1.0 V Precision Low Noise Shunt Voltage Reference

# ADR510

## FEATURES

**Precision 1.000 V voltage reference**
**Ultracompact 3 mm × 3 mm SOT-23 package**
**No external capacitor required**
**Low output noise: 4 μV p-p (0.1 Hz to 10 Hz)**
**Initial accuracy: ±0.35% maximum**
**Temperature coefficient: 70 ppm/°C maximum**
**Operating current range: 100 μA to 10 mA**
**Output impedance: 0.3 Ω maximum**
**Temperature range: −40°C to +85°C**

## APPLICATIONS

**Precision data acquisition systems**
**Battery-powered equipment**
- **Cellular phone**
- **Notebook computer**
- **PDA**
- **GPS**

**3 V/5 V, 8-/12-bit data converters**
**Portable medical instruments**
**Industrial process control systems**
**Precision instruments**

## GENERAL DESCRIPTION

Designed for space critical applications, the ADR510 is a low voltage (1.000 V), precision shunt-mode voltage reference in an ultracompact (3 mm × 3 mm) SOT-23-3 package. The ADR510 features low temperature drift (70 ppm/°C), high accuracy (±0.35%), and ultralow noise (4 μV p-p) performance.

The ADR510 advanced design eliminates the need for an external capacitor, yet it is stable with any capacitive load. The minimum operating current increases from 100 μA to a maximum of 10 mA. This low operating current and ease of use make the ADR510 ideally suited for handheld battery-powered applications.

A TRIM terminal is available on the ADR510 to provide adjustment of the output voltage over ±0.5% without affecting the temperature coefficient of the device. This feature provides users with the flexibility to trim out any system errors.

## PIN CONFIGURATION

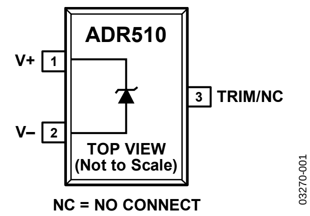


*Figure 1. 3-Lead SOT-23-3*

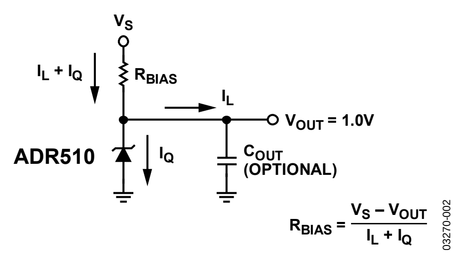


*Figure 2. Typical Operating Circuit*

**Table 1. ADR510**

| Part | Output Voltage, $V_{OUT}$ | Initial Accuracy | | Temperature Coefficient |
|---|---|---|---|---|
| ADR510A | 1.000 V | 3.5 mV | 0.35% | 70 ppm/°C |



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## Documentation

### Application Notes

- AN-713: The Effect of Long-Term Drift on Voltage References

### Data Sheet

- ADR510: 1.0 V Precision Low Noise Shunt Voltage Reference Data Sheet

## Design Resources

- ADR510 Material Declaration
- PCN-PDN Information
- Quality And Reliability
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**8/03—Revision 0: Initial Version**

# SPECIFICATIONS

## ELECTRICAL CHARACTERISTICS

$I_{IN}$ = 100 μA to 10 mA @ $T_A$ = 25°C, unless otherwise noted.

**Table 2.**

| Parameter | Symbol | Conditions | Min | Typ | Max | Unit |
|---|---|---|---|---|---|---|
| Output Voltage[1] | $V_{OUT}$ | | 0.9965 | 1.0 | 1.0035 | V |
| Initial Accuracy | $V_{OUTERR}$ | | −3.5 | | +3.5 | mV |
| | $V_{OUTERR\%}$ | | −0.35 | | +0.35 | % |
| Temperature Coefficient, A Grade | $TCV_{OUT}$ | 0°C < $T_A$ < 70°C | | | 70 | ppm/°C |
| | | −40°C < $T_A$ < +85°C | | | 85 | ppm/°C |
| Output Voltage Change vs. $I_{IN}$ | $\Delta V_R$ | $I_{IN}$ = 0.1 mA to 10 mA | | | 3 | mV |
| Dynamic Output Impedance | $(\Delta V_R/\Delta I_R)$ | $I_{IN}$ = 1 mA ± 100 μA | | | 0.3 | Ω |
| Minimum Operating Current | $I_{IN}$ | 0°C < $T_A$ < 70°C | 100 | | | μA |
| Voltage Noise | $e_N$ p-p | f = 0.1 Hz to 10 Hz | | 4 | | μV p-p |
| Turn-On Settling Time[2] | $t_R$ | To within 0.1% of output | | 10 | | μs |
| Output Voltage Hysteresis | $V_{OUT\_HYS}$ | | | 50 | | ppm |

[1] The forward diode voltage characteristic at −1 mA is typically 0.65 V.
[2] Measured without a load capacitor.

# ABSOLUTE MAXIMUM RATINGS

**Table 3.**

| Parameter | Rating |
|---|---|
| Reverse Current | 25 mA |
| Forward Current | 20 mA |
| Storage Temperature Range | −65°C to +150°C |
| Operating Temperature Range | −40°C to +85°C |
| Junction Temperature Range | −65°C to +150°C |
| Lead Temperature (Soldering, 60 sec) | 300°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. Package power dissipation = $(T_{JMAX} - T_A)/\theta_{JA}$.

**Table 4. Thermal Resistance**

| Package Type | $\theta_{JA}$ | $\theta_{JC}$ | Unit |
|---|---|---|---|
| 3-Lead SOT-23-3 (RT-3) | 230 | 146 | °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

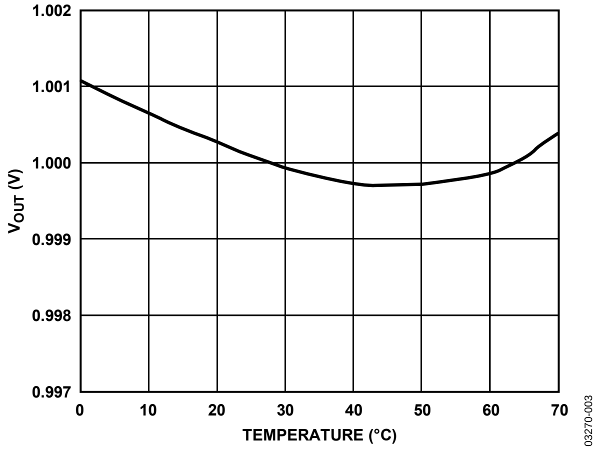


Figure 3. Typical $V_{OUT}$ vs. Temperature

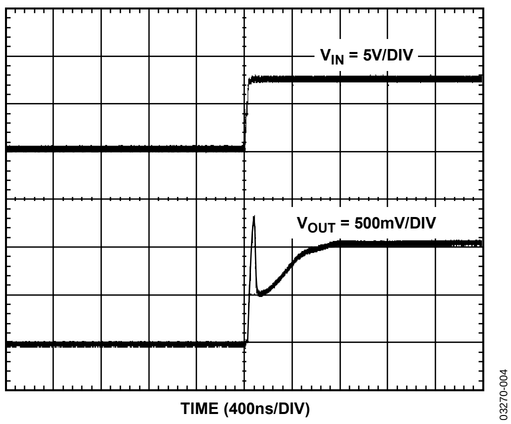


Figure 4. Turn-On Time

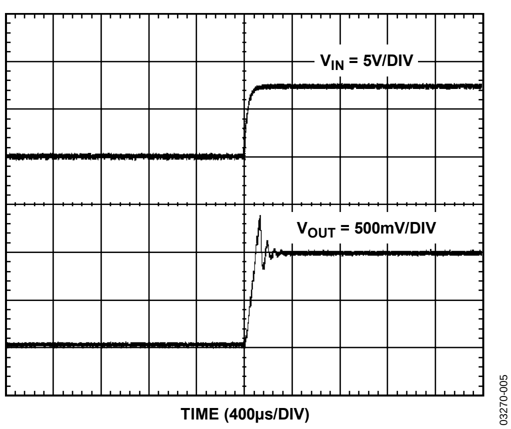


Figure 5. Turn-On Time with 1 µF Input Capacitor

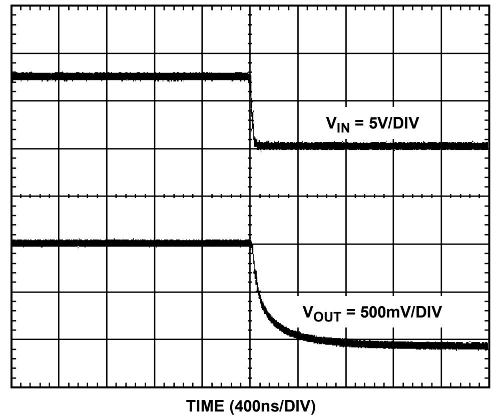


Figure 6. Turn-Off Time

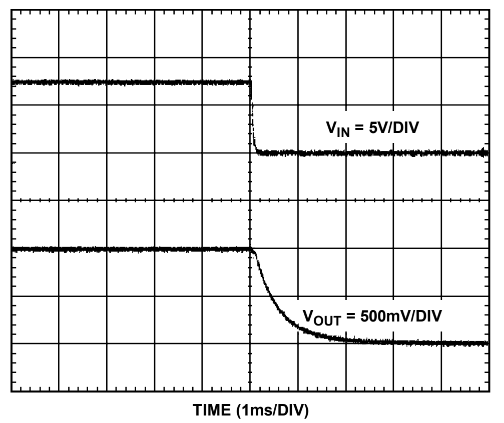


Figure 7. Turn-Off Time with 1 µF Input Capacitor

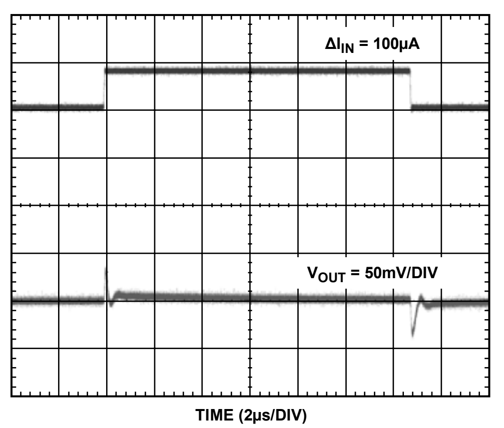


Figure 8. Output Response to 100 µA Input Current Change

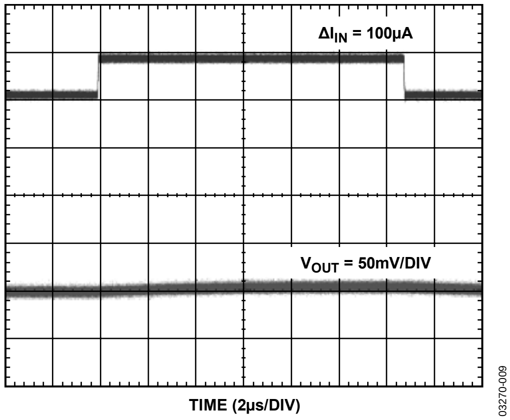


*Figure 9. Output Response to 100 µA Input Current Change with 1 µF Capacitor*

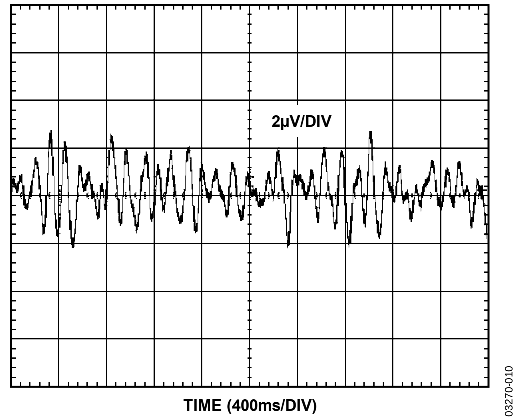


*Figure 10. 1 Hz to 10 Hz Noise*

# PARAMETER DEFINITIONS

## TEMPERATURE COEFFICIENT

This is the change of output voltage with respect to the operating temperature changes, normalized by the output voltage at 25°C. This parameter is expressed in parts per million/degrees Celsius (ppm/°C) and can be determined with the following equation:

$$TCV_{OUT}[\text{ppm}/°\text{C}] = \frac{V_{OUT}(T2) - V_{OUT}(T1)}{V_{OUT}(25°C) \times (T2 - T1)} \times 10^6 \qquad (1)$$

where:
$V_{OUT}(25°C)$ is the output voltage at 25°C.
$V_{OUT}(T_1)$ is the output voltage at Temperature 1.
$V_{OUT}(T_2)$ is the output voltage at Temperature 2.

## THERMAL HYSTERESIS

Thermal hysteresis is the change of output voltage after the device is cycled through the temperature from 25°C to 0°C to 85°C and back to 25°C.

$$V_{OUT\_HYS} = V_{OUT}(25°C) - V_{OUT\_TC}$$

$$V_{OUT\_HYS}[\text{ppm}] = \frac{V_{OUT}(25°C) - V_{OUT\_TC}}{V_{OUT}(25°C)} \times 10^6 \qquad (2)$$

where:
$V_{OUT}(25°C)$ is the output voltage at 25°C.
$V_{OUT\_TC}$ is the output voltage at 25°C after temperature cycle at +25°C to −40°C to +85°C and back to +25°C.

# APPLICATIONS INFORMATION

The ADR510 is a 1.0 V precision shunt voltage reference designed to operate without an external output capacitor between the positive terminal and the negative terminal for stability. An external capacitor can be used for additional filtering of the supply.

As with all shunt voltage references, an external bias resistor ($R_{BIAS}$) is required between the supply voltage and the ADR510 (see Figure 2). $R_{BIAS}$ sets the current that is required to pass through the load ($I_L$) and the ADR510 ($I_Q$). The load and the supply voltage can vary, thus $R_{BIAS}$ is chosen based on the following conditions:

- $R_{BIAS}$ must be small enough to supply the minimum $I_Q$ current to the ADR510 even when the supply voltage is at minimum value and the load current is at maximum value.
- $R_{BIAS}$ also needs to be large enough so that $I_Q$ does not exceed 10 mA when the supply voltage is at its maximum value and the load current is at its minimum value.

Given these conditions, $R_{BIAS}$ is determined by the supply voltage ($V_S$), the load and operating current ($I_L$ and $I_Q$) of the ADR510, and the ADR510 output voltage.

$$R_{BIAS} = \frac{V_S - V_{OUT}}{I_L + I_Q} \quad (3)$$

## ADJUSTABLE PRECISION VOLTAGE SOURCE

The ADR510, combined with a precision low input bias op amp such as the AD860x, can be used to output a precise adjustable voltage. Figure 11 illustrates implementation of this application using the ADR510.

Output of the op amp, $V_{OUT}$, is determined by the gain of the circuit, which is completely dependent on the R2 and R1 resistors.

$$V_{OUT} = 1 + \frac{R2}{R1} \quad (4)$$

An additional capacitor in parallel with R2 can be added to filter out high frequency noise. The value of C2 is dependent on the value of R2.

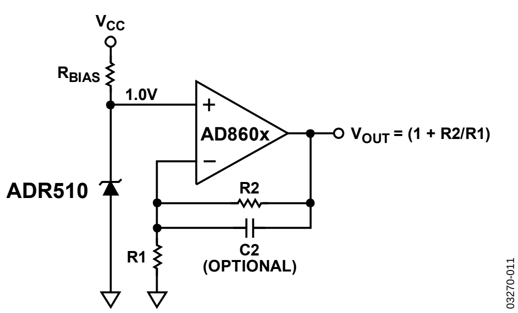


Figure 11. Adjustable Precision Voltage Source

## OUTPUT VOLTAGE TRIM

Using a mechanical or digital potentiometer, the output voltage of the ADR510 can be trimmed ±0.5%. The circuit in Figure 12 illustrates how the output voltage can be trimmed using a 10 kΩ potentiometer. Note that trimming using other resistor values may not produce an accurate output from the ADR510.

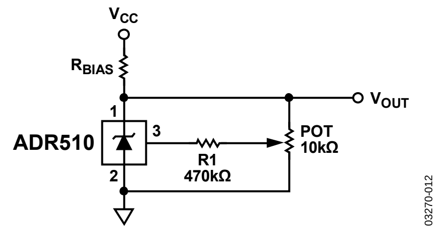


Figure 12. Output Voltage Trim

## USING THE ADR510 WITH PRECISION DATA CONVERTERS

The compact ADR510 and its low minimum operating current requirement make it ideal for use in battery-powered portable instruments, such as the AD7533 CMOS multiplying DAC, that use precision data converters.

Figure 13 shows the ADR510 serving as an external reference to the AD7533, a CMOS multiplying DAC. Such a DAC requires a negative voltage input in order to provide a positive output range. In this application, the ADR510 is supplying a −1.0 V reference to the REF input of the AD7533.

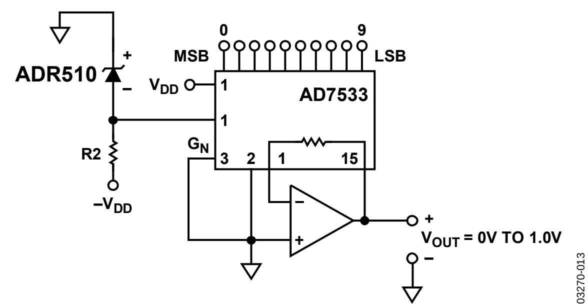


Figure 13. ADR510 as a Reference for a 10-Bit CMOS DAC (AD7533)

## PRECISE NEGATIVE VOLTAGE REFERENCE

The ADR510 is suitable for use in applications where a precise negative voltage reference is desired, including the application detailed in Figure 13.

Figure 14 shows the ADR510 configured to provide an output of −1.0 V.

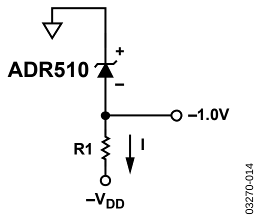


*Figure 14. Precise −1.0 V Reference Configuration*

Because the ADR510 characteristics resemble those of a Zener diode, the cathode shown in Figure 14 is 1.0 V higher with respect to the anode (V+ with respect to V− on the ADR510 package). Because the cathode of the ADR510 is tied to ground, the anode must be −1.0 V.

R1 in Figure 14 should be chosen so that 100 μA to 10 mA is provided to properly bias the ADR510.

$$R1 = \frac{-1 - (-V_{DD})}{I} \quad (5)$$

The R1 resistor should be chosen so that power dissipation is at a minimum. An ideal resistor value can be determined through manipulation of Equation 5.

# OUTLINE DIMENSIONS

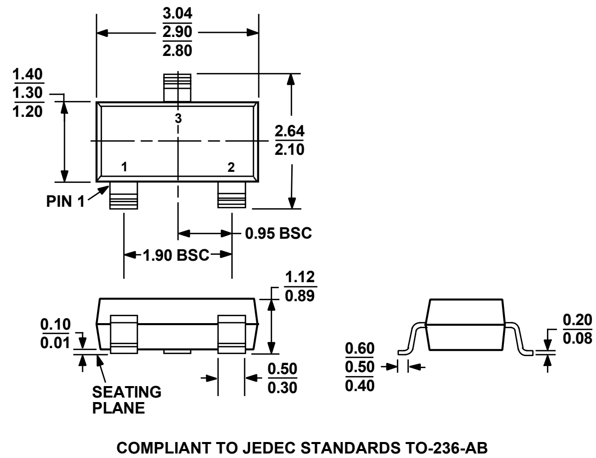


*Figure 15. 3-Lead Small Outline Transistor Package [SOT-23-3]*
*(RT-3)*
*Dimensions shown in millimeters*

## ORDERING GUIDE

| Model | Output Voltage ($V_{OUT}$) | Initial Accuracy | | Temperature Coefficient | Temperature Range | Package Description | Package Option | Ordering Quantity | Branding |
|---|---|---|---|---|---|---|---|---|---|
| ADR510ART-REEL7 | 1.0 V | 3.5 mV | 0.35% | 70 ppm/°C | −40°C to +85°C | 3-Lead SOT-23-3 | RT-3 | 3,000 | RAA |
| ADR510ART-R2 | 1.0 V | 3.5 mV | 0.35% | 70 ppm/°C | −40°C to +85°C | 3-Lead SOT-23-3 | RT-3 | 250 | RAA |
| ADR510ARTZ-REEL7[1] | 1.0 V | 3.5 mV | 0.35% | 70 ppm/°C | −40°C to +85°C | 3-Lead SOT-23-3 | RT-3 | 3,000 | RAA# |
| ADR510ARTZ-R2[1] | 1.0 V | 3.5 mV | 0.35% | 70 ppm/°C | −40°C to +85°C | 3-Lead SOT-23-3 | RT-3 | 250 | RAA# |

[1] Z = RoHS Compliant Part. # denotes lead free, may be top or bottom marked.

## NOTES

## NOTES


D03270-0-9/07(B)