

ABSOLUTE MAXIMUM RATINGS (Note 1)

Input Voltage	40V	Output Short-Circuit Duration	
Input/Output Voltage Differential	35V	$V_{IN} = 35V$	10 sec
Output-to-Ground Voltage (Shunt Mode Current Limit)		$V_{IN} \leq 20V$	Indefinite
LT1021-5	10V	Operating Temperature Range	
LT1021-7	10V	Commercial	0°C to 70°C
LT1021-10	16V	Industrial	-40°C to 85°C
Trim Pin-to-Ground Voltage		Military	-55°C to 125°C
Positive	Equal to V_{OUT}	Storage Temperature Range	-65°C to 150°C
Negative	-20V	Lead Temperature (Soldering, 10 sec)	300°C

PACKAGE/ORDER INFORMATION

TOP VIEW H PACKAGE 8-LEAD TO-5 METAL CAN *CONNECTED INTERNALLY. DO NOT CONNECT EXTERNAL CIRCUITRY TO THESE PINS. **NO TRIM PIN ON LT1021-7. DO NOT CONNECT EXTERNAL CIRCUITRY TO PIN 5 ON LT1021-7 $T_{JMAX} = 150^{\circ}C$, $\theta_{JA} = 150^{\circ}C/W$, $\theta_{JC} = 45^{\circ}C/W$		TOP VIEW N8 PACKAGE 8-LEAD PDIP S8 PACKAGE 8-LEAD PLASTIC SO *CONNECTED INTERNALLY. DO NOT CONNECT EXTERNAL CIRCUITRY TO THESE PINS. **NO TRIM PIN ON LT1021-7. DO NOT CONNECT EXTERNAL CIRCUITRY TO PIN 5 ON LT1021-7 $T_{JMAX} = 130^{\circ}C$, $\theta_{JA} = 130^{\circ}C/W$ (N) $T_{JMAX} = 130^{\circ}C$, $\theta_{JA} = 150^{\circ}C/W$ (S)	
ORDER PART NUMBER		N8 ORDER PART NUMBER	
LT1021BCH-5 LT1021BMH-5 LT1021CCH-5 LT1021CMH-5 LT1021BMH-10	LT1021DCH-5 LT1021DMH-5 LT1021BCH-7 LT1021BMH-7 LT1021DCH-7 LT1021DMH-7 LT1021BCH-10 LT1021CMH-10 LT1021DCH-10 LT1021DMH-10 OBSELETE	LT1021BCN8-5 LT1021CCN8-5 LT1021CIN8-5 LT1021DCN8-5 LT1021DIN8-5 LT1021BCN8-7 LT1021DCN8-7 LT1021BCN8-10 LT1021CCN8-10 LT1021CIN8-10 LT1021DCN8-10 LT1021DIN8-10	
		S8 ORDER PART NUMBER	S8 PART MARKING
		LT1021DCS8-5	2105
		LT1021DCS8-7	2107
		LT1021DCS8-10	2110

Order Options Tape and Reel: Add #TR

Lead Free: Add #PBF Lead Free Tape and Reel: Add #TRPBF

Lead Free Part Marking: <http://www.linear.com/leadfree/>

Consult LTC Marketing for parts specified with wider operating temperature ranges.

ELECTRICAL CHARACTERISTICS

The ● denotes specifications that apply over the full operating temperature range, otherwise specifications are $T_A = 25^\circ\text{C}$. $V_{IN} = 10\text{V}$, $I_{OUT} = 0$, unless otherwise noted.

PARAMETER	CONDITIONS		LT1021-5			UNITS
			MIN	TYP	MAX	
Output Voltage (Note 2)	LT1021C-5		4.9975	5.000	5.0025	V
	LT1021B-5/LT1021D-5		4.9500	5.000	5.0500	V
Output Voltage Temperature Coefficient (Note 3)	$T_{MIN} \leq T_J \leq T_{MAX}$ LT1021B-5	●		2	5	ppm/ $^\circ\text{C}$
	LT1021C-5/LT1021D-5	●		3	20	ppm/ $^\circ\text{C}$
Line Regulation (Note 4)	$7.2\text{V} \leq V_{IN} \leq 10\text{V}$	●		4	12	ppm/V
		●			20	ppm/V
	$10\text{V} \leq V_{IN} \leq 40\text{V}$	●		2	6	ppm/V
		●			10	ppm/V
Load Regulation (Sourcing Current)	$0 \leq I_{OUT} \leq 10\text{mA}$ (Note 4)	●		10	20	ppm/mA
					35	ppm/mA
Load Regulation (Sinking Current)	$0 \leq I_{OUT} \leq 10\text{mA}$ (Note 4)	●		60	100	ppm/mA
					150	ppm/mA
Supply Current		●		0.8	1.2	mA
					1.5	mA
Output Voltage Noise (Note 6)	$0.1\text{Hz} \leq f \leq 10\text{Hz}$			3.0		μV_{P-P}
	$10\text{Hz} \leq f \leq 1\text{kHz}$			2.2	3.5	μV_{RMS}
Long Term Stability of Output Voltage (Note 7)	$\Delta t = 1000\text{Hrs}$ Noncumulative			15		ppm
Temperature Hysteresis of Output	$\Delta T = \pm 25^\circ\text{C}$			10		ppm

The ● denotes specifications that apply over the full operating temperature range, otherwise specifications are $T_A = 25^\circ\text{C}$. $V_{IN} = 12\text{V}$, $I_{OUT} = 0$, unless otherwise noted.

PARAMETER	CONDITIONS		LT1021-7			UNITS
			MIN	TYP	MAX	
Output Voltage (Note 2)			6.95	7.00	7.05	V
Output Voltage Temperature Coefficient (Note 3)	$T_{MIN} \leq T_J \leq T_{MAX}$ LT1021B-7	●		2	5	ppm/ $^\circ\text{C}$
	LT1021D-7	●		3	20	ppm/ $^\circ\text{C}$
Line Regulation (Note 4)	$8.5\text{V} \leq V_{IN} \leq 12\text{V}$	●		1.0	4	ppm/V
		●		2.0	8	ppm/V
	$12\text{V} \leq V_{IN} \leq 40\text{V}$	●		0.5	2	ppm/V
		●		1.0	4	ppm/V
Load Regulation (Sourcing Current)	$0 \leq I_{OUT} \leq 10\text{mA}$ (Note 4)	●		12	25	ppm/mA
					40	ppm/mA
Load Regulation (Shunt Mode)	$1.2\text{mA} \leq I_{SHUNT} \leq 10\text{mA}$ (Notes 4, 5)	●		50	100	ppm/mA
					150	ppm/mA
Supply Current (Series Mode)		●		0.75	1.2	mA
					1.5	mA
Minimum Current (Shunt Mode)	V_{IN} is Open	●		0.7	1.0	mA
					1.2	mA
Output Voltage Noise (Note 6)	$0.1\text{Hz} \leq f \leq 10\text{Hz}$			4.0		μV_{P-P}
	$10\text{Hz} \leq f \leq 1\text{kHz}$			2.5	4.0	μV_{RMS}
Long Term Stability of Output Voltage (Note 7)	$\Delta t = 1000\text{Hrs}$ Noncumulative			7		ppm
Temperature Hysteresis of Output	$\Delta T = \pm 25^\circ\text{C}$			3		ppm

ELECTRICAL CHARACTERISTICS

The ● denotes specifications that apply over the full operating temperature range, otherwise specifications are $T_A = 25^\circ\text{C}$. $V_{IN} = 15\text{V}$, $I_{OUT} = 0$, unless otherwise noted.

PARAMETER	CONDITIONS		LT1021-10			UNITS
			MIN	TYP	MAX	
Output Voltage (Note 2)	LT1021C-10		9.995	10.00	10.005	V
	LT1021B-10/LT1021D-10		9.950	10.00	10.050	V
Output Voltage Temperature Coefficient (Note 3)	$T_{MIN} \leq T_J \leq T_{MAX}$					
	LT1021B-10	●		2	5	ppm/ $^\circ\text{C}$
	LT1021C-10/LT1021D-10	●		5	20	ppm/ $^\circ\text{C}$
Line Regulation (Note 4)	$11.5\text{V} \leq V_{IN} \leq 14.5\text{V}$			1.0	4	ppm/V
		●			6	ppm/V
	$14.5\text{V} \leq V_{IN} \leq 40\text{V}$			0.5	2	ppm/V
		●			4	ppm/V
Load Regulation (Sourcing Current)	$0 \leq I_{OUT} \leq 10\text{mA}$			12	25	ppm/mA
	(Note 4)	●			40	ppm/mA
Load Regulation (Shunt Mode)	$1.7\text{mA} \leq I_{SHUNT} \leq 10\text{mA}$			50	100	ppm/mA
	(Notes 4, 5)	●			150	ppm/mA
Supply Current (Series Mode)				1.2	1.7	mA
		●			2.0	mA
Minimum Current (Shunt Mode)	V_{IN} is Open			1.1	1.5	mA
		●			1.7	mA
Output Voltage Noise (Note 6)	$0.1\text{Hz} \leq f \leq 10\text{Hz}$			6.0		μV_{P-P}
	$10\text{Hz} \leq f \leq 1\text{kHz}$			3.5	6	μV_{RMS}
Long Term Stability of Output Voltage (Note 7)	$\Delta t = 1000\text{Hrs}$ Noncumulative			15		ppm
Temperature Hysteresis of Output	$\Delta T = \pm 25^\circ\text{C}$			5		ppm

Note 1: Absolute Maximum Ratings are those values beyond which the life of a device may be impaired.

Note 2: Output voltage is measured immediately after turn-on. Changes due to chip warm-up are typically less than 0.005%.

Note 3: Temperature coefficient is measured by dividing the change in output voltage over the temperature range by the change in temperature. Separate tests are done for hot and cold; T_{MIN} to 25°C and 25°C to T_{MAX} . Incremental slope is also measured at 25°C .

Note 4: Line and load regulation are measured on a pulse basis. Output changes due to die temperature change must be taken into account separately. Package thermal resistance is 150°C/W for TO-5 (H), 130°C/W for N and 150°C/W for the SO-8.

Note 5: Shunt mode regulation is measured with the input open. With the input connected, shunt mode current can be reduced to 0mA. Load regulation will remain the same.

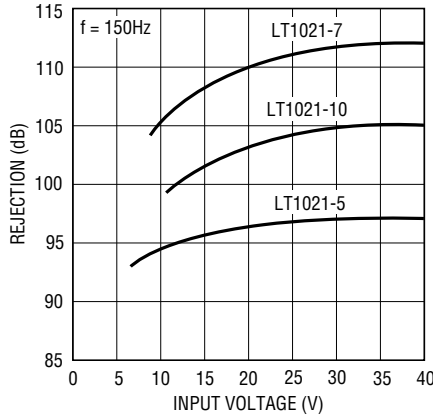
Note 6: RMS noise is measured with a 2-pole highpass filter at 10Hz and a 2-pole lowpass filter at 1kHz. The resulting output is full-wave rectified and then integrated for a fixed period, making the final reading an average as opposed to RMS. Correction factors are used to convert from average to RMS and correct for the non-ideal bandpass of the filters.

Peak-to-peak noise is measured with a single highpass filter at 0.1Hz and a 2-pole lowpass filter at 10Hz. The unit is enclosed in a still-air environment to eliminate thermocouple effects on the leads. Test time is 10 seconds.

Note 7: Consult factory for units with long term stability data.

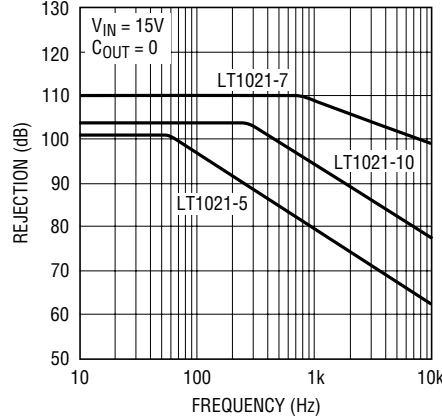
TYPICAL PERFORMANCE CHARACTERISTICS

Ripple Rejection



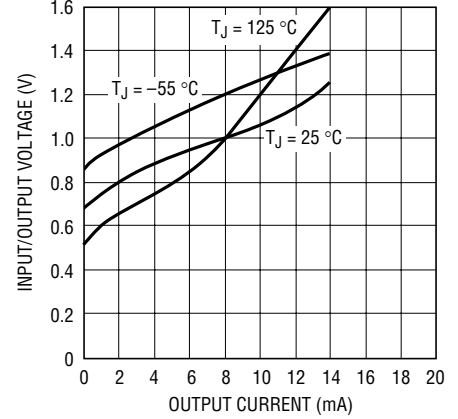
LT1021 G01

Ripple Rejection



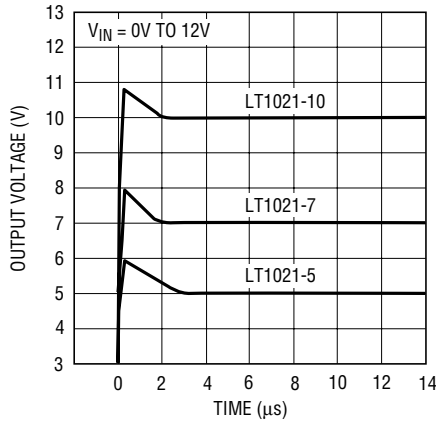
LT1021 G02

**Minimum Input/Output Differential
LT1021-7, LT1021-10**



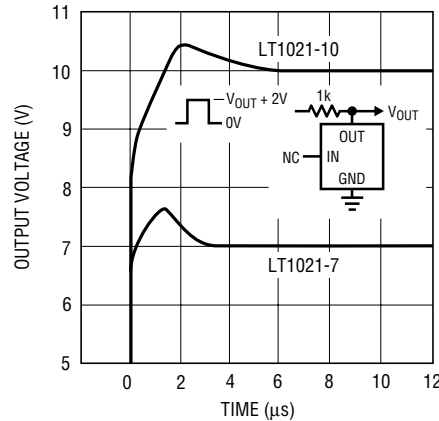
1021 G03

Start-Up (Series Mode)



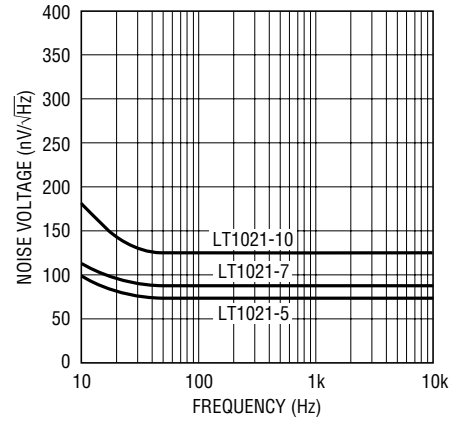
LT1021 G04

**Start-Up (Shunt Mode)
LT1021-7, LT1021-10**



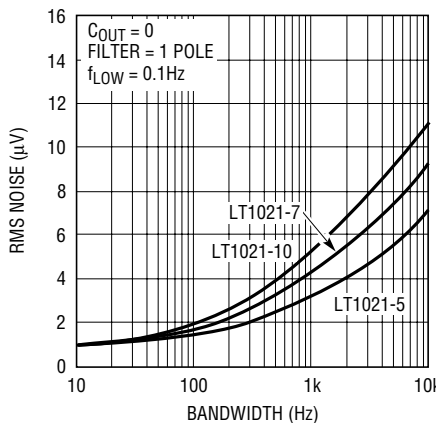
LT1021 G05

Output Voltage Noise Spectrum



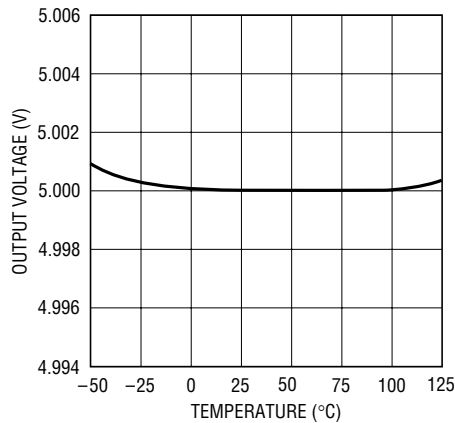
LT1021 G06

Output Voltage Noise



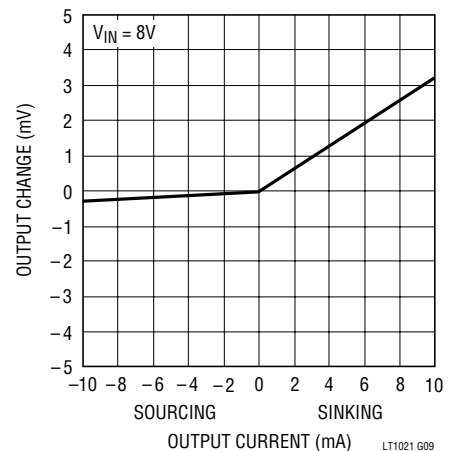
LT1021 G07

**Output Voltage Temperature Drift
LT1021-5**



LT1021 G08

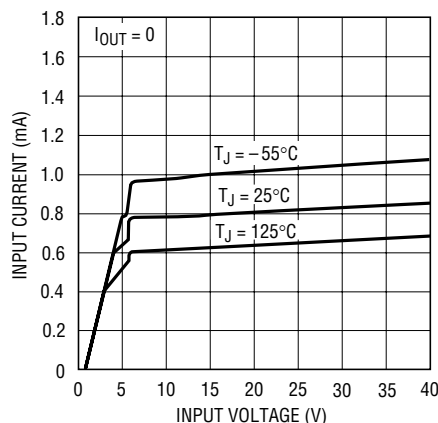
Load Regulation LT1021-5



LT1021 G09

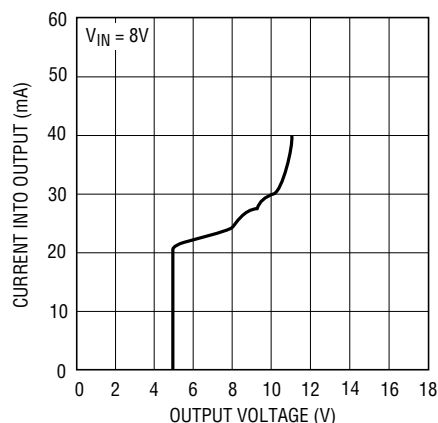
TYPICAL PERFORMANCE CHARACTERISTICS

Quiescent Current LT1021-5



LT1021 G10

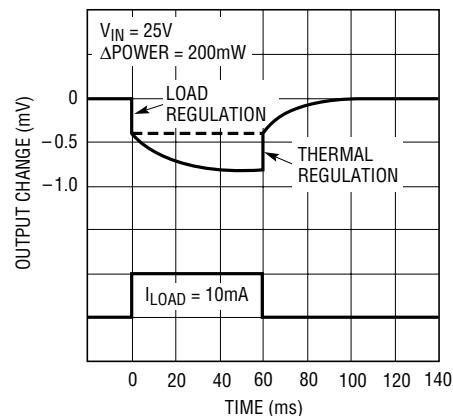
Sink Mode* Current Limit
LT1021-5



*NOTE THAT AN INPUT VOLTAGE IS REQUIRED FOR 5V UNITS.

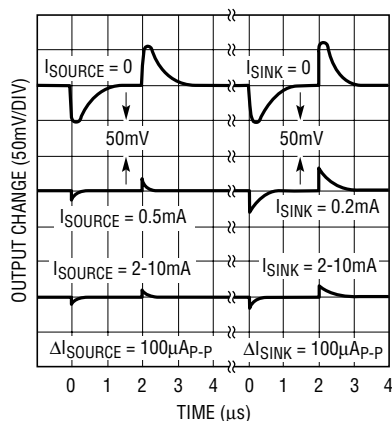
LT1021 G11

Thermal Regulation LT1021-5



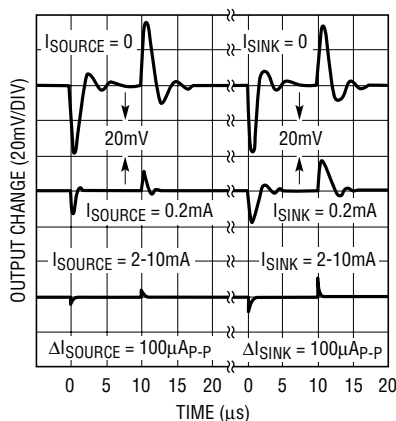
LT1021 G12

Load Transient Response
LT1021-5, C_{LOAD} = 0



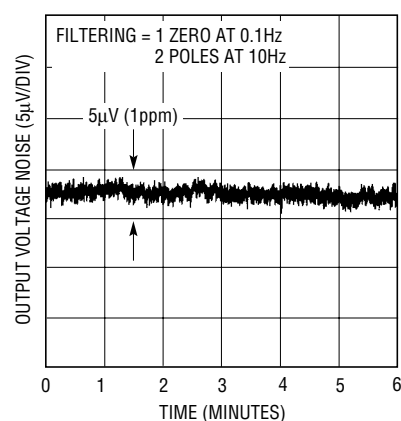
LT1021 G13

Load Transient Response
LT1021-5, C_{LOAD} = 1000pF



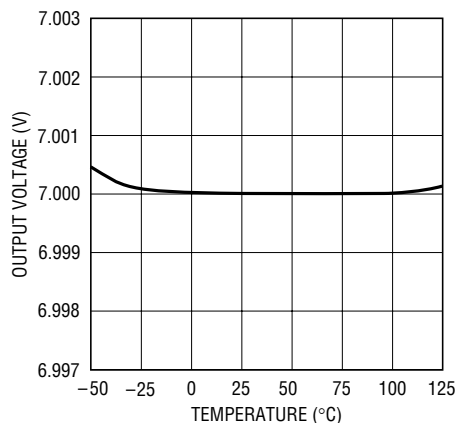
LT1021 G14

Output Noise 0.1Hz to 10Hz
LT1021-5



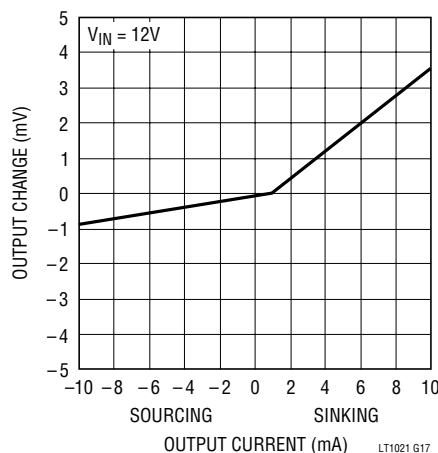
LT1021 G15

Output Voltage Temperature
Drift LT1021-7



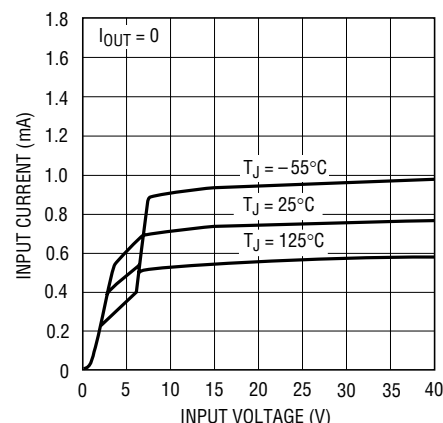
LT1021 G16

Load Regulation
LT1021-7, LT1021-10



LT1021 G17

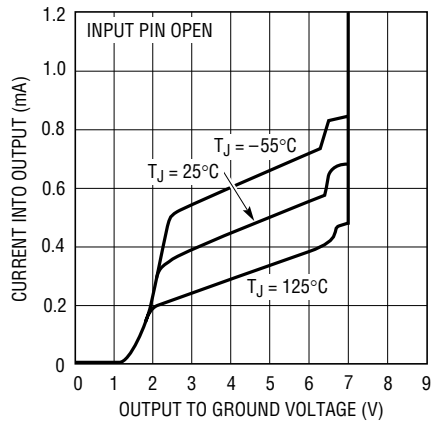
Quiescent Current LT1021-7



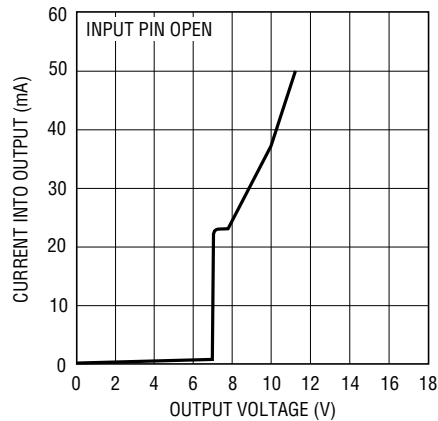
LT1021 G18
1021fc

TYPICAL PERFORMANCE CHARACTERISTICS

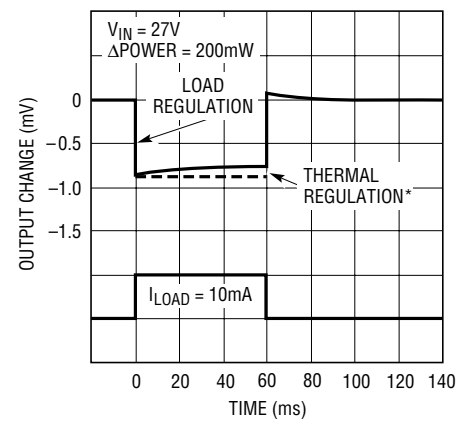
Shunt Characteristics LT1021-7



Shunt Mode Current Limit LT1021-7

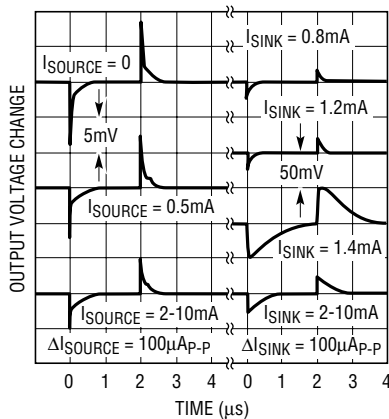


Thermal Regulation LT1021-7



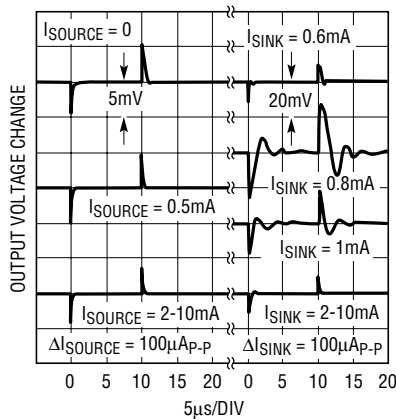
*INDEPENDENT OF TEMPERATURE COEFFICIENT

Load Transient Response LT1021-7, $C_{LOAD} = 0$



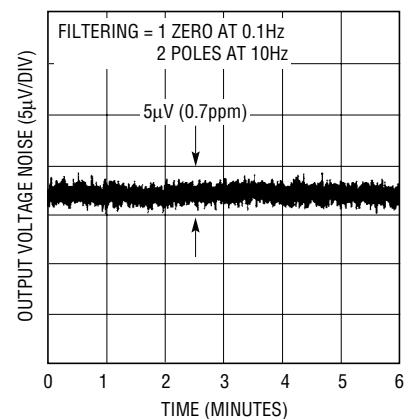
NOTE VERTICAL SCALE CHANGE BETWEEN SOURCING AND SINKING

Load Transient Response LT1021-7, $C_{LOAD} = 1000pF$

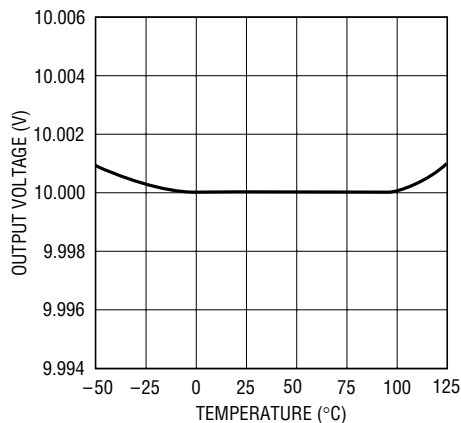


NOTE VERTICAL SCALE CHANGE BETWEEN SOURCING AND SINKING

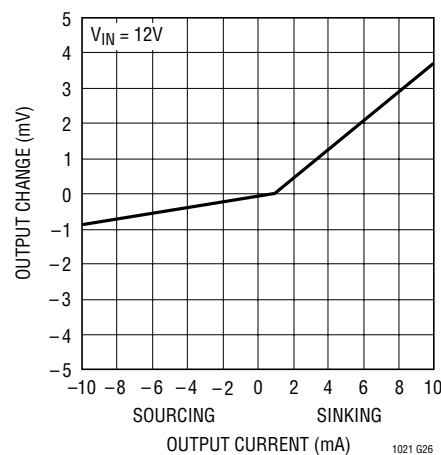
Output Noise 0.1Hz to 10Hz LT1021-7



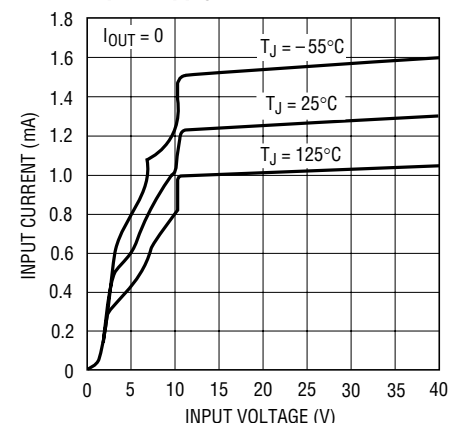
Output Voltage Temperature Drift LT1021-10



Load Regulation LT1021-7, LT1021-10

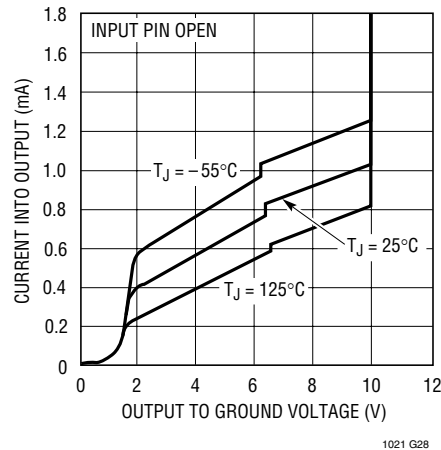


Input Supply Current LT1021-10

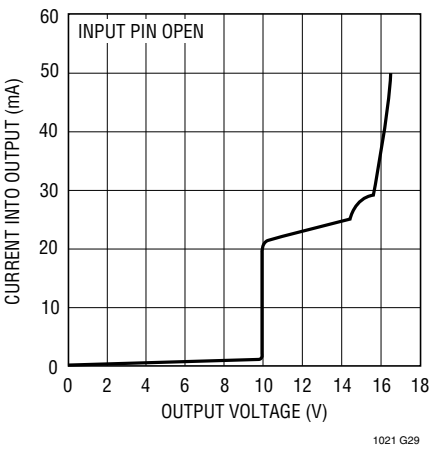


TYPICAL PERFORMANCE CHARACTERISTICS

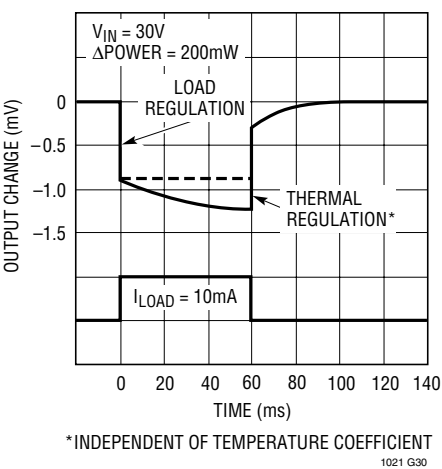
Shunt Characteristics LT1021-10



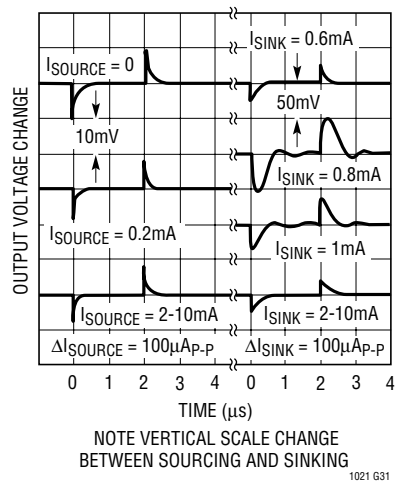
Shunt Mode Current Limit LT1021-10



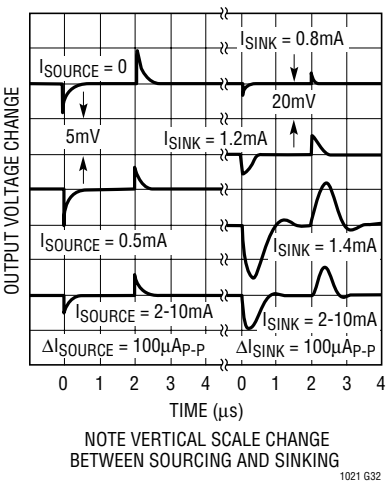
Thermal Regulation LT1021-10



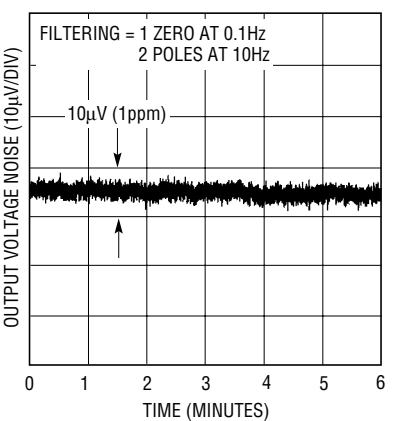
Load Transient Response LT1021-10, $C_{LOAD} = 0$



Load Transient Response LT1021-10, $C_{LOAD} = 1000pF$



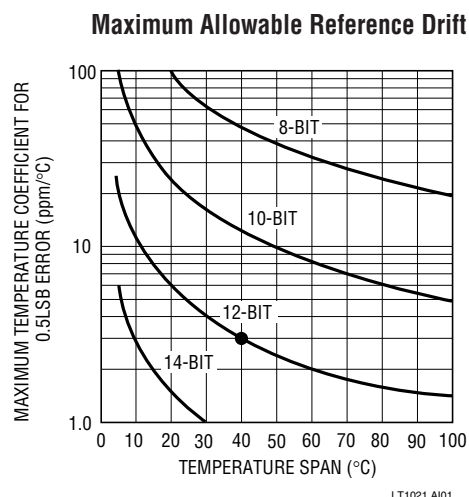
Output Noise 0.1Hz to 10Hz LT1021-10



APPLICATIONS INFORMATION

Effect of Reference Drift on System Accuracy

A large portion of the temperature drift error budget in many systems is the system reference voltage. This graph indicates the maximum temperature coefficient allowable if the reference is to contribute no more than 0.5LSB error to the overall system performance. The example shown is a 12-bit system designed to operate over a temperature range from 25°C to 65°C. Assuming the system calibration is performed at 25°C, the temperature span is 40°C. It can be seen from the graph that the temperature coefficient of the reference must be no worse than 3ppm/°C if it is to contribute less than 0.5LSB error. For this reason, the LT1021 family has been optimized for low drift.



Trimming Output Voltage

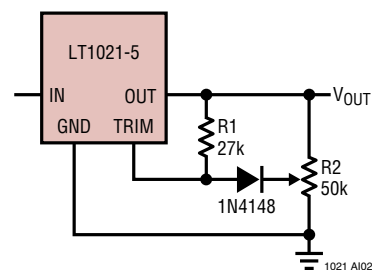
LT1021-10

The LT1021-10 has a trim pin for adjusting output voltage. The impedance of the trim pin is about 12k Ω with a nominal open-circuit voltage of 5V. It is designed to be driven from a source impedance of 3k Ω or less to minimize changes in the LT1021 TC with output trimming. Attenuation between the trim pin and the output is 70:1. This allows ± 70 mV trim range when the trim pin is tied to the wiper of a potentiometer connected between the output and ground. A 10k Ω potentiometer is recommended, preferably a 20 turn cermet type with stable characteristics over time and temperature.

The LT1021-10 “C” version is pre-trimmed to ± 5 mV and therefore can utilize a restricted trim range. A 75k resistor in series with a 20k Ω potentiometer will give ± 10 mV trim range. Effect on the output TC will be only 1ppm/°C for the ± 5 mV trim needed to set the “C” device to 10.000V.

LT1021-5

The LT1021-5 does have an output voltage trim pin, but the TC of the nominal 4V open-circuit voltage at this pin is about -1.7 mV/°C. For the voltage trimming not to affect reference output TC, the external trim voltage must track the voltage on the trim pin. Input impedance of the trim pin is about 100k Ω and attenuation to the output is 13:1. The technique shown below is suggested for trimming the output of the LT1021-5 while maintaining minimum shift in output temperature coefficient. The R1/R2 ratio is chosen to minimize interaction of trimming and TC shifts, so the exact values shown should be used.



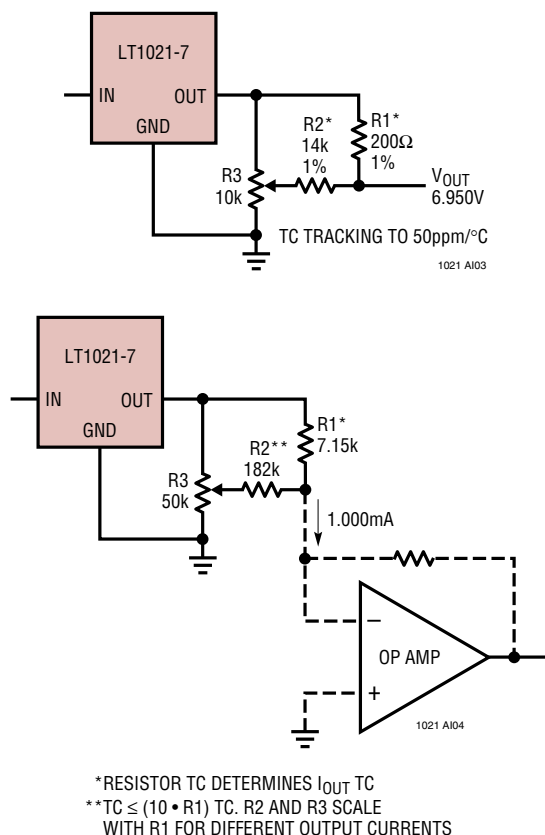
LT1021-7

The 7V version of the LT1021 has no trim pin because the internal architecture does not have a point which could be driven conveniently from the output. Trimming must therefore be done externally, as is the case with ordinary reference diodes. Unlike these diodes, however, the output of the LT1021 can be loaded with a trim potentiometer. The following trim techniques are suggested; one for voltage output and one for current output. The voltage output is trimmed for 6.95V. Current output is 1mA, as shown, into a summing junction, but all resistors may be scaled for currents up to 10mA.

Both of these circuits use the trimmers in a true potentiometric mode to reduce the effects of trimmer TC. The voltage output has a 200 Ω impedance, so loading must be

APPLICATIONS INFORMATION

minimized. In the current output circuit, R1 determines output current. It should have a TC commensurate with the LT1021 or track closely with the feedback resistor around the op amp.



Capacitive Loading and Transient Response

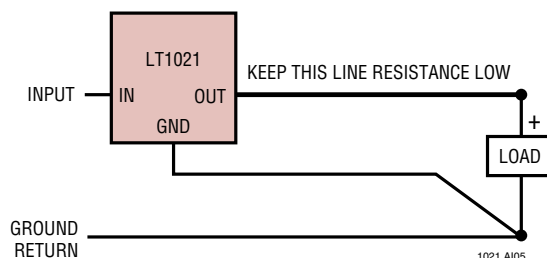
The LT1021 is stable with all capacitive loads, but for optimum settling with load transients, output capacitance should be under 1000pF. The output stage of the reference is class AB with a fairly low idling current. This makes transient response worst-case at light load currents. Because of internal current drain on the output, actual worst-case occurs at $I_{LOAD} = 0$ on LT1021-5, $I_{LOAD} = -0.8\text{mA}$ (sinking) on LT1021-7 and $I_{LOAD} = 1.4\text{mA}$ (sinking) on LT1021-10. Significantly better load transient response is obtained by moving slightly away from these points. See Load Transient Response curves for details. In general, best transient response is obtained when the output is sourcing current. In critical applications, a 10μF solid tantalum capacitor with several ohms in series provides optimum output bypass.

Kelvin Connections

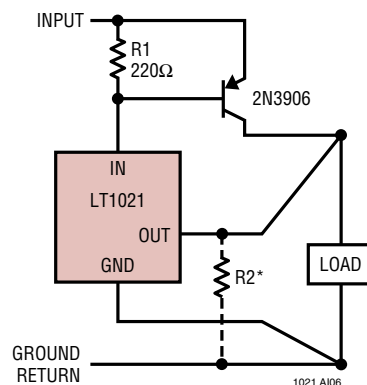
Although the LT1021 does not have true force/sense capability at its outputs, significant improvements in ground loop and line loss problems can be achieved with proper hook-up. In series mode operation, the ground pin of the LT1021 carries only $\approx 1\text{mA}$ and can be used as a sense line, greatly reducing ground loop and loss problems on the low side of the reference. The high side supplies load current so line resistance must be kept low. Twelve feet of #22 gauge hook-up wire or 1 foot of 0.025 inch printed circuit trace will create 2mV loss at 10mA output current. This is equivalent to 1LSB in a 10V, 12-bit system.

The following circuits show proper hook-up to minimize errors due to ground loops and line losses. Losses in the output lead can be greatly reduced by adding a PNP boost transistor if load currents are 5mA or higher. R2 can be added to further reduce current in the output sense lead.

Standard Series Mode



Series Mode with Boost Transistor



*OPTIONAL—REDUCES CURRENT IN OUTPUT SENSE LEAD
R2 = 2.4k (LT1021-5), 3k (LT1021-7), 5.6k (LT1021-10)

1021fc

APPLICATIONS INFORMATION

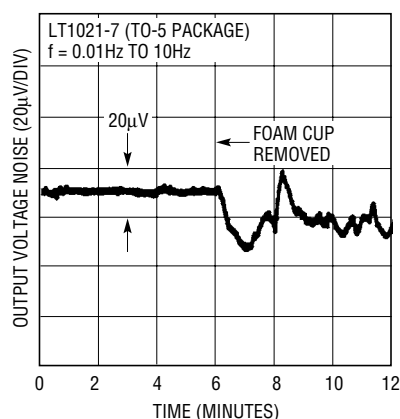
Effects of Air Movement on Low Frequency Noise

The LT1021 has very low noise because of the buried zener used in its design. In the 0.1Hz to 10Hz band, peak-to-peak noise is about 0.5ppm of the DC output. To achieve this low noise, however, care must be taken to shield the reference from ambient air turbulence. Air movement can create noise because of thermoelectric differences between IC package leads (especially kovar lead TO-5) and printed circuit board materials and/or sockets. Power dissipation in the reference, even though it rarely exceeds 20mW, is enough to cause small temperature gradients in the package leads. Variations in thermal resistance, caused by uneven air flow, create differential lead temperatures, thereby causing thermoelectric voltage noise at the output of the reference. The following XY plotter trace dramatically illustrates this effect. The first half of the plot was done with the LT1021 shielded from ambient air with a small foam cup. The cup was then removed for the second half of the trace. Ambient in both cases was a lab environment with no excessive air turbulence from air conditioners, opening/closing doors, etc. Removing the foam cup increases the output noise by almost an order of magnitude in the 0.01Hz to 1Hz band! The kovar leads of the TO-5 (H) package are the primary culprit. Alloy 42 and

copper lead frames used on dual-in-line packages are not nearly as sensitive to thermally generated noise because they are intrinsically matched.

There is nothing magical about foam cups—any enclosure which blocks air flow from the reference will do. Smaller enclosures are better since they do not allow the build-up of internally generated air movement. Naturally, heat generating components external to the reference itself should not be included inside the enclosure.

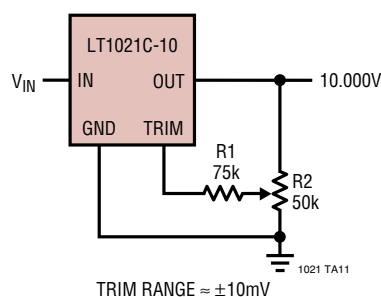
Noise Induced By Air Turbulence (TO-5 Package)



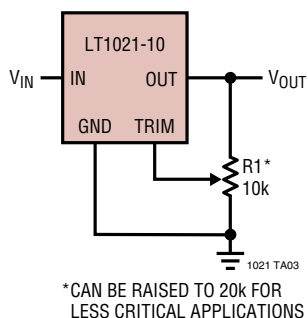
1021 A107

TYPICAL APPLICATIONS

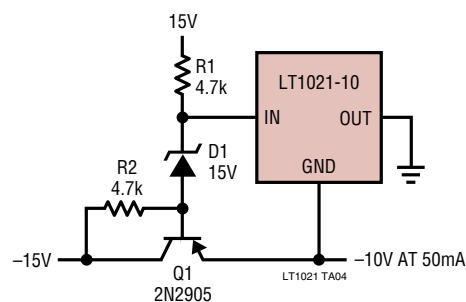
Restricted Trim Range for Improved Resolution, 10V, "C" Version Only



LT1021-10 Full Trim Range ($\pm 0.7\%$)

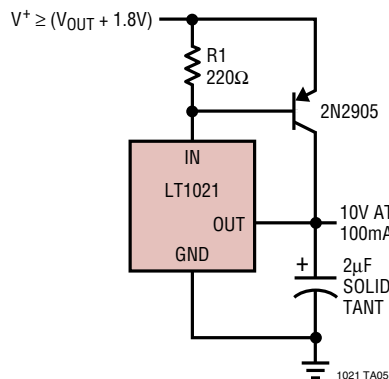
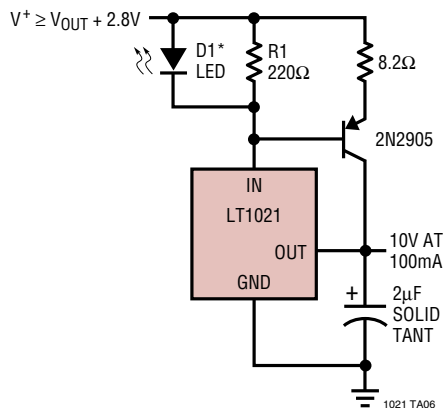


Negative Series Reference



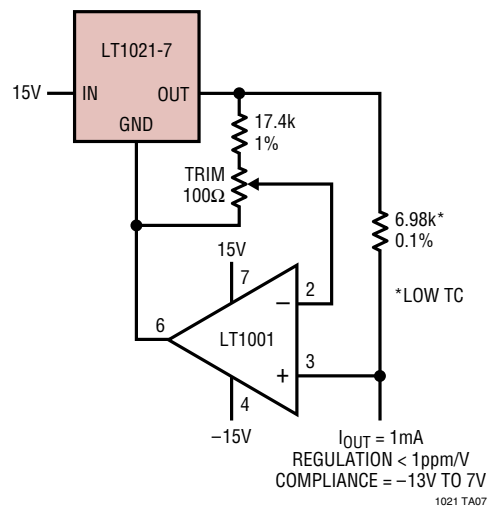
1021fc

TYPICAL APPLICATIONS

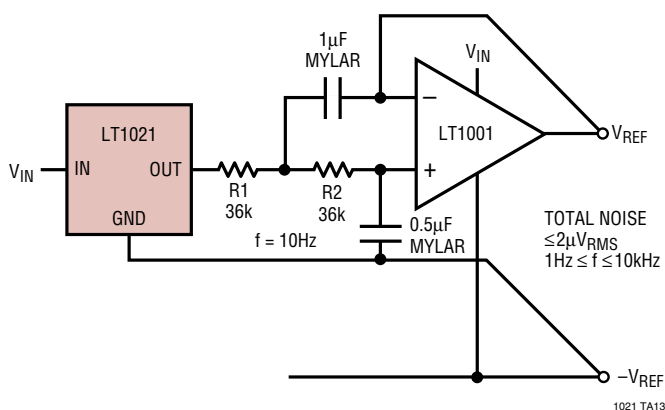
Boosted Output Current
with No Current LimitBoosted Output Current
with Current Limit

*GLOWS IN CURRENT LIMIT,
DO NOT OMIT

Ultraprecise Current Source

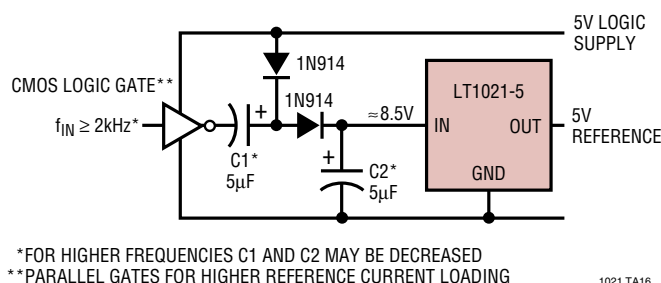


2-Pole Lowpass Filtered Reference



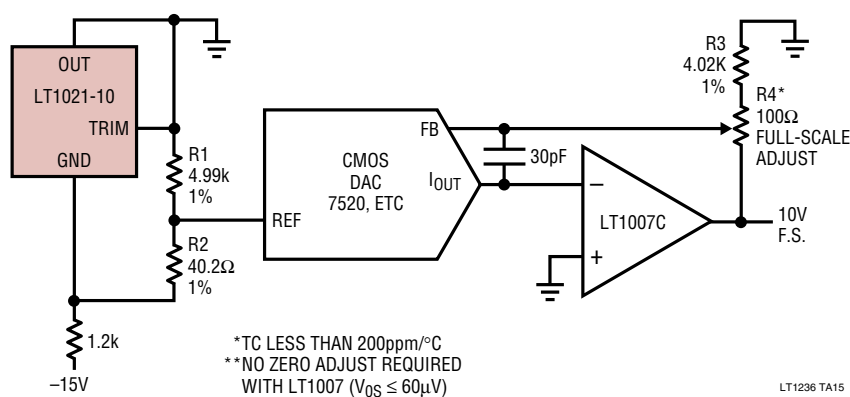
TOTAL NOISE
 $\leq 2\mu\text{VRMS}$
 $1\text{Hz} \leq f \leq 10\text{kHz}$

Operating 5V Reference from 5V Supply



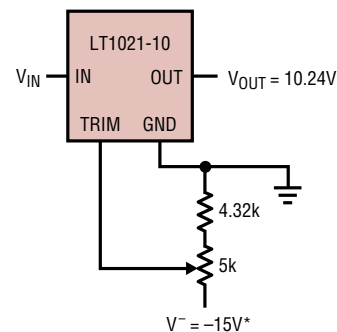
*FOR HIGHER FREQUENCIES C1 AND C2 MAY BE DECREASED
**PARALLEL GATES FOR HIGHER REFERENCE CURRENT LOADING

CMOS DAC with Low Drift Full-Scale Trimming**



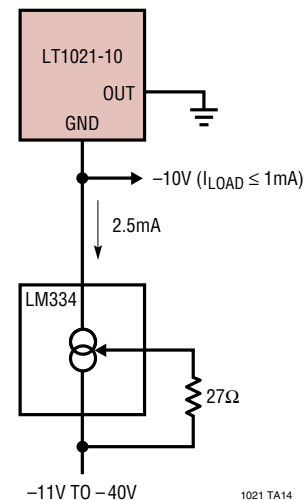
*TC LESS THAN 200ppm/°C
**NO ZERO ADJUST REQUIRED
WITH LT1007 ($V_{OS} \leq 60\mu\text{V}$)

Trimming 10V Units to 10.24V



*MUST BE WELL REGULATED
 $\frac{dV_{OUT}}{dV^-} = \frac{15\text{mV}}{\text{V}}$

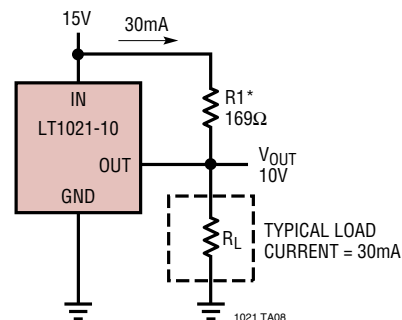
Negative Shunt Reference Driven by Current Source



***BRIDGE IS ULTRALINEAR WHEN ALL LEGS ARE ACTIVE, TWO IN COMPRESSION AND TWO IN TENSION, OR WHEN ONE SIDE IS ACTIVE WITH ONE COMPRESSED AND ONE TENSIONED LEG**

†OFFSET AND DRIFT OF LM301A ARE VIRTUALLY ELIMINATED BY DIFFERENTIAL CONNECTION OF LT1012C

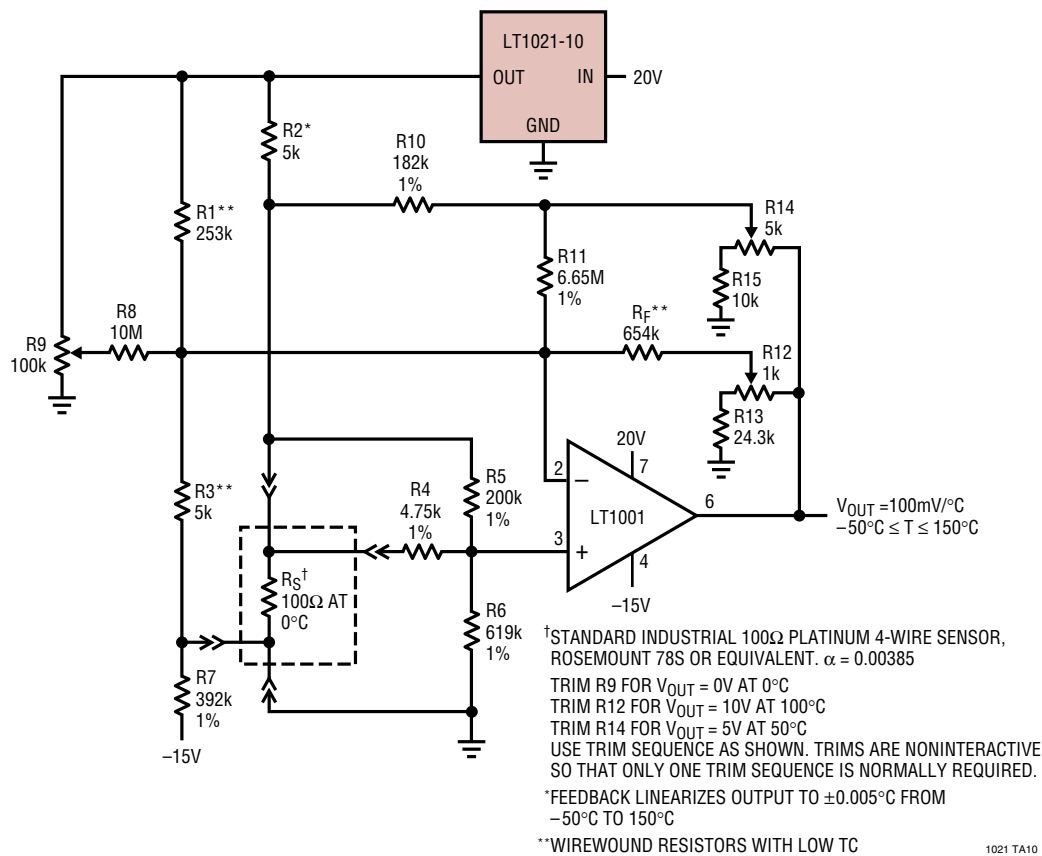
Handling Higher Load Currents



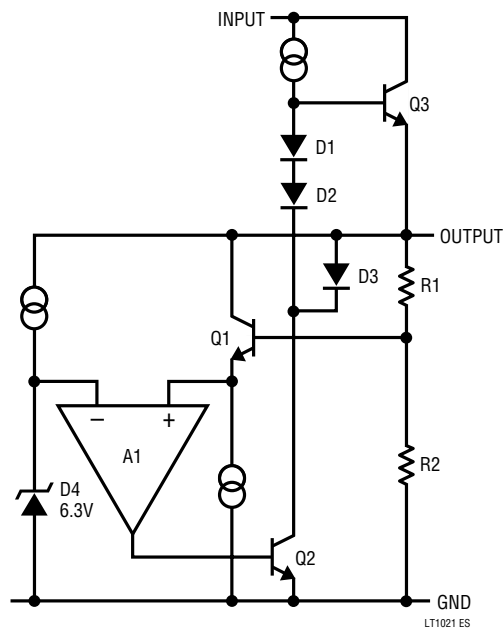
*SELECT R1 TO DELIVER TYPICAL LOAD CURRENT.
LT1021 WILL THEN SOURCE OR SINK AS NECESSARY
TO MAINTAIN PROPER OUTPUT. DO NOT REMOVE LOAD
AS OUTPUT WILL BE DRIVEN UNREGULATED HIGH. LINE
REGULATION IS DEGRADED IN THIS APPLICATION

TYPICAL APPLICATIONS

Ultralinear Platinum Temperature Sensor*

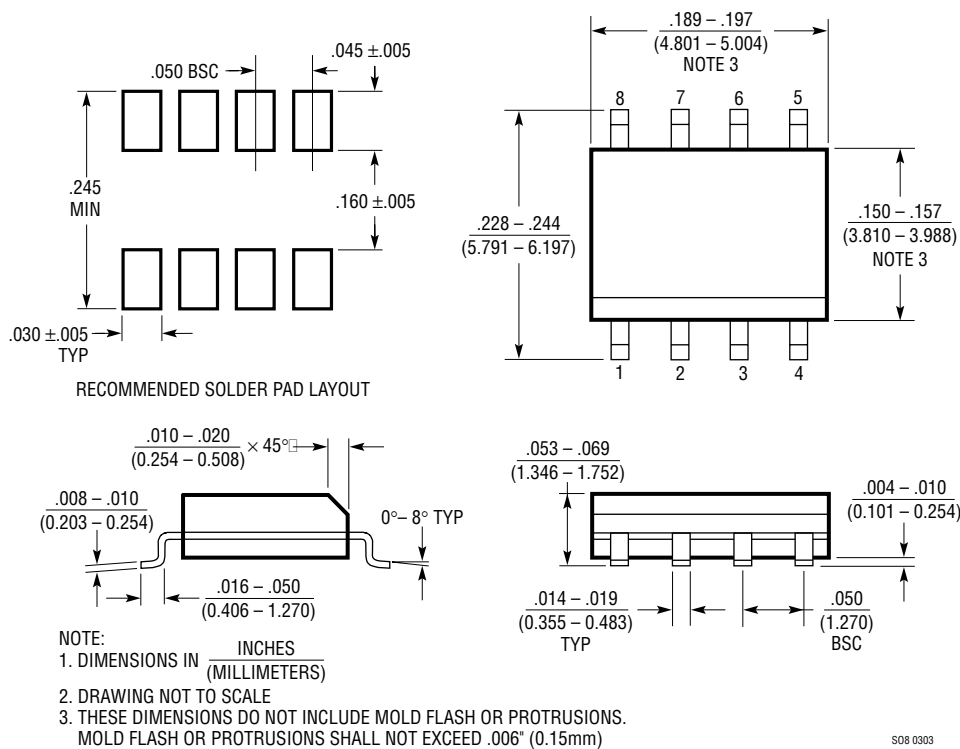


EQUIVALENT SCHEMATIC



PACKAGE DESCRIPTION

S8 Package 8-Lead Plastic Small Outline (Narrow .150 Inch) (Reference LTC DWG # 05-08-1610)



RELATED PARTS

PART NUMBER	DESCRIPTION	COMMENTS
LT1019	Precision Bandgap Reference	0.05%, 5ppm/°C
LT1027	Precision 5V Reference	0.02%, 2ppm/°C
LT1236	Precision Reference	SO-8, 5V and 10V, 0.05%, 5ppm/°C
LTC®1258	Micropower Reference	200mV Dropout, MSOP
LT1389	Nanopower Shunt Reference	800nA Operating Current
LT1460	Micropower Reference	SOT-23, 2.5V, 5V, 10V
LT1634	Micropower Shunt Reference	0.05%, 10ppm/°C, MSOP