# Low Cost, 24 MHz, Rail-to-Rail, Quad Amplifiers

# AD8648

## FEATURES

**Low offset voltage: 2.5 mV max**
**Single-supply operation: 2.7 V to 5.5 V**
**Low noise: 6 nV/√Hz**
**Wide bandwidth: 24 MHz**
**Slew rate: 12 V/µs**
**High output current: 150 mA**
**No phase reversal**
**Low input bias current: 1 pA**
**Low supply current: 2 mA max**
**Unity-gain stable**

## APPLICATIONS

**Barcode scanners**
**Battery-powered instrumentation**
**Multipole filters**
**Sensors**
**ASIC input or output amplifiers**
**Audio**
**Photodiode amplification**

## PIN CONFIGURATIONS

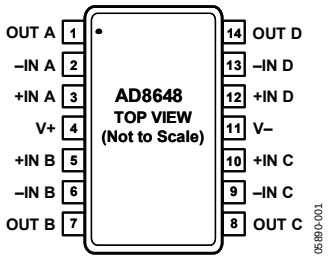


*Figure 1. 14-Lead TSSOP (RU-14)*

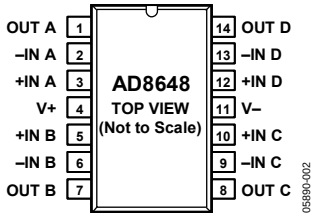


*Figure 2. 14-Lead SOIC (R-14)*

## GENERAL DESCRIPTION

The AD8648 is a quad, rail-to-rail, input and output, single-supply amplifier featuring low offset voltage, wide signal bandwidth, and low input voltage and current noise.

The combination of 24 MHz bandwidth, low offset, low noise, and very low input bias current makes these amplifiers useful in a wide variety of applications. Filters, integrators, photodiode amplifiers, and high impedance sensors all benefit from the combination of performance features. AC applications benefit from the wide bandwidth and low distortion. The AD8648 family offers high output drive capability, which is excellent for audio line drivers and other low impedance applications.

Applications for the part include portable and low powered instrumentation, audio amplification for portable devices, portable phone headsets, bar code scanners, and multipole filters. The ability to swing rail to rail at both the input and output enables designers to buffer CMOS ADCs, DACs, ASICs, and other wide output swing devices in single-supply systems.

**Rev. 0**


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## REVISION HISTORY

**1/06—Rev 0: Initial Version**

# SPECIFICATIONS

$V_{DD}$ = 5.0 V, $V_{CM}$ = $V_{DD}$/2, $T_A$ = 25°C, unless otherwise noted.

**Table 1.**

| Parameter | Symbol | Conditions | Min | Typ | Max | Unit |
|---|---|---|---|---|---|---|
| INPUT CHARACTERISTICS | | | | | | |
| Offset Voltage | $V_{OS}$ | $V_{CM}$ = 0 V to 5 V | | 0.7 | 2.5 | mV |
| | | −40°C < $T_A$ < +125°C | | | 3.2 | mV |
| Offset Voltage Drift | $\Delta V_{OS}/\Delta T$ | −40°C < $T_A$ < +125°C | | 2.0 | 7.5 | µV/°C |
| Input Bias Current | $I_B$ | | | 0.2 | 1 | pA |
| | | −40°C < $T_A$ < +85°C | | | 50 | pA |
| | | −40°C < $T_A$ < +125°C | | | 550 | pA |
| Input Offset Current | $I_{OS}$ | | | 0.1 | 0.5 | pA |
| | | −40°C < $T_A$ < +85°C | | | 50 | pA |
| | | −40°C < $T_A$ < +125°C | | | 250 | pA |
| Input Voltage Range | $V_{CM}$ | | 0 | | 5 | V |
| Common-Mode Rejection Ratio | CMRR | $V_{CM}$ = 0 V to 5.0 V | 67 | 84 | | dB |
| Large-Signal Voltage Gain | $A_{VO}$ | $R_L$ = 2 kΩ, $V_O$ = 0.5 V to 4.5 V | 160 | 700 | | V/mV |
| Input Capacitance | $C_{DIFF}$ | | | 2.5 | | pF |
| | $C_{CM}$ | | | 6.7 | | pF |
| OUTPUT CHARACTERISTICS | | | | | | |
| Output Voltage High | $V_{OH}$ | $I_{OUT}$ = 1 mA | 4.98 | 4.99 | | V |
| | | $I_{OUT}$ = 10 mA | 4.87 | 4.92 | | V |
| | | −40°C < $T_A$ < +125°C | 4.70 | | | V |
| Output Voltage Low | $V_{OL}$ | $I_{OUT}$ = 1 mA | | 8.4 | 20 | mV |
| | | $I_{OUT}$ = 10 mA | | 78 | 145 | mV |
| | | −40°C < $T_A$ < +125°C | | | 200 | mV |
| Short-Circuit Output Current | $I_{SC}$ | | | ±150 | | mA |
| Closed-Loop Output Impedance | $Z_{OUT}$ | At 1 MHz, $A_V$ = 1 | | 3 | | Ω |
| POWER SUPPLY | | | | | | |
| Power Supply Rejection Ratio | PSRR | $V_{DD}$ = 2.7 V to 5.5 V | 63 | 80 | | dB |
| Supply Current per Amplifier | $I_{SY}$ | | | 1.8 | 2.0 | mA |
| | | −40°C < $T_A$ < +125°C | | | 2.5 | mA |
| DYNAMIC PERFORMANCE | | | | | | |
| Slew Rate | SR | $R_L$ = 2 kΩ | | 12 | | V/µs |
| Settling Time | $t_s$ | To 0.01% | | 0.5 | | µs |
| Gain Bandwidth Product | GBP | | | 24 | | MHz |
| Phase Margin | $\Phi_M$ | | | 74 | | Degrees |
| NOISE PERFORMANCE | | | | | | |
| Peak-to-Peak Noise | $e_n$ p-p | 0.1 Hz to 10 Hz | | 2.4 | | µV |
| Voltage Noise Density | $e_n$ | f = 1 kHz | | 8 | | nV/√Hz |
| | | f = 10 kHz | | 6 | | nV/√Hz |
| Channel Separation | CS | f = 10 kHz | | −115 | | dB |
| | | f = 100 kHz | | −110 | | dB |

$V_{DD}$ = 2.7 V, $V_{CM}$ = $V_{DD}$/2, $T_A$ = 25°C, unless otherwise noted.

**Table 2.**

| Parameter | Symbol | Conditions | Min | Typ | Max | Unit |
|---|---|---|---|---|---|---|
| INPUT CHARACTERISTICS | | | | | | |
| Offset Voltage | $V_{OS}$ | $V_{CM}$ = 0 V to 2.7 V | | 0.7 | 2.5 | mV |
| | | −40°C < $T_A$ < +125°C | | | 3.2 | mV |
| Offset Voltage Drift | $\Delta V_{OS}/\Delta T$ | −40°C < $T_A$ < +125°C | | 1.8 | 7.0 | µV/°C |
| Input Bias Current | $I_B$ | | | 0.2 | 1 | pA |
| | | −40°C < $T_A$ < +85°C | | | 50 | pA |
| | | −40°C < $T_A$ < +125°C | | | 550 | pA |
| Input Offset Current | $I_{OS}$ | | | 0.1 | 0.5 | pA |
| | | −40°C < $T_A$ < +85°C | | | 50 | pA |
| | | −40°C < $T_A$ < +125°C | | | 250 | pA |
| Input Voltage Range | $V_{CM}$ | | 0 | | 2.7 | V |
| Common-Mode Rejection Ratio | CMRR | $V_{CM}$ = 0 V to 2.7 V | 62 | 79 | | dB |
| Large-Signal Voltage Gain | $A_{VO}$ | $R_L$ = 2 kΩ, $V_O$ = 0.5 V to 2.2 V | 60 | 130 | | V/mV |
| Input Capacitance | $C_{DIFF}$ | | | 2.5 | | pF |
| | $C_{CM}$ | | | 7.8 | | pF |
| OUTPUT CHARACTERISTICS | | | | | | |
| Output Voltage High | $V_{OH}$ | $I_{OUT}$ = 1 mA | 2.65 | 2.69 | | V |
| | | −40°C < $T_A$ < +125°C | 2.60 | | | V |
| Output Voltage Low | $V_{OL}$ | $I_{OUT}$ = 1 mA | | 11 | 25 | mV |
| | | −40°C < $T_A$ < +125°C | | | 30 | mV |
| Short-Circuit Output Current | $I_{SC}$ | | | ±50 | | mA |
| Closed-Loop Output Impedance | $Z_{OUT}$ | At 1 MHz, $A_V$ = 1 | | 3 | | Ω |
| POWER SUPPLY | | | | | | |
| Power Supply Rejection Ratio | PSRR | $V_{DD}$ = 2.7 V to 5.5 V | 63 | 80 | | dB |
| Supply Current per Amplifier | $I_{SY}$ | | | 1.7 | 2.0 | mA |
| | | −40°C < $T_A$ < +125°C | | | 2.5 | mA |
| DYNAMIC PERFORMANCE | | | | | | |
| Slew Rate | SR | $R_L$ = 2 kΩ | | 12 | | V/µs |
| Settling Time | $t_s$ | To 0.01% | | 0.3 | | µs |
| Gain Bandwidth Product | GBP | | | 22 | | MHz |
| Phase Margin | $\Phi_M$ | | | 52 | | Degrees |
| NOISE PERFORMANCE | | | | | | |
| Peak-to-Peak Noise | $e_n$ p-p | 0.1 Hz to 10 Hz | | 2.1 | | µV |
| Voltage Noise Density | $e_n$ | f = 1 kHz | | 8 | | nV/√Hz |
| | | f = 10 kHz | | 6 | | nV/√Hz |
| Channel Separation | CS | f = 10 kHz | | −115 | | dB |
| | | f = 100 kHz | | −110 | | dB |

# ABSOLUTE MAXIMUM RATINGS

**Table 3.**

| Parameter | Rating |
|---|---|
| Supply Voltage | 6 V |
| Input Voltage | GND to $V_{DD}$ |
| Differential Input Voltage | ±3 V |
| Output Short Circuit to GND | Indefinite |
| Storage Temperature Range | −65°C to +150°C |
| Operating Temperature Range | −40°C to +125°C |
| Lead Temperature (Soldering, 60 sec) | 300°C |
| Junction Temperature | 150°C |

Stresses above those listed under Absolute Maximum Ratings may cause permanent damage to the device. This is a stress rating only; functional operation of the device at these or any other conditions above those indicated in the operational section of this specification is not implied. Exposure to absolute maximum rating conditions for extended periods may affect device reliability.

## THERMAL RESISTANCE

$\theta_{JA}$ is specified for the worst-case conditions, that is, a device soldered in a circuit board for surface-mount packages.

**Table 4. Thermal Resistance**

| Package Type | $\theta_{JA}$ | $\theta_{JC}$ | Unit |
|---|---|---|---|
| 14-Lead SOIC (R) | 120 | 36 | °C/W |
| 14-Lead TSSOP (RU) | 180 | 35 | °C/W |

## ESD CAUTION

ESD (electrostatic discharge) sensitive device. Electrostatic charges as high as 4000 V readily accumulate on the human body and test equipment and can discharge without detection. Although this product features proprietary ESD protection circuitry, permanent damage may occur on devices subjected to high energy electrostatic discharges. Therefore, proper ESD precautions are recommended to avoid performance degradation or loss of functionality.

# TYPICAL PERFORMANCE CHARACTERISTICS

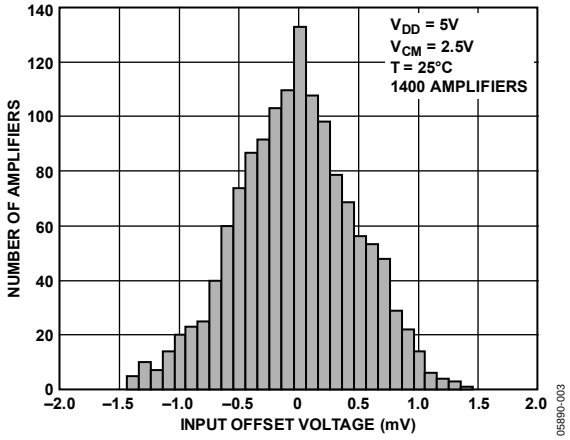



*Figure 3. Input Offset Voltage Distribution*

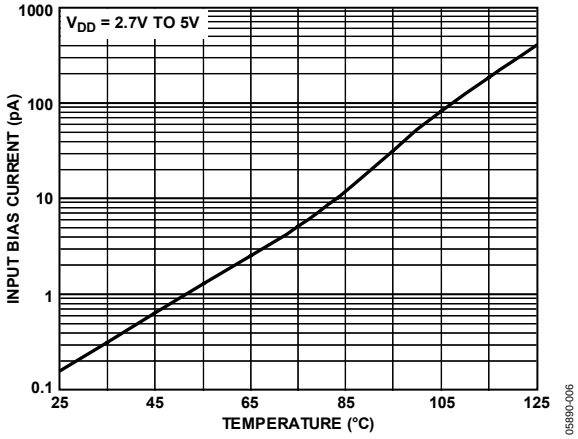



*Figure 6. Input Bias Current vs. Temperature*

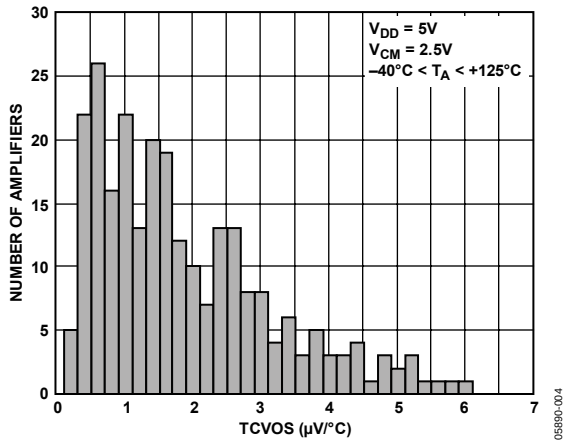



*Figure 4. $V_{OS}$ Drift ($TCV_{OS}$) Distribution*

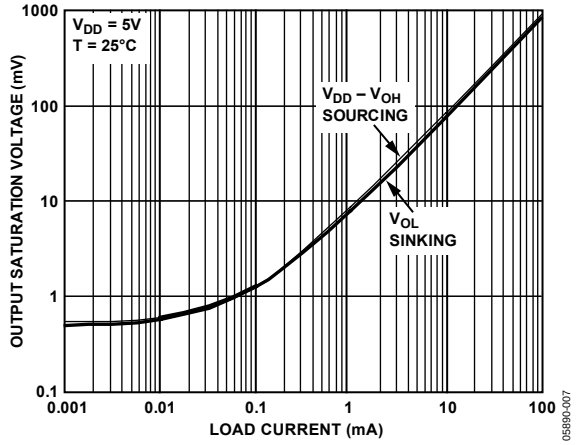



*Figure 7. Output Saturation Voltage vs. Load Current*

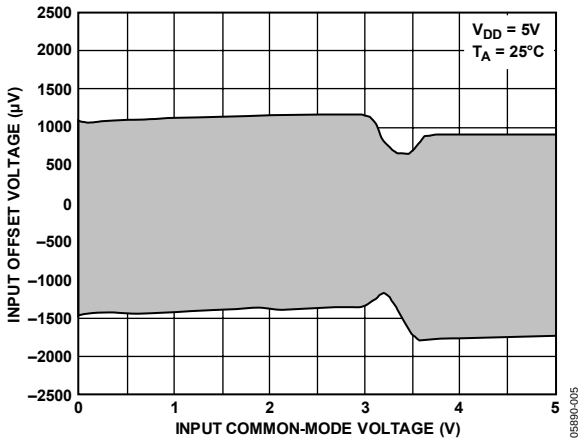



*Figure 5. Input Offset Voltage vs. Input Common-Mode Voltage*

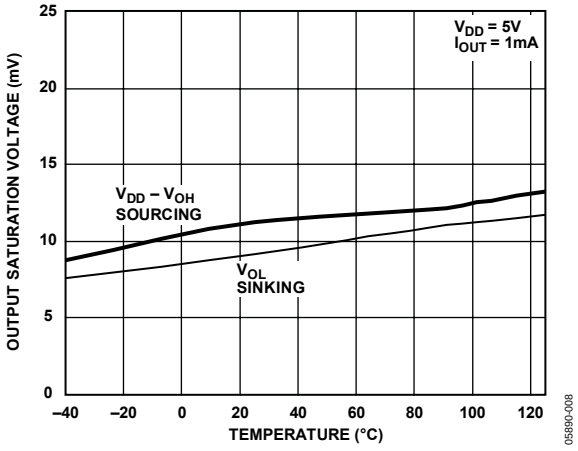



*Figure 8. Output Saturation Voltage vs. Temperature*

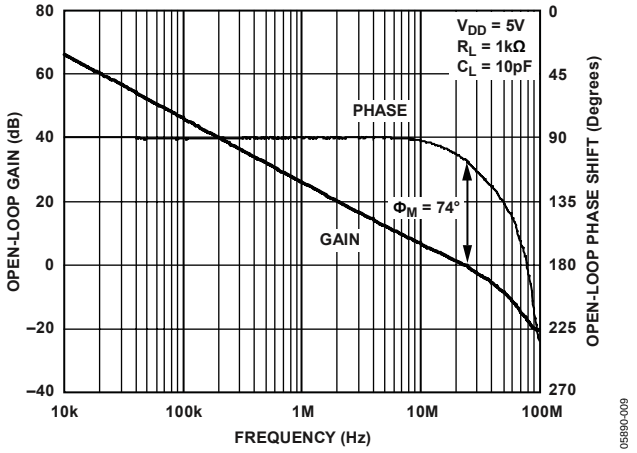



Figure 9. Open-Loop Gain and Phase vs. Frequency

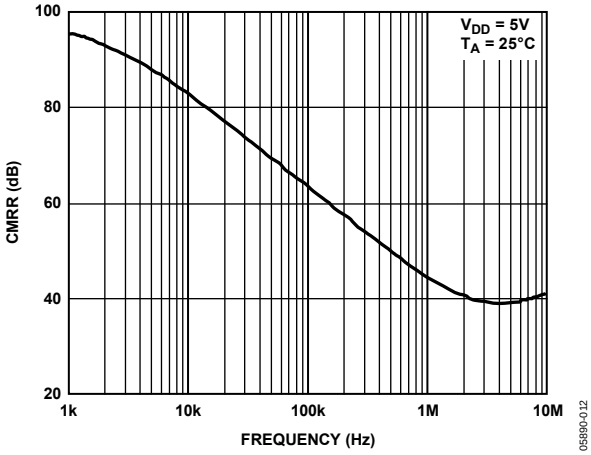



Figure 12. Common-Mode Rejection Ratio vs. Frequency

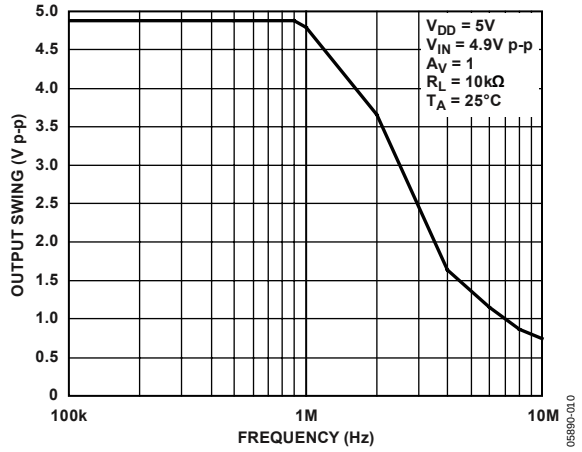



Figure 10. Maximum Output Swing vs. Frequency

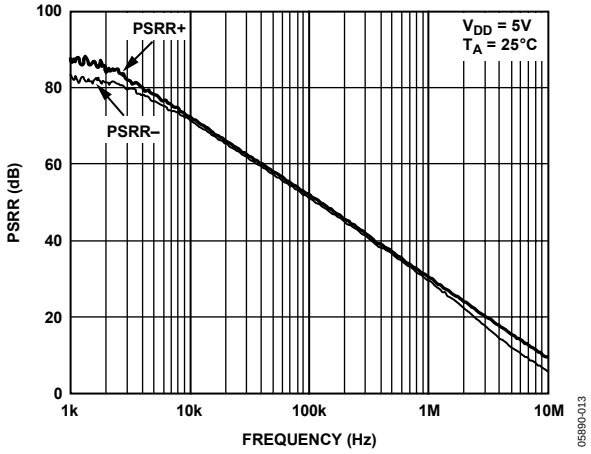



Figure 13. Power Supply Rejection Ratio vs. Frequency

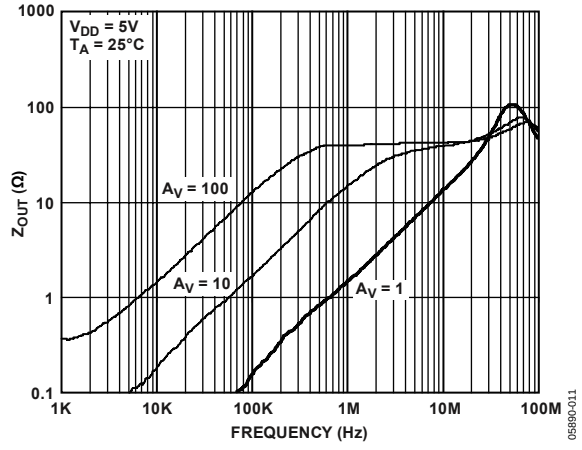



Figure 11. Closed-Loop Output Impedance vs. Frequency

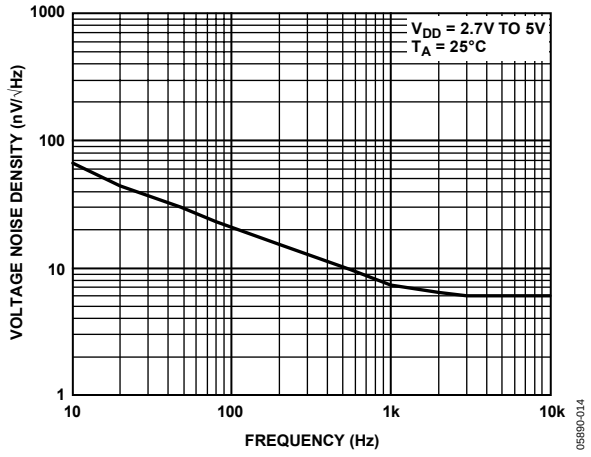



Figure 14. Voltage Noise Density vs. Frequency

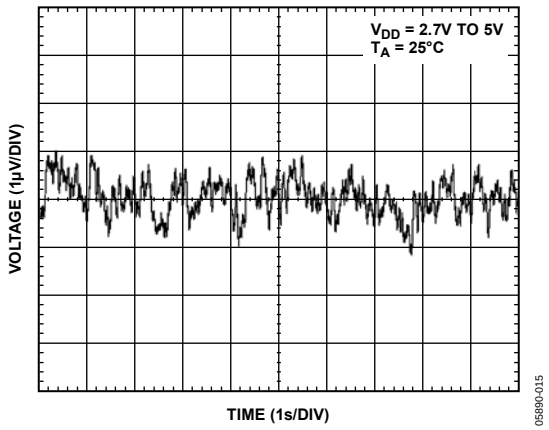



Figure 15. 0.1 Hz to 10 Hz Voltage Noise

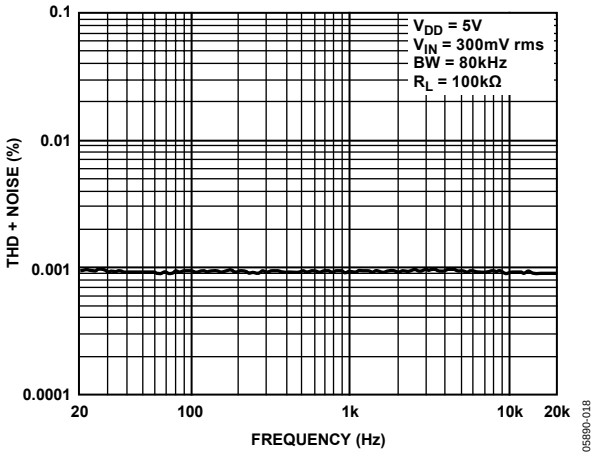



Figure 18. THD + Noise vs. Frequency

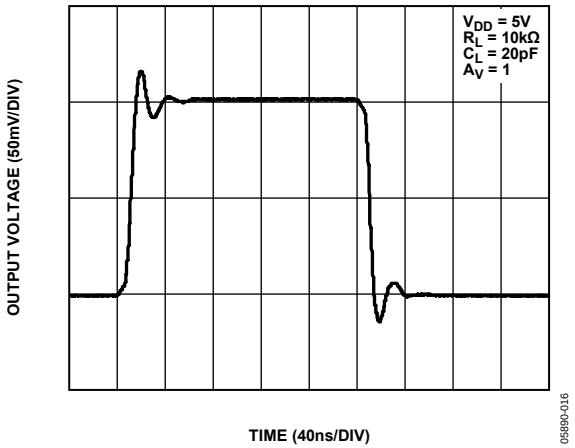



Figure 16. Small-Signal Transient Response

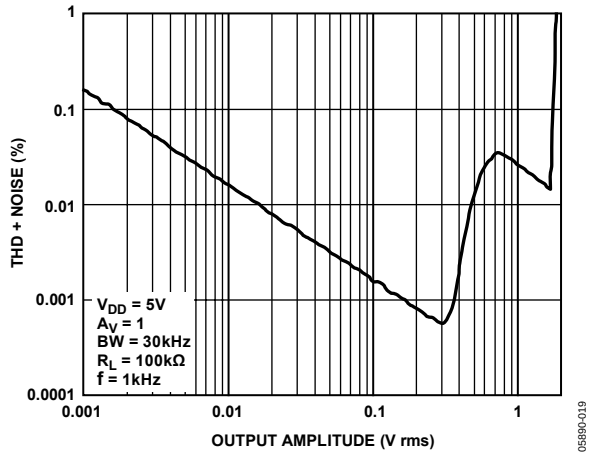



Figure 19. THD + Noise vs. Output Amplitude

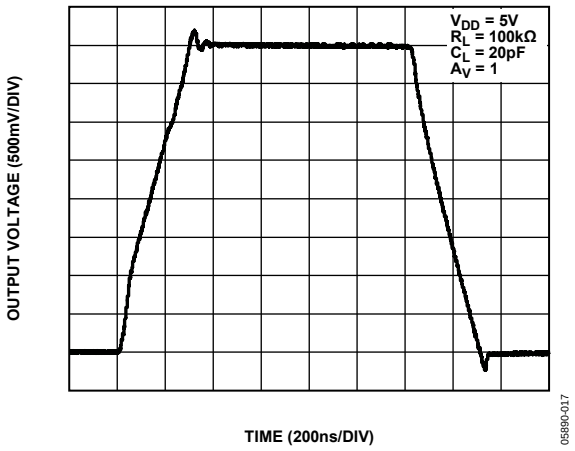



Figure 17. Large-Signal Transient Response

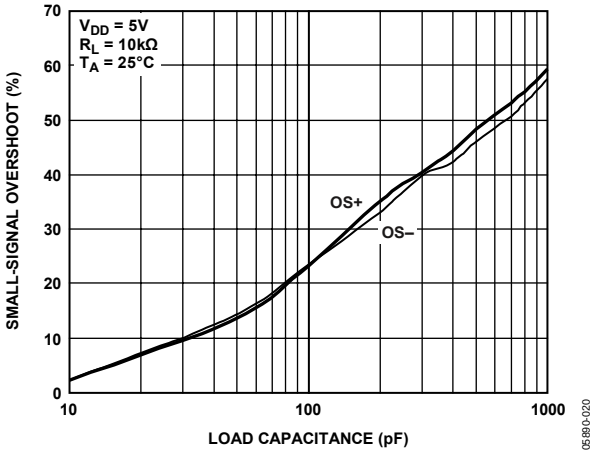



Figure 20. Small-Signal Overshoot vs. Load Capacitance

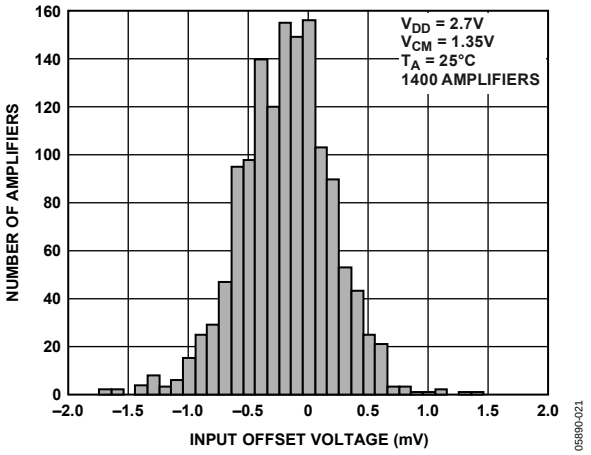



Figure 21. Input Offset Voltage Distribution

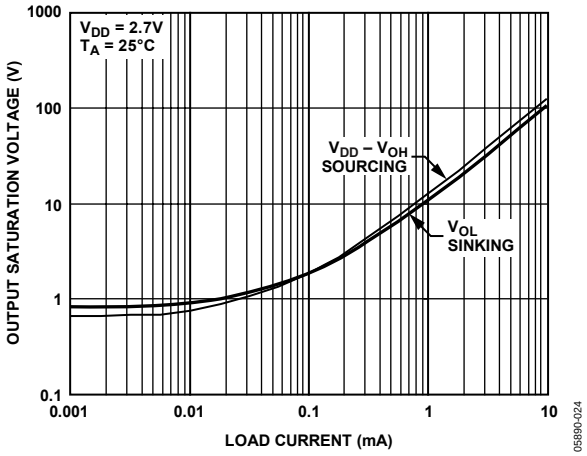



Figure 24. Output Saturation Voltage vs. Load Current

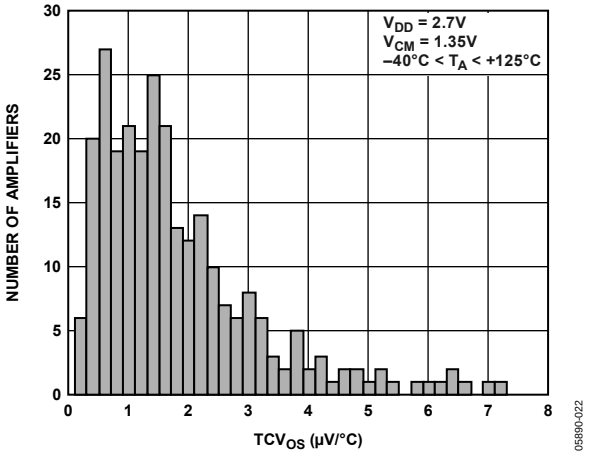



Figure 22. $V_{OS}$ Drift ($TCV_{OS}$) Distribution

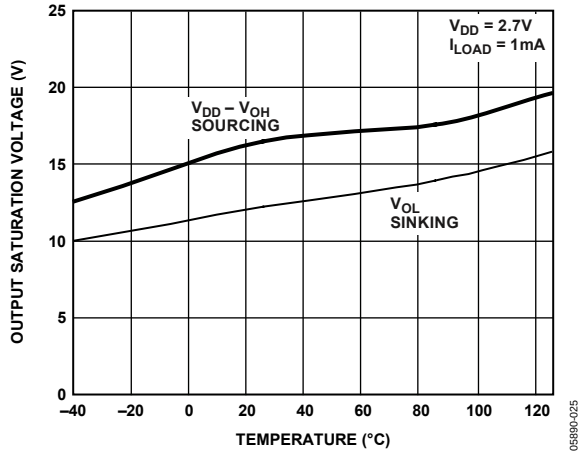



Figure 25. Output Saturation Voltage vs. Temperature

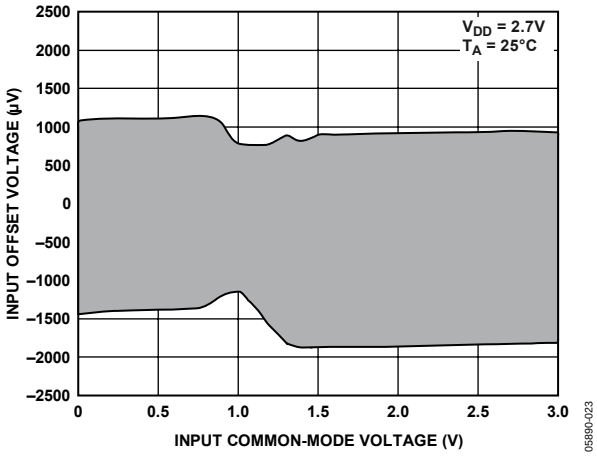



Figure 23. Input Offset Voltage vs. Input Common-Mode Voltage

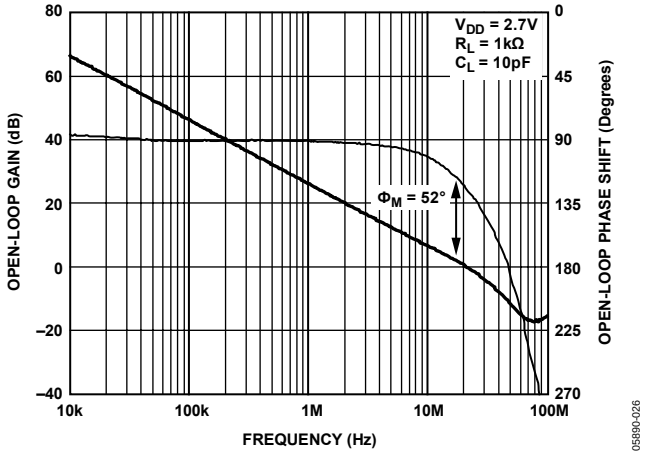



Figure 26. Open-Loop Gain and Phase vs. Frequency

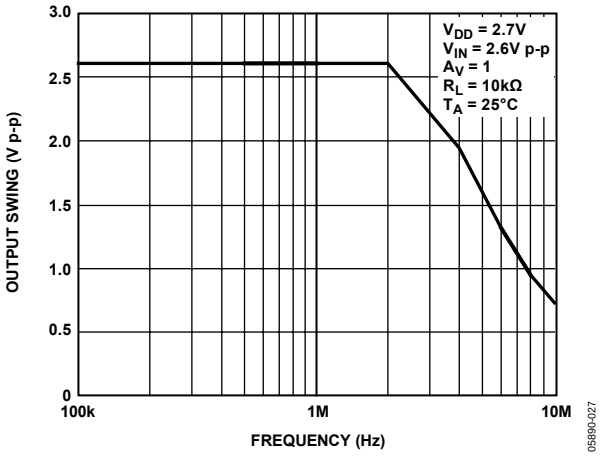



Figure 27. Maximum Output Swing vs. Frequency

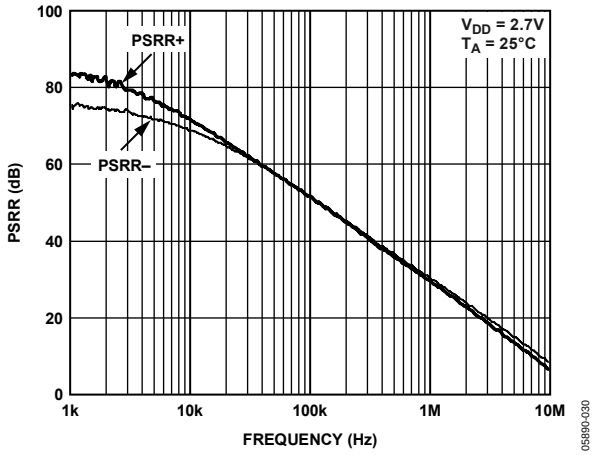



Figure 30. Power Supply Rejection Ratio vs. Frequency

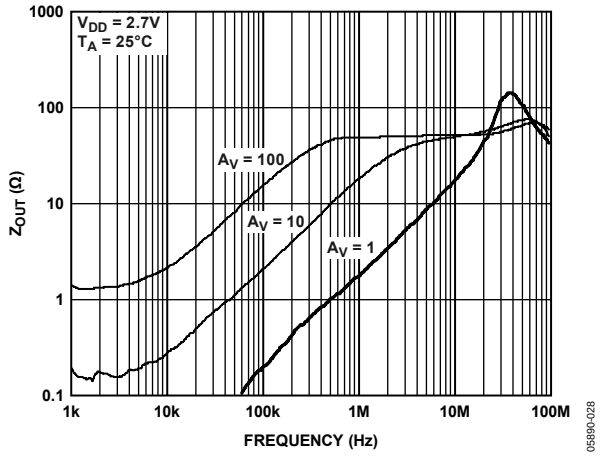



Figure 28. Closed-Loop Output Impedance vs. Frequency

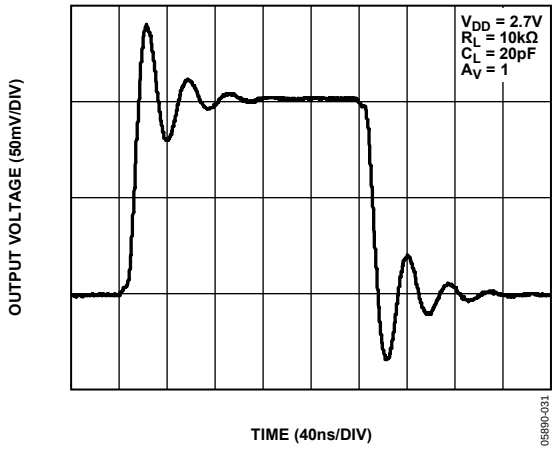



Figure 31. Small-Signal Transient Response

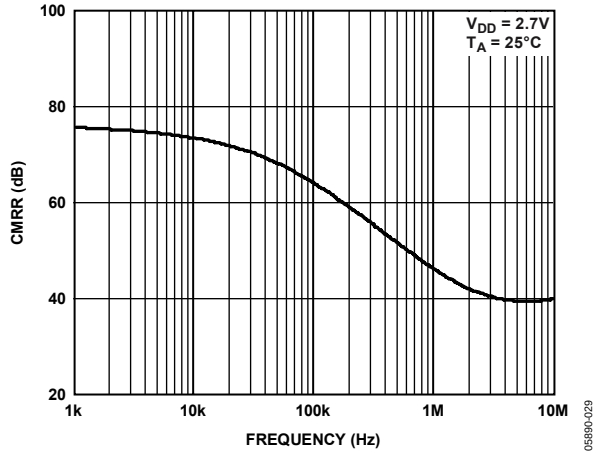



Figure 29. Common-Mode Rejection Ratio vs. Frequency

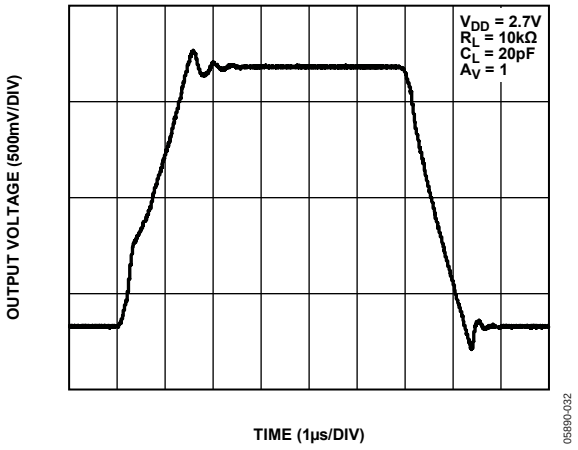



Figure 32. Large-Signal Transient Response

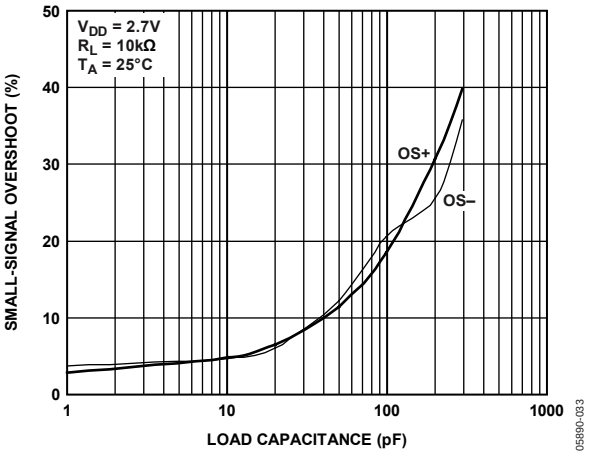



Figure 33. Small-Signal Overshoot vs. Load Capacitance

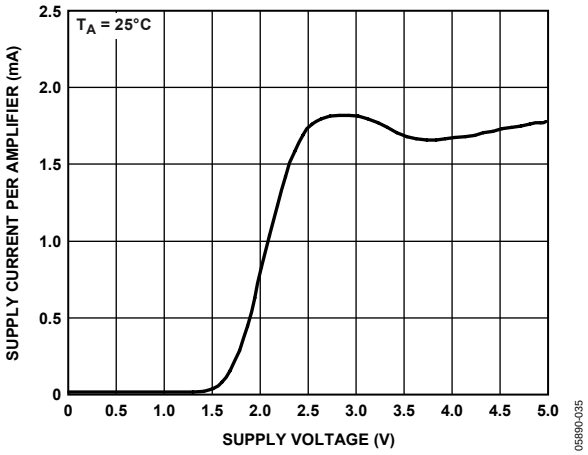



Figure 35. Supply Current per Amplifier vs. Supply Voltage

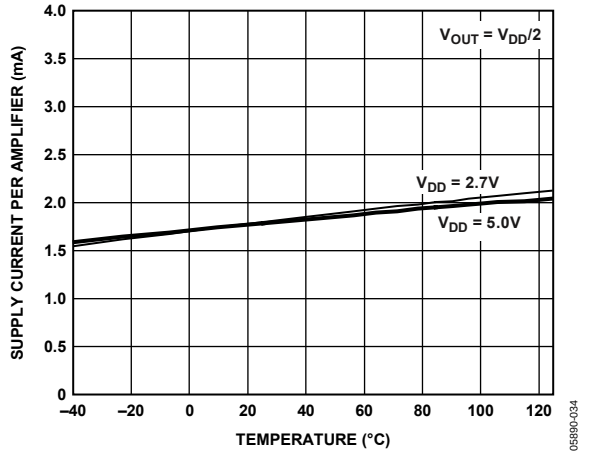
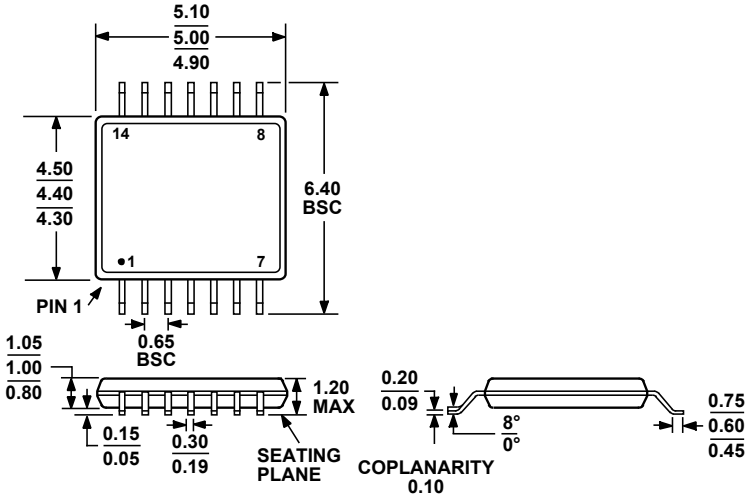


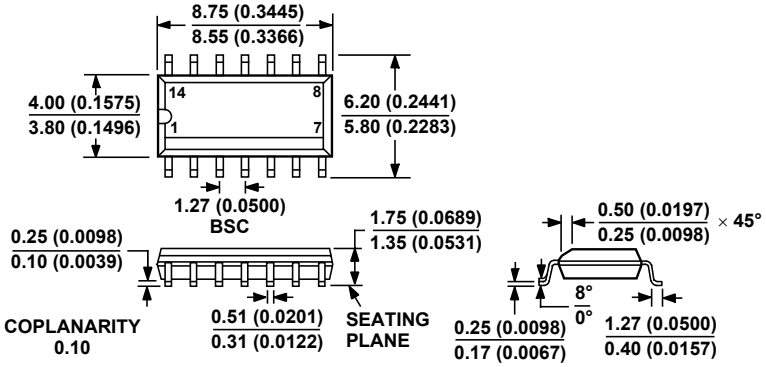

Figure 34. Supply Current per Amplifier vs. Temperature

# OUTLINE DIMENSIONS




**COMPLIANT TO JEDEC STANDARDS MO-153-AB-1**

*Figure 36. 14-Lead Thin Shrink Small Outline Package [TSSOP]*
*(RU-14)*
*Dimensions shown in millimeters*




**COMPLIANT TO JEDEC STANDARDS MS-012-AB**
**CONTROLLING DIMENSIONS ARE IN MILLIMETERS; INCH DIMENSIONS (IN PARENTHESES) ARE ROUNDED-OFF MILLIMETER EQUIVALENTS FOR REFERENCE ONLY AND ARE NOT APPROPRIATE FOR USE IN DESIGN.**

*Figure 37. 14-Lead Standard Small Outline Package [SOIC_N]*
*Narrow Body (R-14)*
*Dimensions shown in millimeters and (inches)*

## ORDERING GUIDE

| Model | Temperature Range | Package Description | Package Option |
|---|---|---|---|
| AD8648ARZ[1] | −40°C to +125°C | 14-Lead SOIC_N | R-14 |
| AD8648ARZ-REEL[1] | −40°C to +125°C | 14-Lead SOIC_N | R-14 |
| AD8648ARZ-REEL7[1] | −40°C to +125°C | 14-Lead SOIC_N | R-14 |
| AD8648ARUZ[1] | −40°C to +125°C | 14-Lead TSSOP | RU-14 |
| AD8648ARUZ-REEL[1] | −40°C to +125°C | 14-Lead TSSOP | RU-14 |

[1] Z = Pb-free part.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