High Precision Shunt Mode Voltage References

ADR525/ADR530/ADR550

FEATURES

Ultracompact SC70 and SOT-23-3 packages
Temperature coefficient: 40 ppm/°C (maximum)
2× the temperature coefficient improvement over the LM4040
Pin compatible with the LM4040/LM4050
Initial accuracy: ±0.2%
Low output voltage noise: 18 μV p-p @ 2.5 V output
No external capacitor required
Operating current range: 50 μA to 15 mA
Industrial temperature range: −40°C to +85°C

APPLICATIONS

Portable, battery-powered equipment
Automotive
Power supplies
Data acquisition systems
Instrumentation and process control
Energy measurement

Table 1. Selection Guide

Part	Voltage (V)	Initial Accuracy (%)	Temperature Coefficient (ppm/°C)
ADR525A	2.5	±0.4	70
ADR525B	2.5	±0.2	40
ADR530A	3.0	±0.4	70
ADR530B	3.0	±0.2	40
ADR550A	5.0	±0.4	70
ADR550B	5.0	±0.2	40

PIN CONFIGURATION

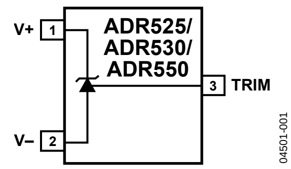

Figure 1. 3-Lead SC70 (KS) and 3-Lead SOT-23-3 (RT)

GENERAL DESCRIPTION

Designed for space-critical applications, the ADR525/ADR530/ADR550 are high precision shunt voltage references, housed in ultrasmall SC70 and SOT-23-3 packages. These references feature low temperature drift of 40 ppm/°C, an initial accuracy of better than ±0.2%, and ultralow output noise of 18 μV p-p.

Available in output voltages of 2.5 V, 3.0 V, and 5.0 V, the advanced design of the ADR525/ADR530/ADR550 eliminates the need for compensation by an external capacitor, yet the references are stable with any capacitive load. The minimum operating current increases from a mere 50 μA to a maximum of 15 mA. This low operating current and ease of use make these references ideally suited for handheld, battery-powered applications.

A trim terminal is available on the ADR525/ADR530/ADR550 to allow adjustment of the output voltage over a ±0.5% range, without affecting the temperature coefficient of the device. This feature provides users with the flexibility to trim out small system errors.

For better initial accuracy and wider temperature range, see the ADR5040/ADR5041/ADR5043/ADR5044/ADR5045 family at www.analog.com.

Rev. F

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SPECIFICATIONS

ADR525 ELECTRICAL CHARACTERISTICS

I_{IN} = 50 μA to 15 mA, T_A = 25°C, unless otherwise noted.

Table 2.

Parameter	Symbol	Conditions	Min	Typ	Max	Unit
Output Voltage	V_{OUT}					
Grade A			2.490	2.500	2.510	V
Grade B			2.495	2.500	2.505	V
Initial Accuracy	V_{OERR}					
Grade A		±0.4%	−10		+10	mV
Grade B		±0.2%	−5		+5	mV
Temperature Coefficient[1]	TCV_O	−40°C < T_A < +85°C				
Grade A				25	70	ppm/°C
Grade B				15	40	ppm/°C
Output Voltage Change vs. I_{IN}	ΔV_R	I_{IN} = 0.1 mA to 15 mA			1	mV
		−40°C < T_A < +85°C			4	mV
		I_{IN} = 1 mA to 15 mA, −40°C < T_A < +85°C			2	mV
Dynamic Output Impedance	$(\Delta V_R/\Delta I_R)$	I_{IN} = 0.1 mA to 15 mA			0.2	Ω
Minimum Operating Current	I_{IN}	−40°C < T_A < +85°C	50			μA
Voltage Noise	$e_{N\ p-p}$	0.1 Hz to 10 Hz		18		μV p-p
Turn-On Settling Time	t_R			2		μs
Output Voltage Hysteresis	ΔV_{OUT_HYS}	I_{IN} = 1 mA		40		ppm

[1] Guaranteed by design, but not production tested.

ADR530 ELECTRICAL CHARACTERISTICS

I_{IN} = 50 μA to 15 mA, T_A = 25°C, unless otherwise noted.

Table 3.

Parameter	Symbol	Conditions	Min	Typ	Max	Unit
Output Voltage	V_{OUT}					
Grade A			2.988	3.000	3.012	V
Grade B			2.994	3.000	3.006	V
Initial Accuracy	V_{OERR}					
Grade A		±0.4%	−12		+12	mV
Grade B		±0.2%	−6		+6	mV
Temperature Coefficient[1]	TCV_O	−40°C < T_A < +85°C				
Grade A				25	70	ppm/°C
Grade B				15	40	ppm/°C
Output Voltage Change vs. I_{IN}	ΔV_R	I_{IN} = 0.1 mA to 15 mA			1	mV
		−40°C < T_A < +85°C			4	mV
		I_{IN} = 1 mA to 15 mA, −40°C < T_A < +85°C			2	mV
Dynamic Output Impedance	$(\Delta V_R/\Delta I_R)$	I_{IN} = 0.1 mA to 15 mA			0.2	Ω
Minimum Operating Current	I_{IN}	−40°C < T_A < +85°C	50			μA
Voltage Noise	$e_{N\ p-p}$	0.1 Hz to 10 Hz		22		μV p-p
Turn-On Settling Time	t_R			2		μs
Output Voltage Hysteresis	ΔV_{OUT_HYS}	I_{IN} = 1 mA		40		ppm

[1] Guaranteed by design, but not production tested.

ADR550 ELECTRICAL CHARACTERISTICS

I_{IN} = 50 μA to 15 mA, T_A = 25°C, unless otherwise noted.

Table 4.

Parameter	Symbol	Conditions	Min	Typ	Max	Unit
Output Voltage	V_{OUT}					
Grade A			4.980	5.000	5.020	V
Grade B			4.990	5.000	5.010	V
Initial Accuracy	V_{OERR}					
Grade A		±0.4%	−20		+20	mV
Grade B		±0.2%	−10		+10	mV
Temperature Coefficient[1]	TCV_O	−40°C < T_A < +85°C				
Grade A				25	70	ppm/°C
Grade B				15	40	ppm/°C
Output Voltage Change vs. I_{IN}	ΔV_R	I_{IN} = 0.1 mA to 15 mA			1	mV
		−40°C < T_A < +85°C			5	mV
		I_{IN} = 1 mA to 15 mA, −40°C < T_A < +85°C			2	mV
Dynamic Output Impedance	$(\Delta V_R/\Delta I_R)$	I_{IN} = 0.1 mA to 15 mA			0.2	Ω
Minimum Operating Current	I_{IN}	−40°C < T_A < +85°C	50			μA
Voltage Noise	$e_{N\ p\text{-}p}$	0.1 Hz to 10 Hz		38		μV p-p
Turn-On Settling Time	t_R			2		μs
Output Voltage Hysteresis	ΔV_{OUT_HYS}	I_{IN} = 1 mA		40		ppm

[1] Guaranteed by design, but not production tested.

ABSOLUTE MAXIMUM RATINGS

Ratings apply at 25°C, unless otherwise noted.

Table 5.

Parameter	Rating
Reverse Current	25 mA
Forward Current	20 mA
Storage Temperature Range	−65°C to +150°C
Industrial 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

Table 6.

Package Type	θ_{JA}[1]	θ_{JC}	Unit
3-Lead SC70 (KS)	580.5	177.4	°C/W
3-Lead SOT-23-3 (RT)	270	102	°C/W

[1] θ_{JA} is specified for worst-case conditions, such as for devices soldered on circuit boards for surface-mount packages.

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.

PARAMETER DEFINITIONS

TEMPERATURE COEFFICIENT

Temperature coefficient is defined as the change in output voltage with respect to operating temperature changes and is normalized by the output voltage at 25°C. This parameter is expressed in ppm/°C and is determined by the following equation:

$$TCV_O\left[\frac{\text{ppm}}{^\circ\text{C}}\right]=\frac{V_{OUT}(T_2)-V_{OUT}(T_1)}{V_{OUT}(25^\circ\text{C})\times(T_2-T_1)}\times 10^6 \quad (1)$$

where:
$V_{OUT}(T_2)$ = V_{OUT} at Temperature 2.
$V_{OUT}(T_1)$ = V_{OUT} at Temperature 1.
V_{OUT}(25°C) = V_{OUT} at 25°C.

THERMAL HYSTERESIS

Thermal hysteresis is defined as the change in output voltage after the device is cycled through temperatures ranging from +25°C to −40°C, then to +85°C, and back to +25°C. The following equation expresses a typical value from a sample of parts put through such a cycle:

$$V_{OUT\_HYS}=V_{OUT}(25^\circ\text{C})-V_{OUT\_END}$$

$$V_{OUT\_HYS}[\text{ppm}]=\frac{V_{OUT}(25^\circ\text{C})-V_{OUT\_END}}{V_{OUT}(25^\circ\text{C})}\times 10^6 \quad (2)$$

where:
V_{OUT}(25°C) = V_{OUT} at 25°C.
V_{OUT_END} = V_{OUT} at 25°C after a temperature cycle from +25°C to −40°C, then to +85°C, and back to +25°C.

TYPICAL PERFORMANCE CHARACTERISTICS

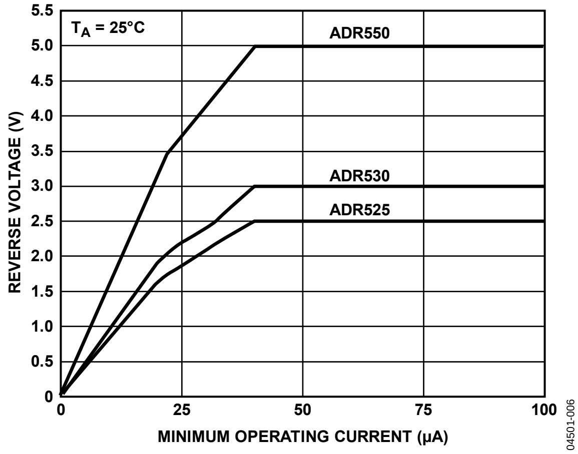

Figure 2. Reverse Characteristics and Minimum Operating Current

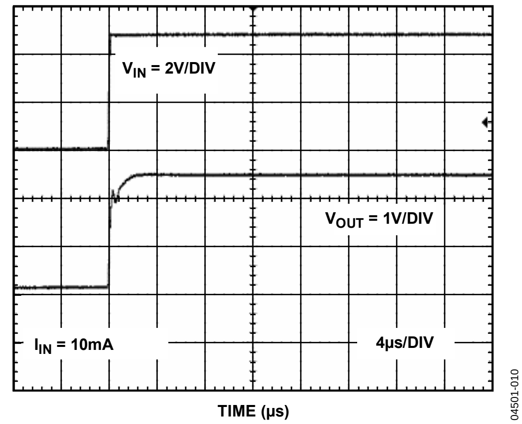

Figure 5. ADR525 Turn-On Response

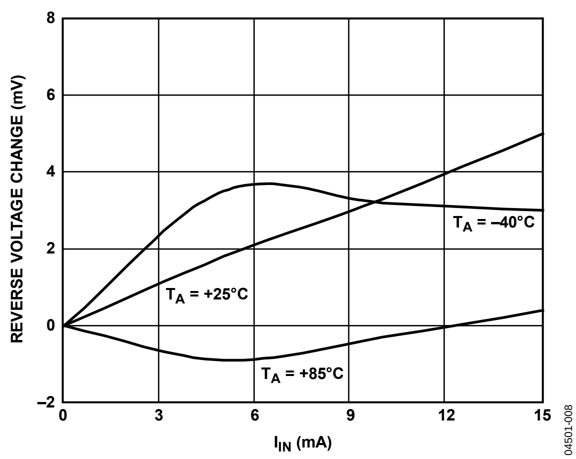

Figure 3. ADR525 Reverse Voltage vs. Operating Current

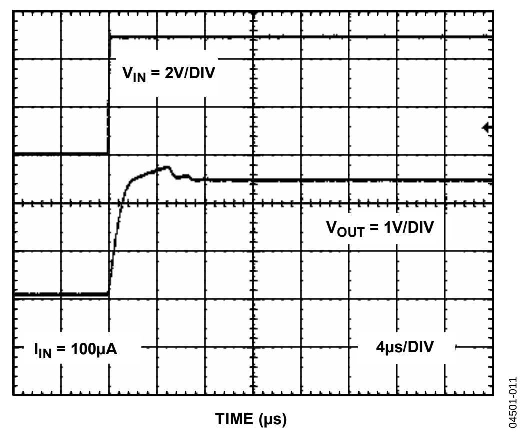

Figure 6. ADR525 Turn-On Response

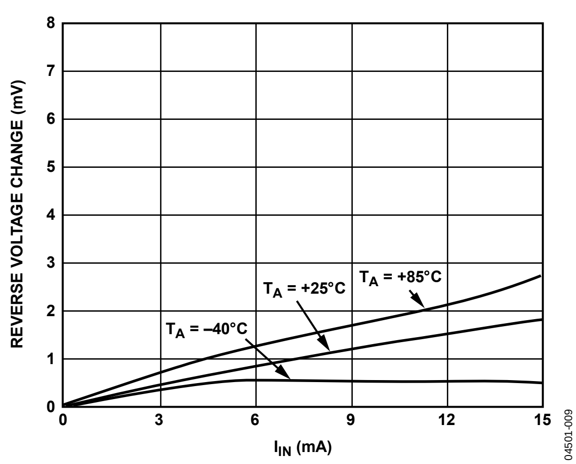

Figure 4. ADR550 Reverse Voltage vs. Operating Current

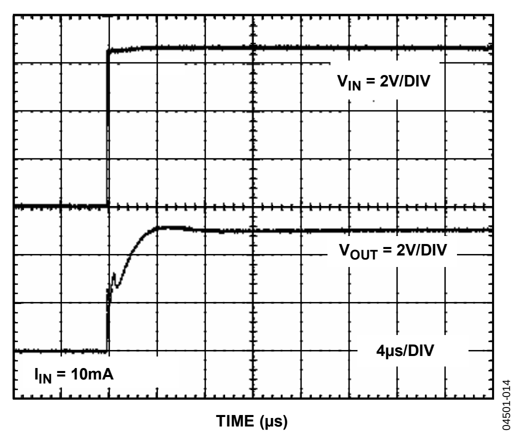

Figure 7. ADR550 Turn-On Response

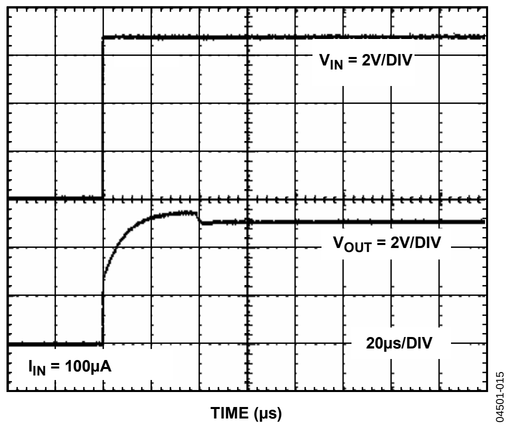

Figure 8. ADR550 Turn-On Response

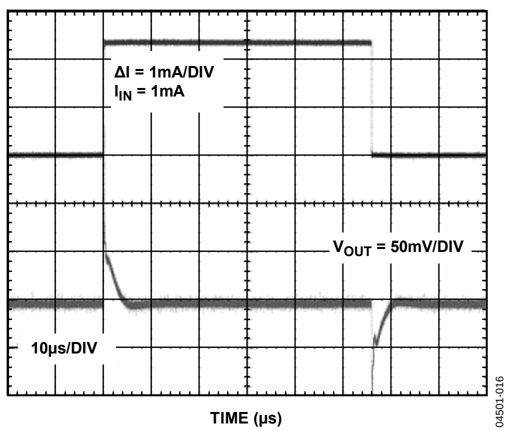

Figure 9. ADR525 Load Transient Response

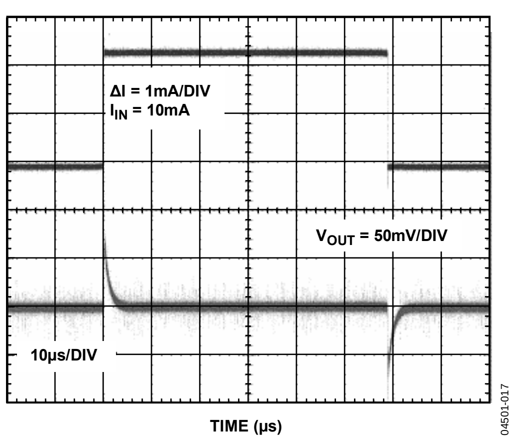

Figure 10. ADR550 Load Transient Response

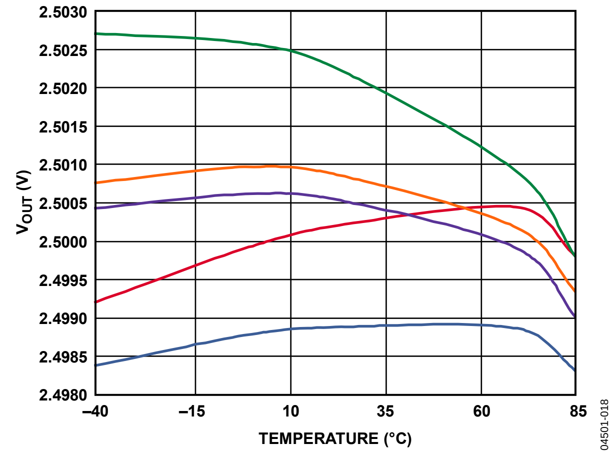

Figure 11. Data for Five Parts of ADR525 V_{OUT} over Temperature

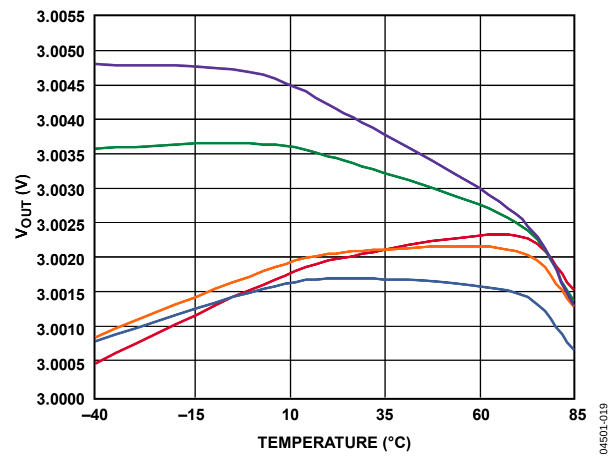

Figure 12. Data for Five Parts of ADR530 V_{OUT} over Temperature

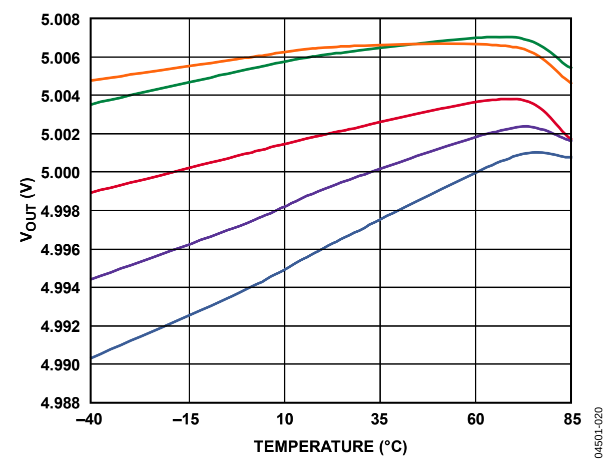

Figure 13. Data for Five Parts of ADR550 V_{OUT} over Temperature

THEORY OF OPERATION

The ADR525/ADR530/ADR550 use the band gap concept to produce a stable, low temperature coefficient voltage reference suitable for high accuracy data acquisition components and systems. The devices use the physical nature of a silicon transistor base-emitter voltage (V_{BE}) in the forward-biased operating region. All such transistors have approximately a −2 mV/°C temperature coefficient (TC), making them unsuitable for direct use as low temperature coefficient references. Extrapolation of the temperature characteristics of any one of these devices to absolute zero (with the collector current proportional to the absolute temperature), however, reveals that its V_{BE} approaches approximately the silicon band gap voltage. Thus, if a voltage develops with an opposing temperature coefficient to sum the V_{BE}, a zero temperature coefficient reference results. The ADR525/ADR530/ADR550 circuit shown in Figure 14 provides such a compensating voltage (V1) by driving two transistors at different current densities and amplifying the resultant V_{BE} difference (ΔV_{BE}, which has a positive temperature coefficient). The sum of V_{BE} and V1 provides a stable voltage reference over temperature.

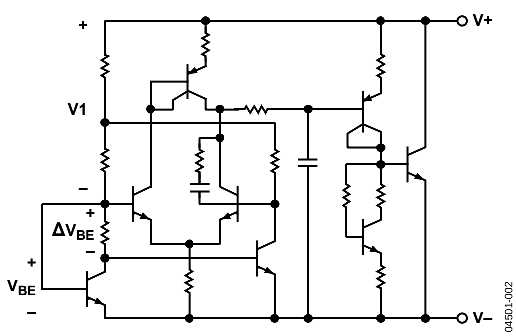

Figure 14. Circuit Schematic

APPLICATIONS

The ADR525/ADR530/ADR550 are a series of precision shunt voltage references. They are designed to operate without an external capacitor between the positive and negative terminals. If a bypass capacitor is used to filter the supply, the references remain stable.

All shunt voltage references require an external bias resistor (R_{BIAS}) between the supply voltage and the reference (see Figure 15). R_{BIAS} sets the current that flows through the load (I_L) and the reference (I_{IN}). Because the load and the supply voltage can vary, R_{BIAS} needs to be chosen based on the following considerations:

- R_{BIAS} must be small enough to supply the minimum I_{IN} current to the ADR525/ADR530/ADR550, even when the supply voltage is at its minimum value and the load current is at its maximum value.
- R_{BIAS} must be large enough so that I_{IN} does not exceed 15 mA when the supply voltage is at its maximum value and the load current is at its minimum value.

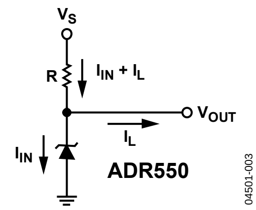

Figure 15. Shunt Reference

Given these conditions, R_{BIAS} is determined by the supply voltage (V_S), the load and operating currents (I_L and I_{IN}) of the ADR525/ADR530/ADR550, and the output voltage (V_{OUT}) of the ADR525/ADR530/ADR550.

$$R_{BIAS} = \frac{V_S - V_{OUT}}{I_L + I_{IN}} \qquad (3)$$

Precision Negative Voltage Reference

The ADR525/ADR530/ADR550 are suitable for applications where a precise negative voltage is desired. Figure 16 shows the ADR525 configured to provide a negative output.

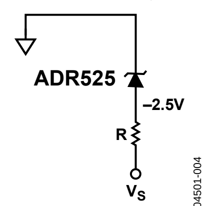

Figure 16. Negative Precision Reference Configuration

Output Voltage Trim

The trim terminal of the ADR525/ADR530/ADR550 can be used to adjust the output voltage over a range of ±0.5%. This allows systems designers to trim small system errors by setting the reference to a voltage other than the preset output voltage. An external mechanical or electrical potentiometer can be used for this adjustment. Figure 17 illustrates how the output voltage can be trimmed using the AD5273, an Analog Devices, Inc., 10 kΩ potentiometer.

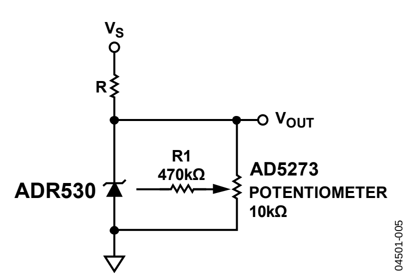

Figure 17. Output Voltage Trim

Stacking the ADR525/ADR530/ADR550 for User-Definable Outputs

Multiple ADR525/ADR530/ADR550 parts can be stacked to allow the user to obtain a desired higher voltage. Figure 18 shows three ADR550s configured to give 15 V. The bias resistor, R_{BIAS}, is chosen using Equation 3; note that the same bias current flows through all the shunt references in series. Figure 19 shows three ADR550s stacked to give −15 V. R_{BIAS} is calculated in the same manner as for Figure 18. Parts of different voltages can also be added together. For example, an ADR525 and an ADR550 can be added together to give an output of +7.5 V or −7.5 V, as desired. Note, however, that the initial accuracy error is now the sum of the errors of all the stacked parts, as are the temperature coefficients and output voltage change vs. input current.

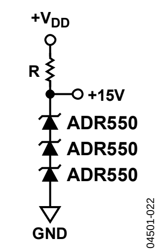

Figure 18. +15 V Output with Stacked ADR550s

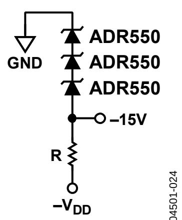

Figure 19. −15 V Output with Stacked ADR550s

Adjustable Precision Voltage Source

The ADR525/ADR530/ADR550, combined with a precision low input bias op amp, such as the AD8610, can be used to output a precise adjustable voltage. Figure 20 illustrates the implementation of this application using the ADR525/ADR530/ADR550. The output of the op amp, V_{OUT}, is determined by the gain of the circuit, which is completely dependent on the resistors, R1 and R2.

$$V_{OUT} = V_{REF} (1 + R2/R1)$$

An additional capacitor, C1, in parallel with R2, can be added to filter out high frequency noise. The value of C1 is dependent on the value of R2.

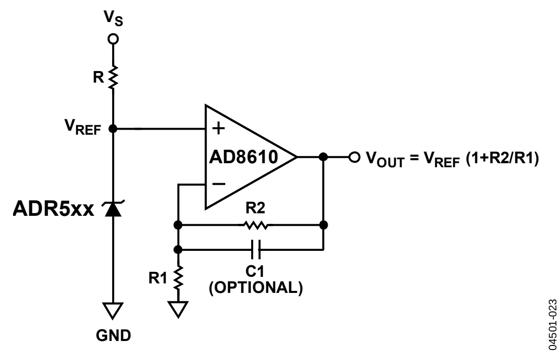

Figure 20. Adjustable Voltage Source

OUTLINE DIMENSIONS

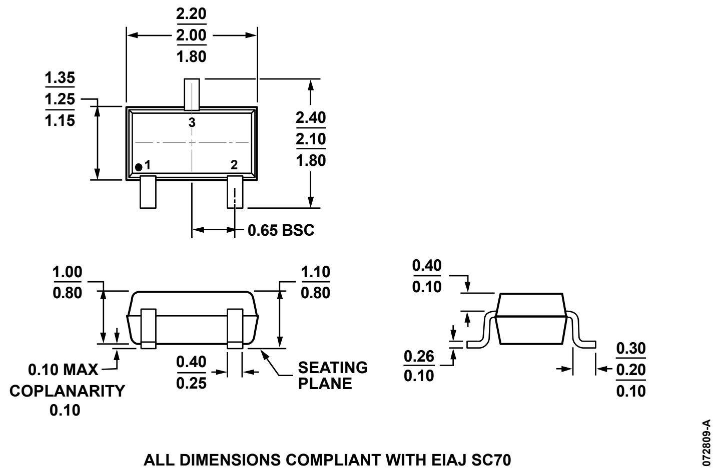

Figure 21. 3-Lead Thin Shrink Small Outline Transistor Package [SC70]
(KS-3)
Dimensions shown in millimeters

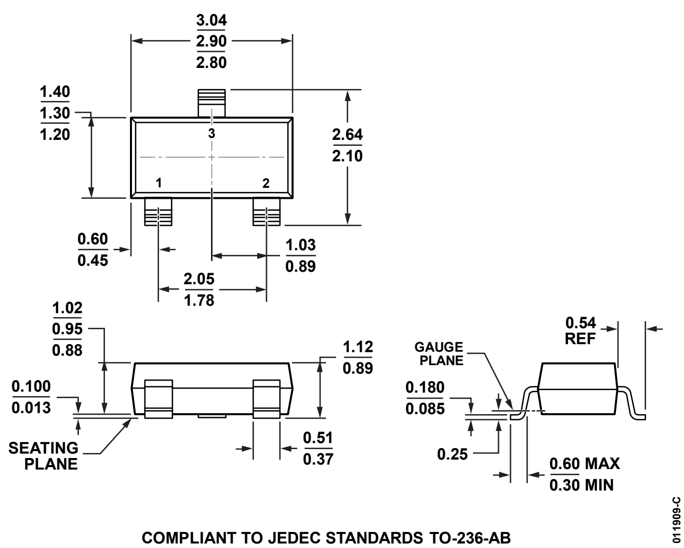

Figure 22. 3-Lead Small Outline Transistor Package [SOT-23-3]
(RT-3)
Dimensions shown in millimeters

ORDERING GUIDE

Model[1]	Output Voltage (V)	Initial Accuracy (mV)	Tempco Industrial (ppm/°C)	Package Description	Package Option	Branding	Ordering Qty	Temperature Range
ADR525ART-REEL7	2.5	10	70	3-Lead SOT-23-3	RT-3	RRA	3,000	−40°C to +85°C
ADR525ARTZ-R2	2.5	10	70	3-Lead SOT-23-3	RT-3	R1W	250	−40°C to +85°C
ADR525ARTZ-REEL7	2.5	10	70	3-Lead SOT-23-3	RT-3	R1W	3,000	−40°C to +85°C
ADR525BKSZ-REEL7	2.5	5	40	3-Lead SC70	KS-3	R1N	3,000	−40°C to +85°C
ADR525BRTZ-REEL7	2.5	5	40	3-Lead SOT-23-3	RT-3	R1N	3,000	−40°C to +85°C
ADR530ARTZ-REEL7	3.0	12	70	3-Lead SOT-23-3	RT-3	R1X	3,000	−40°C to +85°C
ADR530BKSZ-REEL7	3.0	6	40	3-Lead SC70	KS-3	R1Y	3,000	−40°C to +85°C
ADR530BRTZ-REEL7	3.0	6	40	3-Lead SOT-23-3	RT-3	R1Y	3,000	−40°C to +85°C
ADR550ARTZ-REEL7	5.0	20	70	3-Lead SOT-23-3	RT-3	R1Q	3,000	−40°C to +85°C
ADR550BRTZ-REEL7	5.0	10	40	3-Lead SOT-23-3	RT-3	R1P	3,000	−40°C to +85°C

[1] Z = RoHS Compliant Part.

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D04501-0-8/10(F)

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