

## FEATURES

- **Ultralow Drift: 5ppm/°C Max Slope**
- **Very Low Noise: <1ppm p-p (0.1Hz to 10Hz)**
- **100% Noise Tested**
- Pin Compatible with Most Bandgap Reference Applications, Including Ref 01, Ref 02, LM368, MC1400 and MC1404 with Greatly Improved Stability, Noise and Drift
- Trimmed Output Voltage
- Operates in Series or Shunt Mode
- Output Sinks and Sources in Series Mode
- >100dB Ripple Rejection
- Minimum Input/Output Differential of 1V
- Available in 5-Lead Can, N8 and S8 Packages

## APPLICATIONS

- A/D and D/A Converters
- Precision Regulators
- Digital Voltmeters
- Inertial Navigation Systems
- Precision Scales
- Portable Reference Standard

## DESCRIPTION

The LT<sup>®</sup>1021 is a precision reference with ultralow drift and noise, extremely good long term stability and almost total immunity to input voltage variations. The reference output will both source and sink up to 10mA. Three voltages are available: 5V, 7V and 10V. The 7V and 10V units can be used as shunt regulators (two-terminal zeners) with the same precision characteristics as the three-terminal connection. Special care has been taken to minimize thermal regulation effects and temperature induced hysteresis.

The LT1021 references are based on a buried zener diode structure that eliminates noise and stability problems associated with surface breakdown devices. Further, a subsurface zener exhibits better temperature drift and time stability than even the best bandgap references.

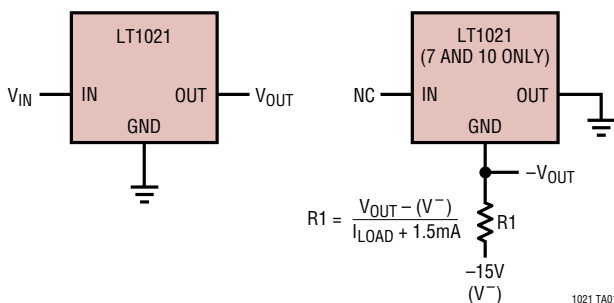
Unique circuit design makes the LT1021 the first IC reference to offer ultralow drift without the use of high power on-chip heaters.

The LT1021-7 uses no resistive divider to set output voltage, and therefore exhibits the best long term stability and temperature hysteresis. The LT1021-5 and LT1021-10 are intended for systems requiring a precise 5V or 10V reference with an initial tolerance as low as ±0.05%.

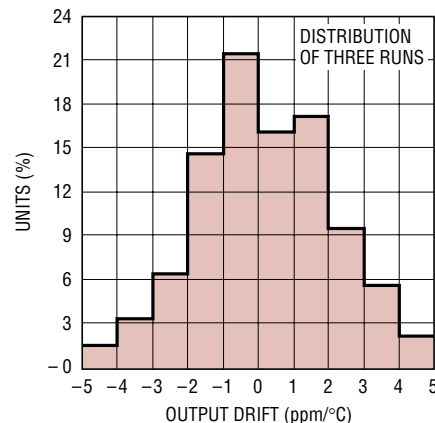
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## TYPICAL APPLICATION

Basic Positive and Negative Connections



Typical Distribution of Temperature Drift



1021 TA01

1021fc

# LT1021

## 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

|   |   |
|---|---|
| <p style="text-align: center;">TOP VIEW</p> <p style="text-align: center;">H PACKAGE<br/>8-LEAD TO-5 METAL CAN</p> <p>*CONNECTED INTERNALLY. DO NOT CONNECT EXTERNAL CIRCUITRY TO THESE PINS.<br/>**NO TRIM PIN ON LT1021-7. DO NOT CONNECT EXTERNAL CIRCUITRY TO PIN 5 ON LT1021-7<br/><math>T_{JMAX} = 150^{\circ}C, \theta_{JA} = 150^{\circ}C/W, \theta_{JC} = 45^{\circ}C/W</math></p> | <p style="text-align: center;">TOP VIEW</p> <p style="text-align: center;">N8 PACKAGE      S8 PACKAGE<br/>8-LEAD PDIP      8-LEAD PLASTIC SO</p> <p>*CONNECTED INTERNALLY. DO NOT CONNECT EXTERNAL CIRCUITRY TO THESE PINS.<br/>**NO TRIM PIN ON LT1021-7. DO NOT CONNECT EXTERNAL CIRCUITRY TO PIN 5 ON LT1021-7<br/><math>T_{JMAX} = 130^{\circ}C, \theta_{JA} = 130^{\circ}C/W (N)</math><br/><math>T_{JMAX} = 130^{\circ}C, \theta_{JA} = 150^{\circ}C/W (S)</math></p> |
|---|---|

| ORDER PART NUMBER  |  | N8 ORDER PART NUMBER  |                      |
|--|--|---|----------------------|
| LT1021BCH-5<br>LT1021BMH-5<br>LT1021CCH-5<br>LT1021CMH-5<br>LT1021BMH-10 | LT1021DCH-5<br>LT1021DMH-5<br>LT1021BCH-7<br>LT1021BMH-7<br>LT1021DCH-7<br>LT1021DMH-7<br>LT1021BCH-10<br>LT1021CMH-10<br>LT1021DCH-10<br>LT1021DMH-10<br><p style="text-align: center; font-weight: bold;">OBSOLETE</p> | LT1021BCN8-5<br>LT1021CCN8-5<br>LT1021CIN8-5<br>LT1021DCN8-5<br>LT1021DIN8-5<br>LT1021BCN8-7<br>LT1021DCN8-7<br>LT1021BCN8-10<br>LT1021CCN8-10<br>LT1021CIN8-10<br>LT1021DCN8-10<br>LT1021DIN8-10 |                      |
|  |  | S8 ORDER PART NUMBER  | S8 PART MARKING      |
|  |  | LT1021DCS8-5<br>LT1021DCS8-7<br>LT1021DCS8-10   | 2105<br>2107<br>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) | $T_{MIN} \leq T_J \leq T_{MAX}$<br>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                 |
|   | $10\text{V} \leq V_{IN} \leq 40\text{V}$      | ●        | 2     | 6      | ppm/V                 |
| Load Regulation (Sourcing Current)              | $0 \leq I_{OUT} \leq 10\text{mA}$<br>(Note 4) | ●        | 10    | 20     | ppm/mA                |
|   |   | ●        |       | 35     | ppm/mA                |
| Load Regulation (Sinking Current)               | $0 \leq I_{OUT} \leq 10\text{mA}$<br>(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   |        | $\mu\text{V}_{P-P}$   |
|   | $10\text{Hz} \leq f \leq 1\text{kHz}$         |          | 2.2   | 3.5    | $\mu\text{V}_{RMS}$   |
| 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) | $T_{MIN} \leq T_J \leq T_{MAX}$<br>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                 |
|   | $12\text{V} \leq V_{IN} \leq 40\text{V}$                       | ●        | 2.0  | 8    | ppm/V                 |
| Load Regulation (Sourcing Current)              | $0 \leq I_{OUT} \leq 10\text{mA}$<br>(Note 4)                  | ●        | 0.5  | 2    | ppm/V                 |
|   |  | ●        | 1.0  | 4    | ppm/V                 |
| Load Regulation (Shunt Mode)                    | $1.2\text{mA} \leq I_{SHUNT} \leq 10\text{mA}$<br>(Notes 4, 5) | ●        | 12   | 25   | ppm/mA                |
|   |  | ●        |      | 40   | ppm/mA                |
| Supply Current (Series Mode)                    |  | ●        | 50   | 100  | ppm/mA                |
|   |  | ●        |      | 150  | ppm/mA                |
| Minimum Current (Shunt Mode)                    | $V_{IN}$ is Open   | ●        | 0.75 | 1.2  | mA                    |
|   |  | ●        |      | 1.5  | mA                    |
| Output Voltage Noise (Note 6)                   | $0.1\text{Hz} \leq f \leq 10\text{Hz}$                         |          | 0.7  | 1.0  | mA                    |
|   | $10\text{Hz} \leq f \leq 1\text{kHz}$                          |          |      | 1.2  | mA                    |
| Output Voltage Noise (Note 6)                   | $0.1\text{Hz} \leq f \leq 10\text{Hz}$                         |          | 4.0  |      | $\mu\text{V}_{P-P}$   |
|   | $10\text{Hz} \leq f \leq 1\text{kHz}$                          |          | 2.5  | 4.0  | $\mu\text{V}_{RMS}$   |
| 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) | $T_{MIN} \leq T_J \leq T_{MAX}$<br>LT1021B-10                  | ●         | 2     | 5      | ppm/°C              |
|   | LT1021C-10/LT1021D-10  | ●         | 5     | 20     | ppm/°C              |
| Line Regulation (Note 4)                        | $11.5\text{V} \leq V_{IN} \leq 14.5\text{V}$                   | ●         | 1.0   | 4      | ppm/V               |
|   | $14.5\text{V} \leq V_{IN} \leq 40\text{V}$                     | ●         | 0.5   | 2      | ppm/V               |
| Load Regulation (Sourcing Current)              | $0 \leq I_{OUT} \leq 10\text{mA}$<br>(Note 4)                  | ●         | 12    | 25     | ppm/mA              |
|   |  | ●         |       | 40     | ppm/mA              |
| Load Regulation (Shunt Mode)                    | $1.7\text{mA} \leq I_{SHUNT} \leq 10\text{mA}$<br>(Notes 4, 5) | ●         | 50    | 100    | ppm/mA              |
|   |  | ●         |       | 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   |        | $\mu\text{V}_{P-P}$ |
|   | $10\text{Hz} \leq f \leq 1\text{kHz}$                          |           | 3.5   | 6      | $\mu\text{V}_{RMS}$ |
| 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  $25^\circ\text{C}$  and  $25^\circ\text{C}$  to  $T_{MAX}$ . **Incremental slope is also measured at  $25^\circ\text{C}$ .**

**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  $150^\circ\text{C/W}$  for TO-5 (H),  $130^\circ\text{C/W}$  for N and  $150^\circ\text{C/W}$  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.

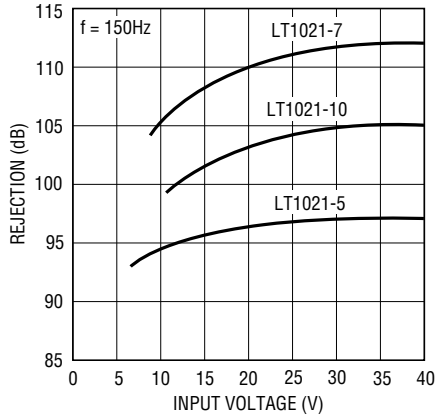
**Note 6:** RMS noise is measured with a 2-pole highpass filter at 10Hz and a 2-pole lowpass filter at 1kHz. The resulting output is full-wave rectified and then integrated for a fixed period, making the final reading an average as opposed to RMS. Correction factors are used to convert from average to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

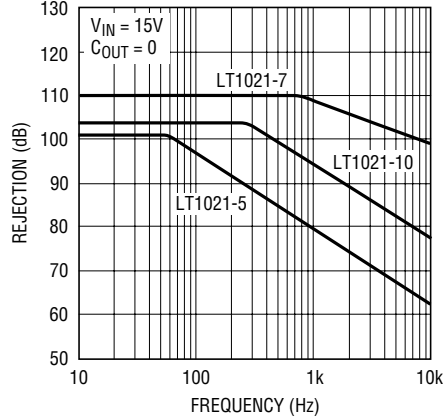
# TYPICAL PERFORMANCE CHARACTERISTICS

**Ripple Rejection**



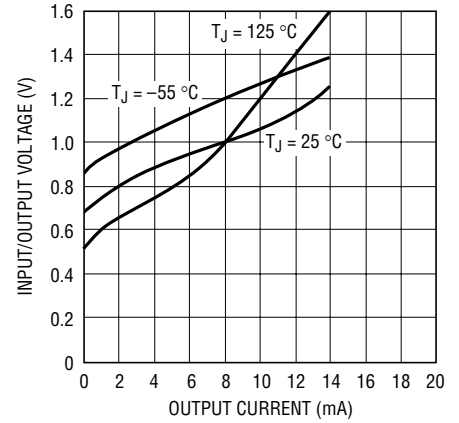
LT1021 G01

**Ripple Rejection**



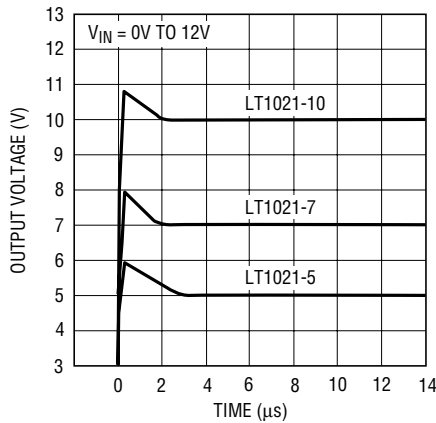
LT1021 G02

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



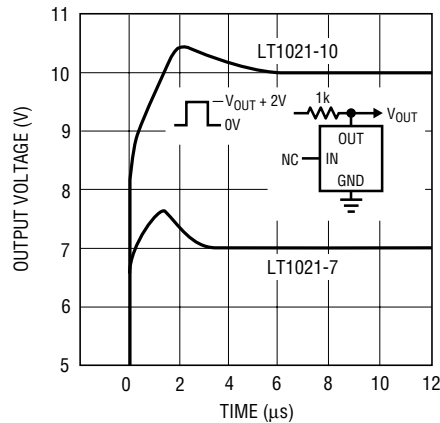
1021 G03

**Start-Up (Series Mode)**



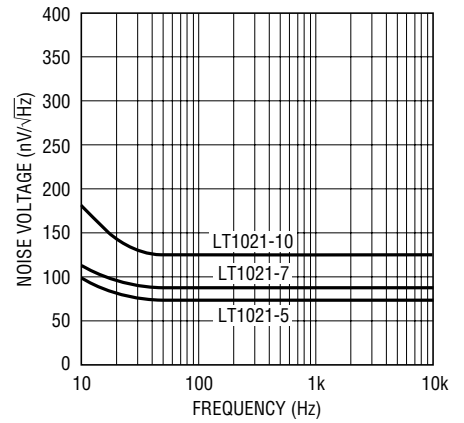
LT1021 G04

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



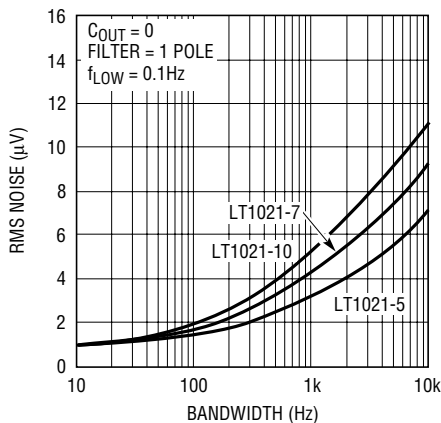
LT1021 G05

**Output Voltage Noise Spectrum**



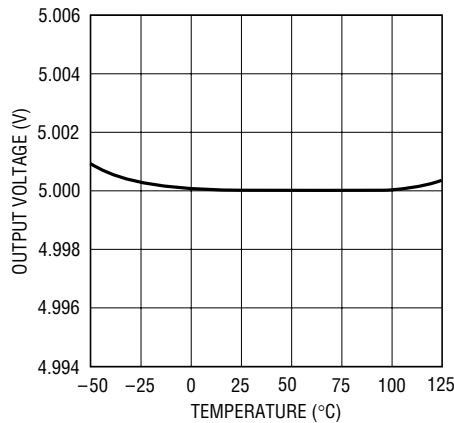
LT1021 G06

**Output Voltage Noise**



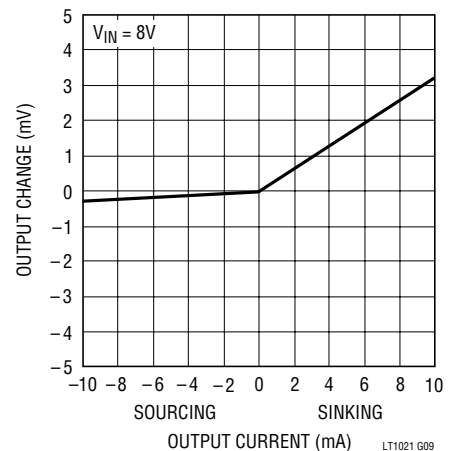
LT1021 G07

**Output Voltage Temperature Drift  
LT1021-5**



LT1021 G08

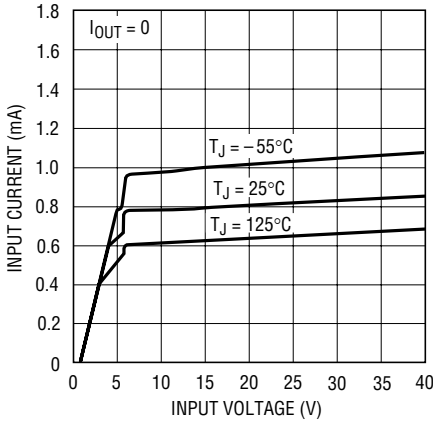
**Load Regulation LT1021-5**



LT1021 G09

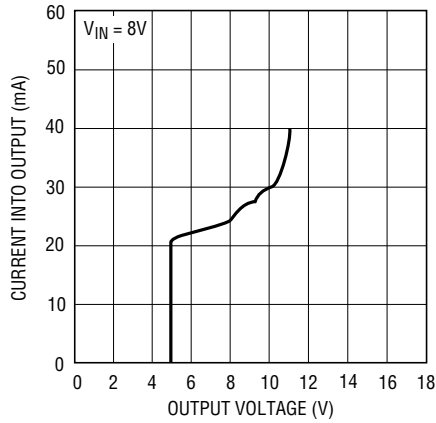
## TYPICAL PERFORMANCE CHARACTERISTICS

**Quiescent Current LT1021-5**



LT1021 G10

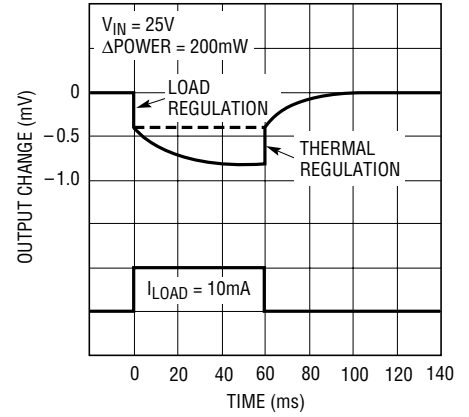
**Sink Mode\* Current Limit LT1021-5**



LT1021 G11

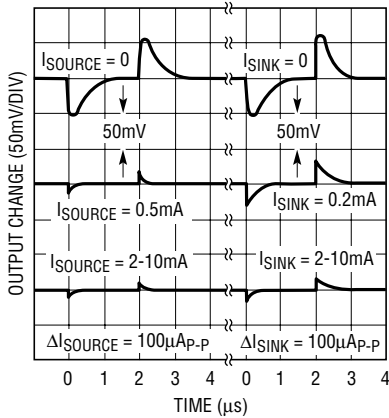
\*NOTE THAT AN INPUT VOLTAGE IS REQUIRED FOR 5V UNITS.

**Thermal Regulation LT1021-5**



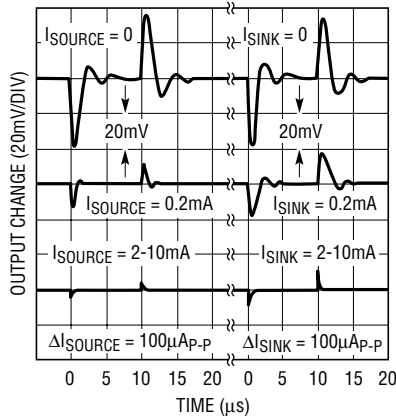
LT1021 G12

**Load Transient Response LT1021-5, CLOAD = 0**



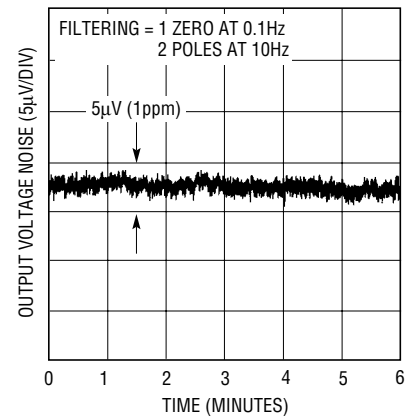
LT1021 G13

**Load Transient Response LT1021-5, CLOAD = 1000pF**



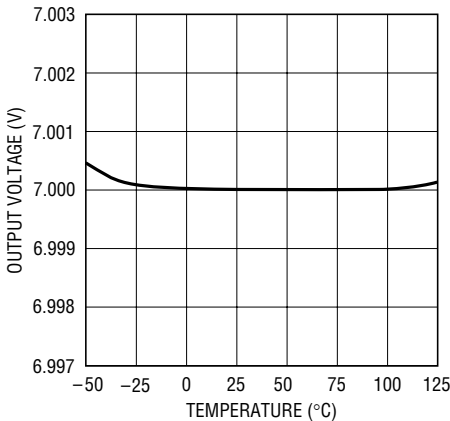
LT1021 G14

**Output Noise 0.1Hz to 10Hz LT1021-5**



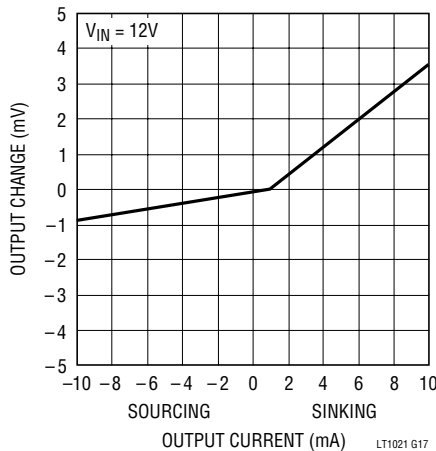
LT1021 G15

**Output Voltage Temperature Drift LT1021-7**



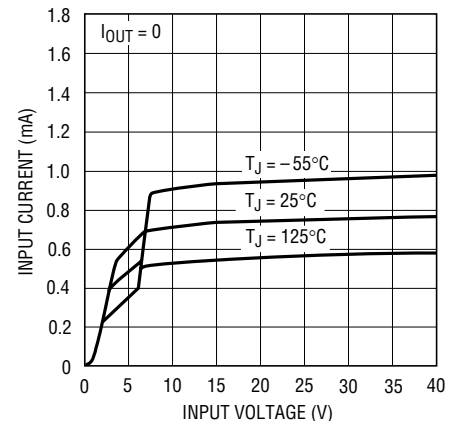
LT1021 G16

**Load Regulation LT1021-7, LT1021-10**



LT1021 G17

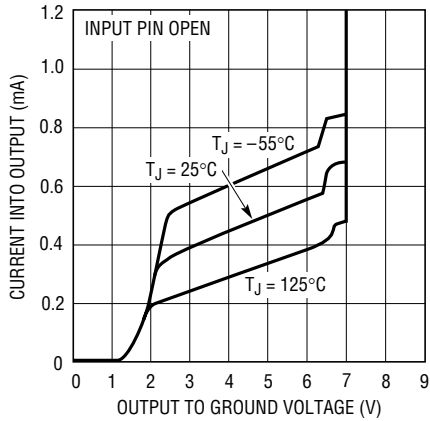
**Quiescent Current LT1021-7**



LT1021 G18  
10211c

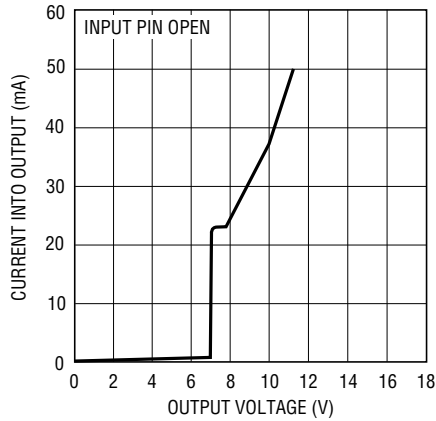
# TYPICAL PERFORMANCE CHARACTERISTICS

**Shunt Characteristics LT1021-7**



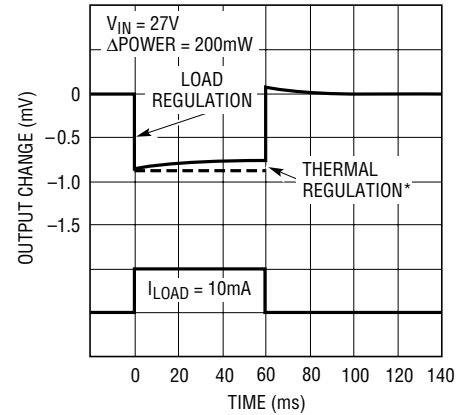
1021 G19

**Shunt Mode Current Limit LT1021-7**



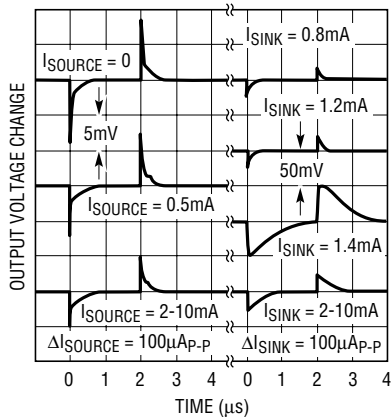
LT1021 G20

**Thermal Regulation LT1021-7**



\*INDEPENDENT OF TEMPERATURE COEFFICIENT  
LT1021 G21

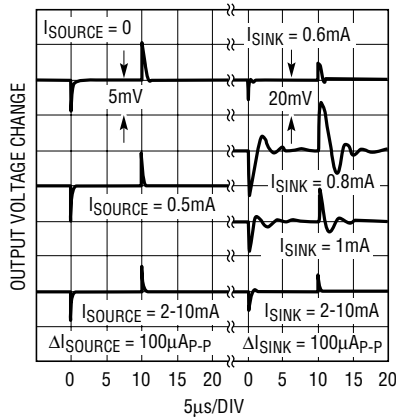
**Load Transient Response LT1021-7, C<sub>LOAD</sub> = 0**



NOTE VERTICAL SCALE CHANGE BETWEEN SOURCING AND SINKING

LT1021 G22

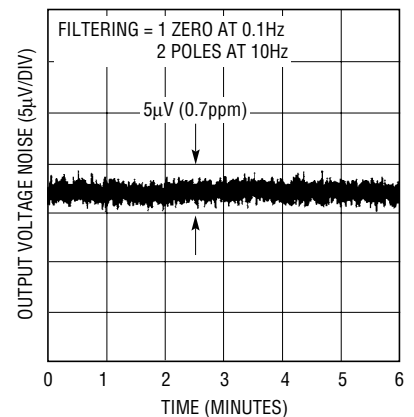
**Load Transient Response LT1021-7, C<sub>LOAD</sub> = 1000pF**



NOTE VERTICAL SCALE CHANGE BETWEEN SOURCING AND SINKING

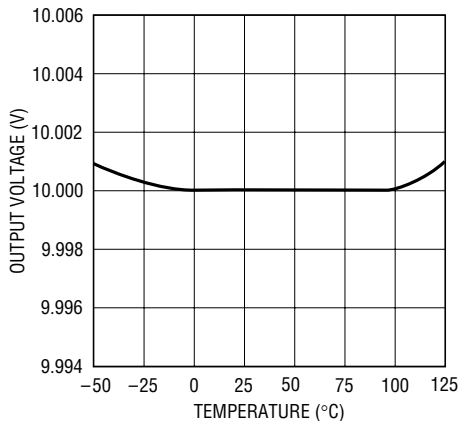
LT1021 G23

**Output Noise 0.1Hz to 10Hz LT1021-7**



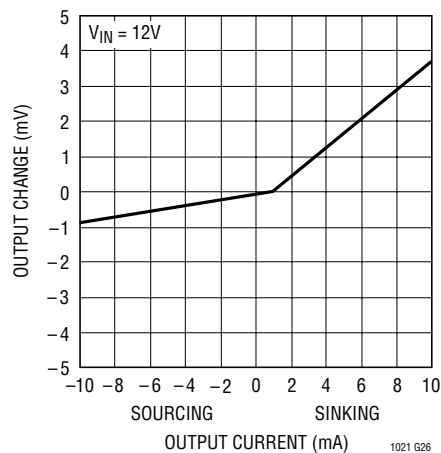
LT1021 G24

**Output Voltage Temperature Drift LT1021-10**



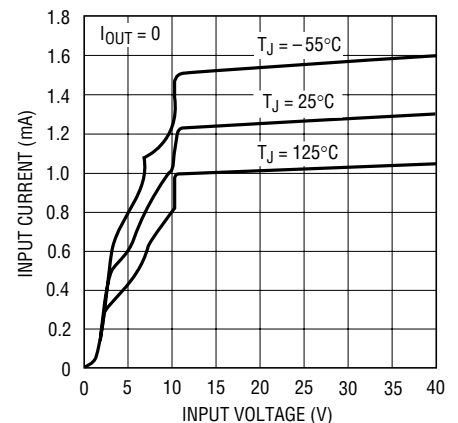
LT1021 G25

**Load Regulation LT1021-7, LT1021-10**



1021 G26

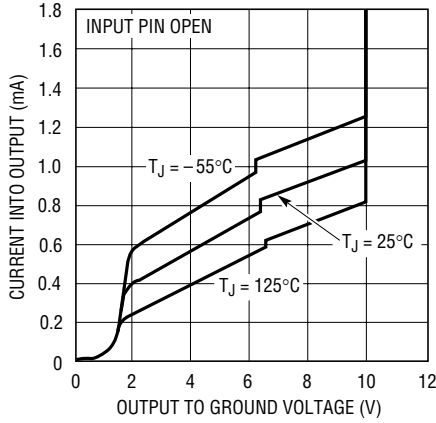
**Input Supply Current LT1021-10**



1021 G27  
1021fc

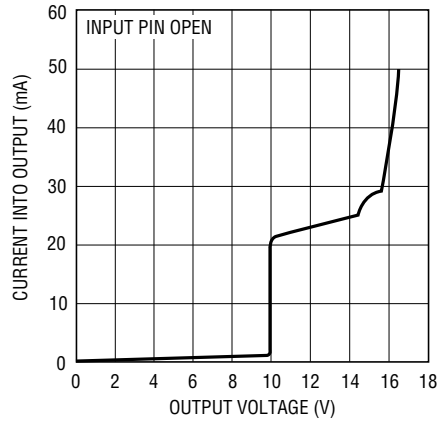
## TYPICAL PERFORMANCE CHARACTERISTICS

### Shunt Characteristics LT1021-10



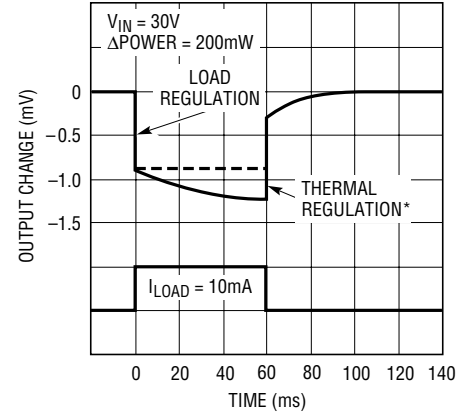
1021 G28

### Shunt Mode Current Limit LT1021-10



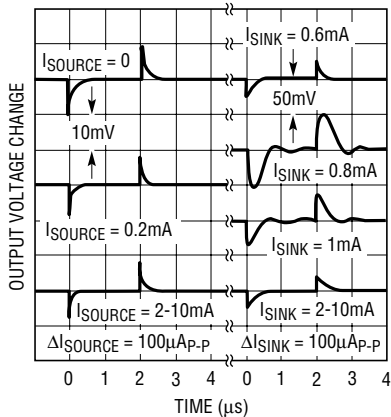
1021 G29

### Thermal Regulation LT1021-10



\*INDEPENDENT OF TEMPERATURE COEFFICIENT  
1021 G30

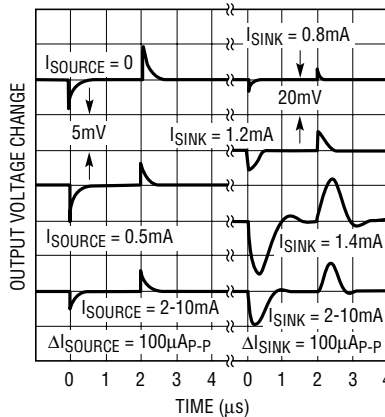
### Load Transient Response LT1021-10, $C_{LOAD} = 0$



NOTE VERTICAL SCALE CHANGE BETWEEN SOURCING AND SINKING

1021 G31

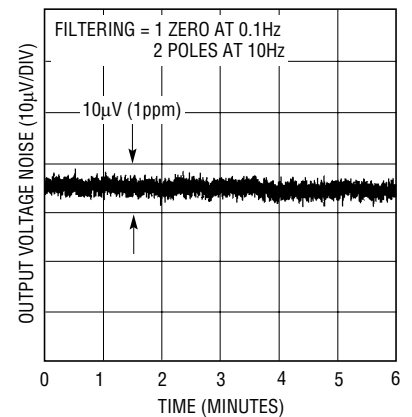
### Load Transient Response LT1021-10, $C_{LOAD} = 1000\text{pF}$



NOTE VERTICAL SCALE CHANGE BETWEEN SOURCING AND SINKING

1021 G32

### Output Noise 0.1Hz to 10Hz LT1021-10



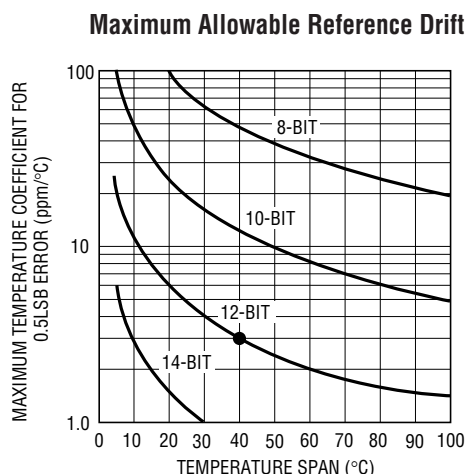
1021 G33



## 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

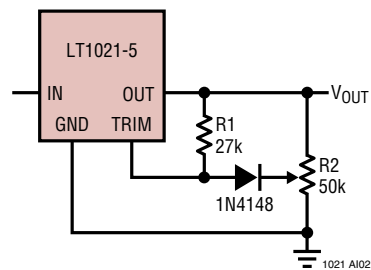
#### LT1021-10

The LT1021-10 has a trim pin for adjusting output voltage. The impedance of the trim pin is about 12kΩ with a nominal open-circuit voltage of 5V. It is designed to be driven from a source impedance of 3kΩ 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 ±70mV trim range when the trim pin is tied to the wiper of a potentiometer connected between the output and ground. A 10kΩ 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 ±5mV and therefore can utilize a restricted trim range. A 75k resistor in series with a 20kΩ potentiometer will give ±10mV trim range. Effect on the output TC will be only 1ppm/°C for the ±5mV 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 -1.7mV/°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 100kΩ 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.



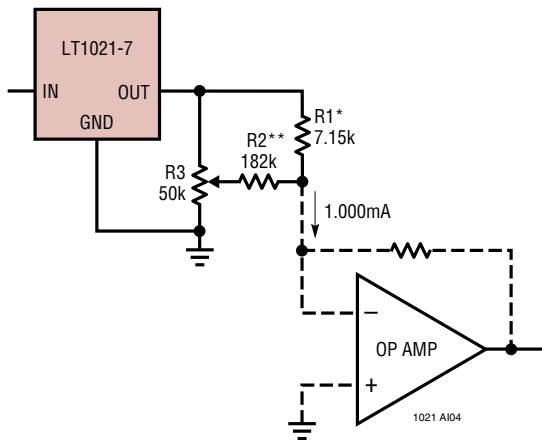
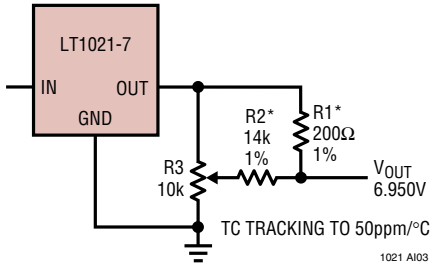
#### LT1021-7

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 200Ω 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.



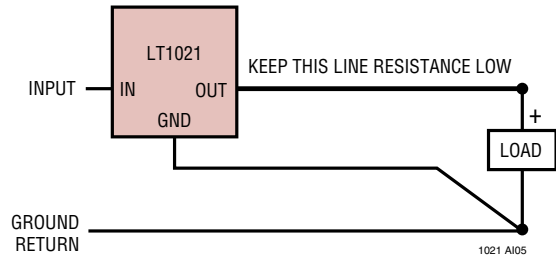
\*RESISTOR TC DETERMINES  $I_{OUT}$  TC  
 \*\*TC  $\leq (10 \cdot R1)$  TC. R2 AND R3 SCALE WITH R1 FOR DIFFERENT OUTPUT CURRENTS

### Kelvin Connections

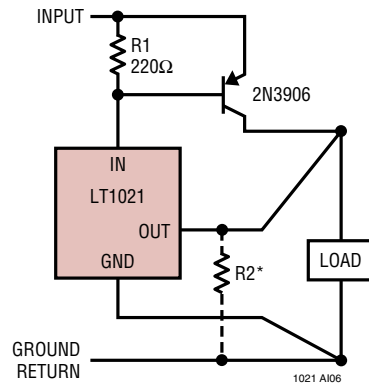
Although the LT1021 does not have true force/sense capability at its outputs, significant improvements in ground loop and line loss problems can be achieved with proper hook-up. In series mode operation, the ground pin of the LT1021 carries only  $\approx 1\text{mA}$  and can be used as a sense line, 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)

### 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 10 $\mu\text{F}$  solid tantalum capacitor with several ohms in series provides optimum output bypass.

## APPLICATIONS INFORMATION

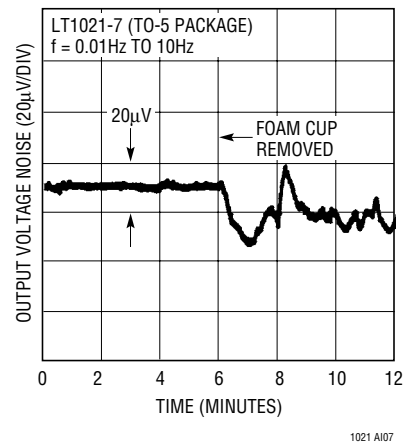
### Effects of Air Movement on Low Frequency Noise

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.

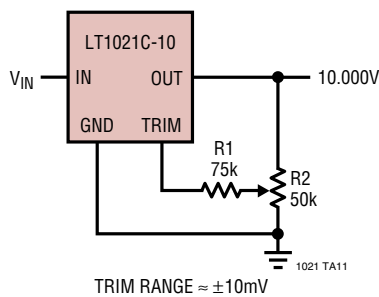
There is nothing magical about foam cups—any enclosure which blocks air flow from the reference will do. Smaller enclosures are better since they do not allow the build-up of internally generated air movement. Naturally, heat generating components external to the reference itself should not be included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

Noise Induced By Air Turbulence (TO-5 Package)

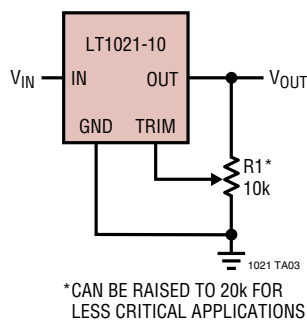


## TYPICAL APPLICATIONS

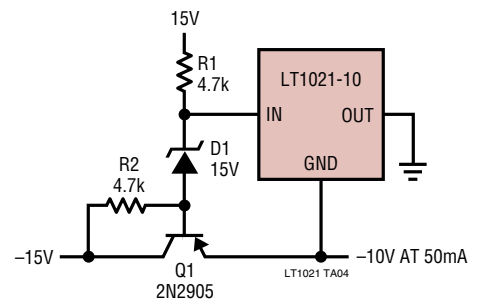
### Restricted Trim Range for Improved Resolution, 10V, "C" Version Only



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

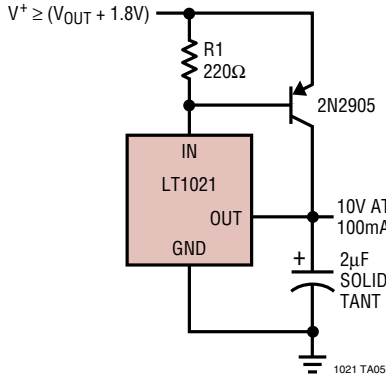


### Negative Series Reference

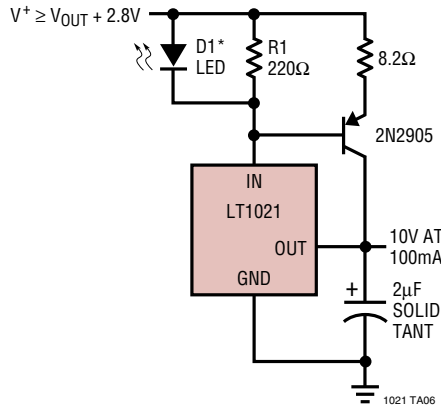


## TYPICAL APPLICATIONS

### Boosted Output Current with No Current Limit

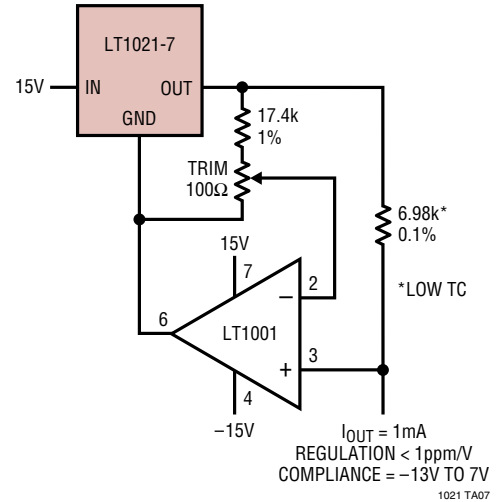


### Boosted Output Current with Current Limit

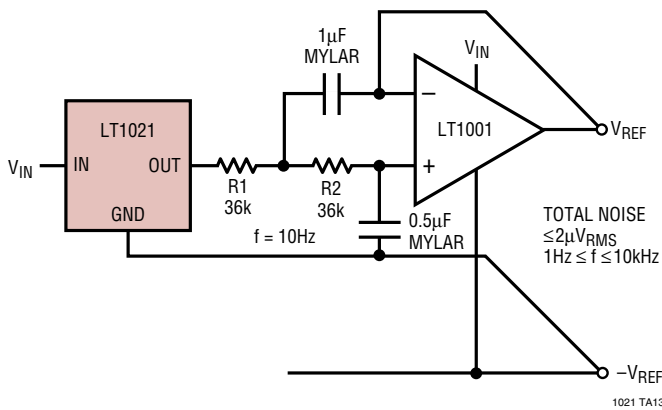


\*GLOWS IN CURRENT LIMIT, DO NOT OMIT

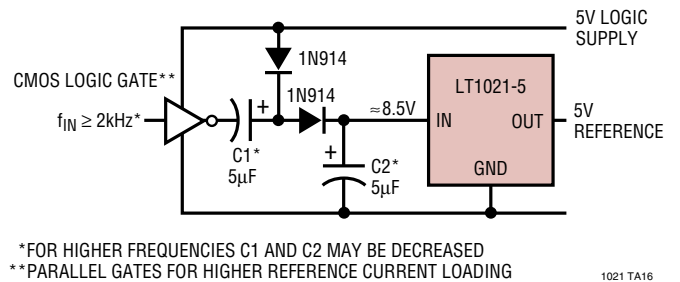
### Ultraprecise Current Source



### 2-Pole Lowpass Filtered Reference

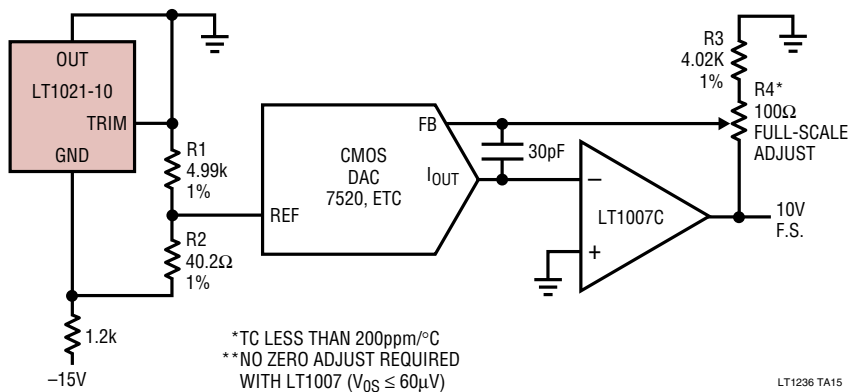


### Operating 5V Reference from 5V Supply



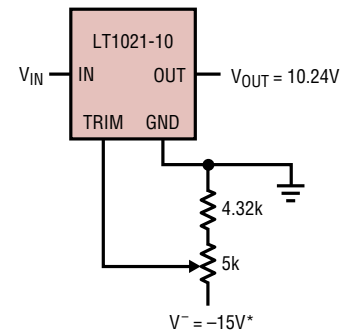
\*FOR HIGHER FREQUENCIES C1 AND C2 MAY BE DECREASED  
\*\*PARALLEL GATES FOR HIGHER REFERENCE CURRENT LOADING

### CMOS DAC with Low Drift Full-Scale Trimming\*\*



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

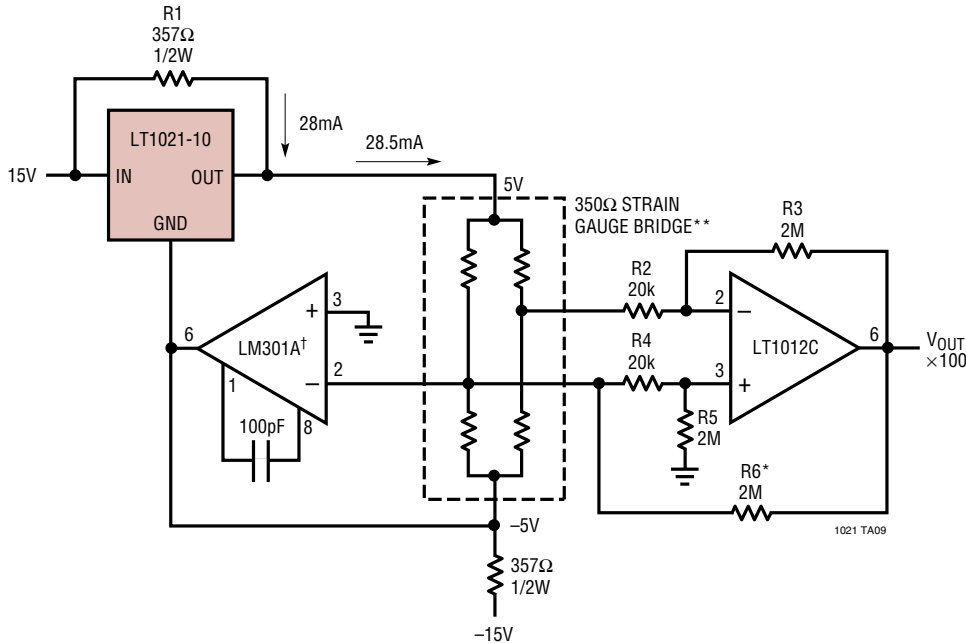
### Trimming 10V Units to 10.24V



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

# TYPICAL APPLICATIONS

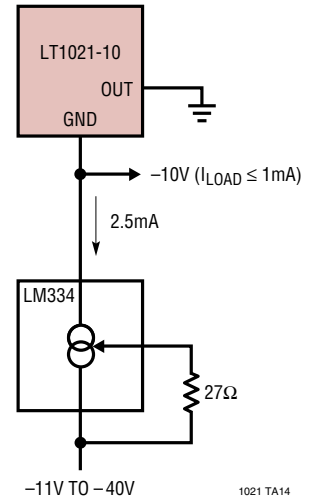
Strain Gauge Conditioner for 350Ω Bridge



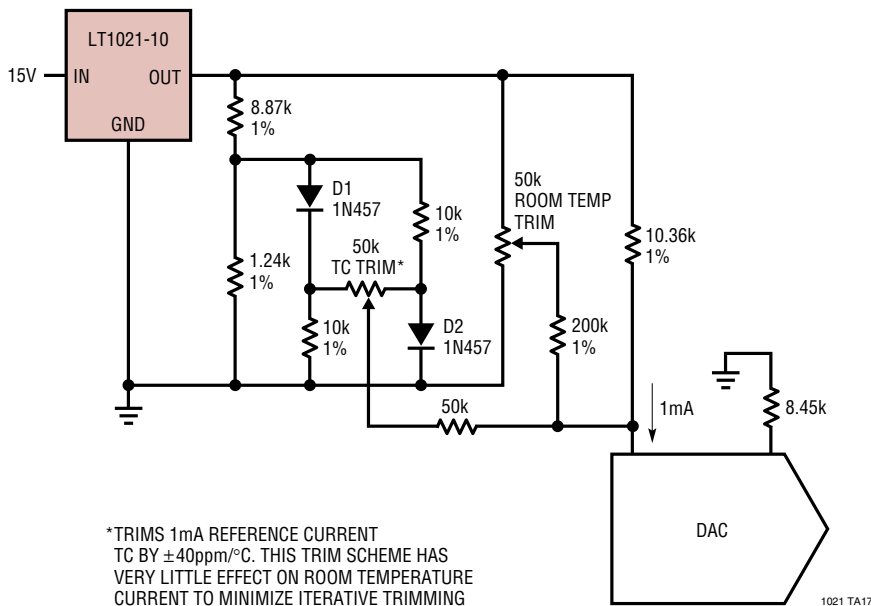
\*THIS RESISTOR PROVIDES POSITIVE FEEDBACK TO THE BRIDGE TO ELIMINATE LOADING EFFECT OF THE AMPLIFIER. EFFECTIVE  $Z_{IN}$  OF AMPLIFIER STAGE IS  $\geq 1M\Omega$ . IF R2 TO R5 ARE CHANGED, SET R6 = R3

\*\*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

Negative Shunt Reference Driven by Current Source

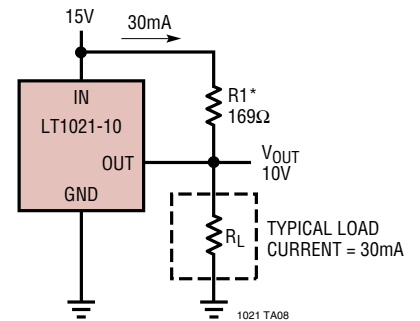


Precision DAC Reference with System TC Trim



\*TRIMS 1mA REFERENCE CURRENT TC BY  $\pm 40ppm/^{\circ}C$ . THIS TRIM SCHEME HAS VERY LITTLE EFFECT ON ROOM TEMPERATURE CURRENT TO MINIMIZE ITERATIVE TRIMMING

Handling Higher Load Currents



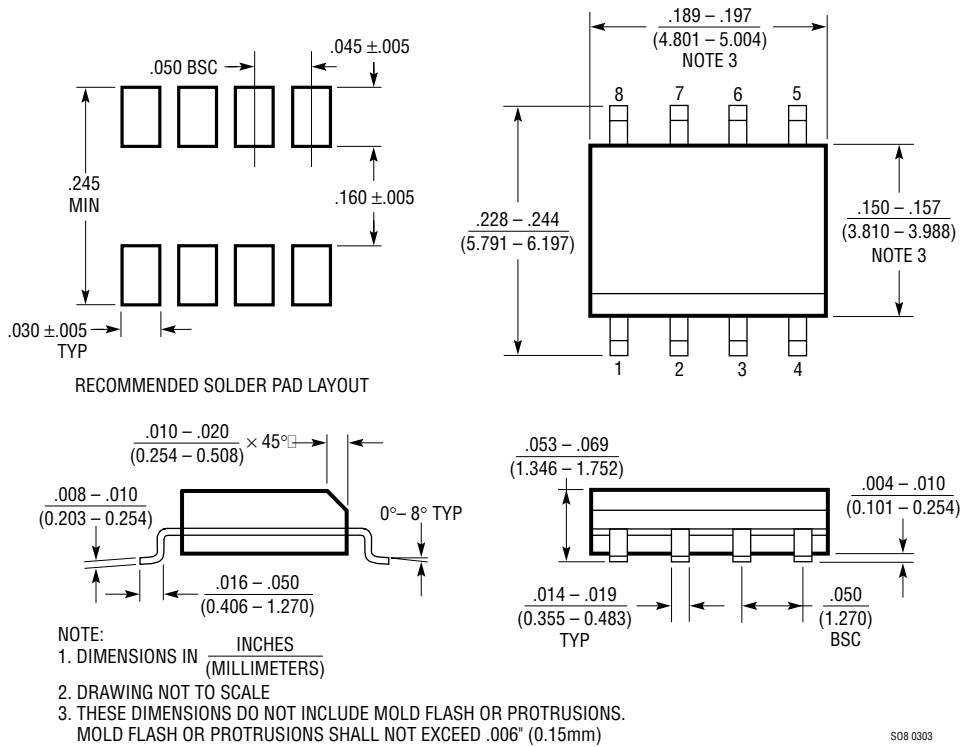
\*SELECT R1 TO DELIVER TYPICAL LOAD CURRENT. LT1021 WILL THEN SOURCE OR SINK AS NECESSARY TO MAINTAIN PROPER OUTPUT. DO NOT REMOVE LOAD AS OUTPUT WILL BE DRIVEN UNREGULATED HIGH. LINE REGULATION IS DEGRADED IN THIS APPLICATION





**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            |





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