

### FEATURES

**Rail-to-rail output swing**  
**Single-supply operation: 3 V to 36 V**  
**Low offset voltage: 300  $\mu$ V**  
**Gain bandwidth product: 75 kHz**  
**High open-loop gain: 1000 V/mV**  
**Unity-gain stable**  
**Low supply current/per amplifier: 150  $\mu$ A maximum**

### APPLICATIONS

**Battery-operated instrumentation**  
**Servo amplifiers**  
**Actuator drives**  
**Sensor conditioners**  
**Power supply control**

### GENERAL DESCRIPTION

Rail-to-rail output swing combined with dc accuracy are the key features of the OP495 quad and OP295 dual CBCMOS operational amplifiers. By using a bipolar front end, lower noise and higher accuracy than those of CMOS designs have been achieved. Both input and output ranges include the negative supply, providing the user with zero-in/zero-out capability. For users of 3.3 V systems such as lithium batteries, the OP295/OP495 are specified for 3 V operation.

Maximum offset voltage is specified at 300  $\mu$ V for 5 V operation, and the open-loop gain is a minimum of 1000 V/mV. This yields performance that can be used to implement high accuracy systems, even in single-supply designs.

The ability to swing rail-to-rail and supply 15 mA to the load makes the OP295/OP495 ideal drivers for power transistors and H bridges. This allows designs to achieve higher efficiencies and to transfer more power to the load than previously possible without the use of discrete components.

For applications such as transformers that require driving inductive loads, increases in efficiency are also possible. Stability while driving capacitive loads is another benefit of this design over CMOS rail-to-rail amplifiers. This is useful for driving coax cable or large FET transistors. The OP295/OP495 are stable with loads in excess of 300 pF.

### PIN CONFIGURATIONS

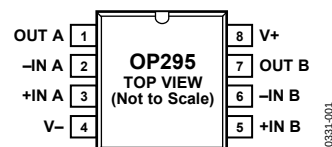


Figure 1. 8-Lead Narrow-Body SOIC\_N S Suffix (R-8)

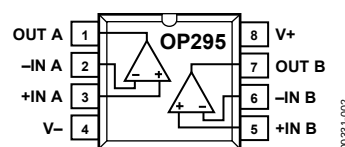


Figure 2. 8-Lead PDIP P Suffix (N-8)

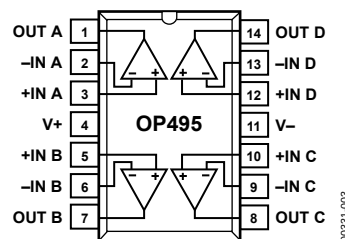


Figure 3. 14-Lead PDIP P Suffix (N-14)

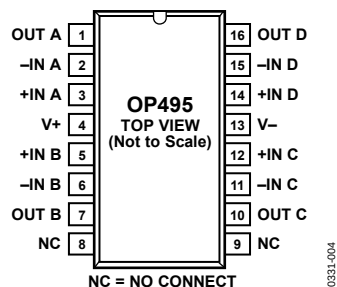


Figure 4. 16-Lead SOIC\_W S Suffix (RW-16)

The OP295 and OP495 are specified over the extended industrial ( $-40^{\circ}\text{C}$  to  $+125^{\circ}\text{C}$ ) temperature range. The OP295 is available in 8-lead PDIP and 8-lead SOIC\_N surface-mount packages. The OP495 is available in 14-lead PDIP and 16-lead SOIC\_W surface-mount packages.

### Rev. G

Information furnished by Analog Devices is believed to be accurate and reliable. However, no responsibility is assumed by Analog Devices for its use, nor for any infringements of patents or other rights of third parties that may result from its use. Specifications subject to change without notice. No license is granted by implication or otherwise under any patent or patent rights of Analog Devices. Trademarks and registered trademarks are the property of their respective owners.

## TABLE OF CONTENTS

|                                             |    |
|---------------------------------------------|----|
| Features .....                              | 1  |
| Applications .....                          | 1  |
| General Description .....                   | 1  |
| Pin Configurations .....                    | 1  |
| Revision History .....                      | 2  |
| Specifications .....                        | 3  |
| Electrical Characteristics .....            | 3  |
| Absolute Maximum Ratings .....              | 5  |
| Thermal Resistance .....                    | 5  |
| ESD Caution .....                           | 5  |
| Typical Performance Characteristics .....   | 6  |
| Applications .....                          | 9  |
| Rail-to-Rail Application Information .....  | 9  |
| Low Drop-Out Reference .....                | 9  |
| Low Noise, Single-Supply Preamplifier ..... | 9  |
| Driving Heavy Loads .....                   | 10 |

|                                                                               |    |
|-------------------------------------------------------------------------------|----|
| Direct Access Arrangement .....                                               | 10 |
| Single-Supply Instrumentation Amplifier .....                                 | 10 |
| Single-Supply RTD Thermometer Amplifier .....                                 | 11 |
| Cold Junction Compensated, Battery-Powered<br>Thermocouple Amplifier .....    | 11 |
| 5 V Only, 12-Bit DAC That Swings 0 V to 4.095 V .....                         | 11 |
| 4 mA to 20 mA Current-Loop Transmitter .....                                  | 12 |
| 3 V Low Dropout Linear Voltage Regulator .....                                | 12 |
| Low Dropout, 500 mA Voltage Regulator with Foldback<br>Current Limiting ..... | 12 |
| Square Wave Oscillator .....                                                  | 13 |
| Single-Supply Differential Speaker Driver .....                               | 13 |
| High Accuracy, Single-Supply, Low Power Comparator .....                      | 13 |
| Outline Dimensions .....                                                      | 14 |
| Ordering Guide .....                                                          | 16 |

## REVISION HISTORY

### 8/09—Rev. F to Rev. G

|                                  |    |
|----------------------------------|----|
| Added Figure 18 .....            | 8  |
| Updated Outline Dimensions ..... | 17 |

### 3/08—Rev. E to Rev. F

|                                                 |    |
|-------------------------------------------------|----|
| Changes to Offset Voltage Unit in Table 1 ..... | 3  |
| Updated Outline Dimensions .....                | 14 |
| Changes to Ordering Guide .....                 | 16 |

### 5/06—Rev. D to Rev. E

|                                  |           |
|----------------------------------|-----------|
| Updated Format .....             | Universal |
| Changes to Features .....        | 1         |
| Changes to Pin Connections ..... | 1         |
| Updated Outline Dimensions ..... | 14        |
| Changes to Ordering Guide .....  | 15        |

### 2/04—Rev. C to Rev. D

|                                           |    |
|-------------------------------------------|----|
| Changes to General Description .....      | 1  |
| Changes to Specifications .....           | 2  |
| Changes to Absolute Maximum Ratings ..... | 4  |
| Changes to Ordering Guide .....           | 4  |
| Updated Outline Dimensions .....          | 12 |

### 3/02—Rev. B to Rev. C

|                                                         |   |
|---------------------------------------------------------|---|
| Figure changes to Pin Connections .....                 | 1 |
| Deleted OP295GBC and OP495GBC from Ordering Guide ..... | 3 |
| Deleted Wafer Test Limits Table .....                   | 3 |
| Changes to Absolute Maximum Ratings .....               | 4 |
| Deleted Dice Characteristics .....                      | 4 |

## SPECIFICATIONS

### ELECTRICAL CHARACTERISTICS

$V_S = 5.0\text{ V}$ ,  $V_{CM} = 2.5\text{ V}$ ,  $T_A = 25^\circ\text{C}$ , unless otherwise noted.

Table 1.

| Parameter                    | Symbol                   | Conditions                                                                                              | Min      | Typ      | Max     | Unit                         |
|------------------------------|--------------------------|---------------------------------------------------------------------------------------------------------|----------|----------|---------|------------------------------|
| INPUT CHARACTERISTICS        |                          |                                                                                                         |          |          |         |                              |
| Offset Voltage               | $V_{OS}$                 | $-40^\circ\text{C} \leq T_A \leq +125^\circ\text{C}$                                                    |          | 30       | 300     | $\mu\text{V}$                |
| Input Bias Current           | $I_B$                    | $-40^\circ\text{C} \leq T_A \leq +125^\circ\text{C}$                                                    |          | 8        | 800     | $\mu\text{V}$                |
| Input Offset Current         | $I_{OS}$                 | $-40^\circ\text{C} \leq T_A \leq +125^\circ\text{C}$                                                    |          | $\pm 1$  | 20      | nA                           |
| Input Voltage Range          | $V_{CM}$                 | $-40^\circ\text{C} \leq T_A \leq +125^\circ\text{C}$                                                    |          |          | 30      | nA                           |
| Common-Mode Rejection Ratio  | CMRR                     | $0\text{ V} \leq V_{CM} \leq 4.0\text{ V}$ , $-40^\circ\text{C} \leq T_A \leq +125^\circ\text{C}$       | 0        | $\pm 1$  | $\pm 3$ | nA                           |
| Large Signal Voltage Gain    | $A_{VO}$                 | $R_L = 10\text{ k}\Omega$ , $0.005 \leq V_{OUT} \leq 4.0\text{ V}$                                      | 90       | 110      | $\pm 5$ | V/mV                         |
| Offset Voltage Drift         | $\Delta V_{OS}/\Delta T$ | $R_L = 10\text{ k}\Omega$ , $-40^\circ\text{C} \leq T_A \leq +125^\circ\text{C}$                        | 500      | 1        | 5       | $\mu\text{V}/^\circ\text{C}$ |
| OUTPUT CHARACTERISTICS       |                          |                                                                                                         |          |          |         |                              |
| Output Voltage Swing High    | $V_{OH}$                 | $R_L = 100\text{ k}\Omega$ to GND                                                                       | 4.98     | 5.0      |         | V                            |
|                              |                          | $R_L = 10\text{ k}\Omega$ to GND                                                                        | 4.90     | 4.94     |         | V                            |
| Output Voltage Swing Low     | $V_{OL}$                 | $I_{OUT} = 1\text{ mA}$ , $-40^\circ\text{C} \leq T_A \leq +125^\circ\text{C}$                          |          | 4.7      |         | V                            |
|                              |                          | $R_L = 100\text{ k}\Omega$ to GND                                                                       |          | 0.7      | 2       | mV                           |
|                              |                          | $R_L = 10\text{ k}\Omega$ to GND                                                                        |          | 0.7      | 2       | mV                           |
| Output Current               | $I_{OUT}$                | $I_{OUT} = 1\text{ mA}$ , $-40^\circ\text{C} \leq T_A \leq +125^\circ\text{C}$                          | $\pm 11$ | 90       |         | mV                           |
|                              |                          |                                                                                                         |          | $\pm 18$ |         | mA                           |
| POWER SUPPLY                 |                          |                                                                                                         |          |          |         |                              |
| Power Supply Rejection Ratio | PSRR                     | $\pm 1.5\text{ V} \leq V_S \leq \pm 15\text{ V}$                                                        | 90       | 110      |         | dB                           |
|                              |                          | $\pm 1.5\text{ V} \leq V_S \leq \pm 15\text{ V}$ , $-40^\circ\text{C} \leq T_A \leq +125^\circ\text{C}$ | 85       |          |         | dB                           |
| Supply Current per Amplifier | $I_{SY}$                 | $V_{OUT} = 2.5\text{ V}$ , $R_L = \infty$ , $-40^\circ\text{C} \leq T_A \leq +125^\circ\text{C}$        |          |          | 150     | $\mu\text{A}$                |
| DYNAMIC PERFORMANCE          |                          |                                                                                                         |          |          |         |                              |
| Slew Rate                    | SR                       | $R_L = 10\text{ k}\Omega$                                                                               |          | 0.03     |         | V/ $\mu\text{s}$             |
| Gain Bandwidth Product       | GBP                      |                                                                                                         |          | 75       |         | kHz                          |
| Phase Margin                 | $\theta_o$               |                                                                                                         |          | 86       |         | Degrees                      |
| NOISE PERFORMANCE            |                          |                                                                                                         |          |          |         |                              |
| Voltage Noise                | $e_n$ p-p                | 0.1 Hz to 10 Hz                                                                                         |          | 1.5      |         | $\mu\text{V p-p}$            |
| Voltage Noise Density        | $e_n$                    | $f = 1\text{ kHz}$                                                                                      |          | 51       |         | nV/ $\sqrt{\text{Hz}}$       |
| Current Noise Density        | $i_n$                    | $f = 1\text{ kHz}$                                                                                      |          | <0.1     |         | pA/ $\sqrt{\text{Hz}}$       |

$V_S = 3.0\text{ V}$ ,  $V_{CM} = 1.5\text{ V}$ ,  $T_A = 25^\circ\text{C}$ , unless otherwise noted.

Table 2.

| Parameter                   | Symbol                   | Conditions                                                                                        | Min | Typ     | Max     | Unit                         |
|-----------------------------|--------------------------|---------------------------------------------------------------------------------------------------|-----|---------|---------|------------------------------|
| INPUT CHARACTERISTICS       |                          |                                                                                                   |     |         |         |                              |
| Offset Voltage              | $V_{OS}$                 |                                                                                                   |     | 100     | 500     | $\mu\text{V}$                |
| Input Bias Current          | $I_B$                    |                                                                                                   |     | 8       | 20      | nA                           |
| Input Offset Current        | $I_{OS}$                 |                                                                                                   |     | $\pm 1$ | $\pm 3$ | nA                           |
| Input Voltage Range         | $V_{CM}$                 |                                                                                                   | 0   |         | 2.0     | V                            |
| Common-Mode Rejection Ratio | CMRR                     | $0\text{ V} \leq V_{CM} \leq 2.0\text{ V}$ , $-40^\circ\text{C} \leq T_A \leq +125^\circ\text{C}$ | 90  | 110     |         | dB                           |
| Large Signal Voltage Gain   | $A_{VO}$                 | $R_L = 10\text{ k}\Omega$                                                                         |     | 750     |         | V/mV                         |
| Offset Voltage Drift        | $\Delta V_{OS}/\Delta T$ |                                                                                                   |     | 1       |         | $\mu\text{V}/^\circ\text{C}$ |

# OP295/OP495

| Parameter                    | Symbol             | Conditions                                                                    | Min | Typ  | Max | Unit    |
|------------------------------|--------------------|-------------------------------------------------------------------------------|-----|------|-----|---------|
| OUTPUT CHARACTERISTICS       |                    |                                                                               |     |      |     |         |
| Output Voltage Swing High    | V <sub>OH</sub>    | R <sub>L</sub> = 10 kΩ to GND                                                 | 2.9 |      |     | V       |
| Output Voltage Swing Low     | V <sub>OL</sub>    | R <sub>L</sub> = 10 kΩ to GND                                                 |     | 0.7  | 2   | mV      |
| POWER SUPPLY                 |                    |                                                                               |     |      |     |         |
| Power Supply Rejection Ratio | PSRR               | ±1.5 V ≤ V <sub>S</sub> ≤ ±15 V                                               | 90  | 110  |     | dB      |
|                              |                    | ±1.5 V ≤ V <sub>S</sub> ≤ ±15 V, −40°C ≤ T <sub>A</sub> ≤ +125°C              | 85  |      |     | dB      |
| Supply Current per Amplifier | I <sub>SY</sub>    | V <sub>OUT</sub> = 1.5 V, R <sub>L</sub> = ∞, −40°C ≤ T <sub>A</sub> ≤ +125°C |     |      | 150 | μA      |
| DYNAMIC PERFORMANCE          |                    |                                                                               |     |      |     |         |
| Slew Rate                    | SR                 | R <sub>L</sub> = 10 kΩ                                                        |     | 0.03 |     | V/μs    |
| Gain Bandwidth Product       | GBP                |                                                                               |     | 75   |     | kHz     |
| Phase Margin                 | θ <sub>O</sub>     |                                                                               |     | 85   |     | Degrees |
| NOISE PERFORMANCE            |                    |                                                                               |     |      |     |         |
| Voltage Noise                | e <sub>n</sub> p-p | 0.1 Hz to 10 Hz                                                               |     | 1.6  |     | μV p-p  |
| Voltage Noise Density        | e <sub>n</sub>     | f = 1 kHz                                                                     |     | 53   |     | nV/√Hz  |
| Current Noise Density        | i <sub>n</sub>     | f = 1 kHz                                                                     |     | <0.1 |     | pA/√Hz  |

V<sub>S</sub> = ±15.0 V, T<sub>A</sub> = 25°C, unless otherwise noted.

Table 3.

| Parameter                    | Symbol               | Conditions                                                                                        | Min       | Typ  | Max       | Unit    |
|------------------------------|----------------------|---------------------------------------------------------------------------------------------------|-----------|------|-----------|---------|
| INPUT CHARACTERISTICS        |                      |                                                                                                   |           |      |           |         |
| Offset Voltage               | V <sub>OS</sub>      | −40°C ≤ T <sub>A</sub> ≤ +125°C                                                                   |           | 300  | 500       | μV      |
|                              |                      |                                                                                                   |           |      | 800       | μV      |
| Input Bias Current           | I <sub>B</sub>       | V <sub>CM</sub> = 0 V                                                                             |           | 7    | 20        | nA      |
|                              |                      | V <sub>CM</sub> = 0 V, −40°C ≤ T <sub>A</sub> ≤ +125°C                                            |           |      | 30        | nA      |
| Input Offset Current         | I <sub>OS</sub>      | V <sub>CM</sub> = 0 V                                                                             |           | ±1   | ±3        | nA      |
|                              |                      | V <sub>CM</sub> = 0 V, −40°C ≤ T <sub>A</sub> ≤ +125°C                                            |           |      | ±5        | nA      |
| Input Voltage Range          | V <sub>CM</sub>      |                                                                                                   | −15       |      | +13.5     | V       |
| Common-Mode Rejection Ratio  | CMRR                 | −15.0 V ≤ V <sub>CM</sub> ≤ +13.5 V, −40°C ≤ T <sub>A</sub> ≤ +125°C                              | 90        | 110  |           | dB      |
| Large Signal Voltage Gain    | A <sub>VO</sub>      | R <sub>L</sub> = 10 kΩ                                                                            | 1000      | 4000 |           | V/mV    |
| Offset Voltage Drift         | ΔV <sub>OS</sub> /ΔT |                                                                                                   |           | 1    |           | μV/°C   |
| OUTPUT CHARACTERISTICS       |                      |                                                                                                   |           |      |           |         |
| Output Voltage Swing High    | V <sub>OH</sub>      | R <sub>L</sub> = 100 kΩ to GND                                                                    | 14.95     |      |           | V       |
|                              |                      | R <sub>L</sub> = 10 kΩ to GND                                                                     | 14.80     |      |           | V       |
| Output Voltage Swing Low     | V <sub>OL</sub>      | R <sub>L</sub> = 100 kΩ to GND                                                                    |           |      | −14.95    | V       |
|                              |                      | R <sub>L</sub> = 10 kΩ to GND                                                                     |           |      | −14.85    | V       |
| Output Current               | I <sub>OUT</sub>     |                                                                                                   | ±15       | ±25  |           | mA      |
| POWER SUPPLY                 |                      |                                                                                                   |           |      |           |         |
| Power Supply Rejection Ratio | PSRR                 | V <sub>S</sub> = ±1.5 V to ±15 V                                                                  | 90        | 110  |           | dB      |
|                              |                      | V <sub>S</sub> = ±1.5 V to ±15 V, −40°C ≤ T <sub>A</sub> ≤ +125°C                                 | 85        |      |           | dB      |
| Supply Current per Amplifier | I <sub>SY</sub>      | V <sub>O</sub> = 0 V, R <sub>L</sub> = ∞, V <sub>S</sub> = ±18 V, −40°C ≤ T <sub>A</sub> ≤ +125°C |           |      | 175       | μA      |
| Supply Voltage Range         | V <sub>S</sub>       |                                                                                                   | 3 (± 1.5) |      | 36 (± 18) | V       |
| DYNAMIC PERFORMANCE          |                      |                                                                                                   |           |      |           |         |
| Slew Rate                    | SR                   | R <sub>L</sub> = 10 kΩ                                                                            |           | 0.03 |           | V/μs    |
| Gain Bandwidth Product       | GBP                  |                                                                                                   |           | 85   |           | kHz     |
| Phase Margin                 | θ <sub>O</sub>       |                                                                                                   |           | 83   |           | Degrees |
| NOISE PERFORMANCE            |                      |                                                                                                   |           |      |           |         |
| Voltage Noise                | e <sub>n</sub> p-p   | 0.1 Hz to 10 Hz                                                                                   |           | 1.25 |           | μV p-p  |
| Voltage Noise Density        | e <sub>n</sub>       | f = 1 kHz                                                                                         |           | 45   |           | nV/√Hz  |
| Current Noise Density        | i <sub>n</sub>       | f = 1 kHz                                                                                         |           | <0.1 |           | pA/√Hz  |

## ABSOLUTE MAXIMUM RATINGS

Table 4.

| Parameter <sup>1</sup>                  | Rating          |
|-----------------------------------------|-----------------|
| Supply Voltage                          | ±18 V           |
| Input Voltage                           | ±18 V           |
| Differential Input Voltage <sup>2</sup> | 36 V            |
| Output Short-Circuit Duration           | Indefinite      |
| Storage Temperature Range               |                 |
| P, S Packages                           | –65°C to +150°C |
| Operating Temperature Range             |                 |
| OP295G, OP495G                          | –40°C to +125°C |
| Junction Temperature Range              |                 |
| P, S Packages                           | –65°C to +150°C |
| Lead Temperature (Soldering, 60 sec)    | 300°C           |

<sup>1</sup> Absolute maximum ratings apply to packaged parts, unless otherwise noted.

<sup>2</sup> For supply voltages less than ±18 V, the absolute maximum input voltage is equal to the supply voltage.

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 worst case mounting conditions; that is,  $\theta_{JA}$  is specified for device in socket for PDIP;  $\theta_{JA}$  is specified for device soldered to printed circuit board for SOIC package.

Table 5. Thermal Resistance

| Package Type           | $\theta_{JA}$ | $\theta_{JC}$ | Unit |
|------------------------|---------------|---------------|------|
| 8-Lead PDIP (N-8)      | 103           | 43            | °C/W |
| 8-Lead SOIC_N (R-8)    | 158           | 43            | °C/W |
| 14-Lead PDIP (N-14)    | 83            | 39            | °C/W |
| 16-Lead SOIC_W (RW-16) | 98            | 30            | °C/W |

## ESD CAUTION



### ESD (electrostatic discharge) sensitive device.

Charged devices and circuit boards can discharge without detection. Although this product features patented or proprietary protection circuitry, damage may occur on devices subjected to high energy ESD. Therefore, proper ESD precautions should be taken to avoid performance degradation or loss of functionality.

## TYPICAL PERFORMANCE CHARACTERISTICS

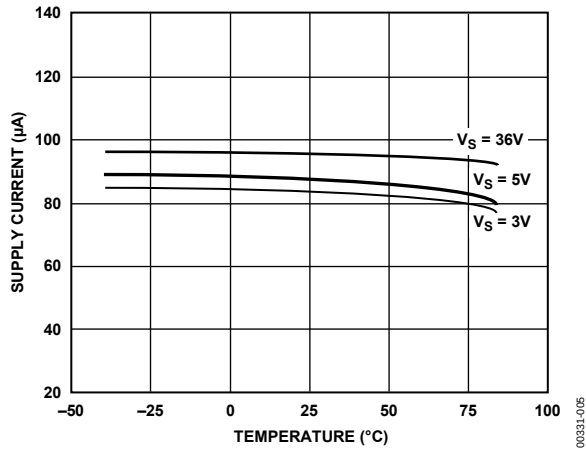


Figure 5. Supply Current Per Amplifier vs. Temperature

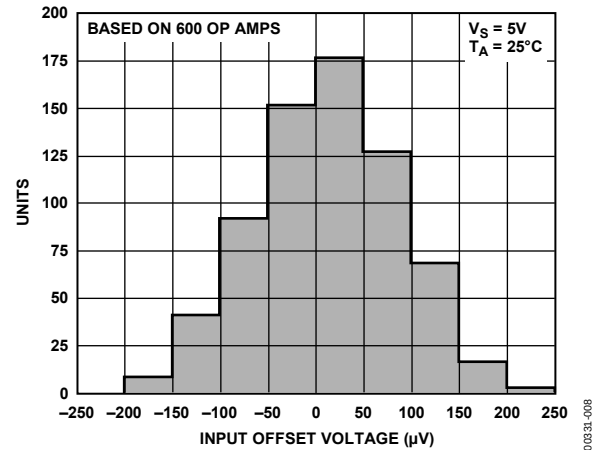


Figure 8. OP295 Input Offset ( $V_{OS}$ ) Distribution

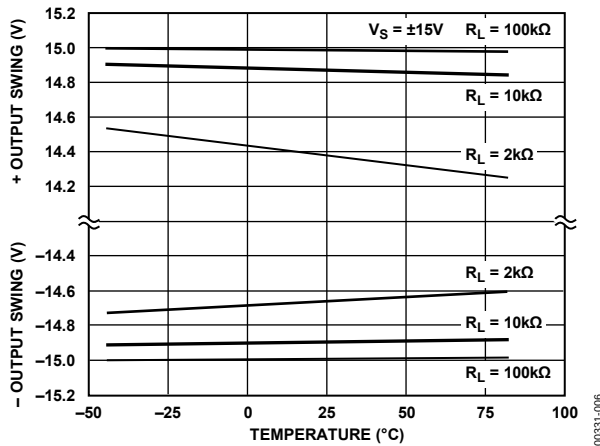


Figure 6. Output Voltage Swing vs. Temperature

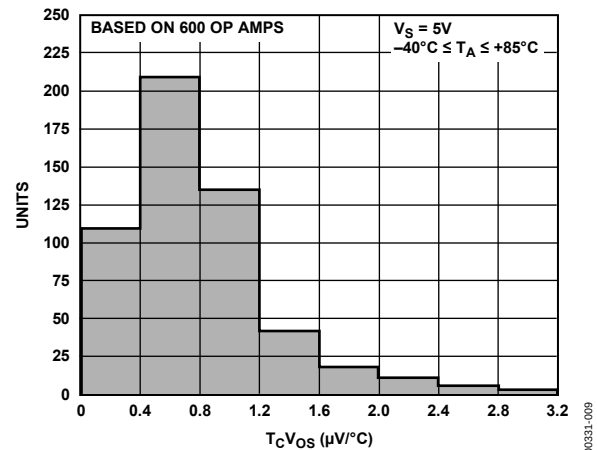


Figure 9. OP295  $T_C V_{OS}$  Distribution

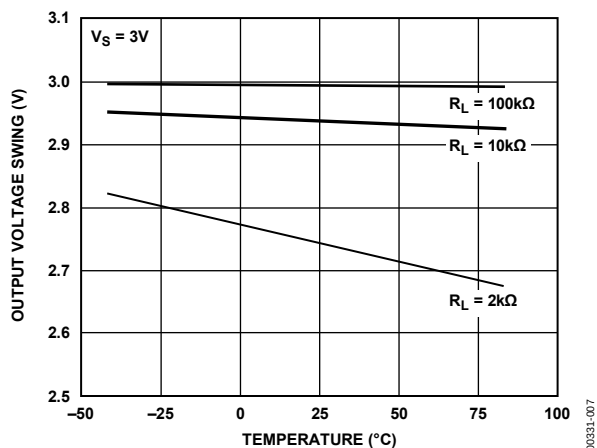


Figure 7. Output Voltage Swing vs. Temperature

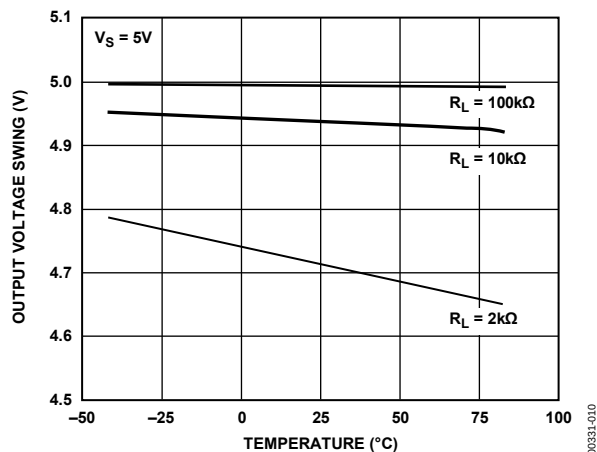


Figure 10. Output Voltage Swing vs. Temperature

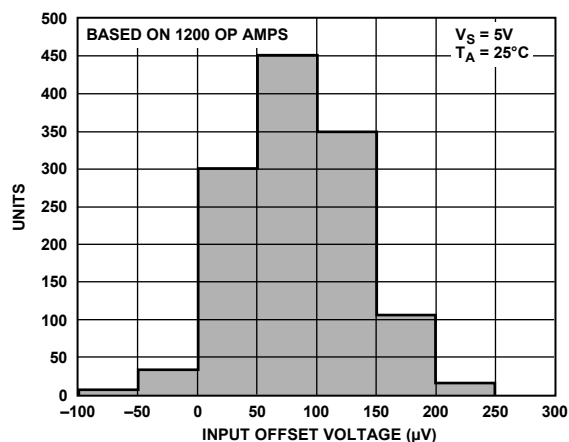


Figure 11. OP495 Input Offset ( $V_{OS}$ ) Distribution

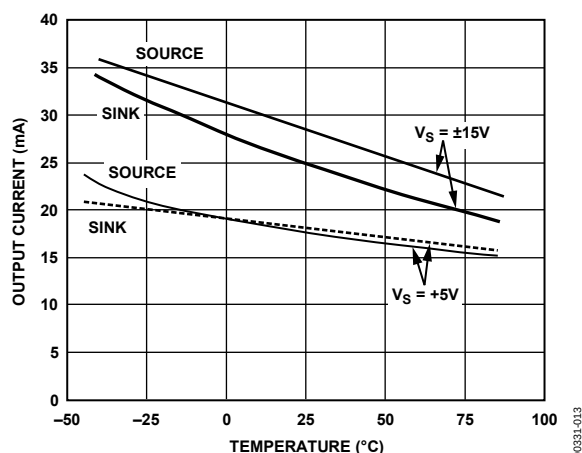


Figure 14. Output Current vs. Temperature

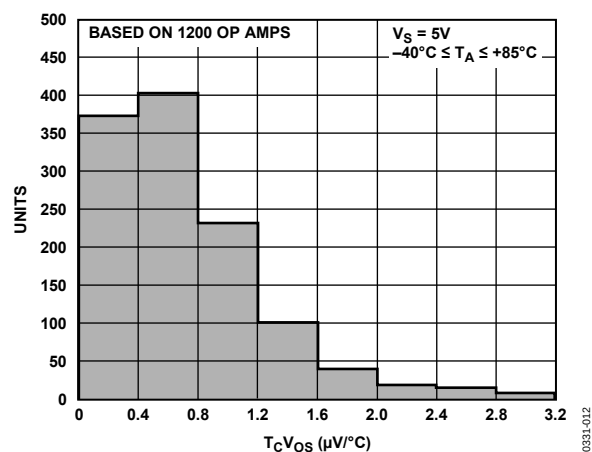


Figure 12. OP495  $T_C V_{OS}$  Distribution

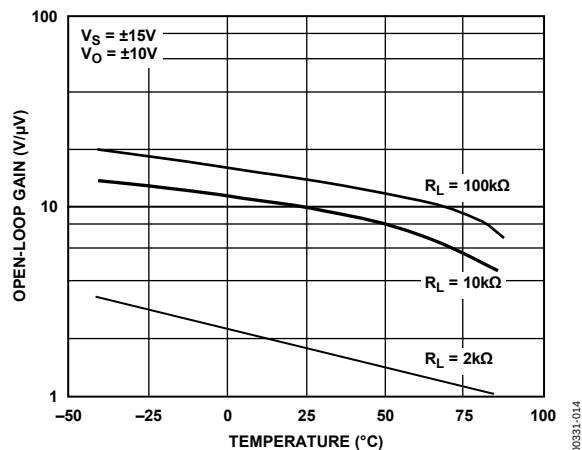


Figure 15. Open-Loop Gain vs. Temperature

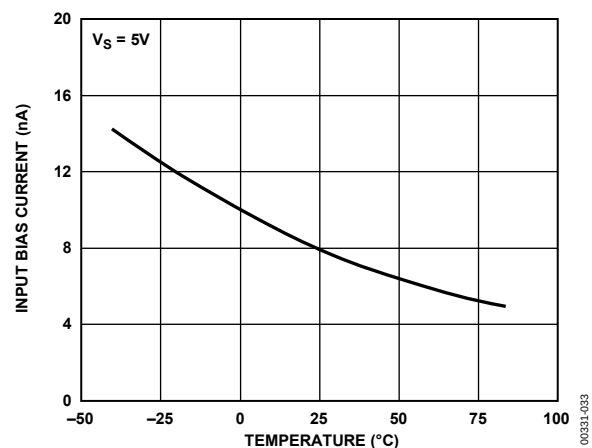


Figure 13. Input Bias Current vs. Temperature

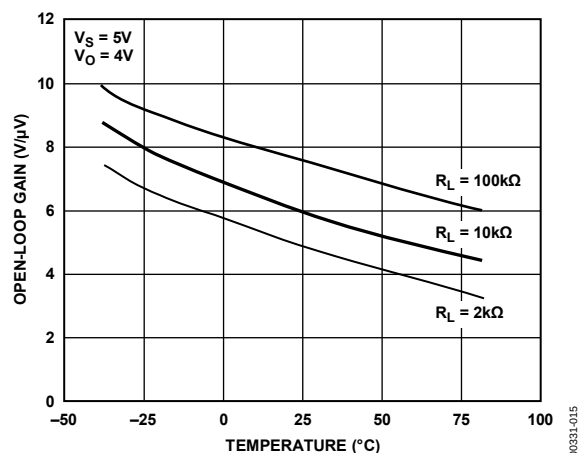


Figure 16. Open-Loop Gain vs. Temperature

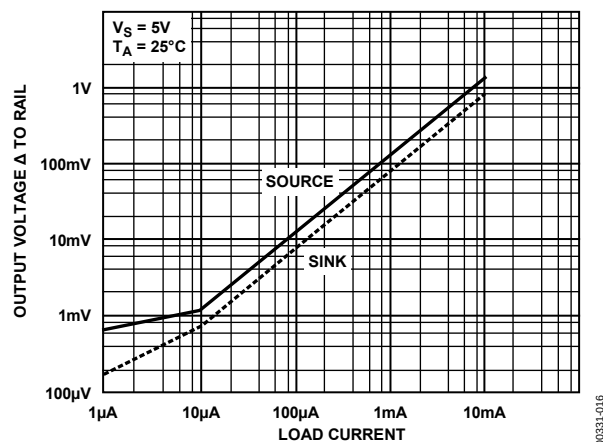


Figure 17. Output Voltage to Supply Rail vs. Load Current

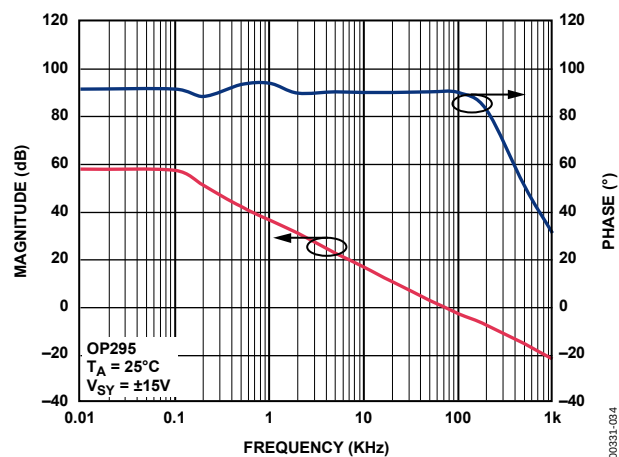


Figure 18. OP295 Gain and Phase vs. Frequency







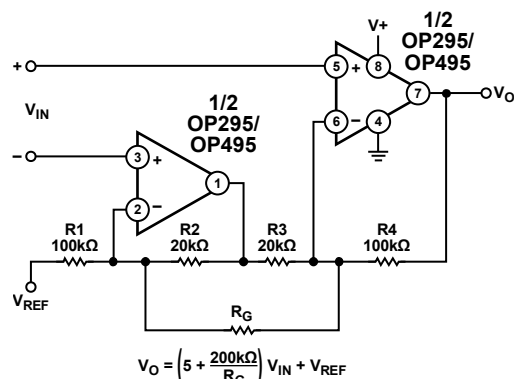


Figure 24. Single-Supply Instrumentation Amplifier

Resistor  $R_G$  sets the gain of the instrumentation amplifier. Minimum gain is 6 (with no  $R_G$ ). All resistors should be matched in absolute value as well as temperature coefficient to maximize common-mode rejection performance and minimize drift. This instrumentation amplifier can operate from a supply voltage as low as 3 V.

## SINGLE-SUPPLY RTD THERMOMETER AMPLIFIER

This RTD amplifier takes advantage of the rail-to-rail swing of the OP295/OP495 to achieve a high bridge voltage in spite of a low 5 V supply. The OP295/OP495 amplifier serves a constant 200  $\mu$ A current to the bridge. The return current drops across the parallel resistors 6.19 k $\Omega$  and 2.55 M $\Omega$ , developing a voltage that is servoed to 1.235 V, which is established by the AD589 band gap reference. The 3-wire RTD provides an equal line resistance drop in both 100  $\Omega$  legs of the bridge, thus improving the accuracy.

The AMP04 amplifies the differential bridge signal and converts it to a single-ended output. The gain is set by the series resistance of the 332  $\Omega$  resistor plus the 50  $\Omega$  potentiometer. The gain scales the output to produce a 4.5 V full scale. The 0.22  $\mu$ F capacitor to the output provides a 7 Hz low-pass filter to keep noise at a minimum.

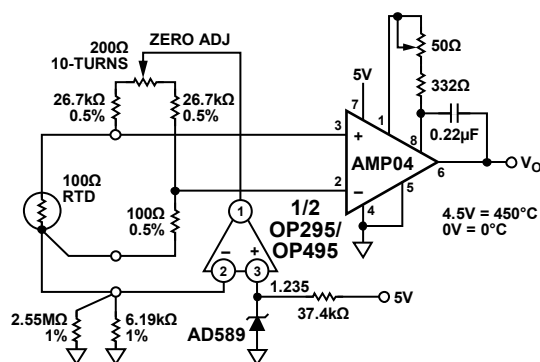


Figure 25. Low Power RTD Amplifier

## COLD JUNCTION COMPENSATED, BATTERY-POWERED THERMOCOUPLE AMPLIFIER

The 150  $\mu$ A quiescent current per amplifier consumption of the OP295/OP495 makes them useful for battery-powered temperature measuring instruments. The K-type thermocouple terminates into an isothermal block where the terminated junctions' ambient temperatures can be continuously monitored and corrected by summing an equal but opposite thermal EMF to the amplifier, thereby canceling the error introduced by the cold junctions.

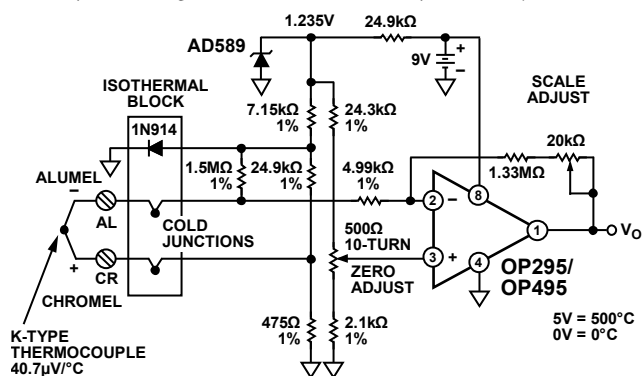


Figure 26. Battery-Powered, Cold-Junction Compensated Thermocouple Amplifier

To calibrate, immerse the thermocouple measuring junction in a 0°C ice bath and adjust the 500  $\Omega$  zero-adjust potentiometer to 0 V out. Then immerse the thermocouple in a 250°C temperature bath or oven and adjust the scale-adjust potentiometer for an output voltage of 2.50 V, which is equivalent to 250°C. Within this temperature range, the K-type thermocouple is quite accurate and produces a fairly linear transfer characteristic. Accuracy of  $\pm 3^\circ\text{C}$  is achievable without linearization.

Even if the battery voltage is allowed to decay to as low as 7 V, the rail-to-rail swing allows temperature measurements to 700°C. However, linearization may be necessary for temperatures above 250°C, where the thermocouple becomes rather nonlinear. The circuit draws just under 500  $\mu$ A supply current from a 9 V battery.

## 5 V ONLY, 12-BIT DAC THAT SWINGS 0 V TO 4.095 V

Figure 27 shows a complete voltage output DAC with wide output voltage swing operating off a single 5 V supply. The serial input, 12-bit DAC is configured as a voltage output device with the 1.235 V reference feeding the current output pin ( $I_{OUT}$ ) of the DAC. The  $V_{REF}$ , which is normally the input, now becomes the output.

The output voltage from the DAC is the binary weighted voltage of the reference, which is gained up by the output amplifier such that the DAC has a 1 mV per bit transfer function.

# OP295/OP495

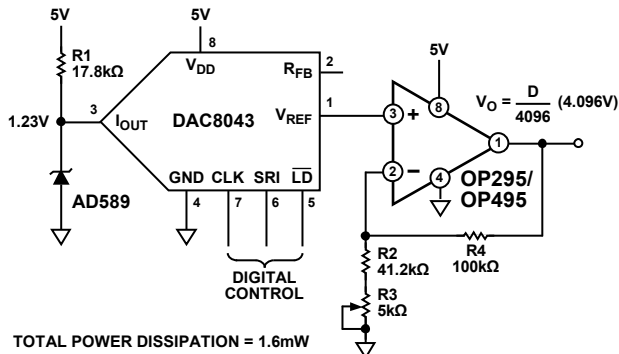


Figure 27. A 5 V 12-Bit DAC with 0 V to 4.095 V Output Swing

## 4 mA TO 20 mA CURRENT-LOOP TRANSMITTER

Figure 28 shows a self-powered 4 mA to 20 mA current-loop transmitter. The entire circuit floats up from the single-supply (12 V to 36 V) return. The supply current carries the signal within the 4 mA to 20 mA range. Thus, the 4 mA establishes the baseline current budget within which the circuit must operate. This circuit consumes only 1.4 mA maximum quiescent current, making 2.6 mA of current available to power additional signal conditioning circuitry or to power a bridge circuit.

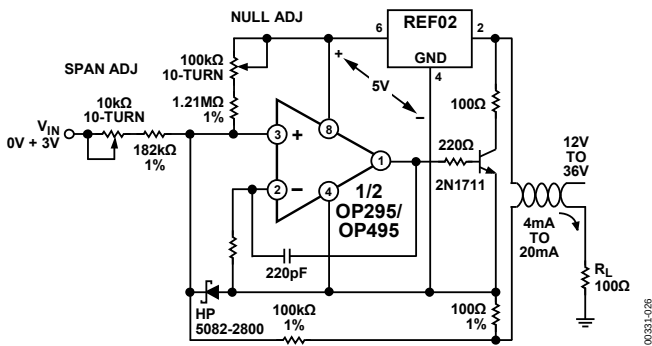


Figure 28. 4 mA to 20 mA Current Loop Transmitter

## 3 V LOW DROPOUT LINEAR VOLTAGE REGULATOR

Figure 29 shows a simple 3 V voltage regulator design. The regulator can deliver 50 mA load current while allowing a 0.2 V dropout voltage. The OP295/OP495 rail-to-rail output swing drives the MJE350 pass transistor without requiring special drive circuitry. At no load, its output can swing less than the pass transistor's base-emitter voltage, turning the device nearly off. At full load, and at low emitter-collector voltages, the transistor beta tends to decrease. The additional base current is easily handled by the OP295/OP495 output.

The amplifier serves the output to a constant voltage, which feeds a portion of the signal to the error amplifier.

Higher output current, to 100 mA, is achievable at a higher dropout voltage of 3.8 V.

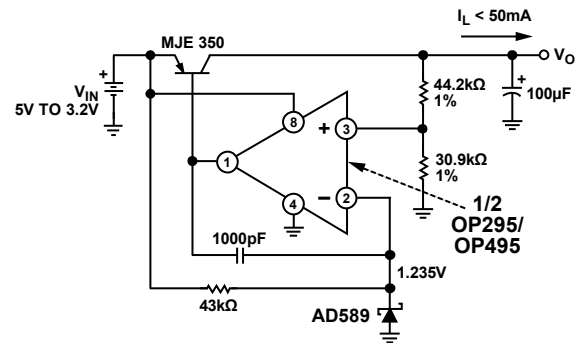


Figure 29. 3 V Low Dropout Voltage Regulator

Figure 30 shows the regulator's recovery characteristic when its output underwent a 20 mA to 50 mA step current change.

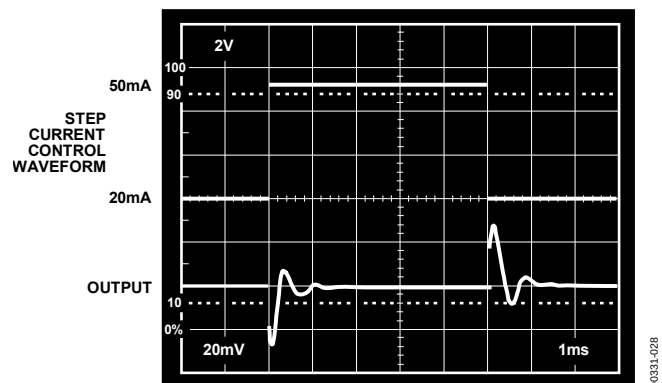


Figure 30. Output Step Load Current Recovery

## LOW DROPOUT, 500 mA VOLTAGE REGULATOR WITH FOLDBACK CURRENT LIMITING

Adding a second amplifier in the regulation loop, as shown in Figure 31, provides an output current monitor as well as foldback current limiting protection.

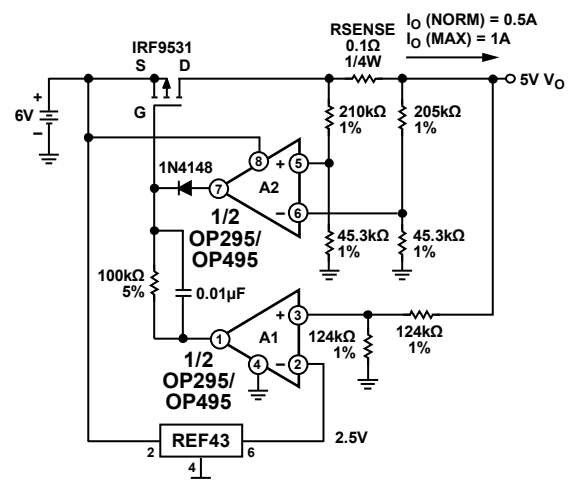


Figure 31. Low Dropout, 500 mA Voltage Regulator with Foldback Current Limiting

Amplifier A1 provides error amplification for the normal voltage regulation loop. As long as the output current is less than 1 A, the output of Amplifier A2 swings to ground, reverse-biasing the diode and effectively taking itself out of the circuit. However, as the output current exceeds 1 A, the voltage that develops across the 0.1  $\Omega$  sense resistor forces the output of Amplifier A2 to go high, forward-biasing the diode, which in turn closes the current-limit loop. At this point, the A2's lower output resistance dominates the drive to the power MOSFET transistor, thereby effectively removing the A1 voltage regulation loop from the circuit.

If the output current greater than 1 A persists, the current limit loop forces a reduction of current to the load, which causes a corresponding drop in output voltage. As the output voltage drops, the current-limit threshold also drops fractionally, resulting in a decreasing output current as the output voltage decreases, to the limit of less than 0.2 A at 1 V output. This fold-back effect reduces the power dissipation considerably during a short circuit condition, thus making the power supply far more forgiving in terms of the thermal design requirements. Small heat sinking on the power MOSFET can be tolerated.

The rail-to-rail swing of the OP295 exerts higher gate drive to the power MOSFET, providing a fuller enhancement to the transistor. The regulator exhibits 0.2 V dropout at 500 mA of load current. At 1 A output, the dropout voltage is typically 5.6 V.

## SQUARE WAVE OSCILLATOR

The circuit in Figure 32 is a square wave oscillator (note the positive feedback). The rail-to-rail swing of the OP295/OP495 helps maintain a constant oscillation frequency even if the supply voltage varies considerably. Consider a battery-powered system where the voltages are not regulated and drop over time. The rail-to-rail swing ensures that the noninverting input sees the full  $V+/2$ , rather than only a fraction of it.

The constant frequency comes from the fact that the 58.7 k $\Omega$  feedback sets up Schmitt trigger threshold levels that are directly proportional to the supply voltage, as are the RC charge voltage levels. As a result, the RC charge time, and therefore, the frequency, remain constant, independent of supply voltage. The slew rate of the amplifier limits oscillation frequency to a maximum of about 800 Hz at a 5 V supply.

## SINGLE-SUPPLY DIFFERENTIAL SPEAKER DRIVER

Connected as a differential speaker driver, the OP295/OP495 can deliver a minimum of 10 mA to the load. With a 600  $\Omega$  load, the OP295/OP495 can swing close to 5 V p-p across the load.

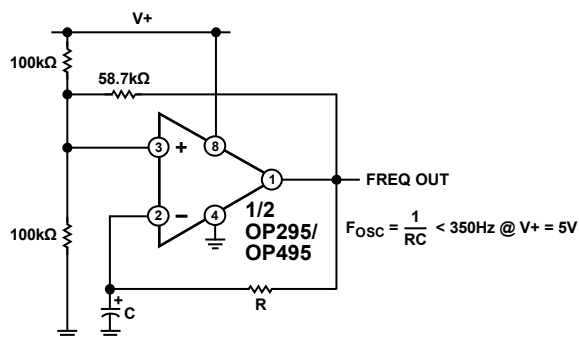


Figure 32. Square Wave Oscillator Has Stable Frequency Regardless of Supply Changes

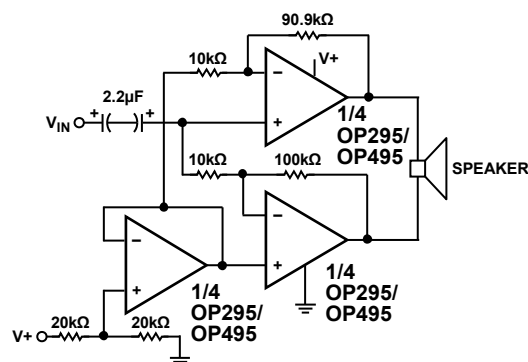


Figure 33. Single-Supply Differential Speaker Driver

## HIGH ACCURACY, SINGLE-SUPPLY, LOW POWER COMPARATOR

The OP295/OP495 make accurate open-loop comparators. With a single 5 V supply, the offset error is less than 300  $\mu$ V. Figure 34 shows the response time of the OP295/OP495 when operating open-loop with 4 mV overdrive. They exhibit a 4 ms response time at the rising edge and a 1.5 ms response time at the falling edge.

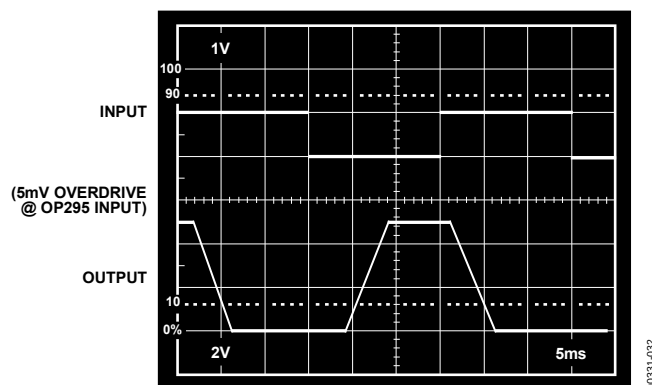
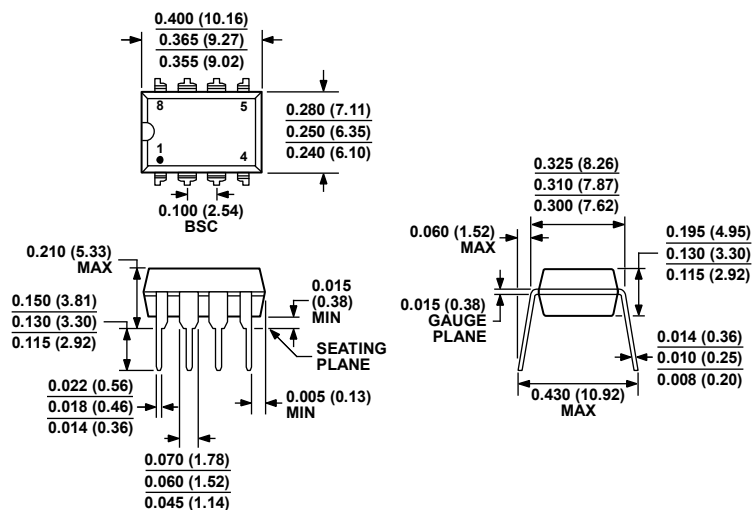


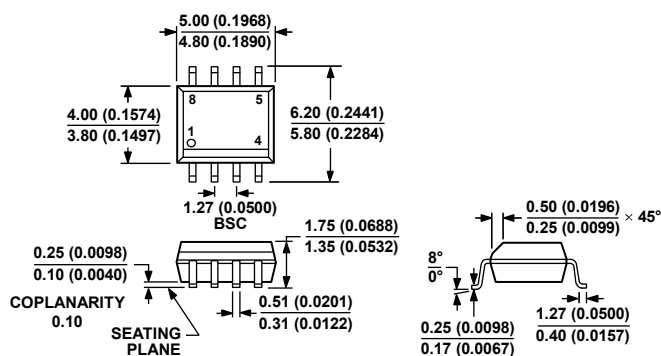
Figure 34. Open-Loop Comparator Response Time with 5 mV Overdrive

# OUTLINE DIMENSIONS



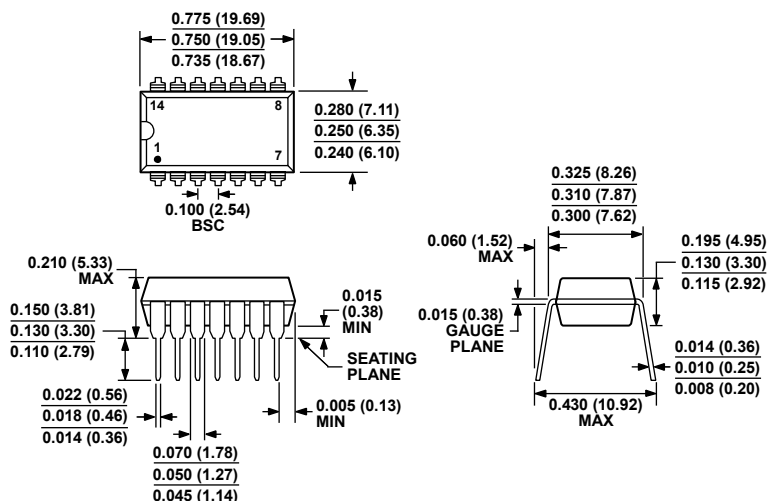
COMPLIANT TO JEDEC STANDARDS MS-001  
CONTROLLING DIMENSIONS ARE IN INCHES; MILLIMETER DIMENSIONS (IN PARENTHESES) ARE ROUNDED-OFF INCH EQUIVALENTS FOR REFERENCE ONLY AND ARE NOT APPROPRIATE FOR USE IN DESIGN. CORNER LEADS MAY BE CONFIGURED AS WHOLE OR HALF LEADS.

Figure 35. 8-Lead Plastic Dual In-Line Package [PDIP]  
(N-8) P Suffix  
Dimensions shown in inches and (millimeters)



COMPLIANT TO JEDEC STANDARDS MS-012-AA  
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.

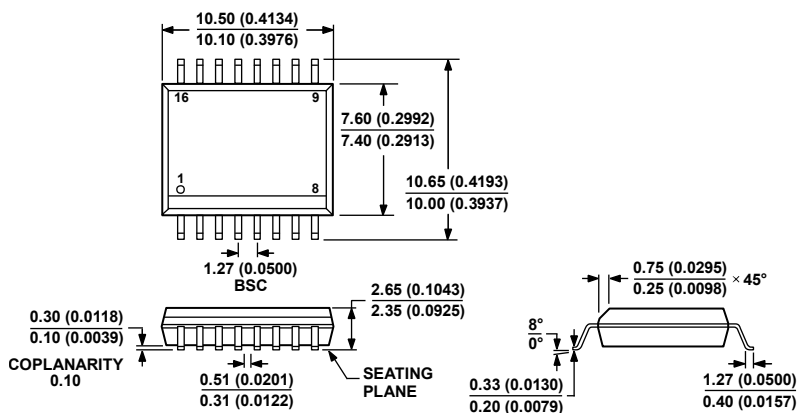
Figure 36. 8-Lead Standard Small Outline Package [SOIC\_N]  
Narrow Body (R-8) S Suffix  
Dimensions shown in millimeters and (inches)



COMPLIANT TO JEDEC STANDARDS MS-001  
CONTROLLING DIMENSIONS ARE IN INCHES; MILLIMETER DIMENSIONS (IN PARENTHESES) ARE ROUNDED-OFF INCH EQUIVALENTS FOR REFERENCE ONLY AND ARE NOT APPROPRIATE FOR USE IN DESIGN. CORNER LEADS MAY BE CONFIGURED AS WHOLE OR HALF LEADS.

Figure 37. 14-Lead Plastic Dual In-Line Package [PDIP]  
(N-14) P Suffix

Dimensions shown in inches and (millimeters)



COMPLIANT TO JEDEC STANDARDS MS-013-AA  
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 38. 16-Lead Standard Small Outline Package [SOIC\_W]

Wide Body (RW-16) S Suffix

Dimensions shown in millimeters and (inches)

# OP295/OP495

## ORDERING GUIDE

| Model                       | Temperature Range | Package Description | Package Option   |
|-----------------------------|-------------------|---------------------|------------------|
| OP295GP                     | –40°C to +125°C   | 8-Lead PDIP         | P-Suffix (N-8)   |
| OP295GPZ <sup>1</sup>       | –40°C to +125°C   | 8-Lead PDIP         | P-Suffix (N-8)   |
| OP295GS                     | –40°C to +125°C   | 8-Lead SOIC_N       | S-Suffix (R-8)   |
| OP295GS-REEL                | –40°C to +125°C   | 8-Lead SOIC_N       | S-Suffix (R-8)   |
| OP295GS-REEL7               | –40°C to +125°C   | 8-Lead SOIC_N       | S-Suffix (R-8)   |
| OP295GSZ <sup>1</sup>       | –40°C to +125°C   | 8-Lead SOIC_N       | S-Suffix (R-8)   |
| OP295GSZ-REEL <sup>1</sup>  | –40°C to +125°C   | 8-Lead SOIC_N       | S-Suffix (R-8)   |
| OP295GSZ-REEL7 <sup>1</sup> | –40°C to +125°C   | 8-Lead SOIC_N       | S-Suffix (R-8)   |
| OP495GP                     | –40°C to +125°C   | 14-Lead PDIP        | P-Suffix (N-14)  |
| OP495GPZ <sup>1</sup>       | –40°C to +125°C   | 14-Lead PDIP        | P-Suffix (N-14)  |
| OP495GS                     | –40°C to +125°C   | 16-Lead SOIC_W      | S-Suffix (RW-16) |
| OP495GS-REEL                | –40°C to +125°C   | 16-Lead SOIC_W      | S-Suffix (RW-16) |
| OP495GSZ <sup>1</sup>       | –40°C to +125°C   | 16-Lead SOIC_W      | S-Suffix (RW-16) |
| OP495GSZ-REEL <sup>1</sup>  | –40°C to +125°C   | 16-Lead SOIC_W      | S-Suffix (RW-16) |

<sup>1</sup> Z = RoHS Compliant Part.



## Данный компонент на территории Российской Федерации

**Вы можете приобрести в компании MosChip.**

Для оперативного оформления запроса Вам необходимо перейти по данной ссылке:

<http://moschip.ru/get-element>

Вы можете разместить у нас заказ для любого Вашего проекта, будь то серийное производство или разработка единичного прибора.

В нашем ассортименте представлены ведущие мировые производители активных и пассивных электронных компонентов.

Нашей специализацией является поставка электронной компонентной базы двойного назначения, продукции таких производителей как XILINX, Intel (ex.ALTERA), Vicor, Microchip, Texas Instruments, Analog Devices, Mini-Circuits, Amphenol, Glenair.

Сотрудничество с глобальными дистрибьюторами электронных компонентов, предоставляет возможность заказывать и получать с международных складов практически любой перечень компонентов в оптимальные для Вас сроки.

На всех этапах разработки и производства наши партнеры могут получить квалифицированную поддержку опытных инженеров.

Система менеджмента качества компании отвечает требованиям в соответствии с ГОСТ Р ИСО 9001, ГОСТ РВ 0015-002 и ЭС РД 009

### Офис по работе с юридическими лицами:

105318, г.Москва, ул.Щербаковская д.3, офис 1107, 1118, ДЦ «Щербаковский»

Телефон: +7 495 668-12-70 (многоканальный)

Факс: +7 495 668-12-70 (доб.304)

E-mail: [info@moschip.ru](mailto:info@moschip.ru)

Skype отдела продаж:

moschip.ru

moschip.ru\_4

moschip.ru\_6

moschip.ru\_9