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We are looking forward to setting up business relationship with you and hope to provide you with the best service and solution. Let us make a better world for our industry!


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# Low Power, Fully Differential Input/Output Amplifier/Driver Family

## FEATURES

- **Available with Adjustable Gain or Fixed Gain of 1, 2, 5 or 10**
- **±0.3% (Max) Gain Error from –40°C to 85°C**
- **3.5ppm/°C Gain Temperature Coefficient**
- **5ppm Gain Long Term Stability**
- **Fully Differential Input and Output**
- **$C_{LOAD}$ Stable up to 10,000pF**
- **Adjustable Output Common Mode Voltage**
- Rail-to-Rail Output Swing
- Low Supply Current: 1mA (Max)
- High Output Current: 10mA (Min)
- Specified on a Single 2.7V to ±5V Supply
- DC Offset Voltage <2.5mV (Max)
- Available in 8-Lead MSOP Package

## APPLICATIONS

- Differential Driver/Receiver
- Differential Amplification
- Single-Ended to Differential Conversion
- Level Shifting
- Trimmed Phase Response for Multichannel Systems



## DESCRIPTION

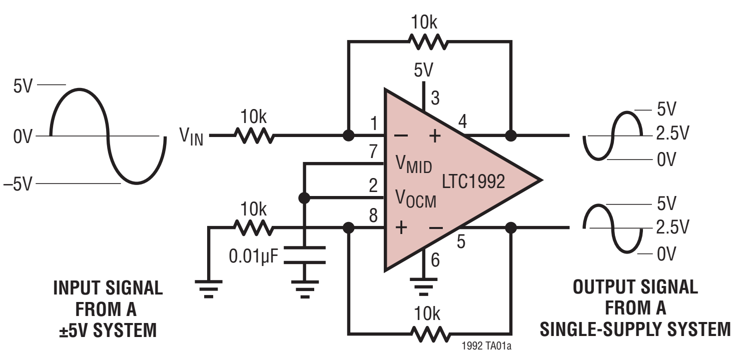
The LTC®1992 product family consists of five fully differential, low power amplifiers. The LTC1992 is an unconstrained fully differential amplifier. The LTC1992-1, LTC1992-2, LTC1992-5 and LTC1992-10 are fixed gain blocks (with gains of 1, 2, 5 and 10 respectively) featuring precision on-chip resistors for accurate and ultrastable gain. All of the LTC1992 parts have a separate internal common mode feedback path for outstanding output phase balancing and reduced second order harmonics. The $V_{OCM}$ pin sets the output common mode level independent of the input common mode level. This feature makes level shifting of signals easy.

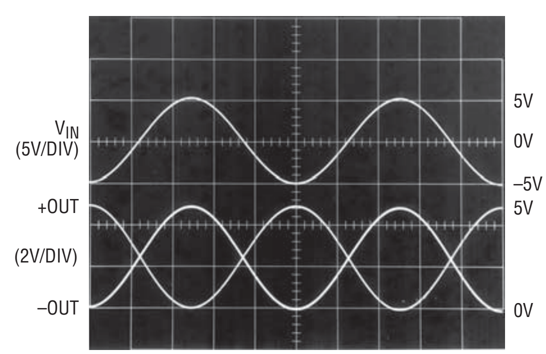
The amplifiers' differential inputs operate with signals ranging from rail-to-rail with a common mode level from the negative supply up to 1.3V from the positive supply. The differential input DC offset is typically 250μV. The rail-to-rail outputs sink and source 10mA. The LTC1992 is stable for all capacitive loads up to 10,000pF.

The LTC1992 can be used in single supply applications with supply voltages as low as 2.7V. It can also be used with dual supplies up to ±5V. The LTC1992 is available in an 8-pin MSOP package.

## TYPICAL APPLICATION

**Single-Supply, Single-Ended to Differential Conversion**



# ABSOLUTE MAXIMUM RATINGS

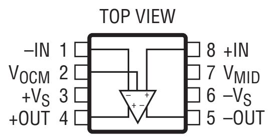
**(Note 1)**

Total Supply Voltage ($+V_S$ to $–V_S$) ............................. 12V
Maximum Voltage
on any Pin ................ $(–V_S – 0.3V) \le V_{PIN} \le (+V_S + 0.3V)$
Output Short-Circuit Duration (Note 3) ............ Indefinite
Operating Temperature Range (Note 5)
LTC1992CMS8/LTC1992-XCMS8/
LTC1992IMS8/LTC1992-XIMS8 ........... –40°C to 85°C
LTC1992HMS8/LTC1992-XHMS8 ...... –40°C to 125°C

Specified Temperature Range (Note 6)
LTC1992CMS8/LTC1992-XCMS8 ............. 0°C to 70°C
LTC1992IMS8/LTC1992-XIMS8 ........... –40°C to 85°C
LTC1992HMS8/LTC1992-XHMS8 ...... –40°C to 125°C
Storage Temperature Range ................. –65°C to 150°C
Lead Temperature (Soldering, 10 sec) ................... 300°C

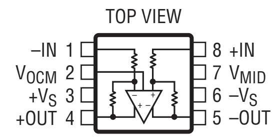
# PIN CONFIGURATION

LTC1992




MS8 PACKAGE
8-LEAD PLASTIC MSOP
$T_{JMAX} = 150°C$, $\theta_{JA} = 250°C/W$

LTC1992-X




MS8 PACKAGE
8-LEAD PLASTIC MSOP
$T_{JMAX} = 150°C$, $\theta_{JA} = 250°C/W$

# ORDER INFORMATION

| LEAD FREE FINISH | TAPE AND REEL | PART MARKING* | PACKAGE DESCRIPTION | SPECIFIED TEMPERATURE RANGE |
|---|---|---|---|---|
| LTC1992CMS8#PBF | LTC1992CMS8#TRPBF | LTYU | 8-Lead Plastic MSOP | 0°C to 70°C |
| LTC1992IMS8#PBF | LTC1992IMS8#TRPBF | LTYU | 8-Lead Plastic MSOP | –40°C to 85°C |
| LTC1992HMS8#PBF | LTC1992HMS8#TRPBF | LTYU | 8-Lead Plastic MSOP | –40°C to 125°C |
| LTC1992-1CMS8#PBF | LTC1992-1CMS8#TRPBF | LTACJ | 8-Lead Plastic MSOP | 0°C to 70°C |
| LTC1992-1IMS8#PBF | LTC1992-1IMS8#TRPBF | LTACJ | 8-Lead Plastic MSOP | –40°C to 85°C |
| LTC1992-1HMS8#PBF | LTC1992-1HMS8#TRPBF | LTACJ | 8-Lead Plastic MSOP | –40°C to 125°C |
| LTC1992-2CMS8#PBF | LTC1992-2CMS8#TRPBF | LTYV | 8-Lead Plastic MSOP | 0°C to 70°C |
| LTC1992-2IMS8#PBF | LTC1992-2IMS8#TRPBF | LTYV | 8-Lead Plastic MSOP | –40°C to 85°C |
| LTC1992-2HMS8#PBF | LTC1992-2HMS8#TRPBF | LTYV | 8-Lead Plastic MSOP | –40°C to 125°C |
| LTC1992-5CMS8#PBF | LTC1992-5CMS8#TRPBF | LTACK | 8-Lead Plastic MSOP | 0°C to 70°C |
| LTC1992-5IMS8#PBF | LTC1992-5IMS8#TRPBF | LTACK | 8-Lead Plastic MSOP | –40°C to 85°C |
| LTC1992-5HMS8#PBF | LTC1992-5HMS8#TRPBF | LTACK | 8-Lead Plastic MSOP | –40°C to 125°C |
| LTC1992-10CMS8#PBF | LTC1992-10CMS8#TRPBF | LTACL | 8-Lead Plastic MSOP | 0°C to 70°C |
| LTC1992-10IMS8#PBF | LTC1992-10IMS8#TRPBF | LTACL | 8-Lead Plastic MSOP | –40°C to 85°C |
| LTC1992-10HMS8#PBF | LTC1992-10HMS8#TRPBF | LTACL | 8-Lead Plastic MSOP | –40°C to 125°C |

Consult LTC Marketing for parts specified with wider operating temperature ranges. *The temperature grade is identified by a label on the shipping container.
Consult LTC Marketing for information on non-standard lead based finish parts.

For more information on lead free part marking, go to: http://www.linear.com/leadfree/
For more information on tape and reel specifications, go to: http://www.linear.com/tapeandreel/

## ELECTRICAL CHARACTERISTICS

**The ● denotes the specifications which apply over the full operating temperature range, otherwise specifications are at $T_A$ = 25°C. $+V_S$ = 5V, $–V_S$ = 0V, $V_{INCM}$ = $V_{OUTCM}$ = $V_{OCM}$ = 2.5V, unless otherwise noted. $V_{OCM}$ is the voltage on the $V_{OCM}$ pin. $V_{OUTCM}$ is defined as $(+V_{OUT} + –V_{OUT})/2$. $V_{INCM}$ is defined as $(+V_{IN} + –V_{IN})/2$. $V_{INDIFF}$ is defined as $(+V_{IN} – –V_{IN})$. $V_{OUTDIFF}$ is defined as $(+V_{OUT} – –V_{OUT})$. Specifications applicable to all parts in the LTC1992 family.**

| SYMBOL | PARAMETER | CONDITIONS | | ALL C AND I GRADE MIN | ALL C AND I GRADE TYP | ALL C AND I GRADE MAX | ALL H GRADE MIN | ALL H GRADE TYP | ALL H GRADE MAX | UNITS |
|---|---|---|---|---|---|---|---|---|---|---|
| $V_S$ | Supply Voltage Range | | ● | 2.7 | | 11 | 2.7 | | 11 | V |
| $I_S$ | Supply Current | $V_S$ = 2.7V to 5V | ● | | 0.65 | 1.0 | | 0.65 | 1.0 | mA |
| | | | | | 0.75 | 1.2 | | 0.8 | 1.5 | mA |
| | | $V_S$ = ±5V | | | 0.7 | 1.2 | | 0.7 | 1.2 | mA |
| | | | ● | | 0.8 | 1.5 | | 0.9 | 1.8 | mA |
| $V_{OSDIFF}$ | Differential Offset Voltage (Input Referred) (Note 7) | $V_S$ = 2.7V | ● | | ±0.25 | ±2.5 | | ±0.25 | ±4 | mV |
| | | $V_S$ = 5V | ● | | ±0.25 | ±2.5 | | ±0.25 | ±4 | mV |
| | | $V_S$ = ±5V | ● | | ±0.25 | ±2.5 | | ±0.25 | ±4 | mV |
| $\Delta V_{OSDIFF}/\Delta T$ | Differential Offset Voltage Drift (Input Referred) (Note 7) | $V_S$ = 2.7V | ● | | 10 | | | 10 | | µV/°C |
| | | $V_S$ = 5V | ● | | 10 | | | 10 | | µV/°C |
| | | $V_S$ = ±5V | ● | | 10 | | | 10 | | µV/°C |
| PSRR | Power Supply Rejection Ratio (Input Referred) (Note 7) | $V_S$ = 2.7V to ±5V | ● | 75 | 80 | | 72 | 80 | | dB |
| GCM | Common Mode Gain($V_{OUTCM}/V_{OCM}$) | | ● | | 1 | | | 1 | | |
| | Common Mode Gain Error | | ● | | ±0.1 | ±0.3 | | ±0.1 | ±0.35 | % |
| | Output Balance ($\Delta V_{OUTCM}/(\Delta V_{OUTDIFF})$) | $V_{OUTDIFF}$ = –2V to +2V | ● | | –85 | –60 | | –85 | –60 | dB |
| $V_{OSCM}$ | Common Mode Offset Voltage ($V_{OUTCM} – V_{OCM}$) | $V_S$ = 2.7V | ● | | ±0.5 | ±12 | | ±0.5 | ±15 | mV |
| | | $V_S$ = 5V | ● | | ±1 | ±15 | | ±1 | ±17 | mV |
| | | $V_S$ = ±5V | ● | | ±2 | ±18 | | ±2 | ±20 | mV |
| $\Delta V_{OSCM}/\Delta T$ | Common Mode Offset Voltage Drift | $V_S$ = 2.7V | ● | | 10 | | | 10 | | µV/°C |
| | | $V_S$ = 5V | ● | | 10 | | | 10 | | µV/°C |
| | | $V_S$ = ±5V | ● | | 10 | | | 10 | | µV/°C |
| $V_{OUTCMR}$ | Output Signal Common Mode Range (Voltage Range for the $V_{OCM}$ Pin) | | ● | $(–V_S)$ + 0.5V | | $(+V_S)$ – 1.3V | $(–V_S)$ + 0.5V | | $(+V_S)$ – 1.3V | V |
| $R_{INVOCM}$ | Input Resistance, $V_{OCM}$ Pin | | ● | | 500 | | | 500 | | MΩ |
| $I_{BVOCM}$ | Input Bias Current, $V_{OCM}$ Pin | $V_S$ = 2.7V to ±5V | ● | | ±2 | | | ±2 | | pA |
| $V_{MID}$ | Voltage at the $V_{MID}$ Pin | | ● | 2.44 | 2.50 | 2.56 | 2.43 | 2.50 | 2.57 | V |
| $V_{OUT}$ | Output Voltage, High (Note 2) | $V_S$ = 2.7V, Load = 10k | ● | 2.60 | 2.69 | | 2.60 | 2.69 | | V |
| | | $V_S$ = 2.7V, Load = 5mA | ● | 2.50 | 2.61 | | 2.50 | 2.61 | | V |
| | | $V_S$ = 2.7V, Load = 10mA | ● | 2.29 | 2.52 | | 2.29 | 2.52 | | V |
| | Output Voltage, Low (Note 2) | $V_S$ = 2.7V, Load = 10k | ● | | 0.02 | 0.10 | | 0.02 | 0.10 | V |
| | | $V_S$ = 2.7V, Load = 5mA | ● | | 0.10 | 0.25 | | 0.10 | 0.25 | V |
| | | $V_S$ = 2.7V, Load = 10mA | ● | | 0.20 | 0.35 | | 0.20 | 0.41 | V |
| | Output Voltage, High (Note 2) | $V_S$ = 5V, Load = 10k | ● | 4.90 | 4.99 | | 4.90 | 4.99 | | V |
| | | $V_S$ = 5V, Load = 5mA | ● | 4.85 | 4.90 | | 4.80 | 4.90 | | V |
| | | $V_S$ = 5V, Load = 10mA | ● | 4.75 | 4.81 | | 4.70 | 4.81 | | V |
| | Output Voltage, Low (Note 2) | $V_S$ = 5V, Load = 10k | ● | | 0.02 | 0.10 | | 0.02 | 0.10 | V |
| | | $V_S$ = 5V, Load = 5mA | ● | | 0.10 | 0.25 | | 0.10 | 0.30 | V |
| | | $V_S$ = 5V, Load = 10mA | ● | | 0.20 | 0.35 | | 0.20 | 0.42 | V |
| | Output Voltage, High (Note 2) | $V_S$ = ±5V, Load = 10k | ● | 4.90 | 4.99 | | 4.85 | 4.99 | | V |
| | | $V_S$ = ±5V, Load = 5mA | ● | 4.85 | 4.89 | | 4.80 | 4.89 | | V |
| | | $V_S$ = ±5V, Load = 10mA | ● | 4.65 | 4.80 | | 4.60 | 4.80 | | V |
| | Output Voltage, Low (Note 2) | $V_S$ = ±5V, Load = 10k | ● | | –4.99 | –4.90 | | –4.98 | –4.85 | V |
| | | $V_S$ = ±5V, Load = 5mA | ● | | –4.90 | –4.75 | | –4.90 | –4.75 | V |
| | | $V_S$ = ±5V, Load = 10mA | ● | | –4.80 | –4.65 | | –4.80 | –4.55 | V |

## ELECTRICAL CHARACTERISTICS

**The ● denotes the specifications which apply over the full operating temperature range, otherwise specifications are at $T_A$ = 25°C. $+V_S$ = 5V, $–V_S$ = 0V, $V_{INCM}$ = $V_{OUTCM}$ = $V_{OCM}$ = 2.5V, unless otherwise noted. $V_{OCM}$ is the voltage on the $V_{OCM}$ pin. $V_{OUTCM}$ is defined as $(+V_{OUT} + –V_{OUT})/2$. $V_{INCM}$ is defined as $(+V_{IN} + –V_{IN})/2$. $V_{INDIFF}$ is defined as $(+V_{IN} – –V_{IN})$. $V_{OUTDIFF}$ is defined as $(+V_{OUT} – –V_{OUT})$. Specifications applicable to all parts in the LTC1992 family.**

| SYMBOL | PARAMETER | CONDITIONS | | ALL C AND I GRADE MIN | TYP | MAX | ALL H GRADE MIN | TYP | MAX | UNITS |
|---|---|---|---|---|---|---|---|---|---|---|
| $I_{SC}$ | Output Short-Circuit Current Sourcing (Notes 2,3) | $V_S$ = 2.7V, $V_{OUT}$ =1.35V<br>$V_S$ = 5V, $V_{OUT}$ = 2.5V<br>$V_S$ = ±5V, $V_{OUT}$ = 0V | ●<br>●<br>● | 20<br>20<br>20 | 30<br>30<br>30 | | 20<br>20<br>20 | 30<br>30<br>30 | | mA<br>mA<br>mA |
| | Output Short-Circuit Current Sinking (Notes 2,3) | $V_S$ = 2.7V, $V_{OUT}$ =1.35V<br>$V_S$ = 5V, $V_{OUT}$ = 2.5V<br>$V_S$ = ±5V, $V_{OUT}$ = 0V | ●<br>●<br>● | 13<br>13<br>13 | 30<br>30<br>30 | | 13<br>13<br>13 | 30<br>30<br>30 | | mA<br>mA<br>mA |
| $A_{VOL}$ | Large-Signal Voltage Gain | | ● | | 80 | | | 80 | | dB |

**The ● denotes the specifications which apply over the full operating temperature range, otherwise specifications are at $T_A$ = 25°C. $+V_S$ = 5V, $–V_S$ = 0V, $V_{INCM}$ = $V_{OUTCM}$ = $V_{OCM}$ = 2.5V, unless otherwise noted. $V_{OCM}$ is the voltage on the $V_{OCM}$ pin. $V_{OUTCM}$ is defined as $(+V_{OUT} + –V_{OUT})/2$. $V_{INCM}$ is defined as $(+V_{IN} + –V_{IN})/2$. $V_{INDIFF}$ is defined as $(+V_{IN} – –V_{IN})$. $V_{OUTDIFF}$ is defined as $(+V_{OUT} – –V_{OUT})$. Specifications applicable to the LTC1992 only.**

| SYMBOL | PARAMETER | CONDITIONS | | LTC1992CMS8 LTC1992ISM8 MIN | TYP | MAX | LTC1992HMS8 MIN | TYP | MAX | UNITS |
|---|---|---|---|---|---|---|---|---|---|---|
| $I_B$ | Input Bias Current | $V_S$ = 2.7V to ±5V | ● | | 2 | 250 | | 2 | 400 | pA |
| $I_{OS}$ | Input Offset Current | $V_S$ = 2.7V to ±5V | ● | | 0.1 | 100 | | 0.1 | 150 | pA |
| $R_{IN}$ | Input Resistance | | ● | | 500 | | | 500 | | MΩ |
| $C_{IN}$ | Input Capacitance | | ● | | 3 | | | 3 | | pF |
| $e_n$ | Input Referred Noise Voltage Density | f = 1kHz | | | 35 | | | 35 | | $nV/\sqrt{Hz}$ |
| $i_n$ | Input Noise Current Density | f = 1kHz | | | 1 | | | 1 | | $fA/\sqrt{Hz}$ |
| $V_{INCMR}$ | Input Signal Common Mode Range | | ● | $(–V_S)$ – 0.1V | | $(+V_S)$ – 1.3V | $(–V_S)$ – 0.1V | | $(+V_S)$ – 1.3V | V |
| CMRR | Common Mode Rejection Ratio (Input Referred) | $V_{INCM}$ = –0.1V to 3.7V | ● | 69 | 90 | | 69 | 90 | | dB |
| SR | Slew Rate (Note 4) | | ● | 0.5 | 1.5 | | 0.5 | 1.5 | | V/µs |
| GBW | Gain-Bandwidth Product ($f_{TEST}$ = 100kHz) | $T_A$ = 25°C<br>LTC1992CMS8<br>LTC1992IMS8/ LTC1992HMS8 | <br>●<br>● | 3.0<br>2.5<br>1.9 | 3.2<br>3.0<br> | 3.5<br>4.0<br>4.0 | 3.0<br><br>1.9 | 3.2<br><br> | 3.5<br><br>4.0 | MHz<br>MHz<br>MHz |

## ELECTRICAL CHARACTERISTICS

**The ● denotes the specifications which apply over the full operating temperature range, otherwise specifications are at $T_A$ = 25°C. +$V_S$ = 5V, –$V_S$ = 0V, $V_{INCM}$ = $V_{OUTCM}$ = $V_{OCM}$ = 2.5V, unless otherwise noted. $V_{OCM}$ is the voltage on the $V_{OCM}$ pin. $V_{OUTCM}$ is defined as (+$V_{OUT}$ + –$V_{OUT}$)/2. $V_{INCM}$ is defined as (+$V_{IN}$ + –$V_{IN}$)/2. $V_{INDIFF}$ is defined as (+$V_{IN}$ – –$V_{IN}$). $V_{OUTDIFF}$ is defined as (+$V_{OUT}$ – –$V_{OUT}$). Typical values are at $T_A$ = 25°C. Specifications apply to the LTC1992-1 only.**

| | | | | LTC1992-1CMS8 LTC1992-1ISM8 | | | LTC1992-1HMS8 | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| SYMBOL | PARAMETER | CONDITIONS | | MIN | TYP | MAX | MIN | TYP | MAX | UNITS |
| $G_{DIFF}$ | Differential Gain<br>Differential Gain Error<br>Differential Gain Nonlinearity<br>Differential Gain Temperature Coefficient | | <br>●<br><br>● | | 1<br>±0.1<br>50<br>3.5 | <br>±0.3 | | 1<br>±0.1<br>50<br>3.5 | <br>±0.35 | V/V<br>%<br>ppm<br>ppm/°C |
| $e_n$ | Input Referred Noise Voltage Density (Note 7) | f = 1kHz | | | 45 | | | 45 | | nV/√Hz |
| $R_{IN}$ | Input Resistance, Single-Ended +IN, –IN Pins | | ● | 22.5 | 30 | 37.5 | 22 | 30 | 38 | kΩ |
| $V_{INCMR}$ | Input Signal Common Mode Range | $V_S$ = 5V | | | –0.1V to 4.9V | | | –0.1V to 4.9V | | V |
| CMRR | Common Mode Rejection Ratio (Amplifier Input Referred) (Note 7) | $V_{INCM}$ = –0.1V to 3.7V | ● | 55 | 60 | | 55 | 60 | | dB |
| SR | Slew Rate (Note 4) | | ● | 0.5 | 1.5 | | 0.5 | 1.5 | | V/µs |
| GBW | Gain-Bandwidth Product | $f_{TEST}$ = 180kHz | | | 3 | | | 3 | | MHz |

**The ● denotes the specifications which apply over the full operating temperature range, otherwise specifications are at $T_A$ = 25°C. +$V_S$ = 5V, –$V_S$ = 0V, $V_{INCM}$ = $V_{OUTCM}$ = $V_{OCM}$ = 2.5V, unless otherwise noted. $V_{OCM}$ is the voltage on the $V_{OCM}$ pin. $V_{OUTCM}$ is defined as (+$V_{OUT}$ + –$V_{OUT}$)/2. $V_{INCM}$ is defined as (+$V_{IN}$ + –$V_{IN}$)/2. $V_{INDIFF}$ is defined as (+$V_{IN}$ – –$V_{IN}$). $V_{OUTDIFF}$ is defined as (+$V_{OUT}$ – –$V_{OUT}$). Typical values are at $T_A$ = 25°C. Specifications apply to the LTC1992-2 only.**

| | | | | LTC1992-2CMS8 LTC1992-2ISM8 | | | LTC1992-2HMS8 | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| SYMBOL | PARAMETER | CONDITIONS | | MIN | TYP | MAX | MIN | TYP | MAX | UNITS |
| $G_{DIFF}$ | Differential Gain<br>Differential Gain Error<br>Differential Gain Nonlinearity<br>Differential Gain Temperature Coefficient | | <br>●<br><br>● | | 2<br>±0.1<br>50<br>3.5 | <br>±0.3 | | 2<br>±0.1<br>50<br>3.5 | <br>±0.35 | V/V<br>%<br>ppm<br>ppm/°C |
| $e_n$ | Input Referred Noise Voltage Density (Note 7) | f = 1kHz | | | 45 | | | 45 | | nV/√Hz |
| $R_{IN}$ | Input Resistance, Single-Ended +IN, –IN Pins | | ● | 22.5 | 30 | 37.5 | 22 | 30 | 38 | kΩ |
| $V_{INCMR}$ | Input Signal Common Mode Range | $V_S$ = 5V | | | –0.1V to 4.9V | | | –0.1V to 4.9V | | V |
| CMRR | Common Mode Rejection Ratio (Amplifier Input Referred) (Note 7) | $V_{INCM}$ = –0.1V to 3.7V | ● | 55 | 60 | | 55 | 60 | | dB |
| SR | Slew Rate (Note 4) | | ● | 0.7 | 2 | | 0.7 | 2 | | V/µs |
| GBW | Gain-Bandwidth Product | $f_{TEST}$ = 180kHz | | | 4 | | | 4 | | MHz |

## ELECTRICAL CHARACTERISTICS

**The ● denotes the specifications which apply over the full operating temperature range, otherwise specifications are at $T_A$ = 25°C. $+V_S$ = 5V, $–V_S$ = 0V, $V_{INCM}$ = $V_{OUTCM}$ = $V_{OCM}$ = 2.5V, unless otherwise noted. $V_{OCM}$ is the voltage on the $V_{OCM}$ pin. $V_{OUTCM}$ is defined as ($+V_{OUT}$ + $–V_{OUT}$)/2. $V_{INCM}$ is defined as ($+V_{IN}$ + $–V_{IN}$)/2. $V_{INDIFF}$ is defined as ($+V_{IN}$ – $–V_{IN}$). $V_{OUTDIFF}$ is defined as ($+V_{OUT}$ – $–V_{OUT}$). Typical values are at $T_A$ = 25°C. Specifications apply to the LTC1992-5 only.**

| SYMBOL | PARAMETER | CONDITIONS | | LTC1992-5CMS8 LTC1992-5ISM8 MIN | TYP | MAX | LTC1992-5HMS8 MIN | TYP | MAX | UNITS |
|---|---|---|---|---|---|---|---|---|---|---|
| $G_{DIFF}$ | Differential Gain<br>Differential Gain Error<br>Differential Gain Nonlinearity<br>Differential Gain Temperature Coefficient | | <br>●<br><br>● | | 5<br>±0.1<br>50<br>3.5 | <br>±0.3 | | 5<br>±0.1<br>50<br>3.5 | <br>±0.35 | V/V<br>%<br>ppm<br>ppm/°C |
| $e_n$ | Input Referred Noise Voltage Density (Note 7) | f = 1kHz | | | 45 | | | 45 | | nV/√Hz |
| $R_{IN}$ | Input Resistance, Single-Ended +IN, –IN Pins | | ● | 22.5 | 30 | 37.5 | 22 | 30 | 38 | kΩ |
| $V_{INCMR}$ | Input Signal Common Mode Range | $V_S$ = 5V | | | –0.1V to 3.9V | | | –0.1V to 3.9V | | V |
| CMRR | Common Mode Rejection Ratio (Amplifier Input Referred) (Note 7) | $V_{INCM}$ = –0.1V to 3.7V | ● | 55 | 60 | | 55 | 60 | | dB |
| SR | Slew Rate (Note 4) | | ● | 0.7 | 2 | | 0.7 | 2 | | V/μs |
| GBW | Gain-Bandwidth Product | $f_{TEST}$ = 180kHz | | | 4 | | | 4 | | MHz |

**The ● denotes the specifications which apply over the full operating temperature range, otherwise specifications are at $T_A$ = 25°C. $+V_S$ = 5V, $–V_S$ = 0V, $V_{INCM}$ = $V_{OUTCM}$ = $V_{OCM}$ = 2.5V, unless otherwise noted. $V_{OCM}$ is the voltage on the $V_{OCM}$ pin. $V_{OUTCM}$ is defined as ($+V_{OUT}$ + $–V_{OUT}$)/2. $V_{INCM}$ is defined as ($+V_{IN}$ + $–V_{IN}$)/2. $V_{INDIFF}$ is defined as ($+V_{IN}$ – $–V_{IN}$). $V_{OUTDIFF}$ is defined as ($+V_{OUT}$ – $–V_{OUT}$). Typical values are at $T_A$ = 25°C. Specifications apply to the LTC1992-10 only.**

| SYMBOL | PARAMETER | CONDITIONS | | LTC1992-10CMS8 LTC1992-10ISM8 MIN | TYP | MAX | LTC1992-10HMS8 MIN | TYP | MAX | UNITS |
|---|---|---|---|---|---|---|---|---|---|---|
| $G_{DIFF}$ | Differential Gain<br>Differential Gain Error<br>Differential Gain Nonlinearity<br>Differential Gain Temperature Coefficient | | <br>●<br><br>● | | 10<br>±0.1<br>50<br>3.5 | <br>±0.3 | | 10<br>±0.1<br>50<br>3.5 | <br>±0.35 | V/V<br>%<br>ppm<br>ppm/°C |
| $e_n$ | Input Referred Noise Voltage Density (Note 7) | f = 1kHz | | | 45 | | | 45 | | nV/√Hz |
| $R_{IN}$ | Input Resistance, Single-Ended +IN, –IN Pins | | ● | 11.3 | 15 | 18.8 | 11 | 15 | 19 | kΩ |
| $V_{INCMR}$ | Input Signal Common Mode Range | $V_S$ = 5V | | | –0.1V to 3.8V | | | –0.1V to 3.8V | | V |
| CMRR | Common Mode Rejection Ratio (Amplifier Input Referred) (Note 7) | $V_{INCM}$ = –0.1V to 3.7V | ● | 55 | 60 | | 55 | 60 | | dB |
| SR | Slew Rate (Note 4) | | ● | 0.7 | 2 | | 0.7 | 2 | | V/μs |
| GBW | Gain-Bandwidth Product | $f_{TEST}$ = 180kHz | | | 4 | | | 4 | | MHz |

**Note 1:** Stresses beyond those listed under Absolute Maximum Ratings may cause permanent damage to the device. Exposure to any Absolute Maximum Rating condition for extended periods may affect device reliability and lifetime.

**Note 2:** Output load is connected to the midpoint of the $+V_S$ and $–V_S$ potentials. Measurement is taken single-ended, one output loaded at a time.

**Note 3:** A heat sink may be required to keep the junction temperature below the absolute maximum when the output is shorted indefinitely.

**Note 4:** Differential output slew rate. Slew rate is measured single ended and doubled to get the listed numbers.

**Note 5:** The LTC1992C/LTC1992-XC/LTC1992I/LTC1992-XI are guaranteed functional over an operating temperature of –40°C to 85°C. The LTC1992H/LTC1992-XH are guaranteed functional over the extended operating temperature of –40°C to 125°C.

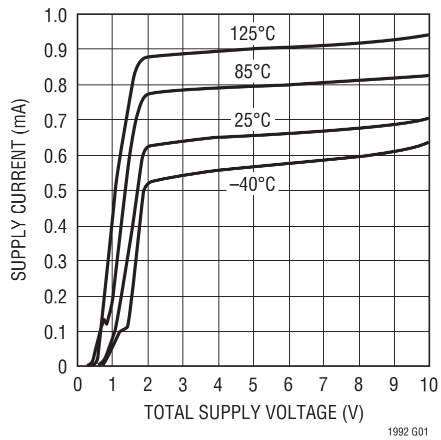
**Note 6:** The LTC1992C/LTC1992-XC are guaranteed to meet the specified performance limits over the 0°C to 70°C temperature range and are designed, characterized and expected to meet the specified performance limits over the –40°C to 85°C temperature range but are not tested or QA sampled at these temperatures. The LTC1992I/LTC1992-XI are guaranteed to meet the specified performance limits over the –40°C to 85°C temperature range. The LTC1992H/LTC1992-XH are guaranteed to meet the specified performance limits over the –40°C to 125°C temperature range.

**Note 7:** Differential offset voltage, differential offset voltage drift, CMRR, noise voltage density and PSRR are referred to the internal amplifier's input to allow for direct comparison of gain blocks with discrete amplifiers.

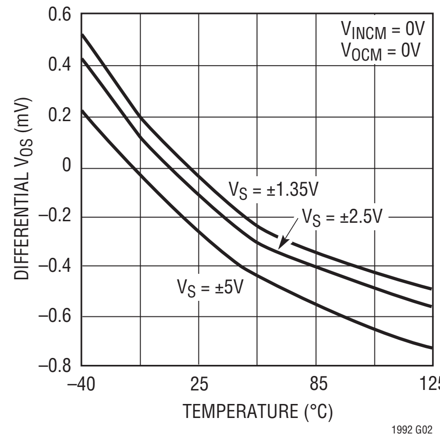
## TYPICAL PERFORMANCE CHARACTERISTICS

**Applicable to all parts in the LTC1992 family.**

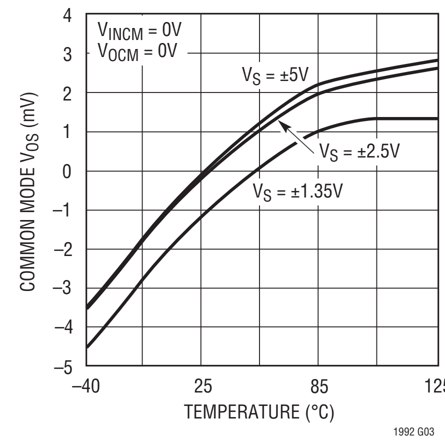
**Supply Current vs Supply Voltage**



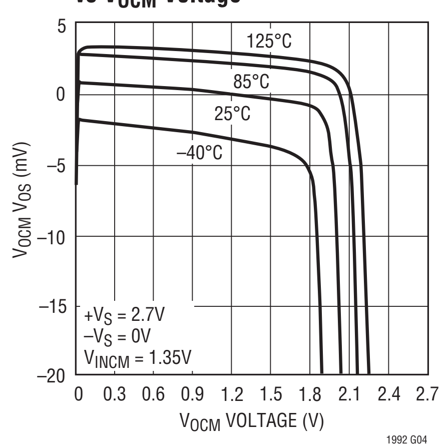

**Differential Input Offset Voltage vs Temperature (Note 7)**



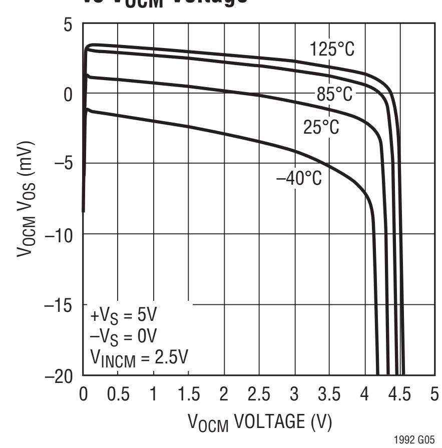

**Common Mode Offset Voltage vs Temperature**



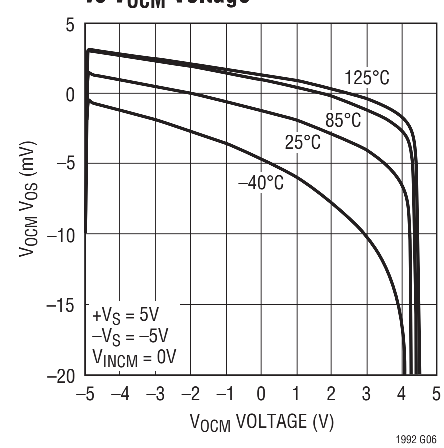

**Common Mode Offset Voltage vs $V_{OCM}$ Voltage**



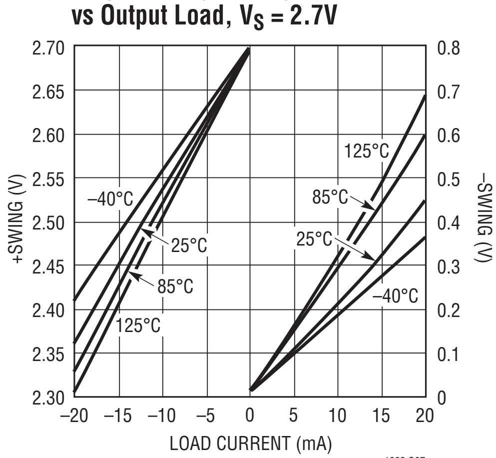

**Common Mode Offset Voltage vs $V_{OCM}$ Voltage**



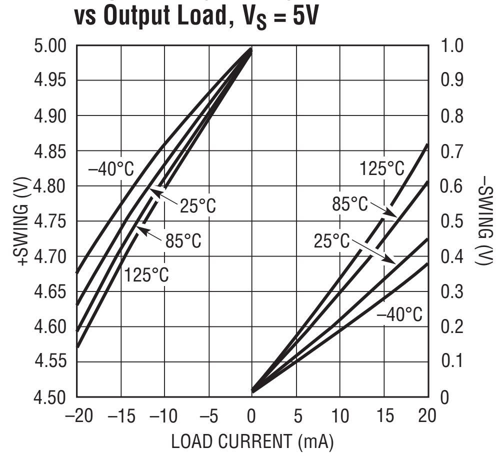

**Common Mode Offset Voltage vs $V_{OCM}$ Voltage**




**Output Voltage Swing vs Output Load, $V_S$ = 2.7V**



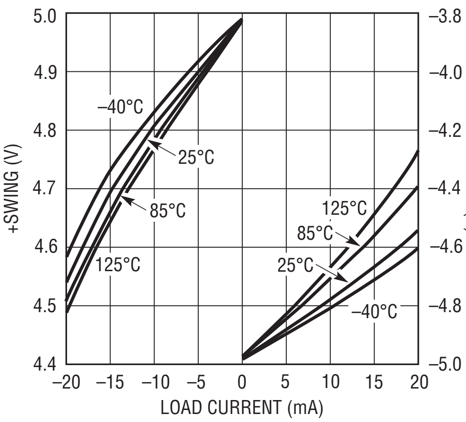

**Output Voltage Swing vs Output Load, $V_S$ = 5V**



## TYPICAL PERFORMANCE CHARACTERISTICS

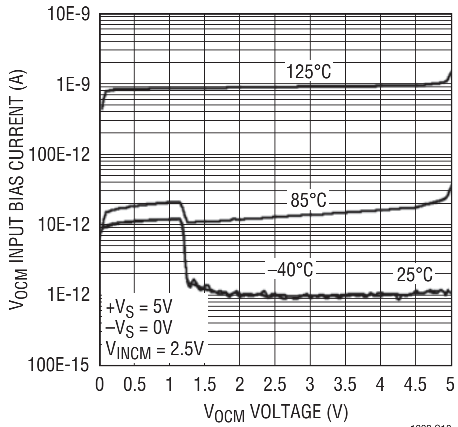
**Applicable to all parts in the LTC1992 family.**

### Output Voltage Swing vs Output Load, $V_S = \pm 5V$



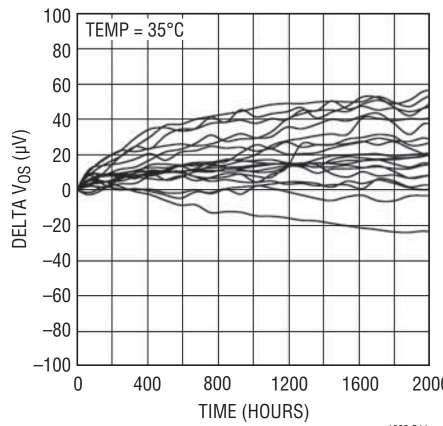

1992 G09

### $V_{OCM}$ Input Bias Current vs $V_{OCM}$ Voltage



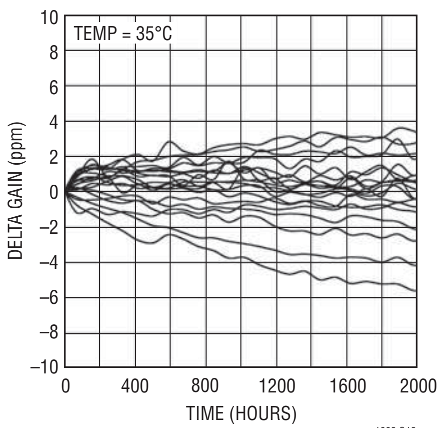

1992 G10

### Differential Input Offset Voltage vs Time (Normalized to t = 0)



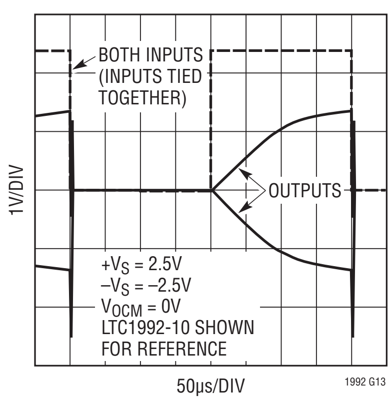

1992 G11

### Differential Gain vs Time (Normalized to t = 0)



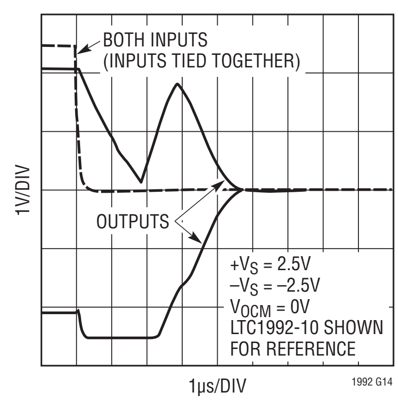

1992 G12

### Input Common Mode Overdrive Recovery (Expanded View)



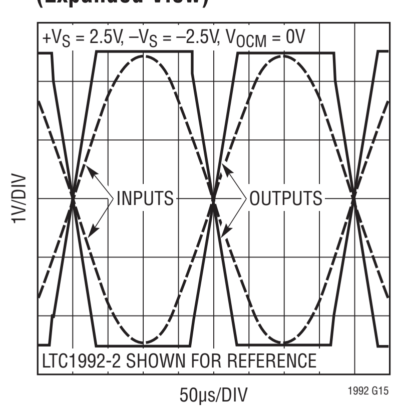

1992 G13

### Input Common Mode Overdrive Recovery (Detailed View)



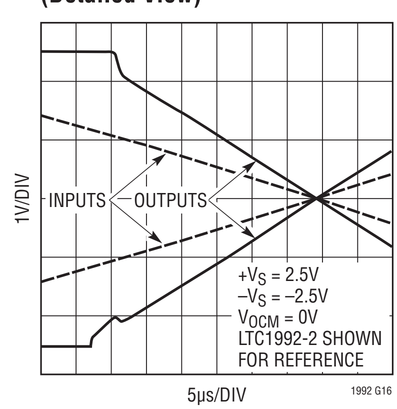

1992 G14

### Output Overdrive Recovery (Expanded View)




1992 G15

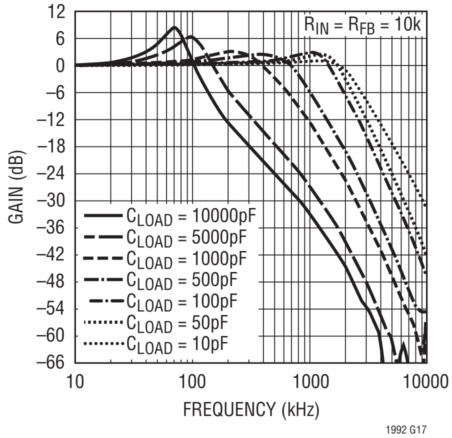
### Output Overdrive Recovery (Detailed View)



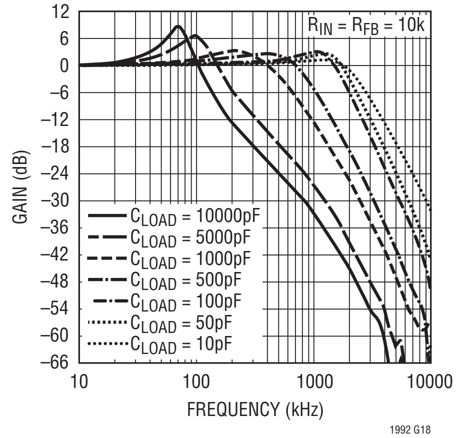

1992 G16

## TYPICAL PERFORMANCE CHARACTERISTICS Applicable to the LTC1992 only.

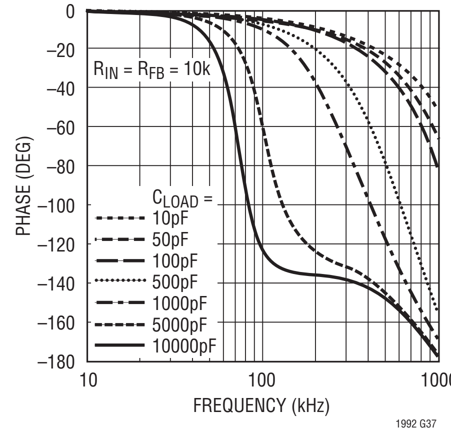
**Differential Input Differential Gain vs Frequency, $V_S$ = ±2.5V**



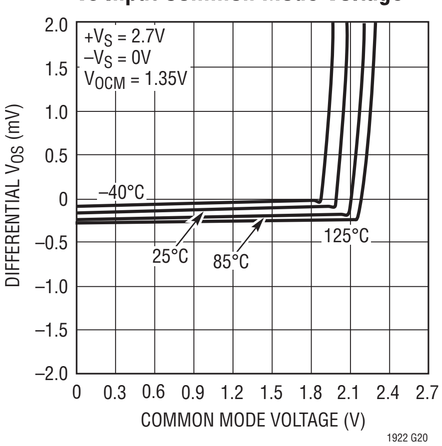

**Single-Ended Input Differential Gain vs Frequency, $V_S$ = ±2.5V**



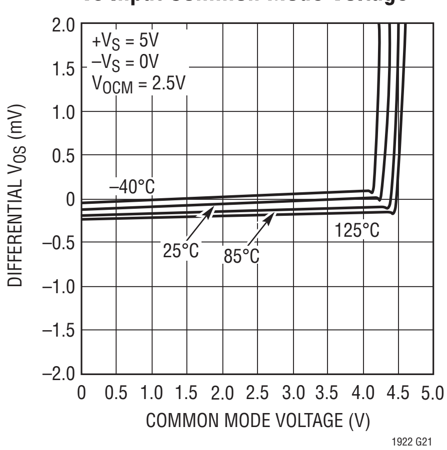

**Differential Phase Response vs Frequency**



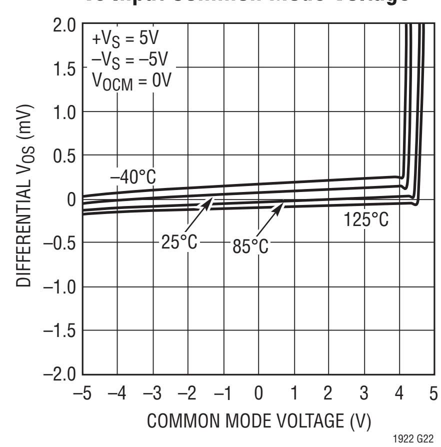

**Differential Input Offset Voltage vs Input Common Mode Voltage**



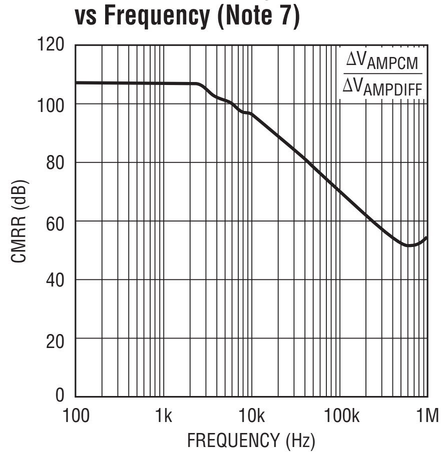

**Differential Input Offset Voltage vs Input Common Mode Voltage**



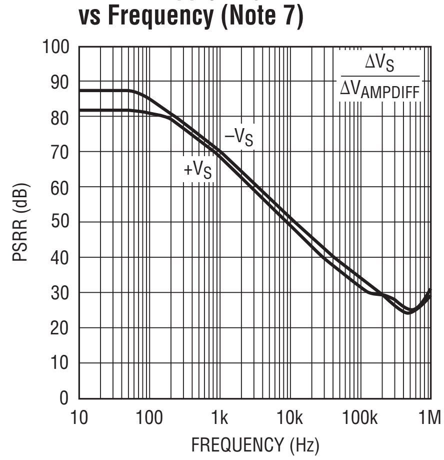

**Differential Input Offset Voltage vs Input Common Mode Voltage**



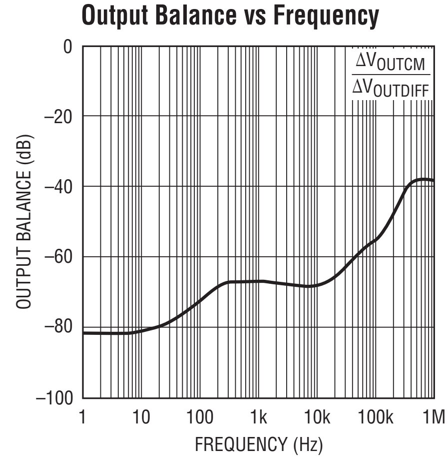

**Common Mode Rejection Ratio vs Frequency (Note 7)**




**Power Supply Rejection Ratio vs Frequency (Note 7)**

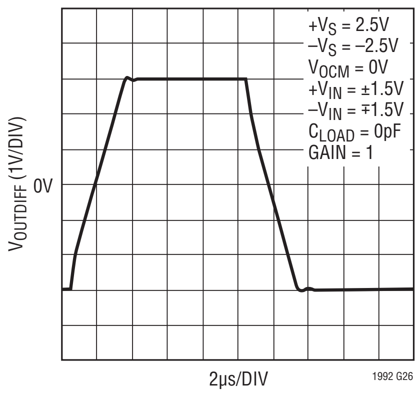



**Output Balance vs Frequency**

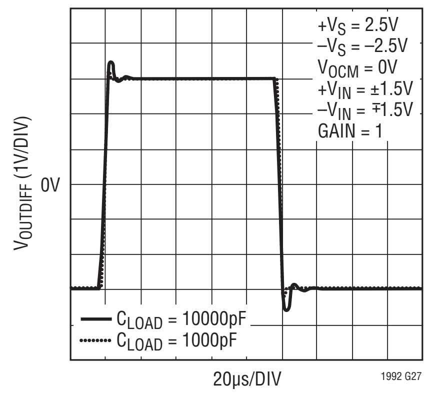


## TYPICAL PERFORMANCE CHARACTERISTICS Applicable to the LTC1992 only.

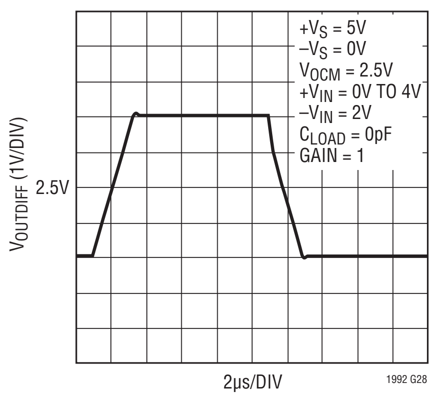
**Differential Input Large-Signal Step Response**



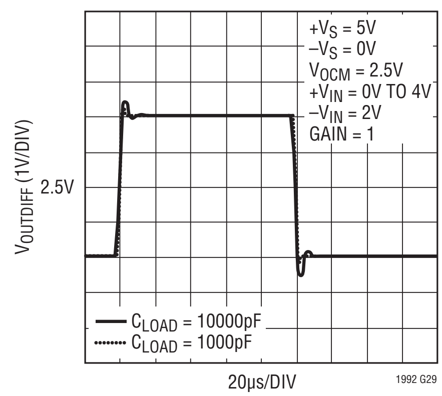

**Differential Input Large-Signal Step Response**



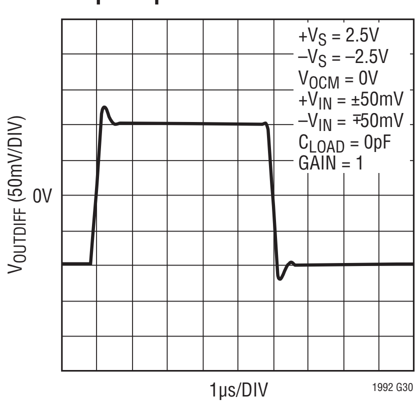

**Single-Ended Input Large-Signal Step Response**



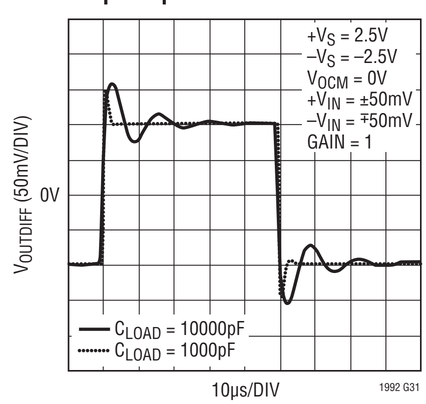

**Single-Ended Input Large-Signal Step Response**




**Differential Input Small-Signal Step Response**

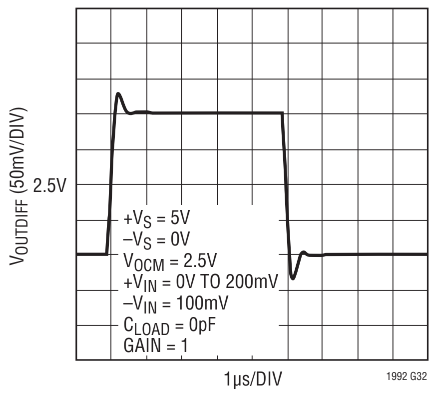



**Differential Input Small-Signal Step Response**

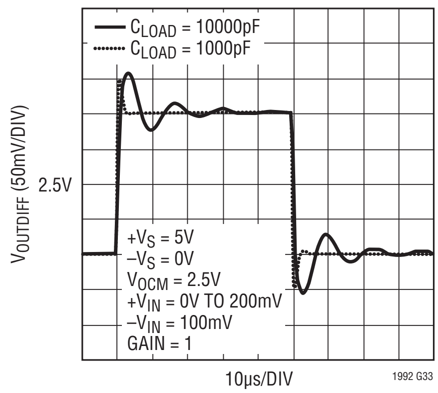


## TYPICAL PERFORMANCE CHARACTERISTICS Applicable to the LTC1992 only.

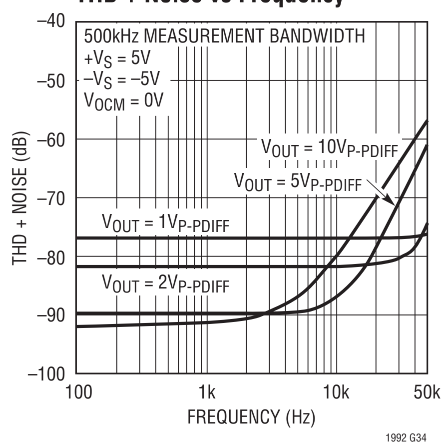
### Single-Ended Input Small-Signal Step Response



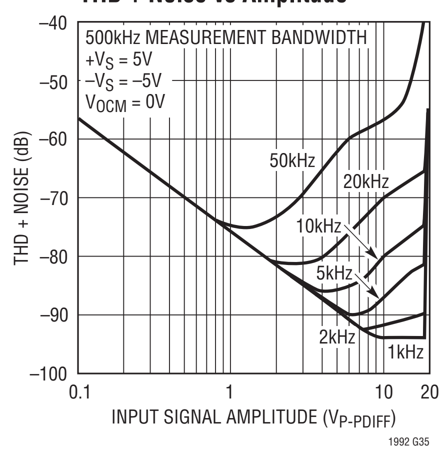

### Single-Ended Input Small-Signal Step Response



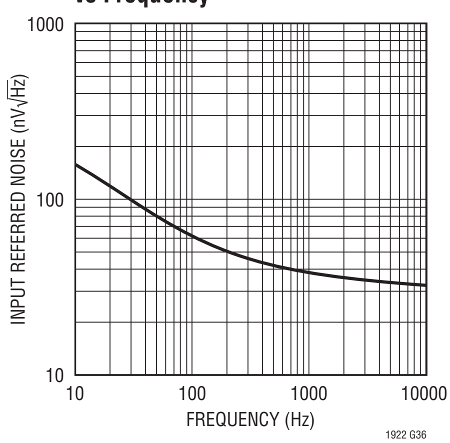

### THD + Noise vs Frequency



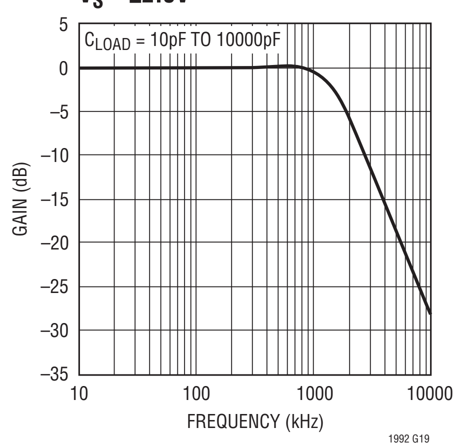

### THD + Noise vs Amplitude




### Differential Noise Voltage Density vs Frequency

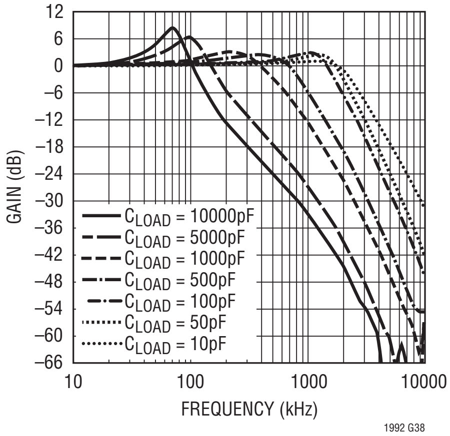



### $V_{OCM}$ Gain vs Frequency, $V_S = \pm 2.5V$

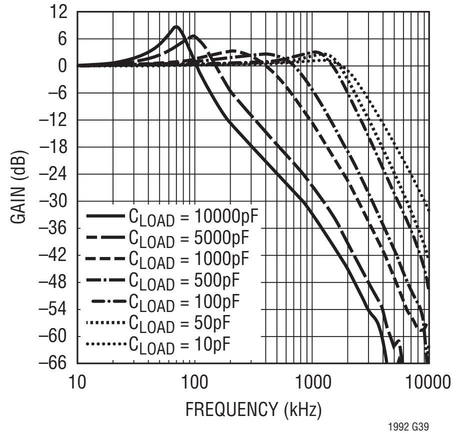


## TYPICAL PERFORMANCE CHARACTERISTICS Applicable to the LTC1992-1 only.

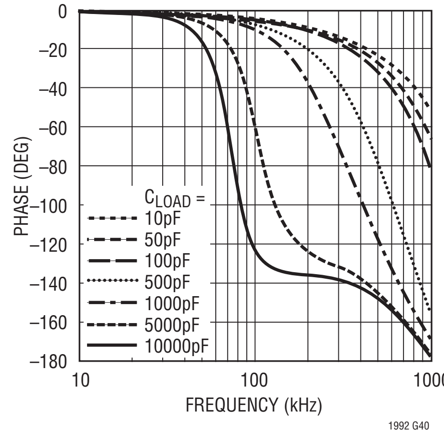
**Differential Input Differential Gain vs Frequency, $V_S$ = ±2.5V**



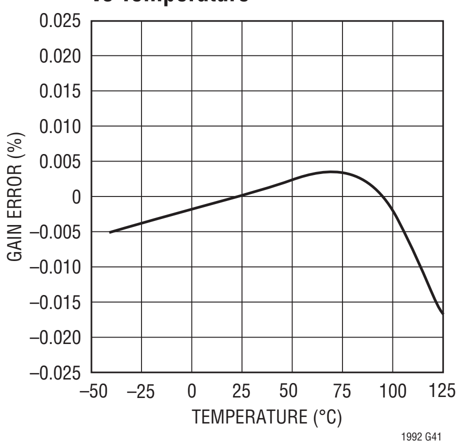

**Single-Ended Input Differential Gain vs Frequency, $V_S$ = ±2.5V**



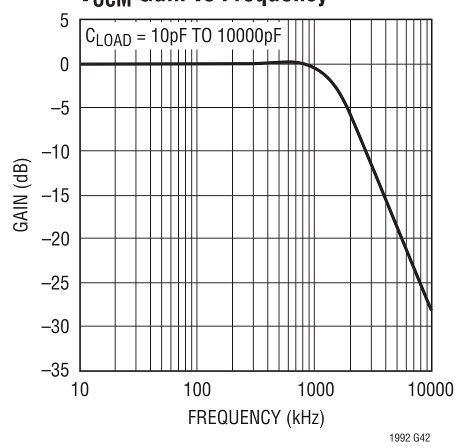

**Differential Phase Response vs Frequency**



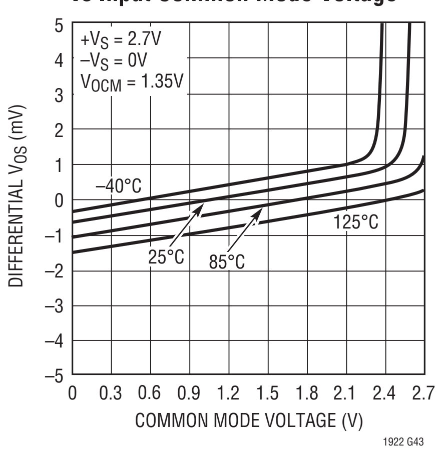

**Differential Gain Error vs Temperature**



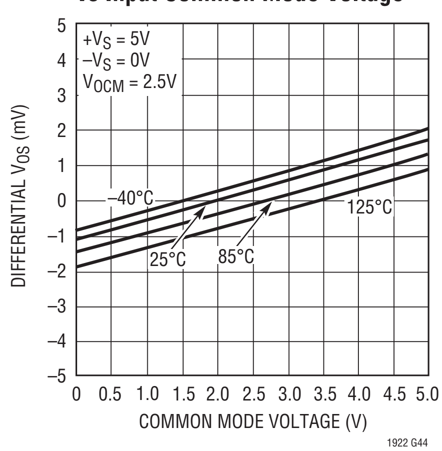

**$V_{OCM}$ Gain vs Frequency**



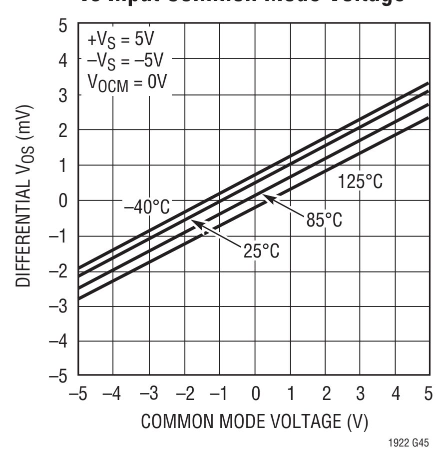

**Differential Input Offset Voltage vs Input Common Mode Voltage**




**Differential Input Offset Voltage vs Input Common Mode Voltage**

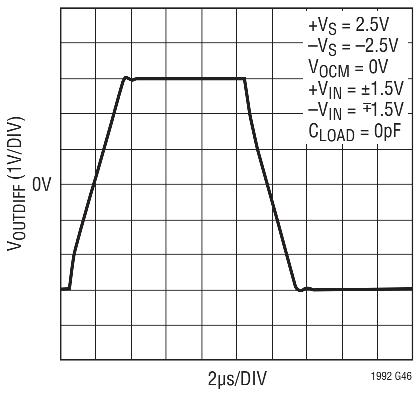



**Differential Input Offset Voltage vs Input Common Mode Voltage**

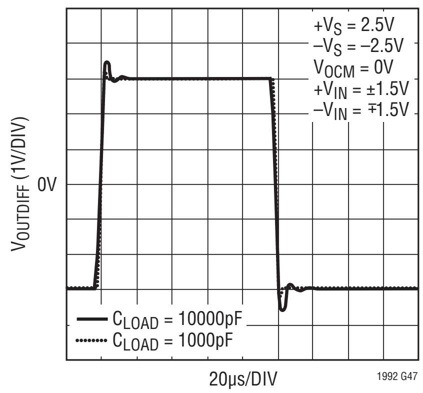


## TYPICAL PERFORMANCE CHARACTERISTICS **Applicable to the LTC1992-1 only.**

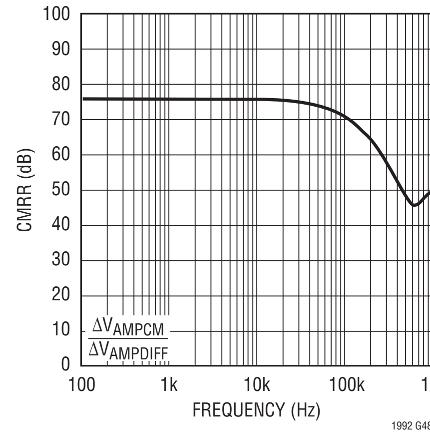
**Differential Input Large-Signal Step Response**



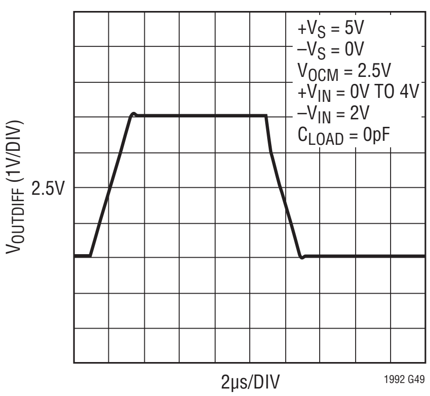

**Differential Input Large-Signal Step Response**



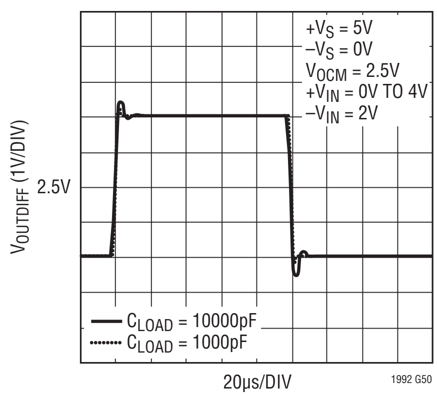

**Common Mode Rejection Ratio vs Frequency**



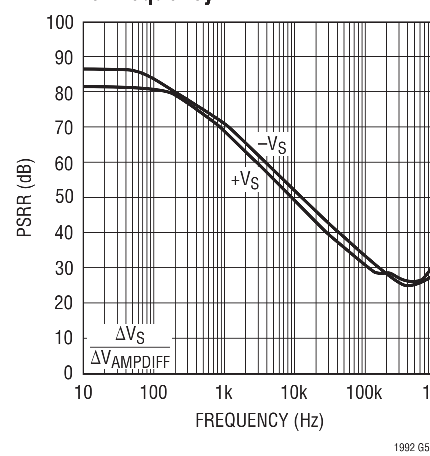

**Single-Ended Input Large-Signal Step Response**



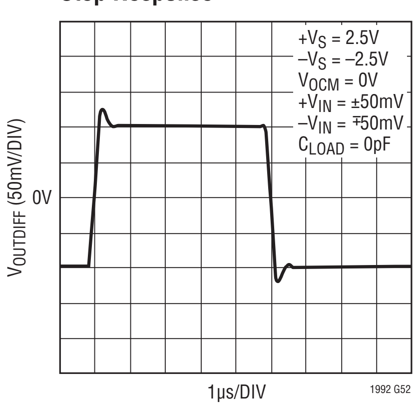

**Single-Ended Input Large-Signal Step Response**



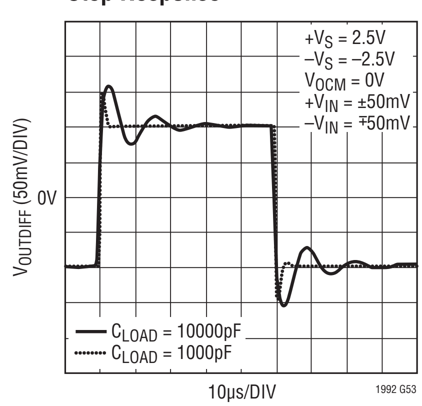

**Power Supply Rejection Ratio vs Frequency**



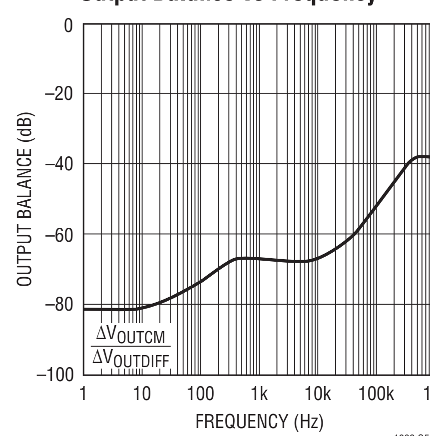

**Differential Input Small-Signal Step Response**




**Differential Input Small-Signal Step Response**

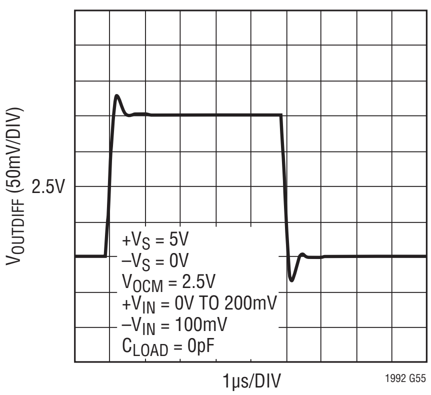



**Output Balance vs Frequency**

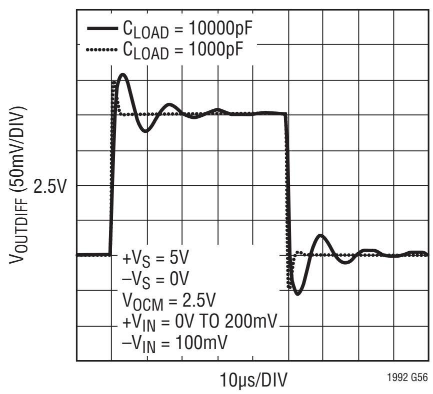


## TYPICAL PERFORMANCE CHARACTERISTICS Applicable to the LTC1992-1 only.

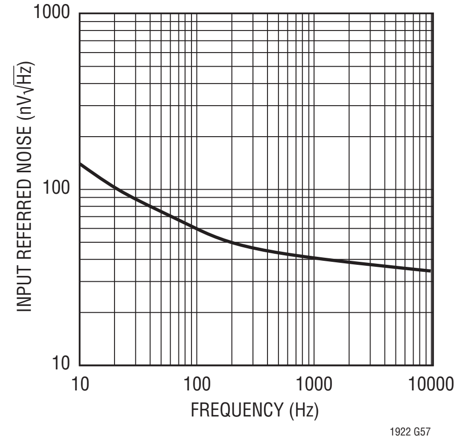
### Single-Ended Input Small-Signal Step Response



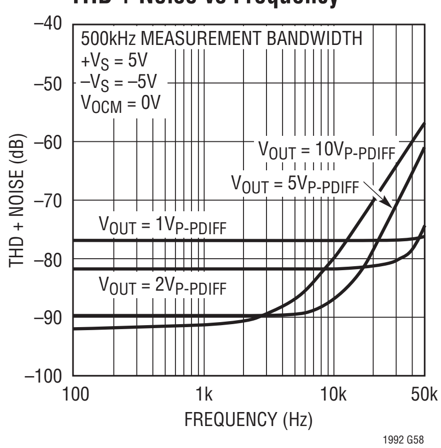

### Single-Ended Input Small-Signal Step Response



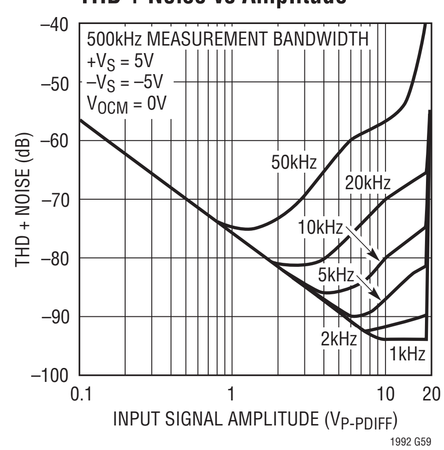

### Differential Noise Voltage Density vs Frequency




### THD + Noise vs Frequency



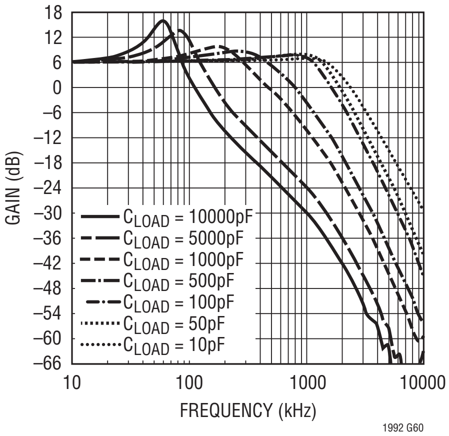

### THD + Noise vs Amplitude



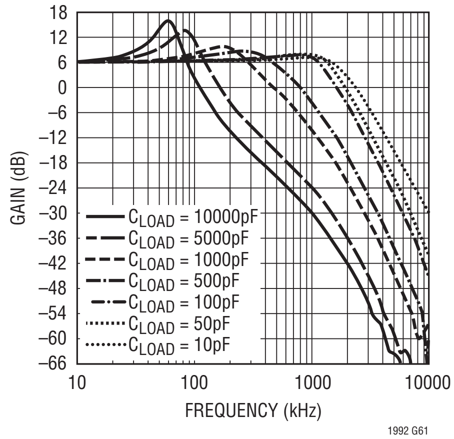
# TYPICAL PERFORMANCE CHARACTERISTICS

**Applicable to the LTC1992-2 only.**

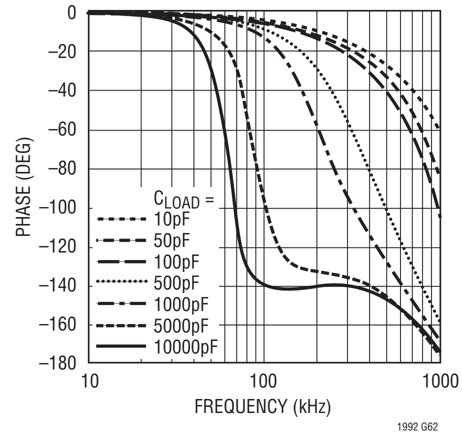
### Differential Input Differential Gain vs Frequency, $V_S$ = ±2.5V



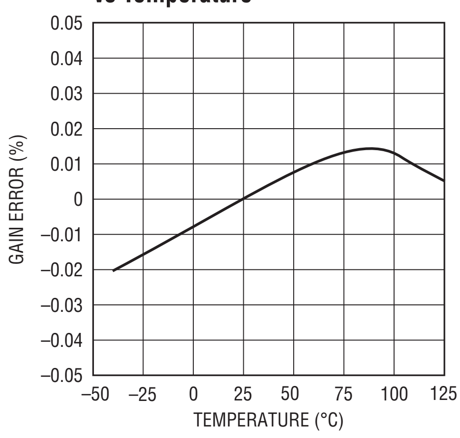

### Single-Ended Input Differential Gain vs Frequency, $V_S$ = ±2.5V



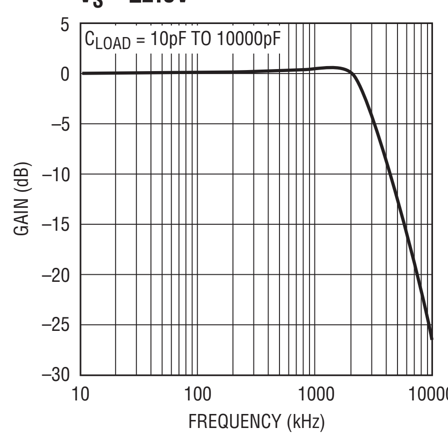

### Differential Phase Response vs Frequency



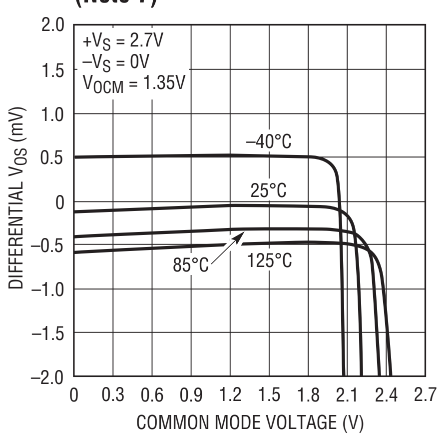

### Differential Gain Error vs Temperature



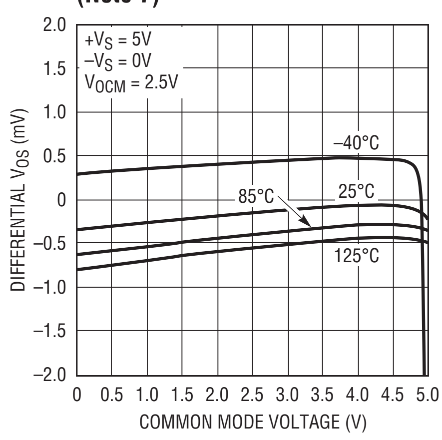

### $V_{OCM}$ Gain vs Frequency, $V_S$ = ±2.5V



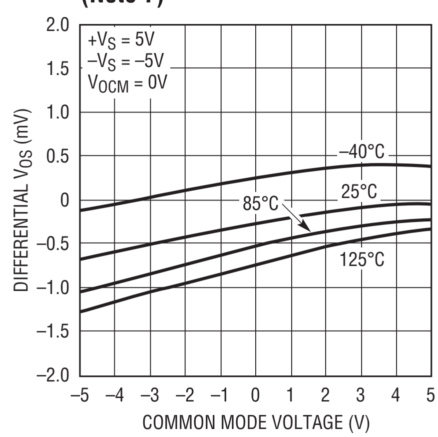

### Differential Input Offset Voltage vs Input Common Mode Voltage (Note 7)




### Differential Input Offset Voltage vs Input Common Mode Voltage (Note 7)

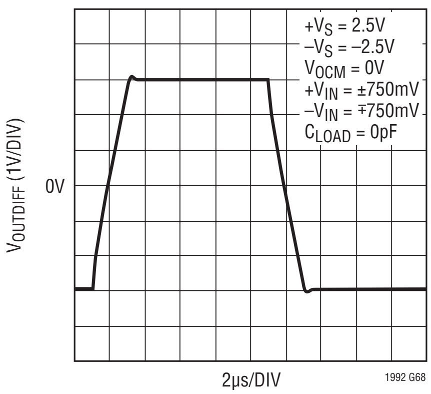



### Differential Input Offset Voltage vs Input Common Mode Voltage (Note 7)

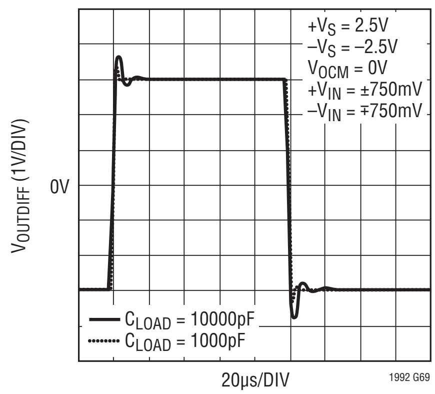


## TYPICAL PERFORMANCE CHARACTERISTICS Applicable to the LTC1992-2 only.

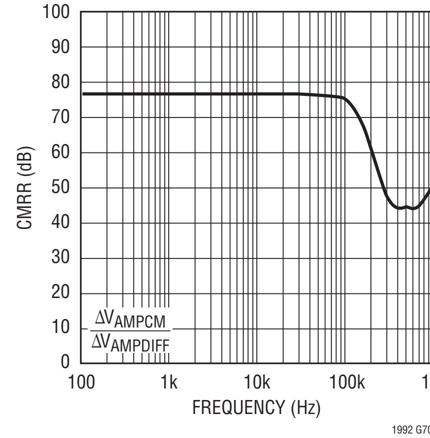
**Differential Input Large-Signal Step Response**



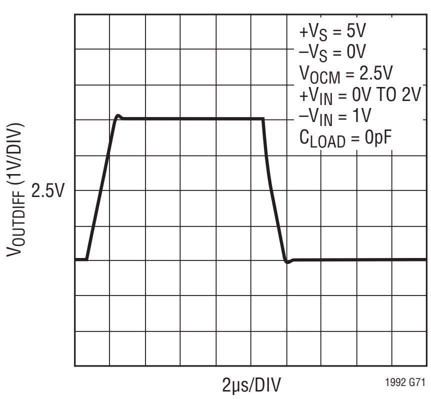

**Differential Input Large-Signal Step Response**



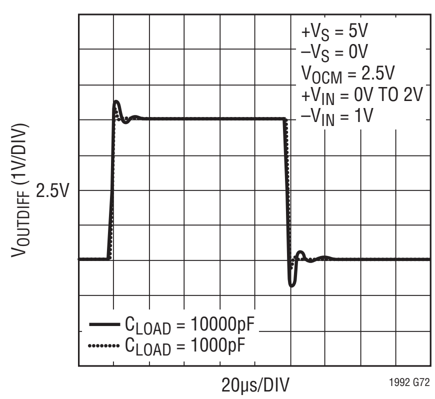

**Common Mode Rejection Ratio vs Frequency (Note 7)**



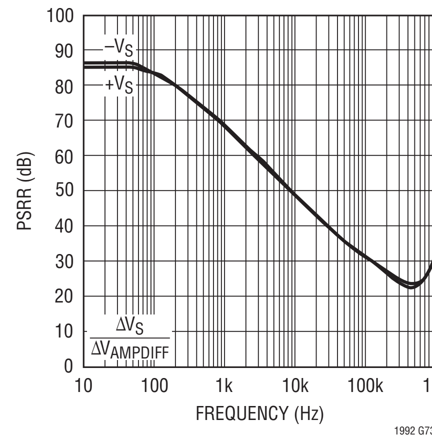

**Single-Ended Input Large-Signal Step Response**



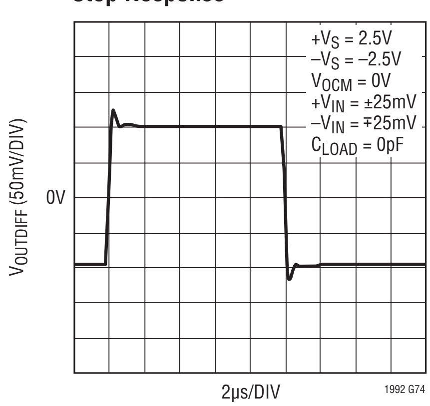

**Single-Ended Input Large-Signal Step Response**



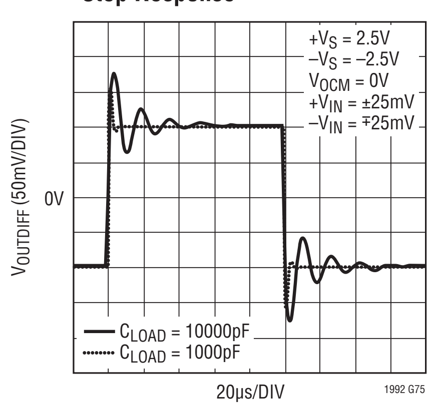

**Power Supply Rejection Ratio vs Frequency (Note 7)**



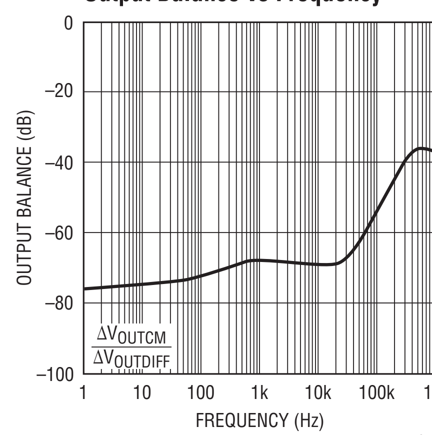

**Differential Input Small-Signal Step Response**




**Differential Input Small-Signal Step Response**

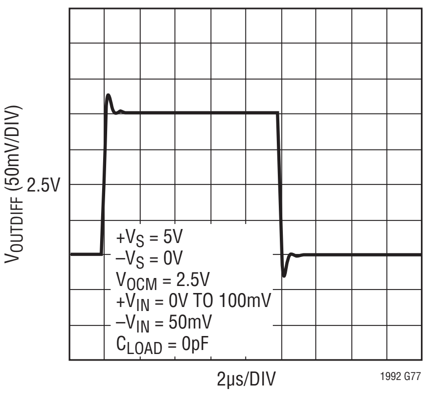



**Output Balance vs Frequency**

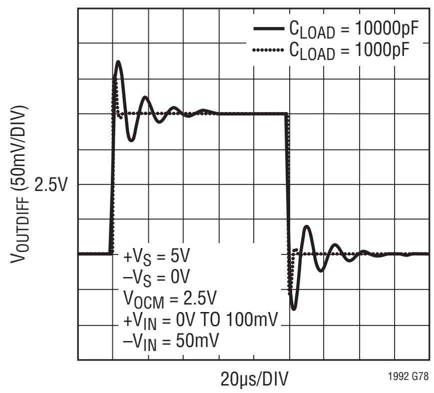


## TYPICAL PERFORMANCE CHARACTERISTICS **Applicable to the LTC1992-2 only.**

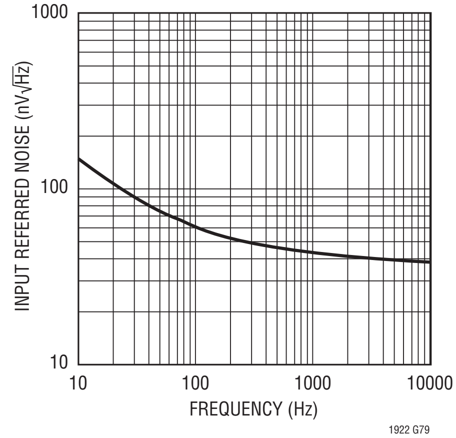
**Single-Ended Input Small-Signal Step Response**



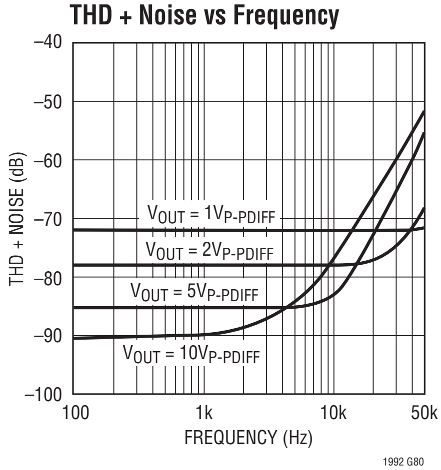

**Single-Ended Input Small-Signal Step Response**



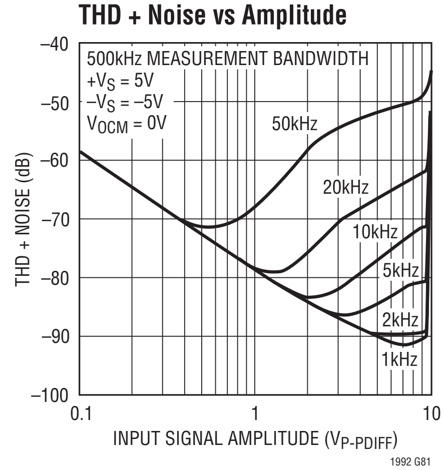

**Differential Noise Voltage Density vs Frequency**




**THD + Noise vs Frequency**

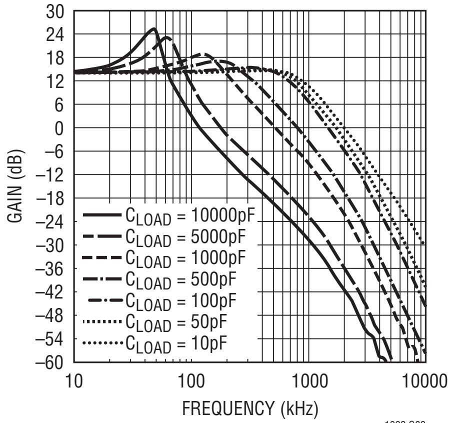



**THD + Noise vs Amplitude**

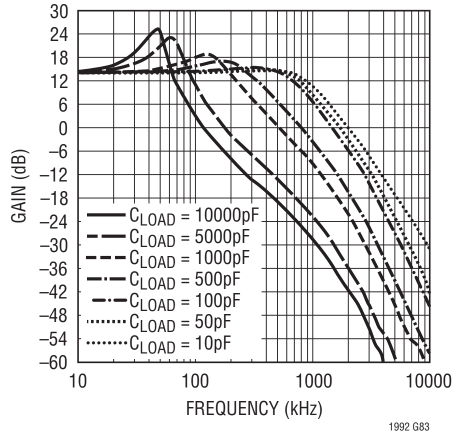


## TYPICAL PERFORMANCE CHARACTERISTICS Applicable to the LTC1992-5 only.

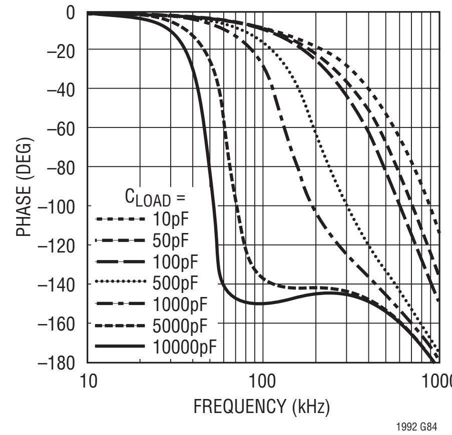
**Differential Input Differential Gain vs Frequency, $V_S = \pm2.5V$**



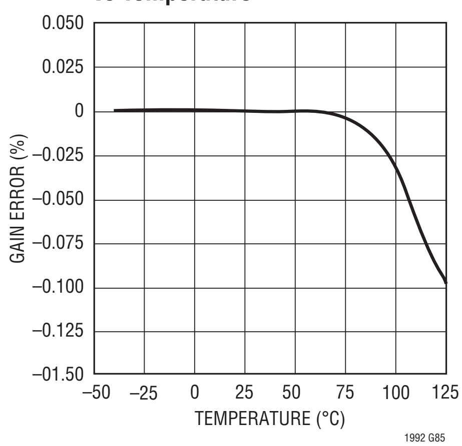

**Single-Ended Input Differential Gain vs Frequency, $V_S = \pm2.5V$**



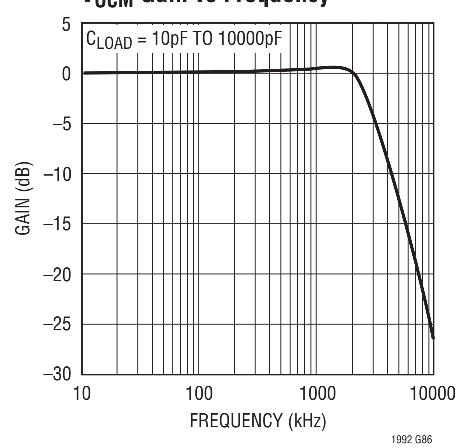

**Differential Phase Response vs Frequency**



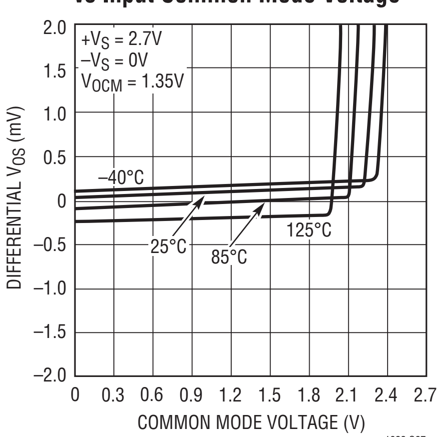

**Differential Gain Error vs Temperature**



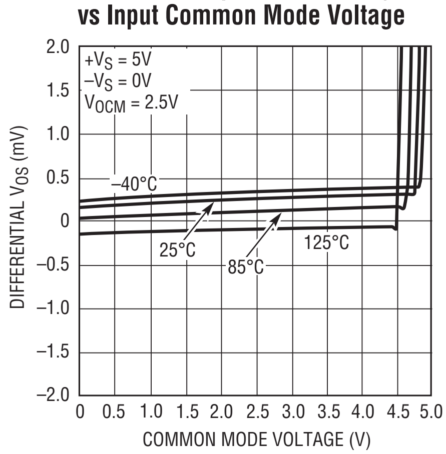

**$V_{OCM}$ Gain vs Frequency**



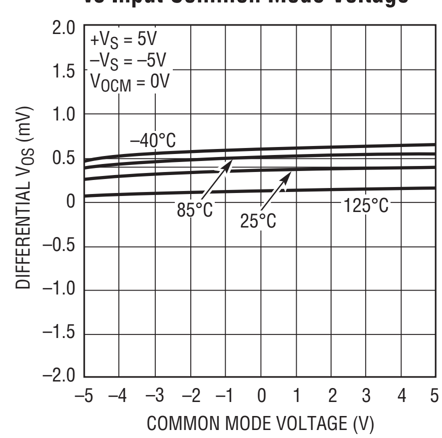

**Differential Input Offset Voltage vs Input Common Mode Voltage**




**Differential Input Offset Voltage vs Input Common Mode Voltage**




**Differential Input Offset Voltage vs Input Common Mode Voltage**

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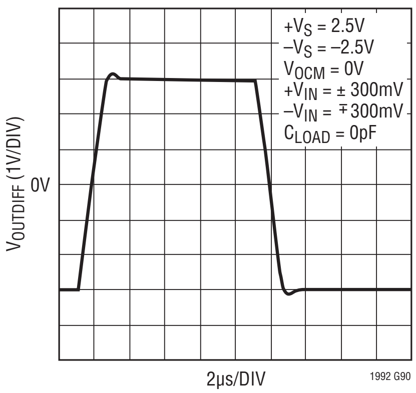
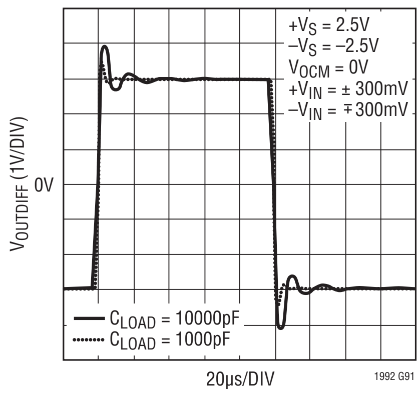
## TYPICAL PERFORMANCE CHARACTERISTICS Applicable to the LTC1992-5 only.

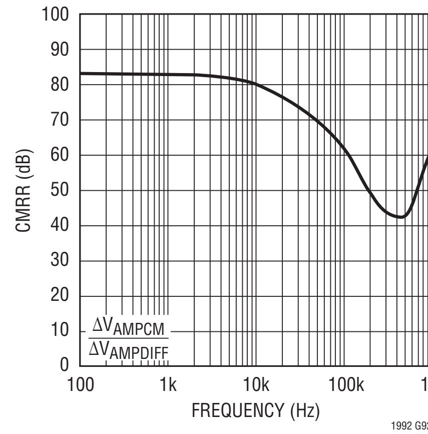
**Differential Input Large-Signal Step Response**



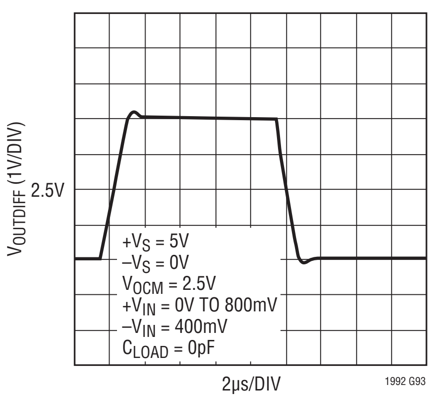

**Differential Input Large-Signal Step Response**



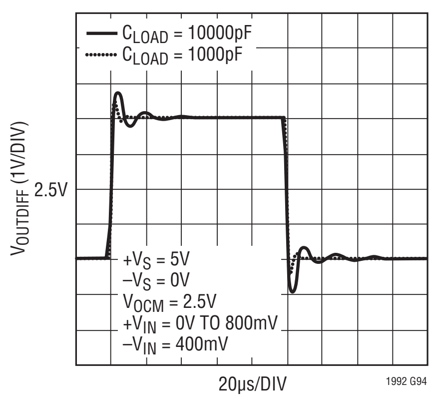

**Common Mode Rejection Ratio vs Frequency (Note 7)**



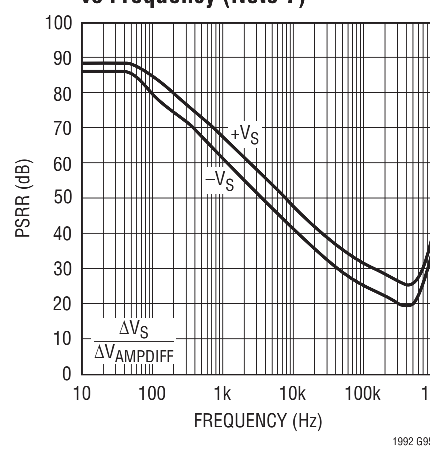

**Single-Ended Input Large-Signal Step Response**



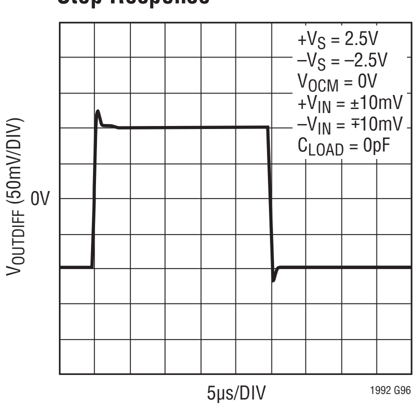

**Single-Ended Input Large-Signal Step Response**



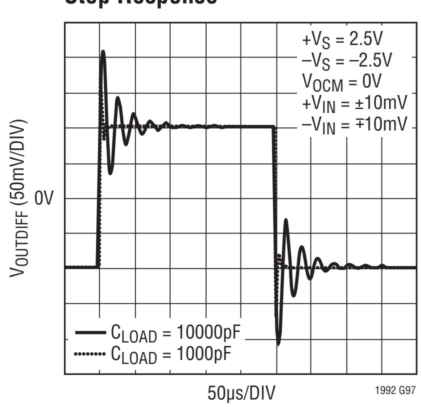

**Power Supply Rejection Ratio vs Frequency (Note 7)**



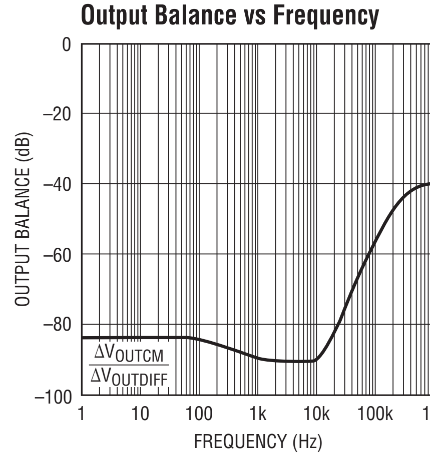

**Differential Input Small-Signal Step Response**




**Differential Input Small-Signal Step Response**

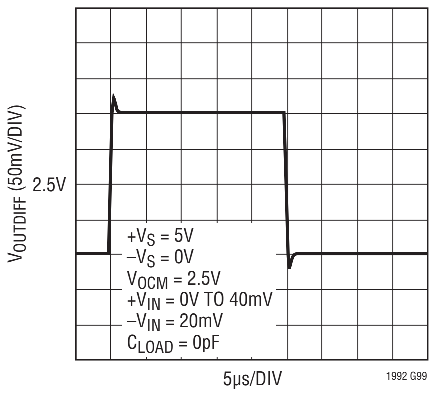



**Output Balance vs Frequency**

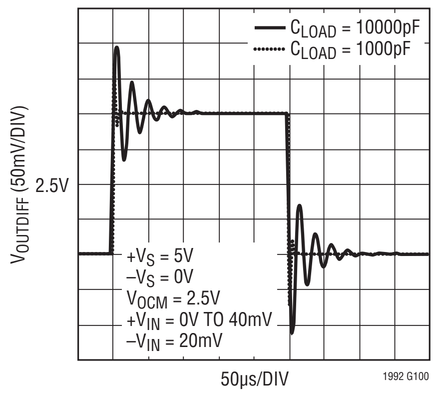


## TYPICAL PERFORMANCE CHARACTERISTICS Applicable to the LTC1992-5 only.

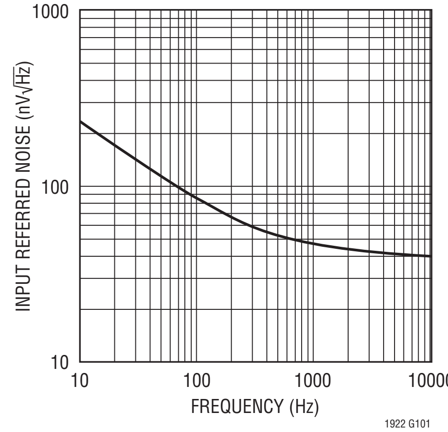
### Single-Ended Input Small-Signal Step Response



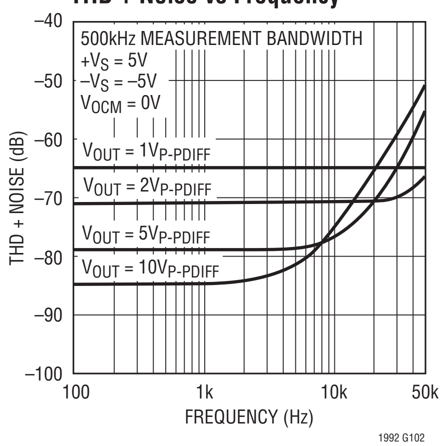

### Single-Ended Input Small-Signal Step Response



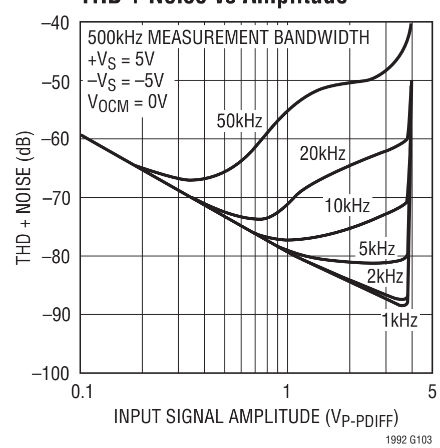

### Differential Noise Voltage Density vs Frequency




### THD + Noise vs Frequency



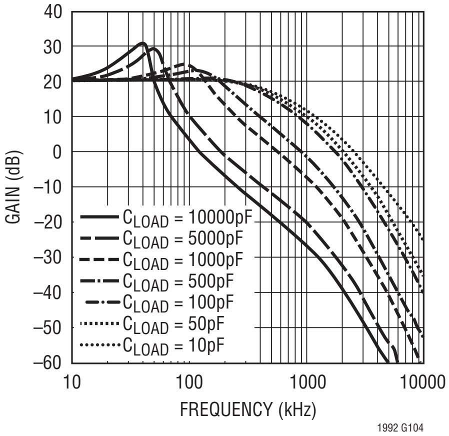

### THD + Noise vs Amplitude



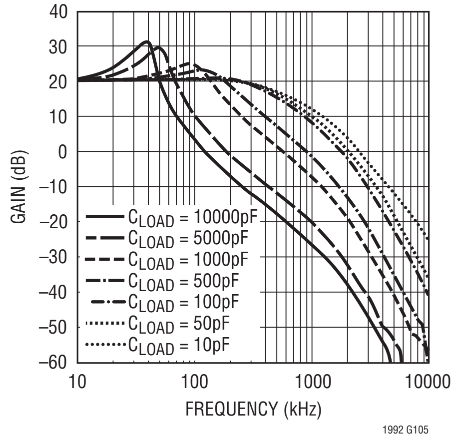
## TYPICAL PERFORMANCE CHARACTERISTICS

**Applicable to the LTC1992-10 only.**

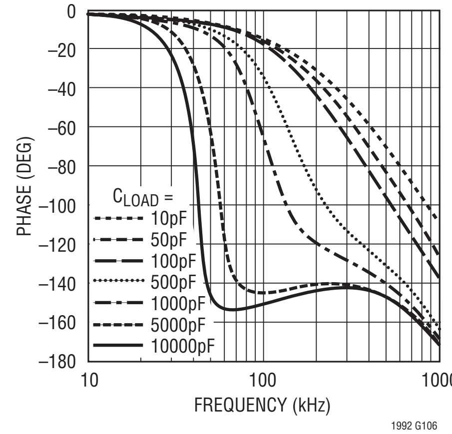
**Differential Input Differential Gain vs Frequency, $V_S = \pm 2.5V$**



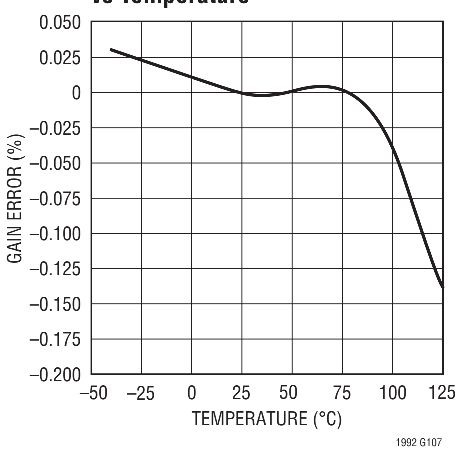

**Single-Ended Input Differential Gain vs Frequency, $V_S = \pm 2.5V$**



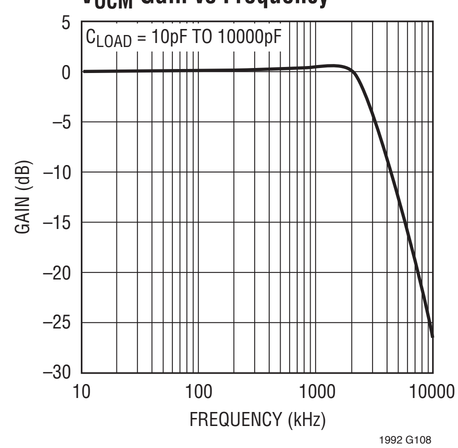

**Differential Phase Response vs Frequency**



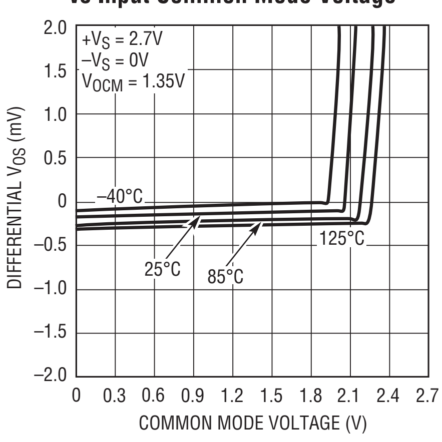

**Differential Gain Error vs Temperature**



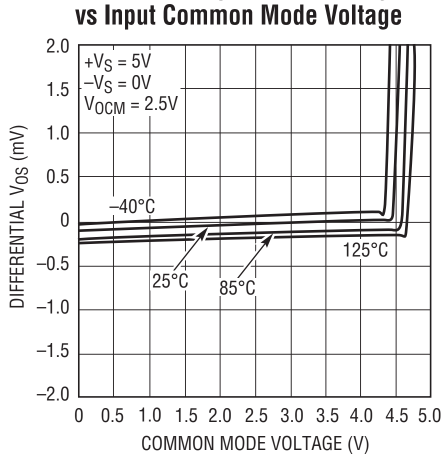

**$V_{OCM}$ Gain vs Frequency**



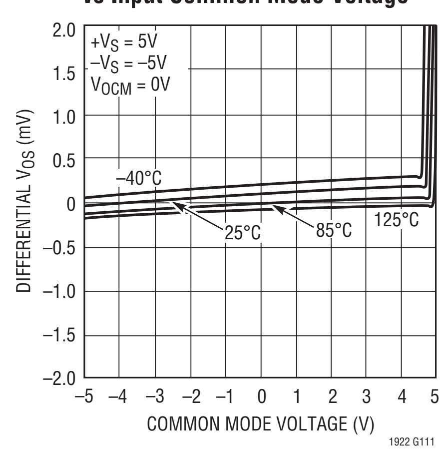

**Differential Input Offset Voltage vs Input Common Mode Voltage**




**Differential Input Offset Voltage vs Input Common Mode Voltage**

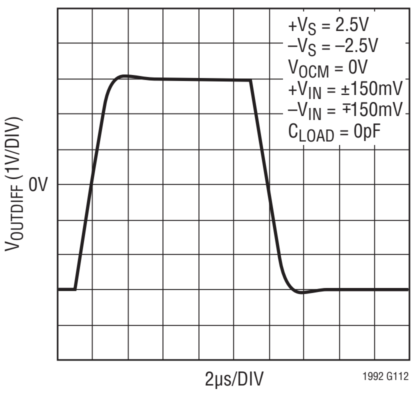



**Differential Input Offset Voltage vs Input Common Mode Voltage**

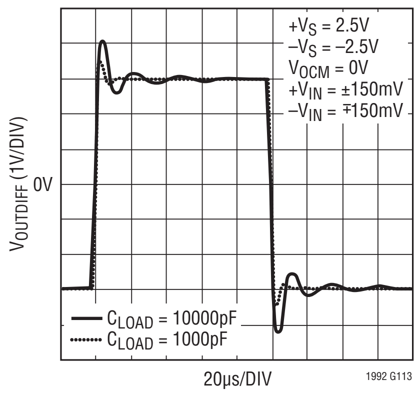


## TYPICAL PERFORMANCE CHARACTERISTICS Applicable to the LTC1992-10 only.

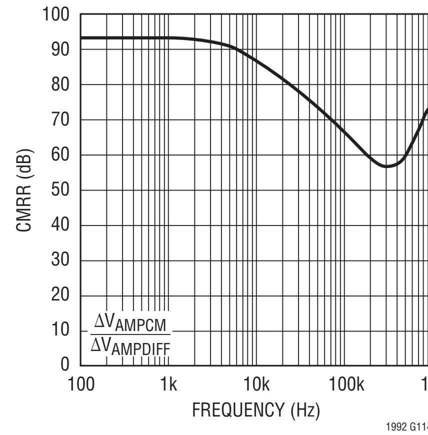
### Differential Input Large-Signal Step Response



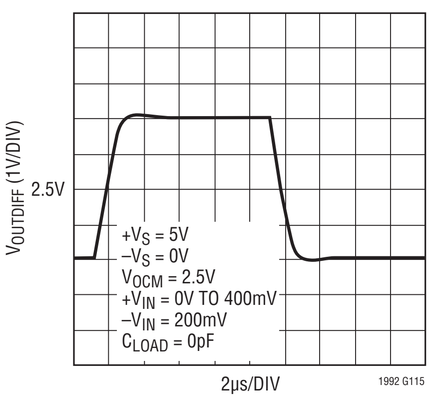

### Differential Input Large-Signal Step Response



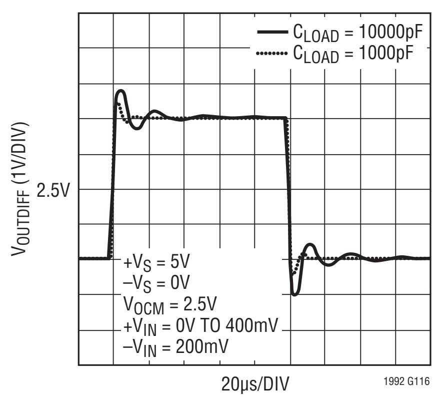

### Common Mode Rejection Ratio vs Frequency (Note 7)



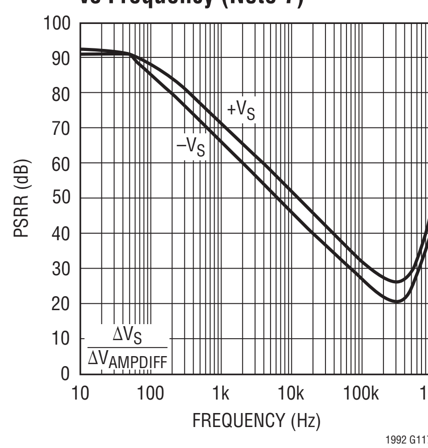

### Single-Ended Input Large-Signal Step Response



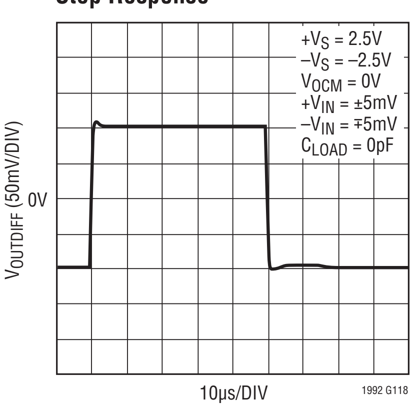

### Single-Ended Input Large-Signal Step Response



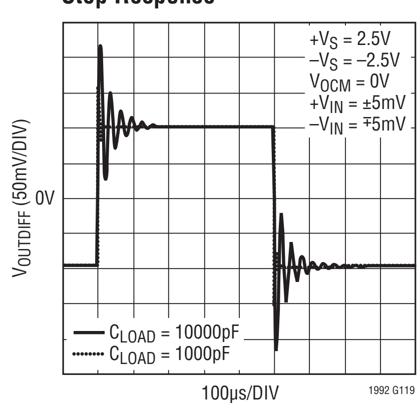

### Power Supply Rejection Ratio vs Frequency (Note 7)



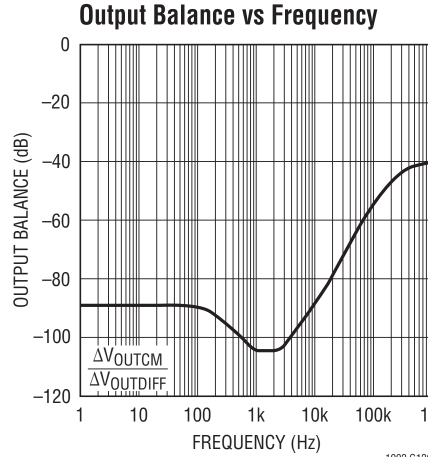

### Differential Input Small-Signal Step Response




### Differential Input Small-Signal Step Response

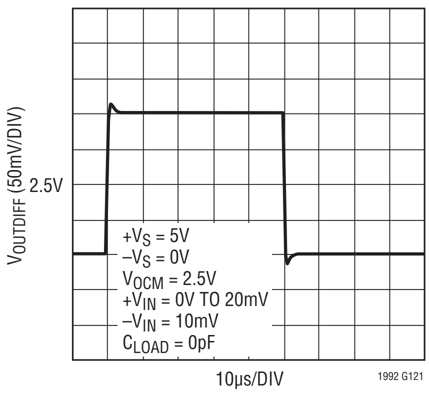



### Output Balance vs Frequency

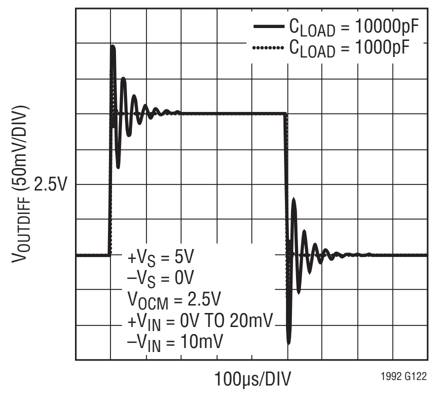


## TYPICAL PERFORMANCE CHARACTERISTICS Applicable to the LTC1992-10 only.

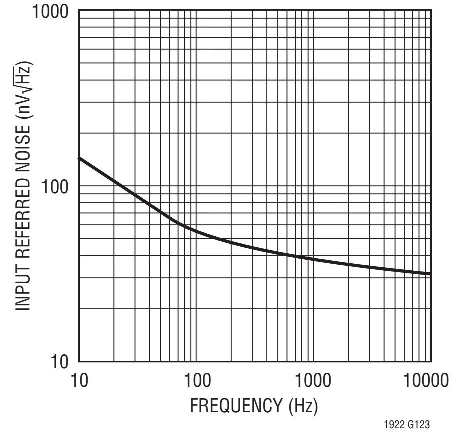
**Single-Ended Input Small-Signal Step Response**



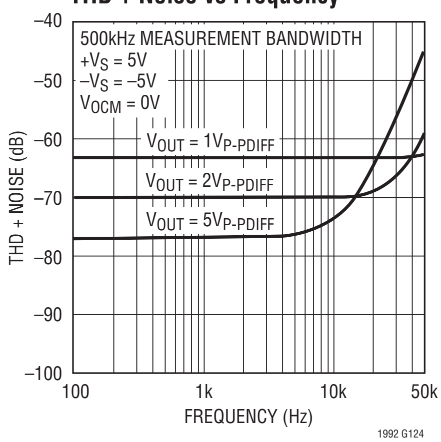

**Single-Ended Input Small-Signal Step Response**



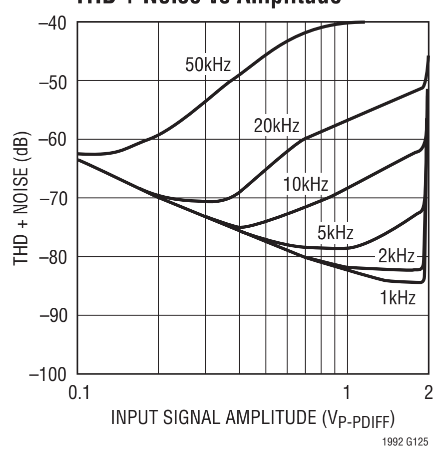

**Differential Noise Voltage Density vs Frequency**




**THD + Noise vs Frequency**




**THD + Noise vs Amplitude**



## PIN FUNCTIONS

**–IN, +IN (Pins 1, 8):** Inverting and Noninverting Inputs of the Amplifier. For the LTC1992 part, these pins are connected directly to the amplifier's P-channel MOSFET input devices. The fixed gain LTC1992-X parts have precision, on-chip gain setting resistors. The input resistors are nominally 30k for the LTC1992-1, LTC1992-2 and LTC1992-5 parts. The input resistors are nominally 15k for the LTC1992-10 part.

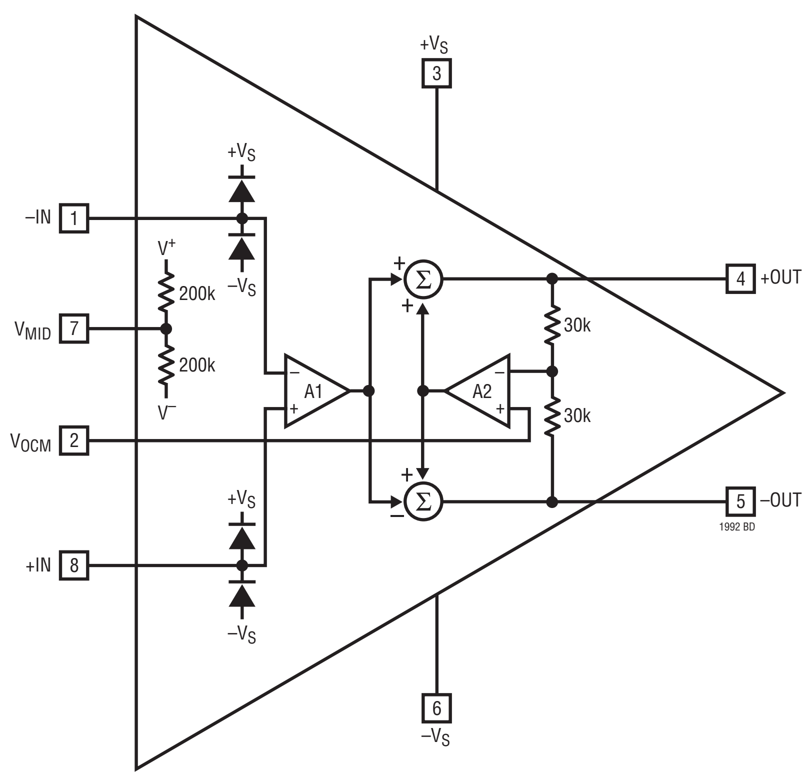
**$V_{OCM}$ (Pin 2):** Output Common Mode Voltage Set Pin. The voltage on this pin sets the output signal's common mode voltage level. The output common mode level is set independent of the input common mode level. This is a high impedance input and must be connected to a known and controlled voltage. It must never be left floating.

**$+V_S$, $–V_S$ (Pins 3, 6):** The $+V_S$ and $–V_S$ power supply pins should be bypassed with 0.1µF capacitors to an adequate analog ground or ground plane. The bypass capacitors should be located as closely as possible to the supply pins.

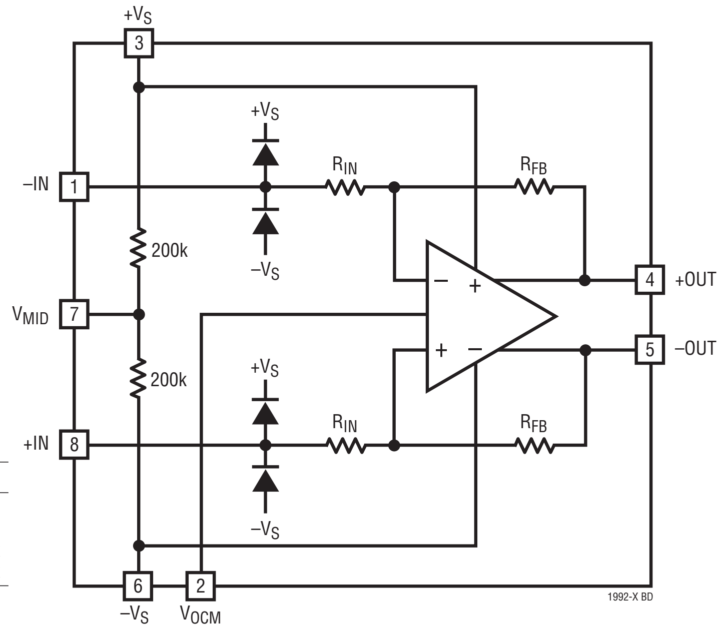
**+OUT, –OUT (Pins 4, 5):** The Positive and Negative Outputs of the Amplifier. These rail-to-rail outputs are designed to drive capacitive loads as high as 10,000pF.

**$V_{MID}$ (Pin 7):** Mid-Supply Reference. This pin is connected to an on-chip resistive voltage divider to provide a mid-supply reference. This provides a convenient way to set the output common mode level at half-supply. If used for this purpose, Pin 2 will be shorted to Pin 7, Pin 7 should be bypassed with a 0.1µF capacitor to ground. If this reference voltage is not used, leave the pin floating.

## BLOCK DIAGRAMS (1992)



## BLOCK DIAGRAMS (1992-X)




| PART | $R_{IN}$ | $R_{FB}$ |
|---|---|---|
| LTC1992-1 | 30k | 30k |
| LTC1992-2 | 30k | 60k |
| LTC1992-5 | 30k | 150k |
| LTC1992-10 | 15k | 150k |

## APPLICATIONS INFORMATION

### Theory of Operation

The LTC1992 family consists of five fully differential, low power amplifiers. The LTC1992 is an unconstrained fully differential amplifier. The LTC1992-1, LTC1992-2, LTC1992-5 and LTC1992-10 are fixed gain blocks (with gains of 1, 2, 5 and 10 respectively) featuring precision on-chip resistors for accurate and ultra stable gain.

In many ways, a fully differential amplifier functions much like the familiar, ubiquitous op amp. However, there are several key areas where the two differ. Referring to Figure 1, an op amp has a differential input, a high open-loop gain and utilizes negative feedback (through resistors) to set the closed-loop gain and thus control the amplifier's gain with great precision. A fully differential amplifier has all of these features plus an additional input and a complementary output. The complementary output reacts to the input signal in the same manner as the other output, but in the opposite direction. Two outputs changing in an equal but opposite manner require a common reference point (i.e., opposite relative to what?). The additional input, the $V_{OCM}$ pin, sets this reference point. The voltage on the $V_{OCM}$ input directly sets the output signal's common mode voltage and allows the output signal's common mode voltage to be set completely independent of the input signal's common mode voltage. **Uncoupling the input and output common mode voltages makes signal level shifting easy.**

For a better understanding of the operation of a fully differential amplifier, refer to Figure 2. Here, the LTC1992 functional block diagram adds external resistors to realize a basic gain block. Note that the LTC1992 functional block diagram is not an *exact* replica of the LTC1992 circuitry. However, the Block Diagram is correct and is a very good tool for understanding the operation of fully differential amplifier circuits. Basic op amp fundamentals together with this block diagram provide all of the tools needed for understanding fully differential amplifier circuit applications.

The LTC1992 Block Diagram has two op amps, two summing blocks (pay close attention the **signs**) and four resistors. Two resistors, $R_{MID1}$ and $R_{MID2}$, connect directly to the $V_{MID}$ pin and simply provide a convenient mid-supply reference. Its use is optional and it is not involved in the operation of the LTC1992's amplifier. The LTC1992 functions through the use of two servo networks each employing