National Semiconductor

February 2004

# LMH6640
# TFT-LCD Single, 16V RRO High Output Current Operational Amplifier



## General Description

The LMH6640 is a voltage feedback operational amplifier with rail-to-rail output drive capability of 110 mA. This, in combination with a supply range of up to 16V, makes the LMH6640 suitable for $V_{COM}$ driver applications in TFT panels. The input common mode voltage range extends to 0.3V below $V^-$ and to within 0.9V of $V^+$, makes the LMH6640 a true single supply op-amp. The output voltage range extends to within 100 mV of either supply rail providing the user with a large dynamic range. Employing National's patented VIP10HV process, the LMH6640 delivers a bandwidth of 190 MHz at a current consumption of only 4 mA. The LMH6640 offers a slew rate of 170 V/µs resulting in a large signal bandwidth of approximately 35 MHz. Special precautions have been taken to ensure device stability under all operating voltages and loads. The result is a very well behaved frequency response characteristic for gain settings, including +1.

## Features

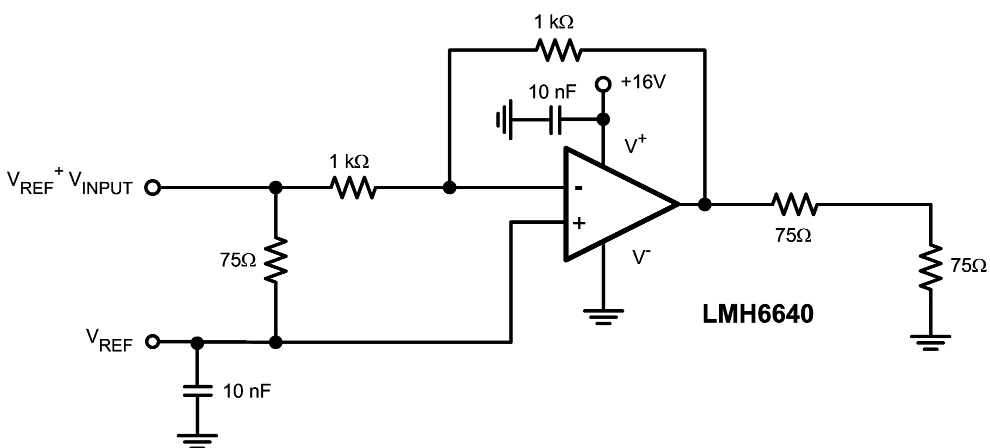
($V_S$ = 16V, $R_L$= 2 kΩ to $V^+/2$, Typical Values Unless Specified)

- Output voltage swing — 100 mV from rails
- Input common mode voltage — −0.3V to 15.1V
- Supply current (no load) — 4 mA
- Linear output current — ±110 mA
- Supply voltage range — 4.5V to 16V
- Unity gain stable
- −3 dB BW ($A_V$ = +1) — 190 MHz
- Slew rate — 170 V/µs
- Output resistance (closed loop 1 MHz) — 0.3Ω
- Total Harmonic Distortion (f = 5 MHz) — −64 dBc
- Excellent overdrive recovery
- Differential gain — 0.12%
- Differential phase — 0.12˚
- SOT23-5 package

## Applications

- TFT panel $V_{COM}$ Driver

## Typical Application

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**Typical Single Supply Schematic**

 DS200862 

## 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) | |
| Human Body Model | 2 KV |
| Machine Model | 200V |
| $V_{IN}$ Differential | ±2.5V |
| Input Current | ±10 mA |
| Supply Voltages ($V^+ - V^-$) | 18V |
| Voltage at Input/Output Pins | $V^+$ +0.8V, $V^-$ −0.8V |
| Storage Temperature Range | −65˚C to +150˚C |
| Junction Temperature (Note 4) | +150˚C |
| Soldering Information | |
| Infrared or Convection (20 sec.) | 235˚C |
| Wave Soldering (10 sec.) | 260˚C |

## Operating Ratings (Note 3)

| | |
|---|---|
| Supply Voltage ($V^+ - V^-$) | 4.5V to 16V |
| Operating Temperature Range (Note 4) | −40˚C to +85˚C |
| Package Thermal Resistance (Note 4) | |
| 5-Pin SOT23 | 265˚C/W |

## 5V Electrical Characteristics

Unless otherwise specified, All limits guaranteed for $T_J$ = 25˚C, $V^+$ = 5V, $V^-$ = 0V, $V_O = V_{CM} = V^+/2$ and $R_L$ = 2 kΩ to $V^+/2$. **Boldface** limits apply at temperature extremes. (Note 9)

| Symbol | Parameter | Conditions | | Min (Note 6) | Typ (Note 5) | Max (Note 6) | Units |
|---|---|---|---|---|---|---|---|
| BW | −3 dB Bandwidth | $A_V$ = +1 ($R_L$ = 100Ω) | | | 147 | | MHz |
| | | $A_V$ = −1 ($R_L$ = 100Ω) | | | 58 | | |
| $BW_{0.1\ dB}$ | 0.1 dB Gain Flatness | $A_V$ = −3 | | | 18 | | MHz |
| LSBW | -3 dB Bandwidth | $A_V$ = +1, $V_O$ = 2 $V_{PP}$ ($R_L$ = 100Ω) | | | 32 | | MHz |
| GBW | Gain Bandwidth Product | $A_V$ = +1, ($R_L$ = 100Ω) | | | 59 | | MHz |
| SR | Slew Rate (Note 8) | $A_V$ = −1 | | | 170 | | V/μs |
| $e_n$ | Input Referred Voltage Noise | | f = 10 kHz | | 19 | | $nV/\sqrt{Hz}$ |
| | | | f = 1 MHz | | 10 | | |
| $i_n$ | Input Referred Current Noise | | f = 10 kHz | | 1.3 | | $pA/\sqrt{Hz}$ |
| | | | f = 1 MHz | | 0.9 | | |
| THD | Total Harmonic Distortion | f = 5 MHz, $V_O$ = 2 $V_{PP}$, $A_V$ = +2<br>$R_L$ = 1 kΩ to $V^+/2$ | | | −65 | | dBc |
| $t_s$ | Settling Time | $V_O$ = 2 $V_{PP}$, ±0.1%, $A_V$ = −1 | | | 35 | | ns |
| $V_{OS}$ | Input Offset Voltage | | | | 1 | 5<br>**7** | mV |
| $I_B$ | Input Bias Current (Note 7) | | | | −1.2 | −2.6<br>**−3.25** | μA |
| $I_{OS}$ | Input Offset Current | | | | 34 | 800<br>**1400** | nA |
| CMVR | Common Mode Input Voltage Range | CMRR ≥ 50 dB | | | −0.3 | −0.2<br>**−0.1** | V |
| | | | | 4.0<br>**3.6** | 4.1 | | |
| CMRR | Common Mode Rejection Ratio | $V^- \le V_{CM} \le V^+$ −1.5V | | 72 | 90 | | dB |
| $A_{VOL}$ | Large Signal Voltage Gain | $V_O$ = 4 $V_{PP}$, $R_L$ = 2 kΩ to $V^+/2$ | | 86<br>**82** | 95 | | dB |
| | | $V_O$ = 3.75 $V_{PP}$, $R_L$ = 150Ω to $V^+/2$ | | 74<br>**70** | 78 | | |
| $V_O$ | Output Swing High | $R_L$ = 2 kΩ to $V^+/2$ | | 4.90 | 4.94 | | V |
| | | $R_L$ = 150Ω to $V^+/2$ | | 4.75 | 4.80 | | |
| | Output Swing Low | $R_L$ = 2 kΩ to $V^+/2$ | | | 0.06 | 0.10 | |
| | | $R_L$ = 150Ω to $V^+/2$ | | | 0.20 | 0.25 | |

## 5V Electrical Characteristics (Continued)

Unless otherwise specified, All limits guaranteed for $T_J = 25^\circ C$, $V^+ = 5V$, $V^- = 0V$, $V_O = V_{CM} = V^+/2$ and $R_L = 2\ k\Omega$ to $V^+/2$. **Boldface** limits apply at temperature extremes. (Note 9)

| Symbol | Parameter | Conditions | Min (Note 6) | Typ (Note 5) | Max (Note 6) | Units |
|---|---|---|---|---|---|---|
| $I_{SC}$ | Output Short Circuit Current (Note 3) | Sourcing to $V^+/2$ | 100 **75** | 130 | | mA |
| | | Sinking from $V^+/2$ | 100 **70** | 130 | | |
| $I_{OUT}$ | Output Current | $V_O$ = 0.5V from either Supply | | +75/−90 | | mA |
| PSRR | Power Supply Rejection Ratio | $4V \leq V^+ \leq 6V$ | 72 | 80 | | dB |
| $I_S$ | Supply Current | No Load | | 3.7 | 5.5 **8.0** | mA |
| $R_{IN}$ | Common Mode Input Resistance | $A_V = +1$, f = 1 kHz, $R_S = 1\ M\Omega$ | | 15 | | MΩ |
| $C_{IN}$ | Common Mode Input Capacitance | $A_V = +1$, $R_S = 100\ k\Omega$ | | 1.7 | | pF |
| $R_{OUT}$ | Output Resistance Closed Loop | $R_F = 10\ k\Omega$, f = 1 kHz, $A_V = -1$ | | 0.1 | | Ω |
| | | $R_F = 10\ k\Omega$, f = 1 MHz, $A_V = -1$ | | 0.4 | | |
| DG | Differential Gain | NTSC, $A_V = +2$ $R_L = 150\Omega$ to $V^+/2$ | | 0.13 | | % |
| DP | Differential Phase | NTSC, $A_V = +2$ $R_L = 150\Omega$ to $V^+/2$ | | 0.10 | | deg |

## 16V Electrical Characteristics

Unless otherwise specified, All limits guaranteed for $T_J = 25^\circ C$, $V^+ = 16V$, $V^- = 0V$, $V_O = V_{CM} = V^+/2$ and $R_L = 2\ k\Omega$ to $V^+/2$. **Boldface** limits apply at temperature extremes. (Note 9)

| Symbol | Parameter | Conditions | Min (Note 6) | Typ (Note 5) | Max (Note 6) | Units |
|---|---|---|---|---|---|---|
| BW | −3 dB Bandwidth | $A_V = +1$ ($R_L = 100\Omega$) | | 190 | | MHz |
| | | $A_V = -1$ ($R_L = 100\Omega$) | | 60 | | |
| $BW_{0.1\ dB}$ | 0.1 dB Gain Flatness | $A_V = -2.7$ | | 20 | | MHz |
| LSBW | -3 dB Bandwidth | $A_V = +1$, $V_O = 2\ V_{PP}$ ($R_L = 100\Omega$) | | 35 | | MHz |
| GBW | Gain Bandwidth Product | $A_V = +1$, ($R_L = 100\Omega$) | | 62 | | MHz |
| SR | Slew Rate (Note 8) | $A_V = -1$ | | 170 | | V/μs |
| $e_n$ | Input Referred Voltage Noise | f = 10 kHz | | 20 | | $nV/\sqrt{Hz}$ |
| | | f = 1 MHz | | 10 | | |
| $i_n$ | Input Referred Current Noise | f = 10 kHz | | 1.0 | | $pA/\sqrt{Hz}$ |
| | | f = 1 MHz | | 0.9 | | |
| THD | Total Harmonic Distortion | f = 5 MHz, $V_O = 2\ V_{PP}$, $A_V = +2$ $R_L = 1\ k\Omega$ to $V^+/2$ | | −64 | | dBc |
| $t_s$ | Settling Time | $V_O = 2\ V_{PP}$, ±0.1%, $A_V = -1$ | | 35 | | ns |
| $V_{OS}$ | Input Offset Voltage | | | 1 | 5 **7** | mV |
| $I_B$ | Input Bias Current (Note 7) | | | −1 | −2.6 **−3.5** | μA |
| $I_{OS}$ | Input Offset Current | | | 34 | 800 **1800** | nA |
| CMVR | Common Mode Input Voltage Range | CMRR ≥ 50 dB | | −0.3 | −0.2 **−0.1** | V |
| | | | 15.0 **14.6** | 15.1 | | |
| CMRR | Common Mode Rejection Ratio | $V^- \leq V_{CM} \leq V^+ - 1.5V$ | 72 | 90 | | dB |

## 16V Electrical Characteristics (Continued)

Unless otherwise specified, All limits guaranteed for $T_J$ = 25˚C, $V^+$ = 16V, $V^-$ = 0V, $V_O$ = $V_{CM}$ = $V^+/2$ and $R_L$ = 2 kΩ to $V^+/2$. **Boldface** limits apply at temperature extremes. (Note 9)

| Symbol | Parameter | Conditions | Min (Note 6) | Typ (Note 5) | Max (Note 6) | Units |
|---|---|---|---|---|---|---|
| $A_{VOL}$ | Large Signal Voltage Gain | $V_O$ = 15 $V_{PP}$, $R_L$ = 2 kΩ to $V^+/2$ | 86<br>**82** | 95 | | dB |
| | | $V_O$ = 14 $V_{PP}$, $R_L$ = 150Ω to $V^+/2$ | 74<br>**70** | 78 | | |
| $V_O$ | Output Swing High | $R_L$ = 2 kΩ to $V^+/2$ | 15.85 | 15.90 | | V |
| | | $R_L$ = 150Ω to $V^+/2$ | 15.45 | 15.78 | | |
| | Output Swing Low | $R_L$ = 2 kΩ to $V^+/2$ | | 0.10 | 0.15 | |
| | | $R_L$ = 150Ω to $V^+/2$ | | 0.21 | 0.55 | |
| $I_{SC}$ | Output Short Circuit Current (Note 3) | Sourcing to $V^+/2$ | 60<br>**30** | 95 | | mA |
| | | Sinking from $V^+/2$ | 50<br>**15** | 75 | | |
| $I_{OUT}$ | Output Current | $V_O$ = 0.5V from either Supply | | ±110 | | mA |
| PSRR | Power Supply Rejection Ratio | 15V ≤ $V^+$ ≤ 17V | 72 | 80 | | dB |
| $I_S$ | Supply Current | No Load | | 4 | 6.5<br>**7.8** | mA |
| $R_{IN}$ | Common Mode Input Resistance | $A_V$ = +1, f = 1 kHz, $R_S$ = 1 MΩ | | 32 | | MΩ |
| $C_{IN}$ | Common Mode Input Capacitance | $A_V$ = +1, $R_S$ = 100 kΩ | | 1.7 | | pF |
| $R_{OUT}$ | Output Resistance Closed Loop | $R_F$ = 10 kΩ, f = 1 kHz, $A_V$ = –1 | | 0.1 | | Ω |
| | | $R_F$ = 10 kΩ, f = 1 MHz, $A_V$ = –1 | | 0.3 | | |
| DG | Differential Gain | NTSC, $A_V$ = +2<br>$R_L$ = 150Ω to $V^+/2$ | | 0.12 | | % |
| DP | Differential Phase | NTSC, $A_V$ = +2<br>$R_L$ = 150Ω to $V^+/2$ | | 0.12 | | deg |

**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, 1.5 kΩ in series with 100 pF. Machine Model, 0Ω in series with 200 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 Short circuit test is a momentary test. Output short circuit duration is infinite for $V_S$ < 6V at room temperature and below. For $V_S$ > 6V, allowable short circuit duration is 1.5 ms.

**Note 4:** The maximum power dissipation is a function of $T_{J(MAX)}$, $\theta_{JA}$ , 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 onto a PC board.

**Note 5:** Typical Values represent the most likely parametric norm.

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

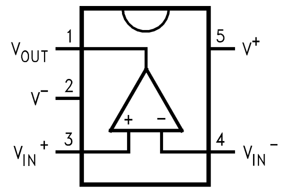
**Note 7:** Positive current corresponds to current flowing into the device.

**Note 8:** Slew rate is the average of the rising and falling slew rates

**Note 9:** 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 Diagram

**5-Pin SOT23**




**Top View**

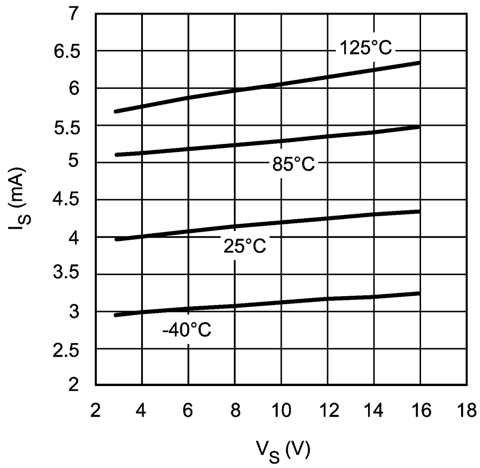
## Ordering Information

| Package | Part Number | Package Marking | Transport Media | NSC Drawing |
|---|---|---|---|---|
| 5-Pin SOT23 | LMH6640MF | AH1A | 1k Units Tape and Reel | MF05A |
| | LMH6640MFX | | 3k Units Tape and Reel | |

## Typical Performance Characteristics

At $T_J$ = 25˚C, $V^+$ = 16 V, $V^-$ = 0V, $R_F$ = 330Ω for $A_V$= +2, $R_F$ = 1 kΩ for $A_V$ = −1. $R_L$ tied to $V^+$/2. Unless otherwise specified.

**$I_S$ vs. $V_S$ for Various Temperature**

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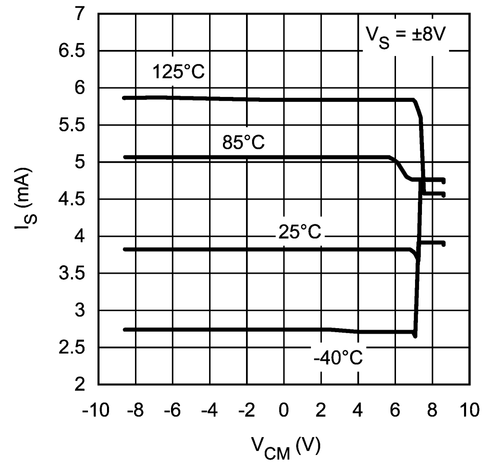
**$I_S$ vs. $V_{CM}$ for Various Temperature**

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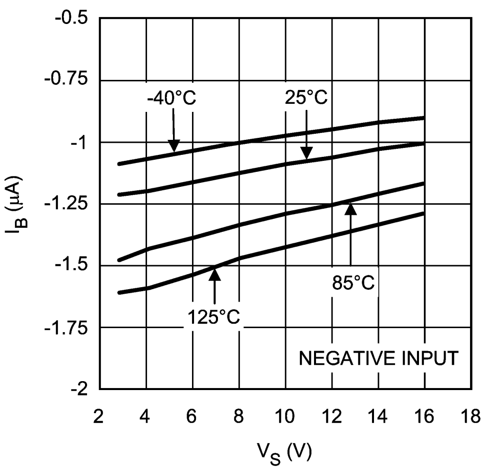
**$I_B$ vs. $V_S$ for Various Temperature**

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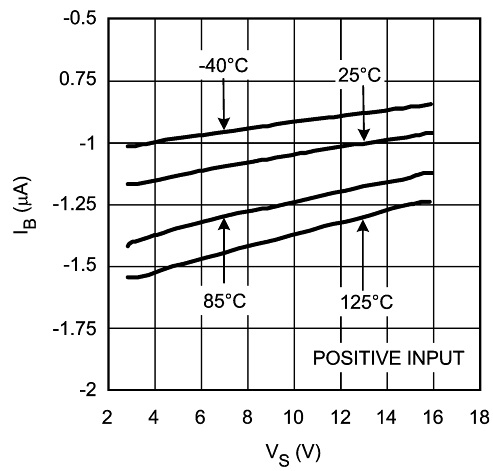
**$I_B$ vs. $V_S$ for Various Temperature**

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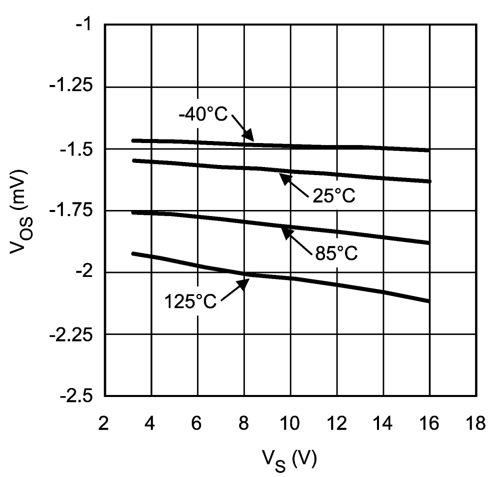
**$V_{OS}$ vs. $V_S$ for Various Temperature (Typical Unit)**

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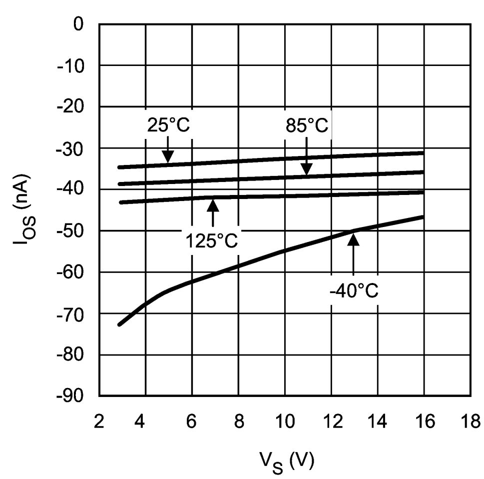
**$I_{OS}$ vs. $V_S$ for Various Temperature**

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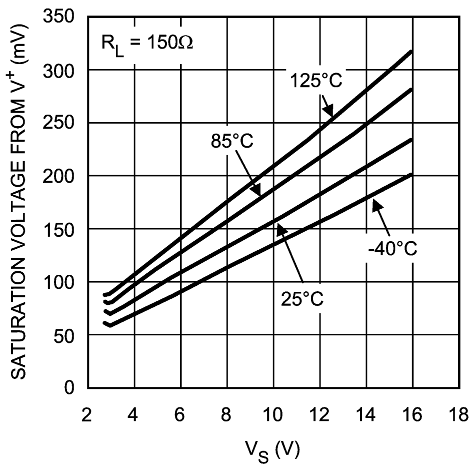
## Typical Performance Characteristics At $T_J$ = 25˚C, $V^+$ = 16 V, $V^-$ = 0V, $R_F$ = 330Ω for $A_V$= +2, $R_F$ = 1 kΩ for $A_V$ = −1. $R_L$ tied to $V^+/2$. Unless otherwise specified. (Continued)

**Positive Output Saturation Voltage vs. $V_S$ for Various Temperature**

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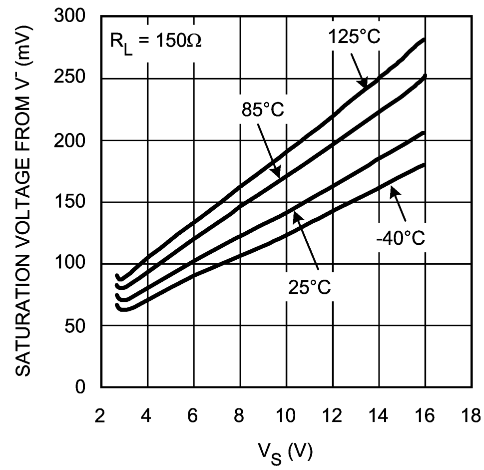
**Negative Output Saturation Voltage vs. $V_S$ for Various Temperature**

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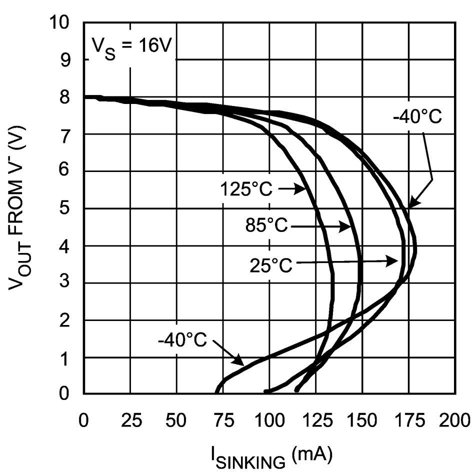
**Output Sinking Saturation Voltage vs. $I_{SINKING}$ for Various Temperature**

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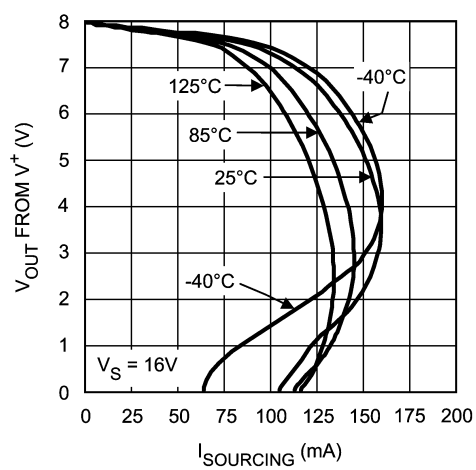
**Output Sourcing Saturation Voltage vs. $I_{SOURCING}$ for Various Temperature**

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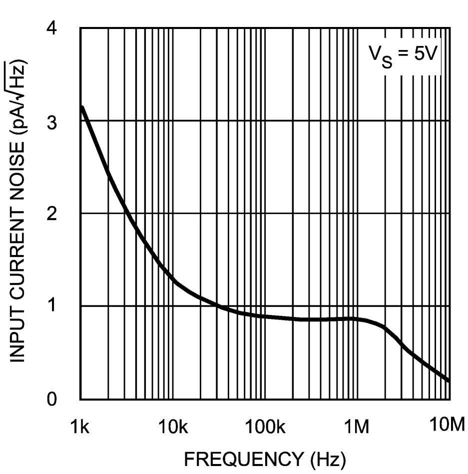
**Input Current Noise vs. Frequency**

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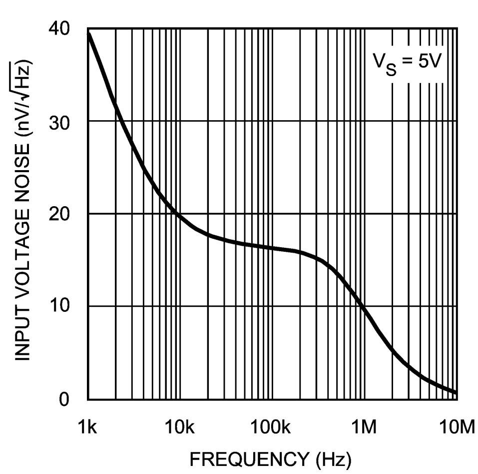
**Input Voltage Noise vs. Frequency**

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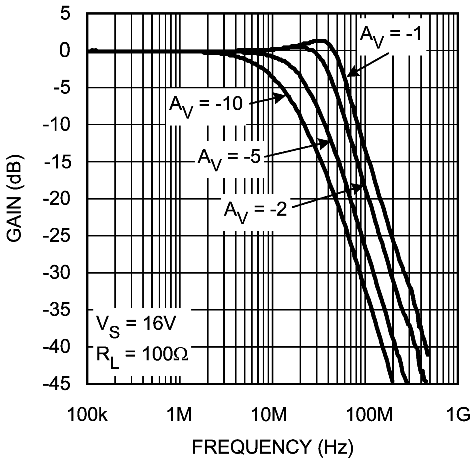
## Typical Performance Characteristics

At $T_J$ = 25˚C, $V^+$ = 16 V, $V^-$ = 0V, $R_F$ = 330Ω for $A_V$= +2, $R_F$ = 1 kΩ for $A_V$ = −1. $R_L$ tied to $V^+$/2. Unless otherwise specified. (Continued)

**Gain vs. Frequency Normalized ($P_{IN}$= −30 dBm)**

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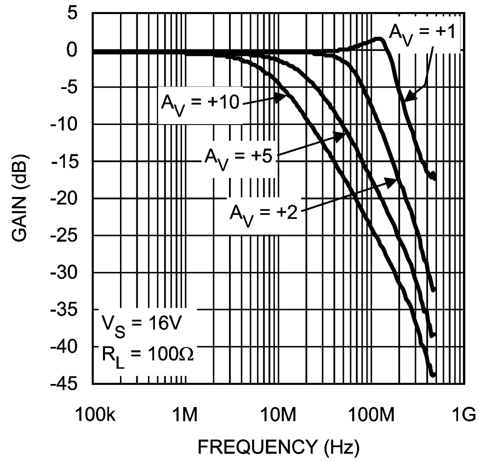
**Gain vs. Frequency Normalized ($P_{IN}$=−30dBm)**

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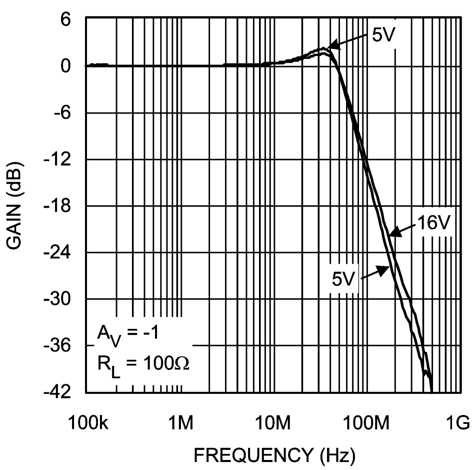
**Gain vs. Frequency for Various $V_S$ ($P_{IN}$ = −30 dBm)**

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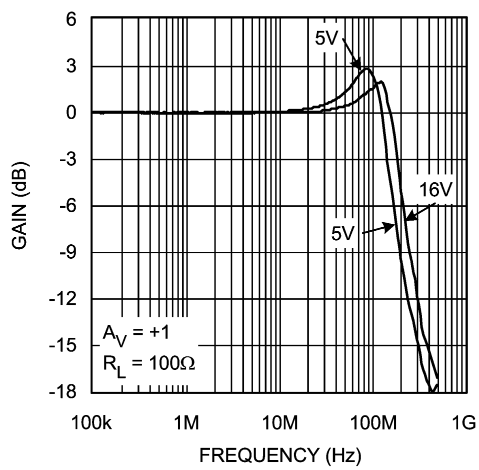
**Gain vs. Frequency for Various $V_S$ ($P_{IN}$ = −30 dBm)**

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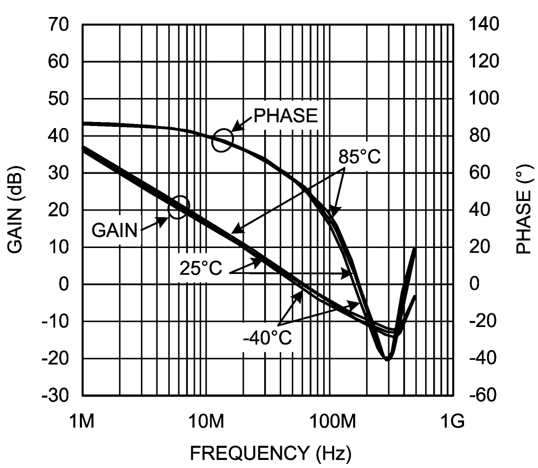
**Open Loop Gain & Phase vs. Frequency for Various Temperature ($P_{IN}$ = −30 dBm)**

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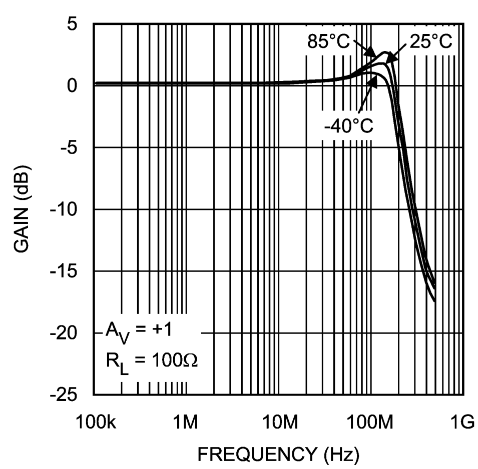
**Relative Gain vs. Frequency for Various Temperature ($P_{IN}$ = −10 dBm)**

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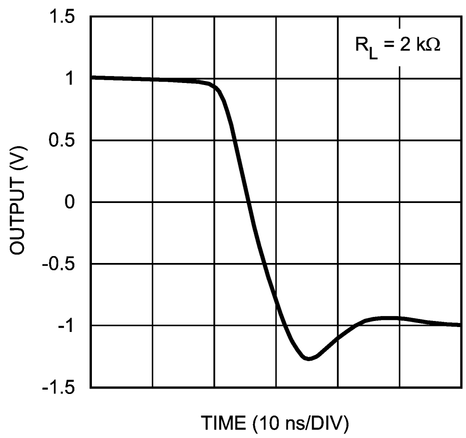
## Typical Performance Characteristics
At $T_J$ = 25˚C, $V^+$ = 16 V, $V^-$ = 0V, $R_F$ = 330Ω for $A_V$= +2, $R_F$ = 1 kΩ for $A_V$ = −1. $R_L$ tied to $V^+/2$. Unless otherwise specified. (Continued)

**Large Signal Transition**

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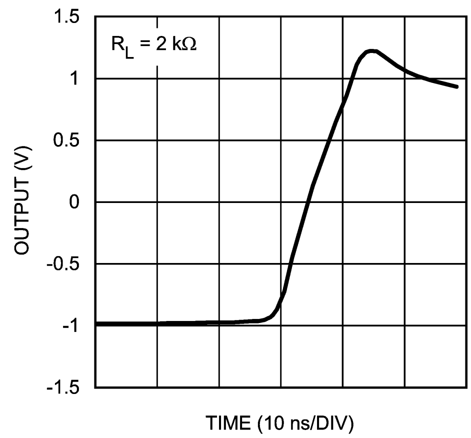
**Large Signal Transition**

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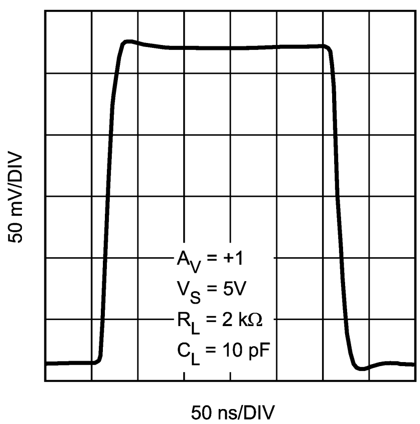
**Small Signal Pulse Response**

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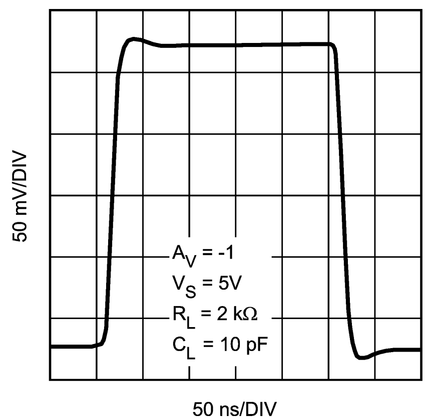
**Small Signal Pulse Response**

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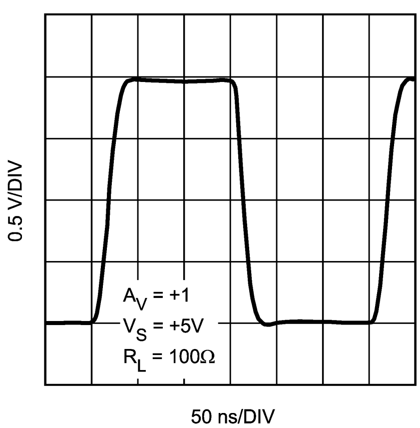
**Large Signal Pulse Response**

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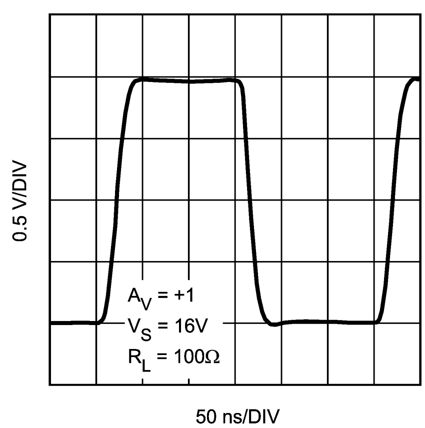
**Large Signal Pulse Response**

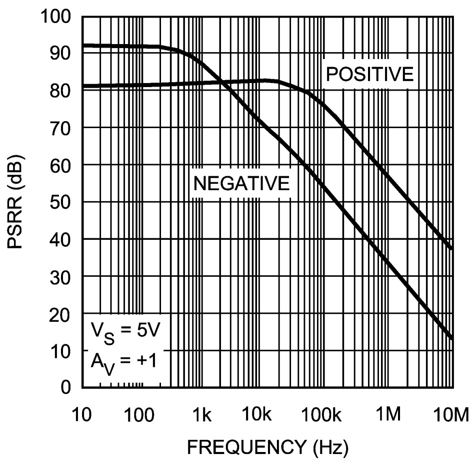



20086212

## Typical Performance Characteristics

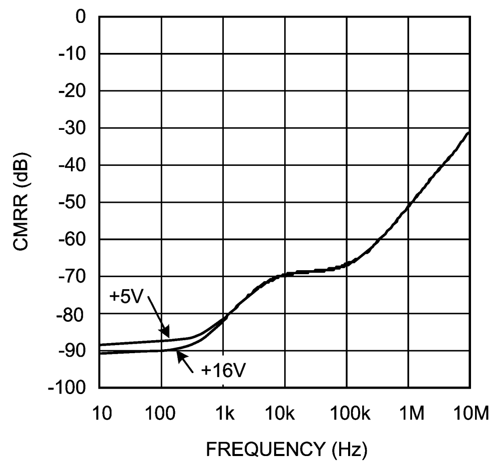
At $T_J$ = 25˚C, $V^+$ = 16 V, $V^-$ = 0V, $R_F$ = 330Ω for $A_V$= +2, $R_F$ = 1 kΩ for $A_V$ = −1. $R_L$ tied to $V^+/2$. Unless otherwise specified. (Continued)

**PSRR vs. Frequency**



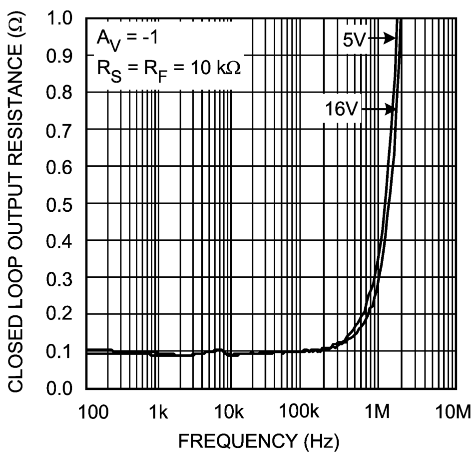

20086201

**CMRR vs. Frequency**



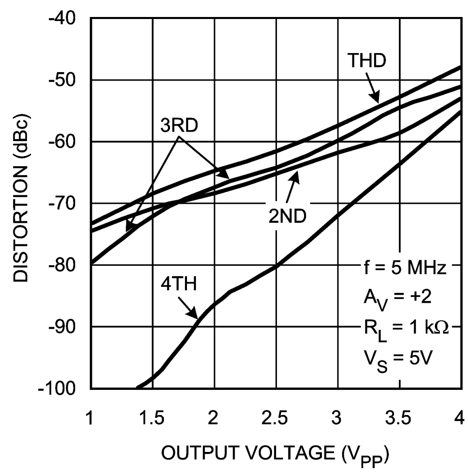

20086217

**Closed Loop Output Resistance vs. Frequency**



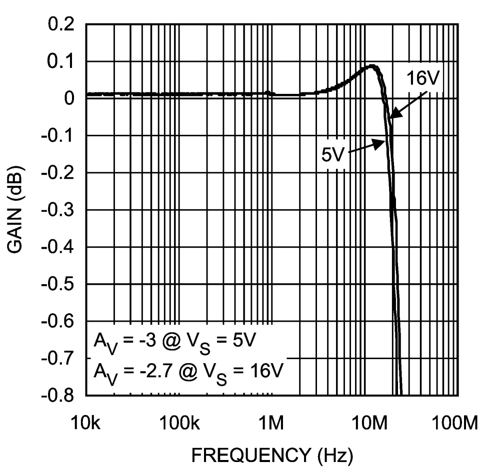

20086203

**Harmonic Distortion**



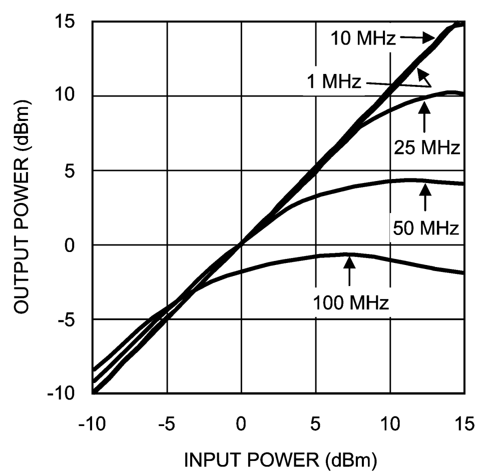

20086226

**0.1 dB Gain Flatness vs. Frequency Normalized**




20086202

**Output Power vs. Input Power**

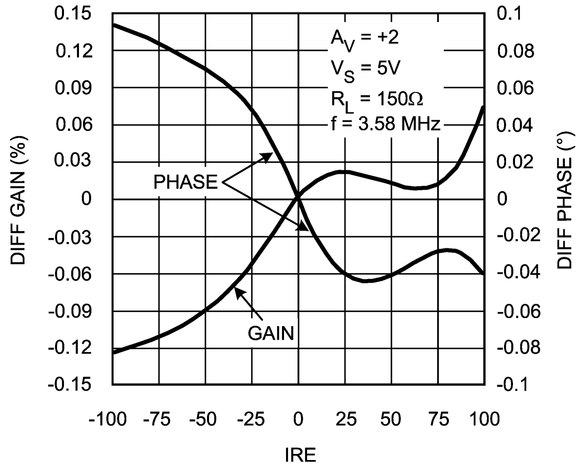



20086229

## Typical Performance Characteristics

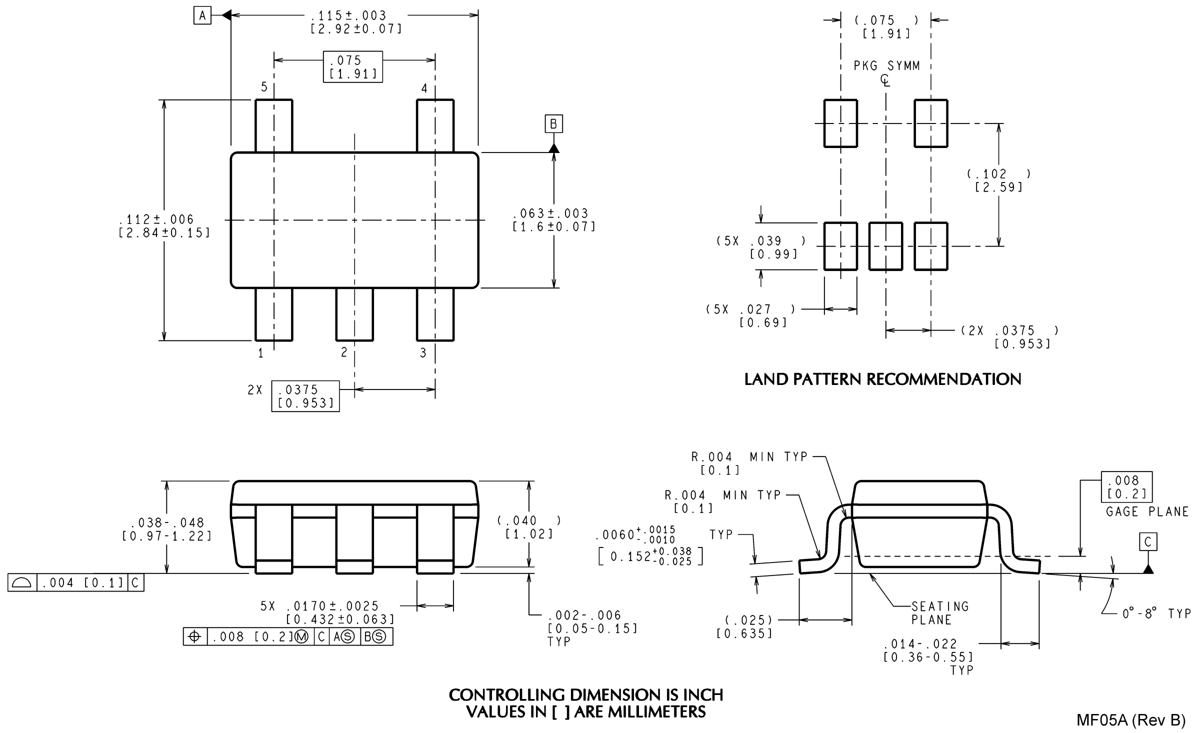
At $T_J$ = 25˚C, $V^+$ = 16 V, $V^-$ = 0V, $R_F$ = 330Ω for $A_V$= +2, $R_F$ = 1 kΩ for $A_V$ = −1. $R_L$ tied to $V^+/2$. Unless otherwise specified. (Continued)

**Differential Gain/Phase vs. IRE**




20086225

## Physical Dimensions inches (millimeters) unless otherwise noted




**5-Pin SOT23**
**NS Product Number MF05A**

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