National Semiconductor

May 1999

# LM6162
# High Speed Operational Amplifier

## General Description

The LM6162 family of high-speed amplifiers exhibits an excellent speed-power product, delivering 300 V/µs and 100 MHz gain-bandwidth product (stable for gains as low as +2 or −1) with only 5 mA of supply current. Further power savings and application convenience are possible by taking advantage of the wide dynamic range in operating supply voltage which extends all the way down to +5V.

These amplifiers are built with National's VIP™ (Vertically Integrated PNP) process which provides fast transistors that are true complements to the already fast NPN devices. This advanced junction-isolated process delivers high speed performance without the need for complex and expensive dielectric isolation.

## Features

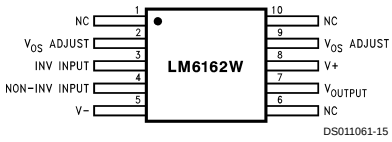
- High slew rate: 300 V/µs
- High gain-bandwidth product: 100 MHz
- Low supply current: 5 mA
- Fast settling time: 120 ns to 0.1%
- Low differential gain: <0.1%
- Low differential phase: <0.1°
- Wide supply range: 4.75V to 32V
- Stable with unlimited capacitive load
- Well behaved; easy to apply

## Applications

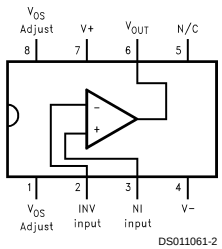
- Video amplifier
- Wide-bandwidth signal conditioning for image processing (FAX, scanners, laser printers)
- Hard disk drive preamplifier
- Error amplifier for high-speed switching regulator

## Connection Diagrams

**10-Pin Ceramic Flatpak**




**Top View**
**See NS Package Number W10A**




**See NS Package Number N08E or J08A**

| Temperature Range | | | Package | NSC Drawing |
|---|---|---|---|---|
| Military<br>−55°C ≤ $T_A$ ≤ +125°C | Industrial<br>−25°C ≤ $T_A$ ≤ +85°C | Commercial<br>0°C ≤ $T_A$ ≤ +70°C | | |
| LM6162N | | | 8-Pin Molded DIP | N08E |
| LM6162J/883<br>5962-9216501PA | | | 8-Pin Ceramic DIP | J08A |
| LM6162WG/883<br>5962-9216501XA | | | 10-Lead Ceramic SOIC | WG10A |

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## Connection Diagrams (Continued)

| Temperature Range | | | Package | NSC Drawing |
|---|---|---|---|---|
| **Military** $-55^{\circ}C \leq T_A \leq +125^{\circ}C$ | **Industrial** $-25^{\circ}C \leq T_A \leq +85^{\circ}C$ | **Commercial** $0^{\circ}C \leq T_A \leq +70^{\circ}C$ | | |
| LM6162W/883<br>5962-9216501HA | | | 10-Pin Ceramic Flatpak | W10A |

## Absolute Maximum Ratings (Note 1)

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

| | |
|---|---|
| Supply Voltage ($V^+$–$V^-$) | 36V |
| Differential Input Voltage (Note 2) | ±8V |
| Common-Mode Input Voltage (Note 3) | ($V^+$−0.7V) to ($V^-$ + 0.7V) |
| Output Short Circuit to GND (Note 4) | Continuous |
| Soldering Information | |
| Dual-In-Line Package (N) | |
| Soldering (10 seconds) | 260˚C |
| Small Outline Package (M) | |
| Vapor Phase (60 seconds) | 215˚C |
| Infrared (15 seconds) | 220˚C |

See AN-450 "Surface Mounting Methods and Their Effect on Product Reliability" for other methods of soldering surface mount devices.

| | |
|---|---|
| Storage Temperature Range | −65˚C ≤ $T_J$ ≤ +150˚C |
| Max Junction Temperature | 150˚C |
| ESD Tolerance (Note 5) | ±1100V |

## Operating Ratings

| | |
|---|---|
| Temperature Range (Note 6) | |
| LM6162 | −55˚C ≤ $T_J$ ≤ +125˚C |
| Supply Voltage Range | 4.75V to 32V |

## DC Electrical Characteristics

These limits apply for supply voltage = ±15V, $V_{CM}$ = 0V, and $R_L \geq 100\ k\Omega$, unless otherwise specified. Limits in standard typeface are for $T_A = T_J = 25˚C$; limits in **boldface type** apply over the **Operating Temperature Range**.

| Symbol | Parameter | Conditions | Typical (Note 7) | LM6162 Limit (Note 8) | Units |
|---|---|---|---|---|---|
| $V_{OS}$ | Input Offset Voltage | | ±3 | ±5 | mV |
| | | | | **±8** | max |
| $\frac{\Delta V_{OS}}{\Delta Temp}$ | Input Offset Voltage Average Drift | | 7 | | µV/˚C |
| $I_{bias}$ | Input Bias Current | | 2.2 | 3 | µA |
| | | | | **6** | max |
| $I_{OS}$ | Input Offset Current | | ±150 | ±350 | nA |
| | | | | **±800** | max |
| $\frac{\Delta I_{OS}}{\Delta Temp}$ | Input Offset Current Average Drift | | 0.3 | | nA/˚C |
| $R_{IN}$ | Input Resistance | Differential | 180 | | kΩ |
| $C_{IN}$ | Input Capacitance | | 2.0 | | pF |
| $A_{VOL}$ | Large Signal Voltage Gain | $V_{OUT}$ = ±10V, $R_L$ = 2 kΩ (Note 9) | 1400 | 1000 | V/V |
| | | | | **500** | min |
| | | $R_L$ = 10 kΩ | 6500 | | V/V |
| $V_{CM}$ | Input Common-Mode Voltage Range | Supply = ±15V | +14.0 | +13.9 | V |
| | | | | **+13.8** | min |
| | | | −13.2 | −12.9 | V |
| | | | | **−12.7** | max |
| | | Supply = +5V (Note 10) | 4.0 | 3.9 | V |
| | | | | **3.8** | min |
| | | | 1.6 | 1.8 | V |
| | | | | **2.0** | max |
| CMRR | Common-Mode Rejection Ratio | −10V ≤ $V_{CM}$ ≤ +10V | 100 | 83 | dB |
| | | | | **79** | min |
| PSRR | Power Supply Rejection Ratio | ±10V ≤ $V_S$ ≤ ±16V | 93 | 83 | dB |
| | | | | **79** | min |

## DC Electrical Characteristics (Continued)

These limits apply for supply voltage = ±15V, $V_{CM}$ = 0V, and $R_L \geq 100\ k\Omega$, unless otherwise specified. Limits in standard typeface are for $T_A = T_J = 25^\circ C$; limits in **boldface type** apply over the **Operating Temperature Range**.

| Symbol | Parameter | Conditions | Typical (Note 7) | LM6162 Limit (Note 8) | Units |
|---|---|---|---|---|---|
| $V_O$ | Output Voltage Swing | Supply = ±15V, $R_L$ = 2 kΩ | +14.2 | +13.5 | V |
| | | | | **+13.3** | min |
| | | | −13.4 | −13.0 | V |
| | | | | **−12.7** | max |
| $V_O$ | Output Voltage Swing | Supply = +5V and $R_L$ = 2 kΩ (Note 10) | 4.2 | 3.5 | V |
| | | | | **3.3** | min |
| | | | 1.3 | 1.7 | V |
| | | | | **2.0** | max |
| $I_{OSC}$ | Output Short Circuit Current | Sourcing | 65 | 30 | mA |
| | | | | **20** | min |
| | | Sinking | 65 | 30 | mA |
| | | | | **20** | min |
| $I_S$ | Supply Current | | 5.0 | 6.5 | mA |
| | | | | **6.8** | max |

## AC Electrical Characteristics

These limits apply for supply voltage = ±15V, $V_{CM}$ = 0V, $R_L \geq 100\ k\Omega$, and $C_L \leq 5$ pF, unless otherwise specified. Limits in standard typeface are for $T_A = T_J = 25^\circ C$; limits in **boldface type** apply over the **Operating Temperature Range**.

| Symbol | Parameter | Conditions | Typical (Note 7) | LM6162 Limit (Note 8) | Units |
|---|---|---|---|---|---|
| GBW | Gain-Bandwidth Product | f = 20 MHz | 100 | 80 | MHz |
| | | | | **55** | min |
| | | Supply = ±5V | 70 | | MHz |
| SR | Slew Rate | $A_V$ = +2 (Note 11) | 300 | 200 | V/µs |
| | | | | **180** | min |
| | | Supply = ±5V | 200 | | V/µs |
| PBW | Power Bandwidth | $V_{OUT} = 20\ V_{PP}$ | 4.5 | | MHz |
| $t_s$ | Settling Time | 10V step, to 0.1% $A_V$ = −1, $R_L$ = 2 kΩ | 100 | | ns |
| $\phi_m$ | Phase Margin | $A_V$ = +2 | 45 | | deg |
| | Differential Gain | NTSC, $A_V$ = +2 | <0.1 | | % |
| | Differential Phase | NTSC, $A_V$ = +2 | <0.1 | | deg |
| $e_n$ | Input Noise Voltage | f = 10 kHz | 10 | | nV/√Hz |
| $i_n$ | Input Noise Current | f = 10 kHz | 1.2 | | pA/√Hz |

**Note 1:** Absolute maximum ratings indicate limits beyond which damage to the component may occur. Electrical specifications do not apply when operating the device beyond its rated operating conditions.

**Note 2:** The ESD protection circuitry between the inputs will begin to conduct when the differential input voltage reaches 8V.

**Note 3:** a) In addition, the voltage between the $V^+$ pin and either input pin must not exceed 36V.

b) When the voltage applied to an input pin is driven more than 3V below the negative supply pin voltage, a substrate diode begins to conduct. Current through this pin must then be kept less than 20 mA to limit damage from self-heating.

**Note 4:** Although the output current is internally limited, continuous short-circuit operation at elevated ambient temperature can result in exceeding the maximum allowed junction temperature of 150°C.

**Note 5:** This value is the average voltage that the weakest pin combinations can withstand and still conform to the datasheet limits. The test circuit used consists of the human body model, 100 pF in series with 1500Ω.

**Note 6:** The typical thermal resistance, junction-to-ambient, of the molded plastic DIP (N package) is 105°C/W. For the molded plastic SO (M package), use 155°C/W. All numbers apply for packages soldered directly into a printed circuit board.

**Note 7:** Typical values are for $T_J = 25^\circ C$, and represent the most likely parametric norm.

**Note 8:** Limits are guaranteed, by testing or correlation.

## AC Electrical Characteristics (Continued)

**Note 9:** Voltage Gain is the total output swing (20V) divided by the magnitude of the input signal required to produce that swing.

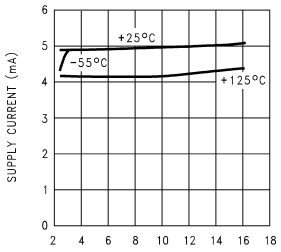
**Note 10:** For single-supply operation, the following conditions apply: $V^+ = 5V$, $V^- = 0V$, $V_{CM} = 2.5V$, $V_{OUT} = 2.5V$. Pin 1 and Pin 8 ($V_{OS}$ Adjust pins) are each connected to pin 4 ($V^-$) to realize maximum output swing. This connection will increase the offset voltage.

**Note 11:** $V_{IN} = 10V$ step. For ±5V supplies, $V_{IN} = 1V$ step.

**Note 12:** A military RETS electrical test specification is available on request.

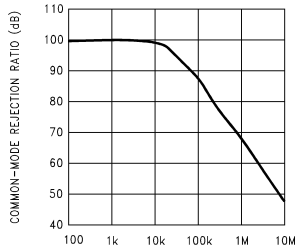
## Typical Performance Characteristics $R_L = 10\ k\Omega$, $T_A = 25^\circ C$ unless otherwise noted

**Supply Current vs Supply Voltage**



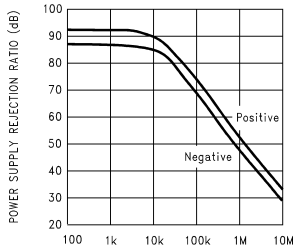
DS011061-16

**Common-Mode Rejection Ratio**



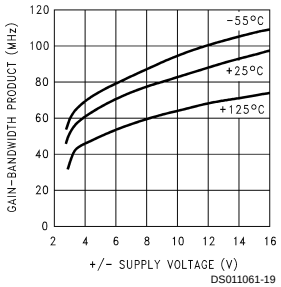
DS011061-17

**Power Supply Rejection Ratio**



DS011061-18

**Gain-Bandwidth Product vs Supply Voltage**



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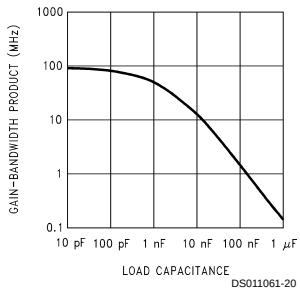
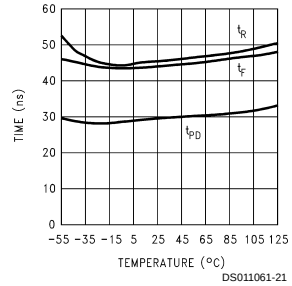
**Gain-Bandwidth Product vs Load Capacitance**



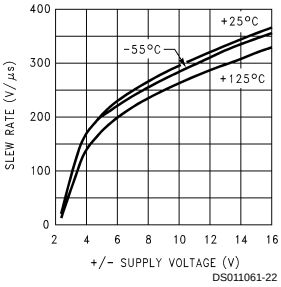
DS011061-20

**Propagation Delay, Rise and Fall Times**



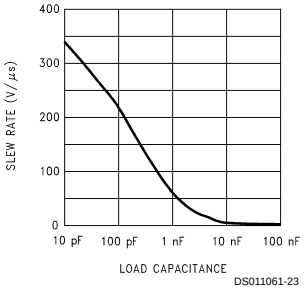
DS011061-21

**Slew Rate vs Supply Voltage**



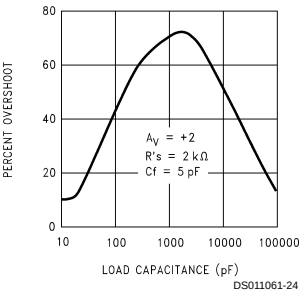
DS011061-22

**Slew Rate vs Load Capacitance**



DS011061-23

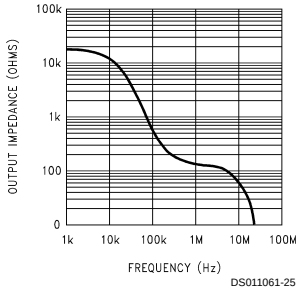
**Overshoot vs Load Capacitance**



DS011061-24

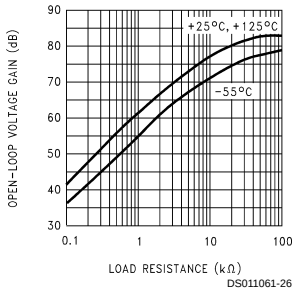
## Typical Performance Characteristics $R_L$ = 10 kΩ, $T_A$ = 25˚C unless otherwise noted (Continued)

**Output Impedance (Open-Loop)**



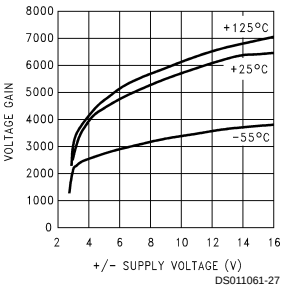

DS011061-25

**Voltage Gain vs Load Resistance**




DS011061-26

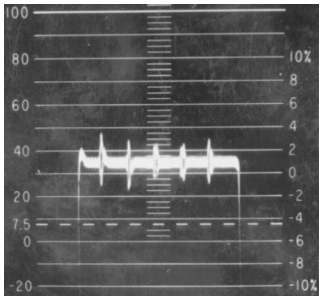
**Voltage Gain vs Supply Voltage**




DS011061-27

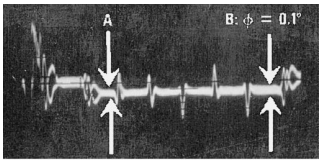
**Differential Gain (Note)**

**Differential Gain** (Note 13)




DS011061-4

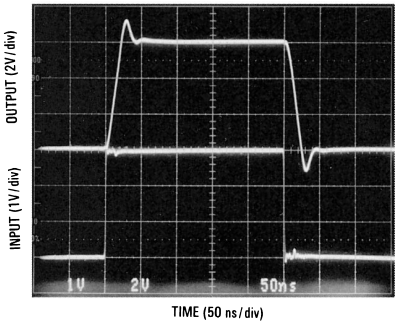
**Differential Phase** (Note 13)




DS011061-5

**Note 13:** Differential gain and differential phase measured for four series LM6162 op amps configured with gain of +2 each, in series with a 1:16 attenuator and an LM6321 buffer. Error added by LM6321 is negligible. Test performed using Tektronix Type 520 NTSC test system.

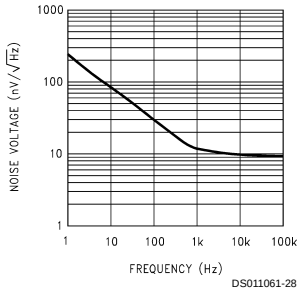
**Step Response; Av = +2**




DS011061-6

## Typical Performance Characteristics $R_L$ = 10 kΩ, $T_A$ = 25˚C unless otherwise noted (Continued)

**Input Noise Voltage**

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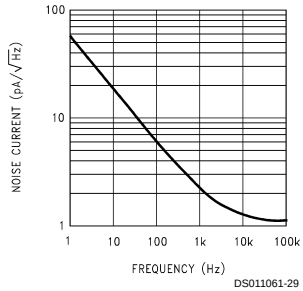
**Input Noise Current**

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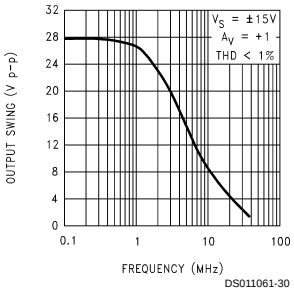
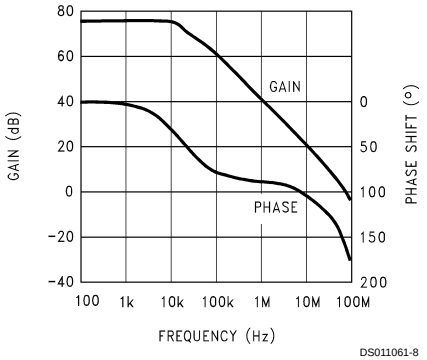
**Power Bandwidth**



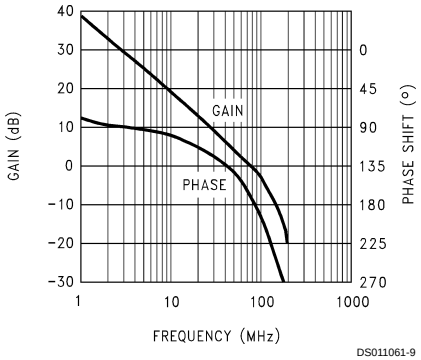

DS011061-30

**Open-Loop Frequency Response**



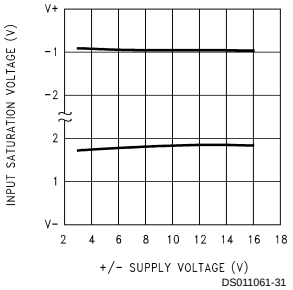

DS011061-8

**Open-Loop High-Frequency Response**



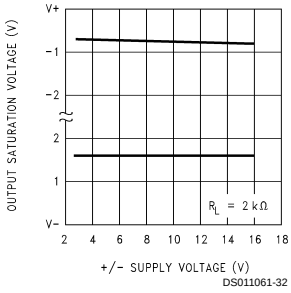

DS011061-9

**Common-Mode Input Voltage Limits**



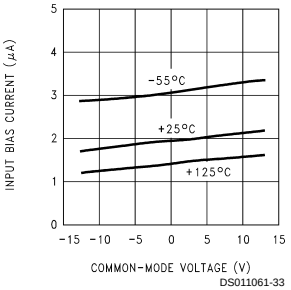

DS011061-31

**Output Saturation Voltage**



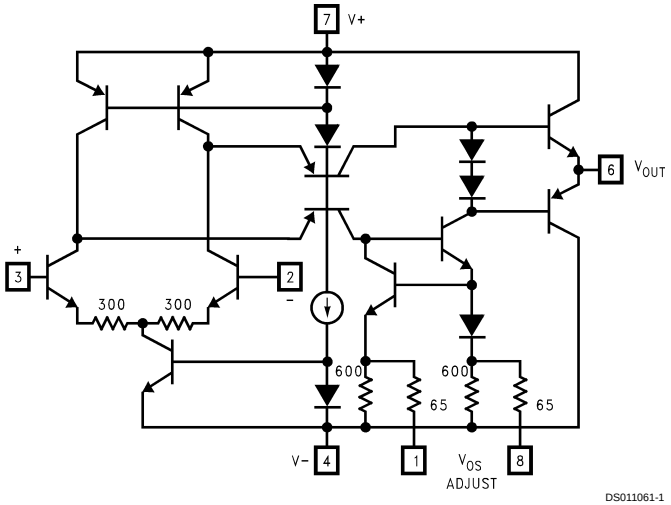

DS011061-32

**Bias Current vs Common-Mode Voltage**




DS011061-33

## Simplified Schematic




DS011061-1

## Application Tips

The LM6162 has been decompensated for a wider gain-bandwidth product than the LM6361. However, the LM6162 still offers stability at gains of 2 (and −1) or greater over the specified ranges of temperature, power supply voltage, and load. Since this decompensation involved reducing the emitter-degeneration resistors in the op amp's input stage, the DC precision has been increased in the form of lower offset voltage and higher open-loop gain.

Other op amps in this family include the LM6361, LM6364, and LM6365. If unity-gain stability is required, the LM6361 should be used. The LM6364 has been decompensated for operation at gains of 5 or more, with corresponding greater gain-bandwidth product (125 MHz, typical) and DC precision. The fully-uncompensated LM6365 offers gain-bandwidth product of 725 MHz, typical, and is stable for gains of 25 or more. All parts in this family, regardless of compensation, have the same high slew rate of 300 V/µs (typ).

The LM6162 is unusually tolerant of capacitive loads. Most op amps tend to oscillate when their load capacitance is greater than about 200 pF (in low-gain circuits). However, load capacitance on the LM6162 effectively increases its compensation capacitance, thus slowing the op amp's response and reducing its bandwidth. The compensation is not ideal, though, and ringing may occur in low-gain circuits with large capacitive loads.

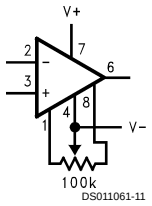
Power supply bypassing is not as critical for LM6162 as it is for other op amps in its speed class. However, bypassing will improve the stability and transient response of the LM6162, and is recommended for every design. 0.01 µF to 0.1 µF ceramic capacitors should be used (from each supply "rail" to ground); if the device is far away from its power supply source, an additional 2.2 µF to 10 µF of tantalum may be required for extra noise reduction.

Keep all leads short to reduce stray capacitance and lead inductance, and make sure ground paths are low-impedance, especially where heavier currents will be flowing. Stray capacitance in the circuit layout can cause signal coupling from one pin, input or lead to another, and can cause circuit gain to unintentionally vary with frequency.

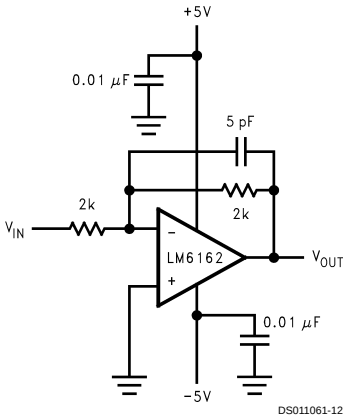
Breadboarded circuits will work best if they are built using generic PC boards with a good ground plane. If the op amps are used with sockets, as opposed to being soldered into the circuit, the additional input capacitance may degrade circuit frequency response. At low gains (+2 or −1), a feedback capacitor $C_f$ from output to inverting input will compensate for the phase lag caused by capacitance at the inverting input. Typically, values from 2 pF to 5 pF work well; however, best results can be obtained by observing the amplifier pulse response and optimizing $C_f$ for the particular layout.

## Typical Applications

**Offset Voltage Adjustment**

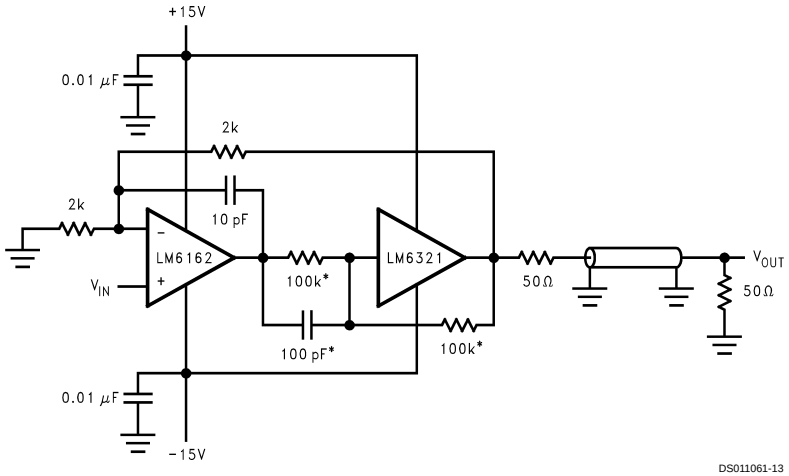



**Inverting Amplifier, 30 MHz Bandwidth**



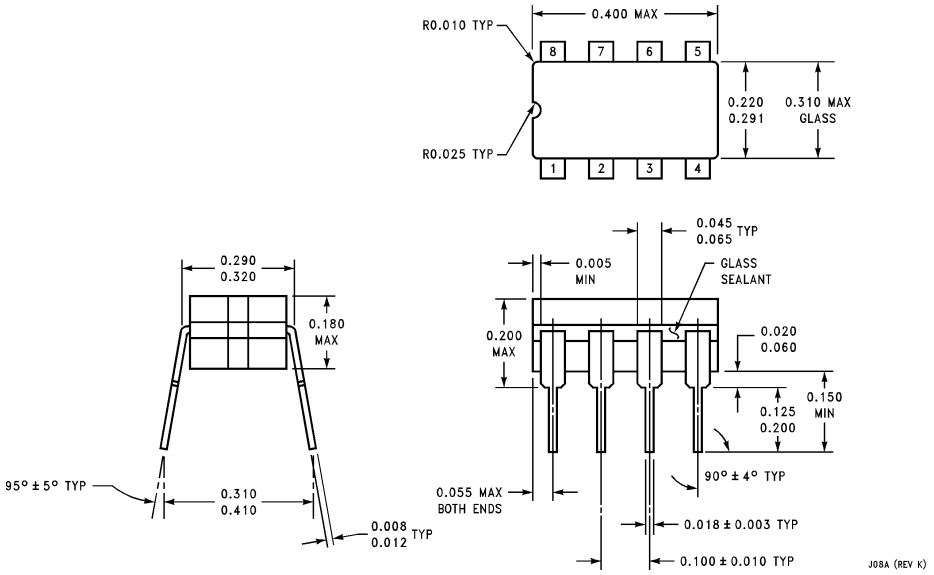

Operation on ±15V supplies results in wider bandwidth, 50 MHz (typ).

**Video Cable Driver**

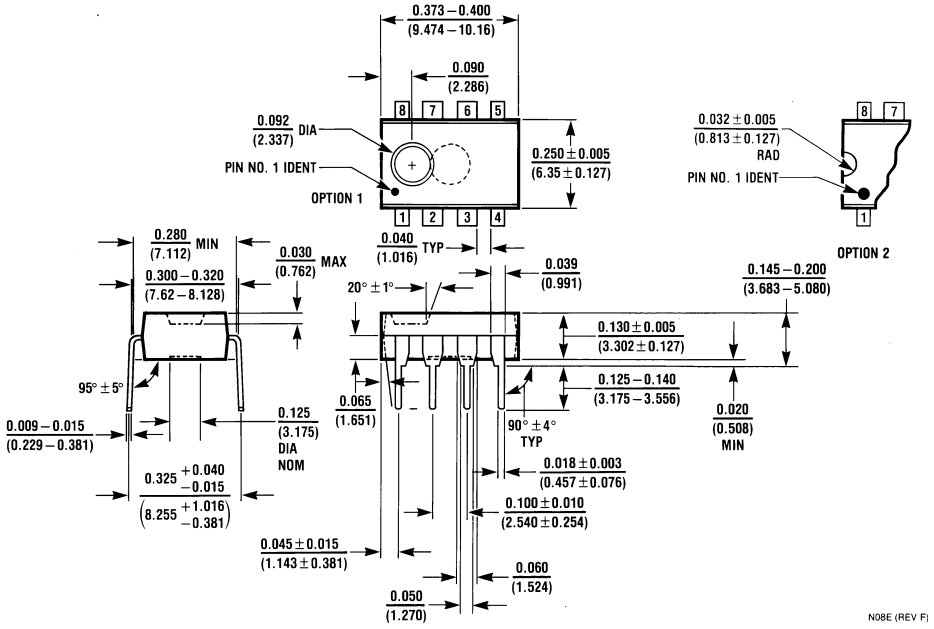



* Network required when operating on supply voltage over ±5V, for overvoltage protection of LM6321. If ±5V supplies are used, omit network and connect output of LM6162 directly to input of LM6321.

## Physical Dimensions inches (millimeters) unless otherwise noted

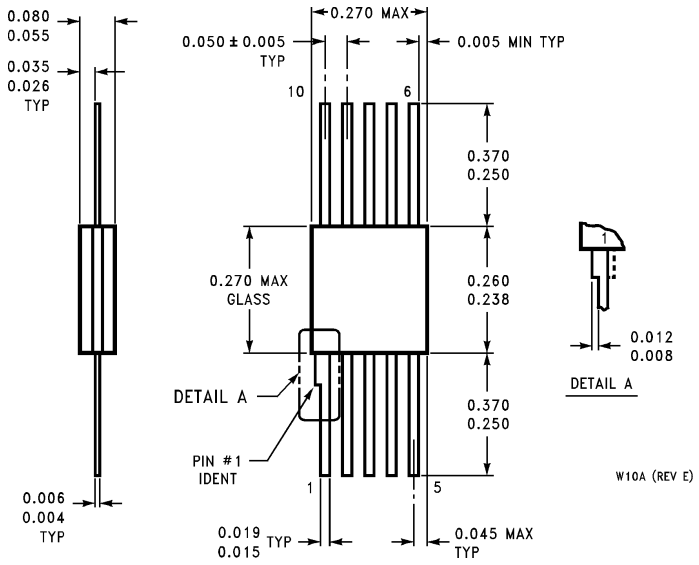



**Ceramic Dual-In-Line Package (J)**
**Order Number LM6162J/883**
**NS Package Number J08A**




**Molded Dual-In-Line Package (N)**
**Order Number LM6162N**
**NS Package Number N08E**

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




**10-Pin Ceramic Flatpak**
**Order Number LM6162W/883**
**NS Package Number W10A**

### LIFE SUPPORT POLICY

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2. A critical component is any component of a life support device or system whose failure to perform can be reasonably expected to cause the failure of the life support device or system, or to affect its safety or effectiveness.

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