May 31, 2012

# LMV601/LMV602/LMV604

# 1 MHz, Low Power General Purpose, 2.7V Operational Amplifiers

## General Description

The LMV601/LMV602/LMV604 are single, dual, and quad low voltage, low power Operational Amplifiers. They are designed specifically for low voltage general purpose applications. Other important product characteristics are low input bias current, rail-to-rail output, and wide temperature range. The LMV601/LMV602/LMV604 have 29nV Voltage Noise at 10KHz, 1MHz GBW, 1.0V/µs Slew Rate, 0.25mV Vos. The LMV601/2/4 operates from a single supply voltage as low as 2.7V, while drawing 100uA (typ) quiescent current. In shutdown mode the current can be reduced to 45pA.

The industrial-plus temperature range of −40°C to 125°C allows the LMV601/LMV602/LMV604 to accommodate a broad range of extended environment applications.

The LMV601 offers a shutdown pin that can be used to disable the device. Once in shutdown mode, the supply current is reduced to 45pA (typical).

The LMV601 is offered in the tiny 6-Pin SC70 package, the LMV602 in space saving 8-Pin MSOP and SOIC, and the LMV604 in 14-Pin TSSOP and SOIC. These small package amplifiers offer an ideal solution for applications requiring minimum PCB footprint. Applications with area constrained PC board requirements include portable and battery operated electronics.

## Features

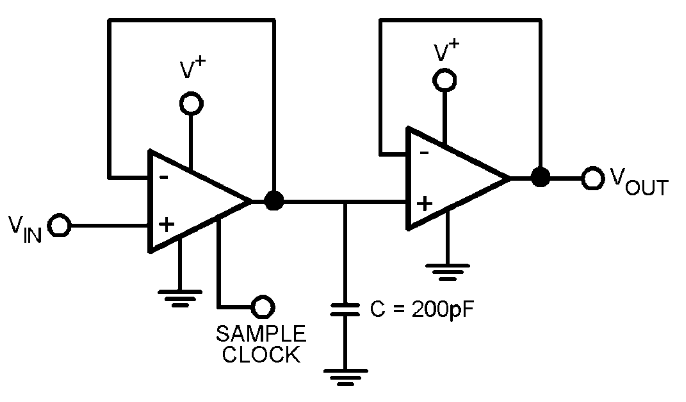
(Typical 2.7V supply values; unless otherwise noted)

- Guaranteed 2.7V and 5V specifications
- Supply current (per amplifier) 100µA
- Gain bandwidth product 1.0MHz
- Shutdown Current (LMV601) 45pA
- Turn-on time from shutdown (LMV601) 5µs
- Input bias current 20fA

## Applications

- Cordless/cellular phones
- Laptops
- PDAs
- PCMCIA/Audio
- Portable/battery-powered electronic equipment
- Supply current monitoring
- Battery monitoring
- Buffer
- Filter
- Driver

## Sample and Hold Circuit



## Absolute Maximum Ratings (Note 1)

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

| | |
|---|---|
| ESD Tolerance (Note 2) | |
| Machine Model | 200V |
| Human Body Model | 2000V |
| Differential Input Voltage | ± Supply Voltage |
| Supply Voltage ($V^+ - V^-$) | 6.0V |
| Output Short Circuit to $V^+$ | (Note 3) |
| Output Short Circuit to $V^-$ | (Note 4) |
| Storage Temperature Range | −65°C to 150°C |
| Junction Temperature (Note 5) | 150°C |
| Mounting Temperature | |
| Infrared or Convection Reflow (20 sec.) | 235°C |
| Wave Soldering Lead Temp. (10 sec.) | 260°C |

## Operating Ratings (Note 1)

| | |
|---|---|
| Supply Voltage | 2.7V to 5.5V |
| Temperature Range | −40°C to 125°C |
| Thermal Resistance ($\theta_{JA}$) | |
| 6-Pin SC70 | 414°C/W |
| 8-Pin SOIC | 190°C/W |
| 8-Pin MSOP | 235°C/W |
| 14-Pin TSSOP | 155°C/W |
| 14-Pin SOIC | 145°C/W |

## 2.7V DC Electrical Characteristics (Note 10)

Unless otherwise specified, all limits guaranteed for $T_J = 25°C$, $V^+ = 2.7V$, $V^- = 0V$, $V_{CM} = V^+/2$, $V_O = V^+/2$ and $R_L > 1M\Omega$. **Boldface** limits apply at the temperature extremes.

| Symbol | Parameter | Conditions | Min (Note 7) | Typ (Note 6) | Max (Note 7) | Units |
|---|---|---|---|---|---|---|
| $V_{OS}$ | Input Offset Voltage | LMV601 | | 0.25 | 4 | mV |
| | | LMV602/LMV604 | | 0.55 | 5 | |
| $TCV_{OS}$ | Input Offset Voltage Average Drift | | | 1.7 | | µV/°C |
| $I_B$ | Input Bias Current | | | 0.02 | | pA |
| $I_{OS}$ | Input Offset Current | | | 6.6 | | fA |
| $I_S$ | Supply Current | Per Amplifier | | 100 | 170 | µA |
| | | Shutdown Mode, $V_{SD} = 0V$ (LMV601) | | 45pA | 1µA | |
| CMRR | Common Mode Rejection Ratio | $0V \le V_{CM} \le 1.7V$<br>$0V \le V_{CM} \le 1.6V$ | | 80 | | dB |
| PSRR | Power Supply Rejection Ratio | $2.7V \le V^+ \le 5V$ | | 82 | | dB |
| $V_{CM}$ | Input Common Mode Voltage | For CMRR ≥ 50dB | 0 | −0.2 to 1.9 (Range) | 1.7 | V |
| $A_V$ | Large Signal Voltage Gain | $R_L = 10k\Omega$ to 1.35V | | 113 | | dB |
| $V_O$ | Output Swing | $R_L = 10k\Omega$ to 1.35V | | 5.0 | 30 | mV |
| | | | 30 | 5.3 | | |
| $I_O$ | Output Short Circuit Current | Sourcing LMV601/LMV602 | | 32 | | mA |
| | | Sourcing LMV604 | | 24 | | |
| | | Sinking | | 24 | | |
| $t_{on}$ | Turn-on Time from Shutdown | (LMV601) | | 5 | | µs |
| $V_{SD}$ | Shutdown Pin Voltage Range | ON Mode (LMV601) | | 1.7 to 2.7 | 2.4 to 2.7 | V |
| | | Shutdown Mode (LMV601) | | 0 to 1 | 0 to 0.8 | |

## 2.7V AC Electrical Characteristics (Note 10)

Unless otherwise specified, all limits guaranteed for $T_J$ = 25°C, $V^+$ = 2.7V, $V^-$ = 0V, $V_{CM}$ = $V^+$/2, $V_O$ = $V^+$/2 and $R_L$ > 1MΩ. **Boldface** limits apply at the temperature extremes.

| Symbol | Parameter | Conditions | Min (Note 7) | Typ (Note 6) | Max (Note 7) | Units |
|---|---|---|---|---|---|---|
| SR | Slew Rate | $R_L$ = 10kΩ, (Note 9) | | 1.0 | | V/µs |
| GBW | Gain Bandwidth Product | $R_L$ = 100kΩ, $C_L$ = 200pF | | 1.0 | | MHz |
| $\Phi_m$ | Phase Margin | $R_L$ = 100kΩ | | 72 | | deg |
| $G_m$ | Gain Margin | $R_L$ = 100kΩ | | 20 | | dB |
| $e_n$ | Input-Referred Voltage Noise | f = 1kHz | | 40 | | $nV/\sqrt{Hz}$ |
| $i_n$ | Input-Referred Current Noise | f = 1kHz | | 0.001 | | $pA/\sqrt{Hz}$ |
| THD | Total Harmonic Distortion | f = 1kHz, $A_V$ = +1<br>$R_L$ = 600Ω, $V_{IN}$ = $1V_{PP}$ | | 0.017 | | % |

## 5V DC Electrical Characteristics (Note 10)

Unless otherwise specified, all limits guaranteed for $T_J$ = 25°C, $V^+$ = 5V, $V^-$ = 0V, $V_{CM}$ = $V^+$/2, $V_O$ = $V^+$/2 and $R_L$ > 1MΩ. **Boldface** limits apply at the temperature extremes.

| Symbol | Parameter | Conditions | Min (Note 7) | Typ (Note 6) | Max (Note 7) | Units |
|---|---|---|---|---|---|---|
| $V_{OS}$ | Input Offset Voltage | LMV601 | | 0.25 | 4 | mV |
| | | LMV602/LMV604 | | 0.70 | 5 | |
| $TCV_{OS}$ | Input Offset Voltage Average Drift | | | 1.9 | | µV/°C |
| $I_B$ | Input Bias Current | | | 0.02 | | pA |
| $I_{OS}$ | Input Offset Current | | | 6.6 | | fA |
| $I_S$ | Supply Current | Per Amplifier | | 107 | 200 | µA |
| | | Shutdown Mode, $V_{SD}$ = 0V (LMV601) | | 0.033 | 1 | µA |
| CMRR | Common Mode Rejection Ratio | 0V ≤ $V_{CM}$ ≤ 4.0V<br>0V ≤ $V_{CM}$ ≤ 3.9V | | 86 | | dB |
| PSRR | Power Supply Rejection Ratio | 2.7V ≤ $V^+$ ≤ 5V | | 82 | | dB |
| $V_{CM}$ | Input Common Mode Voltage | For CMRR ≥ 50dB | 0 | −0.2 to 4.2 (Range) | 4 | V |
| $A_V$ | Large Signal Voltage Gain (Note 8) | $R_L$ = 10kΩ to 2.5V | | 116 | | dB |
| $V_O$ | Output Swing | $R_L$ = 10kΩ to 2.5V | | 7 | 30 | mV |
| | | | 30 | 7 | | |
| $I_O$ | Output Short Circuit Current | Sourcing | | 113 | | mA |
| | | Sinking | | 75 | | |
| $t_{on}$ | Turn-on Time from Shutdown | (LMV601) | | 5 | | µs |
| $V_{SD}$ | Shutdown Pin Voltage Range | ON Mode (LMV601) | | 3.1 to 5 | 4.5 to 5.0 | V |
| | | Shutdown Mode (LMV601) | | 0 to 1 | 0 to 0.8 | |

## 5V AC Electrical Characteristics (Note 10)

Unless otherwise specified, all limits guaranteed for $T_J$ = 25°C, $V^+$ = 5V, $V^-$ = 0V, $V_{CM}$ = $V^+$/2, $V_O$ = $V^+$/2 and $R_L$ > 1MΩ. **Boldface** limits apply at the temperature extremes.

| Symbol | Parameter | Conditions | Min (Note 7) | Typ (Note 6) | Max (Note 7) | Units |
|---|---|---|---|---|---|---|
| SR | Slew Rate | $R_L$ = 10kΩ, (Note 9) | | 1.0 | | V/µs |
| GBW | Gain-Bandwidth Product | $R_L$ = 10kΩ, $C_L$ = 200pF | | 1.0 | | MHz |

| Symbol | Parameter | Conditions | Min (Note 7) | Typ (Note 6) | Max (Note 7) | Units |
|---|---|---|---|---|---|---|
| $\Phi_m$ | Phase Margin | $R_L = 100k\Omega$ | | 70 | | deg |
| $G_m$ | Gain Margin | $R_L = 100k\Omega$ | | 20 | | dB |
| $e_n$ | Input-Referred Voltage Noise | f = 1kHz | | 39 | | $nV/\sqrt{Hz}$ |
| $i_n$ | Input-Referred Current Noise | f = 1kHz | | 0.001 | | $pA/\sqrt{Hz}$ |
| THD | Total Harmonic Distortion | f = 1kHz, $A_V = +1$<br>$R_L = 600\Omega$, $V_{IN} = 1V_{PP}$ | | 0.012 | | % |

**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 and the test conditions, see the Electrical Characteristics.

**Note 2:** Human Body Model, applicable std. MIL-STD-883, Method 3015.7. Machine Model, applicable std. JESD22-A115-A (ESD MM std. of JEDEC) Field-Induced Charge-Device Model, applicable std. JESD22-C101-C (ESD FICDM std. of JEDEC).

**Note 3:** Shorting output to $V^+$ will adversely affect reliability.

**Note 4:** Shorting output to $V^-$ will adversely affect reliability.

**Note 5:** The maximum power dissipation is a function of $T_{J(MAX)}$, $\theta_{JA}$. 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 onto a PC Board.

**Note 6:** Typical values represent the most likely parametric norm as determined at the time of characterization. Actual typical values may vary over time and will also depend on the application and configuration. The typical values are not tested and are not guaranteed on shipped production material.

**Note 7:** All limits are guaranteed by testing or statistical analysis.

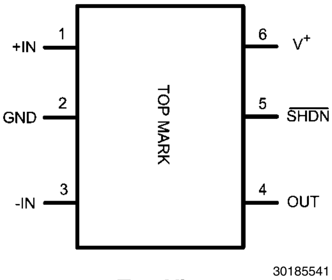
**Note 8:** $R_L$ is connected to mid-supply. The output voltage is GND + 0.2V $\leq V_O \leq V^+$ –0.2V

**Note 9:** Connected as voltage follower with $2V_{PP}$ step input. Number specified is the slower of the positive and negative slew rates.

**Note 10:** 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 $T_J > T_A$.

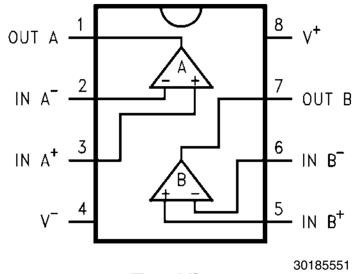
## Connection Diagrams

**6-Pin SC70**



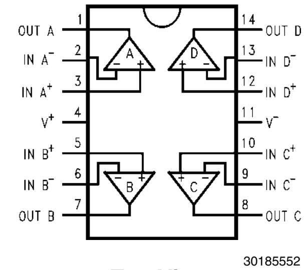

**Top View**

**8-Pin MSOP/SOIC**




**Top View**

**14-Pin TSSOP/SOIC**



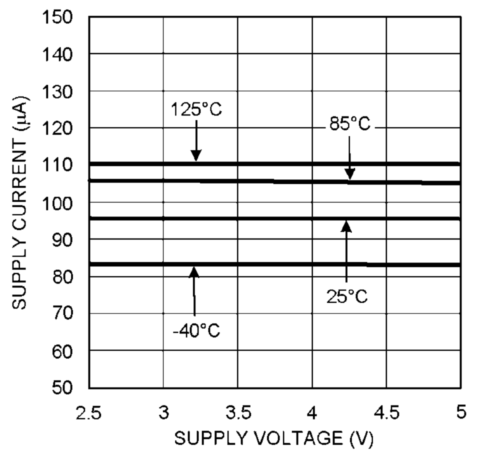

**Top View**

## Ordering Information

| Package | Part Number | Package Marking | Transport Media | NSC Drawing |
|---|---|---|---|---|
| 6-Pin SC70 | LMV601MG | AUA | 1k Units Tape and Reel | MAA06A |
| | LMV601MGX | | 3k Units Tape and Reel | |
| 8-Pin MSOP | LMV602MM | AC9A | 1k Units Tape and Reel | MUA08A |
| | LMV602MMX | | 3.5k Units Tape and Reel | |
| 8-Pin SOIC | LMV602MA | LMV602MA | 95 Units/Rail | M08A |
| | LMV602MAX | | 2.5k Units Tape and Reel | |
| 14-Pin TSSOP | LMV604MT | LMV604MT | Rails | MTC14 |
| | LMV604MTX | | 2.5k Units Tape and Reel | |
| 14-Pin SOIC | LMV604MA | LMV604MA | 55 Units/Rail | M14A |
| | LMV604MAX | | 2.5k Units Tape and Reel | |

# Typical Performance Characteristics

**Supply Current vs. Supply Voltage (LMV601)**

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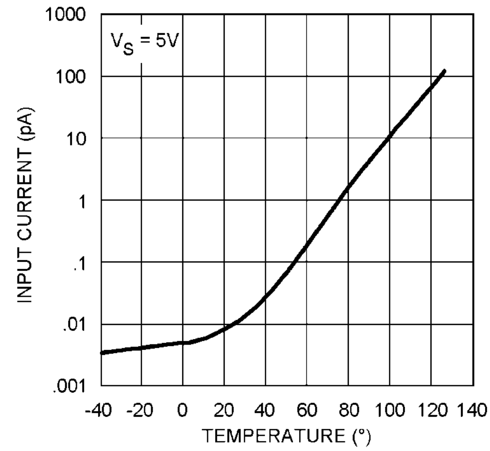
**Input Current vs. Temperature**

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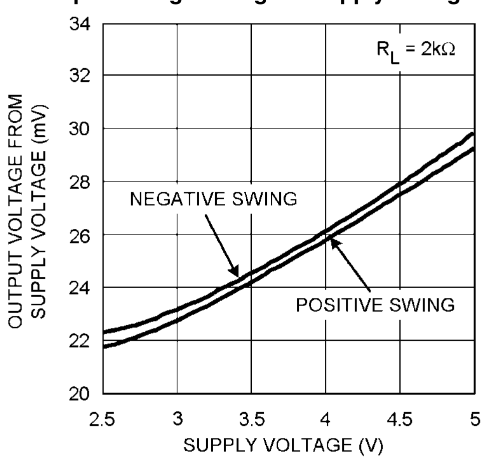
**Output Voltage Swing vs. Supply Voltage**

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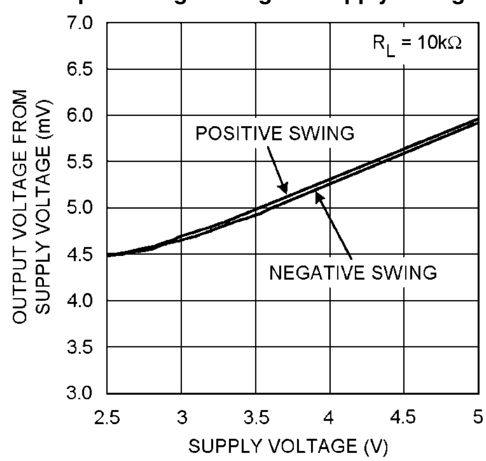
**Output Voltage Swing vs. Supply Voltage**

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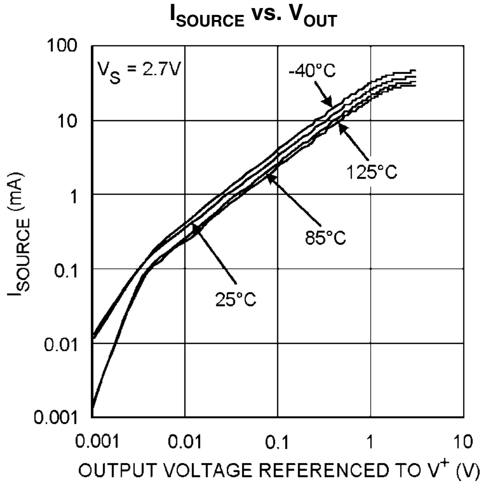
**$I_{SOURCE}$ vs. $V_{OUT}$**

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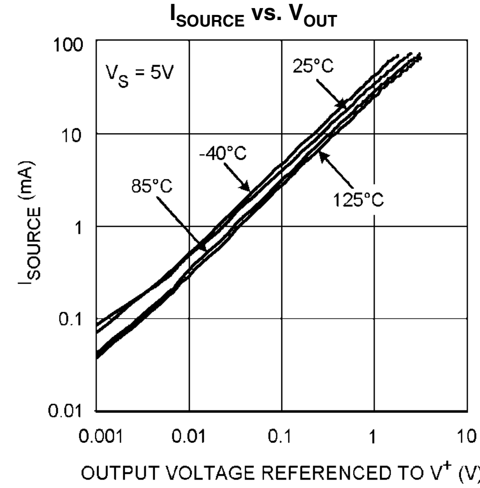
**$I_{SOURCE}$ vs. $V_{OUT}$**

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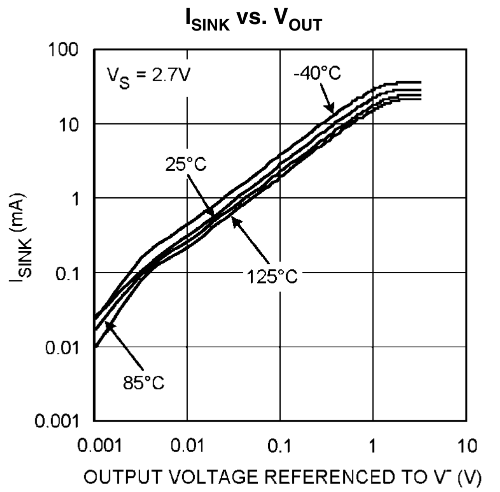

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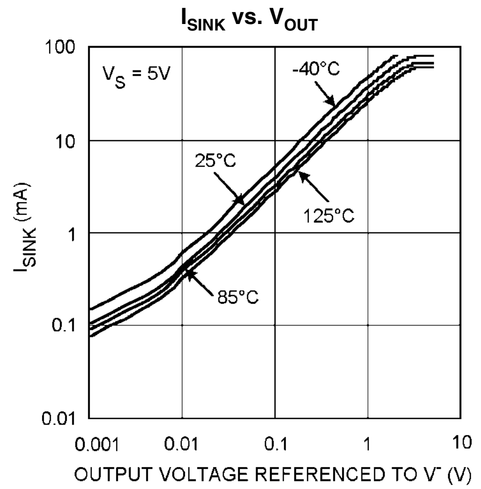

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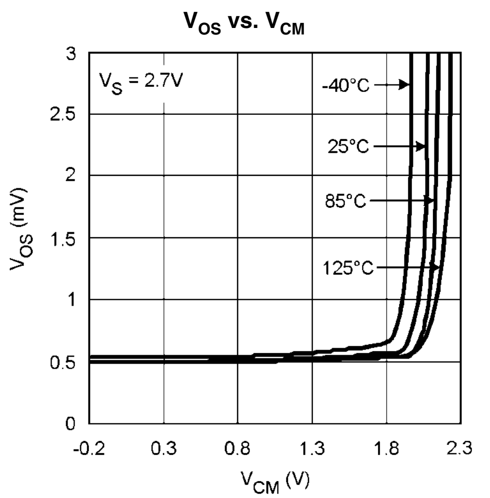

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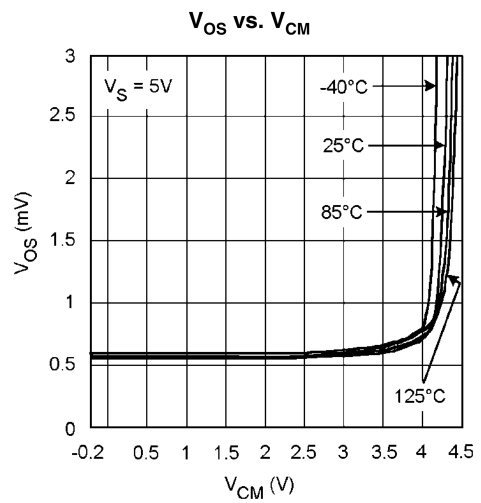

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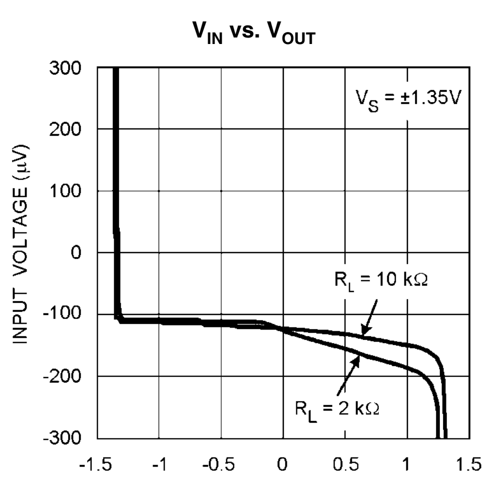

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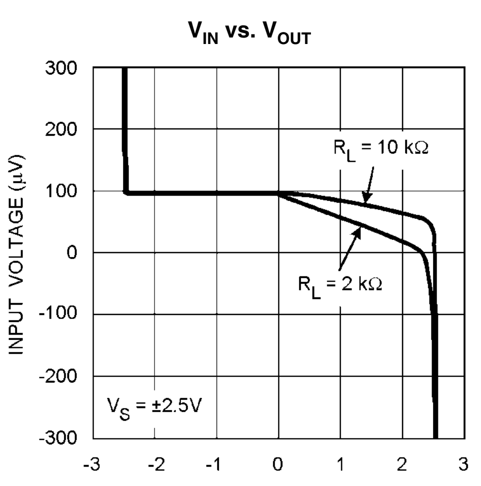

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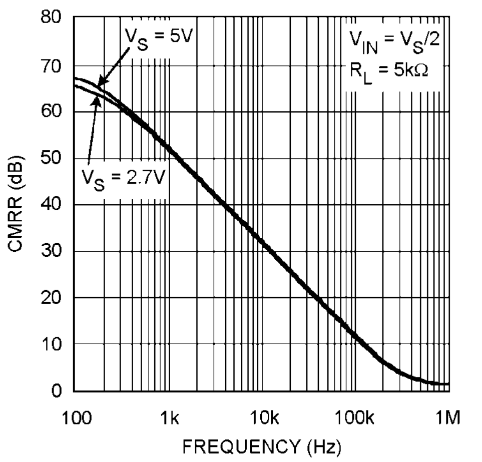
**CMRR vs. Frequency**

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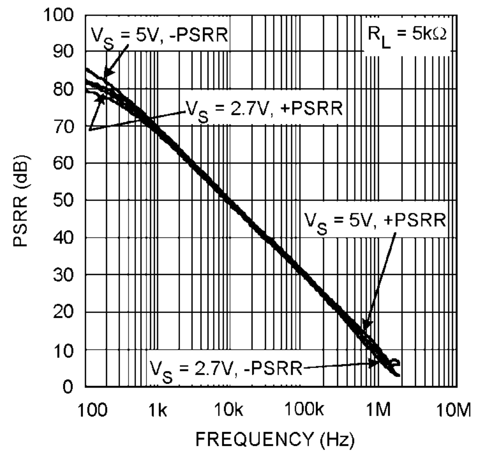
**PSRR vs. Frequency**

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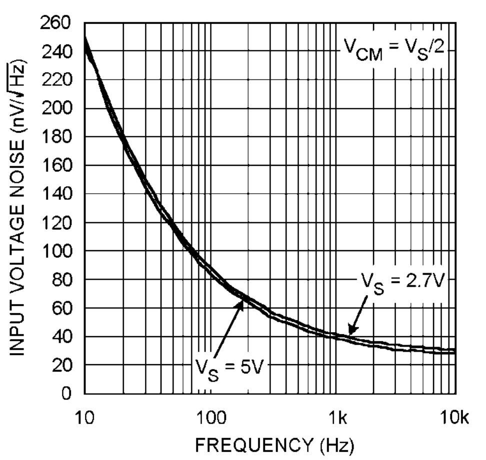
**Input Voltage Noise vs. frequency**

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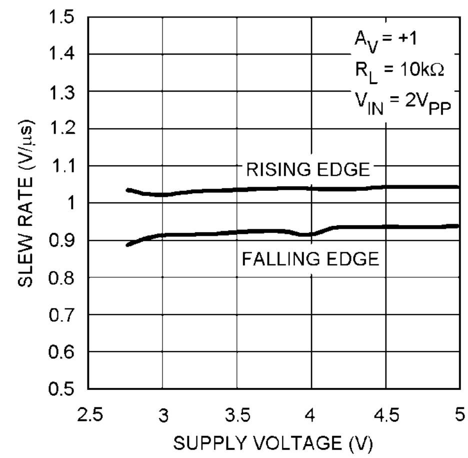
**Slew Rate vs. $V_{SUPPLY}$**

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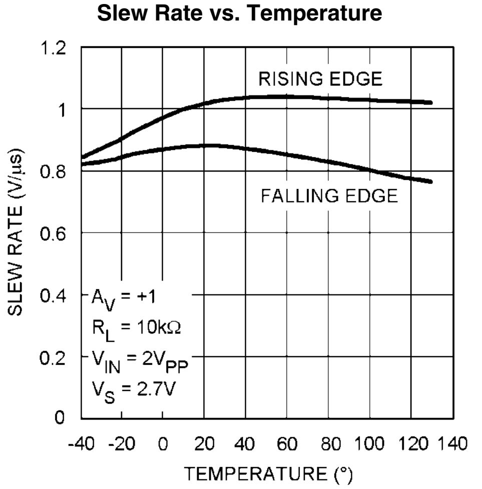
**Slew Rate vs. Temperature**

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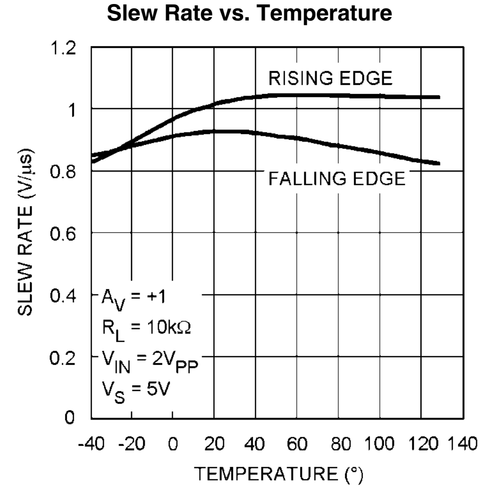
**Slew Rate vs. Temperature**

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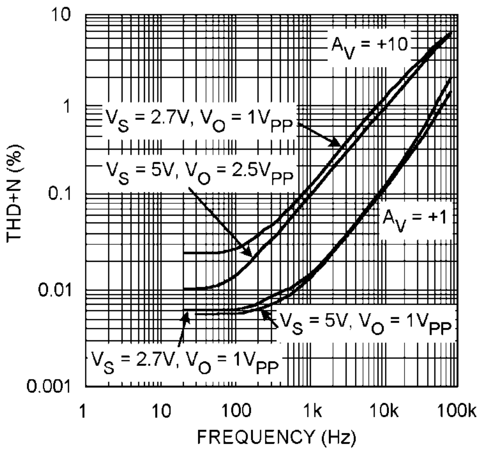
**THD+N vs. Frequency**

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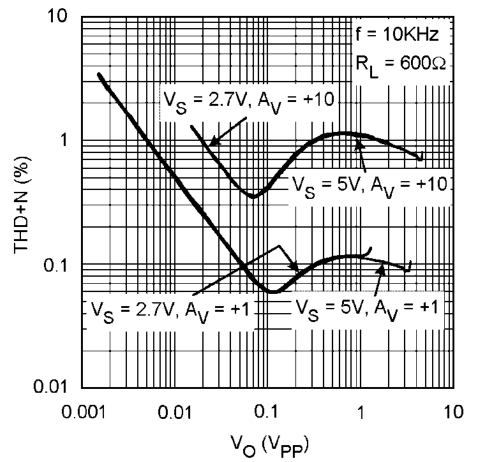
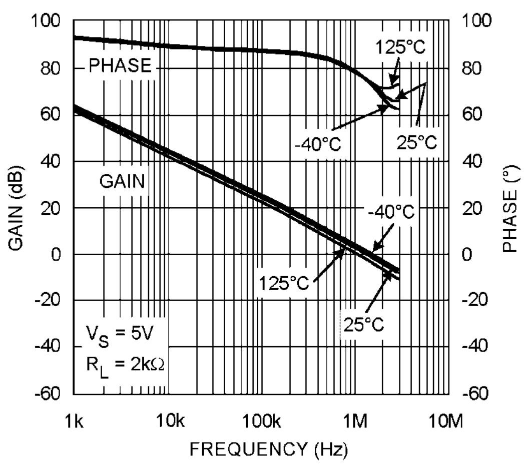
**THD+N vs. $V_{OUT}$**




30185524

**Open Loop Frequency Over Temperature**

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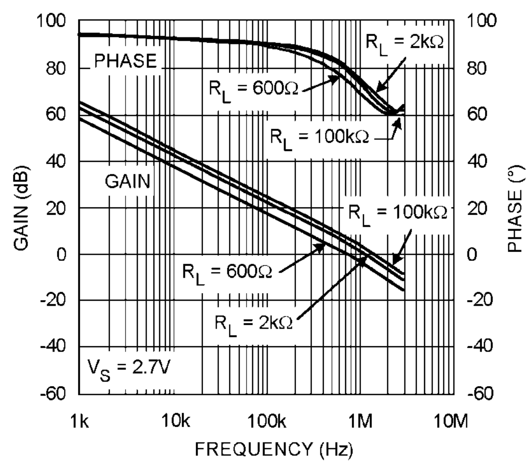
**Open Loop Frequency Response**

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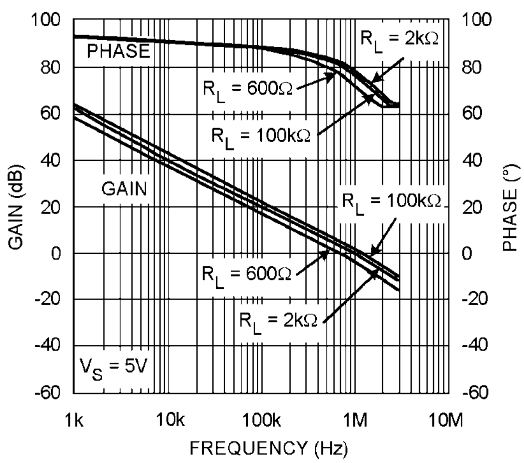
**Open Loop Frequency Response**

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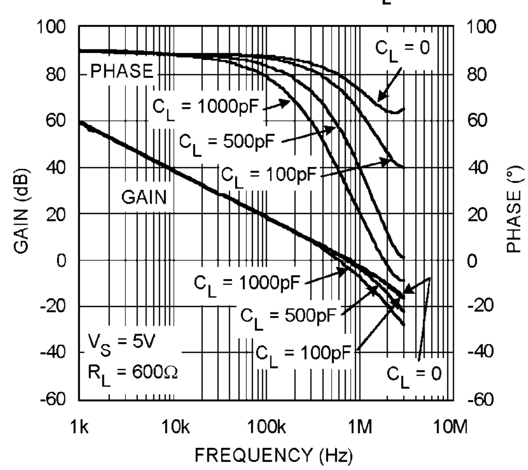
**Gain and Phase vs. $C_L$**

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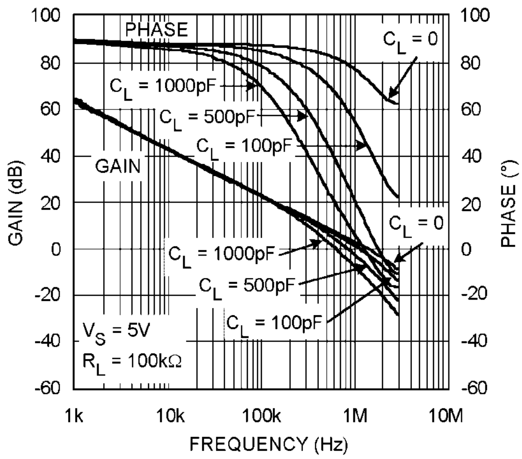
Gain and Phase vs. $C_L$

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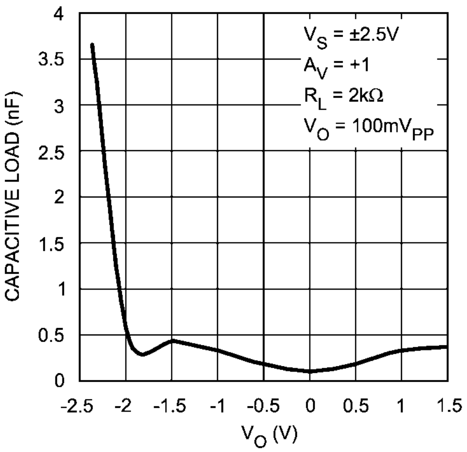
Stability vs. Capacitive Load

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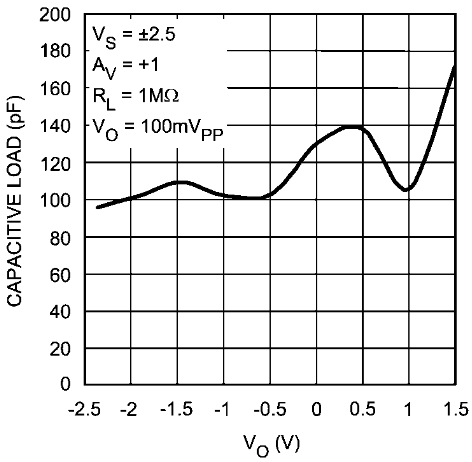
Stability vs. Capacitive Load

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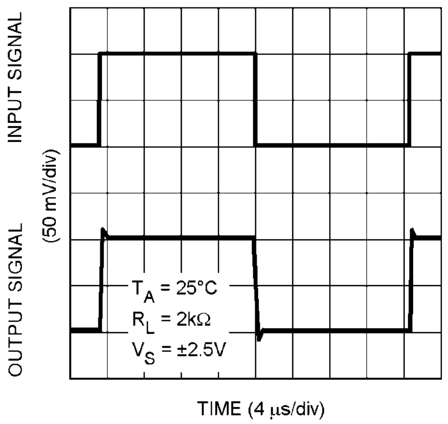
Non-Inverting Small Signal Pulse Response

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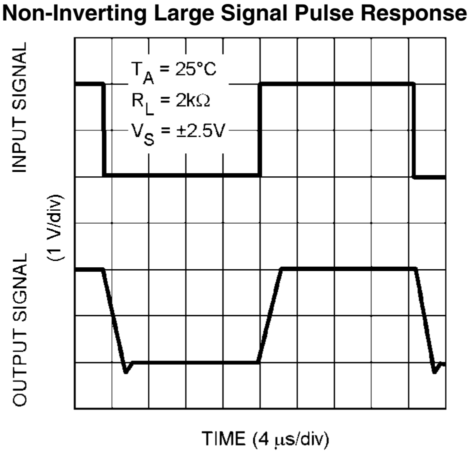
Non-Inverting Large Signal Pulse Response

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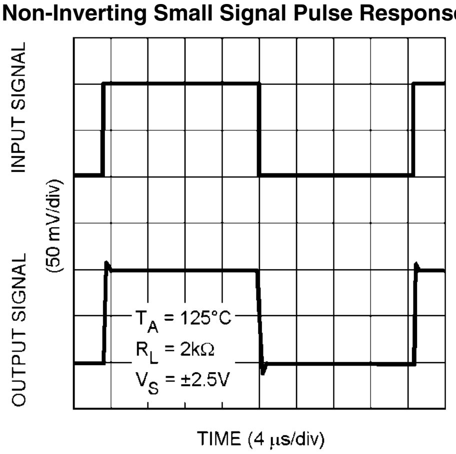
Non-Inverting Small Signal Pulse Response

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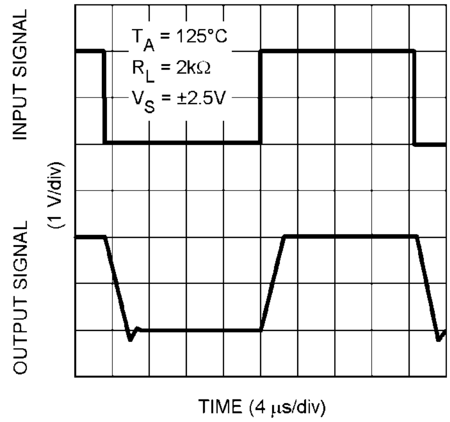
**Non-Inverting Large Signal Pulse Response**

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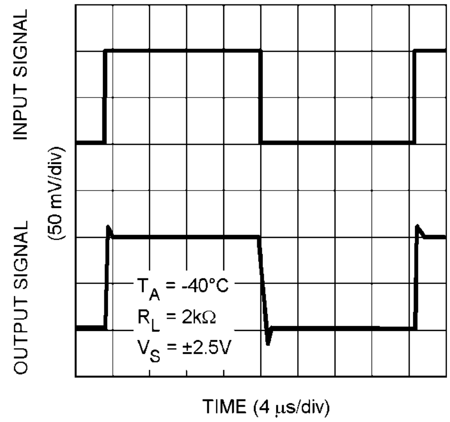
**Non-Inverting Small Signal Pulse Response**

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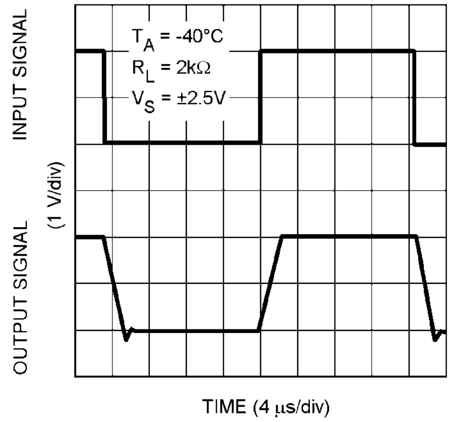
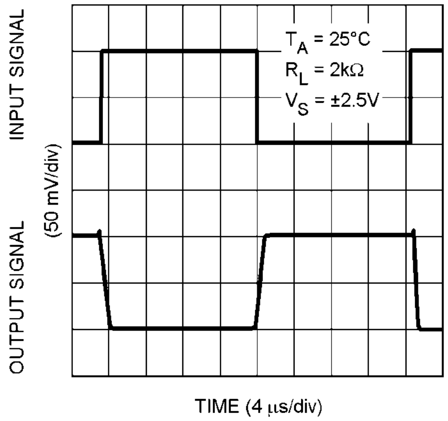
**Non-Inverting Large Signal Pulse Response**



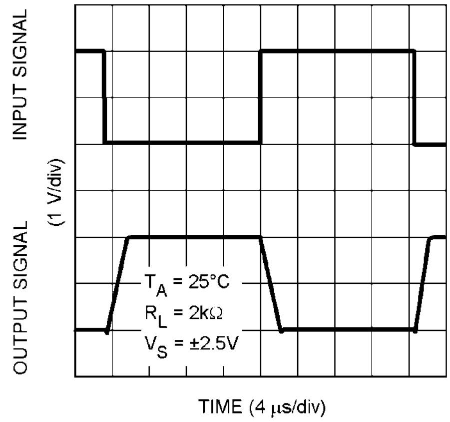

30185510

**Inverting Small Signal Pulse Response**



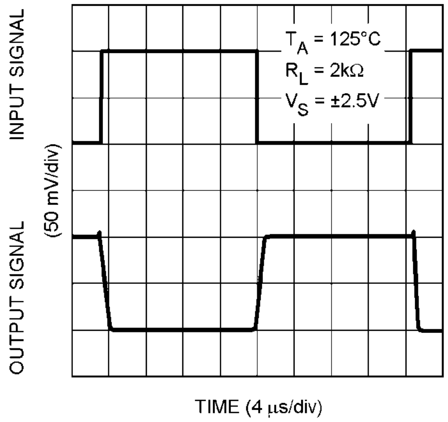

30185511

**Inverting Large Signal Pulse Response**



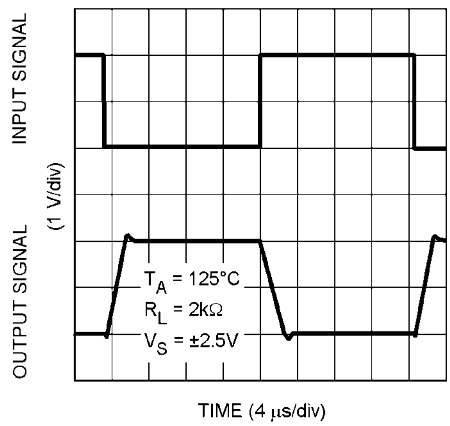

30185514

**Inverting Small Signal Pulse Response**




30185512

**Inverting Large Signal Pulse Response**

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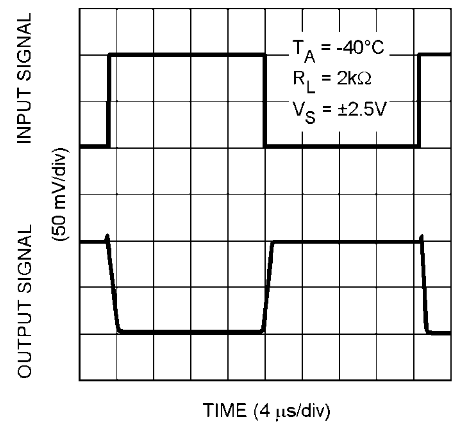
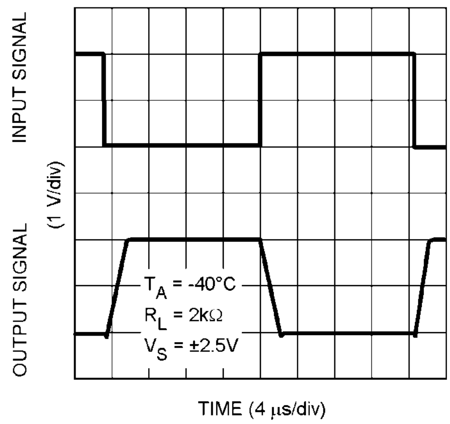
**Inverting Small Signal Pulse Response**




30185513

**Inverting Large Signal Pulse Response**

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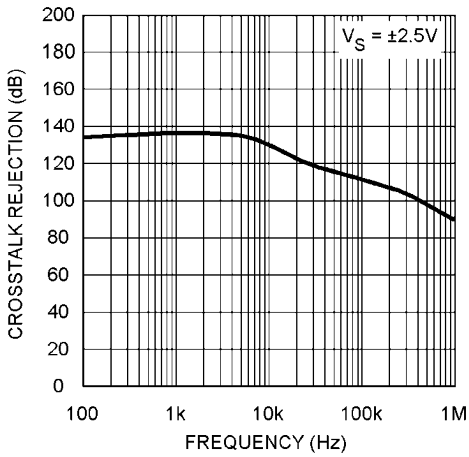
**Crosstalk Rejection vs. Frequency**

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# Application Section

### LMV601/LMV602/LMV604

The LMV601/LMV602/LMV604 family of amplifiers features low voltage, low power, and rail-to-rail output operational amplifiers designed for low voltage portable applications. The family is designed using all CMOS technology. This results in an ultra low input bias current. The LMV601 has a shutdown option, which can be used in portable devices to increase battery life.

A simplified schematic of the LMV601/LMV602/LMV604 family of amplifiers is shown in *Figure 1*. The PMOS input differential pair allows the input to include ground. The output of this differential pair is connected to the Class AB turnaround stage. This Class AB turnaround has a lower quiescent current, compared to regular turnaround stages. This results in lower offset, noise, and power dissipation, while slew rate equals that of a conventional turnaround stage. The output of the Class AB turnaround stage provides gate voltage to the complementary common-source transistors at the output stage. These transistors enable the device to have rail-to-rail output.

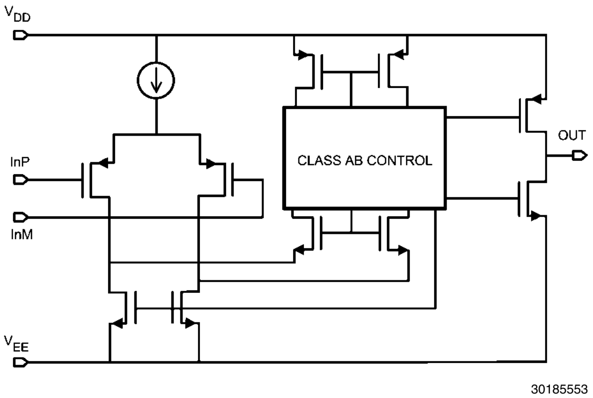


**FIGURE 1. Simplified Schematic**

### CLASS AB TURNAROUND STAGE AMPLIFIER

This patented folded cascode stage has a combined class AB amplifier stage, which replaces the conventional folded cascode stage. Therefore, the class AB folded cascode stage runs at a much lower quiescent current compared to conventional folded cascode stages. This results in significantly smaller offset and noise contributions. The reduced offset and noise contributions in turn reduce the offset voltage level and the voltage noise level at the input of the LMV601/LMV602/LMV604. Also the lower quiescent current results in a high open-loop gain for the amplifier. The lower quiescent current does not affect the slew rate of the amplifier nor its ability to handle the total current swing coming from the input stage.

The input voltage noise of the device at low frequencies, below 1kHz, is slightly higher than devices with a BJT input stage; However the PMOS input stage results in a much lower input bias current and the input voltage noise drops at frequencies above 1kHz.

### SAMPLE AND HOLD CIRCUIT

The lower input bias current of the LMV601 results in a very high input impedance. The output impedance when the device is in shutdown mode is quite high. These high impedances, along with the ability of the shutdown pin to be derived from a separate power source, make LMV601 a good choice for sample and hold circuits. The sample clock should be connected to the shutdown pin of the amplifier to rapidly turn the device on or off.

*Figure 2* shows the schematic of a simple sample and hold circuit. When the sample clock is high the first amplifier is in normal operation mode and the second amplifier acts as a buffer. The capacitor, which appears as a load on the first amplifier, will be charging at this time. The voltage across the capacitor is that of the non-inverting input of the first amplifier since it is connected as a voltage-follower. When the sample clock is low the first amplifier is shut off, bringing the output impedance to a high value. The high impedance of this output, along with the very high impedance on the input of the second amplifier, prevents the capacitor from discharging. There is very little voltage droop while the first amplifier is in shutdown mode. The second amplifier, which is still in normal operation mode and is connected as a voltage follower, also provides the voltage sampled on the capacitor at its output.

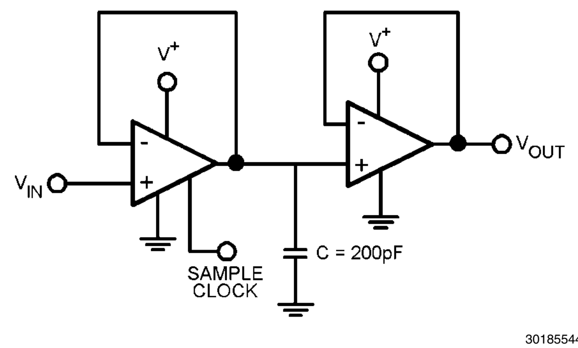


**FIGURE 2. Sample and Hold Circuit**

### SHUTDOWN FEATURE

The LMV601 is capable of being turned off in order to conserve power and increase battery life in portable devices. Once in shutdown mode the supply current is drastically reduced, 1µA maximum, and the output will be "tri-stated."

The device will be disabled when the shutdown pin voltage is pulled low. The shutdown pin should never be left unconnected. Leaving the pin floating will result in an undefined operation mode and the device may oscillate between shutdown and active modes.

The LMV601 typically turns on 2.8µs after the shutdown voltage is pulled high. The device turns off in less than 400ns after shutdown voltage is pulled low. *Figure 3* and *Figure 4* show the turn-on and turn-off time of the LMV601, respectively. In order to reduce the effect of the capacitance added to the circuit by the scope probe, in the turn-off time circuit a resistive load of 600Ω is added. *Figure 5* and *Figure 6* show the test circuits used to obtain the two plots.

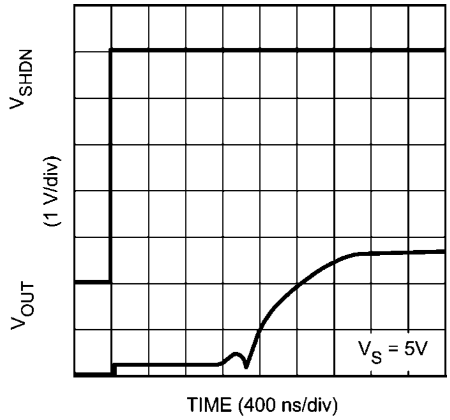


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**FIGURE 3. Turn-on Time**

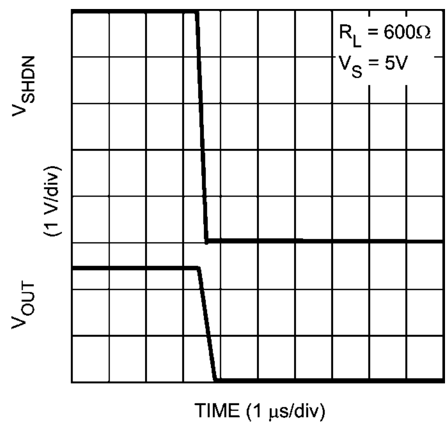


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**FIGURE 4. Turn-off Time**

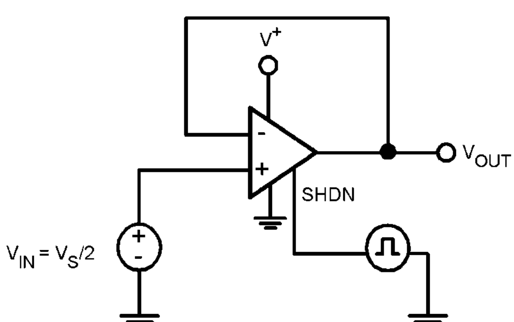


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**FIGURE 5. Turn-on Time**

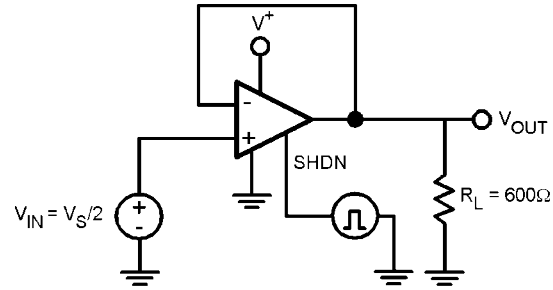


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**FIGURE 6. Turn-off Time**

## LOW INPUT BIAS CURRENT

The LMV601/LMV602/LMV604 Amplifiers have a PMOS input stage. As a result, they will have a much lower input bias current than devices with BJT input stages. This feature makes these devices ideal for sensor circuits. A typical curve of the input bias current of the LMV601 is shown in *Figure 7*.

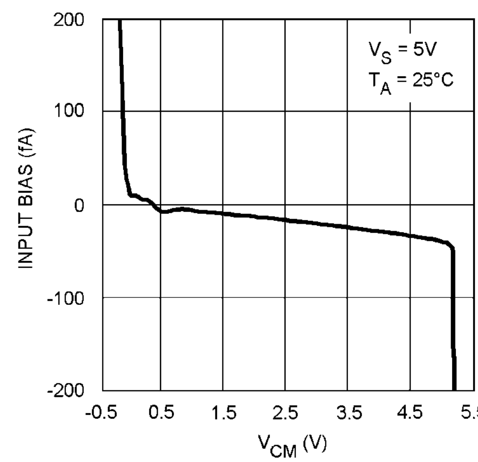


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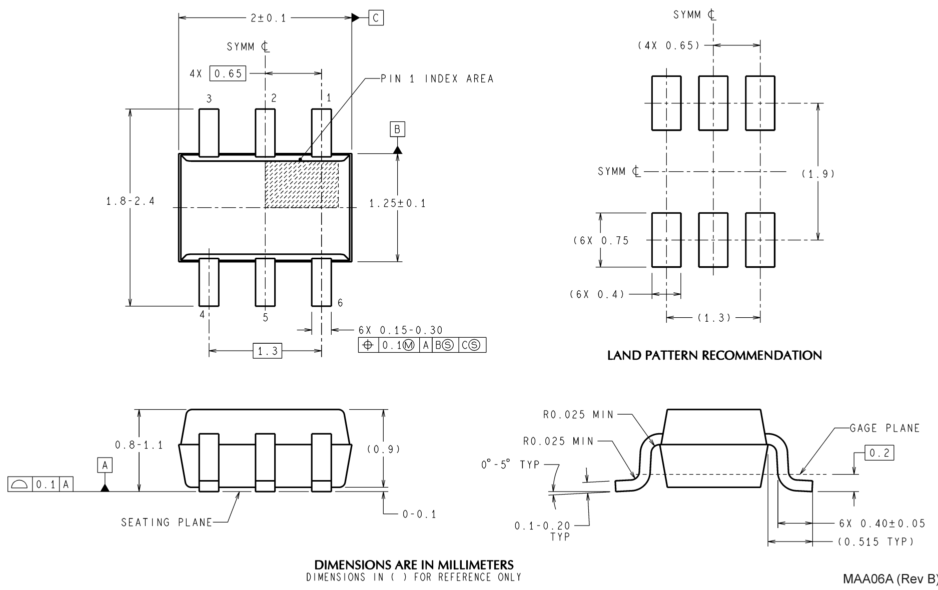
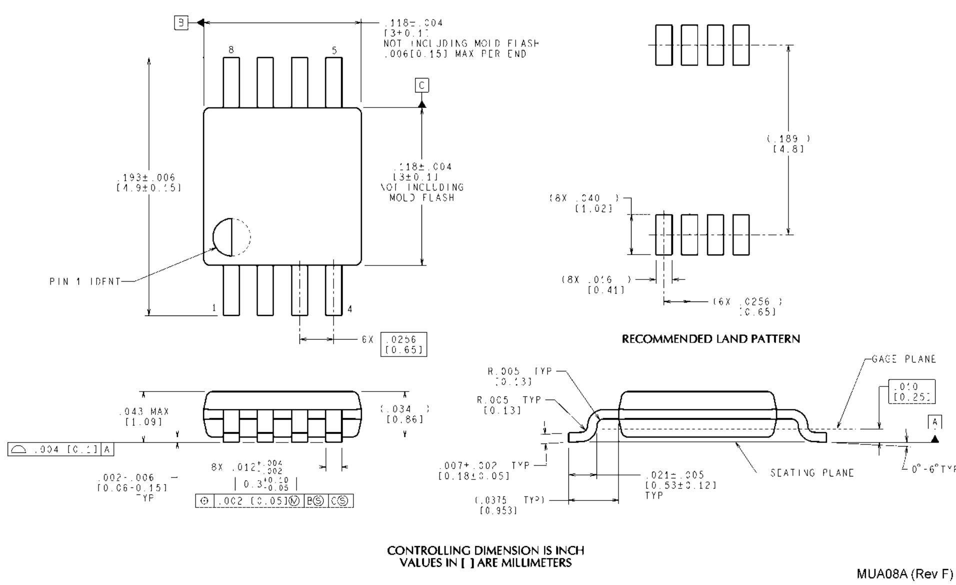
**FIGURE 7. Input Bias Current vs. $V_{CM}$**

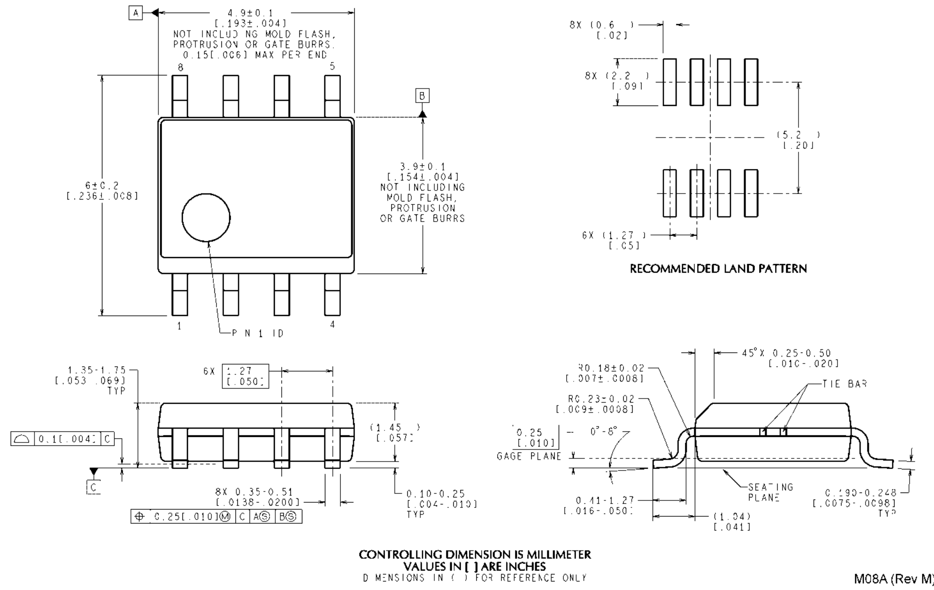
## Physical Dimensions inches (millimeters) unless otherwise noted



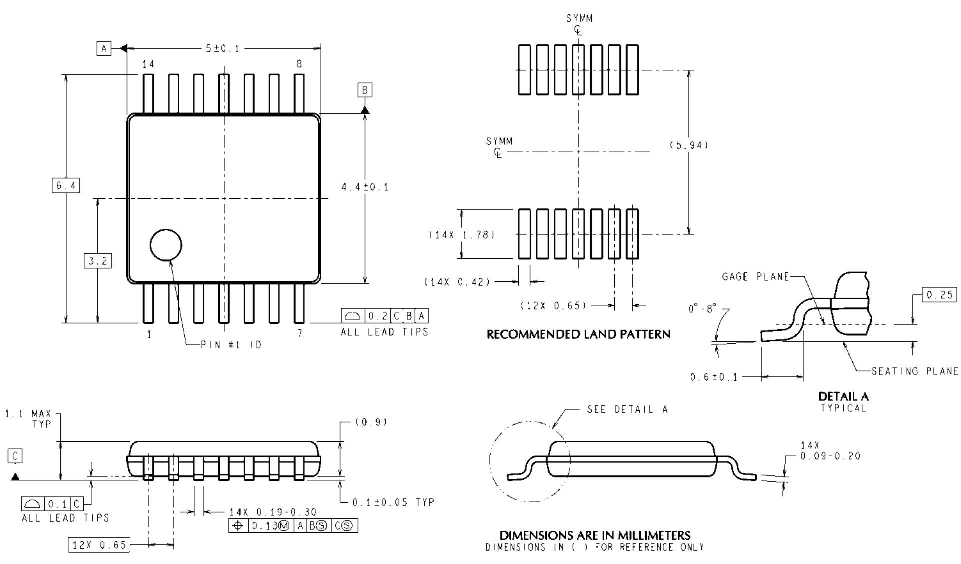

**6-Pin SC70**
**NS Package Number MAA06A**



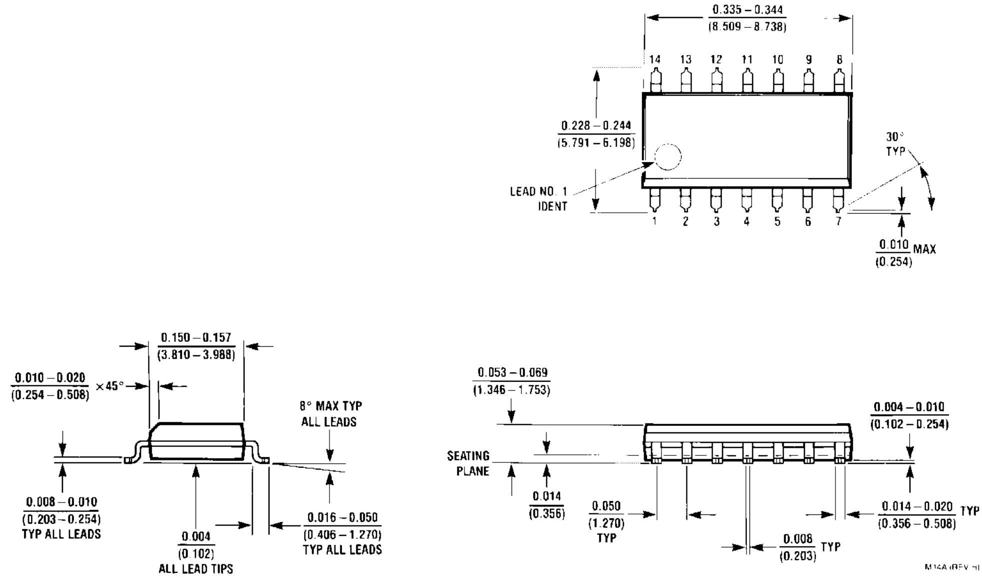

**8-Pin MSOP**
**NS Package Number MUA08A**




**8-Pin SOIC**
**NS Package Number M08A**




**14-Pin TSSOP**
**NS Package Number MTC14**




**14-Pin SOIC**
**NS Package Number M14A**

# Notes

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| DLP® Products | www.dlp.com | Consumer Electronics | www.ti.com/consumer-apps |
| DSP | dsp.ti.com | Energy and Lighting | www.ti.com/energy |
| Clocks and Timers | www.ti.com/clocks | Industrial | www.ti.com/industrial |
| Interface | interface.ti.com | Medical | www.ti.com/medical |
| Logic | logic.ti.com | Security | www.ti.com/security |
| Power Mgmt | power.ti.com | Space, Avionics and Defense | www.ti.com/space-avionics-defense |
| Microcontrollers | microcontroller.ti.com | Video and Imaging | www.ti.com/video |
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