National Semiconductor

November 1995

LM6311 Low Noise High Speed Voltage Feedback Operational Amplifier

General Description

The LM6311 is a low noise voltage feedback operational amplifier with low distortion. This makes the LM6311 ideal for signal recovery, high quality video, audio and medical imaging.

The conventional voltage fedback design makes it easy to use in standard active filter circuits.

The low distortion makes the LM6311 a good choice for driving high resolution analog-to-digital converters.

The 50 mA current drive and good capacitive load tolerance make the LM6311 useful for driving analog-to-digital converters which have switched-capacitor type inputs.

The LM6311 provides low noise and high speed for +5V single supply designs, making it useful for desktop systems and portable designs.

Features

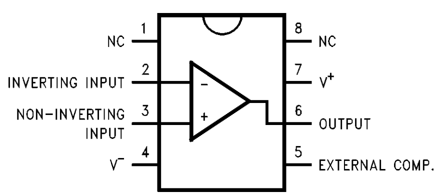
- 110 MHz −3 dB bandwidth
- 2.3 nV/root-Hertz voltage noise
- 3.5 pA/root-Hertz current noise
- 50 mA output current
- 200V/μs slew rate
- Low distortion −60 dB @ 5 MHz
- Pin for external compensation
- Dual ±5V or single +5V or +12V supplies
- Guaranteed specs at +5V

Applications

- High end consumer audio
- Professional video
- Medical imaging
- Instrumentation
- Differential amplifiers and active filters
- Telecommunications signal recovery

Connection Diagrams

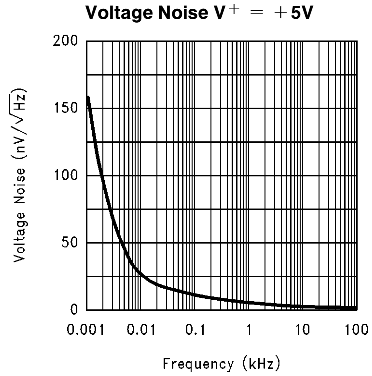
8-Pin DIP/SO-8



TL/H/12546–1

Top View

LM6311 Input Referred Voltage Noise V+ = +5V



TL/H/12546–16

Package	Ordering Information	NSC Drawing Number	Package Marking	Transport Media
8-Pin DIP	LM6311IN	N08E	LM6311IN	Rails
8-Pin SO-8	LM6311IM	M08A	LM6311IM	Rails
8-Pin SO-8	LM6311IMX	M08A	LM6311IM	2.5k Units Tape and Reel

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RRD-B30M76/Printed in U. S. A.

Absolute Maximum Ratings (Note 1)

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

ESD Tolerance (Note 2)	2000V
Differential Input Voltage	±10V
Voltage at Input/Output Pin	(V+), (V−)
Supply Voltage (V+−V−)	12V
Current at Input Pin	±5 mA
Current at Output Pin (Note 3)	±80 mA
Current at Power Supply Pin	80 mA
Lead Temperature (soldering, 10 sec)	260°C
Storage Temp. Range	−65°C to +150°C
Junction Temperature (Note 4)	150°C

Operating Ratings (Note 1)

Supply Voltage	±2.25V to ±6V
Junction Temperature Range	
LM6311I	$-40°C \leq T_J \leq +85°C$
Thermal resistance (θ_{JA})	
N Package, 8-pin Molded DIP	125°C/W
SO-8 Package, 8 Pin Surface Mount	165°C/W

±5V DC Electrical Characteristics

Unless otherwise specified, all limits guaranteed for T_J = 25°C, V+ = 5V, V− = −5V, V_{CM} = V_O = 0V and R_L = ∞. **Boldface** limits apply at the temperature extreme S.

Symbol	Parameter	Conditions	Typ (Note 5)	LM6311I Limit (Note 6)	Units
V_{OS}	Input Offset Voltage		0.5	2.5 **4.0**	mV max
TCV_{OS}	Input Offset Voltage Average Drift		5		μV/°C
I_B	Input Bias Current		8	30 **75**	μA max
TCI_B	Input Bias Current Average Drift		0.3		μA/°C
I_{offset}	Input Offset Current		0.5	5 **14**	μA max
TCI_{offset}	Input Offset Current Average Drift		0.02		μA/°C
CMRR	Common Mode Rejection Ratio	V_{CM} = ±2.5V	90	60 **54**	db min
CMVR	Common Mode Voltage Range	CMRR = 60 db	±3.5	±3.2	V
+PSRR	Positive Power Supply Rejection Ratio	V+ = 4.5V to 5V V− = −5.0V	75	62 **55**	db min
−PSRR	Negative Power Supply Rejection Ratio	V+ = 5.0V V− = −4.5V to −5.0V	75	62 **55**	db min
C_{IN-CM}	Common-Mode Input Capacitance		2.5		pF
$C_{IN-DIFF}$	Differential-Mode Input Capacitance		2.5		pF
A_{VOL}	Voltage Gain	V_O = −2V to +2V R_L = 1 kΩ	70	62 **55**	db

±5V DC Electrical Characteristics

Unless otherwise specified, all limits guaranteed for T_J = 25°C, V^+ = 5V, V^- = −5V, V_{CM} = V_O = 0V and R_L = ∞. **Boldface** limits apply at the temperature extremes. (Continued)

Symbol	Parameter	Conditions	Typ (Note 5)	LM6311I Limit (Note 6)	Units
V_O	Output Swing	R_L = 100Ω	3.4	3.1 **1.2**	V min
			−3.4	−3.1 **−1.2**	V max
		R_L = 1 kΩ	3.9	3.5 **−2.5**	V min
			−3.9	−3.5 **−2.5**	V max
R_{OUT}	Output Resistance	Closed Loop	0.1		Ω max
I_S	Supply Current		14	16 **17**	mA max

±5V AC Electrical Characteristics

Unless otherwise specified, all limits guaranteed for T_J = 25°C, V^+ = 5V, V^- = −5V, V_{CM} = V_O = 0V and R_L = 100Ω. **Boldface** limits apply at the temperature extremes.

Symbol	Parameter	Conditions	Typ (Note 5)	LM6311I Limit (Note 6)	Units
SR	Slew Rate	A_V = +2, 2V Output Pulse	200		V/μs
−3 dB BW	−3db Bandwidth	A_V = +1	110		MHz
−3 db BW	−3 dB Bandwidth	A_V = +2	40		MHz
Dg	Differential Gain (Note 7)	A_V = +2, 150Ω Load	0.12		%
Dp	Differential Phase (Note 7)	A_V = +2, 150Ω Load	0.35		Deg
e_n	Input-Referred Voltage Noise	1 MHz < f < 100 MHz	2.3		$\frac{nV}{\sqrt{Hz}}$
i_n	Input-Referred Current Noise	1 MHz < f < 100 MHz	3.5		$\frac{nV}{\sqrt{Hz}}$

5V DC Electrical Characteristics

Unless otherwise specified, all limits guaranteed for $T_J = 25°C$, $V^+ = 5V$, $V^- = 0V$, $V_{CM} = 2.5V$, $V_O = 2.5V$ and $R_L = \infty$. **Boldface** limits apply at the temperature extremes.

Symbol	Parameter	Conditions	Typ (Note 5)	LM6311I Limit (Note 6)	Units
V_{OS}	Input Offset Voltage		0.3	3.0 **5.0**	mV max
TCV_{OS}	Input Offset Voltage Average Drift		5		μV/°C
I_B	Input Bias Current		6	16 **30**	μA max
TCI_B	Input Bias Current Average Drift		0.3		μA/°C
I_{offset}	Input Offset Current		0.6	6	μA max
TCI_{offset}	Input Offset Current Average Drift		0.02		μA/°C
CMRR	Common Mode Rejection Ratio	$V_{CM} = 1.75$ to 3.25	90	65 **50**	db min
+PSRR	Positive Power Supply Rejection Ratio	$V^+ = 4.75V$ to 6V	70	60 **50**	db min
$C_{IN\text{-}CM}$	Common-Mode Input Capacitance		2.5		pF
$C_{IN\text{-}DIFF}$	Differential-Mode Input Capacitance		2.5		pF
V_O	Output Swing	$R_L = 100\Omega$ to 2.5V	4.2	3.6 **3.4**	V min
			0.9	1.4 **1.6**	V max
		$R_L = 1\ k\Omega$ to 2.5V	4.3	3.8 **3.6**	V min
			0.70	1.2 **1.4**	V max
A_{VOL}	Voltage Gain	$V_O = 2.0V$ to 3.0V $R_L = 1\ k\Omega$ to 2.5V	67	55 **50**	db
I_S	Supply Current		11	13 **14**	mA max

5V AC Electrical Characteristics

Unless otherwise specified, all limits guaranteed for $T_J = 25°C$, $V^+ = 5V$, $V^- = 0V$, $V_{CM} = 2.5V$, $V_O = 2.5V$ and $R_L = 100\Omega$ to 2.5V. **Boldface** limits apply at the temperature extremes.

Symbol	Parameter	Conditions	Typ (Note 5)	LM6311I Limit (Note 6)	Units
SR	Slew Rate	$A_V = +2$, 0.5V Output Pulse	100		V/µs
−3dB BW	−3dB Bandwidth	$A_V = +2$	40		MHz

Note 1: Absolute maximum Ratings indicate limits beyond which damage to the device my occur. Operating Ratings indicate conditions for which the device is intended to be functional, but specific performance is not guaranteed. For guaranteed specifications and the test conditions, see the Electrical characteristics.

Note 2: Human body model, 1.5 kΩ in series with 100 pF.

Note 3: Applies to both single-supply and split-supply operation. Continuous short circuit operation at elevated ambient temperature can result in exceeding the maximum allowed junction temperature of 150°C.

Note 4: The maximum power dissipation is a function of $T_{J(max)}$ θ_{JA} and T_A. The maximum allowable power dissipation at any ambient temperature is $P_D = (T_{J(max)} - T_A)/\theta_{JA}$. All numbers apply for packages soldered directly into a PC board.

Note 5: Typical values represent the most likely parametric norm.

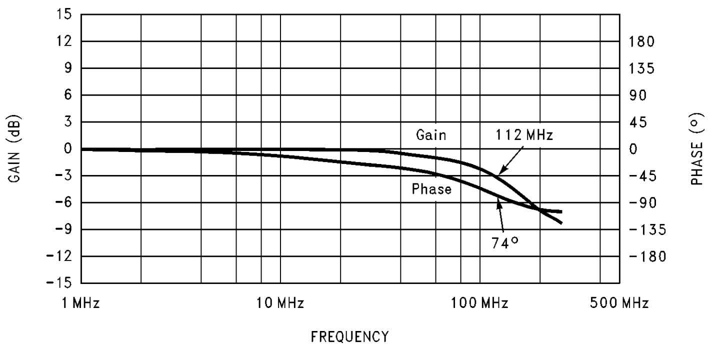
Note 6: All limits are guaranteed by testing or statistical analysis.

Note 7: Differential Gain and Phase performace are sensitive to layout. Follow layout suggestions in text for best results.

Typical Performance Curves $T_A = 25°C$, $V^+ = +5V$, $V^- = -5V$, $R_F = 100\Omega$, $R_L = 100\Omega$ unless noted

±5V CURVES

$A_V = +1$ Gain and Phase vs Frequency



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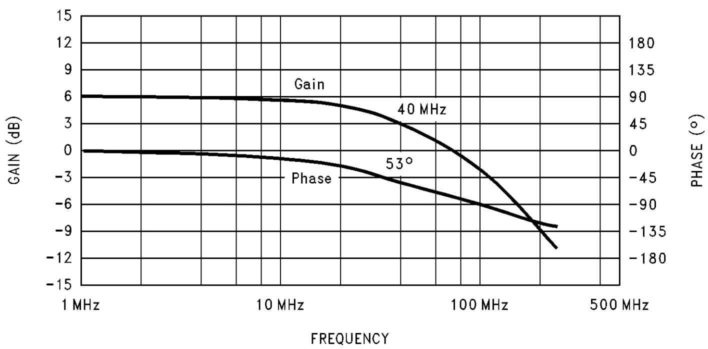
$A_V = +2$ Gain and Phase vs Frequency



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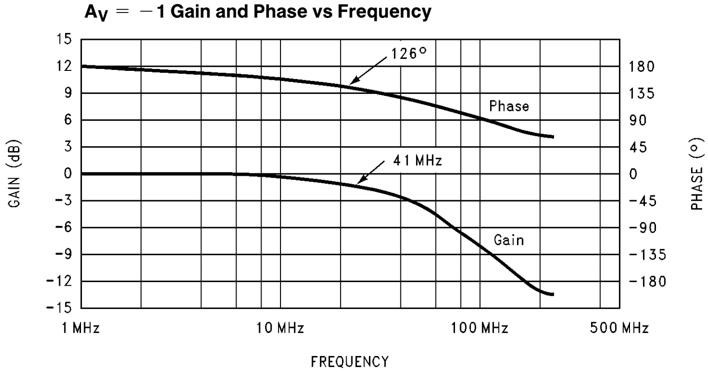
$A_V = -1$ Gain and Phase vs Frequency



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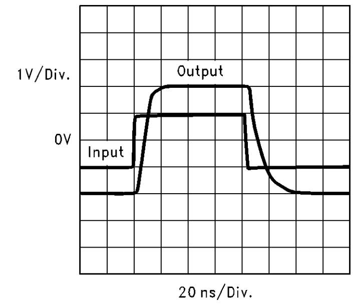
Typical Performance Curves

$T_A = 25°C$, $V^+ = +5V$, $V^- = -5V$, $R_F = 100\Omega$, $R_L = 100\Omega$ unless noted (Continued)

±**5V CURVES** (Continued)

$A_V = +2$ Pulse Response



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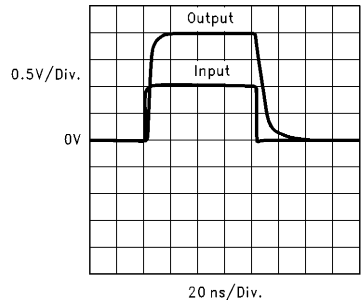
$A_V = +2$ Reference to Ground Pulse Response



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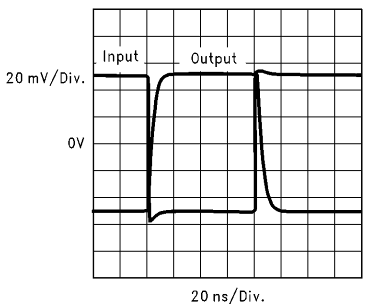
$A_V = -1$ Small Signal Pulse Response



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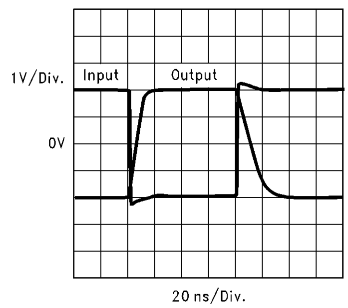
$A_V = -1$ Large Signal Pulse Response



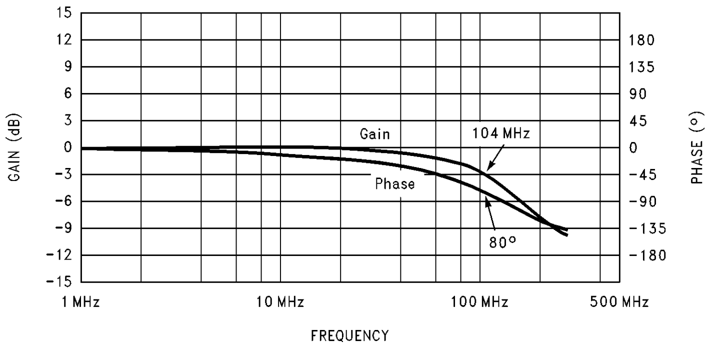
TL/H/12546–9

Typical Performance Curves

$T_A = 25°C$, $V^+ = +5V$, $V^- = 0V$, $R_F = 100\Omega$, $R_L = 100\Omega$ to 2.5V unless noted (Continued)

5V CURVES

$A_V = +1$ Gain and Phase vs Frequency



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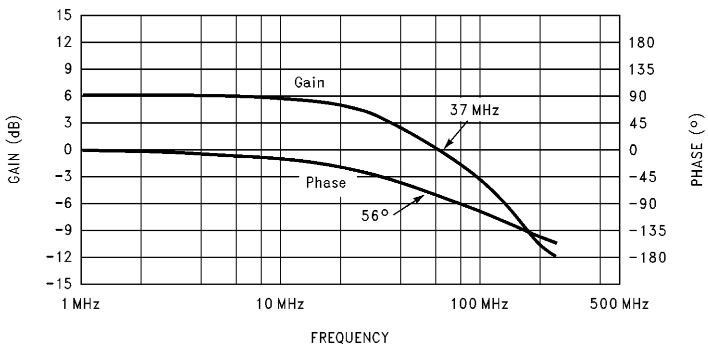
$A_V = +2$ Gain and Phase vs Frequency



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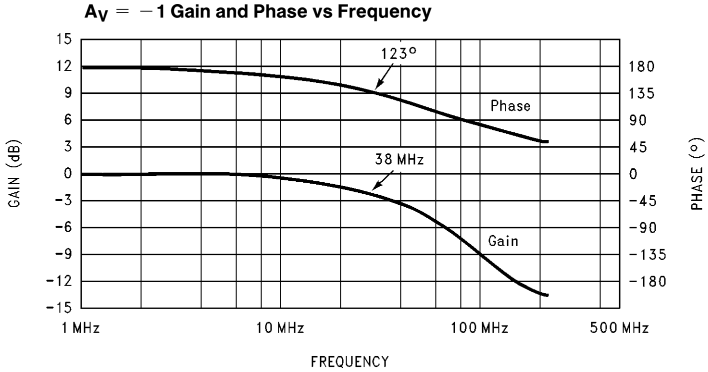
$A_V = -1$ Gain and Phase vs Frequency



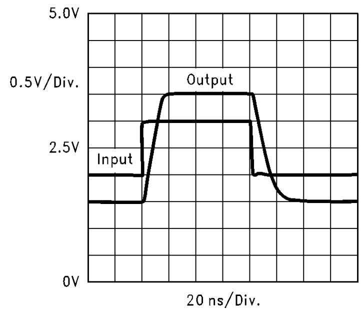
TL/H/12546–12

Typical Performance Curves

T_A = 25°C, V^+ = +5V, V^- = 0V, R_F = 100Ω, R_L = 100Ω to 2.5V unless noted (Continued)

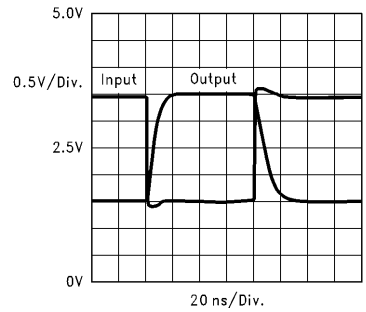
5V CURVES (Continued)

A_V = +2 Pulse Response



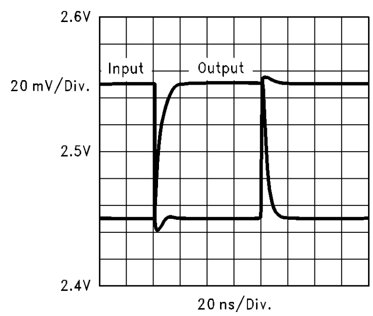
TL/H/12546–13

A_V = −1 Large Signal Pulse Response



TL/H/12546–14

A_V = −1 Small Signal Pulse Response



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Typical Performance Curves (Continued)

Bandwidth vs Supply Voltage, 27 pF External Capacitor (25°C)

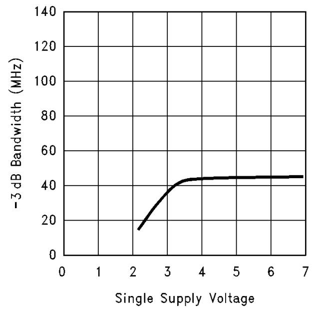

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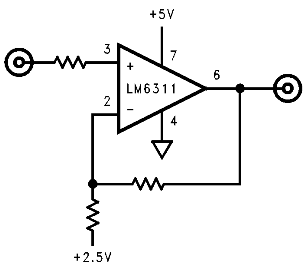
FIGURE 1

Non Inverting Amplifier Center-referenced Input



Inverting Amplifier Center-referenced Input

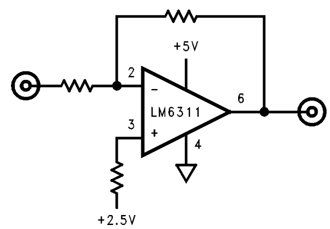


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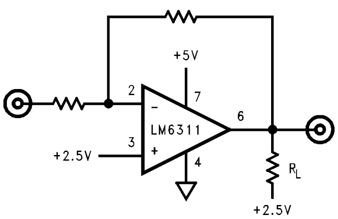
FIGURE 2

Center-referenced Output



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Ground-referenced Output

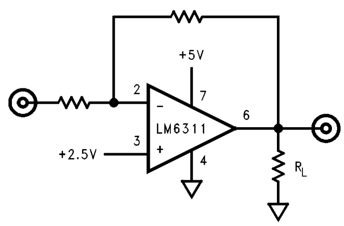

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FIGURE 3

Exceeding the Output Range, +5V Supply No Load

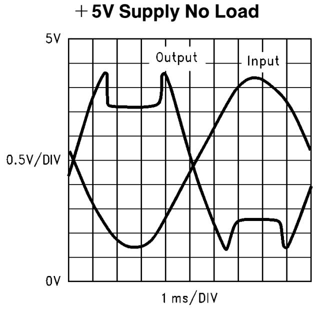

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FIGURE 4

LM6311 Maximum Undistorted Output Swing. Loads Tied to Ground. V^{+} = 5V.

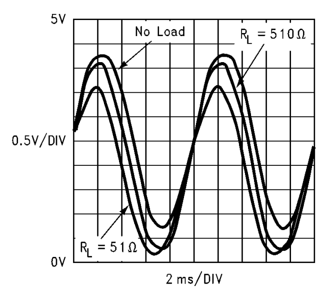

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FIGURE 5

Application Information

GENERAL INFORMATION

The LM6311 is a high speed complementary bipolar amplifier with good video performance. The LM6311 can operate on ±2.5V supplies, or from a +5V single supply.

The LM6311 is available in two package types: DIPs for through hole designs, and SO-8 surface mount packages.

Benefits of the LM6311

LOW NOISE

The low noise performance of the LM6311 (typically 2.3 nV per root-hertz) makes the LM6311 a good choice for signal recovery, high gain amplifiers other low noise designs.

BALANCED DIFFERENTIAL INPUTS

The relatively low offset currents and low offset voltage of the LM6311 make it easy to design differential signal recovery circuits. The low offset currents and voltage feedback design make it easy to use the LM6311 in conventional active filter designs.

+5V SINGLE SUPPLY OPERATION

Single supply operation can avoid the cost of split power supplies, and make it easier to use the LM6311 in single supply digital systems. The LM6311 provides high bandwidth for +5V single supply operation. See *Figure 1*.

Using the LM6311

LIMITS AND PRECAUTIONS

Supply Voltage

The absolute maximum supply voltage which may be applied to the LM6311 is 12V. Designers should not design for more than 10V nominal, and carefully check supply tolerances under all conditions so that the voltages do not exceed the maximum.

Differential Input Voltage

Differential input voltage is the difference in voltage between the non-inverting (+) input and the inverting input (−) of the op amp. The absolute maximum differential input voltage is ±10V across the inputs. This limit also applies when there is no power supplied to the op amp.

Very fast input pulses into high gain circuits may cause the output to saturate, leading to an overload recovery time in the millisecond range. This requires inputs which are faster than those usually used in video systems and gain levels which will push the output of the amplifier toward the limit of its output swing.

Layout and Power Supply Bypassing

Since the LM6311 is a high speed (over 50 MHz) device, good high speed circuit layout practices should be followed. This should include the use of ground planes, adequate power supply bypassing, removing metal from around the input pins to reduce capacitance, and careful routing of the output signal lines to keep them away from the input pins.

The power supply pins should be bypassed on both the negative and positive supply inputs with capacitors placed close to the pins. Surface mount capacitors should be used for best performance, and should be placed as close to the pins as possible. It is generally advisable to use two capacitors at each supply voltage pin. A small surface mount capacitor with a value of around 0.01 µF (10 nF), usually a ceramic type with good RF performance, should be placed closest to the pin. A larger capacitor, usually in the range of 1.0 µF to 4.7 µF, should also be placed near the pin. The larger capacitor should be a device with good RF characteristics and low ESR (equivalent series resistance) for best results. Ceramic and tantalum capacitors generally work well as the larger capacitor.

It is very important to reduce capacitance at the input and output pins. The ground plane and any other planes (power, etc.) should be "opened up" or removed near the pins. The opening should extend to the middle of the nearest pins as a minimum.

The LM6311 is built on a high performance bipolar process. The transistors used in this process have bandwidths much higher than the LM6311 itself. These transistors have a potential to oscillate or ring at 400 MHz to 1 GHz when used in layouts where the components are more than ¼ inch 6 mm) away from the op amp pins. These oscillations may produce apparent shifts in voltage offset or excess current consumption.

To avoid this, keep the input and output resistors as close as possible to their respective pins. Spacing within ⅛″ (3 mm) or less is recommended for best results.

For best performance, low inductance resistors, such as chip resistors, are recommended. The use of wirewound resistors is strongly not recommended.

DIP devices should use socket pins which are flush with the board. Conventional sockets have additional capacitance and are not recommended. Obviously, the use of wire-wrapped sockets or the "white plastic" push in prototype boards is strongly not recommended.

Notes for +5V Single Supply Operation

The LM6311 provides good high speed performance at +5V, however, certain limitations should be observed in applying the LM6311.

INPUT VOLTAGE RANGE

Input voltage should be near the center of the V^+ and V^- supplies. For 5V and ground, the inputs should be between 1.75V and 3.25V. Inputs beyond this range will limit the output swing, reduce the common mode rejection and power supply rejection, lower the bandwidth, and tend to greatly increase distortion.

For +5V designs, using a reference voltage near +2.5V is recommended. See *Figure 2*.

OUTPUT VOLTAGE SWING

Output voltage swing will depend on the load and on what voltage (ground or 2.5V) is on the other side of the load. At room temperature (25°C) and +5V supply with a 1 kΩ load tied to 2.5V, the LM6311 will swing from 1.0V to 4.0V.

For a ground referenced load, this output range will shift about 400 mV–500 mV towards ground. See *Figure 3* for schematics of loads referenced to the center and to ground.

Application Information (Continued)

If the load is too heavy (too low a resistance) for the output swing, or the output tries to go too close to either V^+ or V^- power supply rail, the output will ''foldback'' as shown in *Figure 4*. This will distort the output signal. This should be avoided. There are many ways to avoid this, such as limiting the input signal, lowering the gain of the amplifier, or using a lighter (higher resistance) load.

For designs which require low distortion, it is recommended to keep the output of the amplifier more than 300 mV away from the levels where visible distortion can be seen on an oscilloscope. For designs with wide temperature ranges which have low distortion requirements, additional margin may be required, which should be determined expermentally. See *Figure 5*. *Figure 5* was recorded when visible distortion was just visible.

External Compensation Capacitor

An external compensation capacitor of 27 pF is recommended for use with the LM6311. The capacitor should be connected between pin 5 and ground, and should be placed close to the LM6311. This capacitor increases the phase margin of the LM6311, allowing it to be used in low gain circuits, such as $A_V = +1$.

A lower value of compensation capacitor (such as 10 pF) will increase bandwidth at the expense of phase margin. This will result in more peaking and ringing with low gain circuits (A_V less than 5).

A lower value of compensation capacitor can be useful for single supply (+5V only) circuits.

Designer should avoid very low values of compensation capacitors in low gain circuits since this will reduce phase margin and may cause some circuits to oscillate.

Reflections

The output slew rate of the LM6311 is fast enough to produce reflected signals in many cables and long circuit traces. For best pulse performance, it may be necessary to terminate cables and long circuit traces with their characteristic impedance to reduce reflected signals.

Reflections should not be confused with overshoot. Reflections will depend on cable length, while overshoot will depend on load and feedback resistance and capacitance. When determining the type of problem, often removing or drastically shortening the cable will reduce or eliminate reflections. Overshoot can exist without a cable attached to the op amp output.

Other High Speed and Video Amplifiers

National Semiconductor has an extensive line of high speed amplifiers, with a range of operating voltage from 3V single supply to ±15V, and a range of package types, such as the space saving SOT23-5 TinyPaK™ (3.05 mm x 3.00 mm x 1.43 mm—about the size of a grain of rice) and a wide S0-8 for better power dissipation.

This op amp line includes—

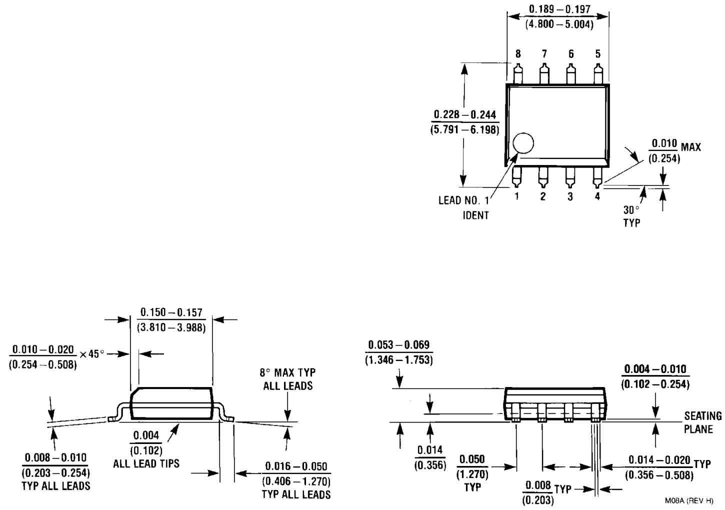
- LM6171 100 MHz Low Distortion Amplifier with > 3000 V/μs slew rate. Voltage Feedback design draws only 2.5 mA. Specified at ±15V and ±5V supplies.
- LM7131 TinyPaK (SOT23-5) Video amplifier with 70 MHz gain bandwidth. Specified at 3V, 5V and ±5V supplies.
- LM7171 200 MHz Voltage Feedback amplifier with 100 mA output current and 4000V/μs slew rate. Supply current of 6.5 mA. Specified at ±15V and ±5V.

Information on these parts is available from your National Semiconductor representative.

SPICE Macromodel

A SPICE macromodel of the LM6311 and many other National Semiconductor op amps is available at no charge from your National Semiconductor representative.

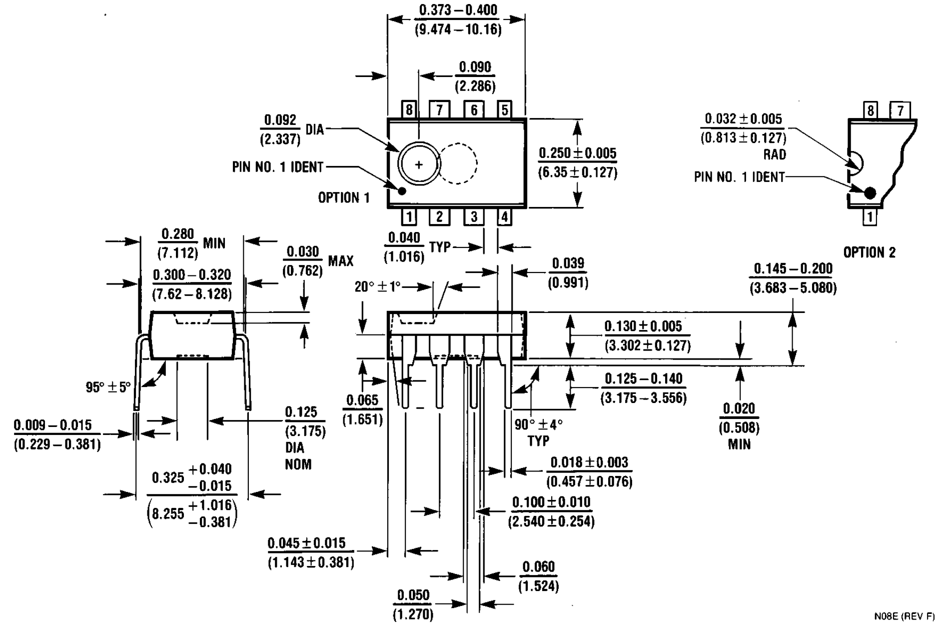
Physical Dimensions inches (millimeters) unless otherwise noted



8-Pin Small Outline Package
Order Number LM6311IM or LM6311MX
NS Package Number M08A

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

Lit. # 108288-001



8-Pin Molded DIP Package
Order Number LM6311IN
NS Package Number N08E

LIFE SUPPORT POLICY

NATIONAL'S PRODUCTS ARE NOT AUTHORIZED FOR USE AS CRITICAL COMPONENTS IN LIFE SUPPORT DEVICES OR SYSTEMS WITHOUT THE EXPRESS WRITTEN APPROVAL OF THE PRESIDENT OF NATIONAL SEMICONDUCTOR CORPORATION. As used herein:

1. Life support devices or systems are devices or systems which, (a) are intended for surgical implant into the body, or (b) support or sustain life, and whose failure to perform, when properly used in accordance with instructions for use provided in the labeling, can be reasonably expected to result in a significant injury to the user.
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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