Low Noise, Low Temperature Drift, Precise Voltage Reference

Features

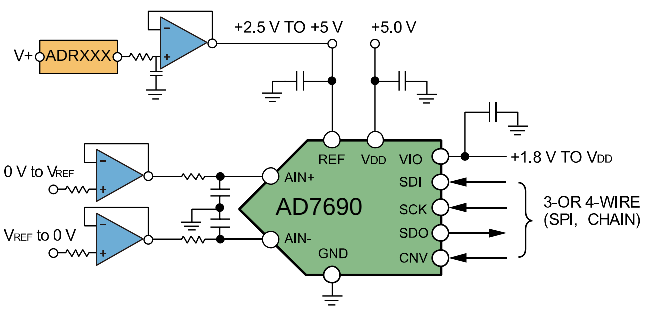
- Low Temperature Drift: 5 ppm/°C max (B Grade)
- High Accuracy: ±0.05% max
- Low Noise (0.1 Hz to 10 Hz): 7.0 μV_{P-P}, 1.25 V Output Voltage
- Wide Supply Range: up to 15 V
- Quiescent Current: 715 μA; 16 μA Shutdown Mode
- Wide Temperature Range: -40 °C to +125 °C

Application

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

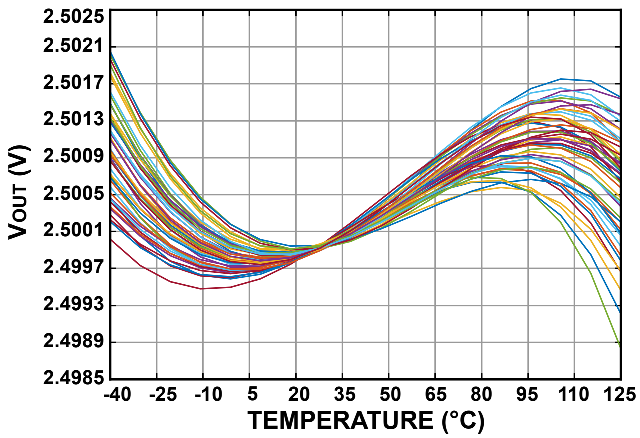
Typical Application

ADR34XX/4XX Used as ADC Voltge Reference

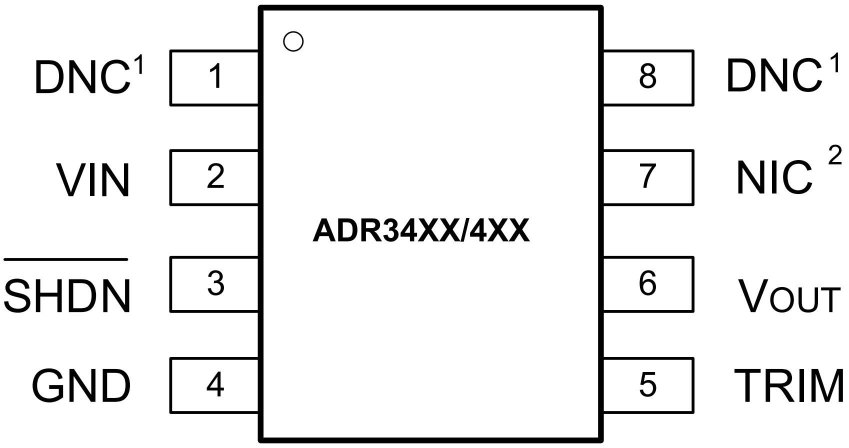


Typical Characteristics

ADR431X Output Voltge vs.Temperature



Pin Configurations and Function Descriptions



Note: 1 DNC = Do Not Connect； 2 NIC = No Internal Connection

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

Mnemonic	Pin No.	I/O[1]	Description
DNC	1,8	--	Do not connect. There are actual connections in DNC pins, but they are reserved for factory testing purposes. Users should not connect anything to DNC pins; otherwise, the device may not function properly.
VIN	2	AI	Input voltage
$\overline{SHDN}$	3	AI	Shutdown Input. This active low input powers down the device to 16 µA. 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.
TRIM	5	AO	Trim Terminal. It can be used to adjust the output voltage over ±0.5 % range without affecting the temperature coefficient.
V_{OUT}	6	AO	Output voltage
NIC	7	--	No Internal Connection. NIC has no internal connection.

[1] AI: Analog Input; P: Power; AO: Analog Output.

Absolute Maximum Ratings [1]

Parameter	Rating
Supply Voltage	15 V
Input Voltage	-0.2 V to 15 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)	3.5 kV

Thermal Resistance [5]

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

Specifications [1]

The ● denotes the specification which apply over the full operating temperature range, otherwise specifications are at VIN = 2.5 V to 15.0 V, I_{LOAD} = 0, C_L = 0.1 μF, T_A = 25 °C, unless otherwise noted.

Parameter	Symbol	Conditions		Min	Typ.	Max	Unit
Output Voltage	V_{OUT}	LT6657			1.25		V
		ADR4520			2.048		V
		ADR431			2.5		V
		AD780			3.0		V
		ADR4540			4.096		V
		ADR445			5.0		V
Initial Accuracy				-0.05		+0.05	%
Temperature Coefficient							
B Grade		-40 °C to +125 °C	●		3.6	5	ppm/°C
A Grade			●		5	8	ppm/°C
Voltage Noise		0.1 Hz to 10 Hz			6		ppm_p-p
Voltage Noise Density	e_{ni}	LT6657 1kHz			76		nV/√Hz
		ADR4520 1kHz			138		nV/√Hz
		ADR431 1kHz			178		nV/√Hz
		AD780 1kHz			240		nV/√Hz
		ADR4540 1kHz			385		nV/√Hz
		ADR445 1kHz			495		nV/√Hz
Line Regulation		VIN = (V_{OUT} + 0.3) V to 15 V	●		1	5	ppm/V
Load Regulation		-5 mA < I_{LOAD} < 5 mA	●		1	20	ppm/mA
Supply Voltage	VIN	I_{LOAD} = 5 mA, Output Voltage Error ≤ 0.1%					
		LT6657/ADR4520	●	2.5		15	V
		Others	●	V_{OUT} + 0.3		15	V
Quiescent Current	I_{SY}	No Load			715		μA
			●	580	765	950	μA
Shutdown Current		$\overline{SHDN}$ Tied to GND	●		16	33	μA

[1] Each parameter can be found in the Terminology section of this data sheet.

Parameter	Symbol	Conditions		Min	Typ.	Max	Unit
Shutdown Pin ($\overline{SHDN}$)		Logic High Input Voltage	●	2		VIN	V
		Logic High Input Current	●		1.5		μA
		Logic Low Input Voltage	●			0.8	V
		Logic Low Input Current	●		1.5	2.5	μA
Output Short Circuit Current	I_{SC}	V_{OUT} = GND or VIN	●	14.5	20		mA
Turn-on Time		0.1% settling, C_L = 0.1 μF			100		μs
Long-Term Stability[2]	LTD	1000 hours, SOIC-8			-35		ppm/1000 hours
		1000 hours, MSOP-8			26		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

[2] Data collected using devices soldered onto the test board.

Typical Performance Characteristics

At VIN = 2.5 V to 15.0 V, I_{LOAD} = 0, C_L = 0.1 µF, T_A = 25 °C, unless otherwise noted.

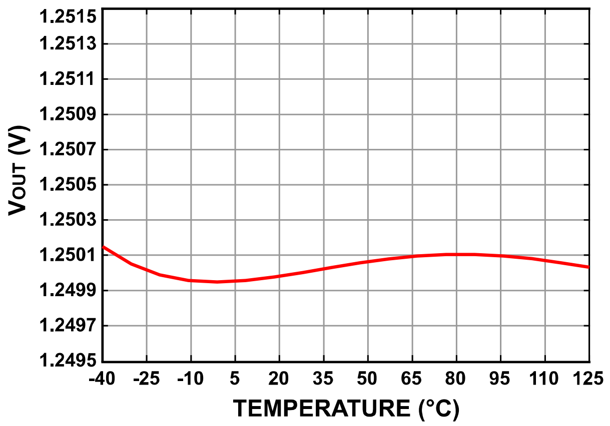


Figure 2. LT6657 Typical Output Voltage vs. Temperature

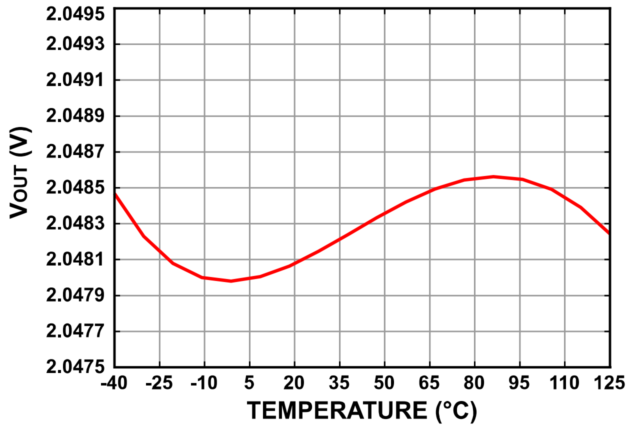


Figure 3. ADR4520 Typical Output Voltage vs. Temperature

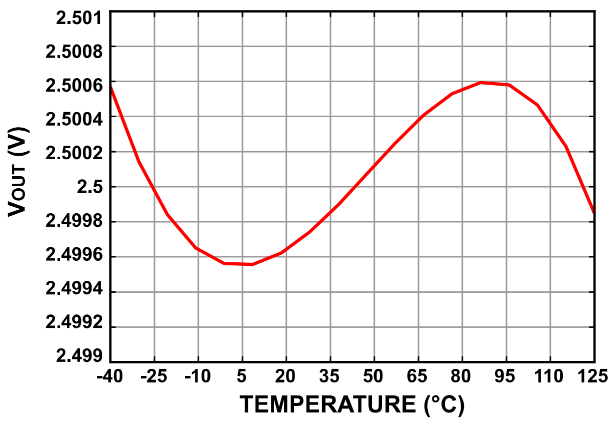


Figure 4. ADR431 Typical Output Voltage vs. Temperature

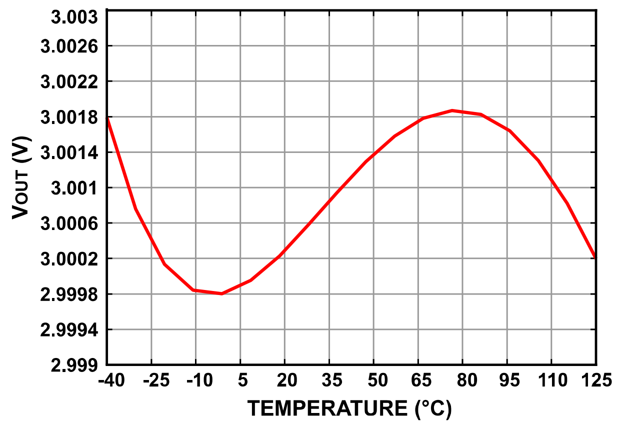


Figure 5. ADR780 Typical Output Voltage vs. Temperature

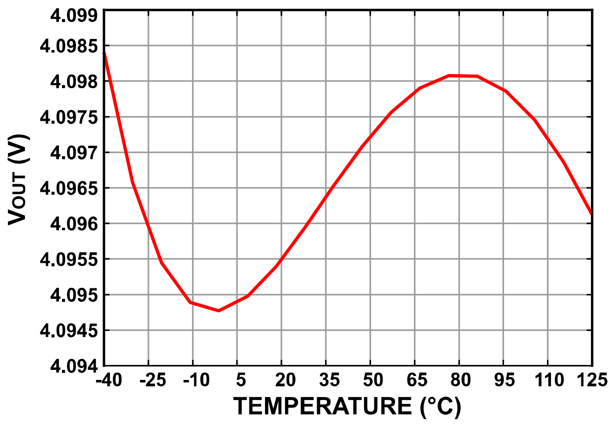


Figure 6. ADR4540 Typical Output Voltage vs. Temperature

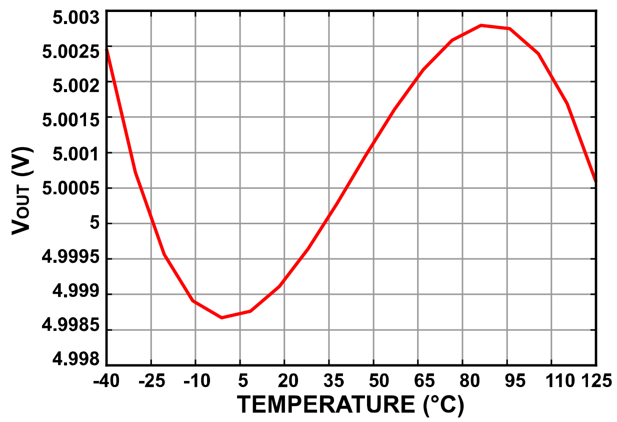


Figure 7. ADR445 Typical Output Voltage vs. Temperature

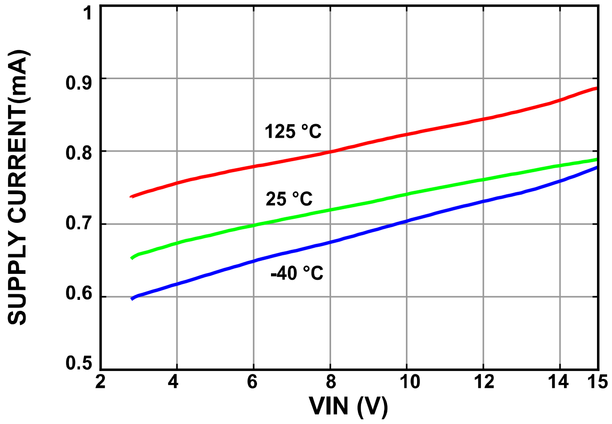


Figure 8. ZADR431 Supply Current vs. Input Voltage

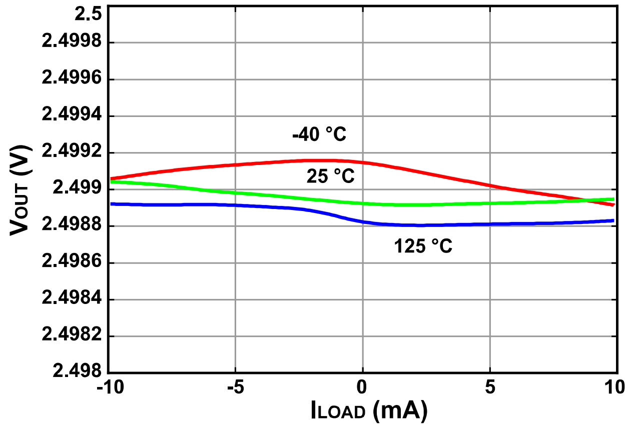


Figure 9. ADR431 Load Regulation vs. Temperature

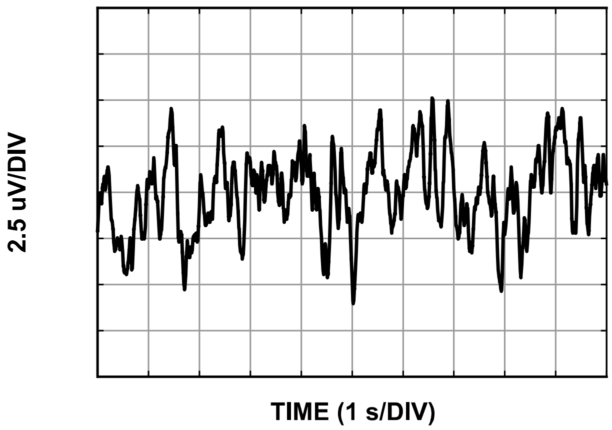


Figure 10. ADR431 Typical Voltage Noise (0.1 Hz to 10 Hz)

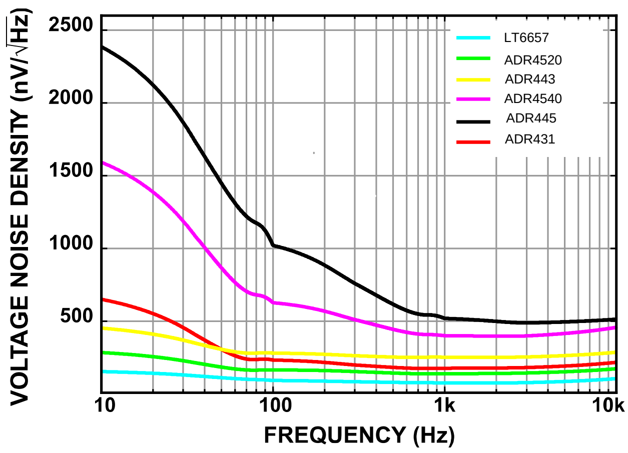


Figure 11. Voltage Noise Density vs. Frequency

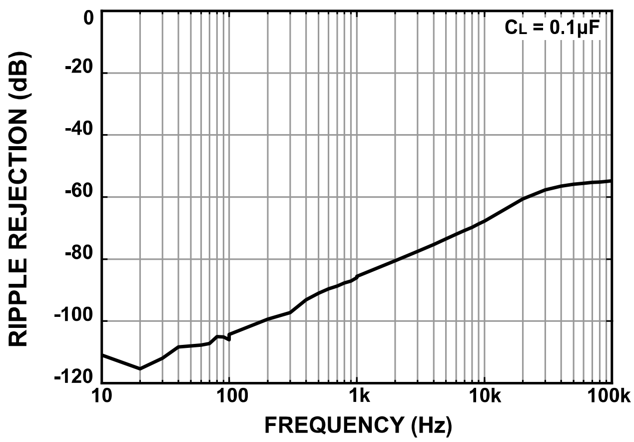


Figure 12. ADR431 Power Supply Rejection Ratio vs. Frequency

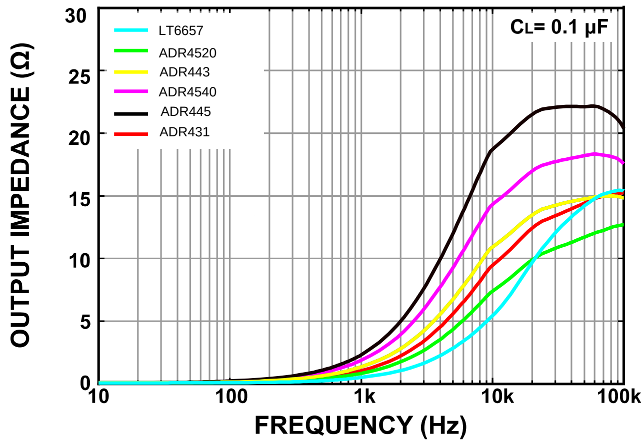


Figure 13. Output Impedance vs. Frequency

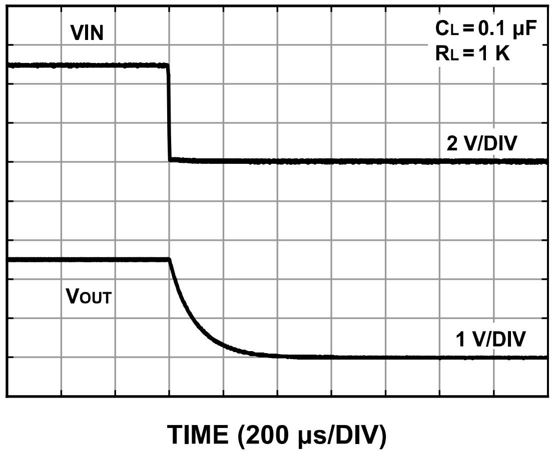


Figure 14. ADR431 Turn-Off Response

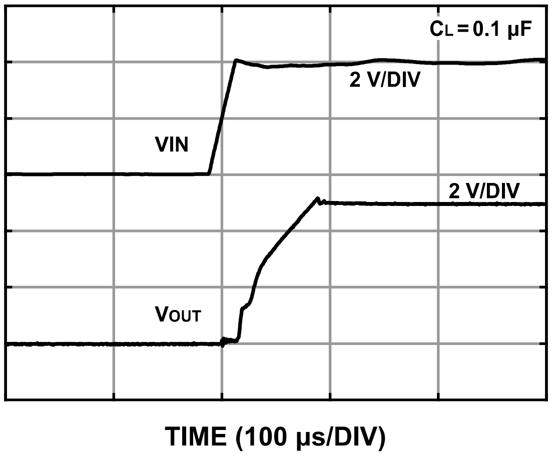


Figure 15. ADR431 Turn-On Response

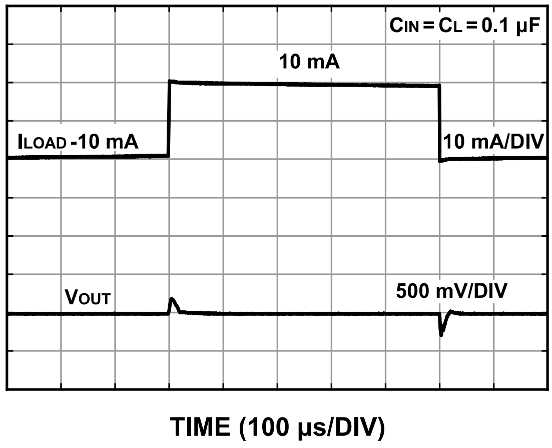


Figure 16. Load Transient Response

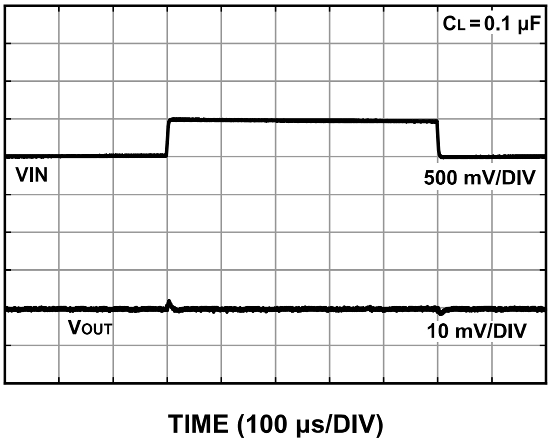


Figure 17. Line Transient Response

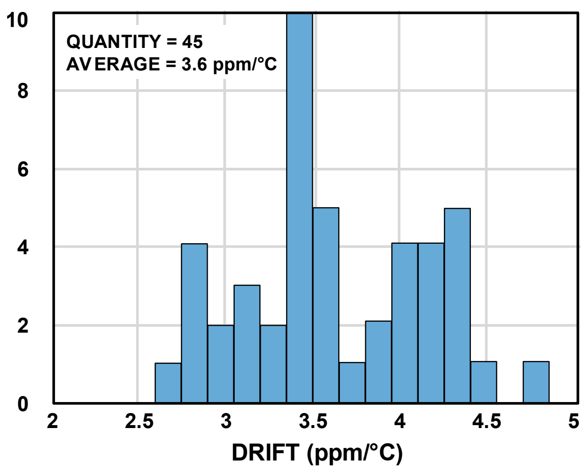


Figure 18. ADR431 Temperature Coefficient Distribution (MSOP-8)

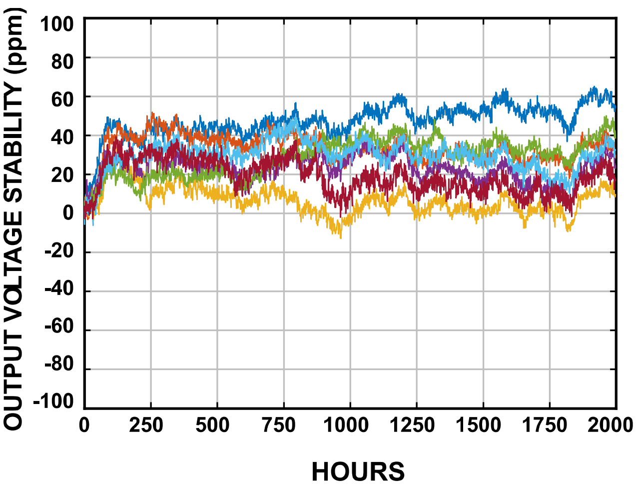


Figure 19. Long-Term Stability (MSOP-8)

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

LT6657 series of precision voltage references adopt 15 V high-voltage CMOS process. Figure 20 shows LT6657'S internal blocks. The bandgap reference is the core, which has been carefully designed and can deliver the key performances by proprietary post-package trimming. The output stage provides enough drive capability while keeping high performances. The TRIM terminal can be used to adjust the output voltage over ±0.5% range. This feature allows the system designer to trim system errors out by setting the reference to a voltage other than the nominal. All pins have the internal protection circuit in order to make LT6657 a reliable part.

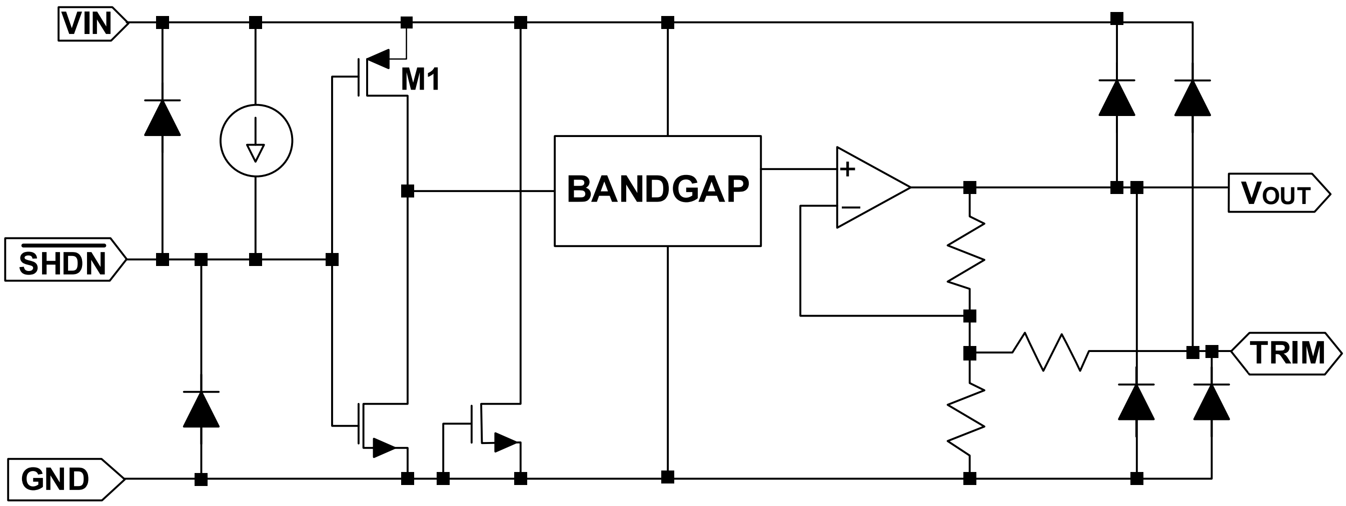


Figure 20. Simplified Schematic of LT6657

Voltage Reference Noise to ADC Resolution

In general, the voltage reference's 0.1 Hz to 10 Hz noise should be within ADC's 1/2 LSB. With the same resolution, the larger the full scale voltage, the lower the noise requirement to the voltage reference as can be found in Table 1. LT6657 is able to be used as 16 -bit ADC voltage reference.

Resolution (bit)	0.1 Hz to 10 Hz Noise (μV_{P-P})	
	2.5 V Full Scale Voltage	5 V Full Scale Voltage
8	4,882.8	9,765.6
10	1,220.7	2,441.4
12	305.2	610.4
14	76.3	152.6
16	19.1	38.1
18	4.8	9.5

Table 1. ADC Resolution vs. Voltage Reference Noise

Negative Output Precision Voltage References

In some systems, negative output voltage reference is needed, Figure 25 shows a simple way to get a negative output precision voltage reference by using LT6657 . Extra resistor R is needed together with the negative power supply. ADR431 is used to verify the circuit, and the power supplies are ±5 V (Vcc = 5 V, Vee = - 5 V). The current on resistor R is (Vee - Vo)/R, and the power dissipation is $(Vee - Vo)^2/R$. In order to get higher performances negative output voltage reference, lower heat is critical. So when the voltage drop on R is high, proper value of R should be picked. Meanwhile, resistor R won't impact the negative output voltage reference's temperature coefficient.

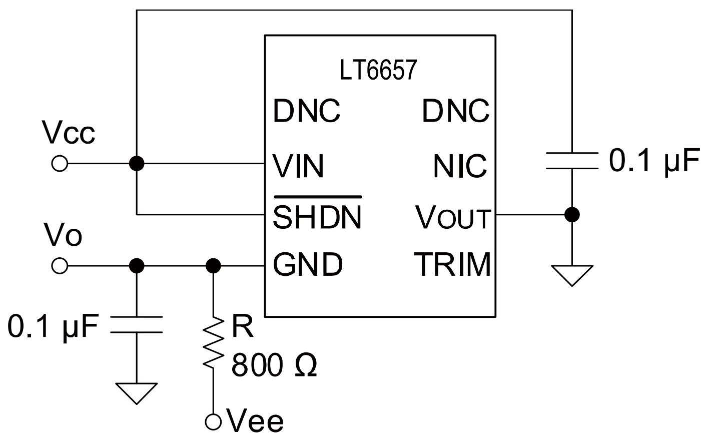


Figure 25. Using LT6657 to Generate Negative Output Precision Voltage Reference

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 μF to 10 μF. 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 μF capacitor. For better noise performance, the recommended ESR on the output capacitor is from 1 Ω to 1.5 Ω. 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 LT6657.

Layout Example

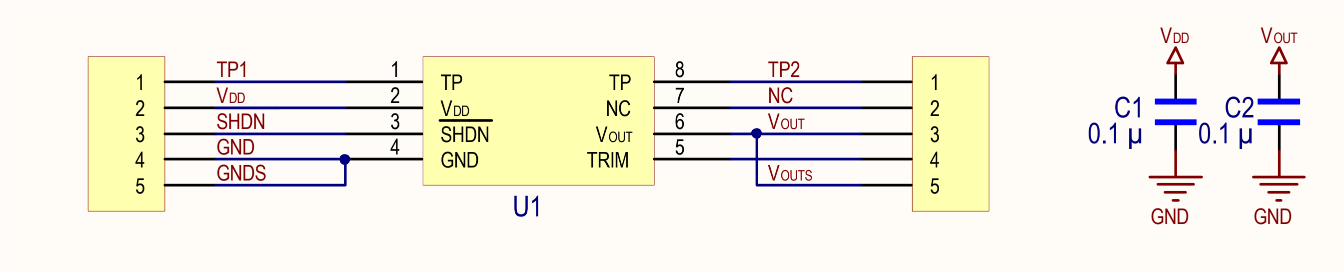


Figure 26. LT6657 Evaluation Board Schematic

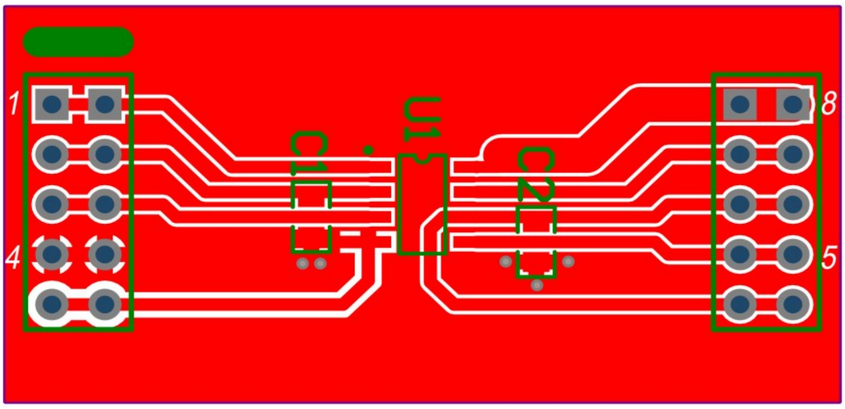


Figure 27. LT6657 Evaluation Board Layout (Top Layer)

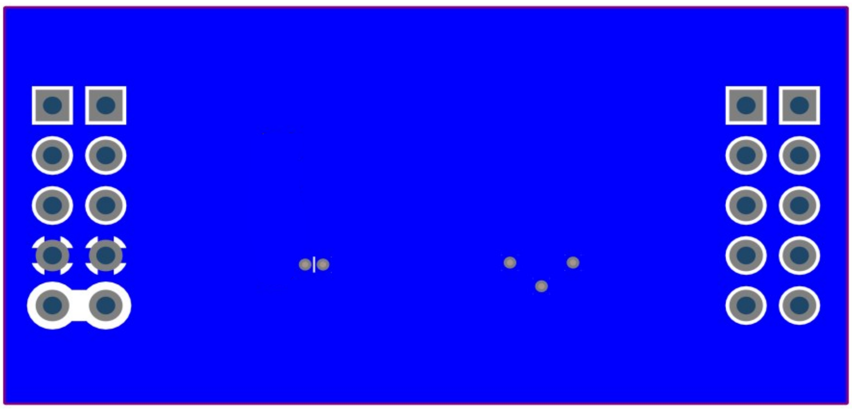


Figure 28. LT6657 Evaluation Board Layout (Bottom Layer)

Outline Dimensions

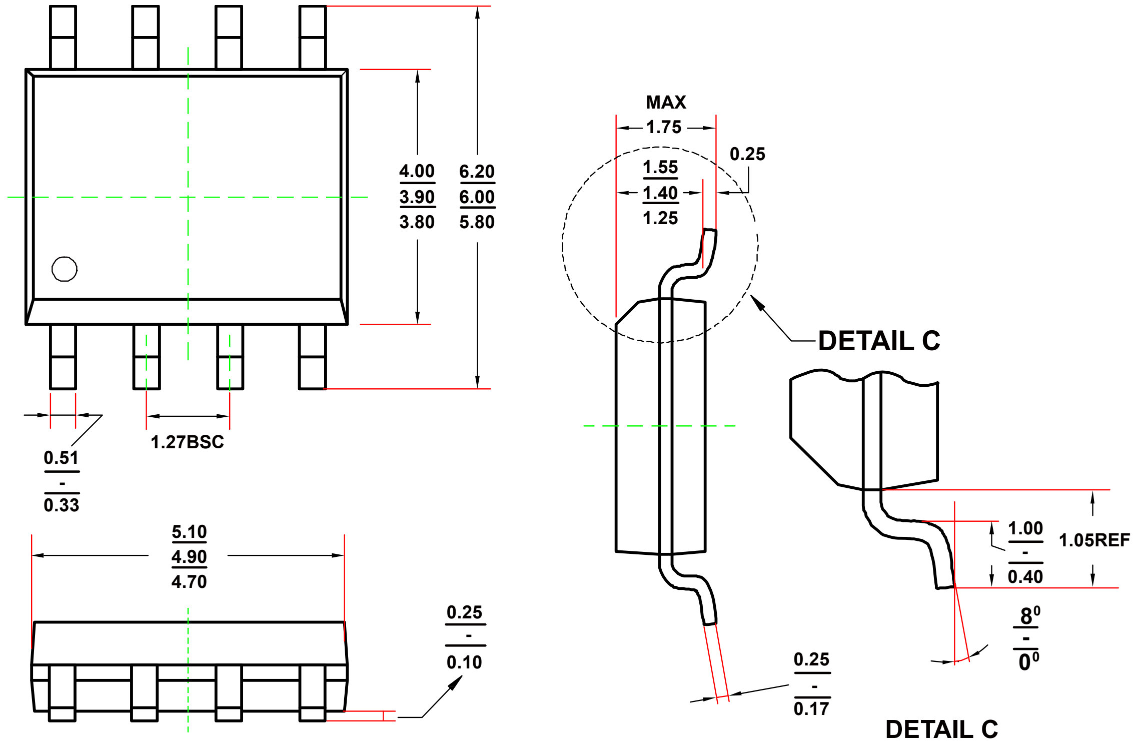


Figure 29. 8-Lead SOIC Package Dimensions shown in millimeters

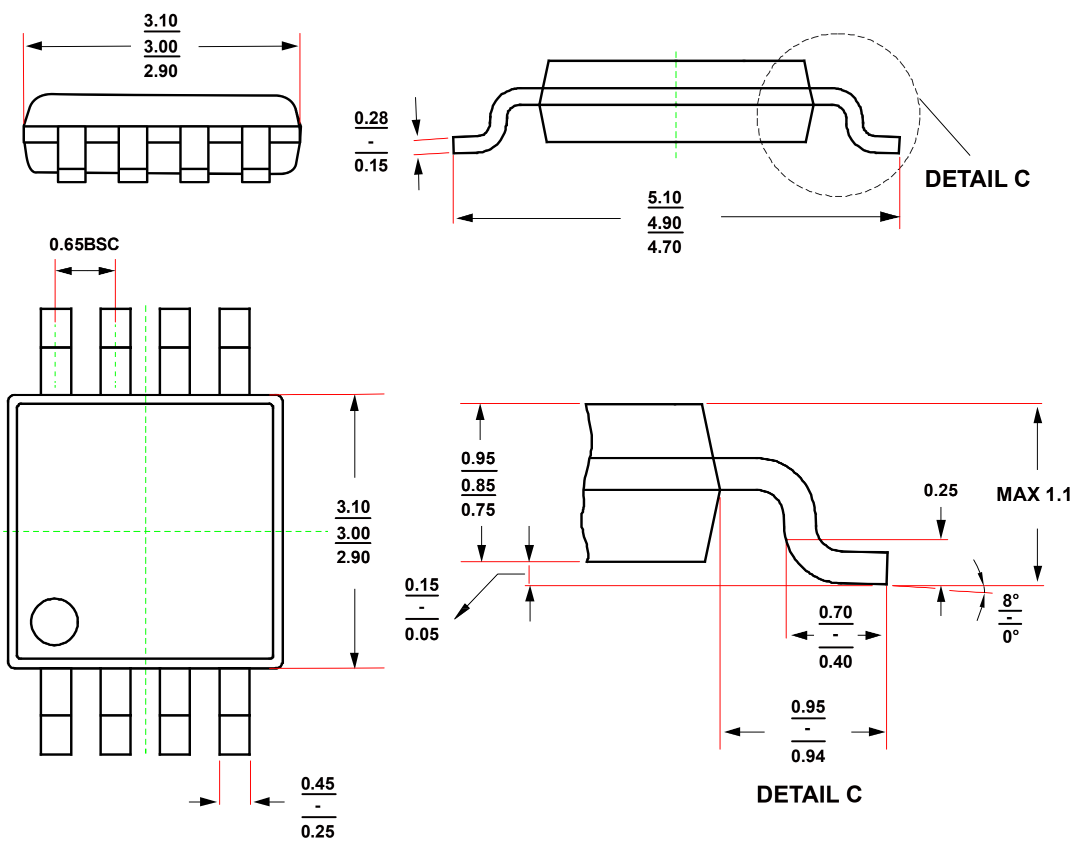


Figure 30. 8-Lead MSOP Package Dimensions shown in millimeters

Ordering Guide

Model	Orderable Device	Status[1]	Output Voltage (V)	Max TempCo (ppm/°C)	Temperature Range (°C)	Package	External Package
LT6657	LT6657A	ACTIVE	1.25	3	-40 to +125	SOIC - 8	Tube
	LT6657M	ACTIVE				SOIC - 8	13" Reel
	LT6657B	ACTIVE				MSOP - 8	Tube
	LT6657C	ACTIVE				MSOP - 8	13" Reel
	LT6657D	ACTIVE		5		SOIC - 8	Tube
	LT6657F	ACTIVE				SOIC - 8	13" Reel
	LT6657G	ACTIVE				MSOP - 8	Tube
	LT6657H	ACTIVE				MSOP - 8	13" Reel
	LT6657I	ACTIVE		8		SOIC - 8	Tube
	LT6657J	ACTIVE				SOIC - 8	13" Reel
	LT6657K	ACTIVE				MSOP - 8	Tube
	LT6657L	ACTIVE				MSOP - 8	13" Reel
ADR4520	ADR4520ARZ	ACTIVE	2.048	5	-40 to +125	SOIC - 8	Tube
	ADR4520ARZ-R7	ACTIVE				SOIC - 8	13" Reel
	ADR4520AR	ACTIVE				MSOP - 8	Tube
	ADR4520R	ACTIVE				MSOP - 8	13" Reel
	ADR4520BRZ	ACTIVE		8		SOIC - 8	Tube
	ADR4520BRZ-R7	ACTIVE				SOIC - 8	13" Reel
	ADR4520BR	ACTIVE				MSOP - 8	Tube
	ADR4520S	ACTIVE				MSOP - 8	13" Reel
ADR431	ADR431ARZ	ACTIVE	2.5	5	-40 to +125	SOIC - 8	Tube
	ADR431ARZ-R7	ACTIVE				SOIC - 8	13" Reel
	ADR431AR	ACTIVE				MSOP - 8	Tube
	ADR431R	ACTIVE				MSOP - 8	13" Reel
	ADR431BRZ	ACTIVE		8		SOIC - 8	Tube
	ADR431BRZ-REE7	ACTIVE				SOIC - 8	13" Reel
	ADR431BRM	ACTIVE				MSOP - 8	Tube
	ADR431BRM-REE7	ACTIVE				MSOP - 8	13" Reel

Model	Package	Orderable Device	Output Voltage (V)	Max TempCo (ppm/°C)	Temperature Range (°C)	External Package
AD780	SOIC - 8	AD780BRZ	3	5	- 40 to +125	Tube
	SOIC - 8	ADR780BRZ-REEL7		5	- 40 to +125	13" Reel
	MSOP - 8	AD780BR		5	- 40 to +125	Tube
	MSOP - 8	AD780BS		5	- 40 to +125	13" Reel
	SOIC - 8	AD780ARZ		8	- 40 to +125	Tube
	SOIC - 8	AD780ARZ-REEL7		8	- 40 to +125	13" Reel
	MSOP - 8	AD780AR		8	- 40 to +125	Tube
	MSOP - 8	AD780AS		8	- 40 to +125	13" Reel
ADR4540	SOIC - 8	ADR4540BRZ	4.096	5	- 40 to +125	Tube
	SOIC - 8	ADR4540BRZ-R7		5	- 40 to +125	13" Reel
	MSOP - 8	ADR4540BR		5	- 40 to +125	Tube
	MSOP - 8	ADR4540BS		5	- 40 to +125	13" Reel
	SOIC - 8	ADR4540ARZ		8	- 40 to +125	Tube
	SOIC - 8	ADR4540ARZ-R7		8	- 40 to +125	13" Reel
	MSOP - 8	ADRAR		8	- 40 to +125	Tube
	MSOP - 8	ADR4540AS		8	- 40 to +125	13" Reel
ADR445	SOIC - 8	ADR445BRZ-REEL7	5	5	- 40 to +125	Tube
	SOIC - 8	ADR445BRZ		5	- 40 to +125	13" Reel
	MSOP - 8	ADR445BR		5	- 40 to +125	Tube
	MSOP - 8	ADR445BS		5	- 40 to +125	13" Reel
	SOIC - 8	ADR445ARZ-REEL7		8	- 40 to +125	Tube
	SOIC - 8	ADR445ARZ		8	- 40 to +125	13" Reel
	MSOP - 8	ADR445AR		8	- 40 to +125	Tube
	MSOP - 8	ADR445AS		8	- 40 to +125	13" Reel