

LMH6609

LMH6609 900MHz Voltage Feedback Op Amp



Literature Number: SNOSA84E

LMH6609

900MHz Voltage Feedback Op Amp

General Description

The LMH6609 is an ultra wideband, unity gain stable, low power, voltage feedback op amp that offers 900MHz bandwidth at a gain of 1, 1400V/μs slew rate and 90mA of linear output current.

The LMH6609 is designed with voltage feedback architecture for maximum flexibility especially for active filters and integrators. The LMH6609 has balanced, symmetrical inputs with well-matched bias currents and minimal offset voltage.

With Differential Gain of 0.01% and Differential Phase of 0.026° the LMH6609 is suited for video applications. The 90-mA of linear output current makes the LMH6609 suitable for multiple video loads and cable driving applications as well.

The supply voltage is specified at 6.6V and 10V. A low supply current of 7mA (at 10V supply) makes the LMH6609 useful in a wide variety of platforms, including portable or remote equipment that must run from battery power.

The LMH6609 is available in the industry standard 8-pin SOIC package and in the space-saving 5-pin SOT package. The LMH6609 is specified for operation over the -40°C to +85°C temperature range. The LMH6609 is manufactured in National Semiconductor's state-of-the-art VIP10™ technology for high performance.

Features

- 900MHz -3dB bandwidth ($A_V = 1$)
- Large signal bandwidth and slew rate 100% tested
- 280MHz -3dB bandwidth ($A_V = +2$, $V_{OUT} = 2V_{PP}$)
- 90mA linear output current
- 1400V/μs slew rate
- Unity gain stable
- <1mV input Offset voltage
- 7mA Supply current (no load)
- 6.6V to 12V supply voltage range
- 0.01%/0.026° differential gain/phase PAL
- 3.1nV/√Hz voltage noise
- Improved replacement for CLC440, 420, 426

Applications

- Test equipment
- IF/RF amplifier
- A/D Input driver
- Active filter
- Integrator
- DAC output buffer
- Transimpedance amplifier

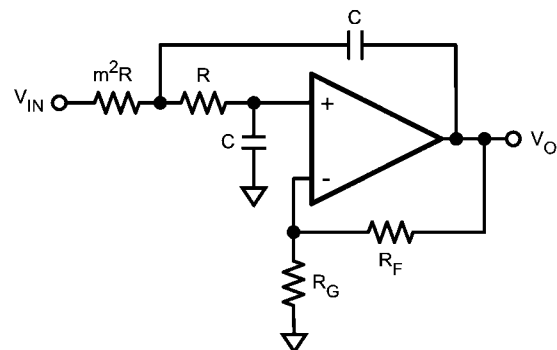
Typical Application

$$K = 1 + \frac{R_F}{R_G} \quad Q = \frac{m}{1 + m^2(2 - K)} \quad \omega_0 = \frac{1}{mRC}$$

Q, K ARE UNITLESS.

ω_0 IS RELATED TO BANDWIDTH AND IS IN UNITS OF RADIANS/SEC. DIVIDE ω_0 BY 2π TO GET IT IN Hz. REFER TO OA-26 FOR MORE INFORMATION.

20079037



20079038

Sallen Key Low Pass Filter with Equal C Values

Absolute Maximum Ratings (Note 1)

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

V_S (V^+ - V^-)	$\pm 6.6V$
I_{OUT}	(Note 3)
Common Mode Input Voltage	V^+ to V^-
Maximum Junction Temperature	$+150^\circ C$
Storage Temperature Range	$-65^\circ C$ to $+150^\circ C$
Lead Temperature Range	$+300^\circ C$
ESD Tolerance (Note 4)	
Human Body Model	2000V
Machine Model	200V

Operating Ratings (Note 3)

Thermal Resistance		
Package	(θ_{JC})	(θ_{JA})
8-Pin SOIC	$65^\circ C/W$	$145^\circ C/W$
5-Pin SOT23	$120^\circ C/W$	$187^\circ C/W$
Operating Temperature	$-40^\circ C$	$+85^\circ C$
Nominal Supply Voltage (Note 6)	$\pm 3.3V$	$\pm 6V$

 $\pm 5V$ Electrical Characteristics

Unless specified, $A_V = +2$, $R_F = 250\Omega$; $V_S = \pm 5V$, $R_L = 100\Omega$; unless otherwise specified. **Boldface** limits apply over temperature Range. (Note 2)

Symbol	Parameter	Conditions	Min	Typ	Max	Units
Frequency Domain Response						
SSBW	-3dB Bandwidth	$V_{OUT} = 0.5V_{PP}$		260		MHz
LSBW	-3dB Bandwidth	$V_{OUT} = 4.0V_{PP}$	150	170		MHz
SSBWG1	-3dB Bandwidth $A_V = 1$	$V_{OUT} = 0.25V_{PP}$		900		MHz
GFP	.1dB Bandwidth	Gain is Flat to .1dB		130		MHz
DG	Differential Gain	$R_L = 150\Omega$, 4.43MHz		0.01		%
DP	Differential Phase	$R_L = 150\Omega$, 4.43MHz		0.026		deg
Time Domain Response						
TRS	Rise and Fall Time	1V Step		1.6		ns
TRL		4V Step		2.6		ns
t_s	Settling Time to 0.05%	2V Step		15		ns
SR	Slew Rate	4V Step (Note 5)	1200	1400		V/ μs
Distortion and Noise Response						
HD2	2 nd Harmonic Distortion	$2V_{PP}$, 20MHz		-63		dBc
HD3	3 rd Harmonic Distortion	$2V_{PP}$, 20MHz		-57		dBc
	Equivalent Input Noise					
VN	Voltage Noise	$>1MHz$		3.1		nV/ $\sqrt{Hz}$
CN	Current Noise	$>1MHz$		1.6		pA/ $\sqrt{Hz}$
Static, DC Performance						
V_{IO}	Input Offset Voltage			± 0.8	± 2.5 ± 3.5	mV
	Input Voltage Temperature Drift			4		$\mu V/^\circ C$
I_{BN}	Input Bias Current			-2	± 5 ± 8	μA
	Bias Current Temperature Drift			11		nA/ $^\circ C$
I_{BI}	Input Offset Current			.1	± 1.5 ± 3	μA
PSRR	Power Supply Rejection Ratio	DC, 1V Step	67 65	73		dB
CMRR	Common Mode Rejection Ratio	DC, 2V Step	67 65	73		dB
I_{CC}	Supply Current	$R_L = \infty$		7.0	7.8 8.5	mA

Symbol	Parameter	Conditions	Min	Typ	Max	Units
Miscellaneous Performance						
R_{IN}	Input Resistance			1		M Ω
C_{IN}	Input Capacitance			1.2		pF
R_{OUT}	Output Resistance	Closed Loop		0.3		Ω
V_O	Output Voltage Range	$R_L = \infty$	± 3.6 ± 3.3	± 3.9		V
V_{OL}		$R_L = 100\Omega$	± 3.2 ± 3.0	± 3.5		V
CMIR	Input Voltage Range	Common Mode, CMRR > 60dB	± 2.8 ± 2.5	± 3.0		V
I_O	Linear Output Current	V_{OUT}	± 60 ± 50	± 90		mA

$\pm 3.3V$ Electrical Characteristics

Unless specified, $A_V = +2$, $R_F = 250\Omega$; $V_S = \pm 3.3V$, $R_L = 100\Omega$; unless otherwise specified. **Boldface** limits apply over temperature Range. (*Note 2*)

Symbol	Parameter	Conditions	Min	Typ	Max	Units
Frequency Domain Response						
SSBW	–3dB Bandwidth	$V_{OUT} = 0.5V_{PP}$		180		MHz
LSBW	–3dB Bandwidth	$V_{OUT} = 3.0V_{PP}$		110		MHz
SSBWG1	–3dB Bandwidth $A_V = 1$	$V_{OUT} = 0.25V_{PP}$		450		MHz
GFP	.1dB Bandwidth	$V_{OUT} = 1V_{PP}$		40		MHz
DG	Differential Gain	$R_L = 150\Omega$, 4.43MHz		.01		%
DP	Differential Phase	$R_L = 150\Omega$, 4.43MHz		.06		deg
Time Domain Response						
TRL		1V Step		2.2		ns
SR	Slew Rate	2V Step (<i>Note 5</i>)		800		V/ μ s
Distortion and Noise Response						
HD2	2 nd Harmonic Distortion	$2V_{PP}$, 20MHz		–63		dBc
HD3	3 rd Harmonic Distortion	$2V_{PP}$, 20MHz		–43		dBc
	Equivalent Input Noise					
VN	Voltage Noise	>1MHz		3.7		nV/ $\sqrt{Hz}$
CN	Current Noise	>1MHz		1.1		pA/ $\sqrt{Hz}$
Static, DC Performance						
V_{IO}	Input Offset Voltage			0.8	± 2.5 ± 3.5	mV
I_{BN}	Input Bias Current			–1	± 3 ± 6	μ A
I_{BI}	Input Offset Current			0	± 1.5 ± 3	μ A
PSRR	Power Supply Rejection Ratio	DC, .5V Step	67	73		dB
CMRR	Common Mode Rejection Ratio	DC, 1V Step	67	75		dB
I_{CC}	Supply Current	$R_L = \infty$		3.6	5 6	mA
Miscellaneous Performance						
R_{OUT}	Input Resistance	Close Loop		.05		Ω
V_O	Output Voltage Range	$R_L = \infty$	± 2.1	± 2.3		V
V_{OL}		$R_L = 100\Omega$	± 1.9	± 2.0		V

Symbol	Parameter	Conditions	Min	Typ	Max	Units
CMIR	Input Voltage Range	Common Mode		± 1.3		V
I_O	Linear Output Current	V_{OUT}	± 30	± 45		mA

Note 1: Absolute Maximum Ratings indicate limits beyond which damage to the device may occur. Operating Ratings indicate conditions for which the device is intended to be functional, but specific performance is not guaranteed. For guaranteed specifications, see the Electrical Characteristics tables.

Note 2: Electrical Table values apply only for factory testing conditions at the temperature indicated. Factory testing conditions result in very limited self-heating of the device such that $T_J = T_A$. No guarantee of parametric performance is indicated in the electrical tables under conditions of internal self heating where $T_J > T_A$. See Applications Section for information on temperature derating of this device. Min/Max ratings are based on product characterization and simulation. Individual parameters are tested as noted.

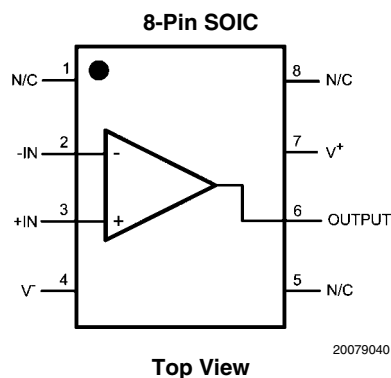
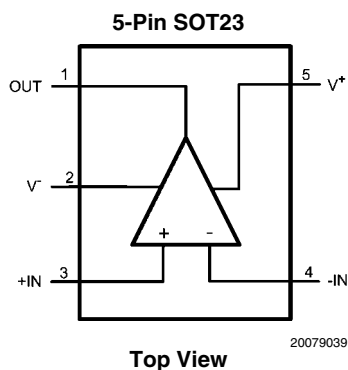
Note 3: The maximum output current (I_{OUT}) is determined by device power dissipation limitations. See the Power Dissipation section of the Application Section for more details.

Note 4: Human body model, 1.5k Ω in series with 100pF. Machine model, 0 Ω in series with 200pF.

Note 5: rate is Average of Rising and Falling 40-60% slew rates.

Note 6: Nominal Supply voltage range is for supplies with regulation of 10% or better.

Connection Diagrams



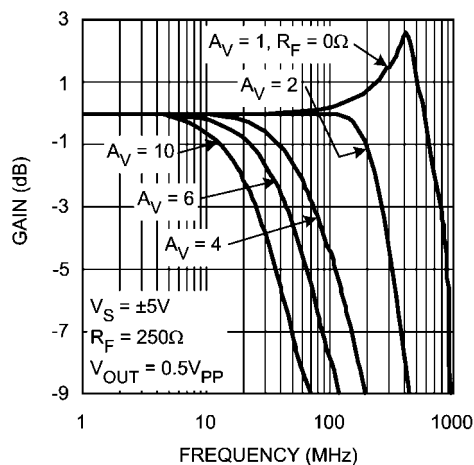
Ordering Information

Package	Part Number	Package Marking	Transport Media	NSC Drawing
8-Pin SOIC	LMH6609MA	LMH6609MA	95 Units/Rails	M08A
	LMH6609MAX		2.5k Units Tape and Reel	
5-SOT23	LMH6609MF	A89A	1k Units Tape and Reel	MF05A
	LMH6609MFX		2.5k Units Tape and Reel	

Typical Performance Characteristics

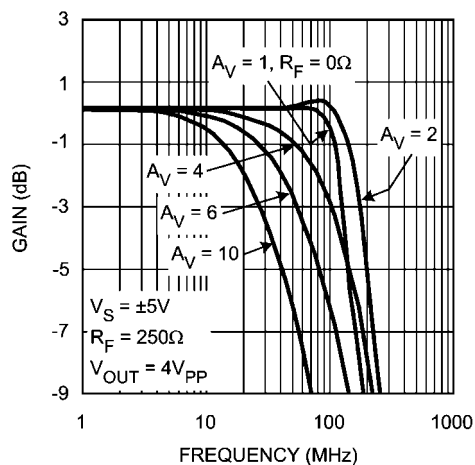
LMH6609

Small Signal Non-Inverting Frequency Response



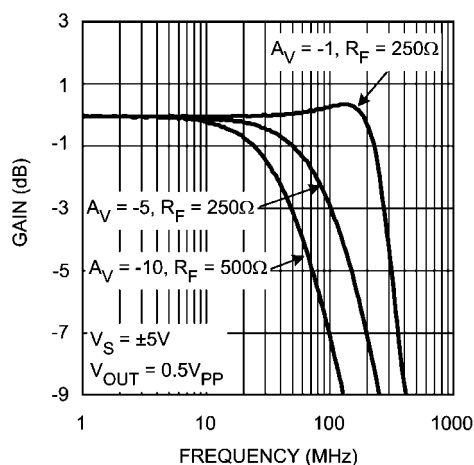
20079004

Large Signal Non-Inverting Frequency Response



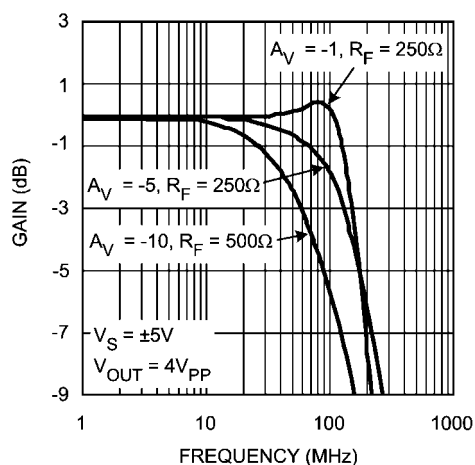
20079003

Small Signal Inverting Frequency Response



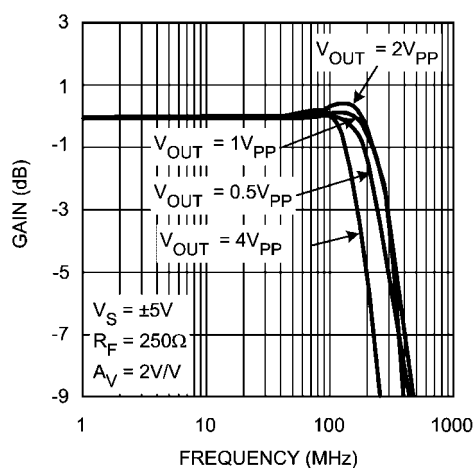
20079002

Large Signal Inverting Frequency Response



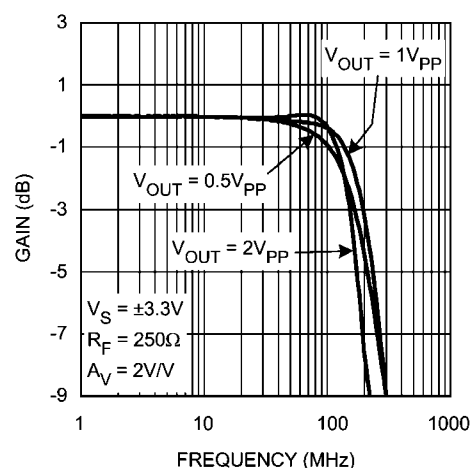
20079010

Frequency Response vs. V_{OUT} $A_V = 2$

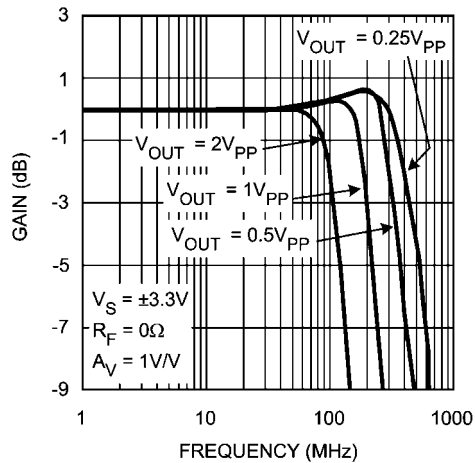


20079009

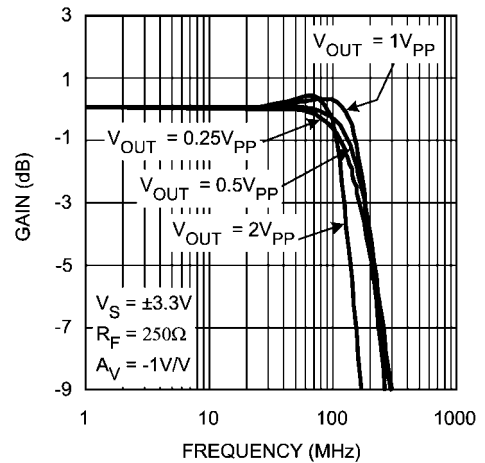
Frequency Response vs. V_{OUT} $A_V = 2$



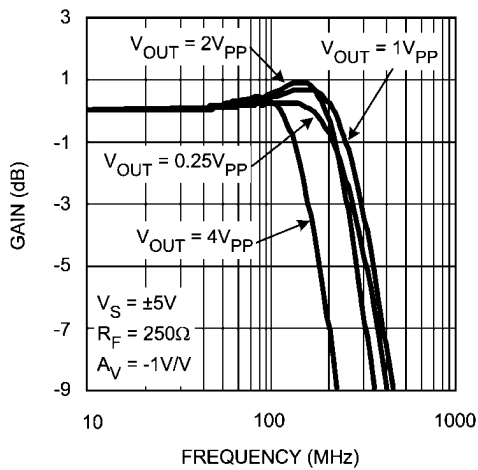
20079001

Frequency Response vs. V_{OUT} $A_V = 1$ 

20079007

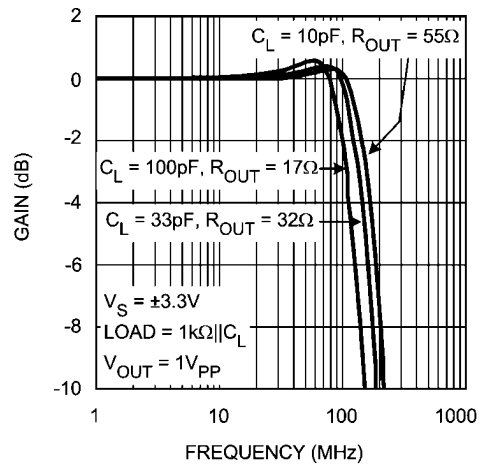
Frequency Response vs. V_{OUT} $A_V = -1$ 

20079008

Frequency Response vs. V_{OUT} $A_V = -1$ 

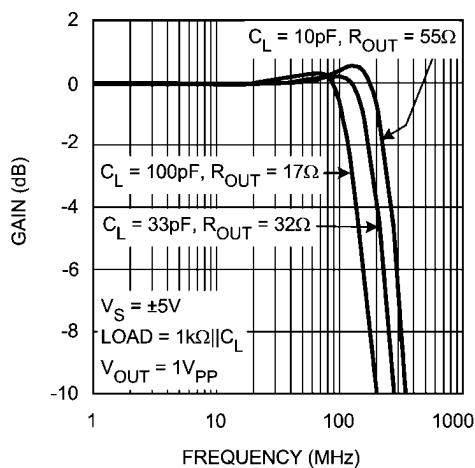
20079006

Frequency Response vs. Cap Load

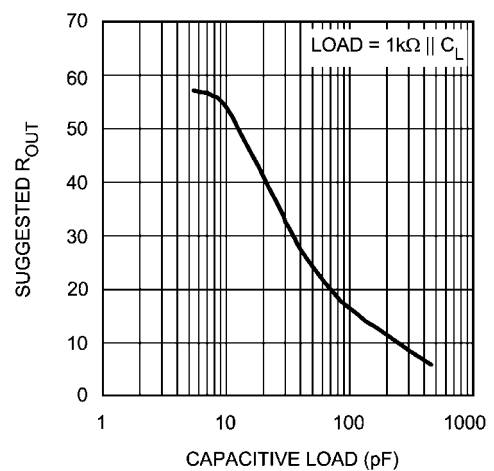


20079042

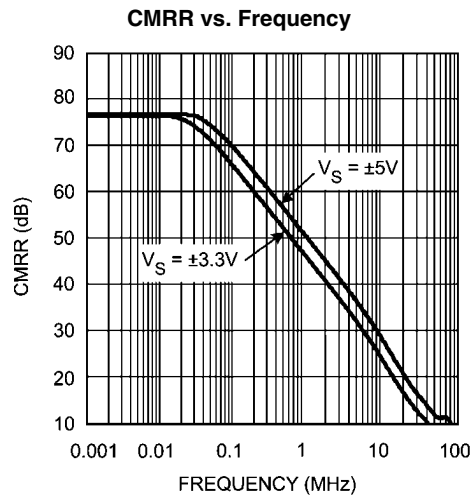
Frequency Response vs. Cap Load



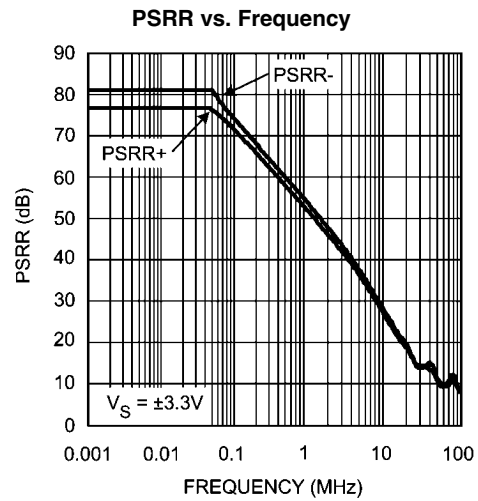
20079043

Suggested R_{OUT} vs. Cap Load

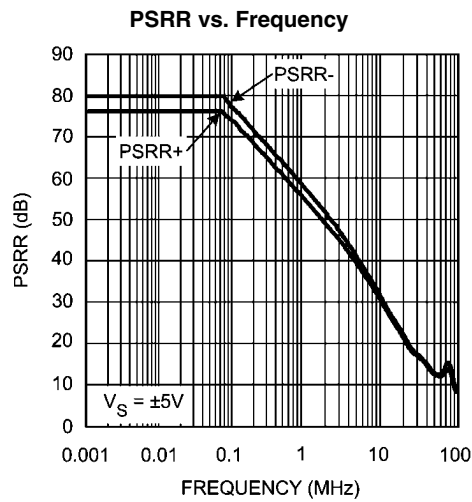
20079041



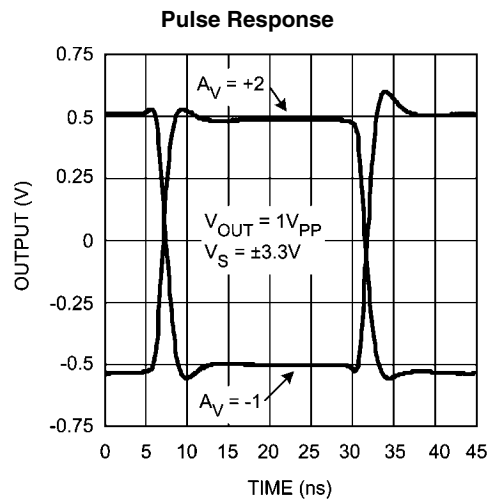
20079011



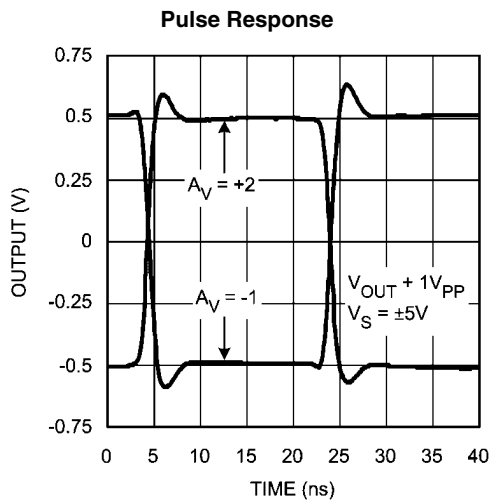
20079012



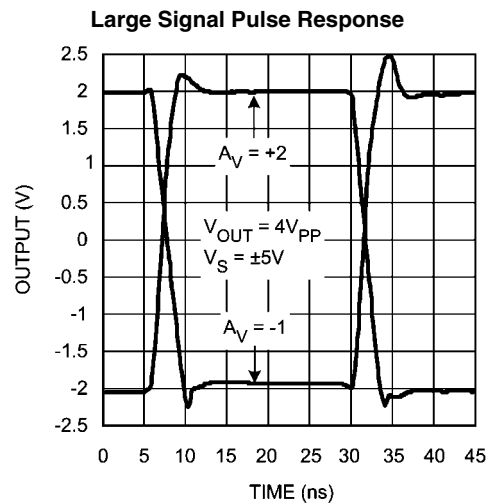
20079013



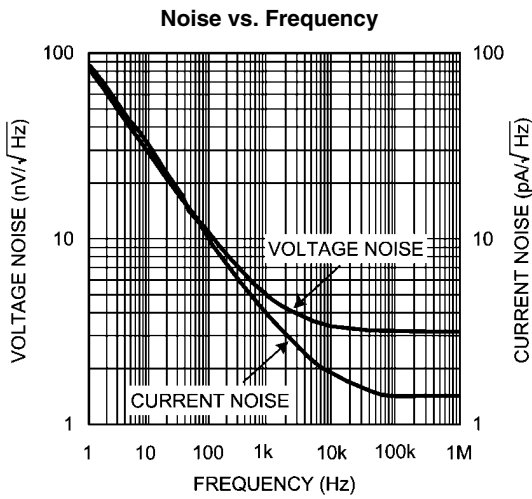
20079016



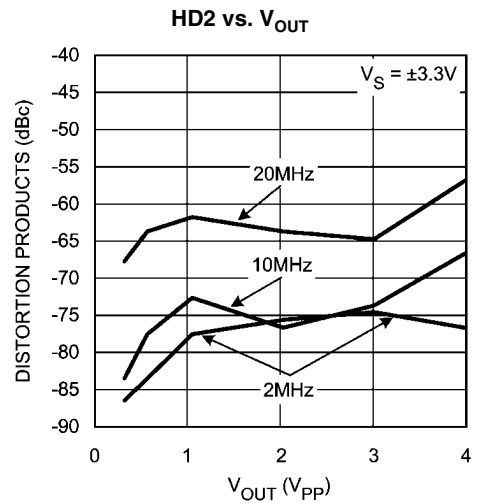
20079014



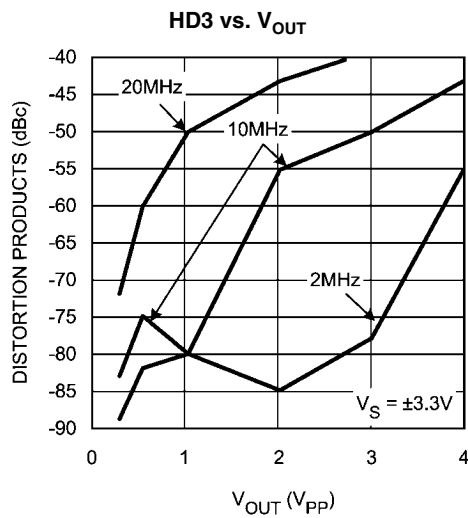
20079015



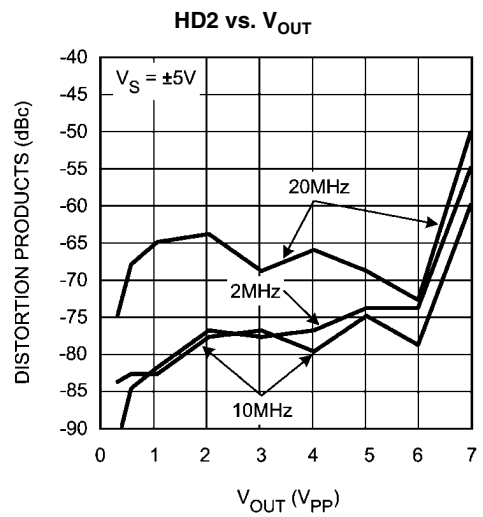
20079025



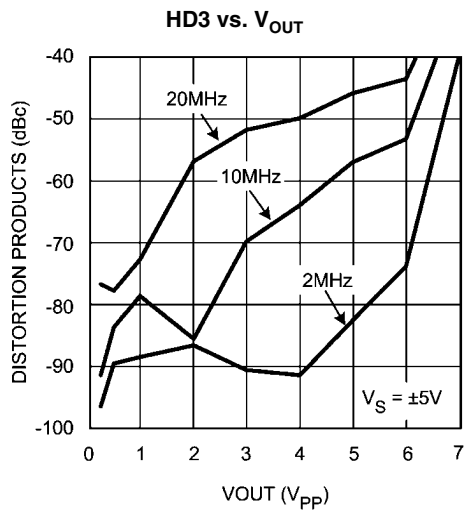
20079018



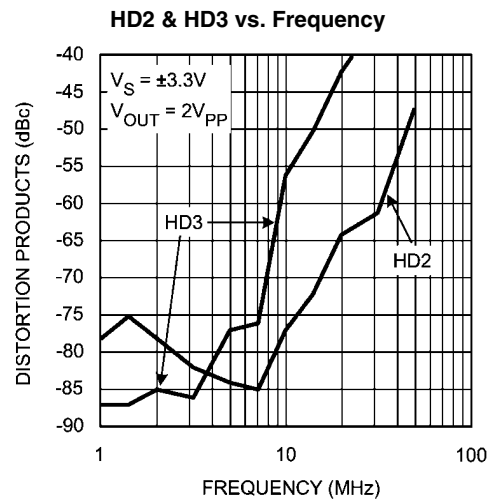
20079017



20079020

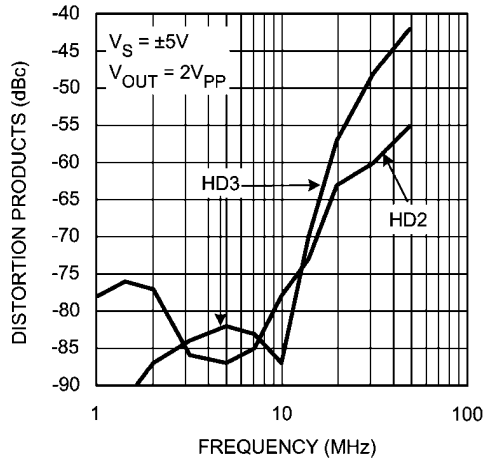


20079019



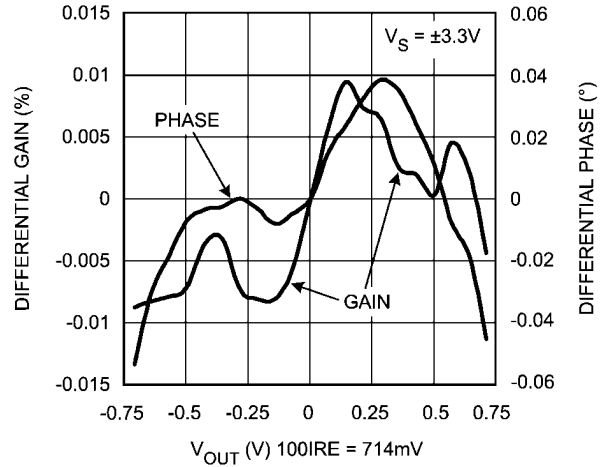
20079021

HD2 & HD3 vs. Frequency



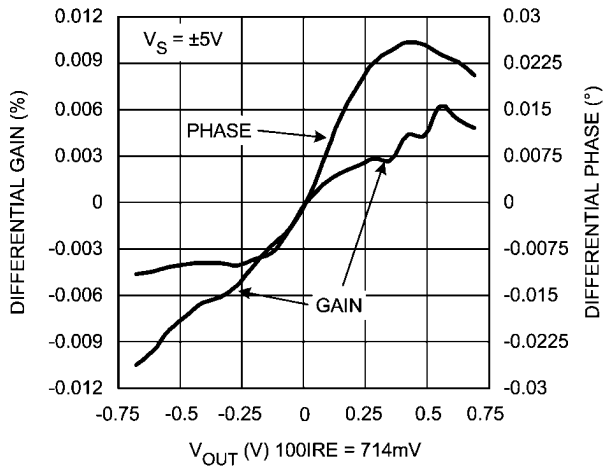
20079022

Differential Gain & Phase



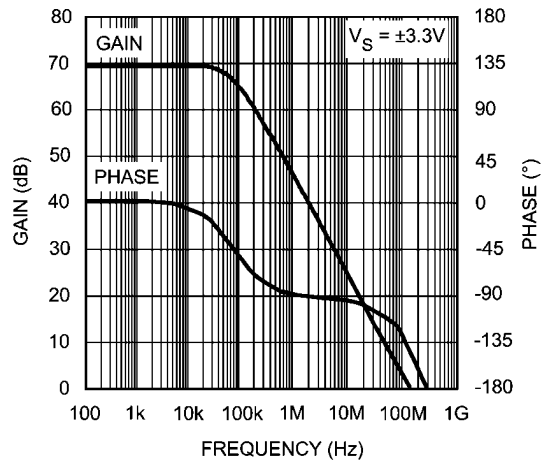
20079046

Differential Gain & Phase



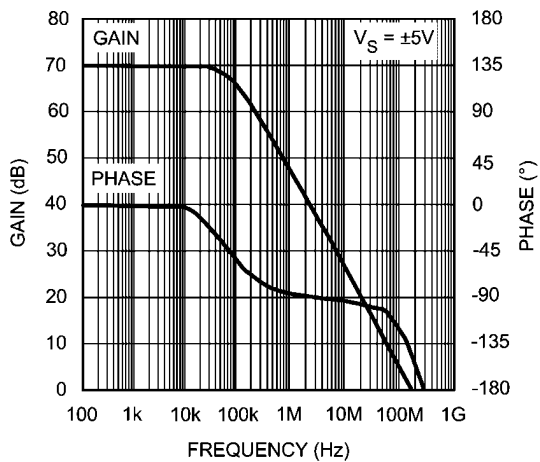
20079047

Open Loop Gain & Phase



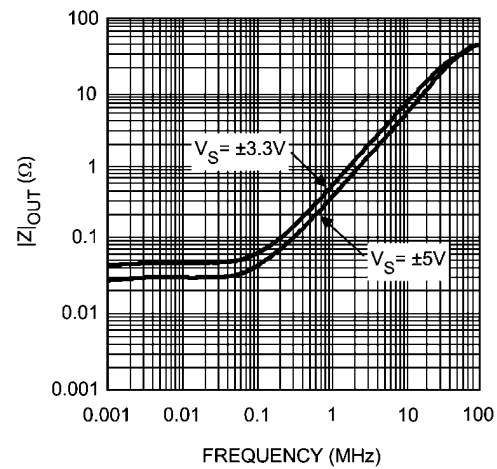
20079044

Open Loop Gain & Phase



20079045

Closed Loop Output Resistance



20079023

Application Section

GENERAL DESIGN EQUATION

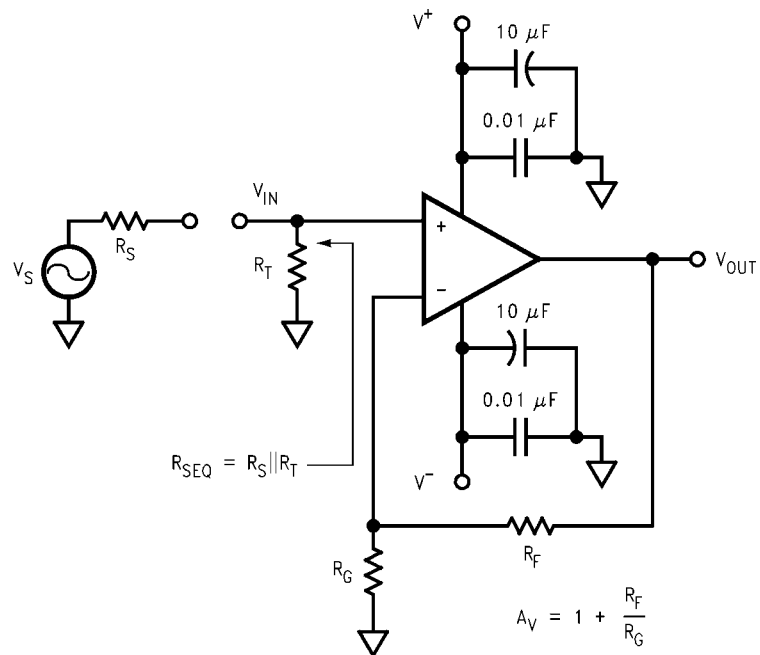
The LMH6609 is a unity gain stable voltage feedback amplifier. The matched input bias currents track well over temperature. This allows the DC offset to be minimized by matching the impedance seen by both inputs.

GAIN

The non-inverting and inverting gain equations for the LMH6609 are as follows:

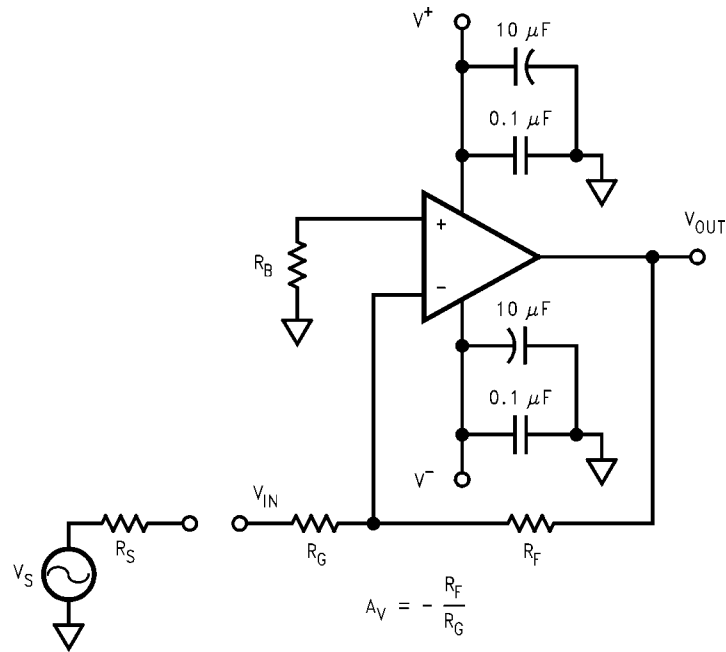
$$\text{NON-INVERTING GAIN} : 1 + \frac{R_F}{R_G}$$

$$\text{INVERTING GAIN} : - \frac{R_F}{R_G}$$



20079027

FIGURE 1. Typical Non-Inverting Application

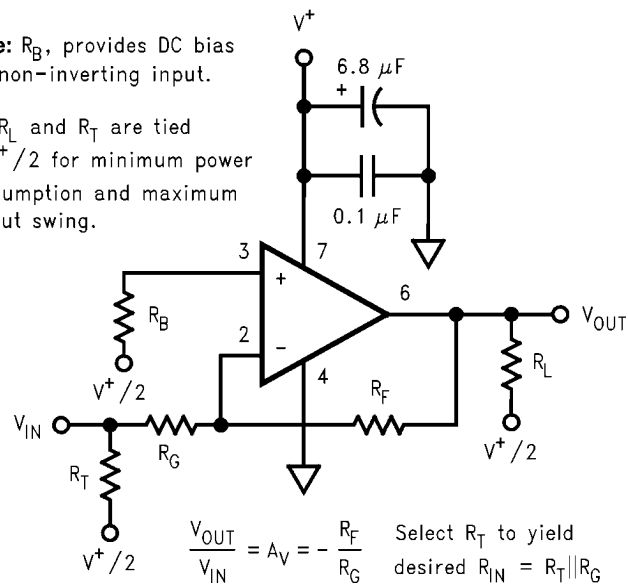


20079028

FIGURE 2. Typical Inverting Application

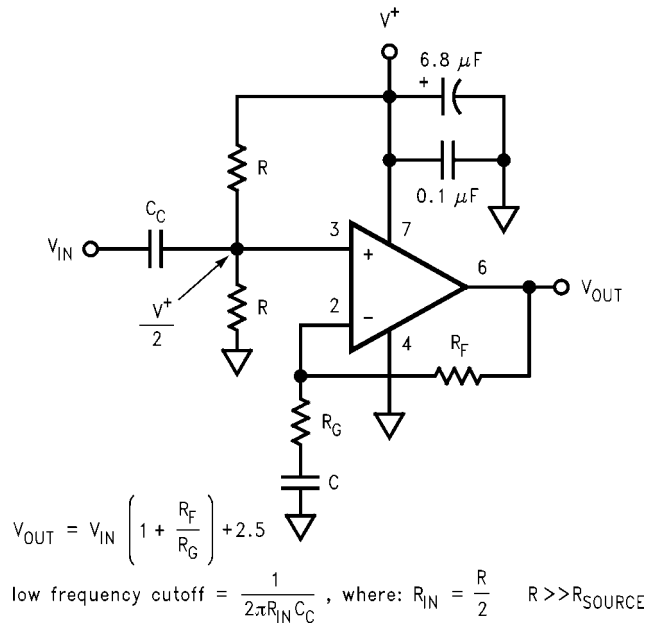
Note: R_B , provides DC bias for non-inverting input.

R_B , R_L and R_T are tied to $V^+/2$ for minimum power consumption and maximum output swing.



20079029

FIGURE 3. Single Supply Inverting



20079030

FIGURE 4. AC Coupled Non-Inverting

GAIN BANDWIDTH PRODUCT

The LMH6609 is a voltage feedback amplifier, whose closed-loop bandwidth is approximately equal to the gain-bandwidth product (GBP) divided by the gain (A_V). For gains greater than 5, A_V sets the closed-loop bandwidth of the LMH6609.

$$\text{CLOSED LOOP BANDWIDTH} = \frac{\text{GBP}}{A_V}$$

$$A_V = \frac{(R_F + R_G)}{R_G}$$

$$\text{GBP} = 240\text{MHz}$$

20079031

For Gains less than 5, refer to the frequency response plots to determine maximum bandwidth. For large signal bandwidth the slew rate is a more accurate predictor of bandwidth.

$$f_{MAX} = \frac{S_R}{2\pi V_P}$$

20079032

Where f_{MAX} = bandwidth, S_R = Slew rate and V_P = peak amplitude.

OUTPUT DRIVE AND SETTLING TIME PERFORMANCE

The LMH6609 has large output current capability. The 100mA of output current makes the LMH6609 an excellent choice for applications such as:

- Video Line Drivers
- Distribution Amplifiers

When driving a capacitive load or coaxial cable, include a series resistance R_{OUT} to back match or improve settling time. Refer to the Driving Capacitive Loads section for guidance on selecting an output resistor for driving capacitive loads.

EVALUATION BOARDS

National Semiconductor offers the following evaluation boards as a guide for high frequency layout and as an aid in device testing and characterization. Many of the datasheet plots were measured with these boards.

Device	Package	Board Part #
LMH6609MA	SOIC	LMH730227
LMH6609MF	SOT-23	LMH730216

See the LMH6609 Product Folder on www.national.com for evaluation board availability and ordering information.

CIRCUIT LAYOUT CONSIDERATION

A proper printed circuit layout is essential for achieving high frequency performance. National provides evaluation boards for the LMH6609 as shown above. These boards were laid out for optimum, high-speed performance. The ground plane was removed near the input and output pins to reduce parasitic capacitance. Also, all trace lengths were minimized to reduce series inductances.

Supply bypassing is required for the amplifiers performance. The bypass capacitors provide a low impedance return current path at the supply pins. They also provide high frequency filtering on the power supply traces. 10μF tantalum and .01μF capacitors are recommended on both supplies (from supply to ground). In addition a .1μF ceramic capacitor can be added from V^+ to V^- to aid in second harmonic suppression.

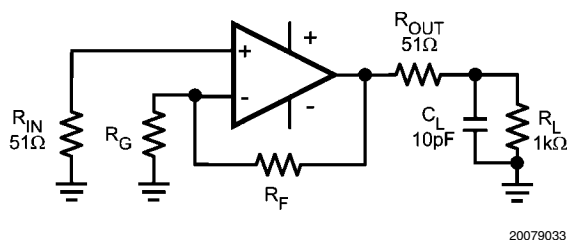


FIGURE 5. Driving Capacitive Loads with R_{OUT} for Improved Stability

DRIVING CAPACITIVE LOADS

Capacitive output loading applications will benefit from the use of a series output resistor R_{OUT} . Figure 5 shows the use of a series output resistor, R_{OUT} as it might be applied when driving an analog to digital converter. The charts "Suggested R_O vs. Cap Load" in the Typical Performance Section give a recommended value for mitigating capacitive loads. The values suggested in the charts are selected for .5dB or less of peaking in the frequency response. This gives a good compromise between settling time and bandwidth. For applications where maximum frequency response is needed and some peaking is tolerable, the value of R_O can be reduced slightly from the recommended values. There will be amplitude lost in the series resistor unless the gain is adjusted to compensate; this effect is most noticeable with heavy resistive loads.

COMPONENT SELECTION AND FEEDBACK RESISTOR

Surface mount components are highly recommended for the LMH6609. Leaded components will introduce unpredictable parasitic loading that will interfere with proper device operation. Do not use wire wound resistors.

The LMH6609 operates best with a feedback resistor of approximately 250Ω for all gains of +2 and greater and for -1 and less. With lower gains in particular, large value feedback resistors will exaggerate the effects of parasitic capacitances and may lead to ringing on the pulse response and frequency response peaking. Large value resistors also add undesirable thermal noise. Feedback resistors that are much below 100Ω will load the output stage, which will reduce voltage output swing, increase device power dissipation, increase distortion and reduce current available for driving the load.

In the buffer configuration the output should be shorted directly to the inverting input. This feedback does not load the output stage because the inverting input is a high impedance point and there is no gain set resistor to ground.

OPTIMIZING DC ACCURACY

The LMH6609 offers excellent DC accuracy. The well-matched inputs of this amplifier allows even better performance if care is taken to balance the impedances seen by the two inputs. The parallel combination of the gain setting R_G and feedback R_F resistors should be equal to R_{SEQ} , the resistance of the source driving the op amp in parallel with any terminating Resistor (See Figure 1). Combining this with the non inverting gain equation gives the following parameters:

$$R_F = A_{VRSEQ}$$

$$R_G = R_F / (A_V - 1)$$

For Inverting gains the bias current cancellation is accomplished by placing a resistor R_B on the non-inverting input

equal in value to the resistance seen by the inverting input (See Figure 2). $R_B = R_F \parallel (R_G + R_S)$

The additional noise contribution of R_B can be minimized by the use of a shunt capacitor (not shown).

POWER DISSIPATION

The LMH6609 has the ability to drive large currents into low impedance loads. Some combinations of ambient temperature and device loading could result in device overheating. For most conditions peak power values are not as important as RMS powers. To determine the maximum allowable power dissipation for the LMH6609 use the following formula:

$$P_{MAX} = (150^\circ - T_{AMB}) / \theta_{JA}$$

Where T_{AMB} = Ambient temperature ($^\circ\text{C}$) and θ_{JA} = Thermal resistance, from junction to ambient, for a given package ($^\circ\text{C}/\text{W}$). For the SOIC package θ_{JA} is 148 $^\circ\text{C}/\text{W}$, for the SOT it is 250 $^\circ\text{C}/\text{W}$. 150 $^\circ\text{C}$ is the absolute maximum limit for the internal temperature of the device.

Either forced air cooling or a heat sink can greatly increase the power handling capability for the LMH6609.

VIDEO PERFORMANCE

The LMH6609 has been designed to provide good performance with both PAL and NTSC composite video signals. The LMH6609 is specified for PAL signals. NTSC performance is typically marginally better due to the lower frequency content of the signal. Performance degrades as the loading is increased, therefore best performance will be obtained with back-terminated loads. The back termination reduces reflections from the transmission line and effectively masks transmission line and other parasitic capacitances from the amplifier output stage. This means that the device should be configured for a gain of 2 in order to have a net gain of 1 after the terminating resistor. (See Figure 6)

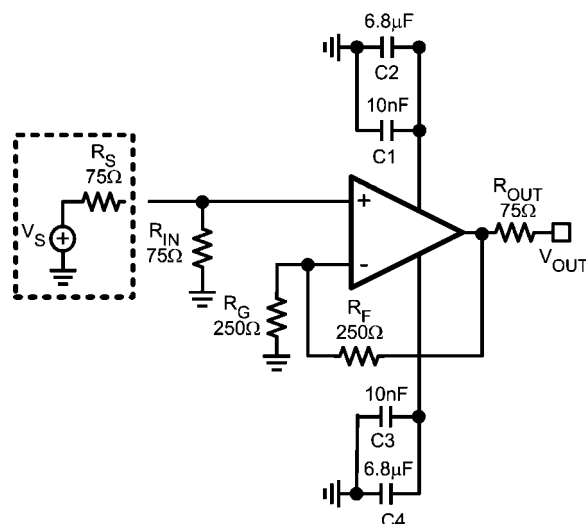


FIGURE 6. Typical Video Application

ESD PROTECTION

The LMH6609 is protected against electrostatic discharge (ESD) on all pins. The LMH6609 will survive 2000V Human Body model or 200V Machine model events.

Under closed loop operation the ESD diodes have no effect on circuit performance. There are occasions, however, when the ESD diodes may be evident. For instance, if the amplifier

is powered down and a large input signal is applied the ESD diodes will conduct.

TRANSIMPEDANCE AMPLIFIER

The low input current noise and unity gain stability of the LMH6609 make it an excellent choice for transimpedance applications. [Figure 7](#) illustrates a low noise transimpedance amplifier that is commonly implemented with photo diodes. R_F sets the transimpedance gain. The photo diode current multiplied by R_F determines the output voltage.

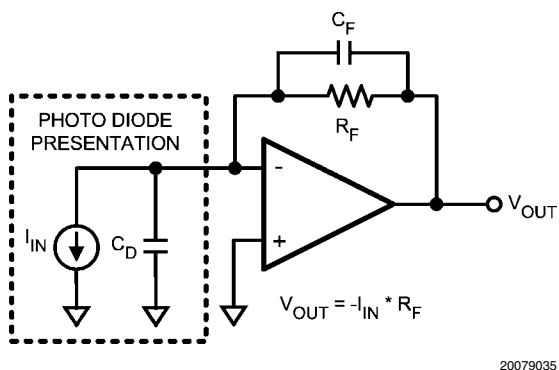


FIGURE 7. Transimpedance Amplifier

The capacitances are defined as:

- C_D = Equivalent Diode Capacitance
- C_F = Feedback Capacitance

The feedback capacitor is used to give optimum flatness and stability. As a starting point the feedback capacitance should be chosen as $\frac{1}{2}$ of the Diode capacitance. Lower feedback capacitors will peak frequency response.

Rectifier

The large bandwidth of the LMH6609 allows for high-speed rectification. A common rectifier topology is shown in [Figure 8](#). R_1 and R_2 set the gain of the rectifier.

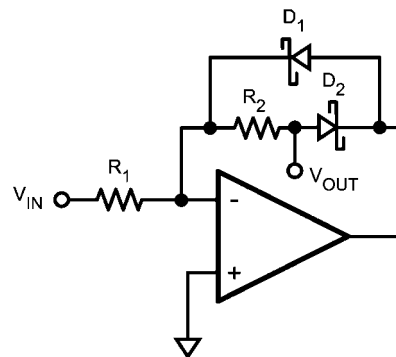
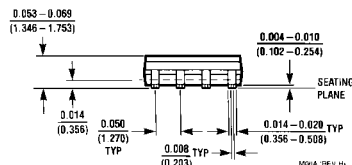
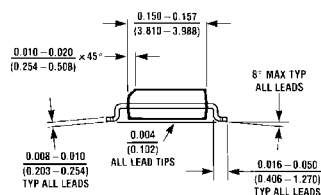
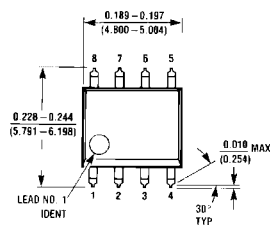
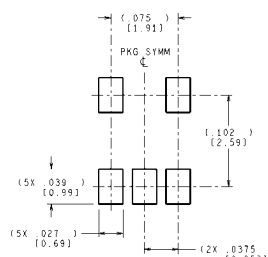
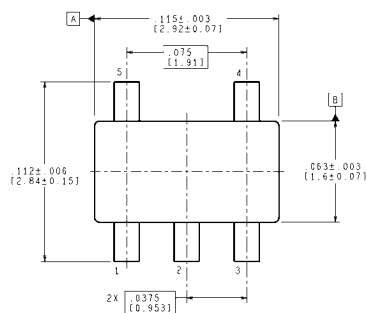


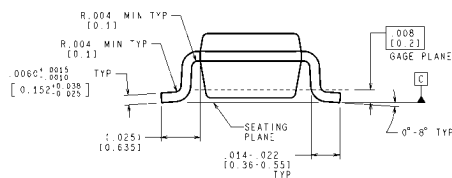
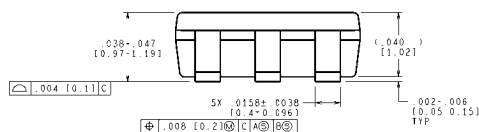
FIGURE 8. Rectifier Topology

Physical Dimensions inches (millimeters) unless otherwise noted

8-Pin SOIC
NS Product Number M08A



LAND PATTERN RECOMMENDATION



CONTROLLING DIMENSION IS INCH
VALUES IN [] ARE MILLIMETERS
DIMENSIONS IN 1:1 FOR REFERENCE ONLY

5-Pin SOT23
NS Product Number MF05A

MF05A (Rev D)

Notes

For more National Semiconductor product information and proven design tools, visit the following Web sites at:
www.national.com

Products		Design Support	
Amplifiers	www.national.com/amplifiers	WEBENCH® Tools	www.national.com/webench
Audio	www.national.com/audio	App Notes	www.national.com/appnotes
Clock and Timing	www.national.com/timing	Reference Designs	www.national.com/refdesigns
Data Converters	www.national.com/adc	Samples	www.national.com/samples
Interface	www.national.com/interface	Eval Boards	www.national.com/evalboards
LVDS	www.national.com/lvds	Packaging	www.national.com/packaging
Power Management	www.national.com/power	Green Compliance	www.national.com/quality/green
Switching Regulators	www.national.com/switchers	Distributors	www.national.com/contacts
LDOs	www.national.com/ldo	Quality and Reliability	www.national.com/quality
LED Lighting	www.national.com/led	Feedback/Support	www.national.com/feedback
Voltage References	www.national.com/vref	Design Made Easy	www.national.com/easy
PowerWise® Solutions	www.national.com/powerwise	Applications & Markets	www.national.com/solutions
Serial Digital Interface (SDI)	www.national.com/sdi	Mil/Aero	www.national.com/milaero
Temperature Sensors	www.national.com/tempsensors	SolarMagic™	www.national.com/solarmagic
PLL/VCO	www.national.com/wireless	PowerWise® Design University	www.national.com/training

THE CONTENTS OF THIS DOCUMENT ARE PROVIDED IN CONNECTION WITH NATIONAL SEMICONDUCTOR CORPORATION ("NATIONAL") PRODUCTS. NATIONAL MAKES NO REPRESENTATIONS OR WARRANTIES WITH RESPECT TO THE ACCURACY OR COMPLETENESS OF THE CONTENTS OF THIS PUBLICATION AND RESERVES THE RIGHT TO MAKE CHANGES TO SPECIFICATIONS AND PRODUCT DESCRIPTIONS AT ANY TIME WITHOUT NOTICE. NO LICENSE, WHETHER EXPRESS, IMPLIED, ARISING BY ESTOPPEL OR OTHERWISE, TO ANY INTELLECTUAL PROPERTY RIGHTS IS GRANTED BY THIS DOCUMENT.

TESTING AND OTHER QUALITY CONTROLS ARE USED TO THE EXTENT NATIONAL DEEMS NECESSARY TO SUPPORT NATIONAL'S PRODUCT WARRANTY. EXCEPT WHERE MANDATED BY GOVERNMENT REQUIREMENTS, TESTING OF ALL PARAMETERS OF EACH PRODUCT IS NOT NECESSARILY PERFORMED. NATIONAL ASSUMES NO LIABILITY FOR APPLICATIONS ASSISTANCE OR BUYER PRODUCT DESIGN. BUYERS ARE RESPONSIBLE FOR THEIR PRODUCTS AND APPLICATIONS USING NATIONAL COMPONENTS. PRIOR TO USING OR DISTRIBUTING ANY PRODUCTS THAT INCLUDE NATIONAL COMPONENTS, BUYERS SHOULD PROVIDE ADEQUATE DESIGN, TESTING AND OPERATING SAFEGUARDS.

EXCEPT AS PROVIDED IN NATIONAL'S TERMS AND CONDITIONS OF SALE FOR SUCH PRODUCTS, NATIONAL ASSUMES NO LIABILITY WHATSOEVER, AND NATIONAL DISCLAIMS ANY EXPRESS OR IMPLIED WARRANTY RELATING TO THE SALE AND/OR USE OF NATIONAL PRODUCTS INCLUDING LIABILITY OR WARRANTIES RELATING TO FITNESS FOR A PARTICULAR PURPOSE, MERCHANTABILITY, OR INFRINGEMENT OF ANY PATENT, COPYRIGHT OR OTHER INTELLECTUAL PROPERTY RIGHT.

LIFE SUPPORT POLICY

NATIONAL'S PRODUCTS ARE NOT AUTHORIZED FOR USE AS CRITICAL COMPONENTS IN LIFE SUPPORT DEVICES OR SYSTEMS WITHOUT THE EXPRESS PRIOR WRITTEN APPROVAL OF THE CHIEF EXECUTIVE OFFICER AND GENERAL COUNSEL OF NATIONAL SEMICONDUCTOR CORPORATION. As used herein:

Life support devices or systems are devices 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. A critical component is any component in 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.

National Semiconductor and the National Semiconductor logo are registered trademarks of National Semiconductor Corporation. All other brand or product names may be trademarks or registered trademarks of their respective holders.

Copyright© 2011 National Semiconductor Corporation

For the most current product information visit us at www.national.com



**National Semiconductor
Americas Technical
Support Center**
Email: support@nsc.com
Tel: 1-800-272-9959

**National Semiconductor Europe
Technical Support Center**
Email: europe.support@nsc.com

**National Semiconductor Asia
Pacific Technical Support Center**
Email: ap.support@nsc.com

**National Semiconductor Japan
Technical Support Center**
Email: jpn.feedback@nsc.com

IMPORTANT NOTICE

Texas Instruments Incorporated and its subsidiaries (TI) reserve the right to make corrections, modifications, enhancements, improvements, and other changes to its products and services at any time and to discontinue any product or service without notice. Customers should obtain the latest relevant information before placing orders and should verify that such information is current and complete. All products are sold subject to TI's terms and conditions of sale supplied at the time of order acknowledgment.

TI warrants performance of its hardware products to the specifications applicable at the time of sale in accordance with TI's standard warranty. Testing and other quality control techniques are used to the extent TI deems necessary to support this warranty. Except where mandated by government requirements, testing of all parameters of each product is not necessarily performed.

TI assumes no liability for applications assistance or customer product design. Customers are responsible for their products and applications using TI components. To minimize the risks associated with customer products and applications, customers should provide adequate design and operating safeguards.

TI does not warrant or represent that any license, either express or implied, is granted under any TI patent right, copyright, mask work right, or other TI intellectual property right relating to any combination, machine, or process in which TI products or services are used. Information published by TI regarding third-party products or services does not constitute a license from TI to use such products or services or a warranty or endorsement thereof. Use of such information may require a license from a third party under the patents or other intellectual property of the third party, or a license from TI under the patents or other intellectual property of TI.

Reproduction of TI information in TI data books or data sheets is permissible only if reproduction is without alteration and is accompanied by all associated warranties, conditions, limitations, and notices. Reproduction of this information with alteration is an unfair and deceptive business practice. TI is not responsible or liable for such altered documentation. Information of third parties may be subject to additional restrictions.

Resale of TI products or services with statements different from or beyond the parameters stated by TI for that product or service voids all express and any implied warranties for the associated TI product or service and is an unfair and deceptive business practice. TI is not responsible or liable for any such statements.

TI products are not authorized for use in safety-critical applications (such as life support) where a failure of the TI product would reasonably be expected to cause severe personal injury or death, unless officers of the parties have executed an agreement specifically governing such use. Buyers represent that they have all necessary expertise in the safety and regulatory ramifications of their applications, and acknowledge and agree that they are solely responsible for all legal, regulatory and safety-related requirements concerning their products and any use of TI products in such safety-critical applications, notwithstanding any applications-related information or support that may be provided by TI. Further, Buyers must fully indemnify TI and its representatives against any damages arising out of the use of TI products in such safety-critical applications.

TI products are neither designed nor intended for use in military/aerospace applications or environments unless the TI products are specifically designated by TI as military-grade or "enhanced plastic." Only products designated by TI as military-grade meet military specifications. Buyers acknowledge and agree that any such use of TI products which TI has not designated as military-grade is solely at the Buyer's risk, and that they are solely responsible for compliance with all legal and regulatory requirements in connection with such use.

TI products are neither designed nor intended for use in automotive applications or environments unless the specific TI products are designated by TI as compliant with ISO/TS 16949 requirements. Buyers acknowledge and agree that, if they use any non-designated products in automotive applications, TI will not be responsible for any failure to meet such requirements.

Following are URLs where you can obtain information on other Texas Instruments products and application solutions:

Products

Audio	www.ti.com/audio
Amplifiers	amplifier.ti.com
Data Converters	dataconverter.ti.com
DLP® Products	www.dlp.com
DSP	dsp.ti.com
Clocks and Timers	www.ti.com/clocks
Interface	interface.ti.com
Logic	logic.ti.com
Power Mgmt	power.ti.com
Microcontrollers	microcontroller.ti.com
RFID	www.ti-rfid.com
OMAP Mobile Processors	www.ti.com/omap
Wireless Connectivity	www.ti.com/wirelessconnectivity

Applications

Communications and Telecom	www.ti.com/communications
Computers and Peripherals	www.ti.com/computers
Consumer Electronics	www.ti.com/consumer-apps
Energy and Lighting	www.ti.com/energy
Industrial	www.ti.com/industrial
Medical	www.ti.com/medical
Security	www.ti.com/security
Space, Avionics and Defense	www.ti.com/space-avionics-defense
Transportation and Automotive	www.ti.com/automotive
Video and Imaging	www.ti.com/video

TI E2E Community Home Page

e2e.ti.com

Mailing Address: Texas Instruments, Post Office Box 655303, Dallas, Texas 75265
Copyright © 2011, Texas Instruments Incorporated