September 1998 File Number 2901.3

# 150MHz, High Slew Rate, Precision Operational Amplifier

The HA-2548 is an op amp that offers a unique combination of bandwidth, slew rate, and precision specifications. These features can eliminate the need for composite op amp designs and external calibration circuitry.

Optimized for gains ≥5, the HA-2548 has a gain-bandwidth product of 150MHz and a slew rate of 120V/µs while maintaining extremely high open loop gain (130dB Typ) and low offset voltage (300µV Typ). These specifications are achieved through uniquely designed input circuitry and a single ultra-high gain stage that minimizes the AC signal path. Capable of delivering over 30mA of output current, the HA-2548 is ideal for precision, high speed applications such as signal conditioning, instrumentation, video/pulse amplifiers and buffers.

For information on the military version of this device please refer to the HA-2548/883 datasheet.

## Features

- High Slew Rate . . . . . . . . . . . . . . . . . . . . . . . . . 120V/µs
- Low Offset Voltage. . . . . . . . . . . . . . . . . . . . . . . . .300µV
- High Open Loop Gain . . . . . . . . . . . . . . . . . . . . . .130dB
- Gain Bandwidth Product . . . . . . . . . . . . . . . . . . 150MHz
- Low Noise Voltage at 1kHz . . . . . . . . . . . . . . . 8.3nV/√Hz
- Minimum Gain Stability . . . . . . . . . . . . . . . . . . . . . . . . ≥5

## Applications

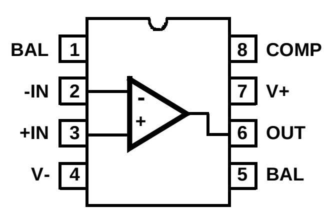
- High Speed Instrumentation
- Data Acquisition Systems
- Analog Signal Conditioning
- Precision, Wideband Amplifiers
  - Pulse/RF Amplifiers

## Part Number Information

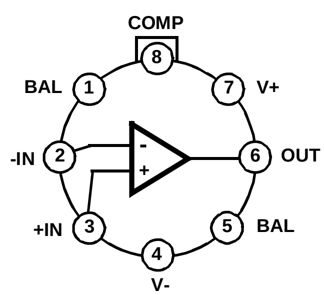
| PART NUMBER | TEMP. RANGE ($^{o}$C) | PACKAGE | PKG. NO. |
|---|---|---|---|
| HA2-2548-5 | 0 to 75 | 8 Pin Metal Can | T8.C |
| HA2-2548-9 | -40 to 85 | 8 Pin Metal Can | T8.C |
| HA3-2548-5 | 0 to 75 | 8 Ld PDIP | E8.3 |
| HA7-2548-5 | 0 to 75 | 8 Ld SBDIP | D8.3 |
| HA9P2548-5 | 0 to 75 | 16 Ld SOIC | M16.3 |

## Pinouts

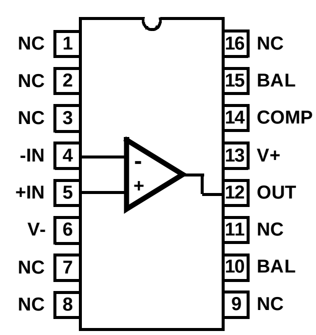
HA-2548
(PDIP, SBDIP)
TOP VIEW




HA-2548
(METAL CAN)
TOP VIEW




HA-2548
(SOIC)
TOP VIEW



## Absolute Maximum Ratings

Supply Voltage Between V+ and V- Terminals . . . . . . . . . . . . . .40V
Differential Input Voltage . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . .5V
Output Current . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . 40mA

## Operating Conditions

Temperature Range
HA-2548-5 . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . $0^oC$ to $75^oC$
HA-2548-9 . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . $-40^oC$ to $85^oC$

## Thermal Information

| Thermal Resistance (Typical, Note 1) | $\theta_{JA}$ ($^oC/W$) | $\theta_{JC}$ ($^oC/W$) |
|---|---|---|
| SBDIP Package | 110 | 30 |
| PDIP Package | 92 | N/A |
| SOIC Package | 96 | N/A |
| Metal Can Package | 165 | 80 |

Maximum Junction Temperature (Hermetic Packages) . . . . . . $175^oC$
Maximum Junction Temperature (Plastic Package) . . . . . . . $150^oC$
Maximum Storage Temperature Range . . . . . . . . . $-65^oC$ to $150^oC$
Maximum Lead Temperature (Soldering 10s) . . . . . . . . . . . . $300^oC$
(SOIC - Lead Tips Only)

*CAUTION: Stresses above those listed in "Absolute Maximum Ratings" may cause permanent damage to the device. This is a stress only rating and operation of the device at these or any other conditions above those indicated in the operational sections of this specification is not implied.*

NOTE:

1. $\theta_{JA}$ is measured with the component mounted on an evaluation PC board in free air.

## Electrical Specifications

$V_{SUPPLY}$ = ±15V, $R_L$ = 1kΩ, $C_L$ = 10pF, Unless Otherwise Specified

| PARAMETER | TEST CONDITIONS | TEMP ($^oC$) | HA-2548-5, -9 MIN | TYP | MAX | UNITS |
|---|---|---|---|---|---|---|
| **INPUT CHARACTERISTICS** | | | | | | |
| Input Offset Voltage | | 25 | - | 300 | 900 | µV |
| | | Full | - | 400 | 1200 | µV |
| Average Offset Voltage Drift (Note 5) | | Full | - | 4 | 9 | µV/$^oC$ |
| Input Bias Current | | 25 | - | 5 | 50 | nA |
| | | Full | - | 20 | 100 | nA |
| Input Offset Current | | 25 | - | 5 | 50 | nA |
| | | Full | - | 20 | 100 | nA |
| Common Mode Range | | 25 | ±7 | ±10 | - | V |
| Differential Input Resistance | | 25 | - | 1 | - | MΩ |
| Input Noise Voltage | f = 0.1Hz to 10Hz | 25 | - | 0.2 | - | $\mu V_{RMS}$ |
| | f = 0.1Hz to 1MHz | 25 | - | 0.8 | - | $\mu V_{RMS}$ |
| Input Noise Voltage Density (Note 2) | f = 10Hz | 25 | - | 30 | - | $nV/\sqrt{Hz}$ |
| | f = 100Hz | 25 | - | 12 | - | $nV/\sqrt{Hz}$ |
| | f = 1000Hz | 25 | - | 8.3 | - | $nV/\sqrt{Hz}$ |
| Input Noise Current Density (Note 2) | f = 10Hz | 25 | - | 1.9 | - | $pA/\sqrt{Hz}$ |
| | f = 100Hz | 25 | - | 0.7 | - | $pA/\sqrt{Hz}$ |
| | f = 1000Hz | 25 | - | 0.4 | - | $pA/\sqrt{Hz}$ |
| **TRANSFER CHARACTERISTICS** | | | | | | |
| Large Signal Voltage Gain | $V_{OUT}$ = ±10V | 25 | 114 | 130 | - | dB |
| | | Full | 108 | 125 | - | dB |
| Common Mode Rejection Ratio | $V_{CM}$ = ±2V | Full | 80 | 90 | - | dB |
| Gain Bandwidth Product (Note 5) | $A_V$ = -100, f = 100kHz to 10MHz | 25 | 130 | 150 | - | MHz |
| | | Full | 110 | 125 | - | MHz |
| Minimum Stable Gain | | Full | 5 | - | - | V/V |
| **OUTPUT CHARACTERISTICS** | | | | | | |
| Output Voltage Swing | | Full | ±11 | ±12 | - | V |
| Output Current | $R_L$ = 1kΩ, $V_{OUT}$ ≥10V | Full | ±30 | ±33 | - | mA |
| Output Resistance | | 25 | - | 5 | - | Ω |
| Full Power Bandwidth (Note 3) | | 25 | - | 1.91 | - | MHz |
| **TRANSIENT RESPONSE** $A_V$ = +5, Unless Otherwise Specified | | | | | | |

## Electrical Specifications
$V_{SUPPLY}$ = ±15V, $R_L$ = 1kΩ, $C_L$ = 10pF, Unless Otherwise Specified **(Continued)**

| PARAMETER | TEST CONDITIONS | TEMP (°C) | HA-2548-5, -9 | | | UNITS |
|---|---|---|---|---|---|---|
| | | | MIN | TYP | MAX | |
| Slew Rate (Note 5) Positive | $V_{OUT}$ = ±5V | 25 | 80 | 120 | - | V/µs |
| | | Full | 70 | 105 | - | V/µs |
| Slew Rate (Note 5) Negative | $V_{OUT}$ = ±5V | 25 | 70 | 110 | - | V/µs |
| | | Full | 60 | 105 | - | V/µs |
| Rise Time (Note 5) | $V_{OUT}$ = ±100mV | 25 | - | 16.5 | 20 | ns |
| | | Full | - | 19 | 23 | ns |
| Fall Time (Note 5) | $V_{OUT}$ = ±100mV | 25 | - | 16 | 20 | ns |
| | | Full | - | 18 | 23 | ns |
| Overshoot (Note 5) Positive | $V_{OUT}$ = ±100mV | 25 | - | 15 | 25 | % |
| | | Full | - | 25 | 35 | % |
| Overshoot (Note 5) Negative | $V_{OUT}$ = ±100mV | 25 | - | 8 | 15 | % |
| | | Full | - | 20 | 30 | % |
| Settling Time | Notes 4, 5 | 25 | - | 200 | 260 | ns |
| **POWER SUPPLY** | | | | | | |
| Power Supply Rejection Ratio | $V_S$ = ±10V to ±20V | Full | 86 | 95 | - | dB |
| $I_{CC}$ | | Full | - | 12 | 18 | mA |

NOTES:

2. Refer to typical performance curve in data sheet.
3. Full Power Bandwidth is calculated by: $FPBW = \frac{\text{Slew Rate}}{2\pi V_{PEAK}}, V_{PEAK} = 10V$.
4. Settling time is specified to 0.01% with a 10V step and $A_V$ = -5.
5. These parameters are not tested. The limits are guaranteed based on lab characterization and reflect lot to lot variation.

## *Test Circuits and Waveforms*

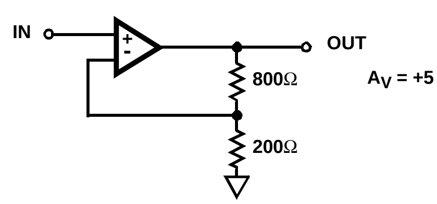
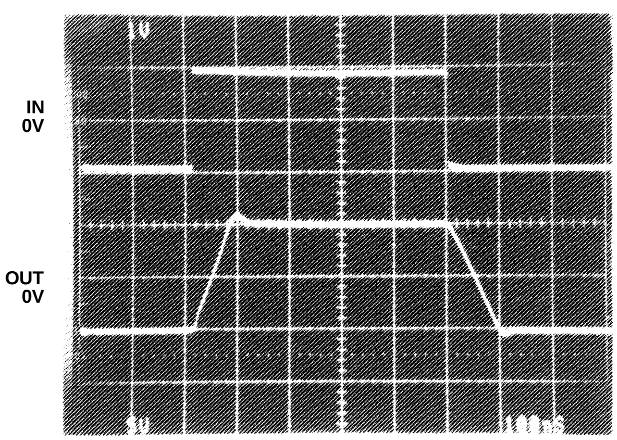
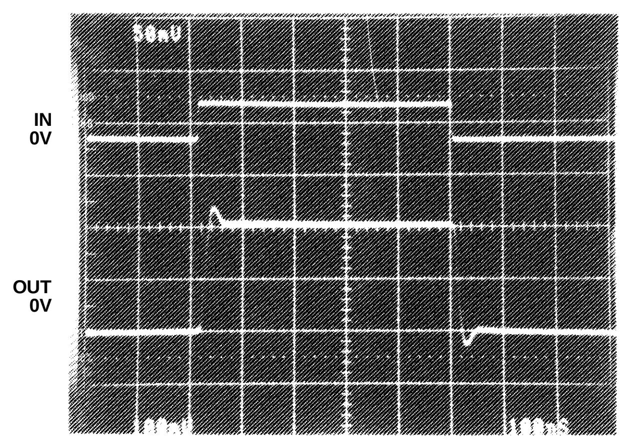



**FIGURE 1. LARGE AND SMALL SIGNAL RESPONSE CIRCUIT**




$V_{OUT}$ = ±5V, $A_V$ = +5, $R_L$ = 1K, $C_L$ ≤ 10pF

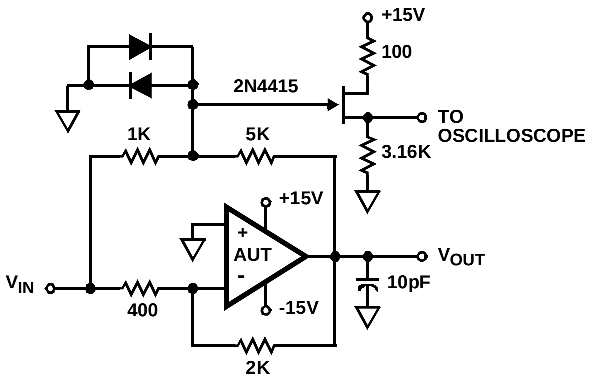
**FIGURE 2. LARGE SIGNAL RESPONSE**




$V_{OUT}$ = ±100mV, $A_V$ = +5, $R_L$ = 1K, $C_L$ ≤ 10pF

**FIGURE 3. SMALL SIGNAL RESPONSE**

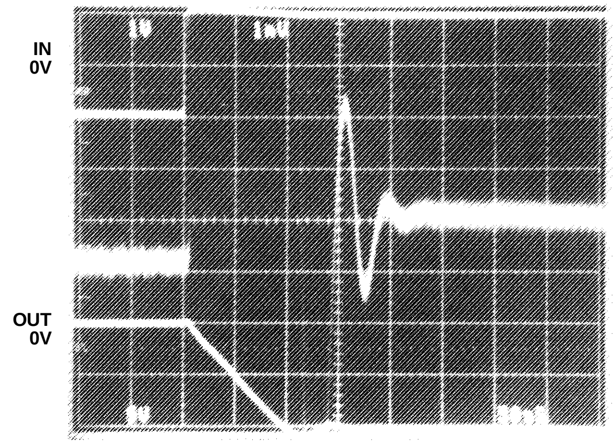
## Test Circuits and Waveforms (Continued)




NOTES:

6. $A_V$ = -5.
7. Feedback and summing resistors should be 0.1% matched.
8. Clipping diodes are optional. HP5082-2810 recommended.

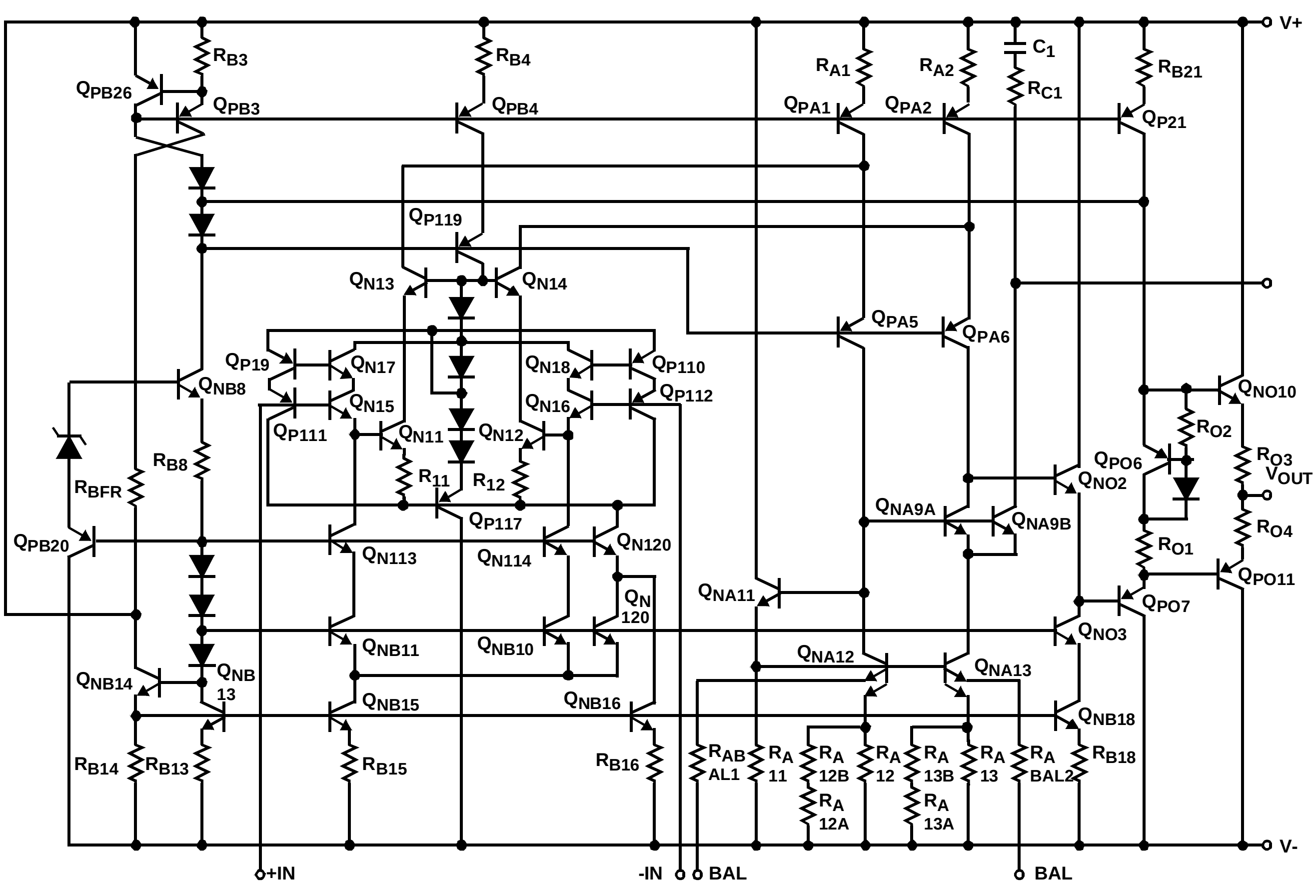
FIGURE 4. SETTLING TIME TEST CIRCUIT



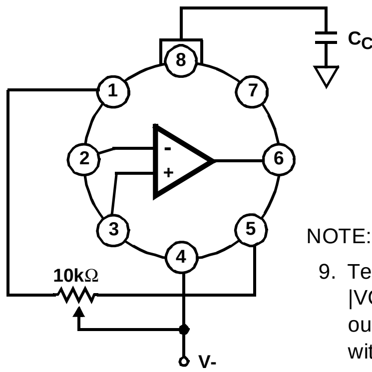

$A_V$ = -5, Output = -10V Output Scale Vertical: 1mV/Div., Horizontal: 50ns/Div.

FIGURE 5. HA-2548 SETTLING TIME

## Schematic Diagram



## Application Information




NOTE:

9. Tested Offset Adjustment Range is |VOS +1mV| minimum referred to output. Typical range is ±20mV with $R_T$ = 10kΩ.

**FIGURE 6. SUGGESTED VOS ADJUSTMENT AND COMPENSATION HOOK UP**

## Typical Performance Curves $V_S = \pm15V$, $T_A = 25^oC$

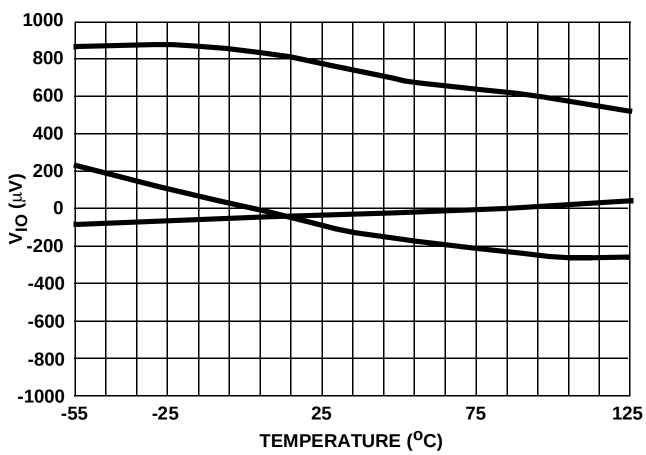



**FIGURE 7. $V_{IO}$ vs TEMPERATURE (3 REPRESENTATIVE UNITS)**

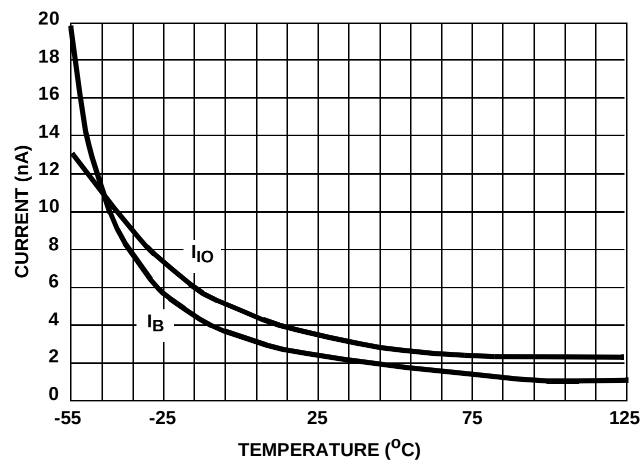



**FIGURE 8. OFFSET CURRENT/BIAS CURRENT vs TEMPERATURE**

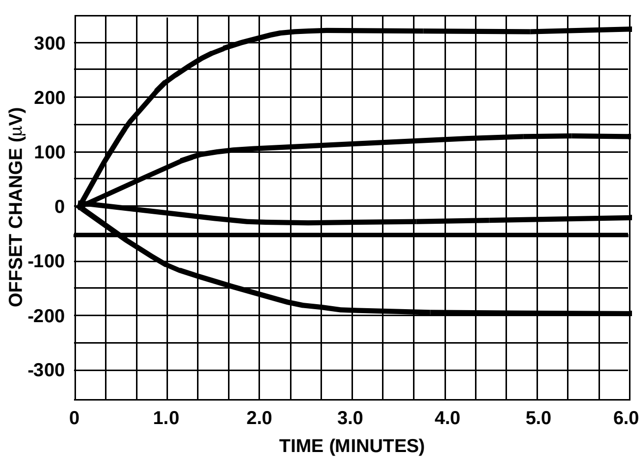



**FIGURE 9. $V_{IO}$ WARM-UP DRIFT (NORMALIZED FROM ZERO) (4 REPRESENTATIVE UNITS)**

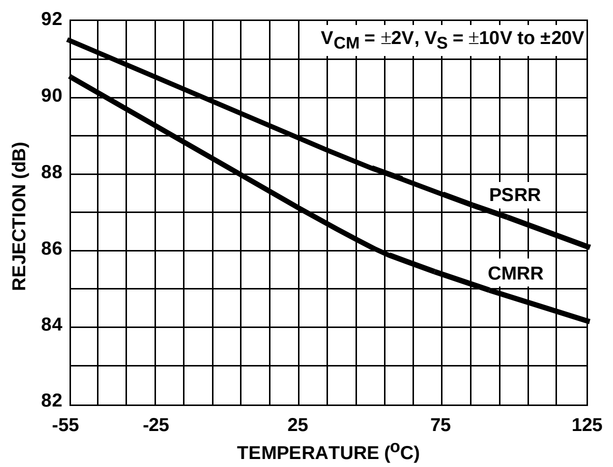



**FIGURE 10. PSRR/CMRR vs TEMPERATURE**

## *Typical Performance Curves* $V_S = \pm15V$, $T_A = 25^oC$ **(Continued)**

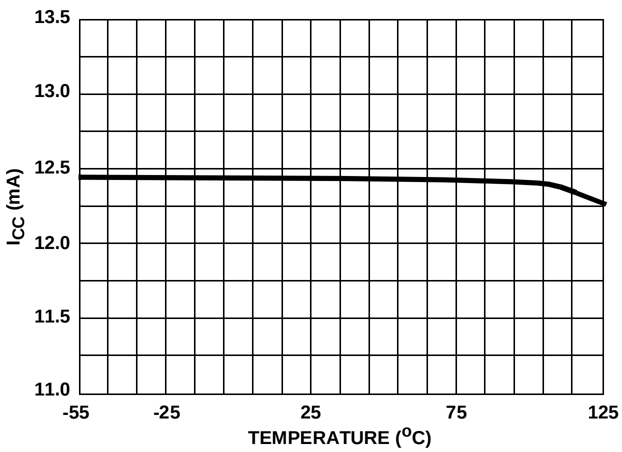



FIGURE 11. $I_{CC}$ vs TEMPERATURE

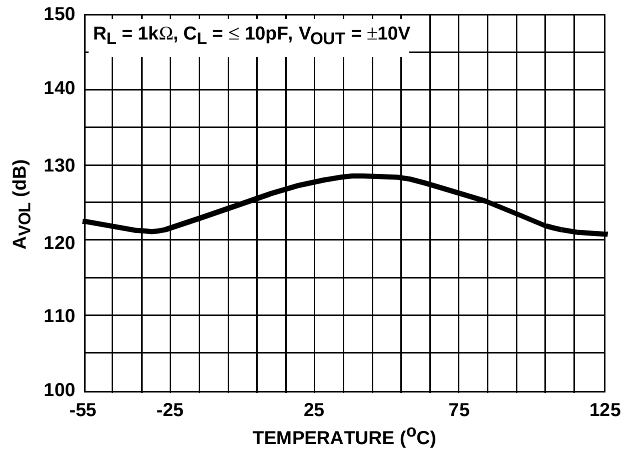



FIGURE 12. $A_{VOL}$ vs TEMPERATURE

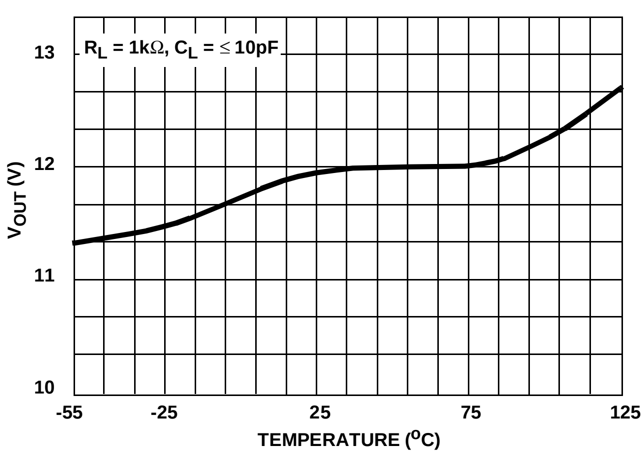



FIGURE 13. $V_{OUT}$ vs TEMPERATURE

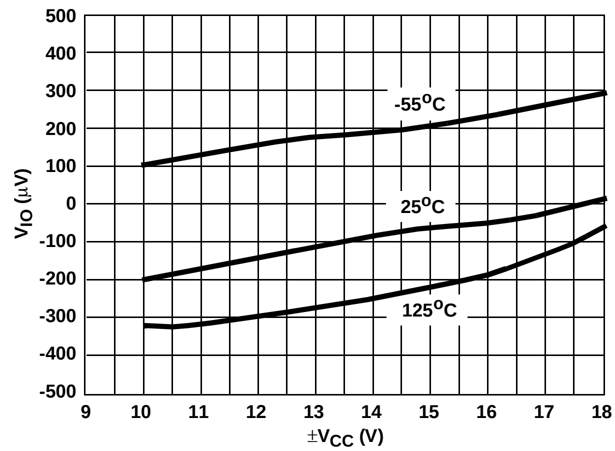



FIGURE 14. $V_{IO}$ vs $\pm V_{CC}$ vs TEMPERATURE

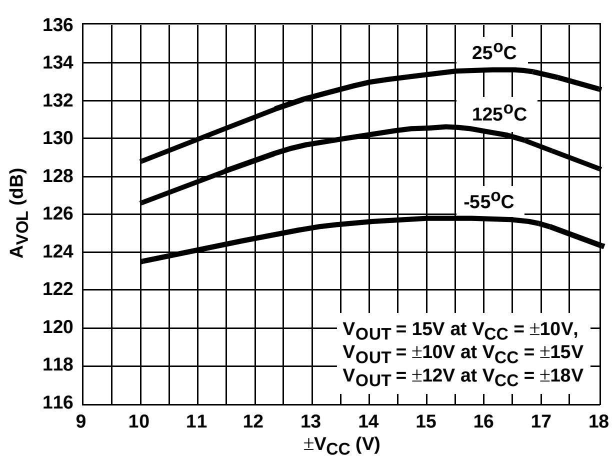



FIGURE 15. $A_{VOL}$ vs $\pm V_{CC}$ vs TEMPERATURE

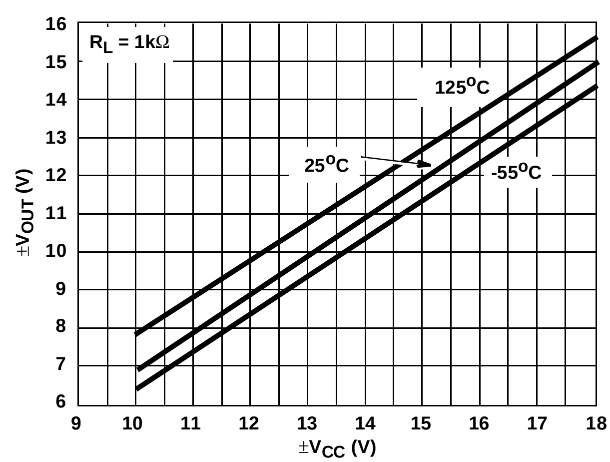



FIGURE 16. $\pm V_{OUT}$ vs $\pm V_{CC}$ vs TEMPERATURE

## *Typical Performance Curves* $V_S = \pm15V$, $T_A = 25^oC$ **(Continued)**

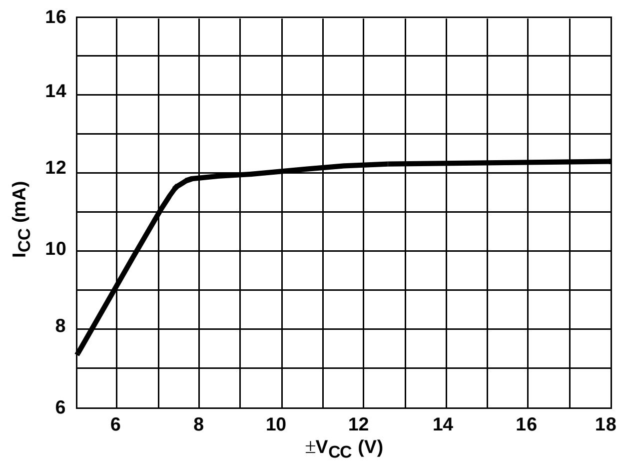



FIGURE 17. SUPPLY CURRENT vs SUPPLY VOLTAGE

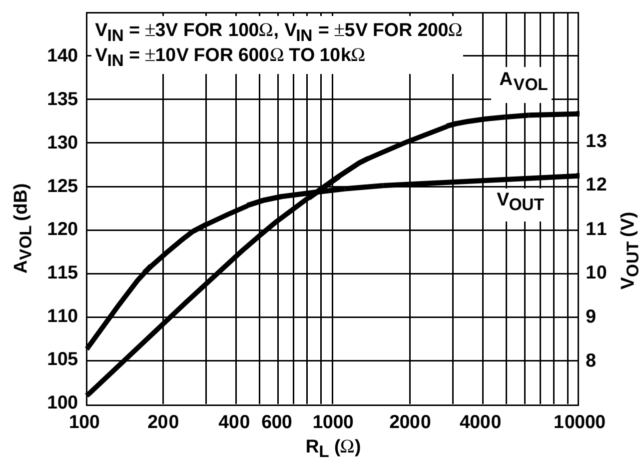



FIGURE 18. $A_{VOL}/V_{OUT}$ vs $R_L$

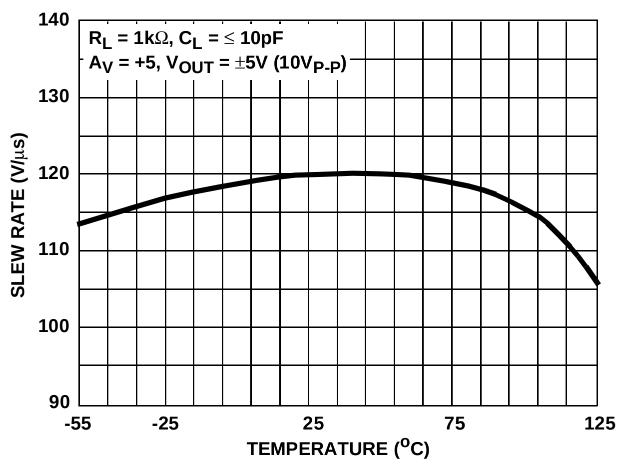



FIGURE 19. SLEW RATE vs TEMPERATURE

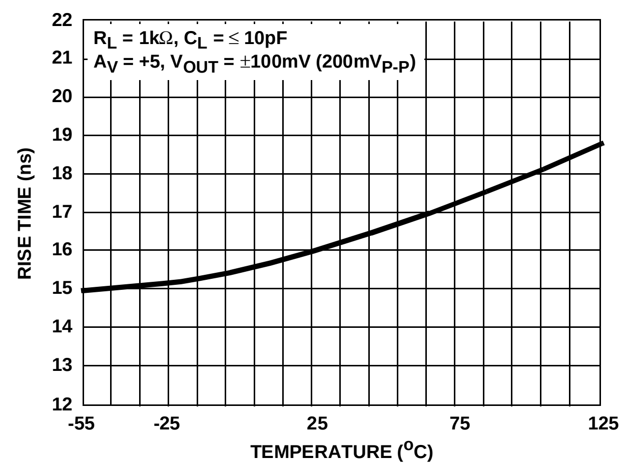



FIGURE 20. RISE TIME vs TEMPERATURE

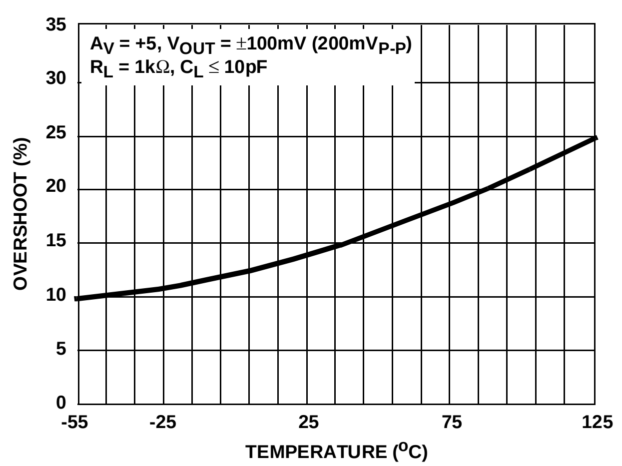



FIGURE 21. OVERSHOOT vs TEMPERATURE

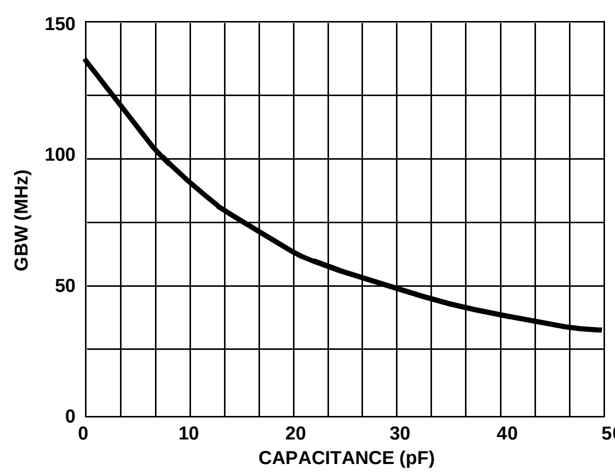



FIGURE 22. GAIN BANDWIDTH PRODUCT vs COMPENSATION CAPACITANCE TO GND

## *Typical Performance Curves* $V_S = \pm15V$, $T_A = 25^oC$ **(Continued)**

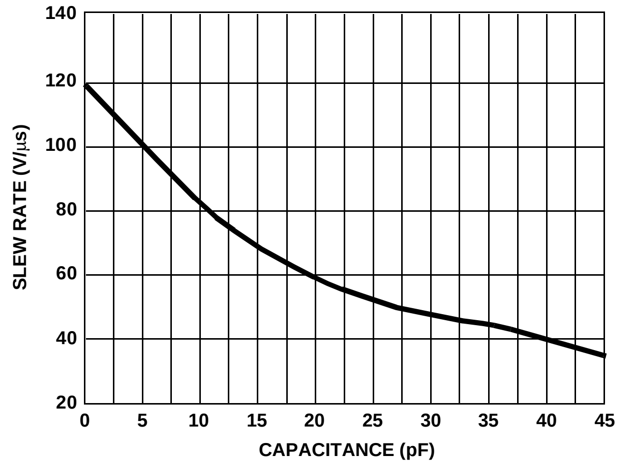



**FIGURE 23. SLEW RATE vs COMPENSATION CAPACITANCE TO GND**

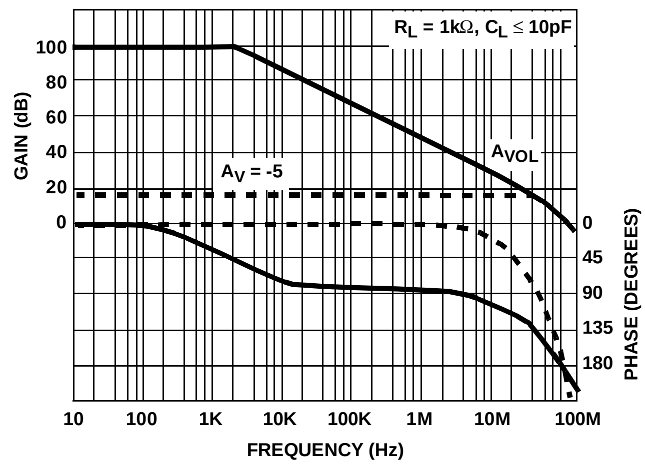



**FIGURE 24. GAIN AND PHASE vs FREQUENCY**

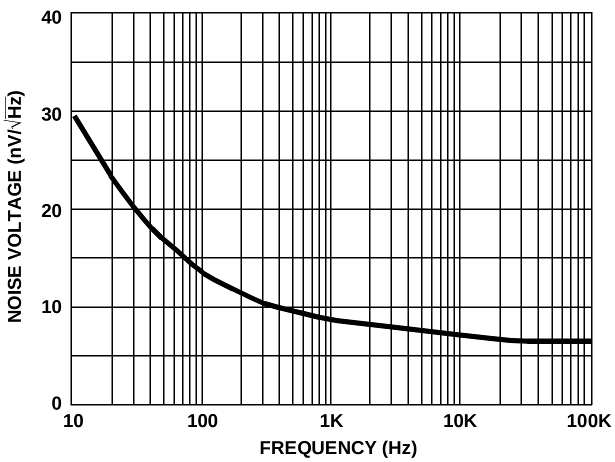



**FIGURE 25. INPUT NOISE VOLTAGE DENSITY**

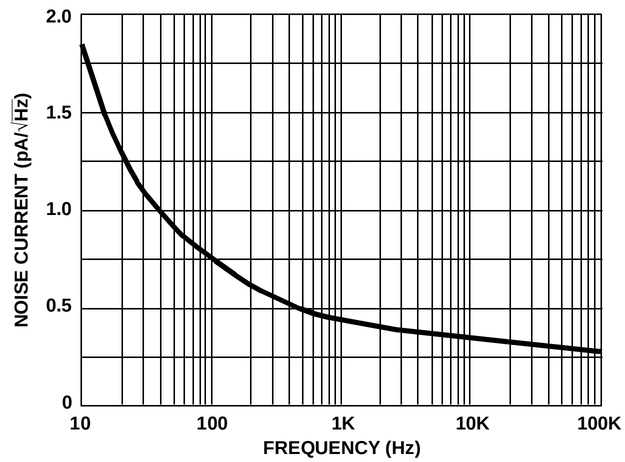
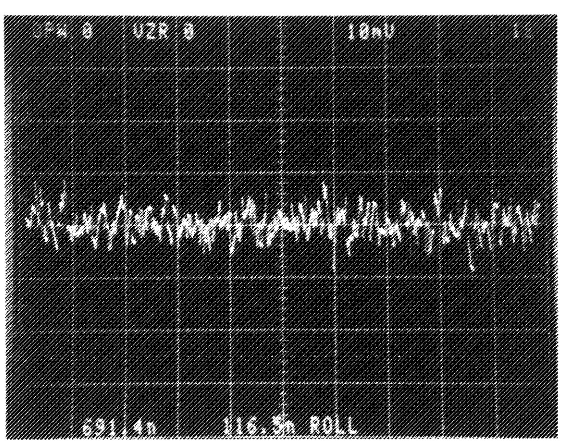
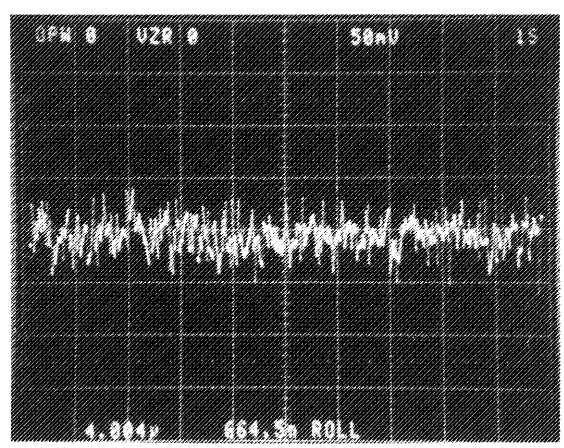



**FIGURE 26. INPUT NOISE CURRENT DENSITY**



P-P(RTI) = 691.4nV, RMS(RTI) = 116.5nV, $A_V$ = 25000

**FIGURE 27. PEAK TO PEAK NOISE 0.1Hz TO 10Hz**



P-P(RTI) = 4.004µV, RMS(RTI) = 664.5nV, $A_V$ = 25000

**FIGURE 28. PEAK TO PEAK NOISE 0.1Hz TO 1MHz**

## Typical Performance Curves $V_S = \pm15V$, $T_A = 25^oC$ **(Continued)**

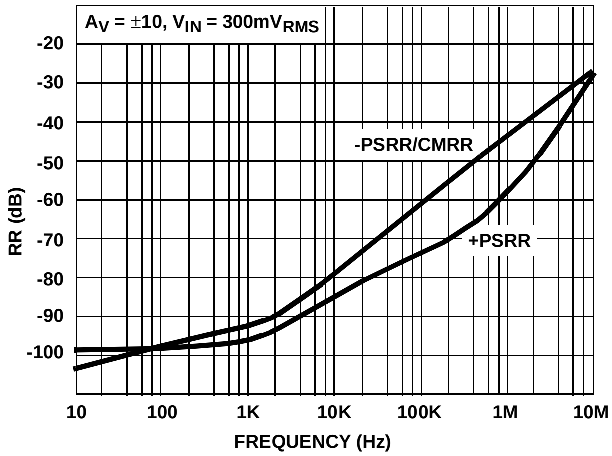



**FIGURE 29. REJECTION RATIOS vs FREQUENCY**

## Die Characteristics

**DIE DIMENSIONS:**

85 mils x 91 mils x 19 mils

2160µm x 2320µm x 483µm

**METALLIZATION:**

Type: Aluminum, 1% Copper

Thickness: 16kÅ ±2kÅ

**SUBSTRATE POTENTIAL**

V-

NOTE: The substrate may be left floating (Insulating Die Mount) or it may be mounted on conductor at V- potential.

**PASSIVATION:**

Type: Nitride over Silox

Silox Thickness: 12kÅ ±2kÅ

Nitride Thickness: 3.5kÅ ±1kÅ

**TRANSISTOR COUNT:**

60

## Metallization Mask Layout

**HA-2548**