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1/2007—Revision 0: Initial Version

SPECIFICATIONS

ADR5040 ELECTRICAL CHARACTERISTICS

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

Table 2.

Parameter	Symbol	Test Conditions/Comments	Min	Typ	Max	Unit
OUTPUT VOLTAGE	V_{OUT}	I_{IN} = 100 μA				
Grade A			2.044	2.048	2.052	V
Grade B			2.046	2.048	2.050	V
INITIAL ACCURACY	V_{OERR}	I_{IN} = 100 μA				
Grade A			−4.096		+4.096	mV
					±0.2	%
Grade B			−2.048		+2.048	mV
					±0.1	%
TEMPERATURE COEFFICIENT[1]	TCV_{OUT}	−40°C < T_A < +125°C				
Grade A				10	100	ppm/°C
Grade B				10	75	ppm/°C
OUTPUT VOLTAGE CHANGE vs. I_{IN}	ΔV_R	I_{IN} = 50 μA to 1 mA				
		−40°C < T_A < +125°C		0.4	1.75	mV
		I_{IN} = 1 mA to 15 mA				
		−40°C < T_A < +125°C		4	8	mV
DYNAMIC OUTPUT IMPEDANCE	$(\Delta V_R/\Delta I_R)$	I_{IN} = 50 μA to 15 mA			0.2	Ω
MINIMUM OPERATING CURRENT	I_{IN}	T_A = 25°C			50	μA
		−40°C < T_A < +125°C			60	μA
VOLTAGE NOISE	e_N	I_{IN} = 100 μA; 0.1 Hz to 10 Hz		2.8		μV rms
		I_{IN} = 100 μA; 10 Hz to 10 kHz		120		μV rms
TURN-ON SETTLING TIME	t_R	C_{LOAD} = 0 μF		28		μs
OUTPUT VOLTAGE HYSTERESIS	ΔV_{OUT_HYS}	I_{IN} = 1 mA		40		ppm

[1] Guaranteed by design.

ADR5041 ELECTRICAL CHARACTERISTICS

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

Table 3.

Parameter	Symbol	Test Conditions/Comments	Min	Typ	Max	Unit
OUTPUT VOLTAGE	V_{OUT}	I_{IN} = 100 μA				
Grade A			2.495	2.500	2.505	V
Grade B			2.4975	2.500	2.5025	V
INITIAL ACCURACY	V_{OERR}	I_{IN} = 100 μA				
Grade A			−5		+5	mV
					±0.2	%
Grade B			−2.5		+2.5	mV
					±0.1	%
TEMPERATURE COEFFICIENT[1]	TCV_{OUT}	−40°C < T_A < +125°C				
Grade A				10	100	ppm/°C
Grade B				10	75	ppm/°C
OUTPUT VOLTAGE CHANGE vs. I_{IN}	ΔV_R	I_{IN} = 50 μA to 1 mA				
		−40°C < T_A < +125°C		0.5	1.8	mV
		I_{IN} = 1 mA to 15 mA				
		−40°C < T_A < +125°C		4	8	mV

Parameter	Symbol	Test Conditions/Comments	Min	Typ	Max	Unit
DYNAMIC OUTPUT IMPEDANCE	$(\Delta V_R/\Delta I_R)$	I_{IN} = 50 µA to 15 mA			0.2	Ω
MINIMUM OPERATING CURRENT	I_{IN}	T_A = 25°C			50	µA
		−40°C < T_A < +125°C			60	µA
VOLTAGE NOISE	e_N	I_{IN} = 100 µA; 0.1 Hz to 10 Hz		3.2		µV rms
		I_{IN} = 100 µA; 10 Hz to 10 kHz		150		µV rms
TURN-ON SETTLING TIME	t_R	C_{LOAD} = 0 µF		35		µs
OUTPUT VOLTAGE HYSTERESIS	ΔV_{OUT_HYS}	I_{IN} = 1 mA		40		ppm

[1] Guaranteed by design.

ADR5043 ELECTRICAL CHARACTERISTICS

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

Table 4.

Parameter	Symbol	Test Conditions/Comments	Min	Typ	Max	Unit
OUTPUT VOLTAGE	V_{OUT}	I_{IN} = 100 µA				
Grade A			2.994	3.000	3.006	V
Grade B			2.997	3.000	3.003	V
INITIAL ACCURACY	V_{OERR}	I_{IN} = 100 µA				
Grade A			−6		+6	mV
					±0.2	%
Grade B			−3		+3	mV
					±0.1	%
TEMPERATURE COEFFICIENT[1]	TCV_{OUT}	−40°C < T_A < +125°C				
Grade A				10	100	ppm/°C
Grade B				10	75	ppm/°C
OUTPUT VOLTAGE CHANGE vs. I_{IN}	ΔV_R	I_{IN} = 50 µA to 1 mA				
		−40°C < T_A < +125°C		0.7	2.2	mV
		I_{IN} = 1 mA to 15 mA				
		−40°C < T_A < +125°C		4	8	mV
DYNAMIC OUTPUT IMPEDANCE	$(\Delta V_R/\Delta I_R)$	I_{IN} = 50 µA to 15 mA			0.2	Ω
MINIMUM OPERATING CURRENT	I_{IN}	T_A = 25°C			50	µA
		−40°C < T_A < +125°C			60	µA
VOLTAGE NOISE	e_N	I_{IN} = 100 µA; 0.1 Hz to 10 Hz		4.3		µV rms
		I_{IN} = 100 µA; 10 Hz to 10 kHz		180		µV rms
TURN-ON SETTLING TIME	t_R	C_{LOAD} = 0 µF		42		µs
OUTPUT VOLTAGE HYSTERESIS	ΔV_{OUT_HYS}	I_{IN} = 1 mA		40		ppm

[1] Guaranteed by design.

ADR5044 ELECTRICAL CHARACTERISTICS

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

Table 5.

Parameter	Symbol	Test Conditions/Comments	Min	Typ	Max	Unit
OUTPUT VOLTAGE	V_{OUT}	I_{IN} = 100 µA				
Grade A			4.088	4.096	4.104	V
Grade B			4.092	4.096	4.100	V
INITIAL ACCURACY	V_{OERR}	I_{IN} = 100 µA				
Grade A			−8.192		+8.192	mV
					±0.2	%

Parameter	Symbol	Test Conditions/Comments	Min	Typ	Max	Unit
Grade B			−4.096		+4.096	mV
					±0.1	%
TEMPERATURE COEFFICIENT[1]	TCV_{OUT}	−40°C < T_A < +125°C				
Grade A				10	100	ppm/°C
Grade B				10	75	ppm/°C
OUTPUT VOLTAGE CHANGE vs. I_{IN}	ΔV_R	I_{IN} = 50 µA to 1 mA				
		−40°C < T_A < +125°C		0.7	3	mV
		I_{IN} = 1 mA to 15 mA				
		−40°C < T_A < +125°C		4	8	mV
DYNAMIC OUTPUT IMPEDANCE	$(\Delta V_R/\Delta I_R)$	I_{IN} = 50 µA to 15 mA			0.2	Ω
MINIMUM OPERATING CURRENT	I_{IN}	T_A = 25°C			50	µA
		−40°C < T_A < +125°C			60	µA
VOLTAGE NOISE	e_N	I_{IN} = 100 µA; 0.1 Hz to 10 Hz		5.4		µV rms
		I_{IN} = 100 µA; 10 Hz to 10 kHz		240		µV rms
TURN-ON SETTLING TIME	t_R	C_{LOAD} = 0 µF		56		µs
OUTPUT VOLTAGE HYSTERESIS	ΔV_{OUT_HYS}	I_{IN} = 1 mA		40		ppm

[1] Guaranteed by design.

ADR5045 ELECTRICAL CHARACTERISTICS

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

Table 6.

Parameter	Symbol	Test Conditions/Comments	Min	Typ	Max	Unit
OUTPUT VOLTAGE	V_{OUT}	I_{IN} = 100 µA				
Grade A			4.990	5.000	5.010	V
Grade B			4.995	5.000	5.005	V
INITIAL ACCURACY	V_{OERR}	I_{IN} = 100 µA				
Grade A			−10		+10	mV
					±0.2	%
Grade B			−5		+5	mV
					±0.1	%
TEMPERATURE COEFFICIENT[1]	TCV_{OUT}	−40°C < T_A < +125°C				
Grade A				10	100	ppm/°C
Grade B				10	75	ppm/°C
OUTPUT VOLTAGE CHANGE vs. I_{IN}	ΔV_R	I_{IN} = 50 µA to 1 mA				
		−40°C < T_A < +125°C		0.8	4	mV
		I_{IN} = 1 mA to 15 mA				
		−40°C < T_A < +125°C		4	8	mV
DYNAMIC OUTPUT IMPEDANCE	$(\Delta V_R/\Delta I_R)$	I_{IN} = 50 µA to 15 mA			0.2	Ω
MINIMUM OPERATING CURRENT	I_{IN}	T_A = 25°C			50	µA
		−40°C < T_A < +125°C			60	µA
VOLTAGE NOISE	e_N	I_{IN} = 100 µA; 0.1 Hz to 10 Hz		6.6		µV rms
		I_{IN} = 100 µA; 10 Hz to 10 kHz		280		µV rms
TURN-ON SETTLING TIME	t_R	C_{LOAD} = 0 µF		70		µs
OUTPUT VOLTAGE HYSTERESIS	ΔV_{OUT_HYS}	I_{IN} = 1 mA		40		ppm

[1] Guaranteed by design.

ABSOLUTE MAXIMUM RATINGS

Ratings apply at 25°C, unless otherwise noted.

Table 7.

Parameter	Rating
Reverse Current	25 mA
Forward Current	20 mA
Storage Temperature Range	−65°C to +150°C
Extended Temperature Range	−40°C to +125°C
Junction Temperature Range	−65°C to +150°C
Lead Temperature (Soldering, 60 sec)	300°C

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

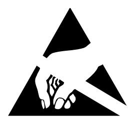
THERMAL RESISTANCE

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

Table 8. Thermal Resistance

Package Type	θ_{JA}	θ_{JC}	Unit
KS-3	580.5	177.4	°C/W
RT-3	270	102	°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

$T_A = 25°C$, $I_{IN} = 100\ \mu A$, unless otherwise noted.

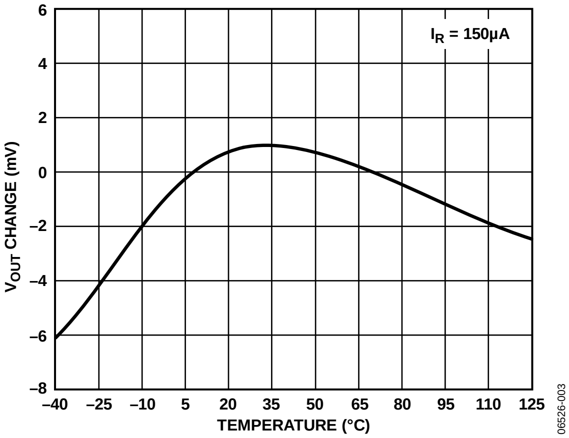


Figure 2. ADR5041 V_{OUT} Change vs. Temperature

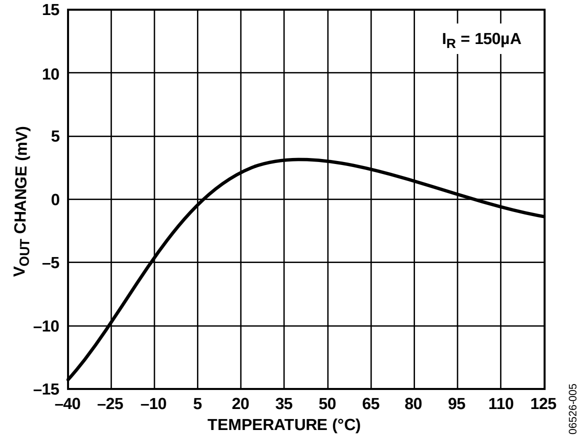


Figure 5. ADR5045 V_{OUT} Change vs. Temperature

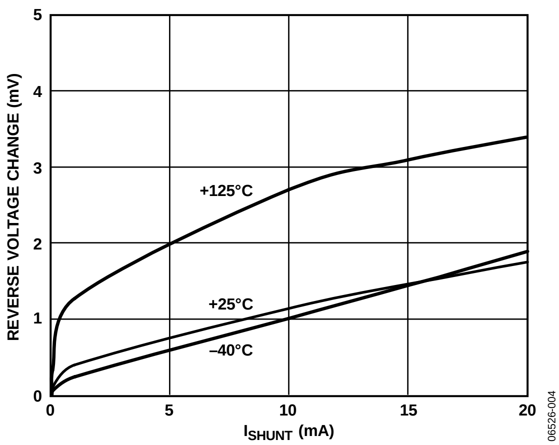


Figure 3. ADR5041 Reverse Voltage Change vs. I_{SHUNT}

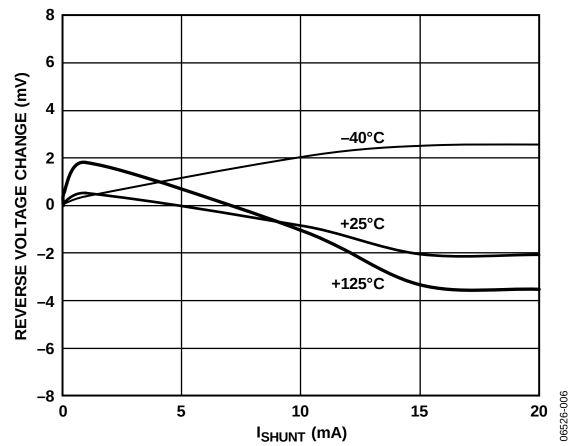


Figure 6. ADR5045 Reverse Voltage Change vs. I_{SHUNT}

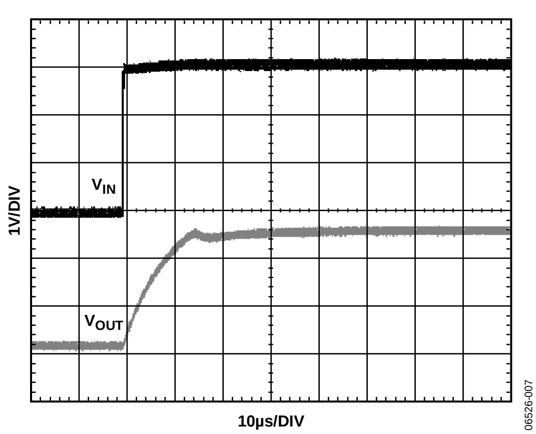


Figure 4. ADR5041 Start-Up Characteristics

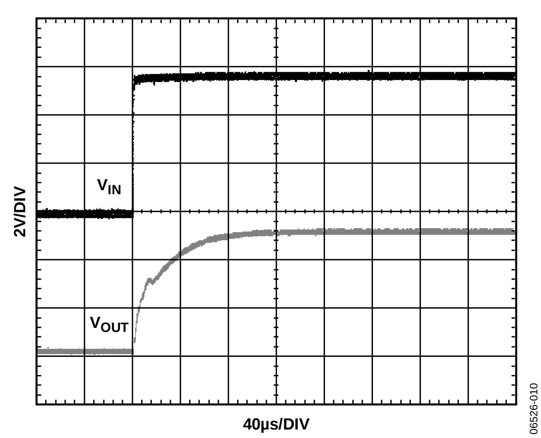


Figure 7. ADR5045 Start-Up Characteristics

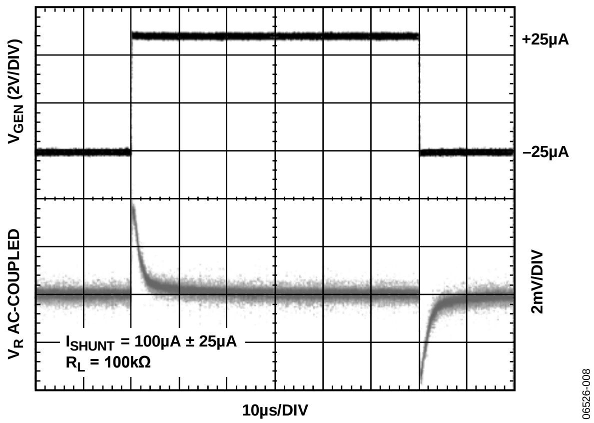


Figure 8. ADR5041 Load Transient Response

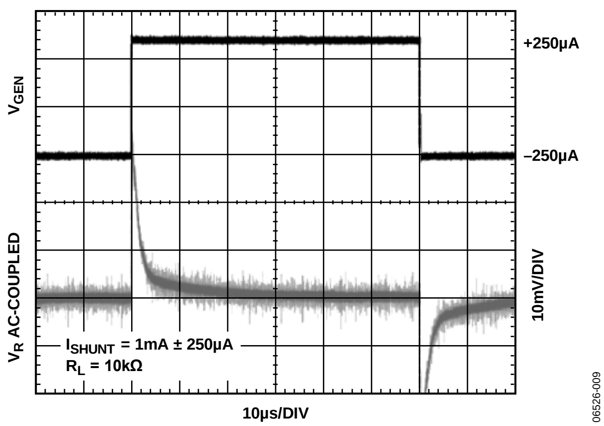


Figure 9. ADR5041 Transient Response

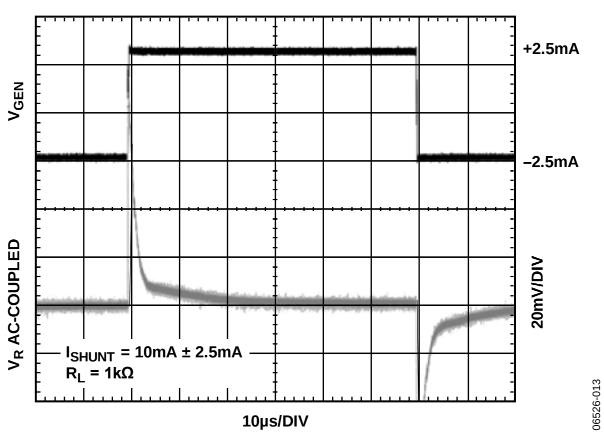


Figure 10. ADR5041 Transient Response

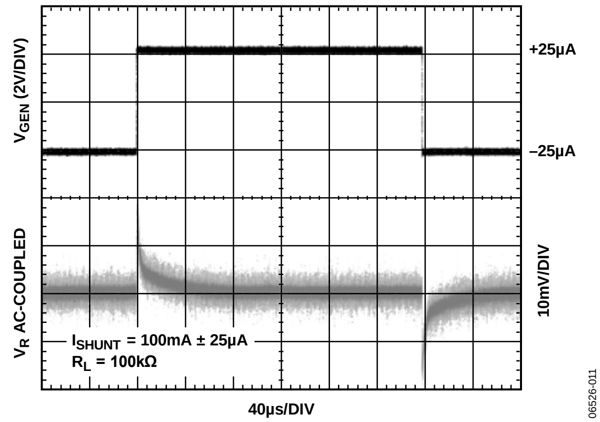


Figure 11. ADR5045 Load Transient Response

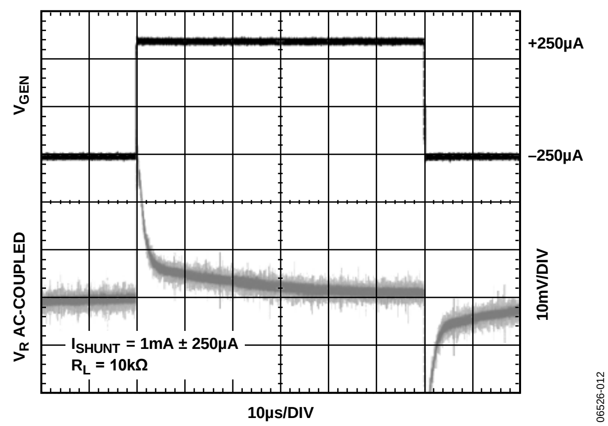


Figure 12. ADR5045 Transient Response

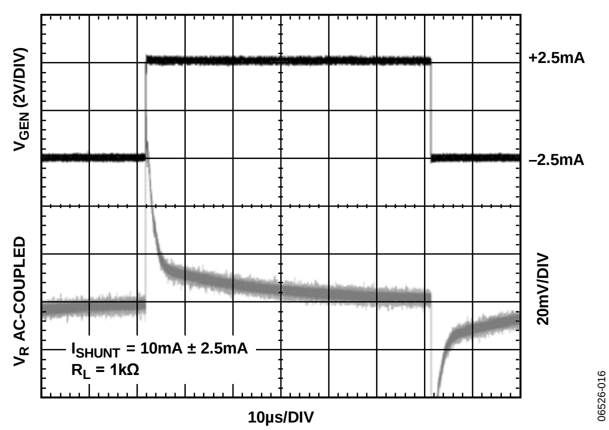


Figure 13. ADR5045 Transient Response

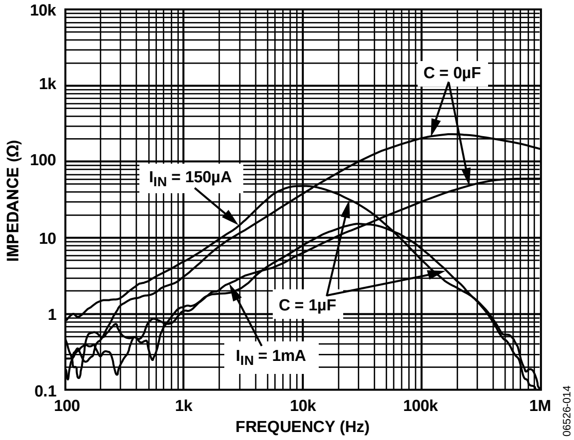


Figure 14. ADR5041 Output Impedance vs. Frequency

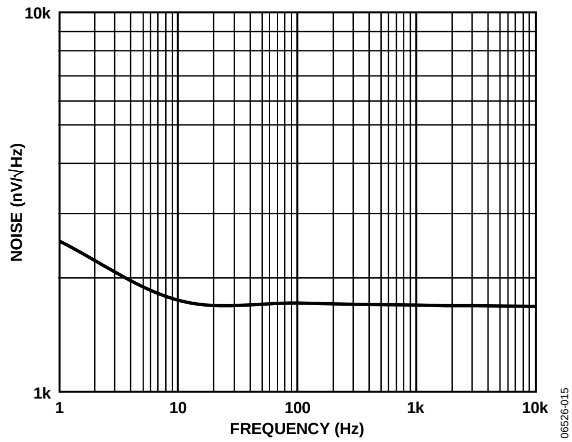


Figure 15. ADR5041 Voltage Noise Density

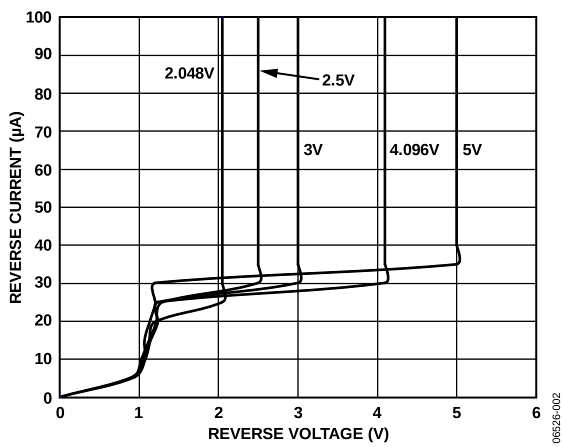


Figure 16. ADR5040/ADR5041/ADR5043/ADR5044/ADR5045 Reverse Characteristics and Minimum Operating Current

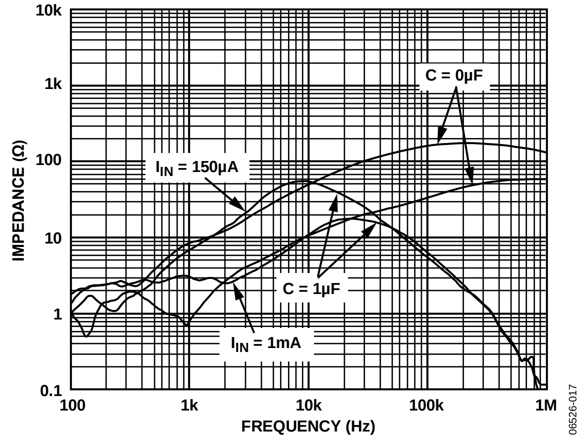


Figure 17. ADR5045 Output Impedance vs. Frequency

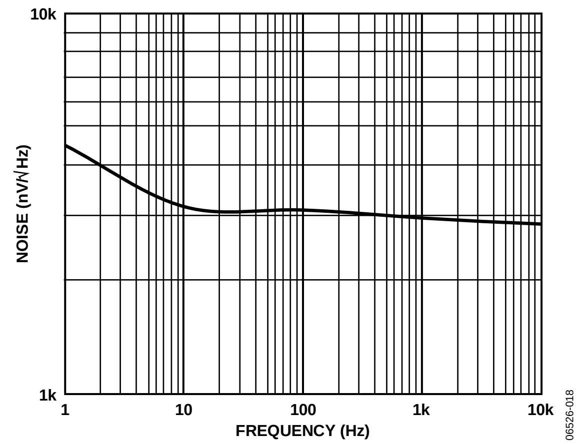


Figure 18. ADR5045 Voltage Noise Density

TERMINOLOGY

Temperature Coefficient

The change in output voltage with respect to operating temperature changes. It is normalized by an output voltage of 25°C. This parameter is expressed in ppm/°C and is determined by the following equation:

$$TCV_{OUT}\left[\frac{\text{ppm}}{°\text{C}}\right]=\frac{V_{OUT}(T_2)-V_{OUT}(T_1)}{V_{OUT}(25°\text{C})\times(T_2-T_1)}\times10^6 \quad (1)$$

where:

$V_{OUT}(25°C)$ = V_{OUT} at 25°C.
$V_{OUT}(T_1)$ = V_{OUT} at −40°C.
$V_{OUT}(T_2)$ = V_{OUT} at 125°C.

Thermal Hysteresis

The change in output voltage after the device is cycled through temperatures ranging from +25°C to −40°C, then to +125°C, and back to +25°C. This is common in precision reference and is caused by thermal-mechanical package stress. Changes in environmental storage temperature, board mounting temperature, and the operating temperature are some of the factors that can contribute to thermal hysteresis. The following equation expresses a typical value from a sample of parts put through such a cycle:

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

$$V_{OUT\_HYS}[\text{ppm}]=\frac{V_{OUT}(25°\text{C})-V_{OUT\_TC}}{V_{OUT}(25°\text{C})}\times10^6 \quad (2)$$

where:

$V_{OUT}(25°C)$ = V_{OUT} at 25°C.
V_{OUT_TC} = V_{OUT} at 25°C after a temperature cycle from +25°C to −40°C, then to +125°C, and back to +25°C.

THEORY OF OPERATION

The ADR5040/ADR5041/ADR5043/ADR5044/ADR5045 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 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 a low temperature coefficient reference. Extrapolation of the temperature characteristic 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. Therefore, if a voltage develops with an opposing temperature coefficient to sum the V_{BE}, a zero temperature coefficient reference results.

APPLICATIONS INFORMATION

The ADR5040/ADR5041/ADR5043/ADR5044/ADR5045 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.

For a stable voltage, all shunt voltage references require an external bias resistor (R_{BIAS}) between the supply voltage and the reference (see Figure 19). The 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, the 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 ADR5040/ADR5041/ADR5043/ADR5044/ADR5045, 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.

Given these conditions, R_{BIAS} is determined by the supply voltage (V_S), the ADR5040/ADR5041/ADR5043/ADR5044/ADR5045 load and operating current (I_L and I_{IN}), and the ADR5040/ADR5041/ADR5043/ADR5044/ADR5045 output voltage (V_{OUT}).

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

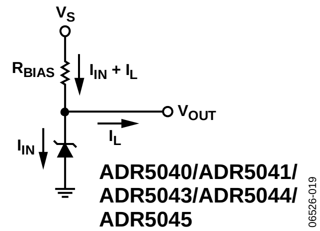


Figure 19. Shunt Reference

Precision Negative Voltage Reference

The ADR5040/ADR5041/ADR5043/ADR5044/ADR5045 are suitable for applications where a precise negative voltage is desired. Figure 20 shows the ADR5045 configured to provide a negative output. Exercise caution in using a low temperature sensitive resistor to avoid errors from the resistor.

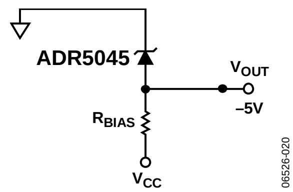


Figure 20. Negative Precision Reference Configuration

Stacking the ADR5040/ADR5041/ADR5043/ADR5044/ ADR5045 for User-Definable Outputs

Multiple ADR5040/ADR5041/ADR5043/ADR5044/ADR5045 devices can be stacked together to allow the user to obtain a desired higher voltage. Figure 21a shows three ADR5045 devices configured to give 15 V. The bias resistor, R_{BIAS}, is chosen using Equation 3, noting that the same bias current flows through all the shunt references in series. Figure 21b shows three ADR5045 devices stacked together to give −15 V. R_{BIAS} is calculated in the same manner as before. Parts of different voltages can also be added together; that is, an ADR5041 and an ADR5045 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 the sum of the errors of all the stacked parts, as are the temperature coefficient and output voltage change vs. input current.

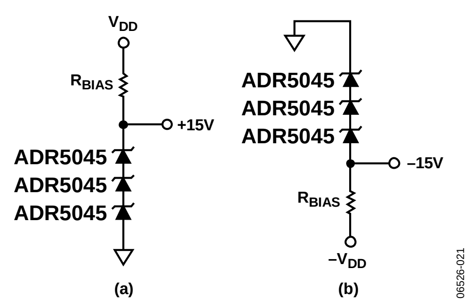


Figure 21. ±15 V Output with Stacked ADR5045 Devices

Adjustable Precision Voltage Source

The ADR5040/ADR5041/ADR5043/ADR5044/ADR5045, combined with a precision low input bias op amp such as the AD8610, can be used to output a precise adjustable voltage. Figure 22 illustrates the implementation of this application using the ADR5040/ADR5041/ADR5043/ADR5044/ADR5045. 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.

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

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.

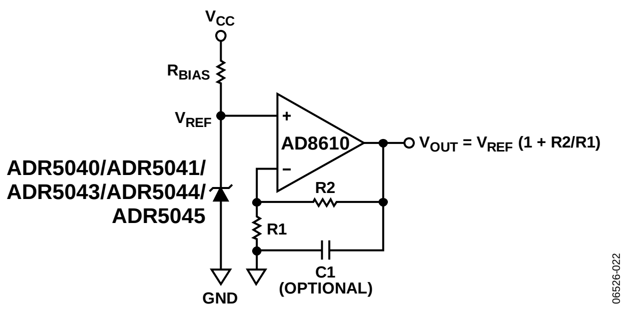


Figure 22. Adjustable Voltage Source

Programmable Current Source

By using just a few ultrasmall and inexpensive parts, it is possible to build a programmable current source, as shown in Figure 23. The constant voltage on the gate of the transistor sets the current through the load. Varying the voltage on the gate changes the current. The AD5247 is a digital potentiometer with I²C® digital interface, and the AD8601 is a precision rail-to-rail input op amp. Each incremental step of the digital potentiometer increases or decreases the voltage at the noninverting input of the op amp. Therefore, this voltage varies with respect to the reference voltage.

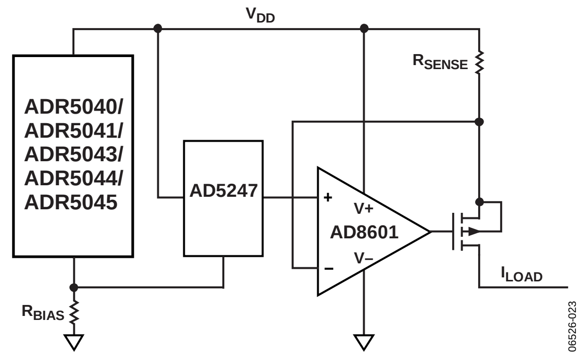


Figure 23. Programmable Current Source

OUTLINE DIMENSIONS

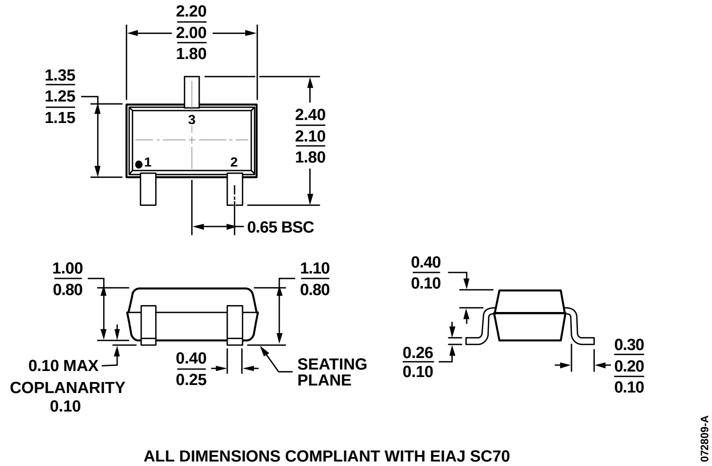


Figure 24. 3-Lead Thin Shrink Small Outline Transistor Package [KS-SC-70]
(KS-3)
Dimensions shown in millimeters

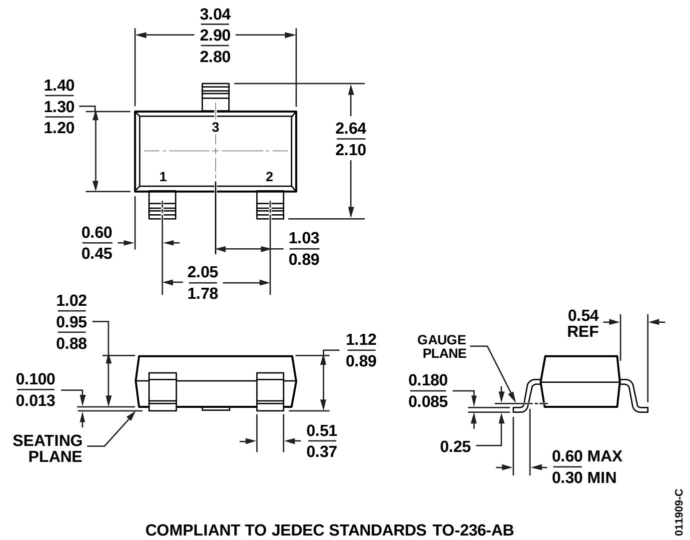


Figure 25. 3-Lead Small Outline Transistor Package [RT-SOT-23-3]
(RT-3)
Dimensions shown in millimeters

ORDERING GUIDE

Model[1, 2]	Output Voltage (V)	Temperature Range	Package Description	Package Option	Ordering Quantity	Marking Code
ADR5040AKSZ-REEL7	2.048	−40°C to +125°C	KS-SC-70	KS-3	3,000	R2J
ADR5040ARTZ-REEL7	2.048	−40°C to +125°C	RT-SOT-23-3	RT-3	3,000	R2J
ADR5040BKSZ-REEL7	2.048	−40°C to +125°C	KS-SC-70	KS-3	3,000	R2L
ADR5040BRTZ-REEL7	2.048	−40°C to +125°C	RT-SOT-23-3	RT-3	3,000	R2L
ADR5040WARTZ-R7	2.048	−40°C to +125°C	RT-SOT-23-3	RT-3	3,000	A3R
ADR5041AKSZ-REEL7	2.500	−40°C to +125°C	KS-SC-70	KS-3	3,000	R2N
ADR5041ARTZ-REEL7	2.500	−40°C to +125°C	RT-SOT-23-3	RT-3	3,000	R2N
ADR5041BKSZ-REEL7	2.500	−40°C to +125°C	KS-SC-70	KS-3	3,000	R2Q
ADR5041BRTZ-REEL7	2.500	−40°C to +125°C	RT-SOT-23-3	RT-3	3,000	R2Q
ADR5041WARTZ-R7	2.500	−40°C to +125°C	RT-SOT-23-3	RT-3	3,000	R2N
ADR5041WBRTZ-R7	2.500	−40°C to +125°C	RT-SOT-23-3	RT-3	3,000	R2Q
ADR5043AKSZ-REEL7	3.0	−40°C to +125°C	KS-SC-70	KS-3	3,000	R2S
ADR5043ARTZ-REEL7	3.0	−40°C to +125°C	RT-SOT-23-3	RT-3	3,000	R2S
ADR5043BKSZ-REEL7	3.0	−40°C to +125°C	KS-SC-70	KS-3	3,000	R2U
ADR5043BRTZ-REEL7	3.0	−40°C to +125°C	RT-SOT-23-3	RT-3	3,000	R2U
ADR5044AKSZ-REEL7	4.096	−40°C to +125°C	KS-SC-70	KS-3	3,000	R2W
ADR5044ARTZ-REEL7	4.096	−40°C to +125°C	RT-SOT-23-3	RT-3	3,000	R2W
ADR5044BKSZ-REEL7	4.096	−40°C to +125°C	KS-SC-70	KS-3	3,000	R2Y
ADR5044BRTZ-REEL7	4.096	−40°C to +125°C	RT-SOT-23-3	RT-3	3,000	R2Y
ADR5044WARTZ-R7	4.096	−40°C to +125°C	RT-SOT-23-3	RT-3	3,000	R2W
ADR5044WBRTZ-R7	4.096	−40°C to +125°C	RT-SOT-23-3	RT-3	3,000	R2Y
ADR5045AKSZ-REEL7	5.0	−40°C to +125°C	KS-SC-70	KS-3	3,000	R30
ADR5045ARTZ-REEL7	5.0	−40°C to +125°C	RT-SOT-23-3	RT-3	3,000	R30
ADR5045BKSZ-REEL7	5.0	−40°C to +125°C	KS-SC-70	KS-3	3,000	R32
ADR5045BRTZ-REEL7	5.0	−40°C to +125°C	RT-SOT-23-3	RT-3	3,000	R32
ADR5045WARTZ-REEL7	5.0	−40°C to +125°C	KS-SC-70	KS-3	3,000	R3P
ADR5045WBRTZ-REEL7	5.0	−40°C to +125°C	KS-SC-70	KS-3	3,000	R3Q

[1] Z = RoHS Compliant Part.
[2] W = Qualified for Automotive Applications.

AUTOMOTIVE PRODUCTS

The ADR5040W, ADR5041W, ADR5044W, and ADR5045W models are available with controlled manufacturing to support the quality and reliability requirements of automotive applications. Note that these automotive models may have specifications that differ from the commercial models; therefore, designers should review the Specifications section of this data sheet carefully. Only the automotive grade products shown are available for use in automotive applications. Contact your local Analog Devices account representative for specific product ordering information and to obtain the specific Automotive Reliability reports for these models.

I²C refers to a communications protocol originally developed by Philips Semiconductors (now NXP Semiconductors).

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