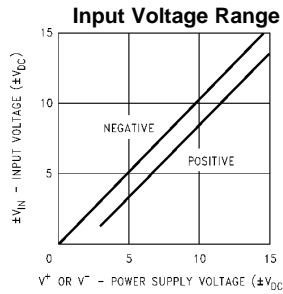
| Parameter | Conditions | LM124/LM224 | | | LM324 | | | LM2902 | | | Units |
|------------------------------|---|-------------|------|-------------------------|-------|------|-------------------------|--------|------|-------------------------|-----------|
| | | Min | Typ | Max | Min | Typ | Max | Min | Typ | Max | |
| Input Offset Voltage | ⁽²⁾ T _A = 25°C | | 2 | 5 | | 2 | 7 | | 2 | 7 | mV |
| Input Bias Current | I _{IN(+)} or I _{IN(-)} , V _{CM} = 0V, ⁽³⁾ T _A = 25°C | | 45 | 150 | | 45 | 250 | | 45 | 250 | nA |
| Input Offset Current | I _{IN(+)} or I _{IN(-)} , V _{CM} = 0V, T _A = 25°C | | 3 | 30 | | 5 | 50 | | 5 | 50 | nA |
| Input Common-Mode | V ⁺ = 30V, (LM2902, V ⁺ = 26V), T _A = 25°C | 0 | | V ⁺ -1 .5 | 0 | | V ⁺ -1 .5 | 0 | | V ⁺ -1 .5 | V |
| Voltage Range ⁽⁴⁾ | T _A = 25°C | | | | | | | | | | |
| Supply Current | Over Full Temperature Range R _L = ∞ On All Op Amps | | | | | | | | | | mA |
| | V ⁺ = 30V (LM2902 V ⁺ = 26V) | | 1.5 | 3 | | 1.5 | 3 | | 1.5 | 3 | |
| | V ⁺ = 5V | | 0.7 | 1.2 | | 0.7 | 1.2 | | 0.7 | 1.2 | |
| Large Signal | V ⁺ = 15V, R _L ≥ 2kΩ, T _A = 25°C | 50 | 100 | | 25 | 100 | | 25 | 100 | | V/m V |
| Voltage Gain | (V _O = 1V to 11V), T _A = 25°C | | | | | | | | | | |
| Common-Mode | DC, V _{CM} = 0V to V ⁺ - 1.5V, T _A = 25°C | 70 | 85 | | 65 | 85 | | 50 | 70 | | dB |
| Rejection Ratio | T _A = 25°C | | | | | | | | | | |
| Power Supply | V ⁺ = 5V to 30V | | | | | | | | | | |
| Rejection Ratio | (LM2902, V ⁺ = 5V to 26V), T _A = 25°C | 65 | 100 | | 65 | 100 | | 50 | 100 | | dB |
| Amplifier-to-Amplifier | f = 1 kHz to 20 kHz, T _A = 25°C | | -120 | | | -120 | | | -120 | | dB |
| Coupling ⁽⁵⁾ | (Input Referred) | | | | | | | | | | |
| Output Current | Source V _{IN⁺} = 1V, V _{IN⁻} = 0V, V ⁺ = 15V, V _O = 2V, T _A = 25°C | 20 | 40 | | 20 | 40 | | 20 | 40 | | mA |
| | Sink V _{IN⁻} = 1V, V _{IN⁺} = 0V, V ⁺ = 15V, V _O = 2V, T _A = 25°C | 10 | 20 | | 10 | 20 | | 10 | 20 | | |
| | V _{IN⁻} = 1V, V _{IN⁺} = 0V, V ⁺ = 15V, V _O = 200 mV, T _A = 25°C | 12 | 50 | | 12 | 50 | | 12 | 50 | | μA |
| Short Circuit to Ground | ⁽⁶⁾ V ⁺ = 15V, T _A = 25°C | | 40 | 60 | | 40 | 60 | | 40 | 60 | mA |
| Input Offset Voltage | ⁽²⁾ | | | 7 | | | 9 | | | 10 | mV |
| V _{OS} Drift | R _S = 0Ω | | 7 | | | 7 | | | 7 | | μV/° C |
| Input Offset Current | I _{IN(+)} - I _{IN(-)} , V _{CM} = 0V | | | 100 | | | 150 | | 45 | 200 | nA |
| I _{OS} Drift | R _S = 0Ω | | 10 | | | 10 | | | 10 | | pA/° C |

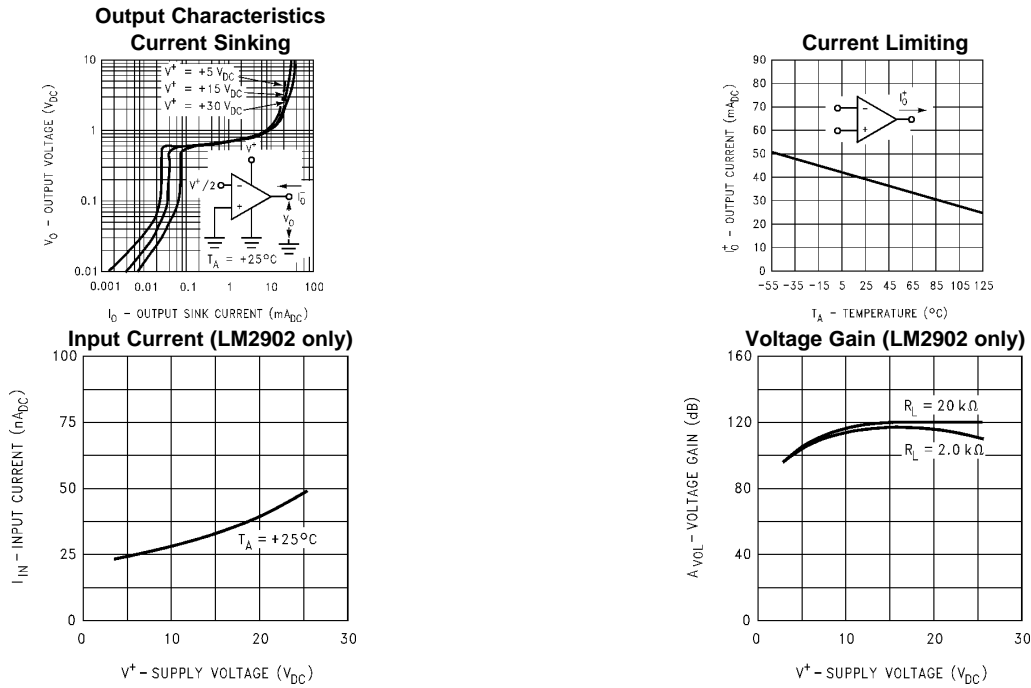
- (1) These specifications are limited to -55°C ≤ T_A ≤ +125°C for the LM124/LM124A. With the LM224/LM224A, all temperature specifications are limited to -25°C ≤ T_A ≤ +85°C, the LM324/LM324A temperature specifications are limited to 0°C ≤ T_A ≤ +70°C, and the LM2902 specifications are limited to -40°C ≤ T_A ≤ +85°C.
- (2) V_O = 1.4V, R_S = 0Ω with V⁺ from 5V to 30V; and over the full input common-mode range (0V to V⁺ - 1.5V) for LM2902, V⁺ from 5V to 26V.
- (3) The direction of the input current is out of the IC due to the PNP input stage. This current is essentially constant, independent of the state of the output so no loading change exists on the input lines.
- (4) The input common-mode voltage of either input signal voltage should not be allowed to go negative by more than 0.3V (at 25°C). The upper end of the common-mode voltage range is V⁺ - 1.5V (at 25°C), but either or both inputs can go to +32V without damage (+26V for LM2902), independent of the magnitude of V⁺.
- (5) Due to 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.
- (6) Short circuits from the output to V⁺ can cause excessive heating and eventual destruction. When considering short circuits to ground, the maximum output current is approximately 40 mA independent of the magnitude of V⁺. At values of supply voltage in excess of +15V, continuous short-circuits can exceed the power dissipation ratings and cause eventual destruction. Destructive dissipation can result from simultaneous shorts on all amplifiers.

ELECTRICAL CHARACTERISTICS (continued)
 $V^+ = +5.0V$, ⁽¹⁾, unless otherwise stated

| Parameter | | Conditions | | LM124/LM224 | | | LM324 | | | LM2902 | | | Units |
|------------------------------|----------|---|---------------------------|-------------|-----|-----------|-------|-----|-----------|--------|-----|-----------|-------|
| | | | | Min | Typ | Max | Min | Typ | Max | Min | Typ | Max | |
| Input Bias Current | | $I_{IN(+)}$ or $I_{IN(-)}$ | | | 40 | 300 | | 40 | 500 | | 40 | 500 | nA |
| Input Common-Mode | | $V^+ = +30V$ | | 0 | | $V^+ - 2$ | 0 | | $V^+ - 2$ | 0 | | $V^+ - 2$ | V |
| Voltage Range ⁽⁴⁾ | | (LM2902, $V^+ = 26V$) | | | | | | | | | | | |
| Large Signal | | $V^+ = +15V$ (V_O Swing = 1V to 11V) | | | | | | | | | | | |
| Voltage Gain | | $R_L \geq 2\text{ k}\Omega$ | | 25 | | | 15 | | | 15 | | | V/mV |
| Output Voltage | V_{OH} | $V^+ = 30V$ | $R_L = 2\text{ k}\Omega$ | 26 | | | 26 | | | 22 | | | V |
| Swing | | (LM2902, $V^+ = 26V$) | $R_L = 10\text{ k}\Omega$ | 27 | 28 | | 27 | 28 | | 23 | 24 | | |
| | V_{OL} | $V^+ = 5V$, $R_L = 10\text{ k}\Omega$ | | | 5 | 20 | | 5 | 20 | | 5 | 100 | mV |
| Output Current | Source | $V_O = 2V$ | $V_{IN}^+ = +1V$, | 10 | 20 | | 10 | 20 | | 10 | 20 | | mA |
| | | | $V_{IN}^- = 0V$, | | | | | | | | | | |
| | | | $V^+ = 15V$ | | | | | | | | | | |
| | Sink | | $V_{IN}^- = +1V$, | 5 | 8 | | 5 | 8 | | 5 | 8 | | |
| | | | $V_{IN}^+ = 0V$, | | | | | | | | | | |
| | | | $V^+ = 15V$ | | | | | | | | | | |

TYPICAL PERFORMANCE CHARACTERISTICS



TYPICAL PERFORMANCE CHARACTERISTICS (continued)

APPLICATION HINTS

The LM124 series are op amps which operate with only a single power supply voltage, have true-differential inputs, and remain in the linear mode with an input common-mode voltage of $0 V_{DC}$. These amplifiers operate over a wide range of power supply voltage with little change in performance characteristics. At $25^\circ C$ amplifier operation is possible down to a minimum supply voltage of $2.3 V_{DC}$.

The pinouts of the package have been designed to simplify PC board layouts. Inverting inputs are adjacent to outputs for all of the amplifiers and the outputs have also been placed at the corners of the package (pins 1, 7, 8, and 14).

Precautions should be taken to insure that the power supply for the integrated circuit never becomes reversed in polarity or that the unit is not inadvertently installed backwards in a test socket as an unlimited current surge through the resulting forward diode within the IC could cause fusing of the internal conductors and result in a destroyed unit.

Large differential input voltages can be easily accommodated and, as input differential voltage protection diodes are not needed, no large input currents result from large differential input voltages. The differential input voltage may be larger than V^+ without damaging the device. Protection should be provided to prevent the input voltages from going negative more than $-0.3 V_{DC}$ (at $25^\circ C$). An input clamp diode with a resistor to the IC input terminal can be used.

To reduce the power supply drain, the amplifiers have a class A output stage for small signal levels which converts to class B in a large signal mode. This allows the amplifiers to both source and sink large output currents. Therefore both NPN and PNP external current boost transistors can be used to extend the power capability of the basic amplifiers. The output voltage needs to raise approximately 1 diode drop above ground to bias the on-chip vertical PNP transistor for output current sinking applications.

For ac applications, where the load is capacitively coupled to the output of the amplifier, a resistor should be used, from the output of the amplifier to ground to increase the class A bias current and prevent crossover distortion.

Where the load is directly coupled, as in dc applications, there is no crossover distortion.

Capacitive loads which are applied directly to the output of the amplifier reduce the loop stability margin. Values of $50 pF$ can be accommodated using the worst-case non-inverting unity gain connection. Large closed loop gains or resistive isolation should be used if larger load capacitance must be driven by the amplifier.

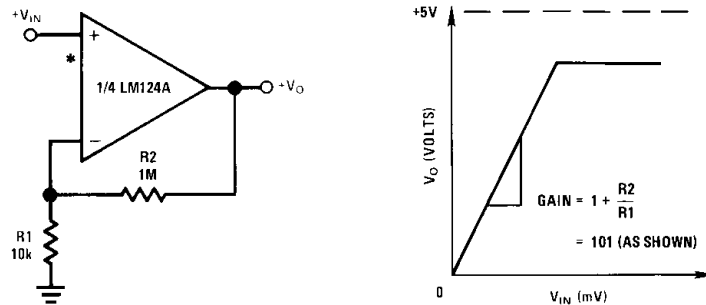
The bias network of the LM124 establishes a drain current which is independent of the magnitude of the power supply voltage over the range of from 3 V_{DC} to 30 V_{DC} .

Output short circuits either to ground or to the positive power supply should be of short time duration. Units can be destroyed, not as a result of the short circuit current causing metal fusing, but rather due to the large increase in IC chip dissipation which will cause eventual failure due to excessive junction temperatures. Putting direct short-circuits on more than one amplifier at a time will increase the total IC power dissipation to destructive levels, if not properly protected with external dissipation limiting resistors in series with the output leads of the amplifiers. The larger value of output source current which is available at 25°C provides a larger output current capability at elevated temperatures (see typical performance characteristics) than a standard IC op amp.

The circuits presented in the section on typical applications emphasize operation on only a single power supply voltage. If complementary power supplies are available, all of the standard op amp circuits can be used. In general, introducing a pseudo-ground (a bias voltage reference of $V^+/2$) will allow operation above and below this value in single power supply systems. Many application circuits are shown which take advantage of the wide input common-mode voltage range which includes ground. In most cases, input biasing is not required and input voltages which range to ground can easily be accommodated.

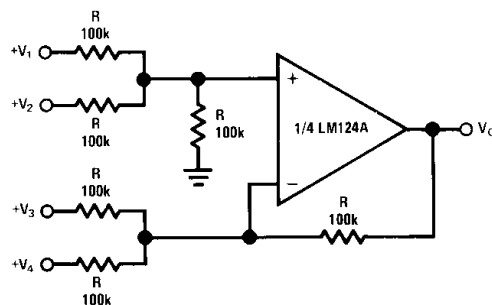
TYPICAL SINGLE-SUPPLY APPLICATIONS

($V^+ = 5.0 V_{DC}$)



*R not needed due to temperature independent I_{IN}

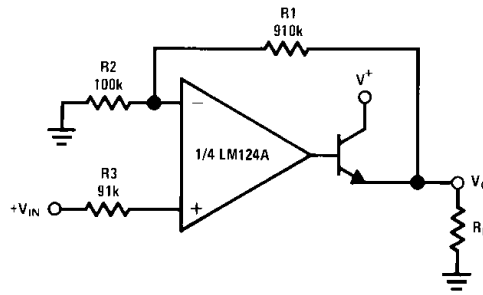
Figure 2. Non-Inverting DC Gain (0V Input = 0V Output)



Where: $V_O = V_1 + V_2 - V_3 - V_4$
 $(V_1 + V_2) \geq (V_3 + V_4)$ to keep $V_O > 0 V_{DC}$

Figure 3. DC Summing Amplifier
 ($V_{IN}'S \geq 0 V_{DC}$ and $V_O \geq V_{DC}$)

($V^+ = 5.0 V_{DC}$)



$V_0 = 0 V_{DC}$ for $V_{IN} = 0 V_{DC}$
 $A_V = 10$

Figure 4. Power Amplifier

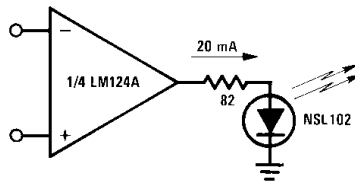
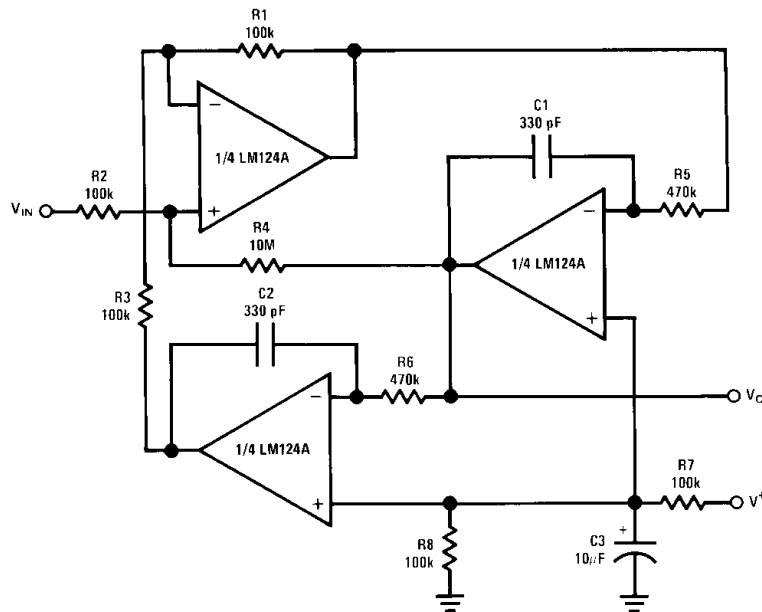


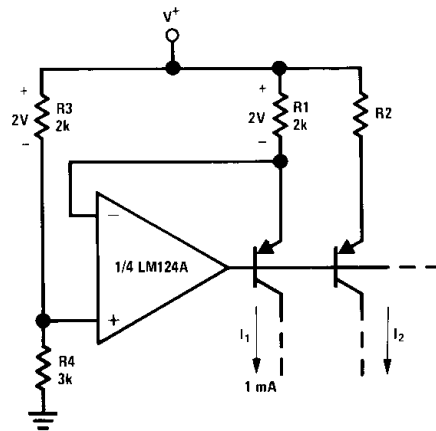
Figure 5. LED Driver



$f_0 = 1 \text{ kHz}$
 $Q = 50$
 $A_V = 100 \text{ (40 dB)}$

Figure 6. "BI-QUAD" RC Active Bandpass Filter

($V^+ = 5.0 V_{DC}$)



$$I_2 = \left(\frac{R1}{R2} \right) I_1$$

Figure 7. Fixed Current Sources

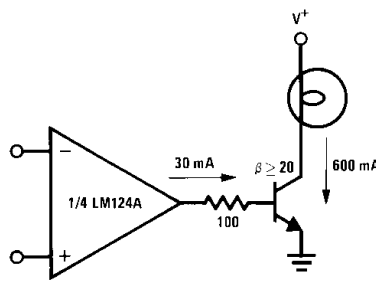
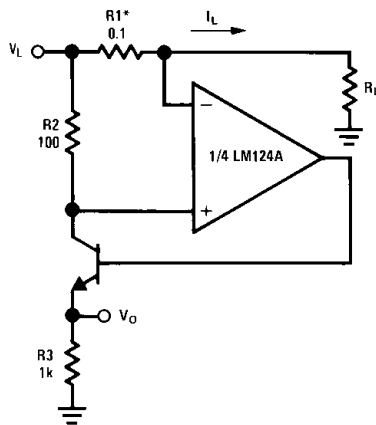


Figure 8. Lamp Driver



$$V_O = \frac{1V(I_L)}{1A}$$

$V_L \leq V^+ - 2V$
 *(Increase R1 for I_L small)

Figure 9. Current Monitor

($V^+ = 5.0 V_{DC}$)

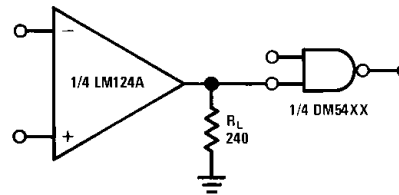


Figure 10. Driving TTL

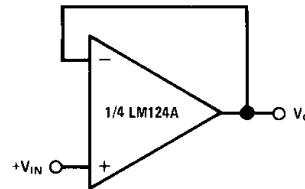


Figure 11. Voltage Follower

Figure 12.

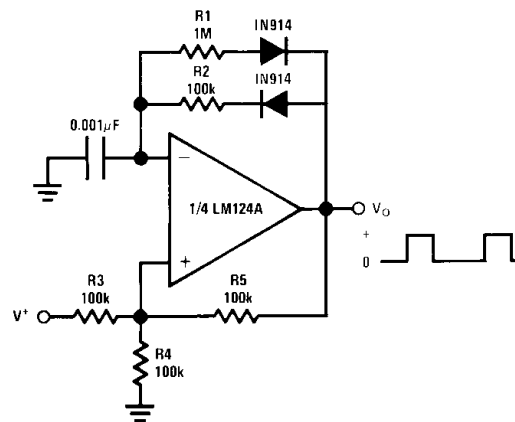


Figure 13. Pulse Generator

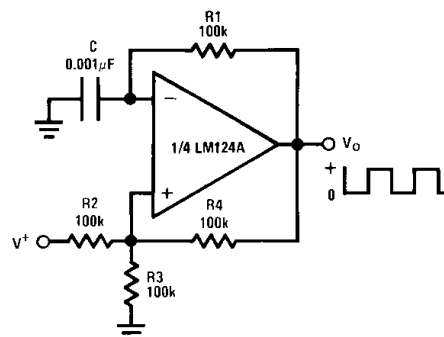


Figure 14. Squarewave Oscillator

($V^+ = 5.0 V_{DC}$)

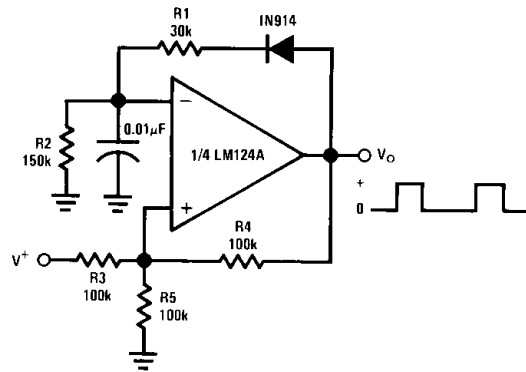
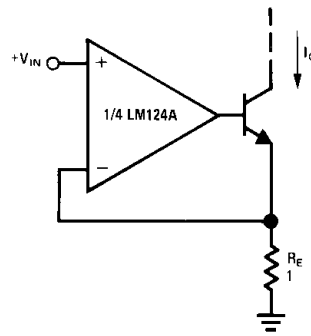


Figure 15. Pulse Generator



$I_O = 1 \text{ amp/volt } V_{IN}$
(Increase R_E for I_O small)

Figure 16. High Compliance Current Sink

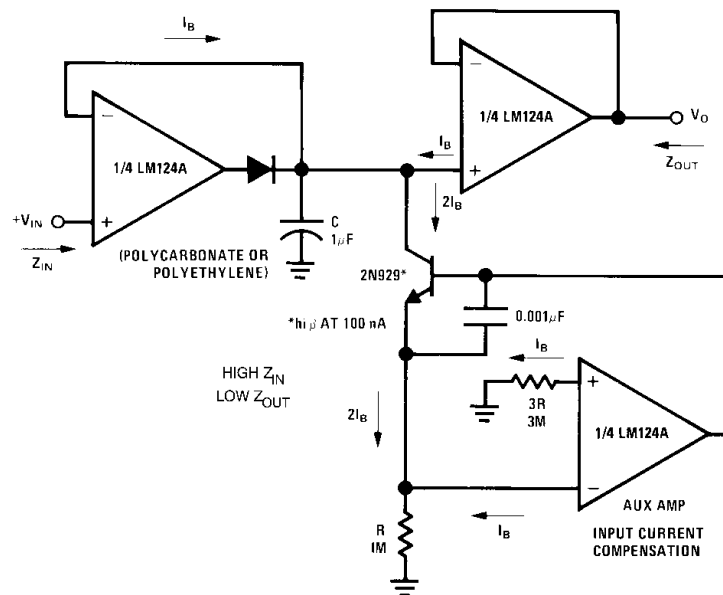


Figure 17. Low Drift Peak Detector

($V^+ = 5.0 V_{DC}$)

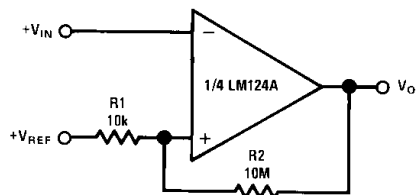
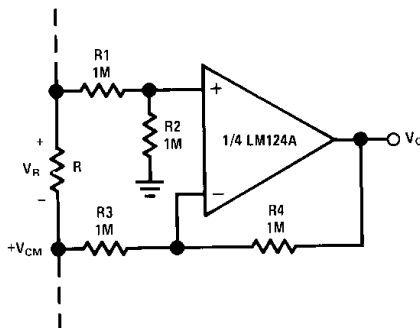
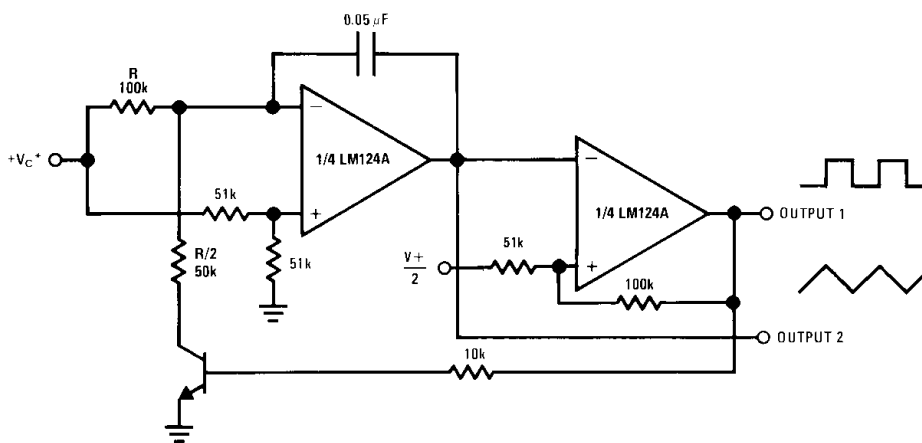


Figure 18. Comparator with Hysteresis



$V_O = V_R$

Figure 19. Ground Referencing a Differential Input Signal



*Wide control voltage range: $0 V_{DC} \leq V_C \leq 2 (V^+ - 1.5 V_{DC})$

Figure 20. Voltage Controlled Oscillator Circuit

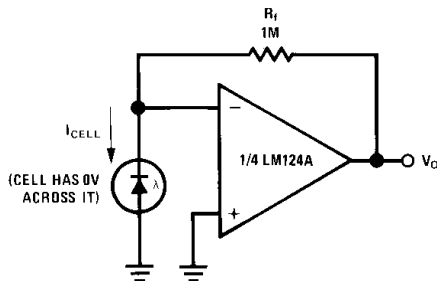
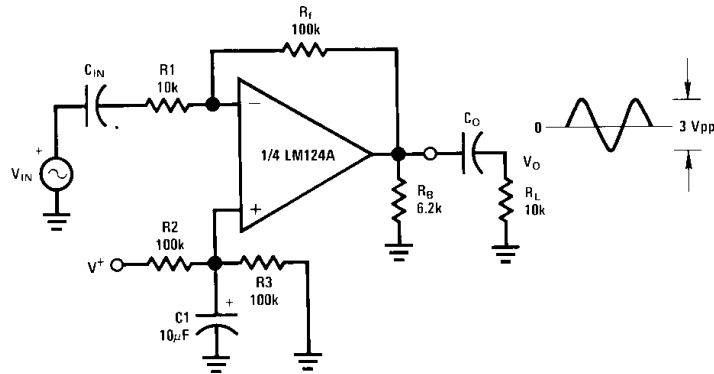


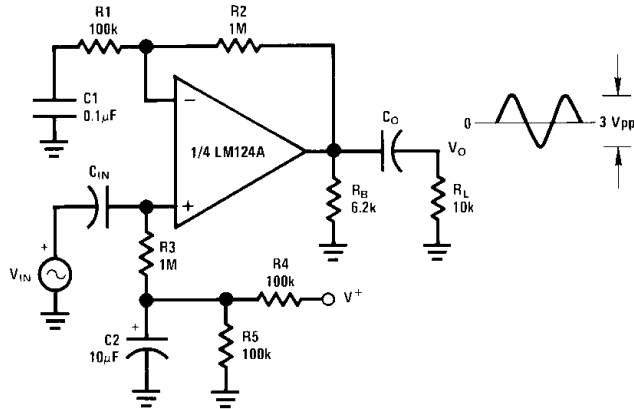
Figure 21. Photo Voltaic-Cell Amplifier

(V⁺ = 5.0 V_{DC})



$$A_V = \frac{R_f}{R_1} \text{ (As shown, } A_V = 10 \text{)}$$

Figure 22. AC Coupled Inverting Amplifier

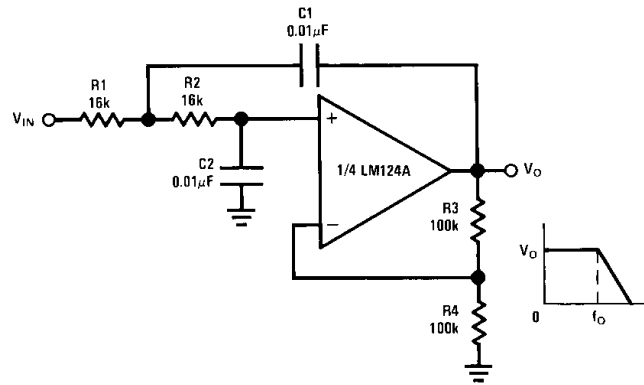


$$A_V = 1 + \frac{R_2}{R_1}$$

A_V = 11 (As shown)

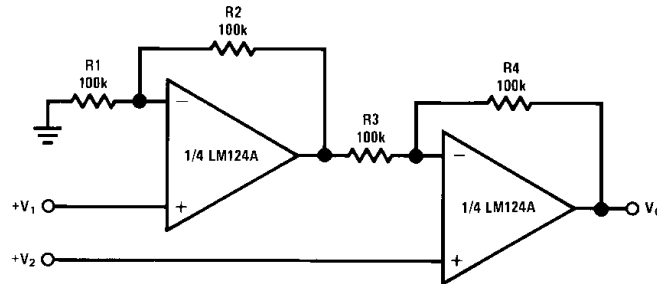
Figure 23. AC Coupled Non-Inverting Amplifier

($V^+ = 5.0 V_{DC}$)



$f_o = 1 \text{ kHz}$
 $Q = 1$
 $A_v = 2$

Figure 24. DC Coupled Low-Pass RC Active Filter



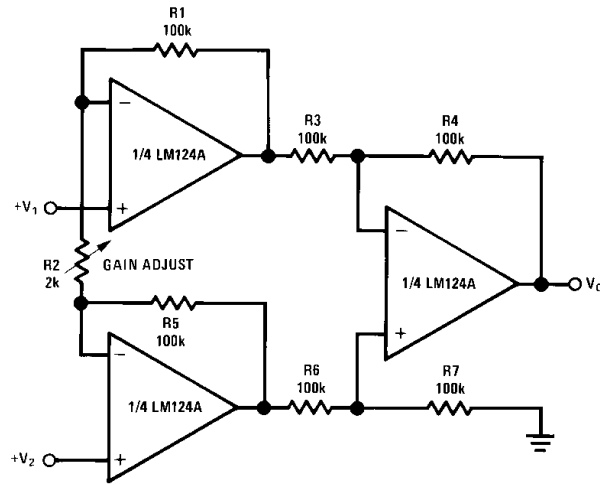
For $\frac{R1}{R2} = \frac{R4}{R3}$ (CMRR depends on this resistor ratio match)

$$V_O = 1 + \frac{R4}{R3}(V_2 - V_1)$$

As shown: $V_O = 2(V_2 - V_1)$

Figure 25. High Input Z, DC Differential Amplifier

($V^+ = 5.0 V_{DC}$)



If $R1 = R5$ & $R3 = R4 = R6 = R7$ (CMRR depends on match)

$$V_O = 1 + \frac{2R1}{R2} (V_2 - V_1)$$

As shown $V_O = 101 (V_2 - V_1)$

Figure 26. High Input Z Adjustable-Gain DC Instrumentation Amplifier

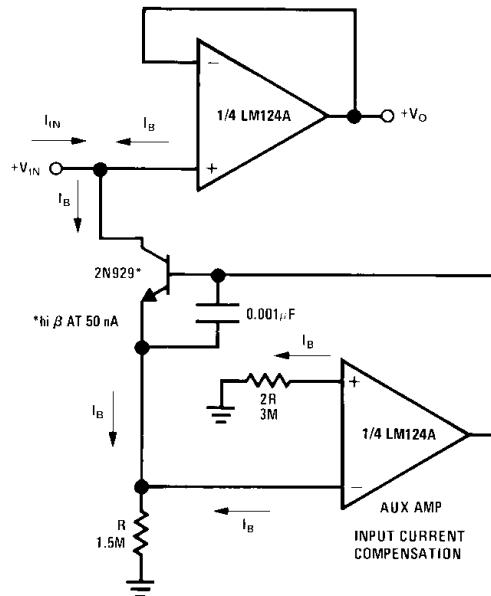
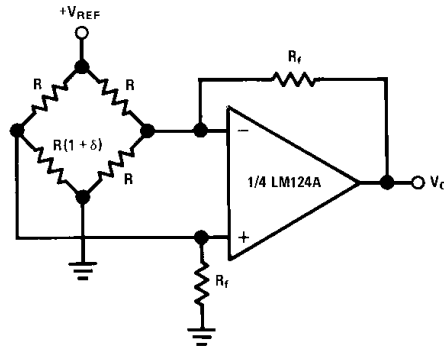


Figure 27. Using Symmetrical Amplifiers to Reduce Input Current (General Concept)

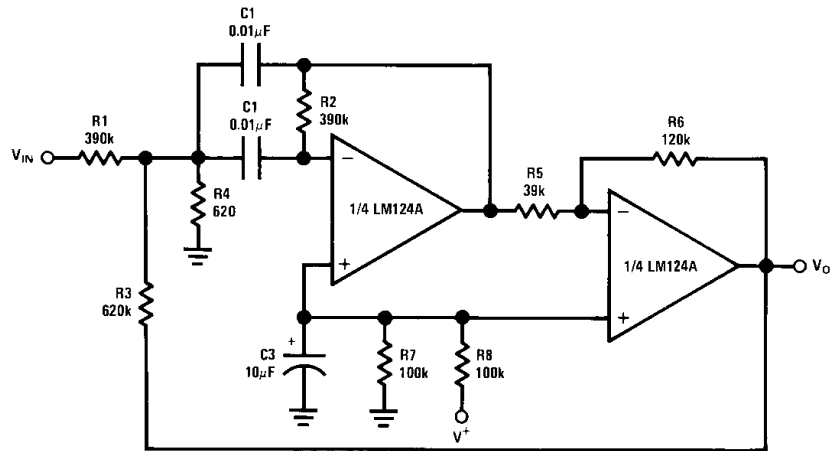
($V^+ = 5.0 V_{DC}$)



For $\delta \ll 1$ and $R_f \gg R$

$$V_O \cong V_{REF} \left(\frac{\delta}{2} \right) \frac{R_f}{R}$$

Figure 28. Bridge Current Amplifier



$f_0 = 1 \text{ kHz}$
 $Q = 25$

Figure 29. Bandpass Active Filter

PACKAGING INFORMATION

| Orderable Device | Status (1) | Package Type | Package Drawing | Pins | Package Qty | Eco Plan (2) | Lead/Ball Finish | MSL Peak Temp (3) | Op Temp (°C) | Top-Side Markings (4) | Samples |
|------------------|---------------|--------------|--------------------|------|-------------|----------------------------|------------------|----------------------|--------------|--------------------------|-------------------------|
| LM124AJ/PB | ACTIVE | CDIP | J | 14 | 25 | TBD | A42 SNPB | Level-1-NA-UNLIM | | LM124AJ | Samples |
| LM124J/PB | ACTIVE | CDIP | J | 14 | 25 | TBD | A42 SNPB | Level-1-NA-UNLIM | | LM124J | Samples |
| LM224J | ACTIVE | CDIP | J | 14 | 25 | TBD | A42 SNPB | Level-1-NA-UNLIM | -25 to 85 | LM224J | Samples |
| LM2902M | ACTIVE | SOIC | D | 14 | 55 | TBD | CU SNPB | Level-1-235C-UNLIM | -40 to 85 | LM2902M | Samples |
| LM2902M/NOPB | ACTIVE | SOIC | D | 14 | 55 | Green (RoHS & no Sb/Br) | CU SN | Level-1-260C-UNLIM | -40 to 85 | LM2902M | Samples |
| LM2902MT | ACTIVE | TSSOP | PW | 14 | 94 | TBD | CU SNPB | Level-1-260C-UNLIM | -40 to 85 | LM290 2MT | Samples |
| LM2902MT/NOPB | ACTIVE | TSSOP | PW | 14 | 94 | Green (RoHS & no Sb/Br) | CU SN | Level-1-260C-UNLIM | -40 to 85 | LM290 2MT | Samples |
| LM2902MTX | ACTIVE | TSSOP | PW | 14 | 2500 | TBD | CU SNPB | Level-1-260C-UNLIM | -40 to 85 | LM290 2MT | Samples |
| LM2902MTX/NOPB | ACTIVE | TSSOP | PW | 14 | 2500 | Green (RoHS & no Sb/Br) | CU SN | Level-1-260C-UNLIM | -40 to 85 | LM290 2MT | Samples |
| LM2902MX | ACTIVE | SOIC | D | 14 | 2500 | TBD | CU SNPB | Level-1-235C-UNLIM | -40 to 85 | LM2902M | Samples |
| LM2902MX/NOPB | ACTIVE | SOIC | D | 14 | 2500 | Green (RoHS & no Sb/Br) | CU SN | Level-1-260C-UNLIM | -40 to 85 | LM2902M | Samples |
| LM2902N/NOPB | ACTIVE | PDIP | NFF | 14 | 25 | Green (RoHS & no Sb/Br) | CU SN | Level-1-NA-UNLIM | -40 to 85 | LM2902N | Samples |
| LM2902N/PB | ACTIVE | PDIP | NFF | 14 | 25 | TBD | CU SNPB | Level-1-NA-UNLIM | | LM2902N | Samples |
| LM324AM | ACTIVE | SOIC | D | 14 | 55 | TBD | CU SNPB | Level-1-235C-UNLIM | 0 to 70 | LM324AM | Samples |
| LM324AM/NOPB | ACTIVE | SOIC | D | 14 | 55 | Green (RoHS & no Sb/Br) | CU SN | Level-1-260C-UNLIM | 0 to 70 | LM324AM | Samples |
| LM324AMX | ACTIVE | SOIC | D | 14 | 2500 | TBD | CU SNPB | Level-1-235C-UNLIM | 0 to 70 | LM324AM | Samples |
| LM324AMX/NOPB | ACTIVE | SOIC | D | 14 | 2500 | Green (RoHS & no Sb/Br) | CU SN | Level-1-260C-UNLIM | 0 to 70 | LM324AM | Samples |
| LM324AN/NOPB | ACTIVE | PDIP | NFF | 14 | 25 | Green (RoHS & no Sb/Br) | CU SN | Level-1-NA-UNLIM | 0 to 70 | LM324AN | Samples |

| Orderable Device | Status (1) | Package Type | Package Drawing | Pins | Package Qty | Eco Plan (2) | Lead/Ball Finish | MSL Peak Temp (3) | Op Temp (°C) | Top-Side Markings (4) | Samples |
|------------------|---------------|--------------|-----------------|------|-------------|-------------------------|------------------|----------------------|--------------|--------------------------|-------------------------|
| LM324AN/PB | ACTIVE | PDIP | NFF | 14 | 25 | TBD | Call TI | Level-1-NA-UNLIM | | LM324AN | Samples |
| LM324J | ACTIVE | CDIP | J | 14 | 25 | TBD | A42 SNPB | Level-1-NA-UNLIM | 0 to 70 | LM324J | Samples |
| LM324M | ACTIVE | SOIC | D | 14 | 55 | TBD | CU SNPB | Level-1-235C-UNLIM | 0 to 70 | LM324M | Samples |
| LM324M/NOPB | ACTIVE | SOIC | D | 14 | 55 | Green (RoHS & no Sb/Br) | CU SN | Level-1-260C-UNLIM | 0 to 70 | LM324M | Samples |
| LM324MT | ACTIVE | TSSOP | PW | 14 | 94 | TBD | CU SNPB | Level-1-260C-UNLIM | 0 to 70 | LM324 MT | Samples |
| LM324MT/NOPB | ACTIVE | TSSOP | PW | 14 | 94 | Green (RoHS & no Sb/Br) | CU SN | Level-1-260C-UNLIM | 0 to 70 | LM324 MT | Samples |
| LM324MTX | ACTIVE | TSSOP | PW | 14 | 2500 | TBD | CU SNPB | Level-1-260C-UNLIM | 0 to 70 | LM324 MT | Samples |
| LM324MTX/NOPB | ACTIVE | TSSOP | PW | 14 | 2500 | Green (RoHS & no Sb/Br) | CU SN | Level-1-260C-UNLIM | 0 to 70 | LM324 MT | Samples |
| LM324MX | ACTIVE | SOIC | D | 14 | 2500 | TBD | CU SNPB | Level-1-235C-UNLIM | 0 to 70 | LM324M | Samples |
| LM324MX/NOPB | ACTIVE | SOIC | D | 14 | 2500 | Green (RoHS & no Sb/Br) | CU SN | Level-1-260C-UNLIM | 0 to 70 | LM324M | Samples |
| LM324N/NOPB | ACTIVE | PDIP | NFF | 14 | 25 | Green (RoHS & no Sb/Br) | Call TI | Level-1-NA-UNLIM | 0 to 70 | LM324N | Samples |
| LM324N/PB | ACTIVE | PDIP | NFF | 14 | 25 | TBD | Call TI | Level-1-NA-UNLIM | | LM324N | Samples |
| MLM324P | ACTIVE | PDIP | NFF | 14 | 25 | TBD | Call TI | Level-1-NA-UNLIM | | LM324N | Samples |

(1) The marketing status values are defined as follows:

ACTIVE: Product device recommended for new designs.

LIFEBUY: TI has announced that the device will be discontinued, and a lifetime-buy period is in effect.

NRND: Not recommended for new designs. Device is in production to support existing customers, but TI does not recommend using this part in a new design.

PREVIEW: Device has been announced but is not in production. Samples may or may not be available.

OBSOLETE: TI has discontinued the production of the device.

(2) Eco Plan - The planned eco-friendly classification: Pb-Free (RoHS), Pb-Free (RoHS Exempt), or Green (RoHS & no Sb/Br) - please check <http://www.ti.com/productcontent> for the latest availability information and additional product content details.

TBD: The Pb-Free/Green conversion plan has not been defined.

Pb-Free (RoHS): TI's terms "Lead-Free" or "Pb-Free" mean semiconductor products that are compatible with the current RoHS requirements for all 6 substances, including the requirement that lead not exceed 0.1% by weight in homogeneous materials. Where designed to be soldered at high temperatures, TI Pb-Free products are suitable for use in specified lead-free processes.

Pb-Free (RoHS Exempt): This component has a RoHS exemption for either 1) lead-based flip-chip solder bumps used between the die and package, or 2) lead-based die adhesive used between the die and leadframe. The component is otherwise considered Pb-Free (RoHS compatible) as defined above.

Green (RoHS & no Sb/Br): TI defines "Green" to mean Pb-Free (RoHS compatible), and free of Bromine (Br) and Antimony (Sb) based flame retardants (Br or Sb do not exceed 0.1% by weight in homogeneous material)

⁽³⁾ MSL, Peak Temp. -- The Moisture Sensitivity Level rating according to the JEDEC industry standard classifications, and peak solder temperature.

⁽⁴⁾ Only one of markings shown within the brackets will appear on the physical device.

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TAPE AND REEL INFORMATION

QUADRANT ASSIGNMENTS FOR PIN 1 ORIENTATION IN TAPE


*All dimensions are nominal

| Device | Package Type | Package Drawing | Pins | SPQ | Reel Diameter (mm) | Reel Width W1 (mm) | A0 (mm) | B0 (mm) | K0 (mm) | P1 (mm) | W (mm) | Pin1 Quadrant |
|----------------|--------------|-----------------|------|------|--------------------|--------------------|---------|---------|---------|---------|--------|---------------|
| LM2902MTX | TSSOP | PW | 14 | 2500 | 330.0 | 12.4 | 6.95 | 8.3 | 1.6 | 8.0 | 12.0 | Q1 |
| LM2902MTX/NOPB | TSSOP | PW | 14 | 2500 | 330.0 | 12.4 | 6.95 | 8.3 | 1.6 | 8.0 | 12.0 | Q1 |
| LM2902MX | SOIC | D | 14 | 2500 | 330.0 | 16.4 | 6.5 | 9.35 | 2.3 | 8.0 | 16.0 | Q1 |
| LM2902MX/NOPB | SOIC | D | 14 | 2500 | 330.0 | 16.4 | 6.5 | 9.35 | 2.3 | 8.0 | 16.0 | Q1 |
| LM324AMX | SOIC | D | 14 | 2500 | 330.0 | 16.4 | 6.5 | 9.35 | 2.3 | 8.0 | 16.0 | Q1 |
| LM324AMX/NOPB | SOIC | D | 14 | 2500 | 330.0 | 16.4 | 6.5 | 9.35 | 2.3 | 8.0 | 16.0 | Q1 |
| LM324MTX | TSSOP | PW | 14 | 2500 | 330.0 | 12.4 | 6.95 | 8.3 | 1.6 | 8.0 | 12.0 | Q1 |
| LM324MTX/NOPB | TSSOP | PW | 14 | 2500 | 330.0 | 12.4 | 6.95 | 8.3 | 1.6 | 8.0 | 12.0 | Q1 |
| LM324MX | SOIC | D | 14 | 2500 | 330.0 | 16.4 | 6.5 | 9.35 | 2.3 | 8.0 | 16.0 | Q1 |
| LM324MX/NOPB | SOIC | D | 14 | 2500 | 330.0 | 16.4 | 6.5 | 9.35 | 2.3 | 8.0 | 16.0 | Q1 |

TAPE AND REEL BOX DIMENSIONS


*All dimensions are nominal

| Device | Package Type | Package Drawing | Pins | SPQ | Length (mm) | Width (mm) | Height (mm) |
|----------------|--------------|-----------------|------|------|-------------|------------|-------------|
| LM2902MTX | TSSOP | PW | 14 | 2500 | 349.0 | 337.0 | 45.0 |
| LM2902MTX/NOPB | TSSOP | PW | 14 | 2500 | 349.0 | 337.0 | 45.0 |
| LM2902MX | SOIC | D | 14 | 2500 | 349.0 | 337.0 | 45.0 |
| LM2902MX/NOPB | SOIC | D | 14 | 2500 | 349.0 | 337.0 | 45.0 |
| LM324AMX | SOIC | D | 14 | 2500 | 349.0 | 337.0 | 45.0 |
| LM324AMX/NOPB | SOIC | D | 14 | 2500 | 349.0 | 337.0 | 45.0 |
| LM324MTX | TSSOP | PW | 14 | 2500 | 349.0 | 337.0 | 45.0 |
| LM324MTX/NOPB | TSSOP | PW | 14 | 2500 | 349.0 | 337.0 | 45.0 |
| LM324MX | SOIC | D | 14 | 2500 | 349.0 | 337.0 | 45.0 |
| LM324MX/NOPB | SOIC | D | 14 | 2500 | 349.0 | 337.0 | 45.0 |

J (R-GDIP-T**)

14 LEADS SHOWN

CERAMIC DUAL IN-LINE PACKAGE



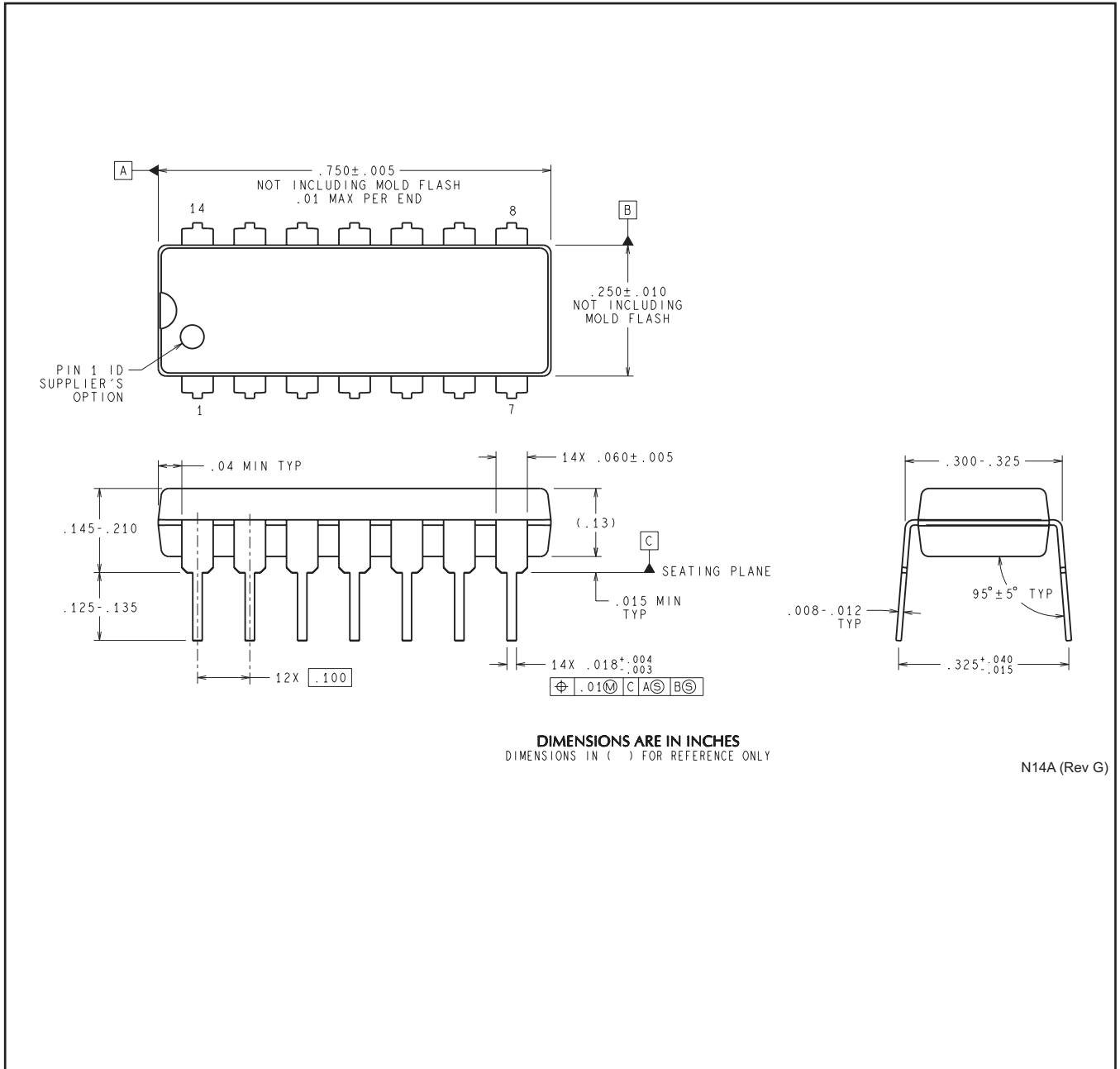
| DIM \ PINS ** | 14 | 16 | 18 | 20 |
|---------------|------------------------|------------------------|------------------------|------------------------|
| A | 0.300 (7,62) BSC | 0.300 (7,62) BSC | 0.300 (7,62) BSC | 0.300 (7,62) BSC |
| B MAX | 0.785 (19,94) | .840 (21,34) | 0.960 (24,38) | 1.060 (26,92) |
| B MIN | — | — | — | — |
| C MAX | 0.300 (7,62) | 0.300 (7,62) | 0.310 (7,87) | 0.300 (7,62) |
| C MIN | 0.245 (6,22) | 0.245 (6,22) | 0.220 (5,59) | 0.245 (6,22) |



4040083/F 03/03

- NOTES:
- All linear dimensions are in inches (millimeters).
 - This drawing is subject to change without notice.
 - This package is hermetically sealed with a ceramic lid using glass frit.
 - Index point is provided on cap for terminal identification only on press ceramic glass frit seal only.
 - Falls within MIL STD 1835 GDIP1-T14, GDIP1-T16, GDIP1-T18 and GDIP1-T20.

NFF0014A





N14A (Rev G)

D (R-PDSO-G14)

PLASTIC SMALL OUTLINE

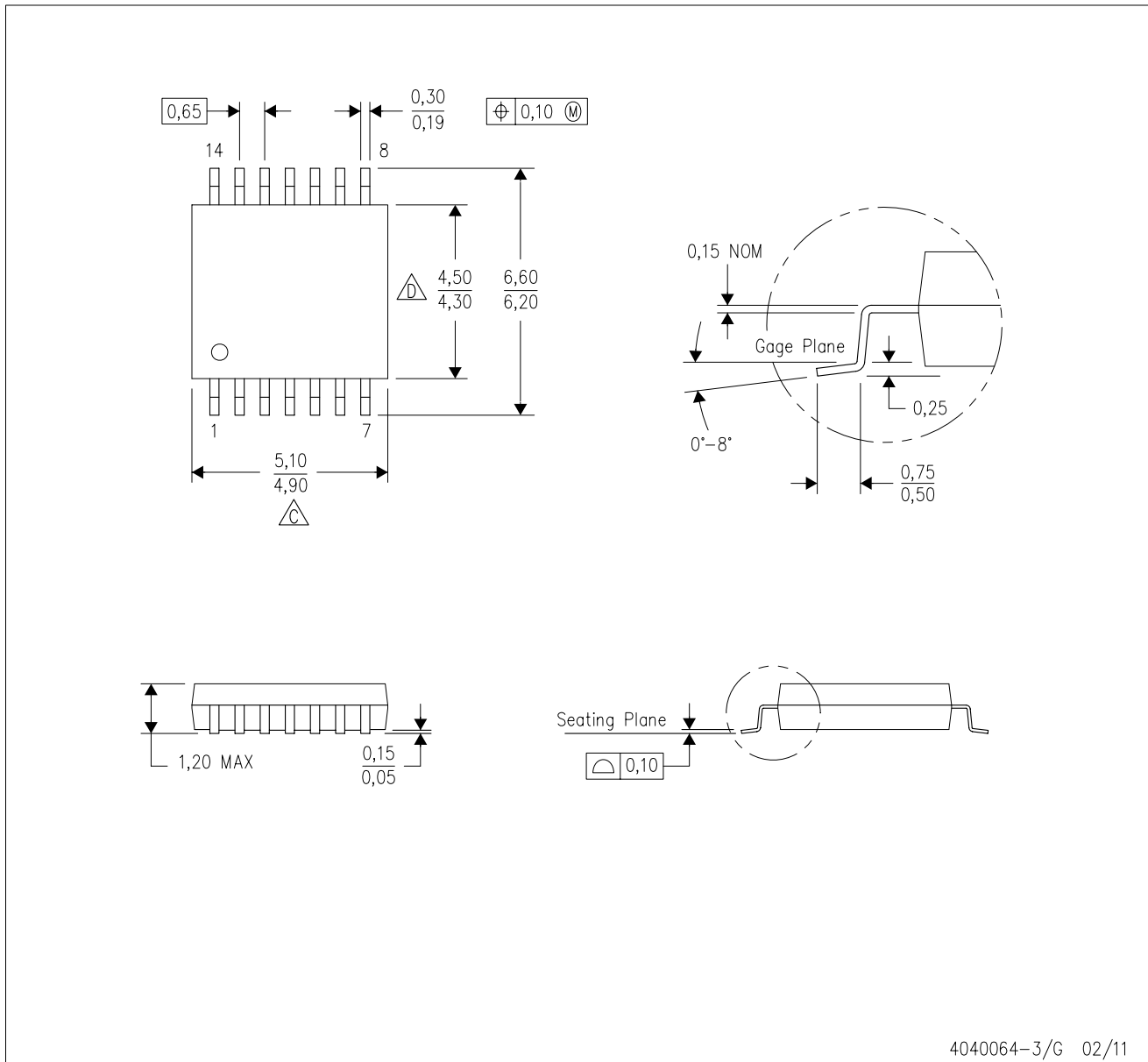


- NOTES:
- A. All linear dimensions are in inches (millimeters).
 - B. This drawing is subject to change without notice.
 -  Body length does not include mold flash, protrusions, or gate burrs. Mold flash, protrusions, or gate burrs shall not exceed 0.006 (0,15) each side.
 -  Body width does not include interlead flash. Interlead flash shall not exceed 0.017 (0,43) each side.
 - E. Reference JEDEC MS-012 variation AB.

MECHANICAL DATA

PW (R-PDSO-G14)

PLASTIC SMALL OUTLINE



- NOTES:
- A. All linear dimensions are in millimeters. Dimensioning and tolerancing per ASME Y14.5M-1994.
 - B. This drawing is subject to change without notice.
 - △ C Body length does not include mold flash, protrusions, or gate burrs. Mold flash, protrusions, or gate burrs shall not exceed 0,15 each side.
 - △ D Body width does not include interlead flash. Interlead flash shall not exceed 0,25 each side.
 - E. Falls within JEDEC MO-153

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