National Semiconductor

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

## General 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 ±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

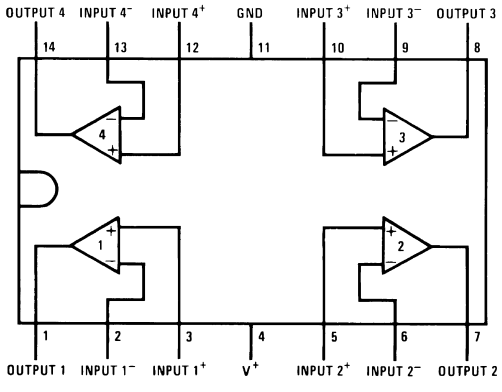
- Eliminates need for dual supplies
- Four internally compensated op amps in a single package
- Allows directly sensing near GND and $V_{OUT}$ also goes to GND
- Compatible with all forms of logic
- Power drain suitable for battery operation

## 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 ±1.5V to ±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

## Connection Diagrams

**Dual-In-Line Package**

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**Top View**

**Order Number LM124J, LM124AJ, LM124J/883** (Note 2)**, LM124AJ/883** (Note 1)**, LM224J, LM224AJ, LM324J, LM324M, LM324MX, LM324AM, LM324AMX, LM2902M, LM2902MX, LM324N, LM324AN, LM324MT, LM324MTX or LM2902N LM124AJRQML and LM124AJRQMLV**(Note 3)

**See NS Package Number J14A, M14A or N14A**

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## Absolute Maximum Ratings (Note 12)

**If Military/Aerospace specified devices are required, please contact the National Semiconductor Sales Office/ Distributors for availability and specifications.**

| | LM124/LM224/LM324<br>LM124A/LM224A/LM324A | LM2902 |
|---|---|---|
| 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) (Note 6) | 50 mA | 50 mA |
| Power Dissipation (Note 4) | | |
| 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) (Note 5) | | |
| $V^+ \leq 15V$ and $T_A = 25^\circ C$ | 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 (Note 13) | 250V | 250V |

## Electrical Characteristics

$V^+ = +5.0V$, (Note 7), unless otherwise stated

| Parameter | Conditions | LM124A | | | LM224A | | | LM324A | | | Units |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Min | Typ | Max | Min | Typ | Max | Min | Typ | Max | |
| Input Offset Voltage | (Note 8) $T_A = 25^\circ C$ | | 1 | 2 | | 1 | 3 | | 2 | 3 | mV |
| Input Bias Current (Note 9) | $I_{IN(+)}$ or $I_{IN(-)}$, $V_{CM} = 0V$, $T_A = 25^\circ C$ | | 20 | 50 | | 40 | 80 | | 45 | 100 | nA |
| Input Offset Current | $I_{IN(+)}$ or $I_{IN(-)}$, $V_{CM} = 0V$, $T_A = 25^\circ C$ | | 2 | 10 | | 2 | 15 | | 5 | 30 | nA |
| Input Common-Mode Voltage Range (Note 10) | $V^+ = 30V$, (LM2902, $V^+ = 26V$), $T_A = 25^\circ C$ | 0 | | $V^+ - 1.5$ | 0 | | $V^+ - 1.5$ | 0 | | $V^+ - 1.5$ | V |
| Supply Current | Over Full Temperature Range<br>$R_L = \infty$ 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 Voltage Gain | $V^+ = 15V$, $R_L \geq 2k\Omega$, ($V_O = 1V$ to $11V$), $T_A = 25^\circ C$ | 50 | 100 | | 50 | 100 | | 25 | 100 | | V/mV |
| Common-Mode | DC, $V_{CM} = 0V$ to $V^+ - 1.5V$, | 70 | 85 | | 70 | 85 | | 65 | 85 | | dB |

## Electrical Characteristics (Continued)

$V^+$ = +5.0V, (Note 7), unless otherwise stated

| Parameter | | Conditions | | LM124A | | | LM224A | | | LM324A | | | Units |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | Min | Typ | Max | Min | Typ | Max | Min | Typ | Max | |
| Rejection Ratio | | $T_A$ = 25˚C | | | | | | | | | | | |
| Power Supply Rejection Ratio | | $V^+$ = 5V to 30V (LM2902, $V^+$ = 5V to 26V), $T_A$ = 25˚C | | 65 | 100 | | 65 | 100 | | 65 | 100 | | dB |
| Amplifier-to-Amplifier Coupling (Note 11) | | f = 1 kHz to 20 kHz, $T_A$ = 25˚C (Input Referred) | | | −120 | | | −120 | | | −120 | | dB |
| 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 | | mA |
| | | $V_{IN}^-$ = 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 | | (Note 5) $V^+$ = 15V, $T_A$ = 25˚C | | | 40 | 60 | | 40 | 60 | | 40 | 60 | mA |
| Input Offset Voltage | | (Note 8) | | | | 4 | | | 4 | | | 5 | mV |
| $V_{OS}$ Drift | | $R_S$ = 0Ω | | | 7 | 20 | | 7 | 20 | | 7 | 30 | µV/˚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/˚C |
| Input Bias Current | | $I_{IN(+)}$ or $I_{IN(-)}$ | | | 40 | 100 | | 40 | 100 | | 40 | 200 | nA |
| Input Common-Mode Voltage Range (Note 10) | | $V^+$ = +30V (LM2902, $V^+$ = 26V) | | 0 | | $V^+$–2 | 0 | | $V^+$–2 | 0 | | $V^+$–2 | V |
| Large Signal Voltage Gain | | $V^+$ = +15V ($V_O$Swing = 1V to 11V) $R_L \geq 2$ kΩ | | 25 | | | 25 | | | 15 | | | V/mV |
| Output Voltage Swing | $V_{OH}$ | $V^+$ = 30V | $R_L$ = 2 kΩ | 26 | | | 26 | | | 26 | | | V |
| | | (LM2902, $V^+$ = 26V) | $R_L$ = 10 kΩ | 27 | 28 | | 27 | 28 | | 27 | 28 | | |
| | $V_{OL}$ | $V^+$ = 5V, $R_L$ = 10 kΩ | | | 5 | 20 | | 5 | 20 | | 5 | 20 | mV |
| Output Current | Source | $V_O$ = 2V | $V_{IN}^+$ = +1V, $V_{IN}^-$ = 0V, $V^+$ = 15V | 10 | 20 | | 10 | 20 | | 10 | 20 | | mA |
| | Sink | | $V_{IN}^-$ = +1V, $V_{IN}^+$ = 0V, $V^+$ = 15V | 10 | 15 | | 5 | 8 | | 5 | 8 | | |

## Electrical Characteristics

$V^+$ = +5.0V, (Note 7), unless otherwise stated

| Parameter | Conditions | LM124/LM224 | | | LM324 | | | LM2902 | | | Units |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Min | Typ | Max | Min | Typ | Max | Min | Typ | Max | |
| Input Offset Voltage | (Note 8) $T_A$ = 25˚C | | 2 | 5 | | 2 | 7 | | 2 | 7 | mV |
| Input Bias Current (Note 9) | $I_{IN(+)}$ or $I_{IN(-)}$, $V_{CM}$ = 0V, $T_A$ = 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 Voltage Range (Note 10) | $V^+$ = 30V, (LM2902, $V^+$ = 26V), $T_A$ = 25˚C | 0 | | $V^+$–1.5 | 0 | | $V^+$–1.5 | 0 | | $V^+$–1.5 | V |

## Electrical Characteristics (Continued)

$V^+$ = +5.0V, (Note 7), unless otherwise stated

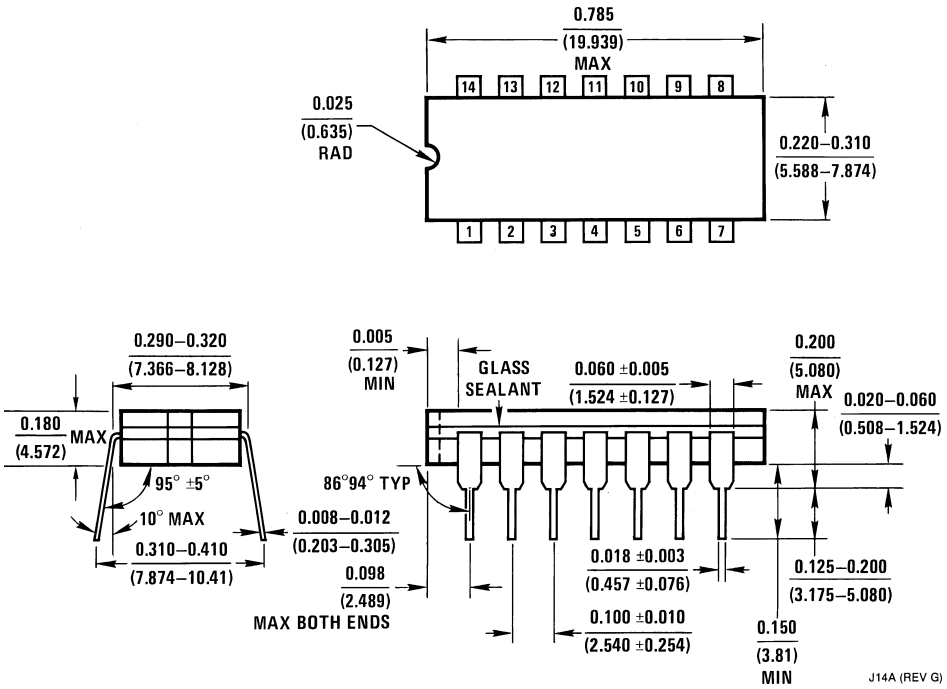
| Parameter | | Conditions | | LM124/LM224 | | | LM324 | | | LM2902 | | | Units |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | Min | Typ | Max | Min | Typ | Max | Min | Typ | Max | |
| Supply Current | | Over Full Temperature Range<br>$R_L = \infty$ On All Op Amps | | | | | | | | | | | 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 Voltage Gain | | $V^+$ = 15V, $R_L \geq 2k\Omega$, ($V_O$ = 1V to 11V), $T_A$ = 25˚C | | 50 | 100 | | 25 | 100 | | 25 | 100 | | V/mV |
| Common-Mode Rejection Ratio | | DC, $V_{CM}$ = 0V to $V^+$ − 1.5V, $T_A$ = 25˚C | | 70 | 85 | | 65 | 85 | | 50 | 70 | | dB |
| Power Supply Rejection Ratio | | $V^+$ = 5V to 30V (LM2902, $V^+$ = 5V to 26V), $T_A$ = 25˚C | | 65 | 100 | | 65 | 100 | | 50 | 100 | | dB |
| Amplifier-to-Amplifier Coupling (Note 11) | | f = 1 kHz to 20 kHz, $T_A$ = 25˚C (Input Referred) | | | −120 | | | −120 | | | −120 | | dB |
| 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 | | mA |
| | | $V_{IN}^-$ = 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 | | (Note 5) $V^+$ = 15V, $T_A$ = 25˚C | | | 40 | 60 | | 40 | 60 | | 40 | 60 | mA |
| Input Offset Voltage | | (Note 8) | | | | 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 |
| Input Bias Current | | $I_{IN(+)}$ or $I_{IN(-)}$ | | | 40 | 300 | | 40 | 500 | | 40 | 500 | nA |
| Input Common-Mode Voltage Range (Note 10) | | $V^+$ = +30V (LM2902, $V^+$ = 26V) | | 0 | | $V^+$–2 | 0 | | $V^+$–2 | 0 | | $V^+$–2 | V |
| Large Signal Voltage Gain | | $V^+$ = +15V ($V_O$Swing = 1V to 11V) $R_L \geq 2$ kΩ | | 25 | | | 15 | | | 15 | | | V/mV |
| Output Voltage Swing | $V_{OH}$ | $V^+$ = 30V | $R_L$ = 2 kΩ | 26 | | | 26 | | | 22 | | | V |
| | | (LM2902, $V^+$ = 26V) | $R_L$ = 10 kΩ | 27 | 28 | | 27 | 28 | | 23 | 24 | | |
| | $V_{OL}$ | $V^+$ = 5V, $R_L$ = 10 kΩ | | | 5 | 20 | | 5 | 20 | | 5 | 100 | mV |
| Output Current | Source | $V_O$ = 2V | $V_{IN}^+$ = +1V, $V_{IN}^-$ = 0V, $V^+$ = 15V | 10 | 20 | | 10 | 20 | | 10 | 20 | | mA |
| | Sink | | $V_{IN}^-$ = +1V, $V_{IN}^+$ = 0V, $V^+$ = 15V | 5 | 8 | | 5 | 8 | | 5 | 8 | | |

**Note 4:** 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 of to reduce the power which is dissipated in the integrated circuit.

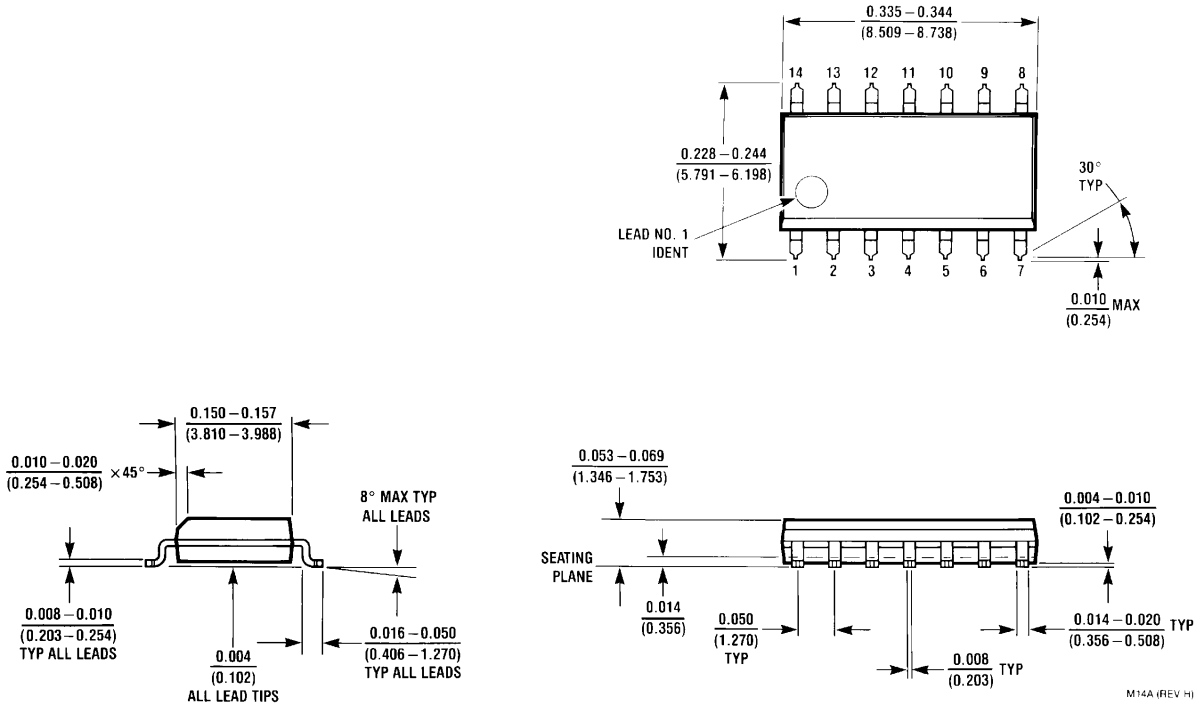
**Note 5:** Short circuits from the output to $V^+$ can cause excessive heating and eventual destruction. When considering short circuits to ground, the maximum output current is approximately 40 mA independent of the magnitude of $V^+$. At values of supply voltage in excess of +15V, continuous short-circuits can exceed the power dissipation ratings and cause eventual destruction. Destructive dissipation can result from simultaneous shorts on all amplifiers.

**Note 6:** 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

## Physical Dimensions inches (millimeters) unless otherwise noted

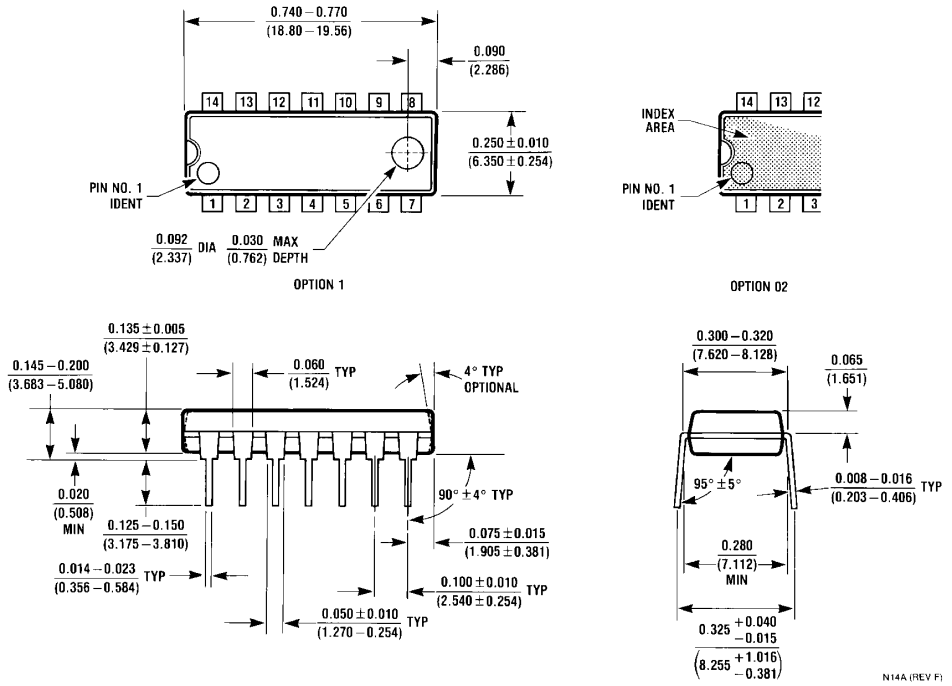



**Ceramic Dual-In-Line Package (J)**
**Order Number JL124ABCA, JL124BCA, JL124ASCA, JL124SCA, LM124J, LM124AJ, LM124AJ/883, LM124J/883, LM224J, LM224AJ or LM324J**
**NS Package Number J14A**

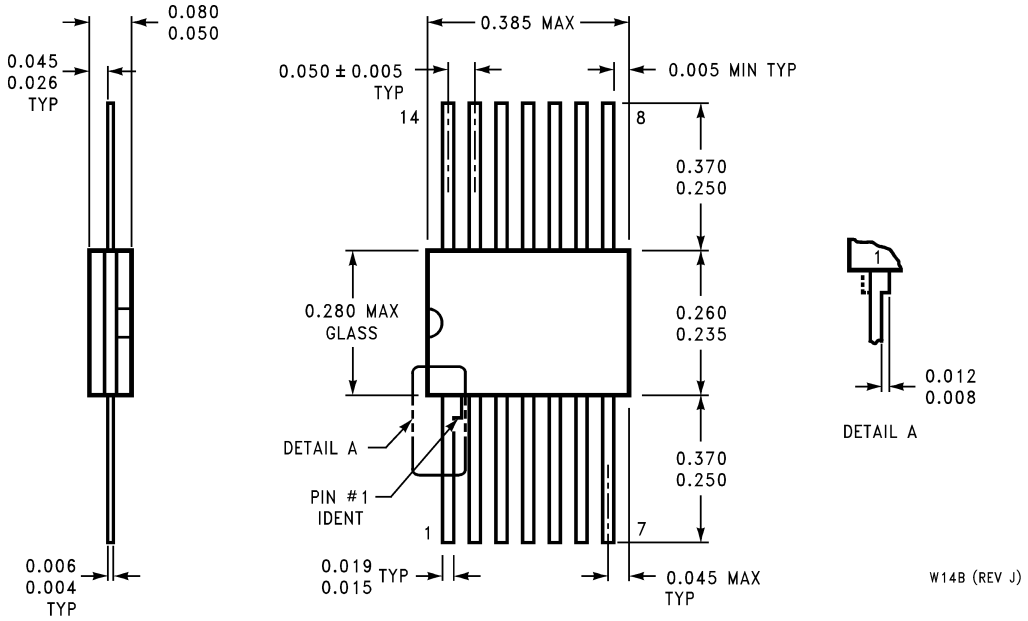



**MX S.O. Package (M)**
**Order Number LM324M, LM324MX, LM324AM, LM324AMX, LM2902M or LM2902MX**
**NS Package Number M14A**

## Physical Dimensions inches (millimeters) unless otherwise noted (Continued)




**Molded Dual-In-Line Package (N)**
**Order Number LM324N, LM324AN or LM2902N**
**NS Package Number N14A**




**Ceramic Flatpak Package**
**Order Number JL124ABDA, JL124ABZA, JL124ASDA, JL124BDA, JL124BZA, JL124SDA, LM124AW/883, LM124AWG/883, LM124W/883 or LM124WG/883**
**NS Package Number W14B**