ANALOG DEVICES

# Quad Matched 741-Type Operational Amplifiers

## OP-09/OP-11

### FEATURES

- Guaranteed $V_{OS}$ ..... 500μV Max
- Guaranteed Matched CMRR ..... 94dB Min
- Guaranteed Matched $V_{OS}$ ..... 750μV Max
- RC/RM4136 Direct Replacement (OP-09)
- LM148/LM348 Direct Replacement (OP-11)
- Low Noise
- Silicon-Nitride Passivation
- Internal Frequency Compensation
- Low Crossover Distortion
- Continuous Short-Circuit Protection
- Low Input Bias Current
- Available in Die Form

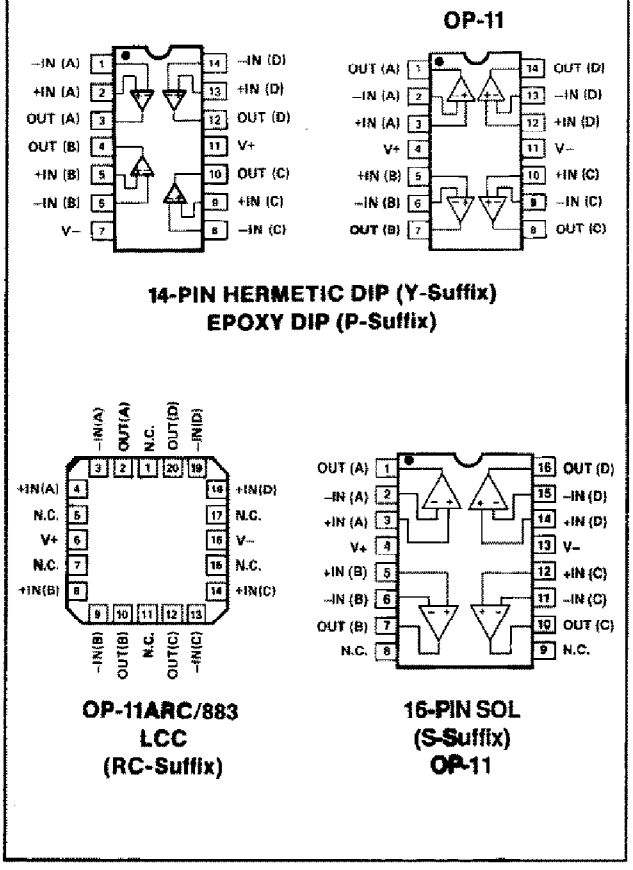
### ORDERING INFORMATION †

| $T_A$ = +25°C $V_{OS}$ MAX (mV) | PACKAGE CERDIP 14-PIN | PACKAGE PLASTIC | PACKAGE LCC 20-CONTACT | OPERATING TEMPERATURE RANGE |
|---|---|---|---|---|
| 0.5 | OP09AY* | – | – | MIL |
| | OP11AY* | – | OP11ARC/883 | |
| 0.5 | OP09EY | – | – | COM |
| | OP11EY | OP11EP | – | |
| 2.5 | OP11BY* | – | – | MIL |
| 2.5 | – | OP09FP | – | XIND |
| | OP11FY | OP11FP | – | |
| 5.0 | OP11CY/883 | – | – | MIL |
| 5.0 | – | OP11GP | – | XIND |
| | – | OP11GS | – | |

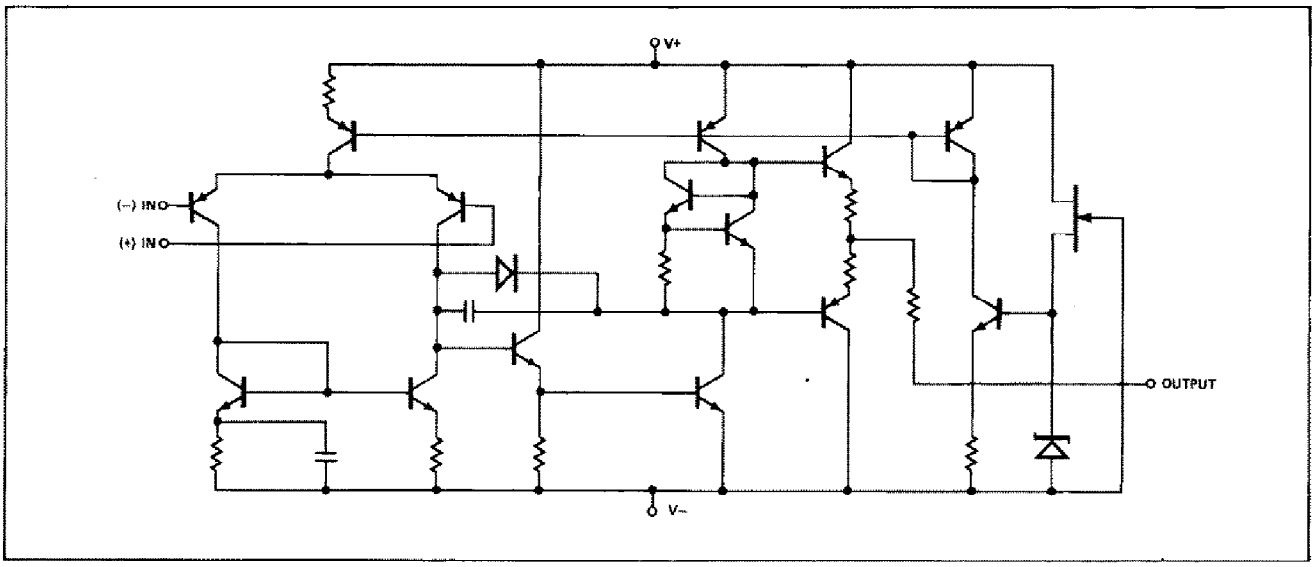
* For devices processed in total compliance to MIL-STD-883, add /883 after part number. Consult factory for 883 data sheet.

† Burn-in is available on commercial and industrial temperature range parts in CerDIP, plastic DIP, and TO-can packages.

### PIN CONNECTIONS




### SIMPLIFIED SCHEMATIC (One of Four Amplifiers is Shown)



## GENERAL DESCRIPTION

The OP-09 and OP-11 provide four matched 741-type operational amplifiers in a single 14-pin DIP package. The OP-11 is pin compatible with the LM148, LM348, RM4156, and HA4741 amplifiers. The OP-09 is pin compatible with the RM4136 and RC4136. The amplifiers are matched for common-mode rejection ratio and offset voltage which is very important in designing instrumentation amplifiers. In addition, the amplifier is designed to have equal positive-going and negative-going slew rates. This is an important consideration for good audio system performance.

Each of the four amplifiers has the proven OP-02 advantages of low noise, low drift, and excellent long-term stability. Precision Monolithics' exclusive Silicon-Nitride "Triple Passivation" process reduces "popcorn noise", provides high reliability, and assures long-term stability of parameters.

The OP-09 and OP-11 are ideal for use in designs requiring minimum space and cost while maintaining OP-02-type performance.

OP-09's and OP-11's with processing per the requirements of MIL-STD-883 are available. For dual-741-type versions, see the OP-04/14 data sheet.

## ABSOLUTE MAXIMUM RATINGS (Note 1)

Supply Voltage ..... ±22V
OP-09GR and OP-11GR (Only) ..... ±18V
Differential Input Voltage ..... ±30V
Input Voltage ..... Supply Voltage
Output Short-Circuit Duration ..... Continuous
(One Amplifier Only)

Storage Temperature Range
RC, Y-Package ..... –65°C to +150°C
P-Package ..... –65°C to +125°C
Lead Temperature Range (Soldering, 60 sec) ..... 300°C
Junction Temperature ($T_J$) ..... –65°C to +150°C
Operating Temperature Range
OP-09A, OP-09B ..... –55°C to +125°C
OP-09E ..... 0°C to +70°C
OP-09F ..... –40°C to +85°C
OP-11A, OP-11B,
OP-11C, OP-11ARC ..... –55°C to +125°C
OP-11E ..... 0°C to +70°C
OP-11F, OP-11G ..... –40°C to +85°C

| PACKAGE TYPE | $\Theta_{JA}$ (Note 2) | $\Theta_{JC}$ | UNITS |
|---|---|---|---|
| 14-Pin Hermetic DIP (Y) | 108 | 16 | °C/W |
| 14-Pin Plastic DIP (P) | 83 | 39 | °C/W |
| 20-Contact LCC (RC) | 98 | 33 | °C/W |
| 16-Pin SOL (S) | 98 | 30 | °C/W |

NOTES:
1. Absolute maximum ratings apply to both DICE and packaged parts, unless otherwise noted.
2. $\Theta_{JA}$ is specified for worst case mounting conditions, i.e., $\Theta_{JA}$ is specified for device in socket for CerDIP, P-DIP, and LCC packages; $\Theta_{JA}$ is specified for device soldered to printed circuit board for SOL package.

## MATCHING CHARACTERISTICS at $V_S = \pm 15V$, $T_A = +25°C$, $R_S \leq 100\Omega$, unless otherwise noted.

| | | | OP-09A, OP-09E OP-11A, OP-11E | | | OP-09B, OP-09F OP-11B, OP-11F | | | |
|---|---|---|---|---|---|---|---|---|---|
| PARAMETER | SYMBOL | CONDITIONS | MIN | TYP | MAX | MIN | TYP | MAX | UNITS |
| Input Offset Voltage Match | $\Delta V_{OS}$ | | — | 0.5 | 0.75 | — | 0.8 | 2.0 | mV |
| Common-Mode Rejection Ratio Match | ΔCMRR | $V_{CM} = \pm 12V$ | — | 1 | 20 | — | 1 | 20 | μV/V |
| | | $V_{CM} = \pm 12V$ | 94 | 120 | — | 94 | 120 | — | dB |

## MATCHING CHARACTERISTICS at $V_S = \pm 15V$, $-55°C \leq T_A \leq +125°C$ for OP-09A, OP-09B, OP-11A, OP-11B, $0°C \leq T_A \leq +70°C$ for OP-09E, OP-11E and $-40°C \leq T_A \leq +85°C$ for OP-09F, OP-11F, $R_S \leq 100\Omega$, unless otherwise noted.

| | | | OP-09A, OP-09E OP-11A, OP-11E | | | OP-09B, OP-09F OP-11B, OP-11F | | | |
|---|---|---|---|---|---|---|---|---|---|
| PARAMETER | SYMBOL | CONDITIONS | MIN | TYP | MAX | MIN | TYP | MAX | UNITS |
| Input Offset Voltage Match | $\Delta V_{OS}$ | | — | 0.6 | 1.0 | — | 1.0 | 2.5 | mV |
| Common-Mode Rejection Ratio Match | ΔCMRR | $V_{CM} = \pm 12V$ | — | 3.2 | 20 | — | 3.2 | 20 | μV/V |
| | | $V_{CM} = \pm 12V$ | 94 | 110 | — | 94 | 110 | — | dB |

## ELECTRICAL CHARACTERISTICS (Each Amplifier) at $V_S = \pm 15V$ $T_A = 25°C$, unless otherwise noted.

| PARAMETER | SYMBOL | CONDITIONS | OP-09A/E OP-11A/E MIN | OP-09A/E OP-11A/E TYP | OP-09A/E OP-11A/E MAX | OP-09B/F OP-11B/F MIN | OP-09B/F OP-11B/F TYP | OP-09B/F OP-11B/F MAX | OP-11C/G MIN | OP-11C/G TYP | OP-11C/G MAX | UNITS |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Input Offset Voltage | $V_{OS}$ | $R_S \leq 10k\Omega$ | — | 0.3 | 0.5 | — | 0.6 | 2.5 | — | 1.2 | 5.0 | mV |
| Input Offset Current | $I_{OS}$ | | — | 5.5 | 20 | — | 25 | 50 | — | 75 | 200 | nA |
| Input Bias Current | $I_B$ | | — | 180 | 300 | — | 300 | 500 | — | 300 | 500 | nA |
| Input Resistance Differential Mode | $R_{IN}$ | (Note 3) | 0.17 | 0.29 | — | 0.1 | 0.17 | — | 0.1 | 0.17 | — | MΩ |
| Input Voltage Range | IVR | | ±12 | ±13 | — | ±12 | ±13 | — | ±12 | ±13 | — | V |
| Common-Mode Rejection Ratio | CMRR | $V_{CM} = \pm 12V$, $R_S \leq 10k\Omega$ | 100 | 120 | — | 100 | 120 | — | 70 | 100 | — | dB |
| Power Supply Rejection Ratio | PSRR | $V_S = \pm 5$ to $\pm 15V$, $R_S \leq 10k\Omega$ | — | 4 | 32 | — | 4 | 32 | — | 10 | 100 | μV/V |
| Output Voltage Swing | $V_O$ | $R_L \geq 2k\Omega$ | ±11 | ±13 | — | ±11 | ±13 | — | ±11 | ±13 | — | V |
| Large-Signal Voltage Gain | $A_{VO}$ | $R_L \leq 2k\Omega$, $V_O = \pm 10V$ | 100 | 650 | — | 100 | 650 | — | 50 | 500 | — | V/mV |
| Power Consumption (Note 1) | $P_d$ | $V_O = 0V$ | — | 105 | 180 | — | 123 | 180 | — | 210 | 340 | mW |
| Input Noise Voltage | $e_{np-p}$ | 0.1Hz to 10Hz | — | 0.7 | — | — | 0.7 | — | — | 0.7 | — | $\mu V_{p-p}$ |
| Input Noise Voltage Density | $e_n$ | $f_O = 10Hz$ | — | 18 | — | — | 18 | — | — | 18 | — | $nV/\sqrt{Hz}$ |
| | | $f_O = 100Hz$ | — | 14 | — | — | 14 | — | — | 14 | — | |
| | | $f_O = 1000Hz$ | — | 12 | — | — | 12 | — | — | 12 | — | |
| Input Noise Current | $i_{np-p}$ | 0.1Hz to 10Hz | — | 17 | — | — | 17 | — | — | 17 | — | $pA_{p-p}$ |
| Input Noise Current Density | $i_n$ | $f_O = 10Hz$ | — | 1.8 | — | — | 1.8 | — | — | 1.8 | — | $pA/\sqrt{Hz}$ |
| | | $f_O = 100Hz$ | — | 1.5 | — | — | 1.5 | — | — | 1.5 | — | |
| | | $f_O = 1000Hz$ | — | 1.2 | — | — | 1.2 | — | — | 1.2 | — | |
| Channel Separation | CS | | 100 | 130 | — | 100 | 130 | — | — | 130 | — | dB |
| Slew Rate (Note 2) | SR | | 0.7 | 1.0 | — | 0.7 | 1.0 | — | 0.7 | 1.0 | — | V/μs |
| Large-Signal Bandwidth (Note 2) | | $V_O = 20V_{p-p}$ | 11 | 16 | — | 11 | 16 | — | 11 | 16 | — | kHz |
| Closed-Loop Bandwidth (Note 4) | BW | $A_{VCL} = +1.0$ | 2.4 | 3.0 | — | 2.4 | 3.0 | — | 2.4 | 3.0 | — | MHz |
| Risetime (Note 2) | $t_r$ | $A_V = +1$, $V_{IN} = 50mV$ | — | 110 | 145 | — | 110 | 145 | — | 110 | 145 | ns |
| Overshoot (Note 2) | OS | | — | 15 | 25 | — | 15 | 25 | — | 15 | 25 | % |

**NOTES:**
1. Total dissipation for all four amplifiers in package.
2. Sample tested.
3. Guaranteed by input bias current.
4. Guaranteed by risetime.

**ELECTRICAL CHARACTERISTICS (Each Amplifier)** at $V_S = \pm 15V$, $-55°C \le T_A \le +125°C$, unless otherwise noted.

| PARAMETER | SYMBOL | CONDITIONS | OP-09A OP-11A MIN | OP-09A OP-11A TYP | OP-09A OP-11A MAX | OP-09B OP-11B MIN | OP-09B OP-11B TYP | OP-09B OP-11B MAX | OP-11C MIN | OP-11C TYP | OP-11C MAX | UNITS |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Input Offset Voltage | $V_{OS}$ | $R_S \le 10k\Omega$ | — | 0.4 | 1.0 | — | 1.0 | 3.5 | — | 1.5 | 6.0 | mV |
| Average Input Offset Voltage Drift (Note 3) | $TCV_{OS}$ | $R_S \le 10k\Omega$ | — | 2.0 | 10 | — | 4.0 | 15 | — | 4.0 | — | $\mu V/°C$ |
| Input Offset Current | $I_{OS}$ | | — | 20 | 40 | — | 40 | 80 | — | 250 | 300 | nA |
| Average Input Offset Current Drift (Note 3) | $TCI_{OS}$ | | — | 0.1 | 0.3 | — | 0.3 | 0.6 | — | 0.3 | 0.6 | nA/°C |
| Input Bias Current | $I_B$ | | — | 200 | 375 | — | 400 | 650 | — | 400 | 800 | nA |
| Input Voltage Range | IVR | | ±12 | ±13 | — | ±12 | ±13 | — | ±12 | ±13 | — | V |
| Common-Mode Rejection Ratio | CMRR | $V_{CM} = \pm 12V$, $R_S \le 10k\Omega$ | 100 | 120 | — | 100 | 120 | — | 70 | 100 | — | dB |
| Power Supply Rejection Ratio | PSRR | $V_S = \pm 5$ to $\pm 15V$, $R_S \le 10k\Omega$ | — | 4 | 32 | — | 4 | 32 | — | 10 | 100 | $\mu V/V$ |
| Large-Signal Voltage Gain | $A_{VO}$ | $R_L \ge 2k\Omega$, $V_O = \pm 10V$ | 50 | 250 | — | 50 | 250 | — | 25 | 100 | — | V/mV |
| Output Voltage Swing | $V_O$ | $R_L \ge 2k\Omega$ | ±11 | ±13 | — | ±11 | ±13 | — | ±11 | ±13 | — | V |
| Power Consumption (Note 1) | $P_d$ | $V_O = 0V$ | — | 115 | 200 | — | 115 | 200 | — | 250 | 400 | mW |

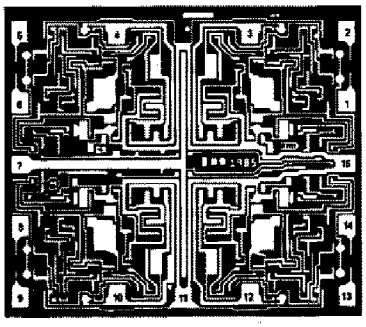
**ELECTRICAL CHARACTERISTICS (Each Amplifier)** at $V_S = \pm 15V$, $0°C \le T_A \le +70°C$ for OP-09E, OP-11E, $-40°C \le T_A \le +85°C$ for OP-09F, OP11F, OP-11G, unless otherwise noted.

| PARAMETER | SYMBOL | CONDITIONS | OP-09E OP-11E MIN | OP-09E OP-11E TYP | OP-09E OP-11E MAX | OP-09F OP-11F MIN | OP-09F OP-11F TYP | OP-09F OP-11F MAX | OP-11G MIN | OP-11G TYP | OP-11G MAX | UNITS |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Input Offset Voltage | $V_{OS}$ | $R_S \le 10k\Omega$ | — | 0.4 | 0.8 | — | 0.8 | 3.0 | — | 1.5 | 6.0 | mV |
| Average Input Offset Voltage Drift | $TCV_{OS}$ | $R_S \le 10k\Omega$ | — | 2.0 | 10 | — | 4.0 | 15 | — | 4.0 | — | $\mu V/°C$ |
| Input Offset Current | $I_{OS}$ | | — | 14 | 30 | — | 40 | 60 | — | 250 | 300 | nA |
| Average Input Offset Current Drift (Note 3) | $TCI_{OS}$ | | — | 0.1 | 0.3 | — | 0.3 | 0.6 | — | 0.3 | 0.6 | nA/°C |
| Input Bias Current | $I_B$ | | — | 200 | 350 | — | 400 | 550 | — | 400 | 800 | nA |
| Input Voltage Range | IVR | | ±12 | ±13 | — | ±12 | ±13 | — | ±12 | ±13 | — | V |
| Common-Mode Rejection Ratio | CMRR | $V_{CM} = \pm 12V$, $R_S \le 10k\Omega$ | 100 | 120 | — | 100 | 120 | — | 70 | 100 | — | dB |
| Power Supply Rejection Ratio | PSRR | $V_S = \pm 5$ to $\pm 15V$, $R_S \le 10k\Omega$ | — | 4 | 32 | — | 4 | 32 | — | 10 | 100 | $\mu V/V$ |
| Large-Signal Voltage Gain | $A_{VO}$ | $R_L \ge 2k\Omega$, $V_O = \pm 10V$ | 50 | 250 | — | 50 | 250 | — | 25 | 100 | — | V/mV |
| Output Voltage Swing | $V_O$ | $R_L \ge 2k\Omega$ | ±11 | ±13 | — | ±11 | ±13 | — | ±11 | ±13 | — | V |
| Power Consumption (Note 1) | $P_d$ | $V_O = 0V$ | — | 115 | 200 | — | 115 | 200 | — | 250 | 400 | mW |

**NOTES:**
1. Total dissipation for all four amplifiers in package.
2. Sample tested.
3. Guaranteed but not tested.

## DICE CHARACTERISTICS (125° C TESTED DICE AVAILABLE)

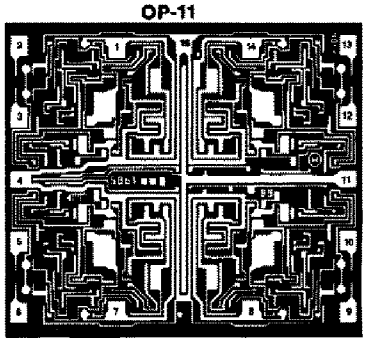
**OP-09**



1. INVERTING INPUT (A)
2. NONINVERTING INPUT (A)
3. OUTPUT (A)
4. OUTPUT (B)
5. NONINVERTING INPUT (B)
6. INVERTING INPUT (B)
7. V−
8. INVERTING INPUT (C)
9. NONINVERTING INPUT (C)
10. OUTPUT (C)
11. V+
12. OUTPUT (D)
13. NONINVERTING INPUT (D)
14. INVERTING INPUT (D)
15. V+

DIE SIZE 0.086 × 0.072 inch, 6192 sq. mils
(2.18 × 1.83 mm, 3.99 sq. mm)

**OP-11**



1. OUTPUT (A)
2. INVERTING INPUT (A)
3. NONINVERTING INPUT (A)
4. V+
5. NONINVERTING INPUT (B)
6. INVERTING INPUT (B)
7. OUTPUT (B)
8. OUTPUT (C)
9. INVERTING INPUT (C)
10. NONINVERTING INPUT (C)
11. V−
12. NONINVERTING INPUT (D)
13. INVERTING INPUT (D)
14. OUTPUT (D)
15. V+

DIE SIZE 0.086 × 0.072 inch, 6192 sq. mils
(2.18 × 1.83 mm, 3.99 sq. mm)

**NOTE:**
Either or both V+ pads may be used without any change in performance.

**WAFER TEST LIMITS** at $V_S = \pm 15V$, $T_A = 25°C$ for OP-09/11N, OP-09/11G and OP-09/11GR devices; $T_A = 125°C$ for OP-09/11NT and OP-09/11GT devices, unless otherwise noted.

| PARAMETER | SYMBOL | CONDITIONS | OP-09NT OP-11NT LIMIT | OP-09N OP-11N LIMIT | OP-09GT OP-11GT LIMIT | OP-11G LIMIT | OP-09GR OP-11GR LIMIT | UNITS |
|---|---|---|---|---|---|---|---|---|
| Input Offset Voltage | $V_{OS}$ | $R_S \le 10k\Omega$ | 1.0 | 0.5 | 3.5 | 2.5 | 5.0 | mV MAX |
| Input Offset Current | $I_{OS}$ | | 20 | 20 | 50 | 50 | 200 | nA MAX |
| Input Bias Current | $I_B$ | | 300 | 300 | 500 | 500 | 500 | nA MAX |
| Input Voltage Range | IVR | | ±12 | ±12 | ±12 | ±12 | ±12 | V MIN |
| Common-Mode Rejection Ratio | CMRR | $V_{CM} = \pm 12V$<br>$R_S \le 10k\Omega$ | 100 | 100 | 100 | 100 | 70 | dB MIN |
| Power Supply Rejection Ratio | PSRR | $V_S = \pm 5V$ to $\pm 15V$<br>$R_S \le 10k\Omega$ | 32 | 32 | 32 | 32 | 100 | µV/V MAX |
| Output Voltage Swing | $V_O$ | $R_L \ge 10k\Omega$<br>$R_L = 2k\Omega$ | ±11<br>±11 | ±12<br>±11 | ±11<br>±11 | ±12<br>±11 | ±11<br>±11 | V MIN |
| Large-Signal Voltage Gain | $A_{VO}$ | $R_L \ge 2k\Omega$<br>$V_O = \pm 10V$ | 50 | 100 | 50 | 100 | 50 | V/mV MIN |
| Power Consumption (Four Amplifiers) | $P_d$ | $V_{OUT} = 0$<br>No Load | 200 | 180 | 200 | 180 | 340 | mW MAX |

**NOTES:**
For 25°C characteristics of NT & GT devices, see N & G characteristics, respectively.

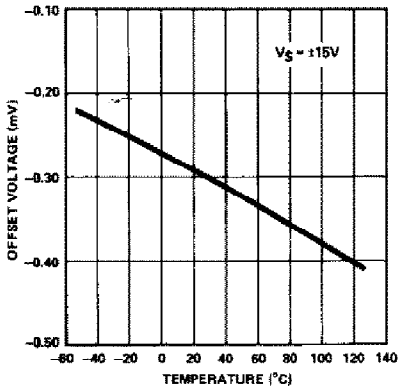
Electrical tests are performed at wafer probe to the limits shown. Due to variations in assembly methods and normal yield loss, yield after packaging is not guaranteed for standard product dice. Consult factory to negotiate specifications based on dice lot qualification through sample lot assembly and testing.

**TYPICAL ELECTRICAL CHARACTERISTICS** at $V_S = \pm 15V$, $T_A = +25°C$, unless otherwise noted.

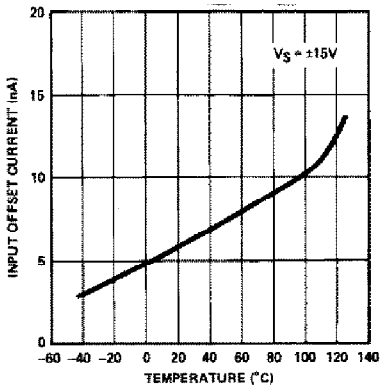
| PARAMETER | SYMBOL | CONDITIONS | OP-09NT OP-11NT TYPICAL | OP-09N OP-11N TYPICAL | OP-09GT OP-11GT TYPICAL | OP-11G TYPICAL | OP-09GR OP-11GR TYPICAL | UNITS |
|---|---|---|---|---|---|---|---|---|
| Slew Rate | SR | $A_V = 1$<br>$R_L \ge 2k\Omega$ | 1 | 1 | 1 | 1 | 1 | V/µs |
| Unity Gain Bandwidth | GBW | | 2 | 2 | 2 | 2 | 2 | MHz |
| Channel Separation | CS | $A_V = 100$<br>f = 10kHz<br>$R_S = 1k\Omega$ | 130 | 130 | 130 | 130 | 130 | dB |

## TYPICAL PERFORMANCE CHARACTERISTICS

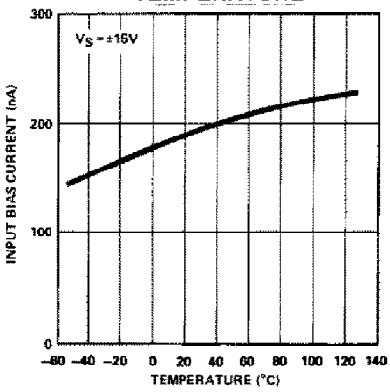
### INPUT OFFSET VOLTAGE vs TEMPERATURE



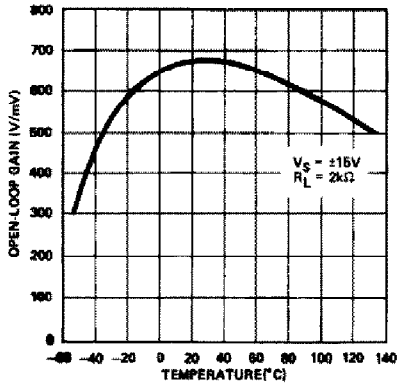

### OFFSET CURRENT vs TEMPERATURE



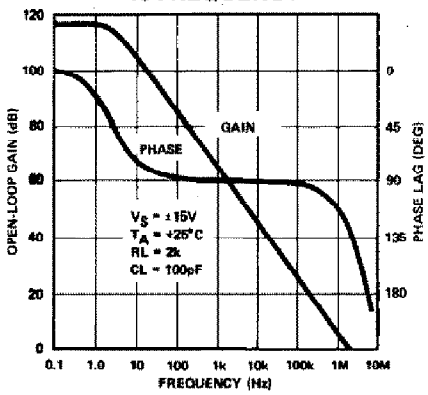

### BIAS CURRENT vs TEMPERATURE



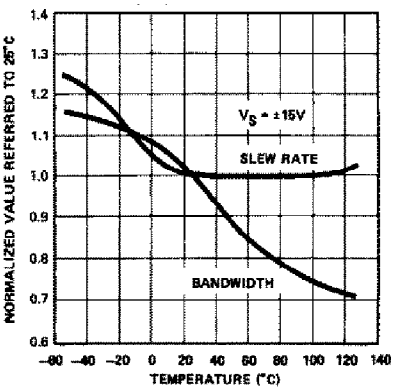

### OPEN-LOOP GAIN vs TEMPERATURE



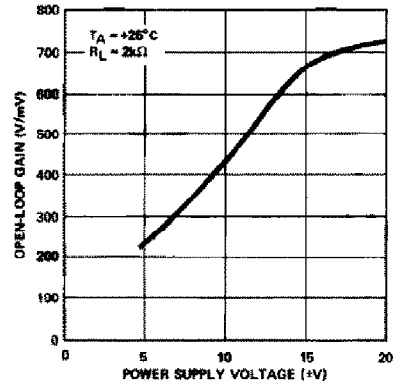

### OPEN-LOOP GAIN AND PHASE vs FREQUENCY



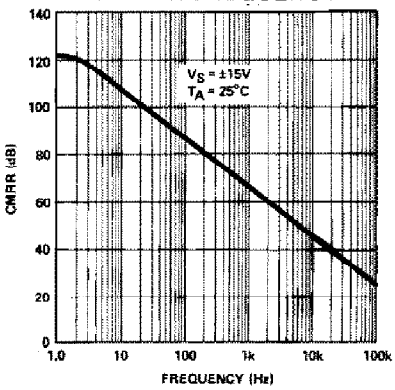

### NORMALIZED SLEW RATE AND BANDWIDTH vs TEMPERATURE



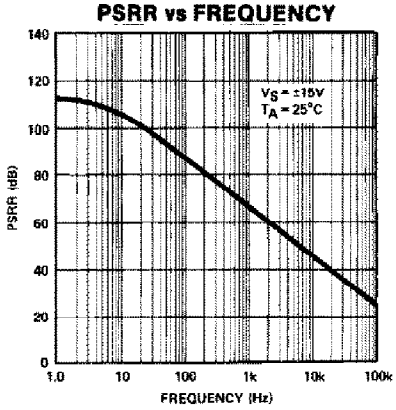

### OPEN-LOOP GAIN vs SUPPLY VOLTAGE




### CMRR vs FREQUENCY

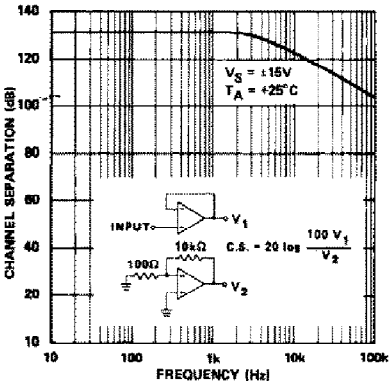



### PSRR vs FREQUENCY

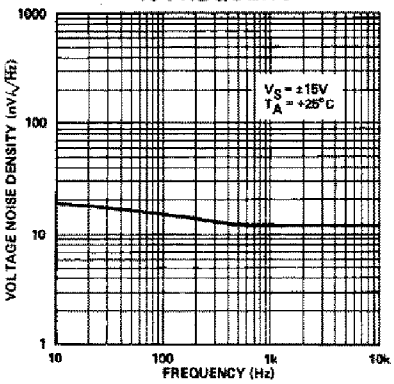


## TYPICAL PERFORMANCE CHARACTERISTICS

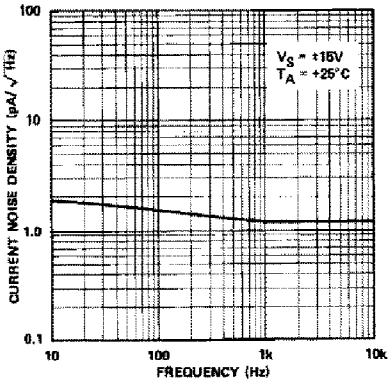
### CHANNEL SEPARATION vs FREQUENCY



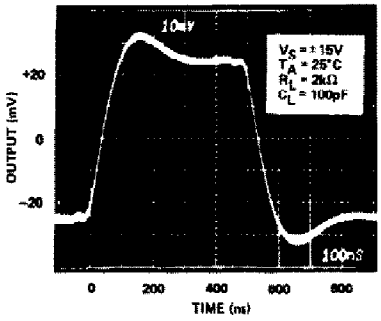

### NOISE VOLTAGE DENSITY vs FREQUENCY



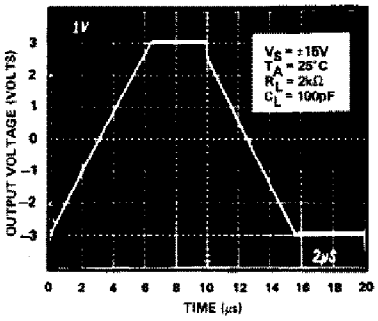

### NOISE CURRENT DENSITY vs FREQUENCY



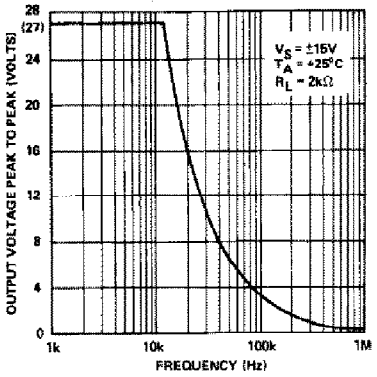

### TRANSIENT RESPONSE



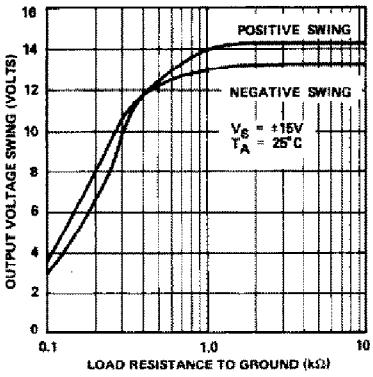

### VOLTAGE FOLLOWER PULSE RESPONSE



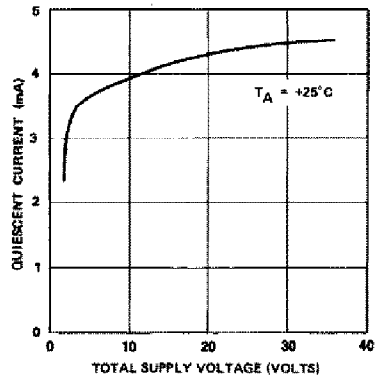

### MAXIMUM OUTPUT SWING vs FREQUENCY




### OUTPUT VOLTAGE vs LOAD RESISTANCE




### QUIESCENT CURRENT vs SUPPLY VOLTAGE




### POWER CONSUMPTION vs TEMPERATURE