

May 1999

LM6164/LM6264/LM6364 High Speed Operational Amplifier

General Description

The LM6164 family of high-speed amplifiers exhibits an excellent speed-power product in delivering 300V per µs and 175 MHz GBW (stable down to gains as low as +5) 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 produces fast PNP 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 GBW product: 175 MHz
 Low supply current: 5 mA
 Fast settling: 100 ns to 0.1%

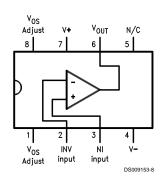
■ Low differential gain: <0.1%
■ Low differential phase: <0.1°
■ Wide supply range: 4.75V to 32V

■ Stable with unlimited capacitive load

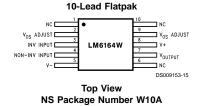
Applications

- Video amplifier
- Wide-bandwidth signal conditioning
- Radar
- Sonar

Connection Diagrams



NS Package Number J08A, M08A or N08E



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Connection Diagrams (Continued)

	Temperature Range	Package	NSC	
Military	Industrial	Commercial		Drawing
-55°C ≤ T _A ≤ +125°C	-25°C ≤ T _A ≤ +85°C	0° C \leq T _A \leq +70 $^{\circ}$ C		
	LM6264N	LM6364N	8-Pin Molded DIP	N08E
LM6164J/883			8-Pin Ceramic DIP	J08A
5962-8962401PA				
		LM6364M	8-Pin Molded Surface Mt.	M08A
LM6164WG/883			10-Lead Ceramic SOIC	WG10A
5962-8962401XA				
LM6164W/883			10-Pin	W10A
5962-8962401HA			Ceramic Flatpak	

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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 7) ±8V

Common-Mode Input Voltage

 $(V^+ - 0.7V)$ to $(V^- + 0.7V)$ (Note 11)

Output Short Circuit to Gnd

(Note 2) Continuous

Soldering Information

Dual-In-Line Package (N, J) 260°C Soldering (10 sec.)

Small Outline Package (M)

215°C Vapor Phase (60 sec.) Infrared (15 sec.) 220°C

Max Junction Temperature

on Product Reliability" for other methods of soldering surface mount devices. Storage Temperature Range

See AN-450 "Surface Mounting Methods and Their Effect

150°C (Note 3) ±700V

ESD Tolerance (Notes 7, 8)

Operating Ratings

Temperature Range (Note 3)

LM6164 $-55^{\circ}\text{C} \le \text{T}_{\text{J}} \le +125^{\circ}\text{C}$ LM6264 $-25^{\circ}\text{C} \le \text{T}_{\text{J}} \le +85^{\circ}\text{C}$ $0^{\circ}\text{C} \leq \text{T}_{\text{J}} \leq +70^{\circ}\text{C}$ LM6364

Supply Voltage Range 4.75V to 32V

Note 1: "Absolute Maximum Ratings" indicate limits beyond which damage to the device may occur. Operating Ratings indicate conditions for which the device is functional, but do not guarantee specific performance limits.

DC Electrical Characteristics

The following specifications apply for Supply Voltage = ± 15 V, V_{CM} = 0, R_L $\geq 100~k\Omega$ and R_S = 50Ω unless otherwise noted. **Boldface** limits apply for T_A = T_J = T_{MIN} to T_{MAX}; all other limits T_A = T_J = 25°C.

				LM6164	LM6264	LM6364	
Symbol	Parameter	Conditions	Тур	Limit	Limit	Limit	Units
				(Notes 4, 12)	(Note 4)	(Note 4)	
Vos	Input Offset Voltage		2	4	4	9	mV
				6	6	11	max
Vos	Input Offset Voltage		6				μV/°C
Drift	Average Drift						
I _b	Input Bias Current		2.5	3	3	5	μA
				6	5	6	max
Ios	Input Offset Current		150	350	350	1500	nA
				800	600	1900	max
Ios	Input Offset Current		0.3				nA/°C
Drift	Average Drift						
R _{IN}	Input Resistance	Differential	100				kΩ
C _{IN}	Input Capacitance		3.0				pF
A _{VOL}	Large Signal	$V_{OUT} = \pm 10V, R_L = 2 k\Omega$	2.5	1.8	1.8	1.3	V/mV
	Voltage Gain	(Note 10)		0.9	1.2	1.1	min
		$R_L = 10 \text{ k}\Omega$	9				1
V _{CM}	Input Common-Mode	Supply = ±15V	+14.0	+13.9	+13.9	+13.8	V
	Voltage Range			+13.8	+13.8	+13.7	min
			-13.5	-13.3	-13.3	-13.2	V
				-13.1	-13.1	-13.1	min
		Supply = +5V	4.0	3.9	3.9	3.8	V
		(Note 5)		3.8	3.8	3.7	min
			1.5	1.7	1.7	1.8	V
				1.9	1.9	1.9	max
CMRR	Common-Mode	-10V ≤ V _{CM} ≤ +10V	105	86	86	80	dB
	Rejection Ratio			80	82	78	min
PSRR	Power Supply	±10V ≤ V± ≤ ±16V	96	86	86	80	dB
	Rejection Ratio			80	82	78	min

DC Electrical Characteristics (Continued)

The following specifications apply for Supply Voltage = ± 15 V, V_{CM} = 0, $R_L \ge 100~k\Omega$ and $R_S = 50\Omega$ unless otherwise noted. **Boldface** limits apply for $T_A = T_J = T_{MIN}$ to T_{MAX} ; all other limits $T_A = T_J = 25$ °C.

				LM6164	LM6264	LM6364	
Symbol	Parameter	Conditions	Тур	Limit	Limit	Limit	Units
				(Notes 4, 12)	(Note 4)	(Note 4)	
Vo	Output Voltage	Supply = +5V	+14.2	+13.5	+13.5	+13.4	V
	Swing	and $R_L = 2 k\Omega$		+13.3	+13.3	+13.3	min
			-13.4	-13.0	-13.0	-12.9	V
				-12.7	-12.8	-12.8	min
		Supply = +5V	4.2	3.5	3.5	3.4	V
		and $R_L = 2 k\Omega$		3.3	3.3	3.3	min
		(Note 10)	1.3	1.7	1.7	1.8	V
				2.0	1.9	1.9	max
	Output Short	Source	65	30	30	30	mA
	Circuit Current			20	25	25	min
		Sink	65	30	30	30	mA
				20	25	25	min
Is	Supply Current		5.0	6.5	6.5	6.8	mA
				6.8	6.7	6.9	min

AC Electrical Characteristics

The following specifications apply for Supply Voltage = ± 15 V, V_{CM} = 0, $R_L \ge 100$ k Ω and R_S = 50Ω unless otherwise noted. **Boldface** limits apply for $T_A = T_J = T_{MIN}$ to T_{MAX} ; all other limits $T_A = T_J = 25$ °C.

				LM6164	LM6264	LM6364	
Symbol	Parameter	Conditions	Тур	Limit	Limit	Limit	Units
				(Notes 4, 12)	(Note 4)	(Note 4)	
GBW	Gain-Bandwidth	F = 20 MHz	175	140	140	120	MHz
	Product			100	120	100	min
		Supply = ±5V	120				
SR	Slew Rate	$A_{V} = +5 \text{ (Note 9)}$	300	200	200	200	V/µs
				180	180	180	min
		Supply = ±5V	200				
PBW	Power Bandwidth	V _{OUT} = 20 V _{PP}	4.5				MHz
T _s	Settling Time	10V Step to 0.1%	100				ns
		$A_V = -4$, $R_L = 2 k\Omega$					
φ _m	Phase Margin	A _V = +5	45				Deg
A _D	Differential Gain	NTSC, A _V = +10	<0.1				%
φ _D	Differential Phase	NTSC, A _V = +10	<0.1				Deg
e _{np-p}	Input Noise	F = 10 kHz	8				nV/√Hz
	Voltage						,
i _{np-p}	Input Noise	F = 10 kHz	1.5				pA/√Hz
	Current						

Note 2: Continuous short-circuit operation at elevated ambient temperature can result in exceeding the maximum allowed junction temperature of 150°C.

Note 3: The typical junction-to-ambient thermal resistance of the molded plastic DIP (N) is 105°C/Watt, the molded plastic SO (M) package is 155°C/Watt, and the cerdip (J) package is 125°C/Watt. All numbers apply for packages soldered directly into a printed circuit board.

Note 4: Limits are guaranteed by testing or correlation.

Note 5: For single supply operation, the following conditions apply: V⁺ = 5V, V⁻ = 0V, V_{CM} = 2.5V, V_{OUT} = 2.5V. Pin 1 & Pin 8 (V_{OS} Adjust) are each connected to Pin 4 (V⁻) to realize maximum output swing. This connection will degrade V_{OS}.

Note 6: $C_L \le 5 \text{ pF}.$

Note 7: In order to achieve optimum AC performance, the input stage was designed without protective clamps. Exceeding the maximum differential input voltage results in reverse breakdown of the base-emitter junction of one of the input transistors and probable degradation of the input parameters (especially V_{OS}, I_{OS}, and Noise).

Note 8: The average voltage that the weakest pin combinations (those involving Pin 2 or Pin 3) can withstand and still conform to the datasheet limits. The test circuit used consists of the human body model of 100 pF in series with 1500Ω.

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AC Electrical Characteristics (Continued)

Note 9: V_{IN} = 4V step. For supply = ±5V, V_{IN} = 1V step.

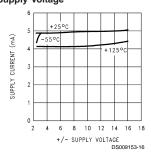
Note 10: Voltage Gain is the total output swing (20V) divided by the input signal required to produce that swing.

Note 11: The voltage between V^+ and either input pin must not exceed 36V.

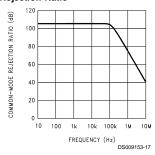
Note 12: A military RETS electrical test specification is available on request. At the time of printing, the LM6164J/883 RETS spec complied with the Boldface limits in this column. The LM6164J/883 may also be procured as Standard Military Drawing #5962-8962401PA.

Typical Performance Characteristics (R_L = 10 kΩ, T_A = 25°C unless otherwise specified)

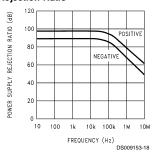
Supply Current vs Supply Voltage



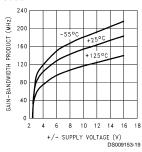
Common-Mode Rejection Ratio



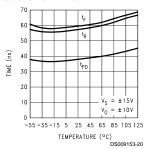
Power Supply Rejection Ratio



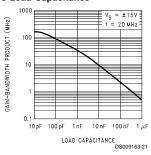
Gain-Bandwidth Product



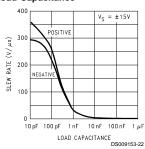
Propagation Delay Rise and Fall Time



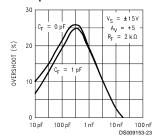
Gain-Bandwidth Product vs Load Capacitance



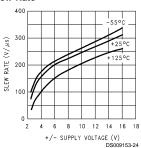
Slew Rate vs Load Capacitance



Overshoot vs Load Capacitance



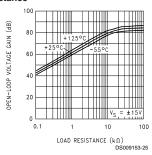
Slew Rate



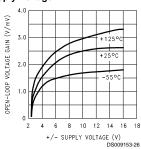
Typical Performance Characteristics (R_L = 10 k Ω , T_A = 25°C unless otherwise

specified) (Continued)

Voltage Gain vs Load Resistance

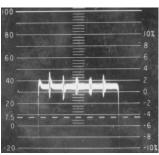


Gain vs Supply Voltage



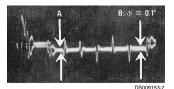
Differential Gain

(Note 13)



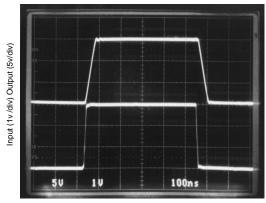
Differential Phase

(Note 13)



Note 13: Differential gain and differential phase measured for four series LM6364 op amps in series with an LM6321 buffer. Error added by LM6321 is negligible. Test performed using Tektronix Type 520 NTSC test system. Configured with a gain of +5 (each output attenuated by 80%)

Step Response; Av = +5



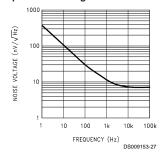
TIME (50 ns /div)

DS009153-1

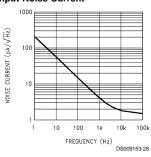
Typical Performance Characteristics (R_L = 10 $k\Omega$, T_A = 25°C unless otherwise

specified) (Continued)

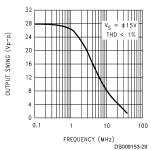
Input Noise Voltage



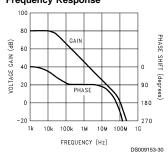
Input Noise Current



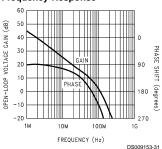
Power Bandwidth



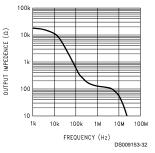
Open-Loop Frequency Response



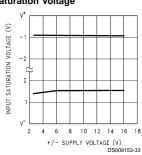
Open-Loop Frequency Response



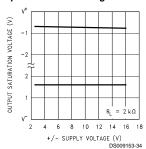
Output Resistance Open-Loop



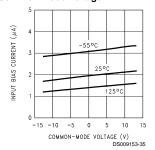
Common-Mode Input Saturation Voltage



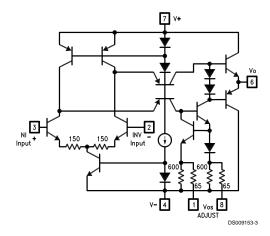
Output Saturation Voltage



Bias Current vs Common-Mode Voltage



Simplified Schematic



Applications Tips

The LM6364 has been compensated for gains of 5 or greater (over specified ranges of temperature, power supply voltage, and load). Since this compensation involved adding emitter-degeneration resistors in the op amp's input stage, the open-loop gain was reduced as the stability increased. Gain error due to reduced $A_{\rm VOL}$ is most apparent at high gains; thus, the uncompensated LM6365 is appropriate for gains of 25 or more. If unity-gain operation is desired, the LM6361 should be used. The LM6361, LM6364, and LM6365 have the same high slew rate (typically 300 V/µs), regardless of their compensation.

The LM6364 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 LM6364 effectively increases its compensation capacitance, thus slowing the op amp's response and reducing its bandwidth. The compensation is not ideal, though, and ringing or oscillation may occur in low-gain circuits with large capacitive loads. To overcompensate the LM6364 for operation at gains less than 5, a series resistor-capacitor network should be added between the input pins (as shown in the Typical Applications, Noise Gain Compensation) so that the high-frequency noise gain rises to at least 5

Power supply bypassing will improve the stability and transient response of the LM6364, 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 (tantalum) may be required for extra noise reduction.

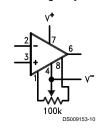
Keep all leads short to reduce stray capacitance and lead inductance, and make sure ground paths are low-impedance, especially where heavier currents will be flowing. Stray capacitance in the circuit layout can cause signal coupling between adjacent nodes, so that circuit gain unintentionally varies 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 performance.

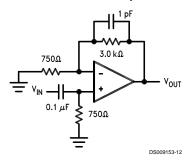
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Typical Applications

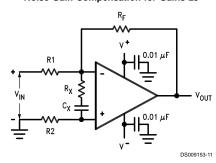
Offset Voltage Adjustment



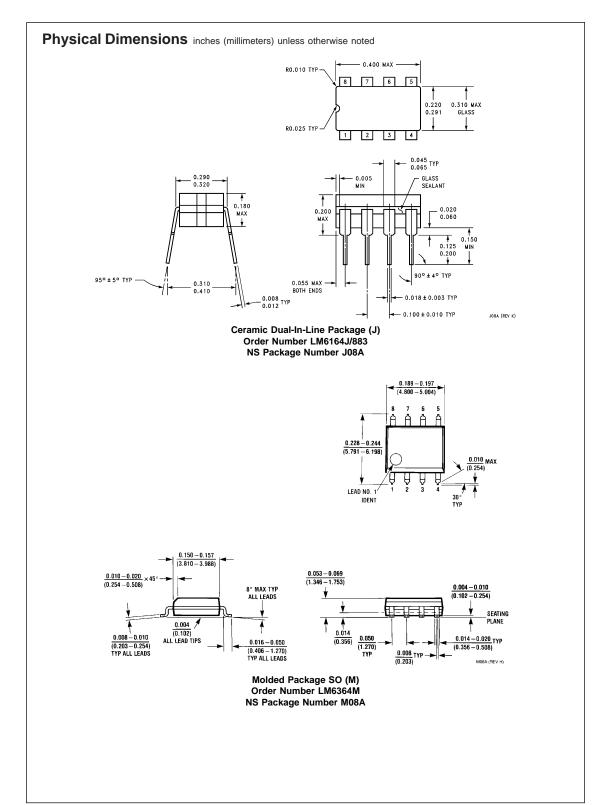
Video-Bandwidth Amplifier

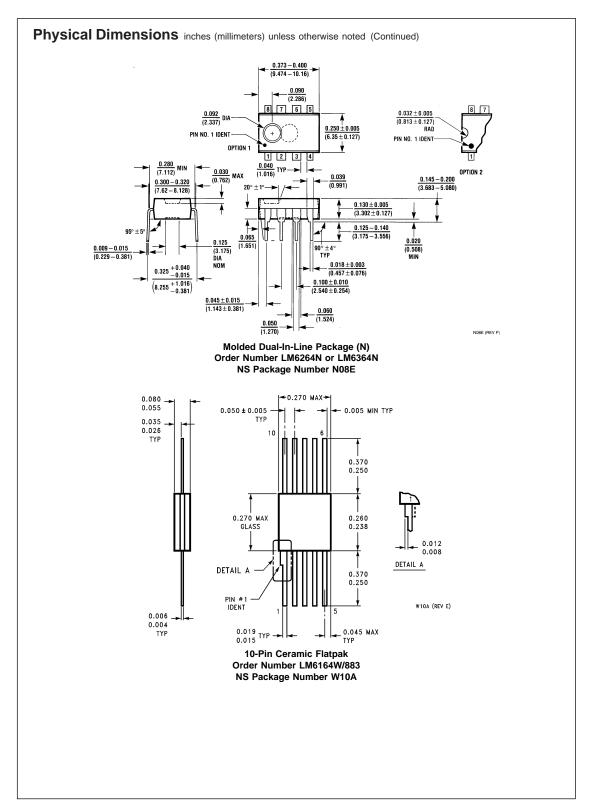


Noise-Gain Compensation for Gains ≤ 5



 $\begin{aligned} R_X C_X &\geq (2\pi \bullet 25 \text{ MHz})^{-1} \\ 5 \ R_X &= R_1 + R_F (1 + R_1/R_2) \end{aligned}$





Notes

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- 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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