## 1.Description

This amplifier has ultralow offset, drift, and bias current. The AD8628/AD8629/AD8630 are wide bandwidth auto-zero amplifiers featuring rail-to-rail input and output swing and low noise. Operation is fully specified from 2.7 V to 5 V single supply (±1.35V to ±2.5V dual supply).

The AD8628/AD8629/AD8630 provide benefits previously found only in expensive auto-zeroing or chopper-stabilized amplifiers. With an offset voltage of only 1 μV, drift of less than 0.005 μV/°C, and noise of only 0.5μV p-p (0Hz to 10Hz), the AD8628/AD8629/AD8630 are suited for applications where error sources cannot be tolerated. Position and pressure sensors, medical equipment, and strain gage amplifiers benefit greatly from nearly zero drift over their operating temperature range. Many systems can take advantage of the rail-to-rail input and output swings provided by the AD8628/AD8629/AD8630 to reduce input biasing complexity and maximize SNR.

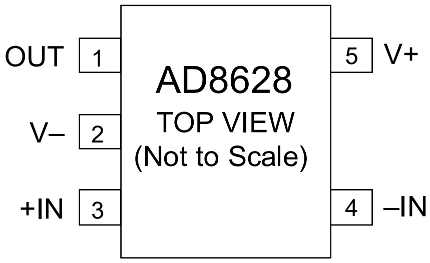
## 2.Features

- Lowest auto-zero amplifier noise
- Low offset voltage: 1μV
- Input offset drift: 0.002μV/°C
- Rail-to-rail input and output swing
- 5 V single-supply operation
- High gain, CMRR, and PSRR: 130dB
- Very low input bias current: 100pA
- maximum Low supply current: 1.0mA
- Overload recovery time: 50μs
- No external components required

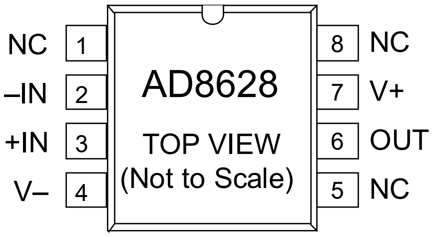
## 3.Applications

- Automotive sensors
- Pressure and position sensors
- Strain gage amplifiers
- Medical instrumentation
- Thermocouple amplifiers
- Precision current sensing
- Photodiode amplifiers

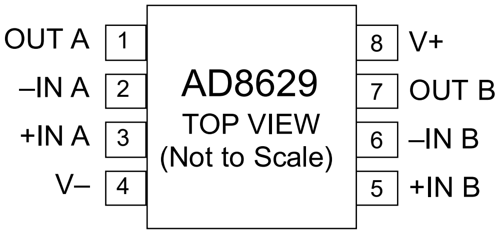
## 4.Pinning information



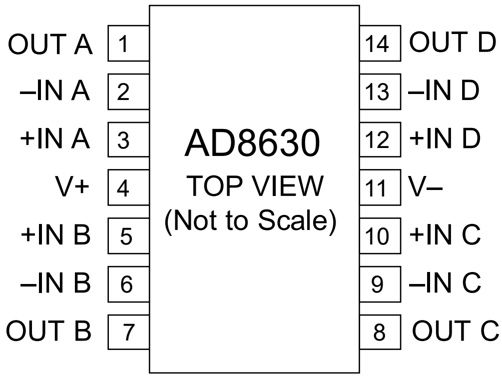

SOT23-5




SOP-8




SOP-8




SOP-14/TSSOP-14

## 5.Absolute Maximum Ratings

| Description | Rating |
|---|---|
| Supply Voltage | 6V |
| Input Voltage | GND − 0.3V to $V_{S-}$ + 0.3V |
| Differential input Voltage (1) | ±5.0V |
| Output Short-Circuit Duration to GND | Indefinite |
| Storage Temperature Range | -65°C to +150°C |
| Operating Temperature Range | -40°C to +125°C |
| Junction Temperature Range | -65°C to +150°C |
| Lead Temperature Range (Soldering, 60 sec) | 300°C |

(1) Differential input voltage is limited to ±5 V or the supply voltage, whichever is less.

## 6.1 Electrical characteristics

$V_S$=5V, $V_{CM}$=2.5V, $T_A$=25°C, unless otherwise noted.

| Parameter | | Symbol | Conditions | Min | Typ | Max | Units |
|---|---|---|---|---|---|---|---|
| **INPUT CHARACTERISTICS** | | | | | | | |
| Offset Voltage | | $V_{OS}$ | | | 1 | 5 | μV |
| | | | −40°C≤$T_A$ ≤+125°C | | | 10 | μV |
| Input Bias Current | AD8628/AD8629 | $I_B$ | | | 30 | 100 | pA |
| | AD8630 | | | | 100 | 300 | pA |
| | | | −40°C≤$T_A$ ≤+125°C | | | 1.5 | nA |
| Input Offset Current | | $I_{OS}$ | | | 50 | 200 | pA |
| | | | −40°C≤$T_A$ ≤+125°C | | | 250 | pA |
| Input Voltage Range | | | | 0 | | 5 | V |
| Common-Mode Rejection Ratio | | CMRR | $V_{CM}$=0V to 5V | 120 | 140 | | dB |
| | | | −40°C≤$T_A$ ≤+125°C | 115 | 130 | | dB |
| Large Signal Voltage Gain | | $A_{VO}$ | $R_L$=10kΩ, $V_O$=0.3V to 4.7V | 125 | 145 | | dB |
| | | | −40°C≤$T_A$ ≤+125°C | 120 | 135 | | dB |
| Offset Voltage Drift | | $\Delta V_{OS}/\Delta T$ | −40°C≤$T_A$ ≤+125°C | | 0.002 | 0.02 | μV/°C |
| **OUTPUT CHARACTERISTICS** | | | | | | | |
| Output Voltage High | | $V_{OH}$ | $R_L$=100kΩ to ground | 4.99 | 4.996 | | V |
| | | | −40°C≤$T_A$ ≤+125°C | 4.99 | 4.995 | | V |
| | | | $R_L$=10kΩ to ground | 4.95 | 4.98 | | V |
| | | | −40°C≤$T_A$ ≤+125°C | 4.95 | 4.97 | | V |
| Output Voltage Low | | $V_{OL}$ | $R_L$=100kΩ to V+ | | 1 | 5 | mV |
| | | | −40°C≤$T_A$ ≤+125°C | | 2 | 5 | mV |
| | | | $R_L$=10kΩ to V+ | | 10 | 20 | mV |
| | | | −40°C≤$T_A$ ≤+125°C | | 15 | 20 | mV |
| Short-Circuit Limit | | $I_{SC}$ | | ±25 | ±50 | | mA |
| | | | −40°C≤$T_A$ ≤+125°C | | ±40 | | mA |
| Output Current | | $I_O$ | | | ±30 | | mA |
| | | | −40°C≤$T_A$ ≤+125°C | | ±15 | | mA |

| Parameter | Symbol | Conditions | Min | Typ | Max | Units |
|---|---|---|---|---|---|---|
| **POWER SUPPLY** | | | | | | |
| Power Supply Rejection Ratio | PSRR | $V_S$=2.7V to 5.5V,-40°C≤$T_A$≤125°C | 115 | 130 | | dB |
| Supply Current per Amplifier | $I_{SY}$ | $V_O$=$V_S$/2 | | 0.85 | 1.1 | mA |
| | | −40°C≤$T_A$≤+125°C | | 1 | 1.2 | mA |
| Input Capacitance | $C_{IN}$ | | | | | |
| Differential | | | | 1.5 | | pF |
| Common Mode | | | | 8 | | pF |
| **DYNAMIC PERFORMANCE** | | | | | | |
| Slew Rate | SR | $R_L$=10kΩ | | 1 | | V/μs |
| Overload Recovery Time | | | | 0.05 | | ms |
| Gain Bandwidth Product | GBP | | | 2.5 | | MHz |
| **NOISE PERFORMANCE** | | | | | | |
| Voltage Noise | $e_n$p-p | 0.1Hz to 10Hz | | 0.5 | | μVp-p |
| | | 0.1Hz to 1Hz | | 0.16 | | μVp-p |
| Voltage Noise Density | $e_n$ | f=1kHz | | 22 | | nV/√Hz |
| Current Noise Density | $i_n$ | f=10Hz | | 5 | | fA/√Hz |

## 6.2 Electrical characteristics

$V_S$=2.7V, $V_{CM}$=1.35V, $V_O$=1.4V, $T_A$=25°C, unless otherwise noted.

| Parameter | | Symbol | Conditions | Min | Typ | Max | Units |
|---|---|---|---|---|---|---|---|
| **INPUT CHARACTERISTICS** | | | | | | | |
| Offset Voltage | | $V_{OS}$ | | | 1 | 5 | μV |
| | | | −40°C≤$T_A$ ≤+125°C | | | 10 | μV |
| Input Bias Current | AD8628/AD8629 | $I_B$ | | | 30 | 100 | pA |
| | AD8630 | | | | 100 | 300 | pA |
| | | | −40°C≤$T_A$ ≤+125°C | | 1 | 1.5 | nA |
| Input Offset Current | | $I_{OS}$ | | | 50 | 200 | pA |
| | | | −40°C≤$T_A$ ≤+125°C | | | 250 | pA |
| Input Voltage Range | | | | 0 | | 2.7 | V |
| Common-Mode Rejection Ratio | | CMRR | $V_{CM}$=0V to 2.7V | 115 | 130 | | dB |
| Large Signal Voltage Gain | | $A_{VO}$ | −40°C≤$T_A$ ≤+125°C | 110 | 120 | | dB |
| | | | $R_L$=10kΩ, $V_O$=0.3V to 2.4V | 110 | 140 | | dB |
| | | | −40°C≤$T_A$ ≤+125°C | 105 | 130 | | dB |
| Offset Voltage Drift | | $\Delta V_{OS}/\Delta T$ | −40°C≤$T_A$ ≤+125°C | | 0.002 | 0.02 | μV/°C |
| **OUTPUT CHARACTERISTICS** | | | | | | | |
| Output Voltage High | | $V_{OH}$ | $R_L$=100kΩ to ground | 2.68 | 2.695 | | V |
| | | | −40°C≤$T_A$ ≤+125°C | 2.68 | 2.695 | | V |
| | | | $R_L$=10kΩ to ground | 2.67 | 2.68 | | V |
| | | | −40°C≤$T_A$ ≤+125°C | 2.67 | 2.675 | | V |
| Output Voltage Low | | $V_{OL}$ | $R_L$=100kΩ to V+ | | 1 | 5 | mV |
| | | | −40°C≤$T_A$ ≤+125°C | | 2 | 5 | mV |
| | | | $R_L$=10kΩ to V+ | | 10 | 20 | mV |
| | | | −40°C≤$T_A$ ≤+125°C | | 15 | 20 | mV |
| Short-Circuit Limit | | $I_{SC}$ | | ±10 | ±15 | | mA |
| | | | −40°C≤$T_A$ ≤+125°C | | ±10 | | mA |
| Output Current | | $I_O$ | | | ±10 | | mA |
| | | | −40°C≤$T_A$ ≤+125°C | | ±5 | | mA |

| Parameter | Symbol | Conditions | Min | Typ | Max | Units |
|---|---|---|---|---|---|---|
| **POWER SUPPLY** | | | | | | |
| Power Supply Rejection Ratio | PSRR | $V_S$=2.7V to 5.5V,-40°C≤$T_A$≤125°C | 115 | 130 | | dB |
| Supply Current per Amplifier | $I_{SY}$ | $V_O$=$V_S$/2 | | 0.75 | 1 | mA |
| | | −40°C≤$T_A$≤+125°C | | 0.9 | 1.2 | mA |
| Input Capacitance | $C_{IN}$ | | | | | |
| Differential | | | | 1.5 | | pF |
| Common Mode | | | | 8 | | pF |
| **DYNAMIC PERFORMANCE** | | | | | | |
| Slew Rate | SR | $R_L$=10kΩ | | 1 | | V/μs |
| Overload Recovery Time | | | | 0.05 | | ms |
| Gain Bandwidth Product | GBP | | | 2 | | MHz |
| **NOISE PERFORMANCE** | | | | | | |
| Voltage Noise | $e_n$p-p | 0.1Hz to 10Hz | | 0.5 | | μVp-p |
| Voltage Noise Density | $e_n$ | f=1kHz | | 22 | | nV/√Hz |
| Current Noise Density | $i_n$ | f=10Hz | | 5 | | fA/√Hz |

## 7.1 Typical Characteristic

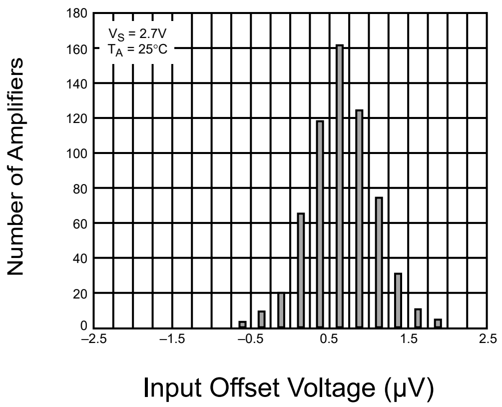



Figure 5: Input Offset Voltage Distribution at 2.7V

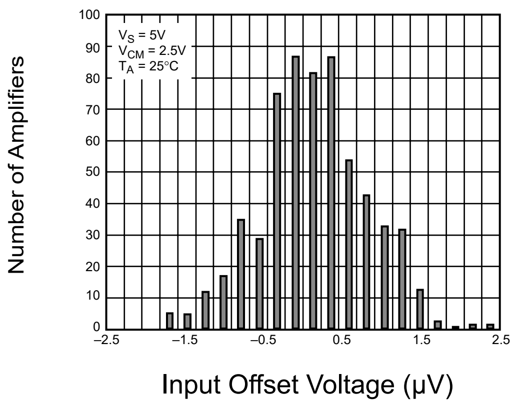



Figure 8: Input Offset Voltage Distribution at 5V

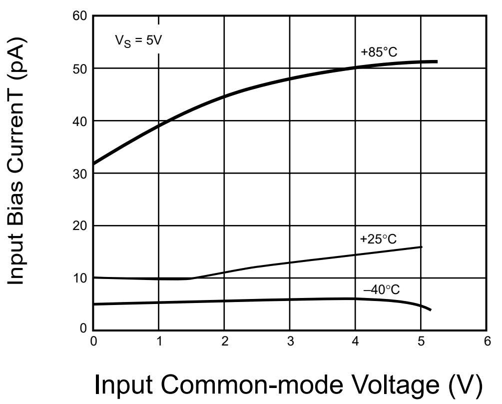



Figure 6: AD8628 Input Bias Current vs.
Input Common-Mode Voltage at 5 V

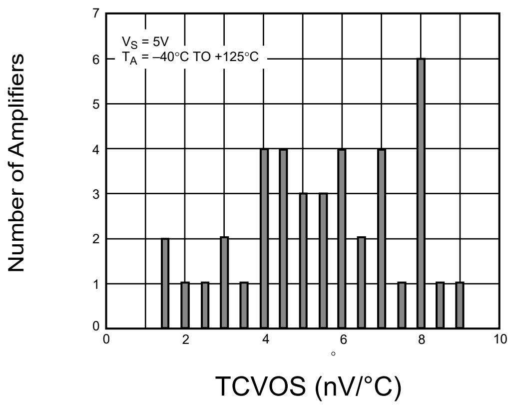



Figure 9: nput Bias Current vs. Common-Mode Voltage

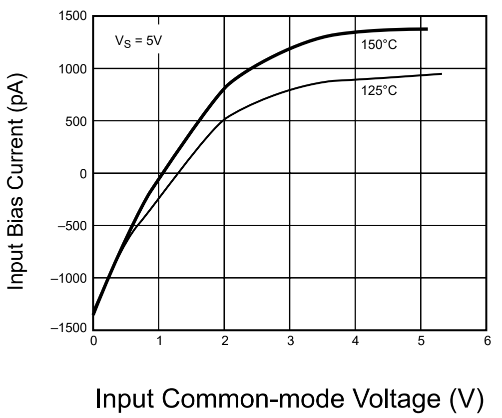



Figure 7: AD8628 Input Bias Current vs.
Input Common-Mode Voltage at 5 V

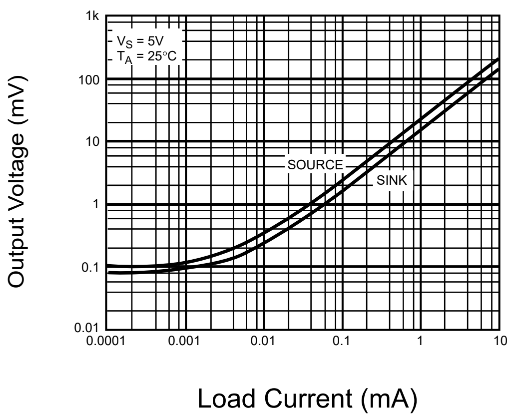



Figure 10: Output Voltage to Supply Rail vs.
Load Current at 5 V

## 7.2 Typical Characteristic

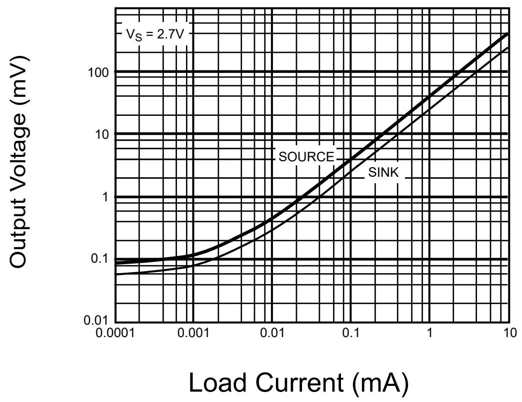



Figure 11: Output Voltage to Supply Rail vs. Load Current at 2.7 V

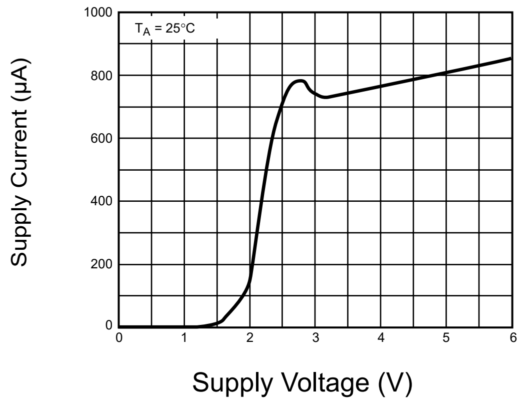



Figure 14: Supply Current vs. Supply Voltage

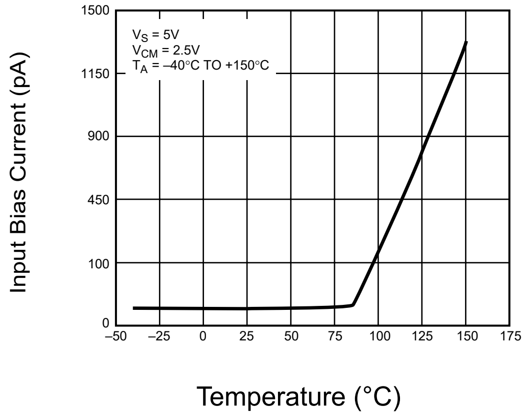



Figure 12: AD8628 Input Bias Current vs. Temperature

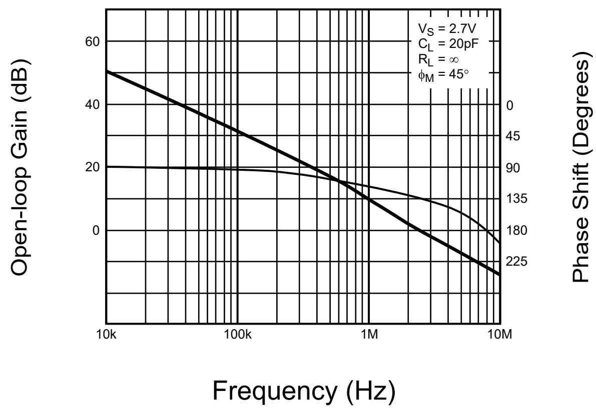



Figure 15: Open-Loop Gain and Phase vs. Frequency

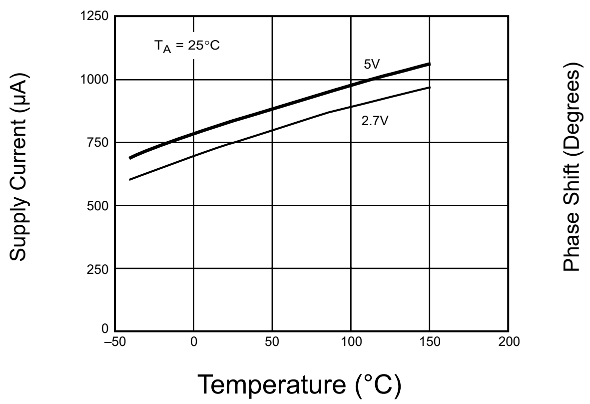



Figure 13: Supply Current vs. Temperature

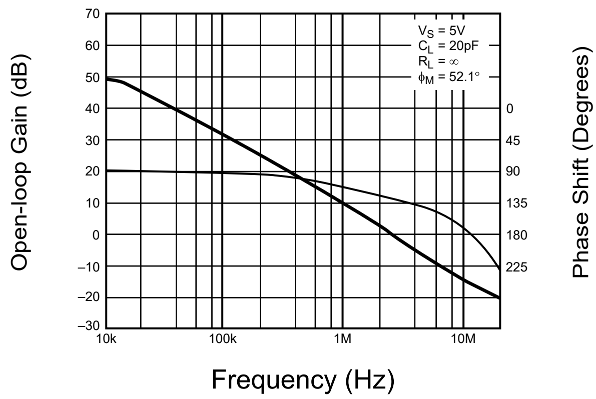



Figure 16: Open-Loop Gain and Phase vs. Frequency

## 7.3 Typical Characteristic

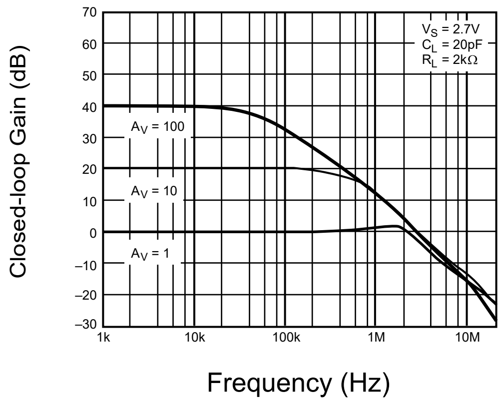



Figure 17: Closed-Loop Gain vs. Frequency at 2.7 V

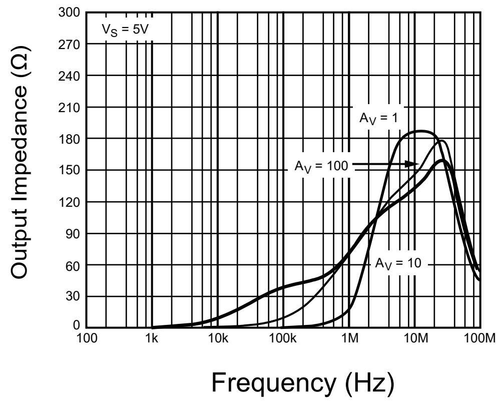



Figure 20: Output Impedance vs. Frequency at 5 V

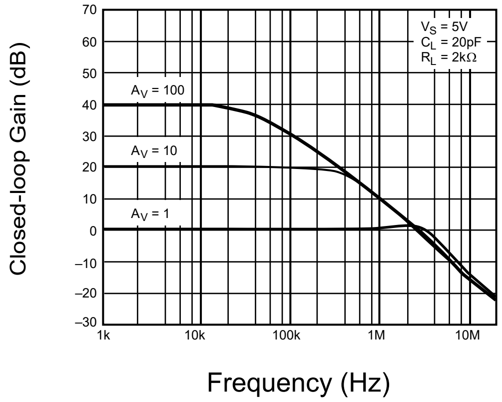



Figure 18: Closed-Loop Gain vs. Frequency at 5 V

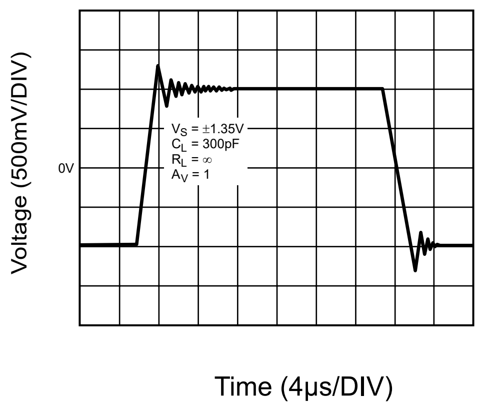



Figure 21: Large Signal Transient Response at 2.7 V

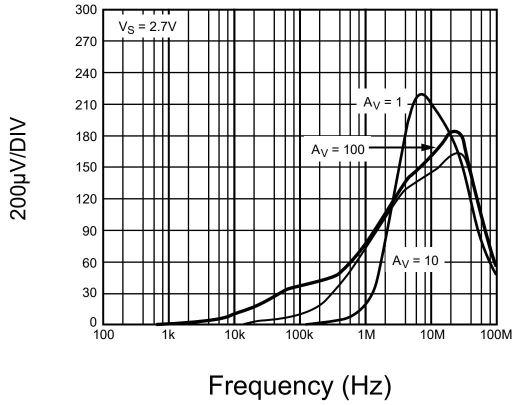



Figure 19: Output Impedance vs. Frequency at 2.7 V

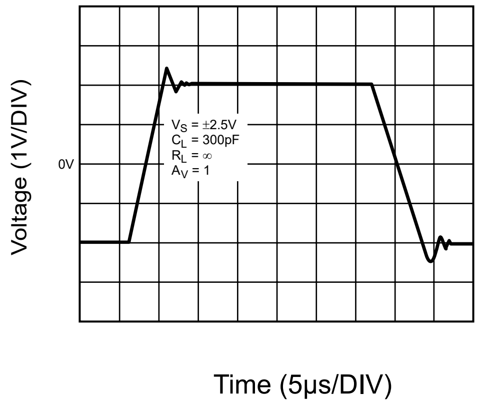



Figure 22: Large Signal Transient Response at 5 V

## 7.4 Typical Characteristic

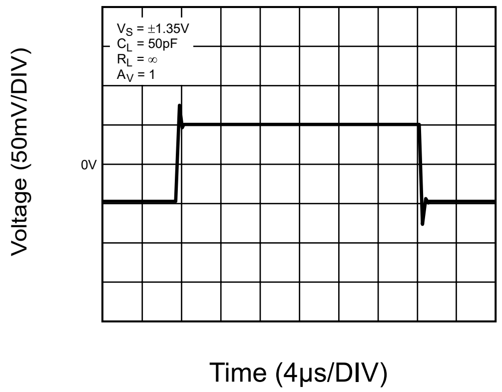



Figure 23: Small Signal Transient Response at 2.7 V

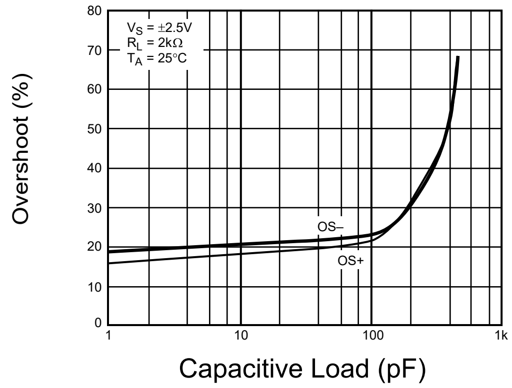



Figure 26: Small Signal Overshoot vs. Load Capacitance at 5 V

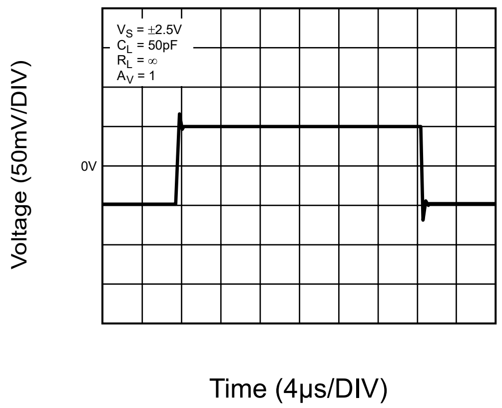



Figure 24: Small Signal Transient Response at 5 V

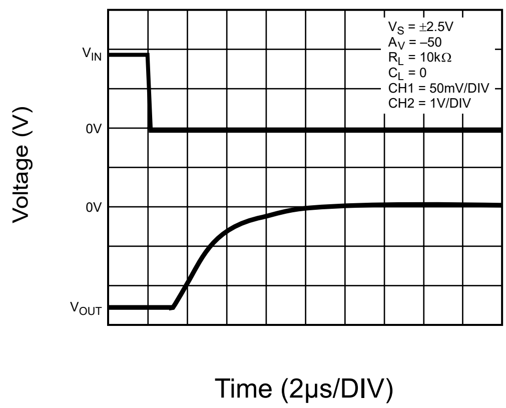



Figure 27: Positive Overvoltage Recovery

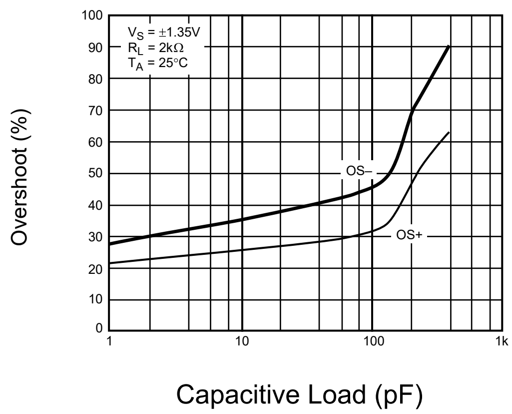



Figure 25: Small Signal Overshoot vs. Load Capacitance at 2.7 V

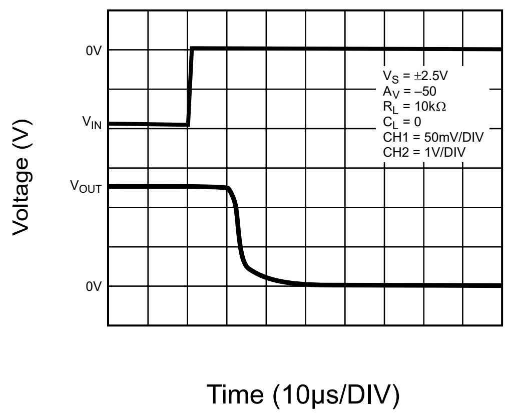



Figure 28: Negative Overvoltage Recovery

## 7.5 Typical Characteristic

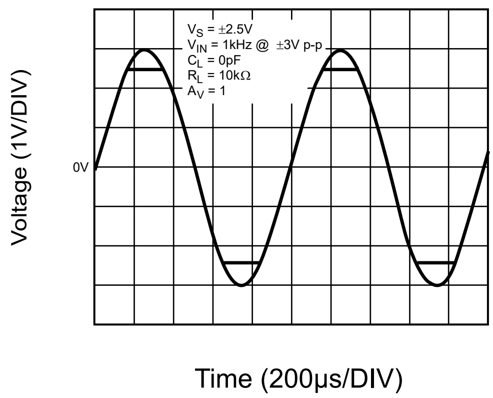



Figure 29: No Phase Reversal

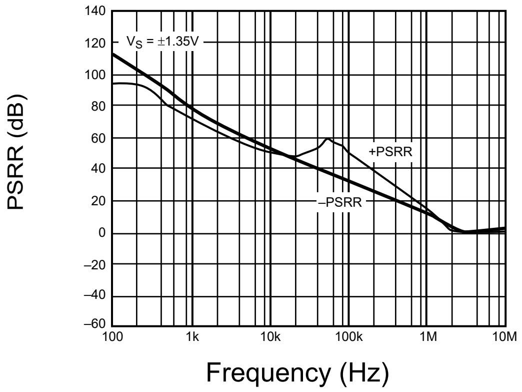



Figure 32: PSRR vs. Frequency

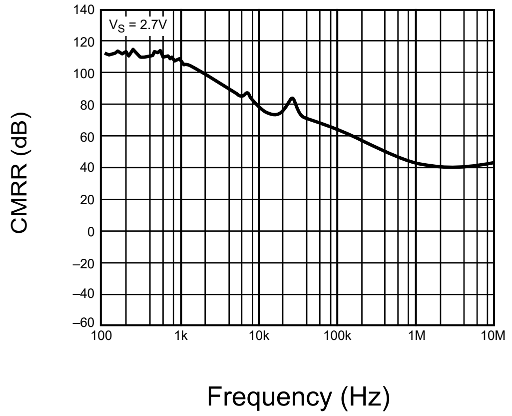



Figure 30: CMRR vs. Frequency at 2.7 V

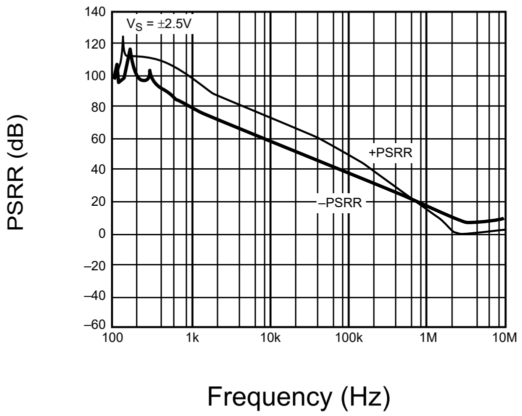



Figure 33: PSRR vs. Frequency

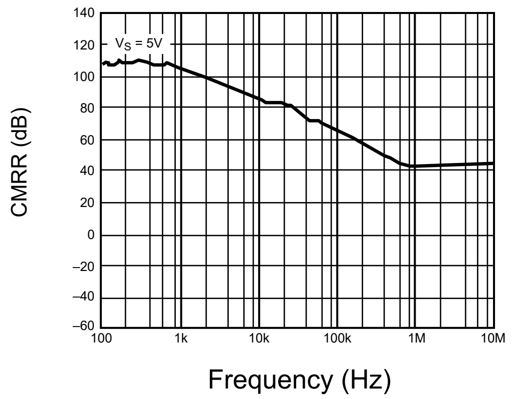



Figure 31: CMRR vs. Frequency at 5 V

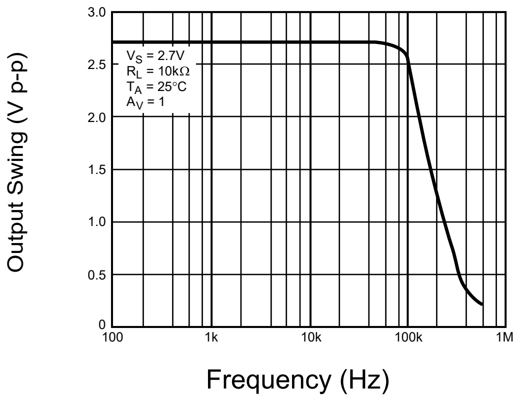



Figure 34: Maximum Output Swing vs. Frequency

## 7.6 Typical Characteristic

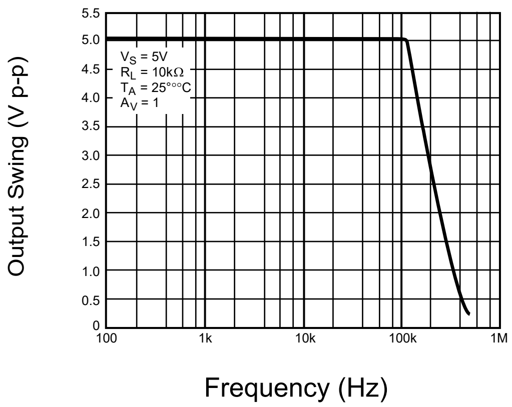



Figure 35: Maximum Output Swing vs. Frequency at 5V

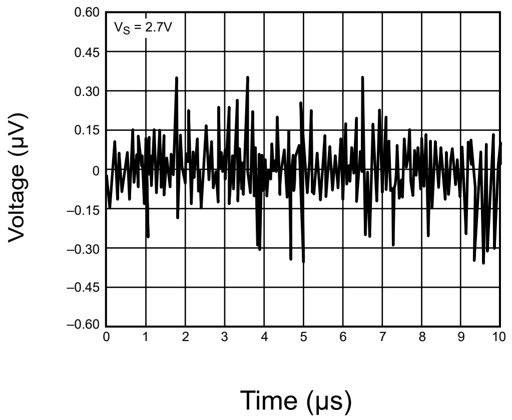



Figure 36: 0.1 Hz to 10 Hz Noise at 2.7V

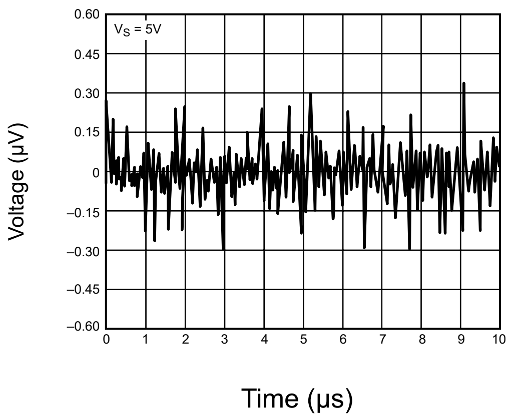



Figure 37: 0.1 Hz to 10 Hz Noise at 5 V

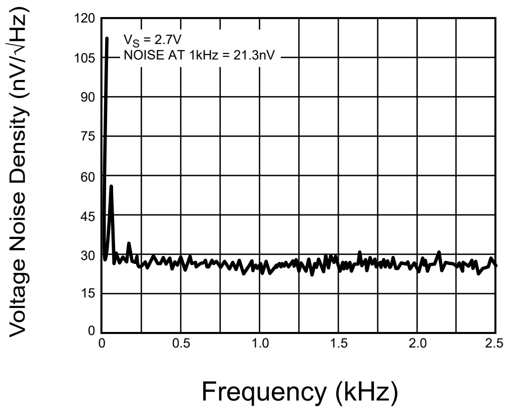



Figure 38: Voltage Noise Density at 2.7V from 0Hz to 2.5kHz

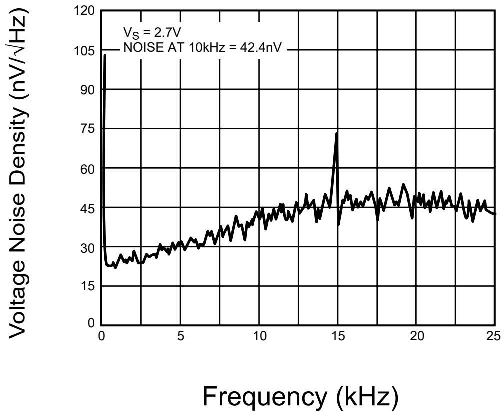



Figure 39: Voltage Noise Density at 2.7V from 0 Hz to 25 kHz

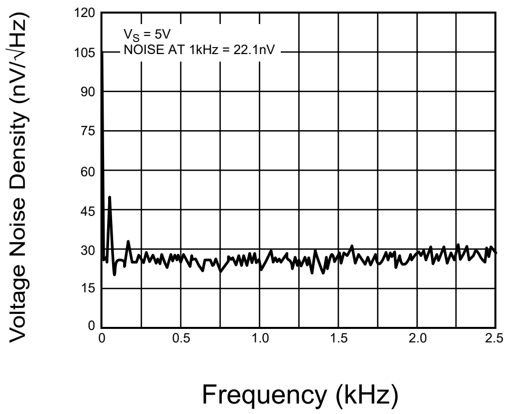



Figure 40: Voltage Noise Density at 5 V from 0 Hz to 2.5 kHz

## 7.7 Typical Characteristic

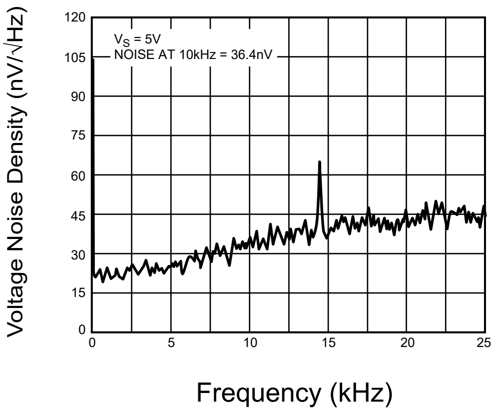



Figure 41: Voltage Noise Density at 5 V from 0 Hz to 25 kHz

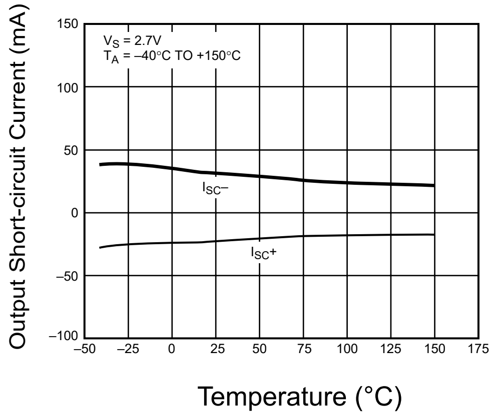



Figure 44: Output Short-Circuit Current vs. Temperature

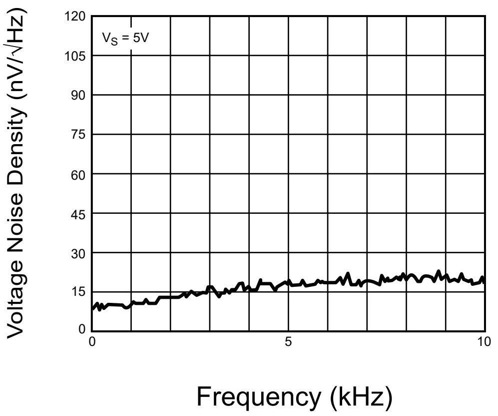



Figure 42: Voltage Noise

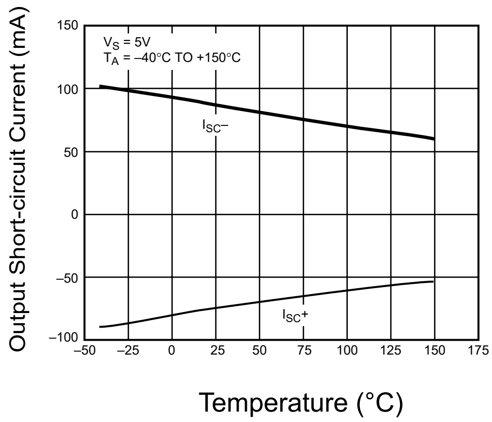



Figure 45: Output Short-Circuit Current vs. Temperature

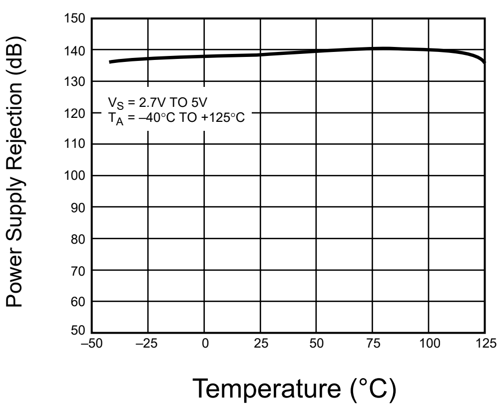



Figure 43: Power Supply Rejection vs. Temperature

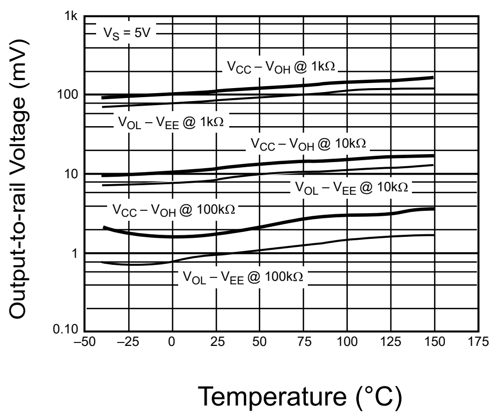



Figure 46: Output-to-Rail Voltage vs. Temperature

## 7.8 Typical Characteristic

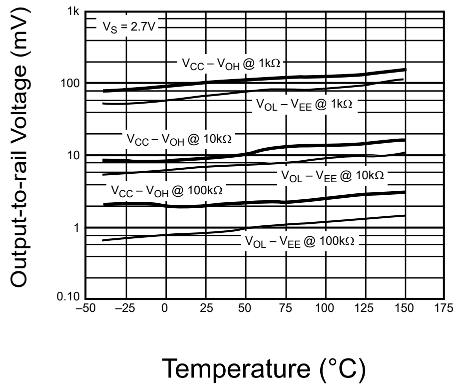



Figure 47: Output -to-Rail Voltage vs. Temperature

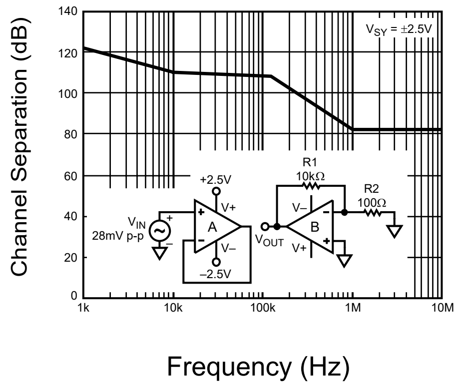



Figure 48: AD8629/AD8630 Channel Separation vs. Frequency

## 7.9 Typical Characteristic

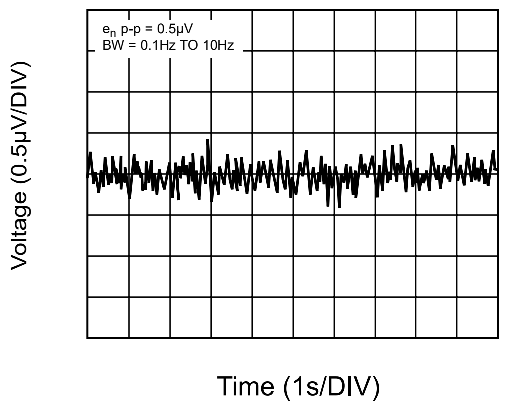



Figure 49: AD8628 Peak-to-Peak Noise

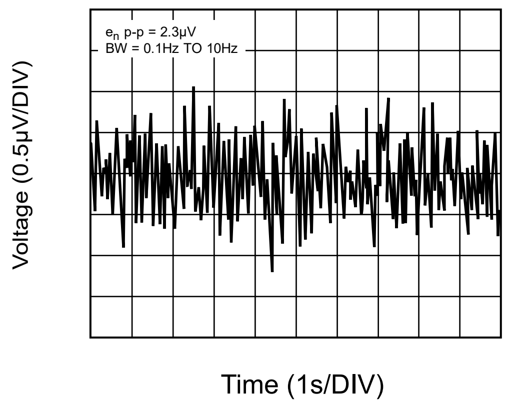



Figure 50: Competitor A Peak-to-Peak Noise

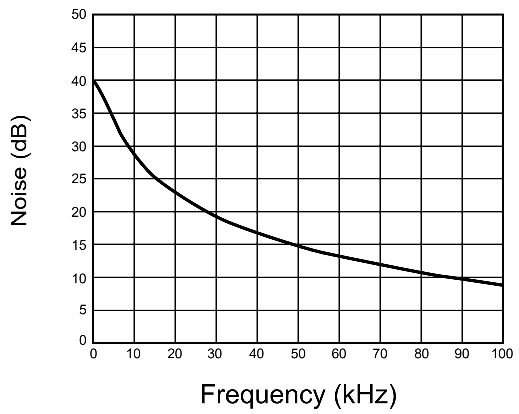



Figure 51: Simulation Transfer Function of the Test Circuit in Figure 51

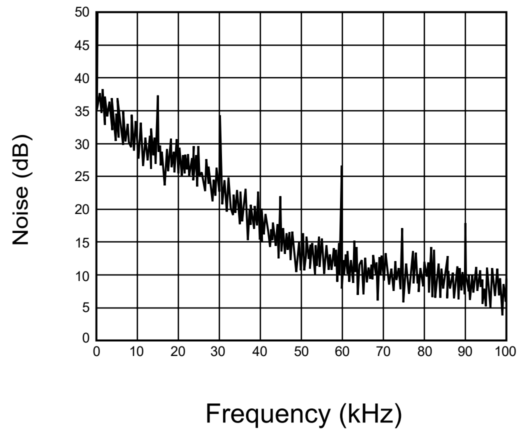



Figure 52: Actual Transfer Function of the Test Circuit in Figure 51

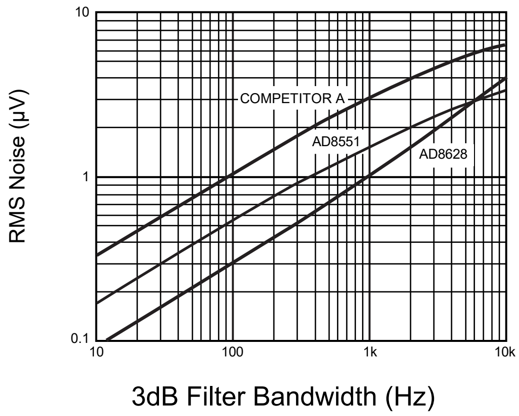



Figure 53: RMS Noise vs.3 dB Filter Bandwidth in Hz

## PEAK-TO-PEAK NOISE

Because of the ping-pong action between auto-zeroing and chopping, the peak-to-peak noise of the AD8628/ AD8629/ AD8630 is much lower than the competition. Figure 50 and Figure 54 show this comparison.

## NOIS E BEHAVIOR WITH FIRST-ORDER , LOW -PASSFILTER

The AD8628 was simulated as a low-pass filter (see Figure 52) and then configured as shown in Figure 51. The behavior of the AD8628 matches the simulated data. It was verified that noise is rolled off by first -order filtering. Figure 52 and Figure 53 show the difference between the simulated and actual transfer functions of the circuit shown in Figure 51 The measured noise spectrum of the test circuit charted in Figure 53 shows that noise between 5 kHz and 45 kHz is successfully rolled off by the first -order filter.

## TOTAL INTEGRATED INPUT-REFERREDNOISE FOR FIRST-ORDER FILTER

For a first -order filter, the total integrated noise from the AD8628 is lower than the noise of Competitor A .

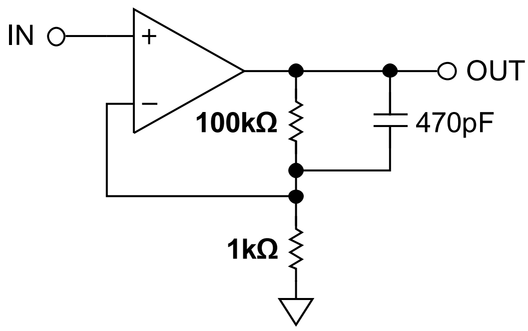



Figure 54: First-Order Low-Pass Filter Test Circuit,
×101 Gain and 3 kHz Corner Frequency

## 7.10 Typical Characteristic

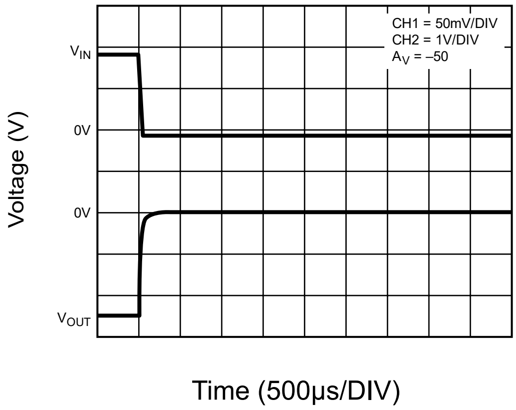



Figure 55: Positive Input Overload Recovery for the AD8628

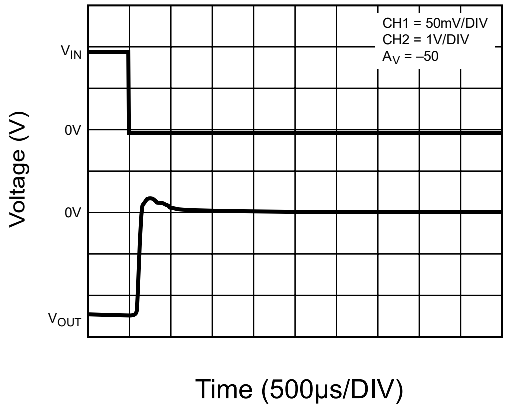



Figure 56: Positive Input Overload Recovery for Competitor A

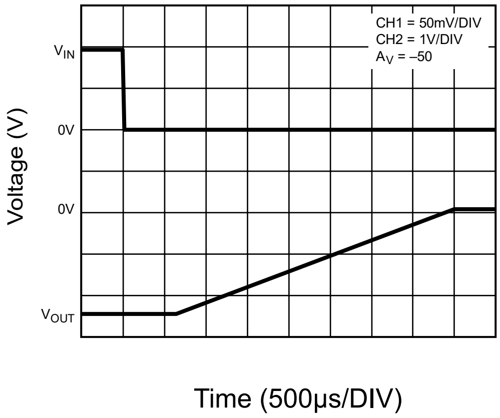



Figure 57: Positive Input Overload Recovery for Competitor B

## INPUT OVERVOLTAGE PROTECTION

Although the AD8628/AD8629/AD8630 are rail-to-rail input amplifiers, care should be taken to ensure that the potential difference between the inputs does not exceed the supply voltage. Under normal negative feedback operating conditions, the amplifier corrects its output to ensure that the two inputs are at the same voltage. However, if either input exceeds either supply rail by more than 0.3 V, large currents begin to flow through the ESD protection diodes in the amp lifier.

These diodes are connected between the inputs and each supply rail to protect the input transistors against an electrostatic discharge event, and they are normally reverse-biased. However, if the input voltage exceeds the supply voltage, these ESD diodes can become forward -biased. Without current limiting, excessive amounts of current could flow through these diodes, causing permanent damage to the device. If inputs are subject to overvoltage, appropriate series resistors should be inserted to lim it the diode current to less than 5 mA maximum.

## OUTPUT PHASE REVE RSAL

Output phase reversal occurs in some amplifiers when the input common -mode voltage range is exceeded. As common-mode voltage is moved outside the common -mode range, the outputs of these amplifiers can suddenly jump in the opposite direction to the supply rail. This is the result of the differential input pair shutting down, causing a radical shifting of internal voltages that results in the erratic output behavior. The AD8628/AD8629/AD8630 amplifiers have been carefully designed to prevent any output phase reversal, provided that both inputs are maintained within the supply voltages. If one or both inputs could exceed either supply voltage, a resistor should be placed in series with the input to l imit the current to less than 5mA. This ensur es that the output does not reverse its phase.

## OVERLOAD RECOVERY TIME

Many auto -zero amplifiers are plagued by a long overload recovery time, often in ms, due to the complicated settling behavior of the internal nulling loops after saturation of the output s. The AD8628/AD8629/AD8630 have been designedso that internal settling occurs within two clock cycles after output saturation occurs. This results in a much shorter recovery time, less than 10 μs, when compared to other auto-zero amplifiers. The wide bandwidth of the AD8628/AD8629/AD8630 enhances performance when the parts are used to drive loads that inject transients into the outputs. This is a common situation when an amplifier is used to drive the input of switched capacitor ADCs.

## 7.11 Typical Characteristic

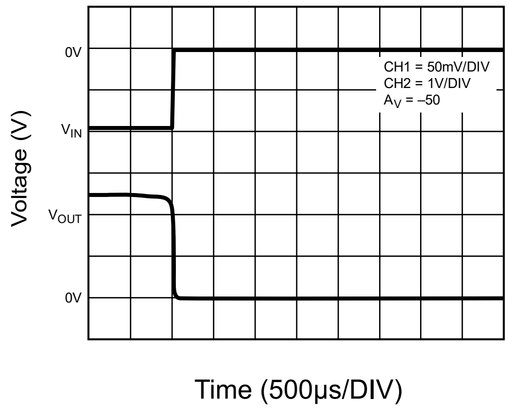



Figure 58: Negative Input Overload Recovery for the AD8628

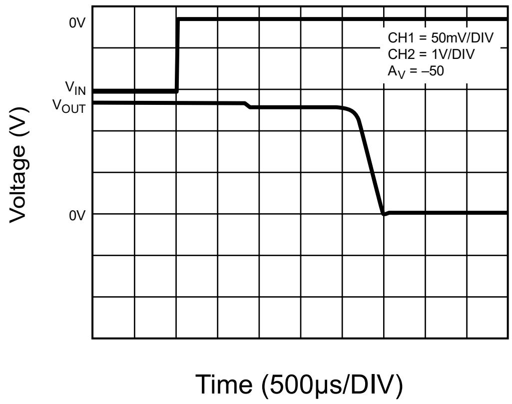



Figure 59: Negative Input Overload Recovery for Competitor A

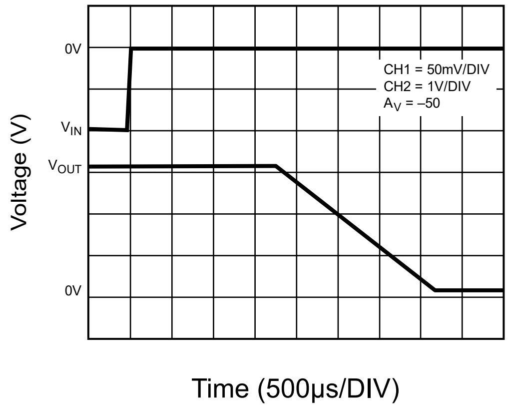



Figure 60: Negative Input Overload Recovery for Competitor B

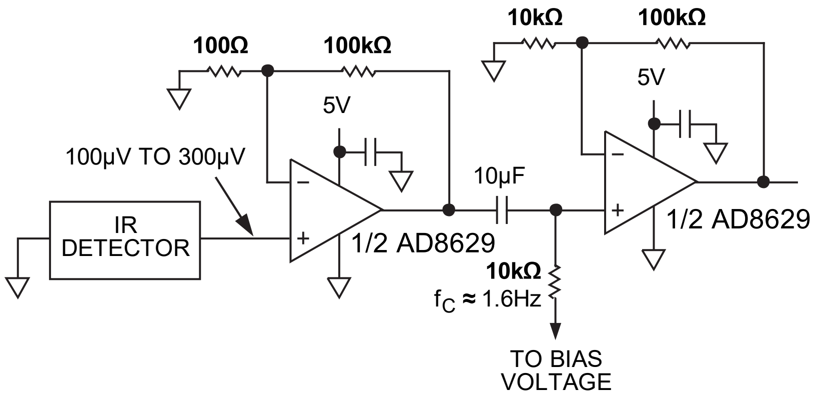
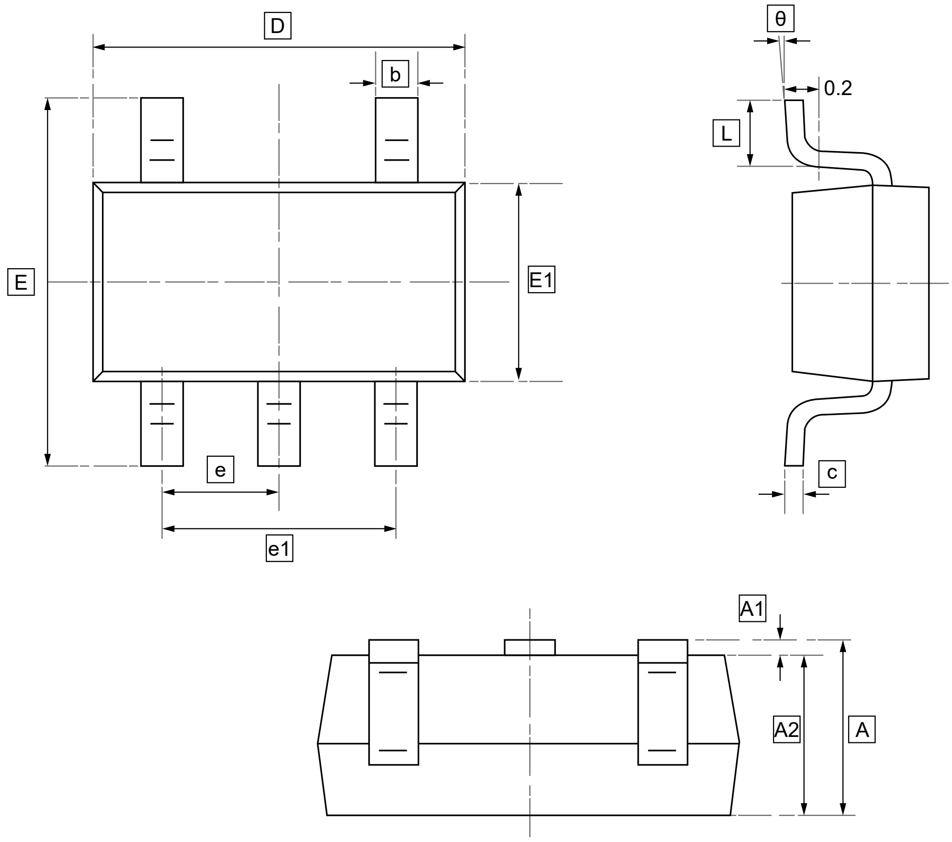



Figure 61. AD8629 Used as Preamplifier for Thermopile

**SENSORS**

Infrared (IR) sensor s, particularly thermopiles, are increasingly being used in temperature measurement for appl-ications as wide ranging as automotive clim ate control, human ear thermometers ,home insulation analysis, and automotive repair diagnostics. The relatively small ou tput signal of the sensor demands high gain with very low offset voltage and drift to avoid dc errors. If interstage ac coupling is used, as in Figure 61, low offset and drift prevent the output of the input amplifi er from drifting close to saturation. The low input bias currents generate minimal errors from the output impedance of the sensor. As with pressure sensors, the very low amplifier drift with time and temperature elimi nate additional errors once the tempera ture measurement is calibrated. The low 1/f noise improves SNR for dc measurements taken over periods often exceeding one-fifth of a second. Figure 61 shows a circuit that can amplify ac signals from 100 μV to 300 μV up to the 1 V to 3 V levels, with a gain of 10,000 for accurate analog-to-digital conversion.

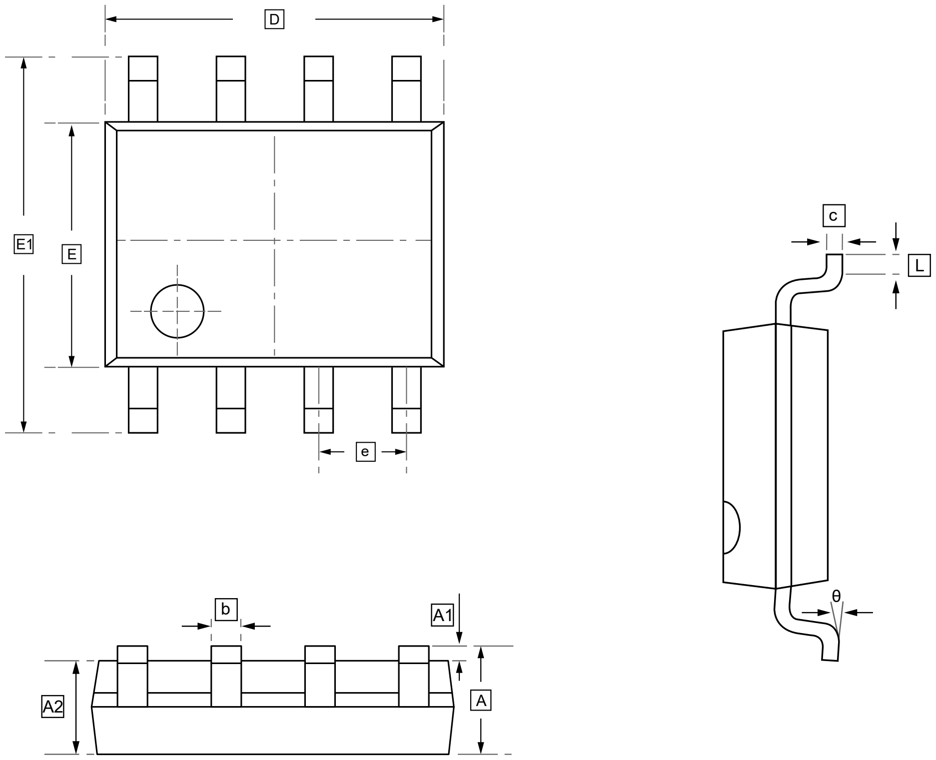
## 8.1 SOT-23-5 Package Outline Dimensions




**DIMENSIONS (mm are the original dimensions)**

| Symbol | A | A1 | A2 | b | c | D | E1 | E | e | e1 | L | θ |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Min** | 1.050 | 0.000 | 1.050 | 0.300 | 0.100 | 2.820 | 1.500 | 2.650 | 0.950 | 1.800 | 0.300 | 0° |
| **Max** | 1.250 | 0.100 | 1.150 | 0.500 | 0.200 | 3.020 | 1.700 | 2.950 | BSC | 2.000 | 0.600 | 8° |

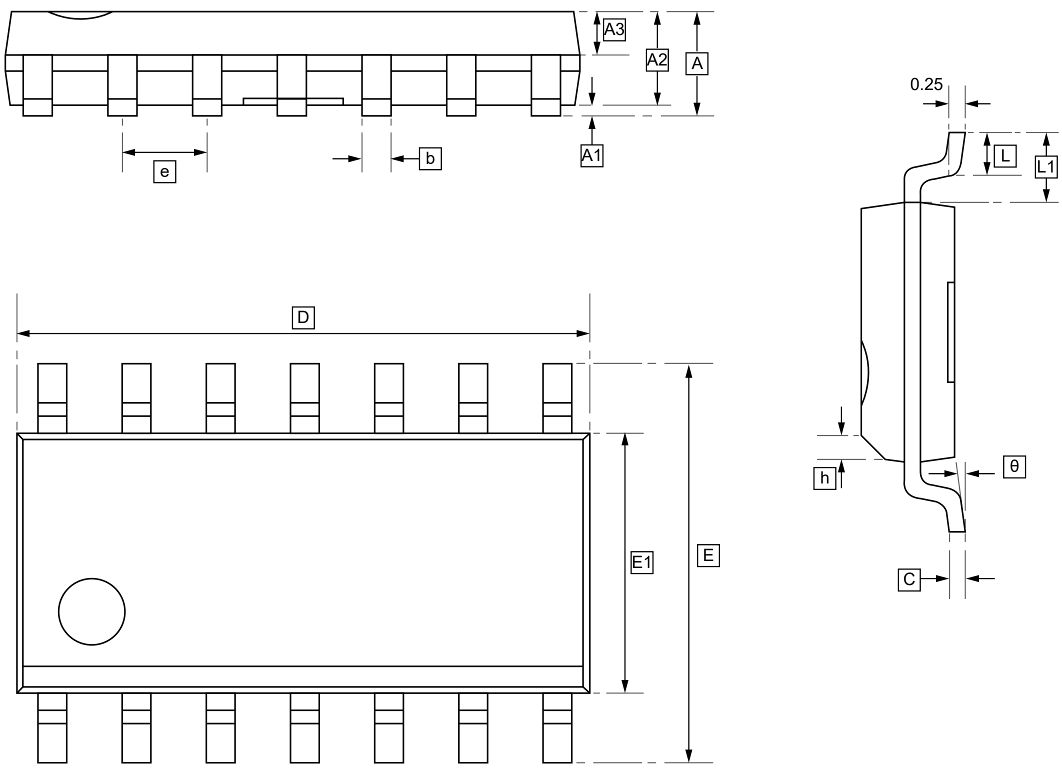
## 8.2 SOP-8 Package Outline Dimensions




**DIMENSIONS (mm are the original dimensions)**

| Symbol | A | A1 | A2 | b | c | D | E | E1 | e | L | θ |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Min | 1.350 | 0.000 | 1.350 | 0.330 | 0.170 | 4.700 | 3.800 | 5.800 | 1.270 | 0.400 | 0° |
| Max | 1.750 | 0.100 | 1.550 | 0.510 | 0.250 | 5.100 | 4.000 | 6.200 | BSC | 1.270 | 8° |

## 8.3 SOP-14 Package Outline Dimensions

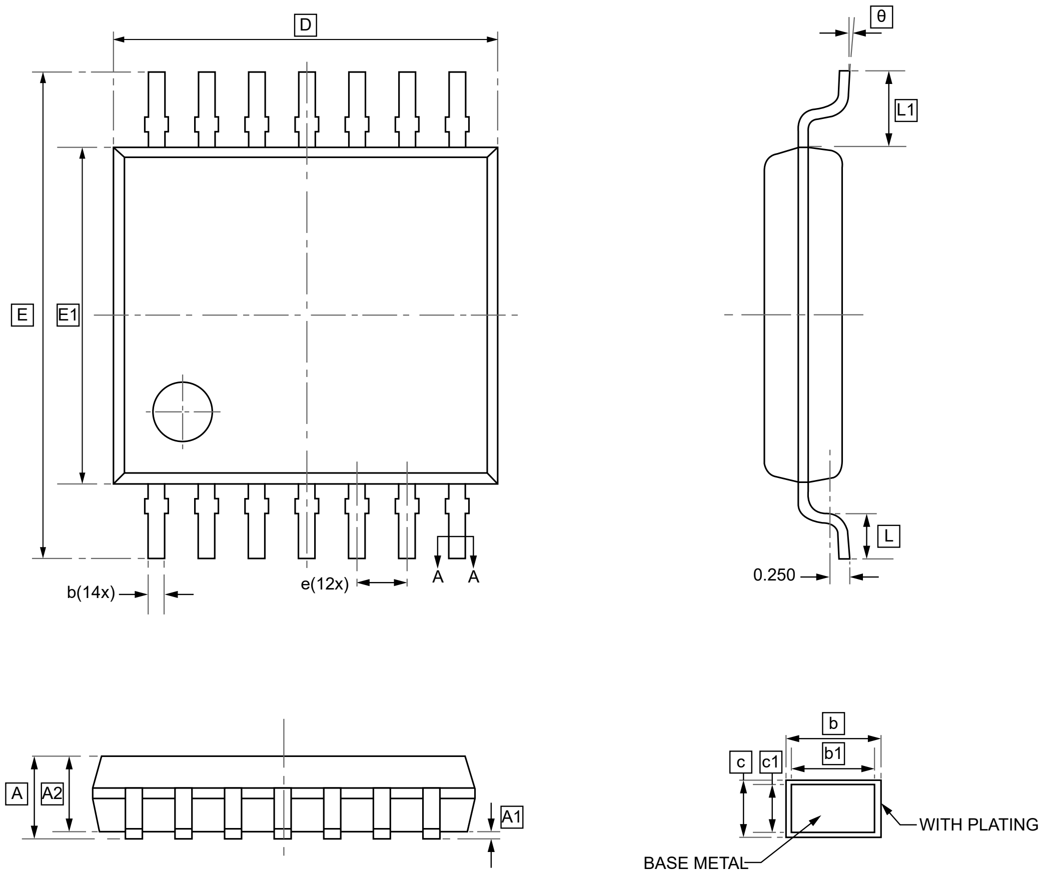



**DIMENSIONS (mm are the original dimensions)**

| Symbol | A | A1 | A2 | A3 | b | C | D | E | E1 | e | h | L |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Min | - | 0.05 | 1.35 | 0.65 | 0.203 | 0.17 | 8.45 | 5.80 | 3.80 | 1.24 | 0.25 | 0.40 |
| Max | 1.75 | 0.25 | 1.55 | 0.75 | 0.305 | 0.25 | 8.85 | 6.20 | 4.00 | 1.30 | 0.50 | 0.80 |

| Symbol | L1 | θ |
|---|---|---|
| Min | 1.00 | 0° |
| Max | 1.10 | 8° |

## 8.4 TSSOP-14 Package Outline Dimensions

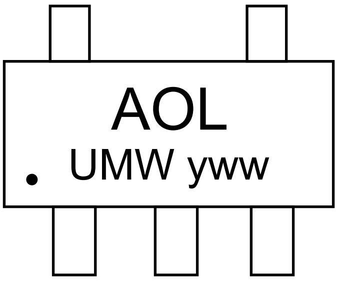



**DIMENSIONS (mm are the original dimensions)**

| Symbol | A | A1 | A2 | b | b1 | c | c1 | D | E | E1 | e | L1 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Min** | - | 0.05 | 0.90 | 0.20 | 0.19 | 0.13 | 0.120 | 4.90 | 6.20 | 4.30 | 0.65 | 0.85 |
| **Max** | 1.20 | 0.15 | 1.05 | 0.28 | 0.25 | 0.17 | 0.14 | 5.10 | 6.60 | 4.50 | BSC | 1.15 |

| Symbol | L | θ |
|---|---|---|
| **Min** | 0.45 | 0° |
| **Max** | 0.75 | 8° |

## 9.Ordering Information




yww: Batch Code

| Order Code | Marking | Package | Base QTY | Delivery Mode |
|---|---|---|---|---|
| UMW AD8628ARTZ | AOL | SOT-23-5 | 3000 | Tape and reel |
| UMW AD8628ARZ | AD8628 | SOP-8 | 2500 | Tape and reel |
| UMW AD8629ARZ | AD8629 | SOP-8 | 2500 | Tape and reel |
| UMW AD8630ARUZ | AD8630 | TSSOP-14 | 4000 | Tape and reel |
| UMW AD8630ARZ | AD8630 | SOP-14 | 2500 | Tape and reel |

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