

# Low Noise, Low Power, Low Temperature Drift, 40 V Precise Voltage Reference

## Features

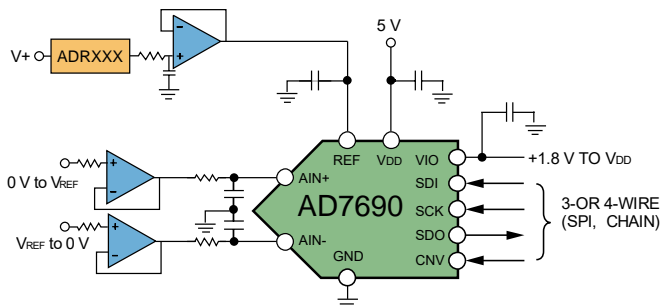
- Low Temperature Drift: 3 ppm/°C max
- High Accuracy:  $\pm 0.05\%$  max
- Multiple Output Voltage: 2.048 V, 2.5 V, 3 V, 3.3 V, 4.096 V, 5 V, 10 V
- Low Noise: 0.1 Hz to 10 Hz, 2.1 ppm<sub>P-P</sub>
- Strong driving capability: 20 mA
- Wide Supply Range: 2.8 V or  $V_{OUT} + 0.3$  V to 40 V
- Low Quiescent Current: 160  $\mu$ A
- Wide Temperature Range: -40 °C to +125 °C

## Application

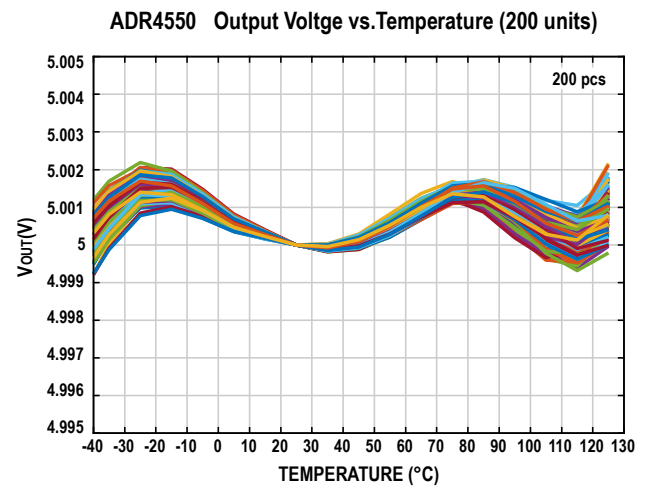
- Precision Data Acquisition
- Precision Instruments
- Industrial Control
- Optical Communication
- Smart Grid

## Typical Application

ADRXXX as ADC voltage Reference



## Typical Characteristics



## Pin Configurations and Function Descriptions

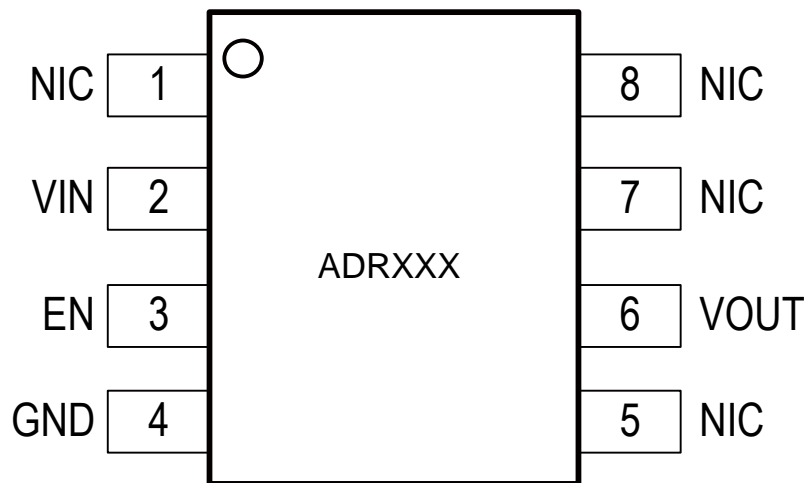


Figure 1. ADRXXX Pin Configuration (8-lead SOIC and MSOP)

Mnemonic	Pin No.	I/O <sup>1</sup>	Description
NIC	1,5,7,8	--	No Internal Connection
VIN	2	AI	Input Voltage
EN	3	AI	EN Input. This active low input powers down the device to 9 $\mu$ A. If left open, an internal pull-up resistor puts the part in normal operation. It is recommended to tie this pin high externally for best performance during normal operation.
GND	4	AI	Ground Pin = 0 V.
VOUT	6	AO	Output Voltage

## Absolute Maximum Ratings

Parameter	Rating
Supply Voltage	40 V
Input Voltage	-0.2 V to 40 V
Output Short-Circuit Current to GND	±30 mA
Operating Temperature Range	-40 °C to +125 °C
Storage Temperature Range	-65 °C to +150 °C
Junction Temperature Range	-65 °C to +150 °C
Maximum Reflow Temperature	260 °C
Lead Temperature (Soldering, 10 sec)	300 °C
Electrostatic Discharge (ESD)	
Human Body Model (HBM)	4.5 kV
Charge Device Model (CDM)	2 kV

## Thermal Resistance

Package Type	$\theta_{JA}$	$\theta_{JC}$	Unit
8-lead SOIC	158	43	°C/W
8-lead MSOP	190	44	°C/W

## Specifications<sup>1</sup>

The ● denotes the specification which apply over the full operating temperature range, otherwise specifications are at  $V_{IN} = 2.8\text{ V}$  to  $40\text{ V}$ ,  $I_{LOAD} = 0$ ,  $C_L = 0.1\ \mu\text{F}$ ,  $T_A = 25\ ^\circ\text{C}$ , unless otherwise noted.

Parameter	Symbol	Conditions	Min	Typ.	Max	Unit
Output Voltage	$V_{OUT}$	ADR4520		2.048		V
		ADR431		2.5		V
		ADR443		3		V
		ADR4533		3.3		V
		ADR4540		4.096		V
		ADR4550		5		V
		AD581		10		V
Initial Accuracy			-0.05		+0.05	%
<b>Temperature Coefficient</b>						
C Grade			●	2.5	3	ppm/ $^\circ\text{C}$
B Grade			●	2.8	5	ppm/ $^\circ\text{C}$
B Grade, Temperature Grade E		0 $^\circ\text{C}$ to +75 $^\circ\text{C}$		3	5	ppm/ $^\circ\text{C}$
A Grade			●	3	8	ppm/ $^\circ\text{C}$
<b>Voltage Noise</b>		0.1 Hz to 10 Hz		2.1		ppm <sub>P-P</sub>
Voltage Noise Density	$e_n$	ADR4520 1 kHz		167		nV/ $\sqrt{\text{Hz}}$
		ADR431 1 kHz		185		nV/ $\sqrt{\text{Hz}}$
		ADR443 1 kHz		225		nV/ $\sqrt{\text{Hz}}$
		ADR4533 1 kHz		233		nV/ $\sqrt{\text{Hz}}$
		ADR4540 1 kHz		348		nV/ $\sqrt{\text{Hz}}$
		ADR4550 1 kHz		380		nV/ $\sqrt{\text{Hz}}$
		AD581 1 kHz		774		nV/ $\sqrt{\text{Hz}}$
Line Regulation		ADR4520 : $V_{IN} = 2.8\text{ V} \sim 40\text{ V}$ Others: $V_{IN} = V_{OUT} + 0.3\text{ V} \sim 40\text{ V}$	●	0.1	3	ppm/V
Load Regulation		-10 mA < $I_{LOAD}$ < 10 mA	●	0.8	20 35	ppm/mA
Supply Voltage	$V_{IN}$	$I_{LOAD} = 5\text{ mA}$ Output Voltage Error $\leq 0.1\%$				
		ADR4520	●	2.8	40	V
		Others	●	$V_{OUT} + 0.3$	40	V

Parameter	Symbol	Conditions	Min	Typ.	Max	Unit
Supply Current	I <sub>SY</sub>	No Load	•	160	200	μA
		SHUTDOWN (EN = GND)	•	10	20	μA
Shutdown Pin (EN)		Logic High Input Voltage	•	2		V
		Logic High Input Current	•	-1	1	μA
		Logic Low Input Voltage	•		0.8	V
		Logic Low Input Current	•	-1	1	μA
Output Short Circuit Current	I <sub>SC</sub>	V <sub>OUT</sub> = GND or V <sub>IN</sub>	•	14	20	mA
Turn-on Time		0.1% settling, C <sub>L</sub> = 0.1 μF		200		μs
Long-Term Stability <sup>2</sup>	LTD	1000 hours, SOIC-8		15		ppm/1000 hours
		1000 hours, MSOP-8		10		ppm/1000 hours
Output Voltage Hysteresis		SOIC-8		50		ppm
		MSOP-8		50		ppm
Temperature Range		Specified Temperature Range		-40	125	°C
		Operating Temperature Range		-55	125	°C

## Typical Performance Characteristics

At  $V_{IN} = 2.8\text{ V to }40\text{ V}$ ,  $I_{LOAD} = 0$ ,  $C_L = 0.1\ \mu\text{F}$ ,  $T_A = 25\ ^\circ\text{C}$ , unless otherwise noted.

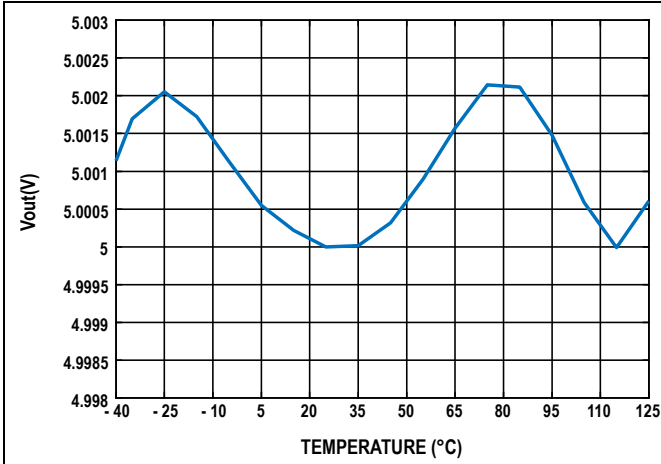


Figure 2. ADR4550 Output Voltage vs. Temperature (B Grade)

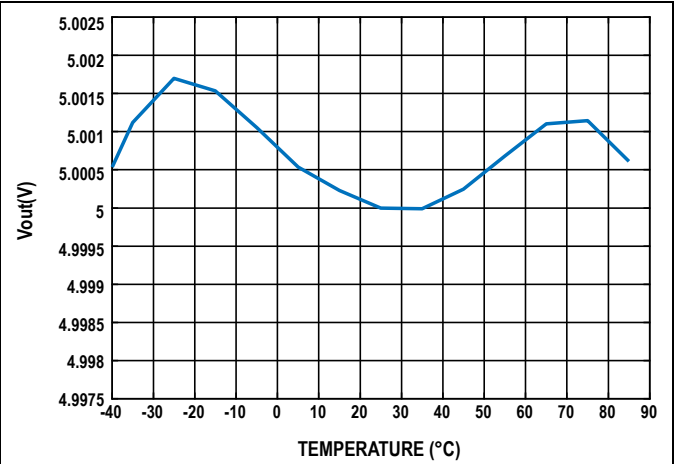


Figure 3. ADR4550 Output Voltage vs. Temperature (E Grade)

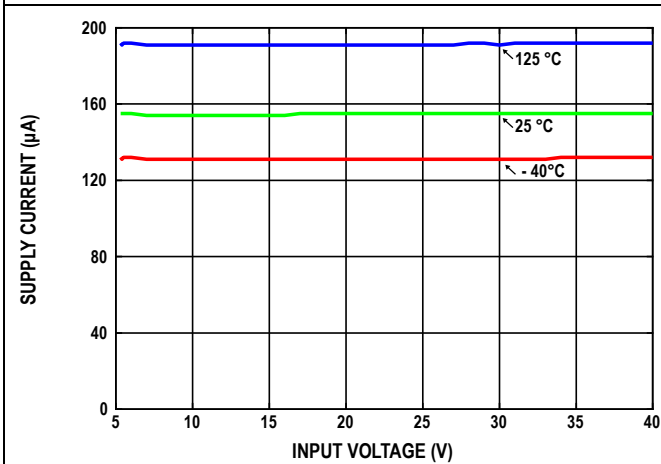


Figure 4. Supply Current vs. Input Voltage

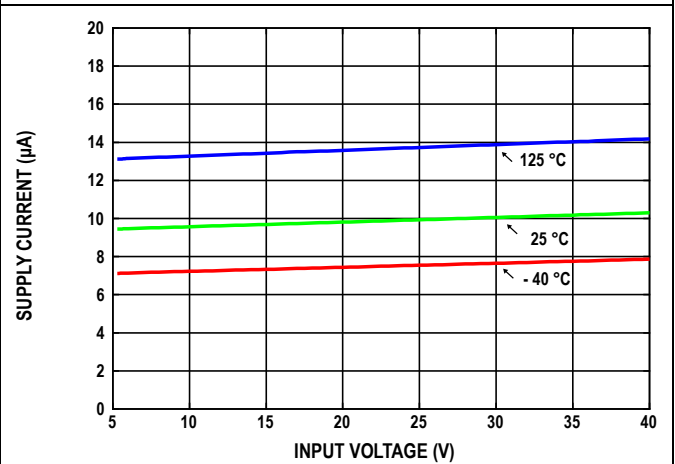


Figure 5. Supply Current vs. Input Voltage in SHUTDOWN mode

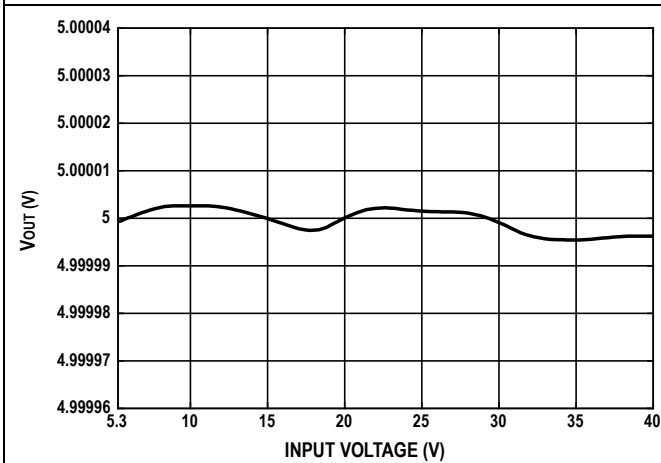


Figure 6. ADR4550 Line Regulation

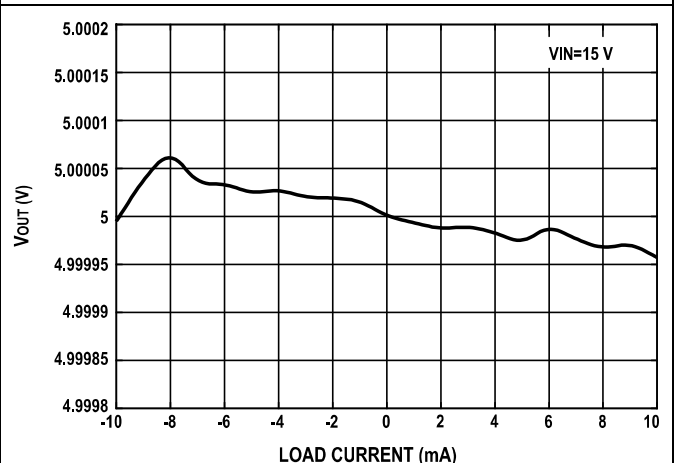
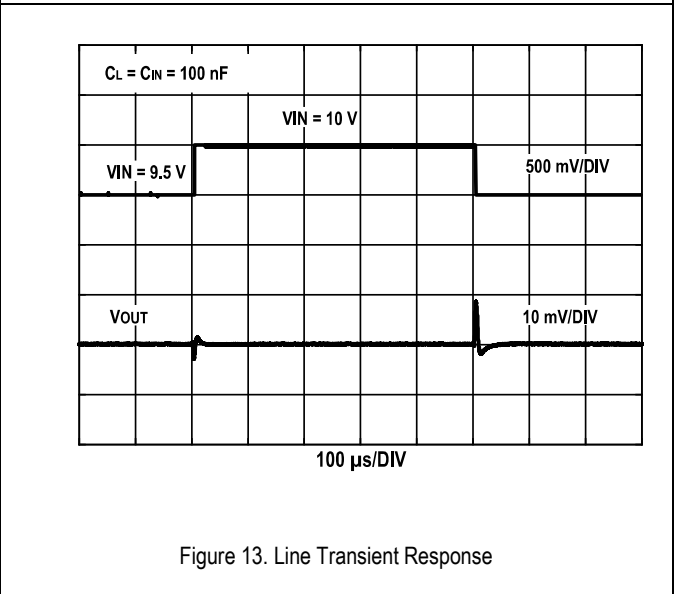
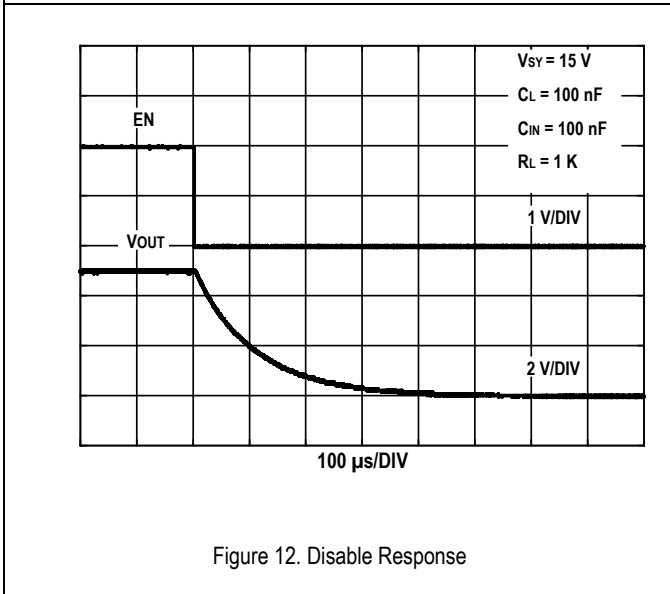
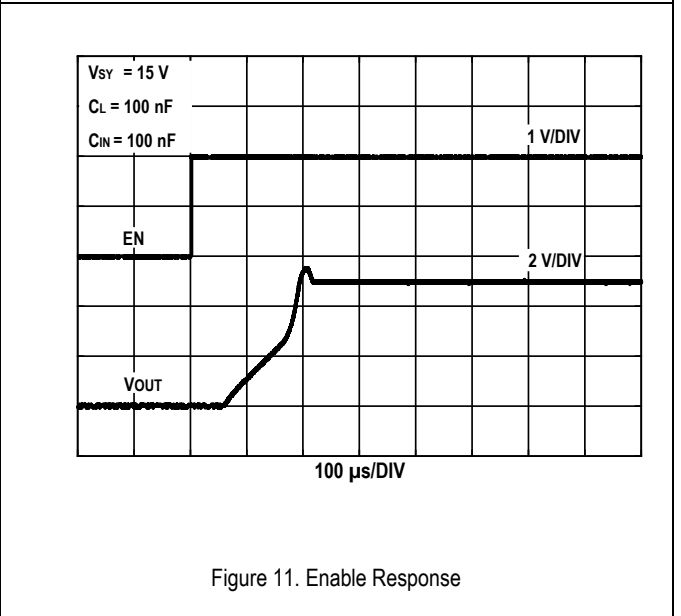
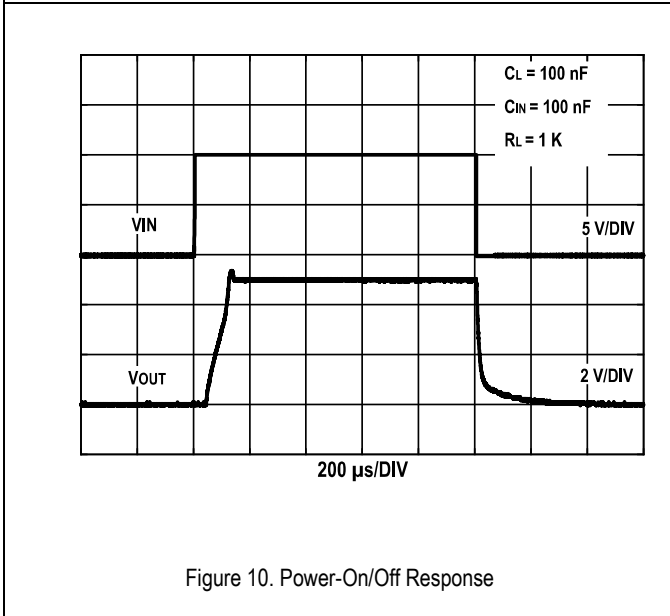
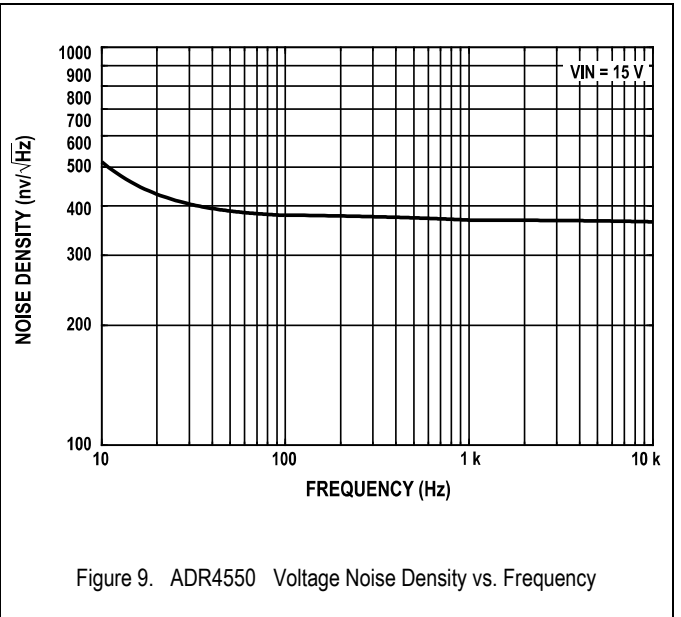
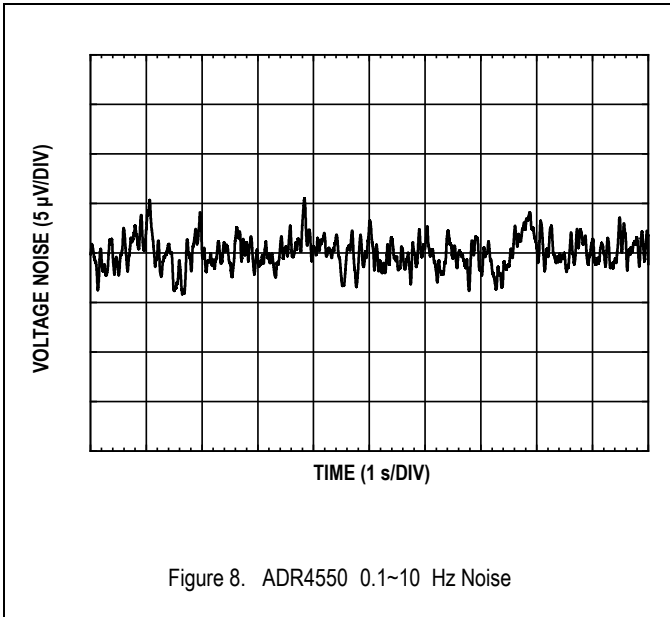


Figure 7. ADR4550 Load Regulation



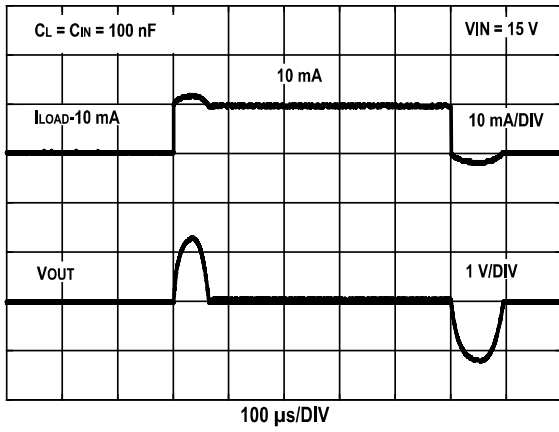


Figure 14. ADR4550 Load Transient Response

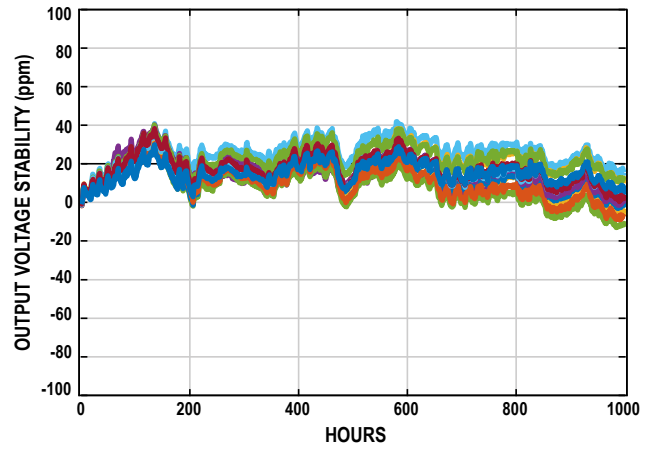


Figure 15. Long-Term Stability (MSOP-8 package)

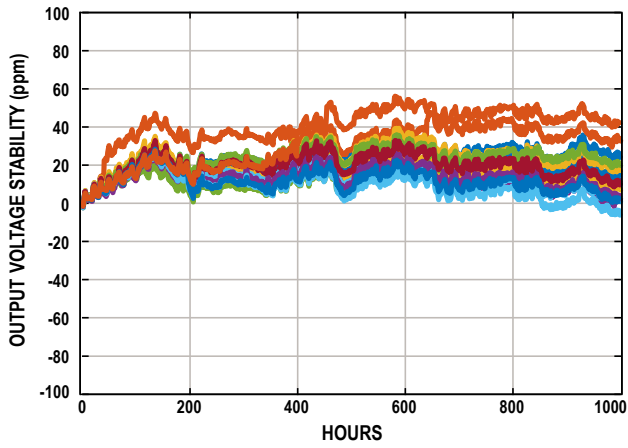


Figure 16. Long-Term Stability (SOIC-8 package)

## Terminology

### Temperature Coefficient

The change of output voltage over the operating temperature range is normalized by the output voltage at 25 °C, and expressed in ppm/°C as

$$dV_{OUT}/dT = \frac{V_{OUT(max)} - V_{OUT(min)}}{V_{OUT(25)} \times (T2 - T1)} \times 10^6$$

Where:

$V_{OUT(25)}$ : Output voltage at 25 °C.

$V_{OUT(min)}$ : The lowest output voltage over temperature T1 to T2 range.

$V_{OUT(max)}$ : The highest output voltage over temperature range T1 to T2.

For TOKMAS voltage references, temperature T1 is -40 °C, and T2 is +125 °C.

### Long-term Stability

This is the measurement of the change in output voltage of the measured device at 25 °C after 1000 hours (approximately 42 days) of operation at a constant ambient temperature. Generally measured in ppm. Long-term stability is not only affected by variations in the device itself, but also by soldering and board materials. Long-term stability generally exhibits a logarithmic characteristic, therefore the change in the second 1000 hours will be much smaller than the change in the first 1000 hours.

$$LTD = \frac{V_{OUT(t0)} - V_{OUT(t1)}}{V_{OUT(t0)}} \times 10^6$$

where:

$V_{OUT(t0)}$ : Output voltage at 25 °C at Time 0.

$V_{OUT(t1)}$ : Output voltage at 25 °C at Time 1 after 1000 hours of operation under constant ambient temperature.

### Thermal Hysteresis

The change of output voltage after the device is cycled through temperatures from +25 °C to -40 °C to +125 °C and back to +25 °C. This is a typical value from a sample of parts put through such a cycle. It is normally in ppm using the following equation:

$$TH = \frac{V_{OUT(25)} - V_{OUT(TC)}}{V_{OUT(25)}} \times 10^6$$

where:

$V_{OUT(25)}$ : Output voltage at 25 °C.

$V_{OUT(TC)}$ : Output voltage at 25 °C after the temperature cycle.

### Line Regulation

The change in output voltage due to a specified change in input voltage. It includes the effects of self-heating. Line regulation is expressed in either percent per volt, parts per million per volt, or microvolts per volt change in input voltage, such as ppm/V.

### Load Regulation

The change in output voltage due to a specified change in load current. It includes the effects of self-heating. Load regulation is expressed in either microvolts per milliampere or parts per million per milliampere, such as ppm/mA.

## Theory of Operation

ADRXXX is a family of low power, low noise and precision voltage reference, which were developed in 40 V BCD process. Figure 17 shows its simplified schematic. The bandgap circuit is the key building block, which was carefully optimized and trimmed in order to deliver the outstanding low temperature co-efficient. The output amplifier provides sufficient driving capability. EN enables or disables the part for normal operation.

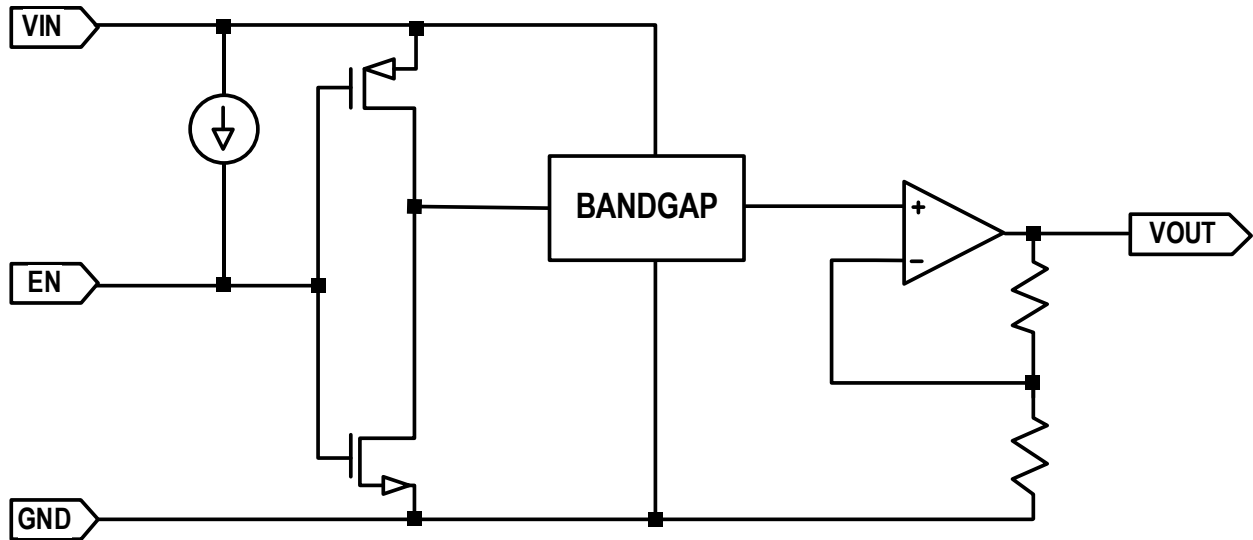


Figure 17. Simplified schematic of ADRXXX

## Applications

### Typical Configuration

Typical configuration of modern series voltage reference is straight forward. ADRXXX normally requires a load cap of  $0.1\ \mu\text{F}$ ~ $10\ \mu\text{F}$  between  $V_{\text{OUT}}$  and GND. An input bypass cap of  $1\ \mu\text{F}$  is desirable for better power supply rejection as show in Figure 18.

Note the load capacitor ranges from  $0.1\ \mu\text{F}$  to  $10\ \mu\text{F}$ . Excessive load cap might lead to output settling problem or sometimes oscillation, as well as slower start up. The equivalent series resistance (ESR) of cap is recommended to be less than  $1.5\ \text{ohm}$  in order to ensure circuit stability. Optimal capacitance value depends on the load condition of the part. For example, if ADRxxx directly drives SAR ADC, such as AD7690,  $1\ \mu\text{F}$  or  $2.2\ \mu\text{F}$  offers good noise and settling performance.

It is recommended to use surface-mounted ceramic capacitors (such as X5R, X7R). If an electrolytic capacitor is used at the output, a  $0.1\ \mu\text{F}$  ceramic capacitor should be placed in parallel to reduce the overall ESR at the output. In addition, the capacitors' operating temperature range and voltage rating shall be at least as wide as the system requirement.

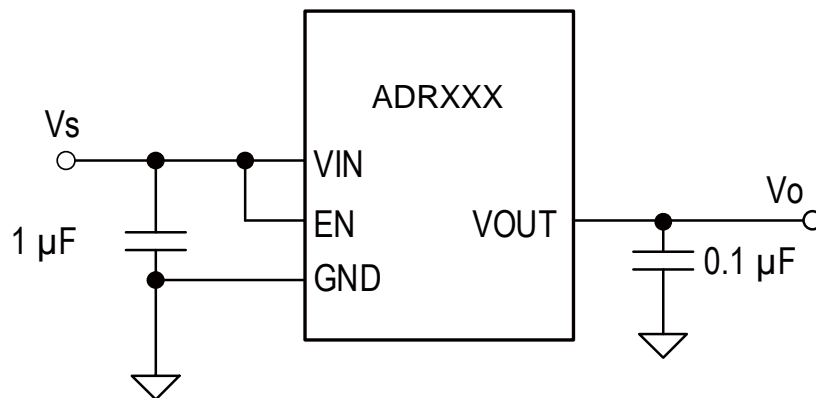


Figure 18. ADRXXX Typical Configuration

### Power on and Shutdown mode

Figure 10 shows the power-on process of ADRXXX. The value of the load capacitor affects the turn-on time. In general, the larger the load cap, the longer the settling time. Settling to higher accuracy sees exponentially longer turn-on time.

For power consumption sensitive applications, ADRXXX offers useful shut down feature. The part burns just  $10\ \mu\text{A}$  in shutdown mode, the shutdown procedure can be found in Figure 11 and Figure 12. Shutdown mode is controlled by pin 3 (EN). The voltage threshold of this pin is around  $1.2\ \text{V}$  and compatible with CMOS/TTL logic.

There is an internal weak pull-up current  $0.22\ \mu\text{A}$  on chip. If the pin is left floating, its voltage rises close to  $V_{\text{IN}}$  and the part is enabled. Due to the weak pull-up nature, it is recommended that the EN pin be pulled high externally for normal operation to prevent accidental shut down.

### Supply Voltage

ADRXXX has a wide supply voltage range. The lowest supply voltage for ADR4520 is  $2.8\ \text{V}$ , while in other versions it can be as low as output voltage plus  $300\ \text{mV}$ . Supply voltage of  $10\ \text{V}$  higher is widely used in many applications, such as industrial control systems. ADRXXX's highest supply voltage of  $40\ \text{V}$  might simplify system power supply design.

It is recommended to power ADRXXX by linear power supplies, such as LDO, in order to ensure high frequency performances.

## Layout Guidelines

- Place the power-supply bypass capacitor as closely as possible to the supply and ground pins. The recommended value of this bypass capacitor is from 1  $\mu\text{F}$  to 10  $\mu\text{F}$ . If necessary, additional decoupling capacitance can be added to compensate for noisy or high-impedance power supplies.
- The output must be decoupled with a bigger than 0.1  $\mu\text{F}$  capacitor. For better noise performance, the recommended ESR on the output capacitor is from 1  $\Omega$  to 1.5  $\Omega$ . For even lower noise, a larger capacitor in parallel or an RC filter can be added.
- Use large area ground plane if possible. Keep fast-changing or high-frequency interference signals far from ADRXXX.

## Layout Example

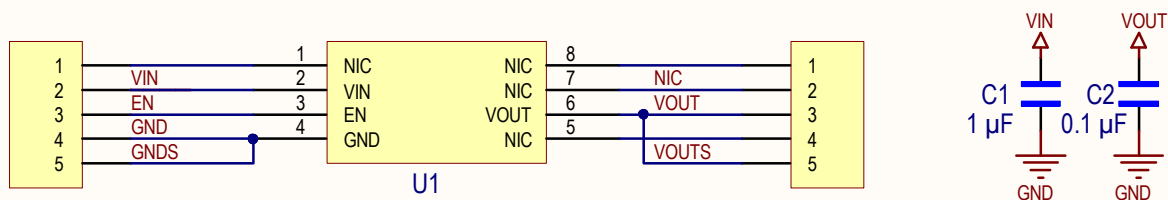


Figure 20. ADRXXX Evaluation Board Schematic

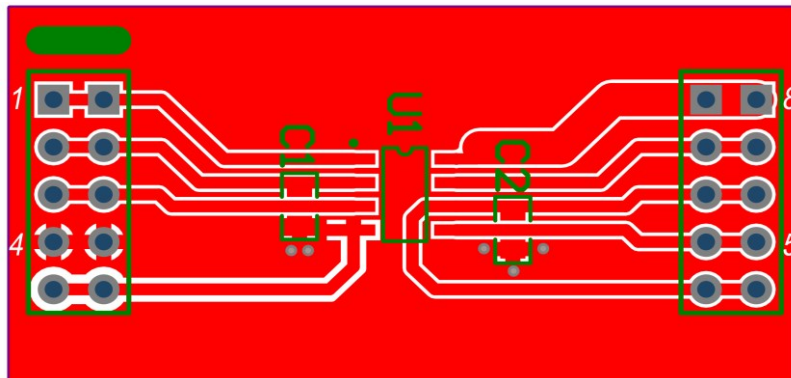


Figure 21. ADRXXX Evaluation Board Layout (Top Layer)



Figure 22. ADRXXX Evaluation Board Layout (Bottom Layer)

### Outline Dimensions

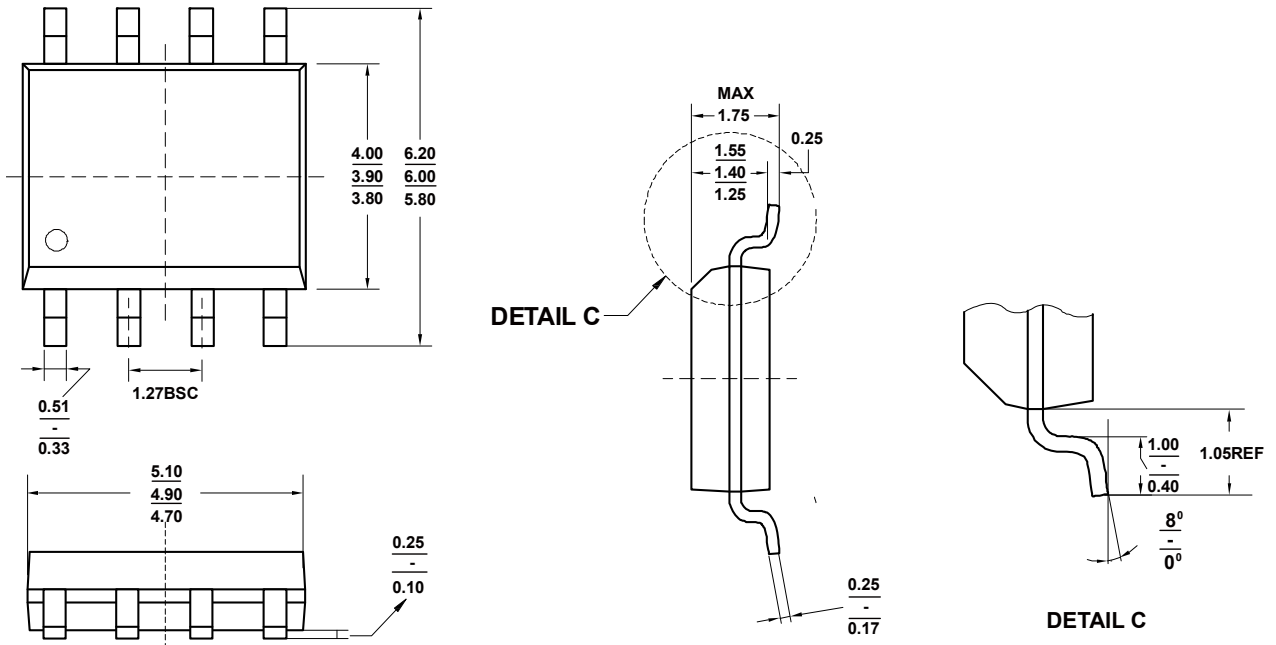


Figure 23. 8-Lead SOIC Package Dimensions shown in millimeters

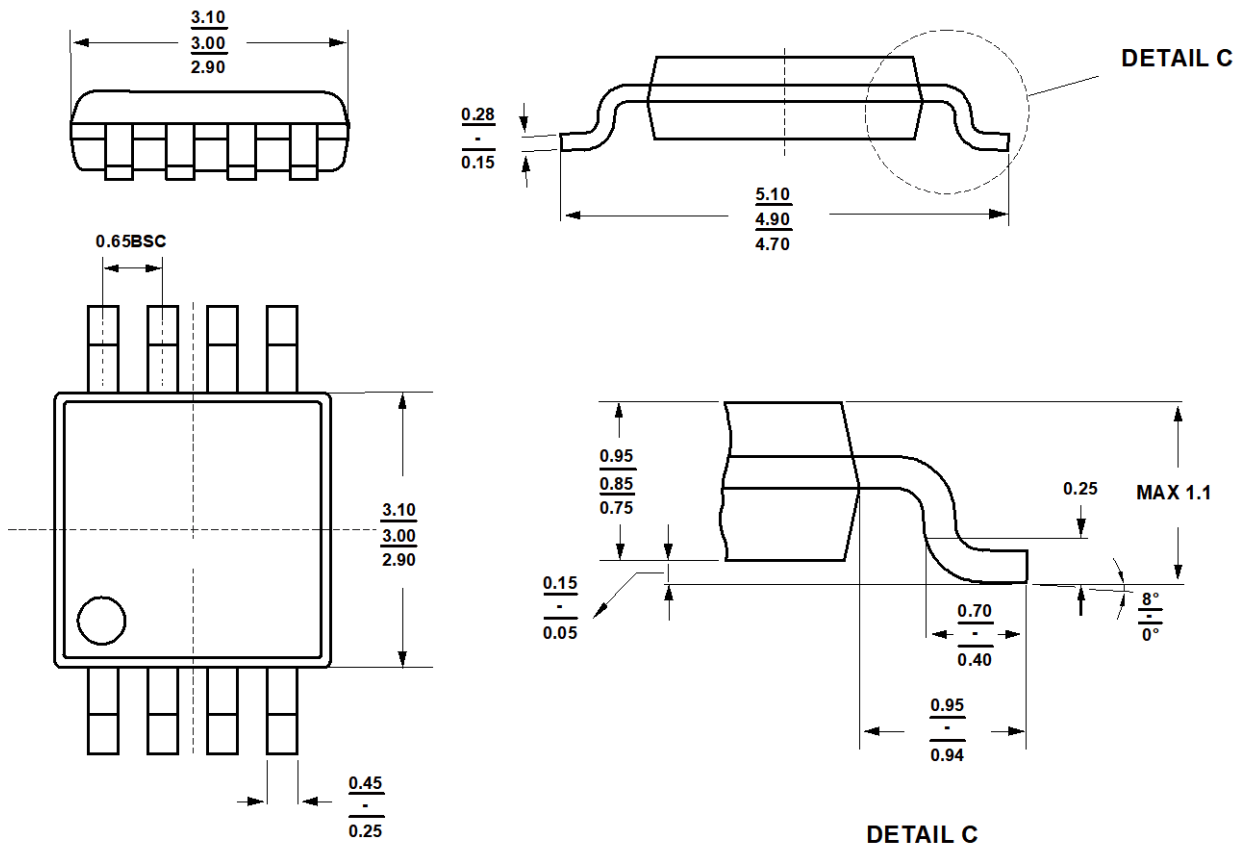


Figure 24. 8-Lead MSOP Package Dimensions shown in millimeters

## Ordering Guide

Model	Orderable Device	Temperature Range (°C)	Output Voltage (V)	Max TempCo (ppm/°C)	Package	External Package
ADR4520	ZADR4520BRZ	-40 to +125	2.048	5	SOIC-8	Tube
	ADR4520BRZ-R7				SOIC-8	13" Reel
	ADR4520BR				MSOP-8	Tube
	ADR4520BS				MSOP-8	13" Reel
	ADR4520ARZ			8	SOIC-8	Tube
	ADR4520ARZ-R7				SOIC-8	13" Reel
	ADR4520AR				MSOP-8	Tube
	ADR4520AS				MSOP-8	13" Reel
	ADR4520CRZ			3	SOIC-8	Tube
	ADR4520CRZ-R7				SOIC-8	13" Reel
	ADR4520CR				MSOP-8	Tube
	ADR4520CS				MSOP-8	13" Reel
	ADR4520DRZ	-40 to +85		5	SOIC-8	Tube
	ADR4520DRZ-R7				SOIC-8	13" Reel
	ADR4520DR				MSOP-8	Tube
	ADR4520DS				MSOP-8	13" Reel
	ADR4520ERZ			8	SOIC-8	Tube
	ADR4520DRZ-R7				SOIC-8	13" Reel
	ADR4520ER				MSOP-8	Tube
	ADR4520ES				MSOP-8	13" Reel
ADR4525	ADR4525ARZP	-40 to +125	2.5	5	SOIC-8	Tube
	ADR4525ARZ				SOIC-8	13" Reel
	ADR4525ARZB				MSOP-8	Tube
	ADR4525ARZC				MSOP-8	13" Reel
	ADR4525ARZE			8	SOIC-8	Tube
	ADR4525ARZ-R7				SOIC-8	13" Reel
	ADR4525AR				MSOP-8	Tube
	ADR4525AS				MSOP-8	13" Reel
	ADR4525BRP			3	SOIC-8	Tube
	ADR4525BRZ				SOIC-8	13" Reel
	ADR4525BR				MSOP-8	Tube
	ADR4525BS				MSOP-8	13" Reel
	ADR4525ARC	-40 to +85		5	SOIC-8	Tube
	ADR4525ARC-R7				SOIC-8	13" Reel
	ADR4525CR				MSOP-8	Tube
	ADR4525CS				MSOP-8	13" Reel
	ADR4525ERZ			8	SOIC-8	Tube
	ADR4525ERZ-R7				SOIC-8	13" Reel
	ADR4525ER				MSOP-8	Tube
	ADR4525ES				MSOP-8	13" Reel

Model	Orderable Device	Temperature Range (°C)	Output Voltage (V)	Max TempCo (ppm/°C)	Package	External Package		
ADR443	ADR443BRZ	-40 to +125	3	5	SOIC-8	Tube		
	ADR443BRZ-R7				SOIC-8	13" Reel		
	ADR443BR				MSOP-8	Tube		
	ADR443BS				MSOP-8	13" Reel		
	ADR443ARZ			SOIC-8	Tube			
	ADR443ARZ-R7			SOIC-8	13" Reel			
	ADR443AR			MSOP-8	Tube			
	ADR443AS			MSOP-8	13" Reel			
	ADR443CRZ	-40 to +85		3	3	SOIC-8	Tube	
	ADR443ARZ-R7					SOIC-8	13" Reel	
	ADR443CR					MSOP-8	Tube	
	ADR443CS					MSOP-8	13" Reel	
	ADR443DRZ	-40 to +85		5	5	SOIC-8	Tube	
	ADR443DRZ-R7					SOIC-8	13" Reel	
	ADR443DR					MSOP-8	Tube	
	ADR443DS					MSOP-8	13" Reel	
	ADR443ERZ				8	8	SOIC-8	Tube
	ADR443ERZ-R7						SOIC-8	13" Reel
	ADR443ER						MSOP-8	Tube
	ADR443ES						MSOP-8	13" Reel
ADR4533	ADR4533BRZ	-40 to +125	3.3	5	SOIC-8	Tube		
	ADR4533BRZ-R7				SOIC-8	13" Reel		
	ADR4533BR				MSOP-8	Tube		
	ADR4533BS				MSOP-8	13" Reel		
	ADR4533ARZ			8	8	SOIC-8	Tube	
	ADR4533ARZ-R7					SOIC-8	13" Reel	
	ADR4533AR					MSOP-8	Tube	
	ADR4533AS					MSOP-8	13" Reel	
	ADR4533CRZ	-40 to +85		3	3	SOIC-8	Tube	
	ADR4533CRZ-R7					SOIC-8	13" Reel	
	ADR4533CR					MSOP-8	Tube	
	ADR4533CS					MSOP-8	13" Reel	
	ADR4533DRZ	-40 to +85		5	5	SOIC-8	Tube	
	ADR4533DRZ-R7					SOIC-8	13" Reel	
	ADR4533DR					MSOP-8	Tube	
	ADR4533DS					MSOP-8	13" Reel	
	ADR4533ERZ			8	8	8	SOIC-8	Tube
	ADR4533ERZ-R7						SOIC-8	13" Reel
	ADR4533ER						MSOP-8	Tube
	ADR4533ES						MSOP-8	13" Reel



Model	Orderable Device	Temperature Range (°C)	Output Voltage (V)	Max TempCo (ppm/°C)	Package	External Package
ADR4540	ADR4540BRZ	-40 to +125	4.096	5	SOIC-8	Tube
	ADR4540BRZ-R7				SOIC-8	13" Reel
	ADR4540BR				MSOP-8	Tube
	ADR4540BS				MSOP-8	13" Reel
	ARZ4540ARZ			8	SOIC-8	Tube
	ADR4540ARZ-R7				SOIC-8	13" Reel
	ADR4540AR				MSOP-8	Tube
	ADR4540AS				MSOP-8	13" Reel
	ADR4540CRZ	3	SOIC-8	Tube		
	ADR4540CRZ-R7		SOIC-8	13" Reel		
	ADR4540CR		MSOP-8	Tube		
	ADR4540CS		MSOP-8	13" Reel		
	ADR4540DRZ	-40 to +85	4.096	5	SOIC-8	Tube
	ADR4540DRZ-R7				SOIC-8	13" Reel
	ADR4540DR				MSOP-8	Tube
	ADR4540DS				MSOP-8	13" Reel
ADR4540ERZ	8			SOIC-8	Tube	
ADR4540ERZ-R7				SOIC-8	13" Reel	
ADR4540ER				MSOP-8	Tube	
ADR4540ES				MSOP-8	13" Reel	
ADR4550	ADR4550BRZ	-40 to +125	5.0	5	SOIC-8	Tube
	ADR4550BRZ-R7				SOIC-8	13" Reel
	ADR4550BR				MSOP-8	Tube
	ADR4550BS				MSOP-8	13" Reel
	ADR4550ARZ			8	SOIC-8	Tube
	ADR4550ARZ-R7				SOIC-8	13" Reel
	ADR4550AR				MSOP-8	Tube
	ADR4550AS				MSOP-8	13" Reel
	ADR4550CRZ	3	SOIC-8	Tube		
	ADR4550CRZ-R7		SOIC-8	13" Reel		
	ADR4550CR		MSOP-8	Tube		
	ADR4550CS		MSOP-8	13" Reel		
	ADR4550DRZ	-40 to +85	5.0	5	SOIC-8	Tube
	ADR4550DRZ-R7				SOIC-8	13" Reel
	ADR4550DR				MSOP-8	Tube
	ADR4550DS				MSOP-8	13" Reel
ADR4550ERZ	8			SOIC-8	Tube	
ADR4550ERZ-R7				SOIC-8	13" Reel	
ADR4550ER				MSOP-8	Tube	
ADR4550ES				MSOP-8	13" Reel	