



Precision Low-Drift 2.048 V/2.500 V SOT-23 Voltage References

ADR380/ADR381

FEATURES

Initial Accuracy: ± 5 mV/ ± 6 mV max
Initial Accuracy Error: $\pm 0.24\%$ / $\pm 0.24\%$
Low TCV₀: 25 ppm/°C max
Load Regulation: 70 ppm/mA
Line Regulation: 25 ppm/V
Wide Operating Range:
2.4 V–18 V for ADR380
2.8 V–18 V for ADR381
Low Power: 120 μ A max
High Output Current: 5 mA
Wide Temperature Range: -40°C to $+85^{\circ}\text{C}$
Tiny 3-Lead SOT-23 Package with Standard Pinout

APPLICATIONS

Battery-Powered Instrumentation
Portable Medical Instruments
Data Acquisition Systems
Industrial Process Control Systems
Hard Disk Drives
Automotive

PIN CONFIGURATION

3-Lead SOT-23
(RT Suffix)

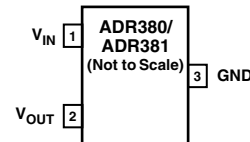


Table I. ADR38x Products

Part Number	Nominal Output Voltage (V)
ADR380	2.048
ADR381	2.500

GENERAL DESCRIPTION

The ADR380 and ADR381 are precision 2.048 V and 2.500 V bandgap voltage references featuring high accuracy, high stability, and low-power consumption in a tiny footprint. Patented temperature drift curvature correction techniques minimize nonlinearity of the voltage change with temperature. The wide operating range and low-power consumption make them ideal for 3 V–5 V battery-powered applications.

The ADR380 and ADR381 are micropower, Low Dropout Voltage (LDV) devices that provide a stable output voltage from supplies as low as 300 mV above the output voltage. They are specified over the industrial (-40°C to $+85^{\circ}\text{C}$) temperature range. ADR380/ADR381 is available in the tiny 3-lead SOT-23 package.

REV. 0

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ADR380/ADR381—SPECIFICATIONS

ADR380 ELECTRICAL CHARACTERISTICS (@ $V_{IN} = 5.0\text{ V}$, $T_A = 25^\circ\text{C}$ unless otherwise noted.)

Parameter	Symbol	Conditions	Min	Typ	Max	Unit
Output Voltage	V_O		2.043	2.048	2.053	V
Initial Accuracy Error	V_{OERR}		-5		+5	mV
Temperature Coefficient	TCV_O	$-40^\circ\text{C} < T_A < +85^\circ\text{C}$ $0^\circ\text{C} < T_A < 70^\circ\text{C}$	-0.24	5	+0.24	%
Minimum Supply Voltage Headroom	$V_{IN} - V_O$	$I_L \leq 3\text{ mA}$		300		mV
Line Regulation	$\Delta V_O / \Delta V_{IN}$	$V_{IN} = 2.5\text{ V to } 15\text{ V}$ $-40^\circ\text{C} < T_A < +85^\circ\text{C}$		10	25	ppm/V
Load Regulation	$\Delta V_O / \Delta I_{LOAD}$	$V_{IN} = 3\text{ V}$, $I_{LOAD} = 0\text{ mA to } 5\text{ mA}$ $-40^\circ\text{C} < T_A < +85^\circ\text{C}$			70	ppm/mA
Quiescent Current	I_{IN}	No Load $-40^\circ\text{C} < T_A < +85^\circ\text{C}$		100	120	μA
Voltage Noise	e_N	0.1 Hz to 10 Hz		5		$\mu\text{V p-p}$
Turn-On Settling Time	t_R			20		μs
Long-Term Stability	ΔV_O	1000 Hrs		50		ppm
Output Voltage Hysteresis	V_{O_HYS}			40		ppm
Ripple Rejection Ratio	RRR	$f_{IN} = 60\text{ Hz}$		85		dB
Short Circuit to GND	I_{SC}			25		mA

Specifications subject to change without notice.

ADR380 ELECTRICAL CHARACTERISTICS (@ $V_{IN} = 15.0\text{ V}$, $T_A = 25^\circ\text{C}$ unless otherwise noted.)

Parameter	Symbol	Conditions	Min	Typ	Max	Unit
Output Voltage	V_O		2.043	2.048	2.053	V
Initial Accuracy Error	V_{OERR}		-5		+5	mV
Temperature Coefficient	TCV_O	$-40^\circ\text{C} < T_A < +85^\circ\text{C}$ $0^\circ\text{C} < T_A < 70^\circ\text{C}$	-0.24	5	+0.24	%
Minimum Supply Voltage Headroom	$V_{IN} - V_O$	$I_L \leq 3\text{ mA}$		300		mV
Line Regulation	$\Delta V_O / \Delta V_{IN}$	$V_{IN} = 2.5\text{ V to } 15\text{ V}$ $-40^\circ\text{C} < T_A < +85^\circ\text{C}$		10	25	ppm/V
Load Regulation	$\Delta V_O / \Delta I_{LOAD}$	$V_{IN} = 3\text{ V}$, $I_{LOAD} = 0\text{ mA to } 5\text{ mA}$ $-40^\circ\text{C} < T_A < +85^\circ\text{C}$			70	ppm/mA
Quiescent Current	I_{IN}	No Load $-40^\circ\text{C} < T_A < +85^\circ\text{C}$		100	120	μA
Voltage Noise	e_N	0.1 Hz to 10 Hz		5		$\mu\text{V p-p}$
Turn-On Settling Time	t_R			20		μs
Long-Term Stability	ΔV_O	1000 Hrs		50		ppm
Output Voltage Hysteresis	V_{O_HYS}			40		ppm
Ripple Rejection Ratio	RRR	$f_{IN} = 60\text{ Hz}$		85		dB
Short Circuit to GND	I_{SC}			25		mA

Specifications subject to change without notice.

SPECIFICATIONS

ADR381 ELECTRICAL CHARACTERISTICS (@ $V_{IN} = 5.0\text{ V}$, $T_A = 25^\circ\text{C}$ unless otherwise noted.)

Parameter	Symbol	Conditions	Min	Typ	Max	Unit
Output Voltage	V_O		2.494	2.5	2.506	V
Initial Accuracy Error	V_{OERR}		-6		+6	mV
			-0.24		+0.24	%
Temperature Coefficient	TCV_O	$-40^\circ\text{C} < T_A < +85^\circ\text{C}$		5	25	ppm/ $^\circ\text{C}$
		$0^\circ\text{C} < T_A < 70^\circ\text{C}$		3	21	ppm/ $^\circ\text{C}$
Minimum Supply Voltage Headroom	$V_{IN} - V_O$	$I_L \leq 2\text{ mA}$		300		mV
Line Regulation	$\Delta V_O / \Delta V_{IN}$	$V_{IN} = 2.8\text{ V to } 15\text{ V}$ $-40^\circ\text{C} < T_A < +85^\circ\text{C}$		10	25	ppm/V
Load Regulation	$\Delta V_O / \Delta I_{LOAD}$	$V_{IN} = 3.5\text{ V}$, $I_{LOAD} = 0\text{ mA to } 5\text{ mA}$ $-40^\circ\text{C} < T_A < +85^\circ\text{C}$			70	ppm/mA
Quiescent Current	I_{IN}	No Load $-40^\circ\text{C} < T_A < +85^\circ\text{C}$		100	120	μA
					140	μA
Voltage Noise	e_N	0.1 Hz to 10 Hz		5		$\mu\text{V p-p}$
Turn-On Settling Time	t_R			20		μs
Long-Term Stability	ΔV_O	1000 Hrs		50		ppm
Output Voltage Hysteresis	V_{O_HYS}			75		ppm
Ripple Rejection Ratio	RRR	$f_{IN} = 60\text{ Hz}$		85		dB
Short Circuit to GND	I_{SC}			25		mA

Specifications subject to change without notice.

ADR381 ELECTRICAL CHARACTERISTICS (@ $V_{IN} = 15.0\text{ V}$, $T_A = 25^\circ\text{C}$ unless otherwise noted.)

Parameter	Symbol	Conditions	Min	Typ	Max	Unit
Output Voltage	V_O		2.494	2.5	2.506	V
Initial Accuracy Error	V_{OERR}		-6		+6	mV
			-0.24		+0.24	%
Temperature Coefficient	TCV_O	$-40^\circ\text{C} < T_A < +85^\circ\text{C}$		5	25	ppm/ $^\circ\text{C}$
		$0^\circ\text{C} < T_A < 70^\circ\text{C}$		3	21	ppm/ $^\circ\text{C}$
Minimum Supply Voltage Headroom	$V_{IN} - V_O$	$I_L \leq 2\text{ mA}$		300		mV
Line Regulation	$\Delta V_O / \Delta V_{IN}$	$V_{IN} = 2.8\text{ V to } 15\text{ V}$ $-40^\circ\text{C} < T_A < +85^\circ\text{C}$		10	25	ppm/V
Load Regulation	$\Delta V_O / \Delta I_{LOAD}$	$V_{IN} = 3.5\text{ V}$, $I_{LOAD} = 0\text{ mA to } 5\text{ mA}$ $-40^\circ\text{C} < T_A < +85^\circ\text{C}$			70	ppm/mA
Quiescent Current	I_{IN}	No Load $-40^\circ\text{C} < T_A < +85^\circ\text{C}$		100	120	μA
					140	μA
Voltage Noise	e_N	0.1 Hz to 10 Hz		5		$\mu\text{V p-p}$
Turn-On Settling Time	t_R			20		μs
Long-Term Stability	ΔV_O	1000 Hrs		50		ppm
Output Voltage Hysteresis	V_{O_HYS}			75		ppm
Ripple Rejection Ratio	RRR	$f_{IN} = 60\text{ Hz}$		85		dB
Short Circuit to GND	I_{SC}			25		mA

Specifications subject to change without notice.

ADR380/ADR381

ABSOLUTE MAXIMUM RATINGS¹

Supply Voltage	18 V
Output Short-Circuit Duration to GND	
$V_{IN} > 15\text{ V}$	10 sec
$V_{IN} \leq 15\text{ V}$	Indefinite
Storage Temperature Range	
RT Package	-65°C to +150°C
Operating Temperature Range	
ADR380/ADR381	-40°C to +85°C
Junction Temperature Range	
RT Package	-65°C to +150°C
Lead Temperature Range (Soldering, 60 Sec)	300°C

Package Type	θ_{JA} ²	θ_{JC}	Unit
3-Lead SOT-23 (RT)	333	—	°C/W

NOTES

¹Absolute maximum ratings apply at 25°C, unless otherwise noted.

² θ_{JA} is specified for the worst case conditions, i.e., θ_{JA} is specified for device soldered in circuit board for surface-mount packages.

ORDERING GUIDE

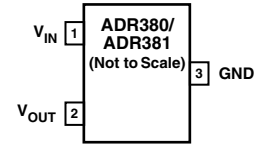
Model	Temperature Range	Package Description	Package Option	Top Mark	Output Voltage	Number of Parts per Reel
ADR380ART-REEL7	-40°C to +85°C	SOT-23	RT-3	R2A	2.048	3,000
ADR380ART-REEL	-40°C to +85°C	SOT-23	RT-3	R2A	2.048	10,000
ADR381ART-REEL7	-40°C to +85°C	SOT-23	RT-3	R3A	2.500	3,000
ADR381ART-REEL	-40°C to +85°C	SOT-23	RT-3	R3A	2.500	10,000

CAUTION

ESD (electrostatic discharge) sensitive device. Electrostatic charges as high as 4000 V readily accumulate on the human body and test equipment and can discharge without detection. Although the ADR380/ADR381 features proprietary ESD protection circuitry, permanent damage may occur on devices subjected to high-energy electrostatic discharges. Therefore, proper ESD precautions are recommended to avoid performance degradation or loss of functionality.

PIN CONFIGURATION

3-Lead SOT-23 (RT Suffix)



PARAMETER DEFINITIONS

Temperature Coefficient

The change of output voltage over the operating temperature change and normalized by the output voltage at 25°C, expressed in ppm/°C. The equation follows:

$$TCV_o [ppm/°C] = \frac{V_o(T_2) - V_o(T_1)}{V_o(25°C) \times (T_2 - T_1)} \times 10^6$$

where:

$$V_o(25°C) = V_o \text{ at } 25°C.$$

$$V_o(T_1) = V_o \text{ at Temperature 1.}$$

$$V_o(T_2) = V_o \text{ at Temperature 2.}$$

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.

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, parts-per-million per milliampere, or ohms of dc output resistance.

Long-Term Stability

A typical shift in output voltage over 1000 hours at a controlled temperature. The graphs (TPC 24 and TPC 25) show a sample of parts measured at different intervals in a controlled environment of 50°C for 1000 hours.

$$\Delta V_o = V_o(t_0) - V_o(t_1)$$

$$\Delta V_o [ppm] = \frac{V_o(t_0) - V_o(t_1)}{V_o(t_0)} \times 10^6$$

where:

$$V_o(t_0) = V_o \text{ at Time 0.}$$

$$V_o(t_1) = V_o \text{ after 1000 hours' operation at a controlled temperature.}$$

Note that 50°C was chosen since most applications we have experienced run at a higher temperature than 25°C.

Thermal Hysteresis

The change of output voltage after the device is cycled through temperature from +25°C to -40°C to +85°C and back to +25°C. This is a typical value from a sample of parts put through such a cycle.

$$V_{o_HYS} = V_o(25°C) - V_{o_TC}$$

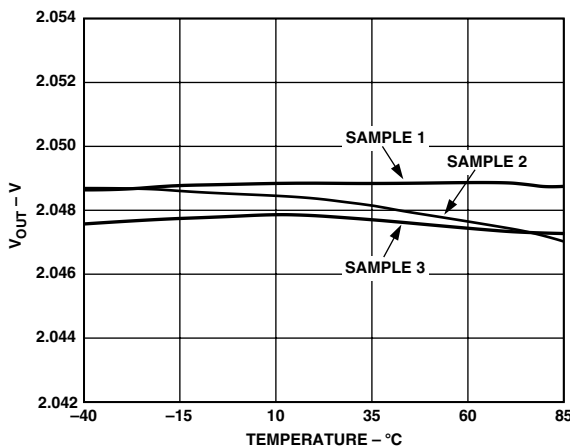
$$V_{o_HYS} [ppm] = \frac{V_o(25°C) - V_{o_TC}}{V_o(25°C)} \times 10^6$$

where:

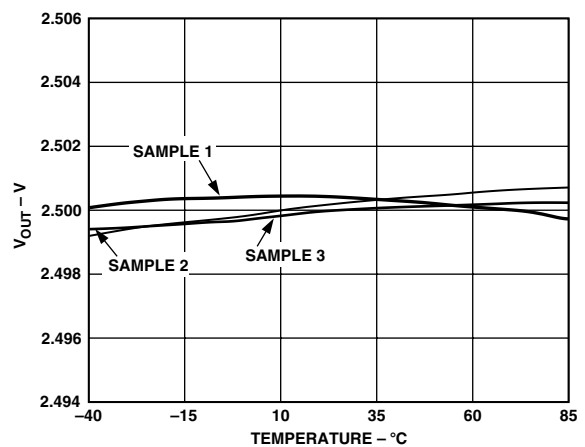
$$V_o(25°C) = V_o \text{ at } 25°C.$$

$$V_{o_TC} = V_o \text{ at } 25°C \text{ after temperature cycle at } +25°C \text{ to } -40°C \text{ to } +85°C \text{ and back to } +25°C.$$

Typical Performance Characteristics

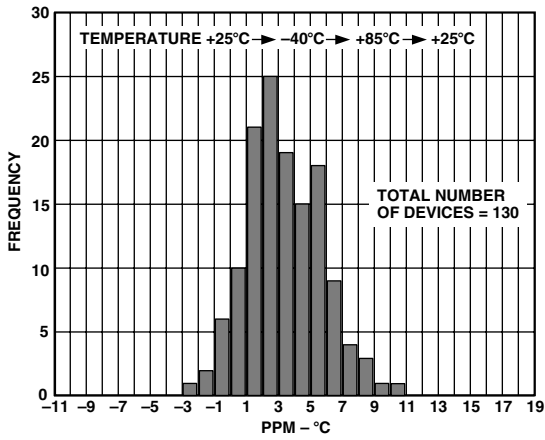


TPC 1. ADR380 Output Voltage vs. Temperature

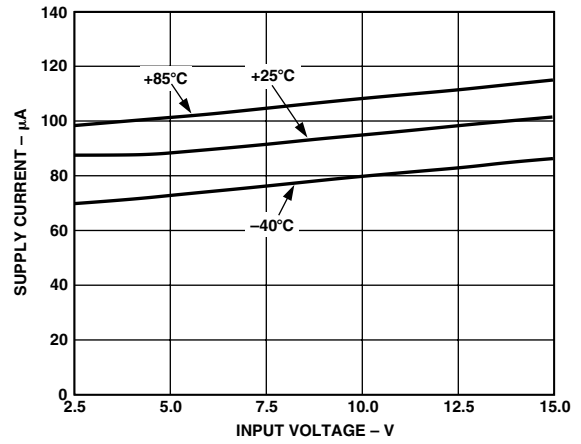


TPC 2. ADR381 Output Voltage vs. Temperature

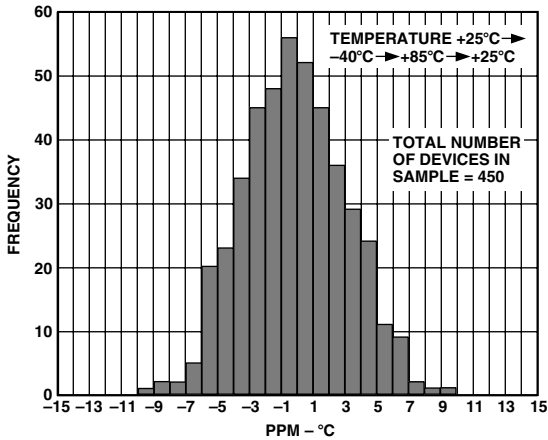
ADR380/ADR381—Typical Performance Characteristics



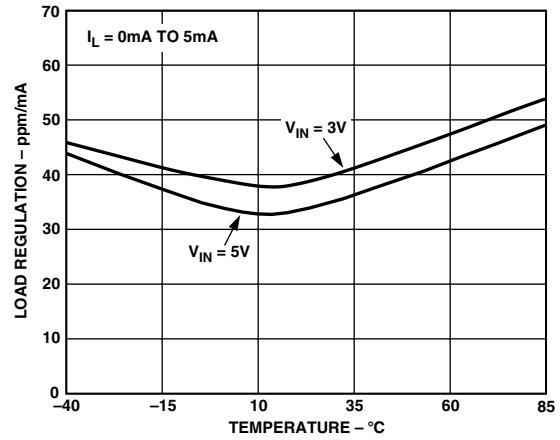
TPC 3. ADR380 Output Voltage Temperature Coefficient



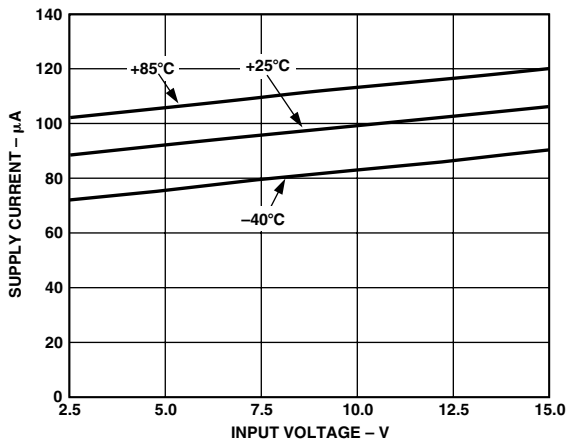
TPC 6. ADR381 Supply Current vs. Input Voltage



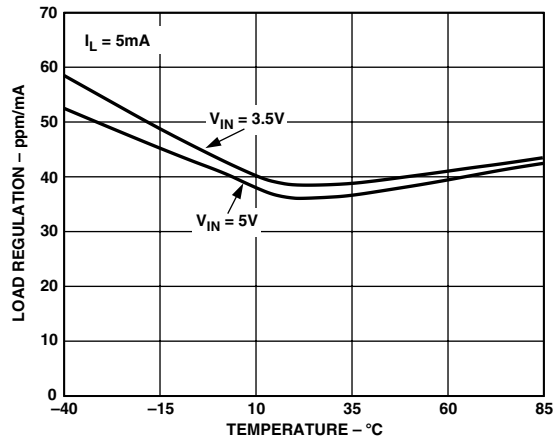
TPC 4. ADR381 Output Voltage Temperature Coefficient



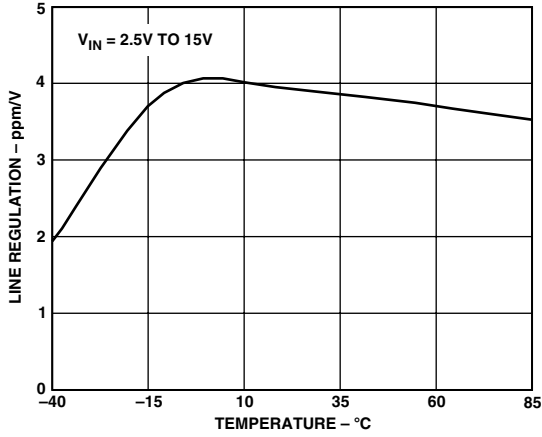
TPC 7. ADR380 Load Regulation vs. Temperature



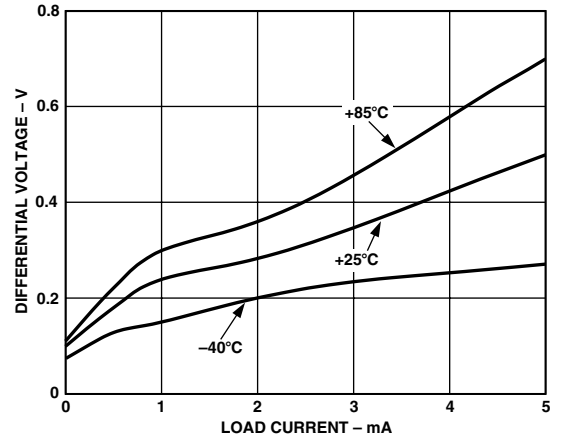
TPC 5. ADR380 Supply Current vs. Input Voltage



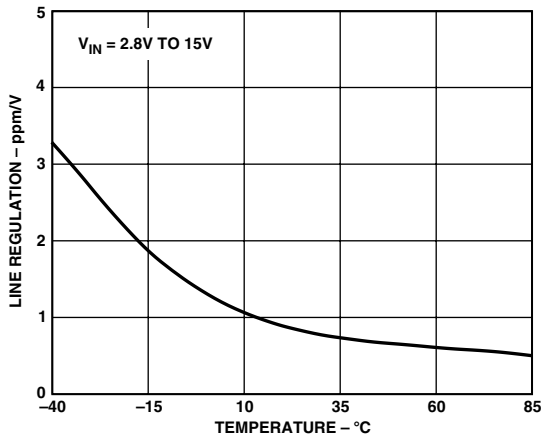
TPC 8. ADR381 Load Regulation vs. Temperature



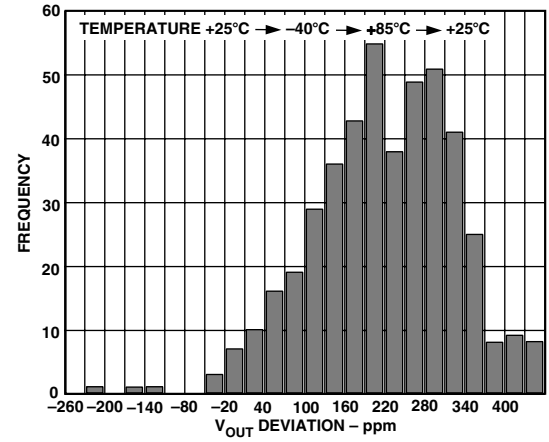
TPC 9. ADR380 Line Regulation vs. Temperature



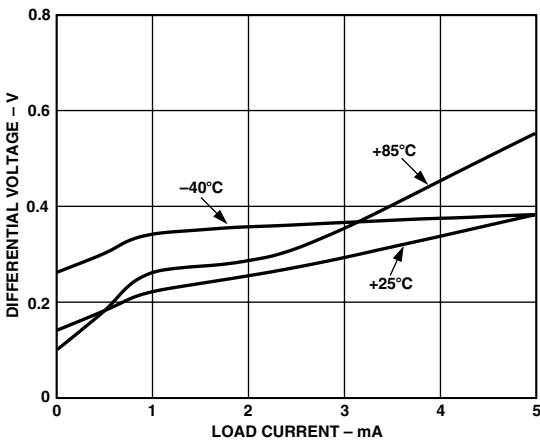
TPC 12. ADR381 Minimum Input/Output Voltage Differential vs. Load Current



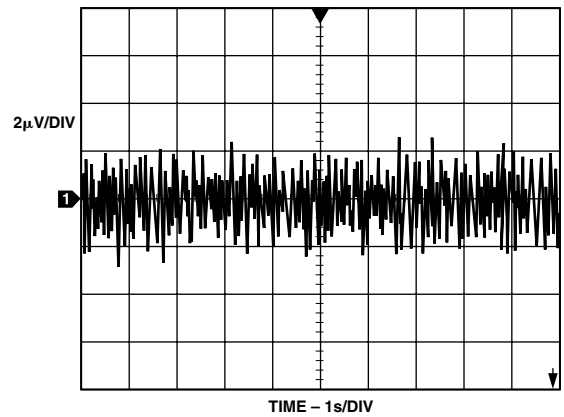
TPC 10. ADR381 Line Regulation vs. Temperature



TPC 13. ADR381 V_{OUT} Hysteresis

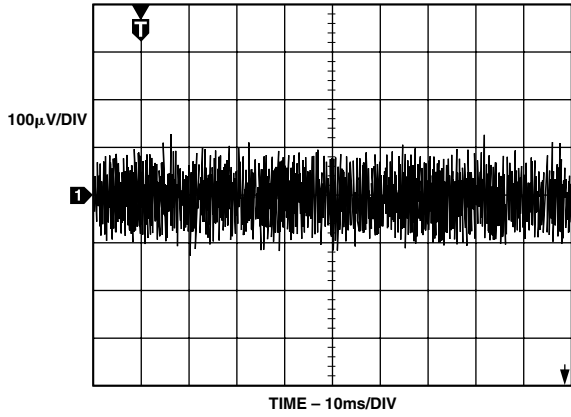


TPC 11. ADR380 Minimum Input/Output Voltage Differential vs. Load Current

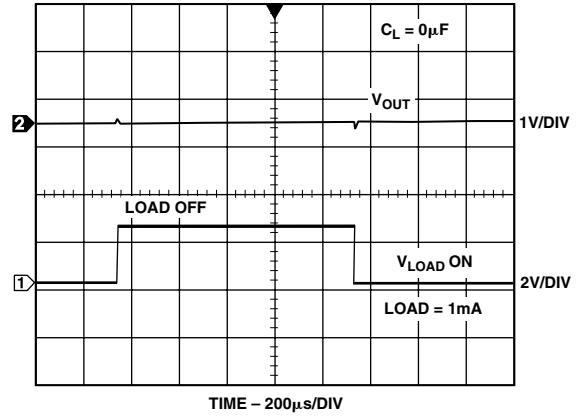


TPC 14. ADR381 Typical Noise Voltage 0.1 Hz to 10 Hz

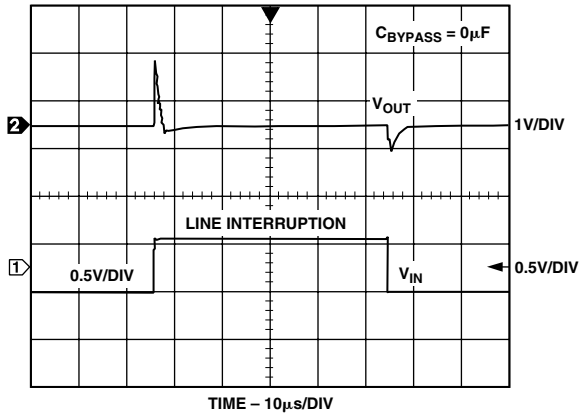
ADR380/ADR381



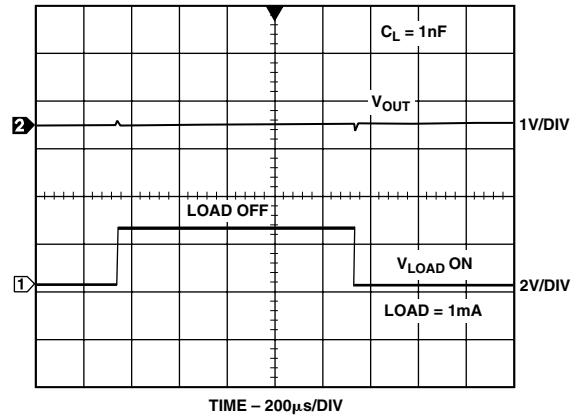
TPC 15. ADR381 Typical Noise Voltage 10 Hz to 10 kHz



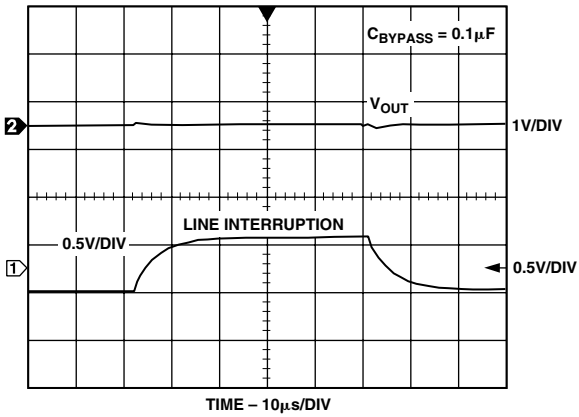
TPC 18. ADR381 Load Transient Response with $C_L = 0 \mu\text{F}$



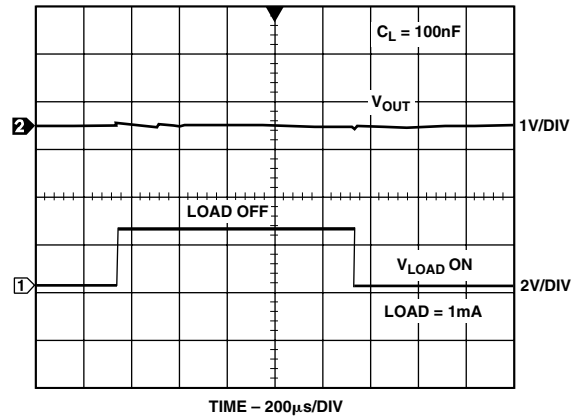
TPC 16. ADR381 Line Transient Response



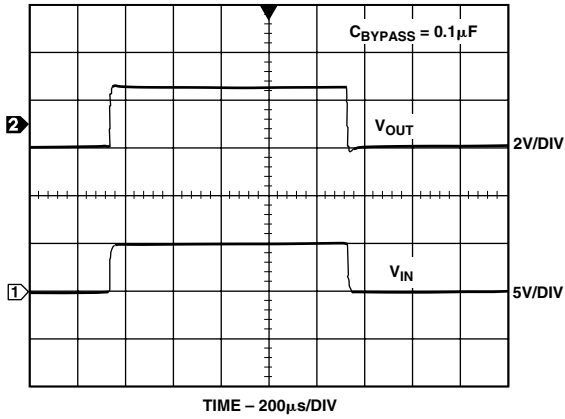
TPC 19. ADR381 Load Transient Response with $C_L = 1 \text{ nF}$



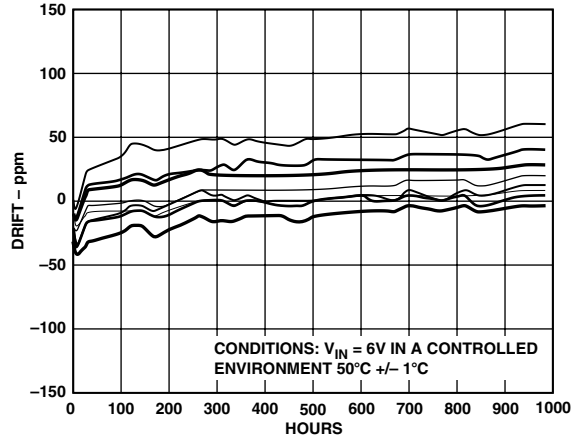
TPC 17. ADR381 Line Transient Response



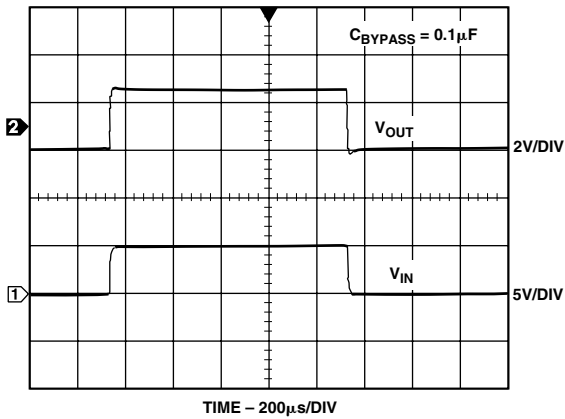
TPC 20. ADR381 Load Transient Response with $C_L = 100 \text{ nF}$



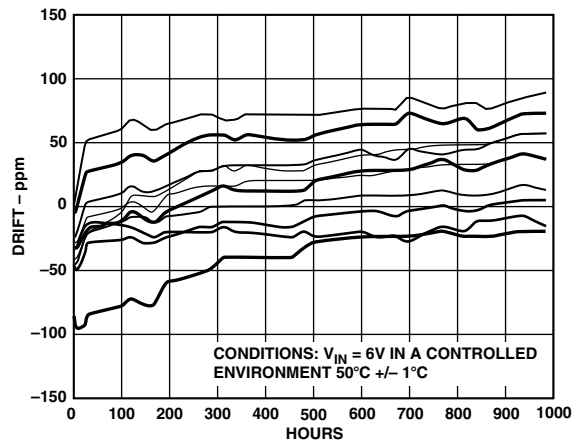
TPC 21. ADR381 Turn-On/Turn-Off Response at 5 V



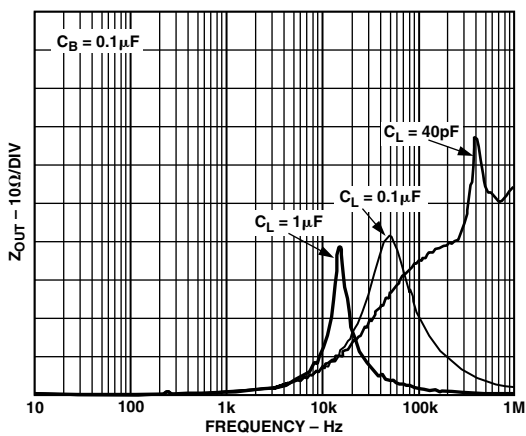
TPC 24. ADR380 Long-Term Drift



TPC 22. ADR381 Turn-On/Turn-Off Response at 5 V



TPC 25. ADR381 Long-Term Drift



TPC 23. ADR381 Output Impedance vs. Frequency

output voltage. In general, any positive voltage reference can be converted into a negative voltage reference through the use of an operational amplifier and a pair of matched resistors in an inverting configuration. The disadvantage to this approach is that the largest single source of error in the circuit is the relative matching of the resistors used.

The circuit in Figure 3 avoids the need for tightly matched resistors with the use of an active integrator circuit. In this circuit, the output of the voltage reference provides the input drive for the integrator. The integrator, to maintain circuit equilibrium, adjusts its output to establish the proper relationship between the reference's V_{OUT} and GND. Thus, any negative output voltage desired can be chosen by simply substituting for the appropriate reference IC. A precaution should be noted with this approach: although rail-to-rail output amplifiers work best in the application, these operational amplifiers require a finite amount (mV) of headroom when required to provide any load current. The choice for the circuit's negative supply should take this issue into account.

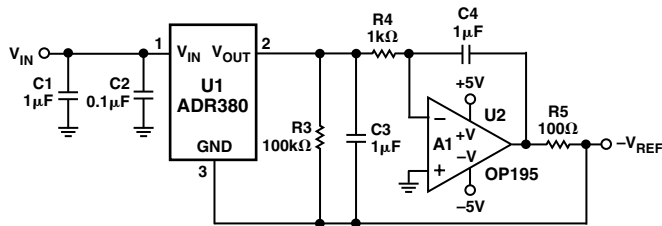


Figure 3. A Negative Precision Voltage Reference Uses No Precision Resistors

Precision Current Source

Many times in low-power applications, the need arises for a precision current source that can operate on low supply voltages. As shown in Figure 4, the ADR380/ADR381 can be configured as a precision current source. The circuit configuration illustrated is a floating current source with a grounded load. The reference's output voltage is bootstrapped across R_{SET} ($R1 + P1$), which sets the output current into the load. With this configuration, circuit precision is maintained for load currents in the range from the reference's supply current, typically 90 μ A to approximately 5 mA.

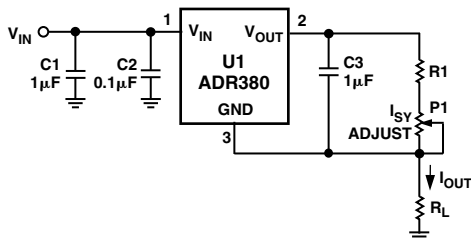


Figure 4. A Precision Current Source

Precision High-Current Voltage Source

In some cases, the user may want higher output current delivered to a load and still achieve better than 0.5% accuracy out of the ADR380/ADR381. The accuracy for a reference is normally specified on the data sheet with no load. However, the output voltage changes with load current.

The circuit in Figure 5 provides high current without compromising the accuracy of the ADR380/ADR381. By op amp action, V_O follows V_{REF} with very low drop in $R1$. To maintain circuit equilibrium, the op amp also drives the N-Ch MOSFET Q1 into saturation to maintain the current needed at different loads. $R2$ is optional to prevent oscillation at Q1. In such an approach, hundreds of milliamp of load current can be achieved and the current is limited by the thermal limitation of Q1. $V_{IN} = V_O + 300$ mV.

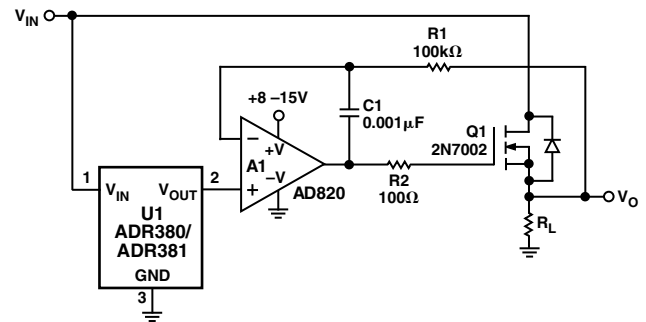


Figure 5. ADR380/ADR381 for Precision High-Current Voltage Source

