Linear Technology Chronicle

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Products of the Month

Dual Micropower 12-Bit DACs Feature Rail-to-Rail Voltage Outputs and Single 5V or 3V Supplies

The **LTC®1454/LTC1454L** are 12-bit dual DACs, complete with rail-to-rail output amplifiers and references for single 5V and 3V supply applications. They have a maximum differential nonlinearity (DNL) of only ±0.5LSB for guaranteed better-than 12-bit monotonic performance, critical in control loop applications. The 5V LTC1454 typically draws just 700µA supply current while the 3V LTC1454L draws only 450µA. They are ideal in digitally controlled systems, such as system calibration DACs in industrial control systems and where multiple compact DACs are required. Their low power consumption also make them ideal for portable battery-powered instruments.

The LTC1454/LTC1454L include output buffer amplifiers that can swing to either supply rail. They produce an accurate full-scale output even when driving heavy loads on reduced supply voltages and have improved capacitive load handling compared to competing devices. The user selects the output amplifier gain (×1 or ×2) and full-scale value independently for maximum flexibility. Power-on reset ensures that the outputs are at zero scale on power-up. An asynchronous clear pin also resets all DACs to zero scale. This can be an essential feature in industrial control systems, such as high powered motion control.

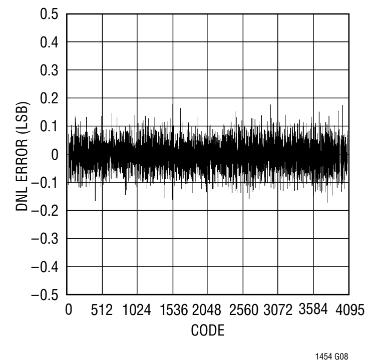

Figure 2. Differential Nonlinearity vs Input Code

The LTC1454/LTC1454L communicate to the digital control system over a cascadable, 3-wire serial interface that is compatible with MICROWIRE™, SPI and QSPI protocols. The on-chip reference is brought out allowing it to be used for external circuitry. Figure 2 shows the typical differential nonlinearity as less than 0.2LSB over the full range of 12-bits. The LTC1454/LTC1454L are packaged in narrow 16-lead PDIP and SO packages. All parts are available from stock screened to the commercial and industrial temperature ranges. For a data sheet and evaluation samples, contact your local Linear Technology sales office.

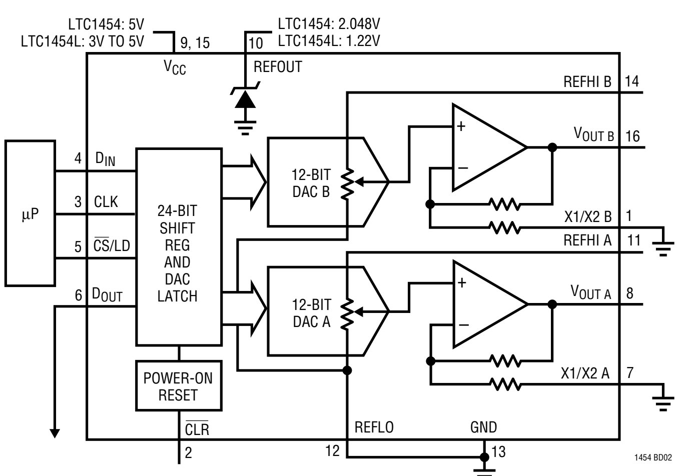

Figure 1. LTC1454/LTC1454L Dual 12-Bit Rail-to-Rail DACs

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Inside This Issue:

Precision Bandgap Voltage References Accurate to 0.075%, 10ppm/°C

The **LT®1460** is a 2.5V output, precision series, bandgap reference that combines very high accuracy and low drift with low power dissipation. It is trimmed to a guaranteed initial accuracy of 0.075% maximum and has a maximum drift of 10ppm/°C (A-grade version). The LT1460 draws a maximum of only 130µA of supply current. This reference can source up to 20mA, making it ideal for precision regulator applications and it is almost totally immune

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to input voltage variations. It is stable with any value of output capacitor, including none, saving components and board space. This is also important where fast settling time is required, such as ADC reference inputs.

The LT1460 is offered in 8-pin PDIP and SO packages. This 2.5V reference offers supply current and power dissipation advantages over shunt references that must idle the entire load current to operate. Typical distribution of output voltage error is shown in Figure 1. Reverse battery protection keeps the LT1460 from conducting current and being damaged in the fault condition of supply reversal. Contact your local Linear Technology sales office for a data sheet and evaluation samples.

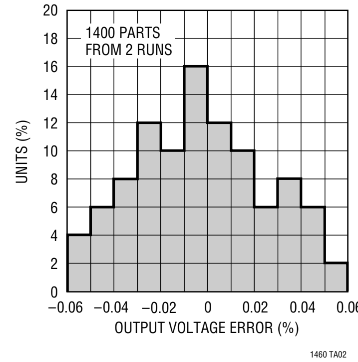

Figure 1. Typical Distribution of Output Voltage Error

12-Bit DAC Includes Clear Pin in SO-8 Package

The **LTC1456** is a micropower, 12-bit, voltage output DAC in an SO-8 package. It is complete with a 2.048V internal bandgap voltage reference, rail-to-rail output buffer amplifier and a 3-wire cascadable serial interface. A Clear pin, shown in Figure 1, asynchronously clears the DAC to zero scale. Better than 12-bit monotonicity is guaranteed by ±0.5LSB maximum DNL error (Figure 2). Power supply current is a low 400mA when operating from a 5V supply, making the LTC1456 ideal for battery-powered and portable applications.

The LTC1456 rail-to-rail output voltage capability maximizes the headroom available in low voltage, single supply applications. It operates on a 4.5V to 5.5V supply and provides a full-scale output of 4.095V. The output can drive 1000pF without going into oscillation. The LTC1456 is offered in 8-pin PDIP and SO packages in industrial and commercial temperature versions. For a data sheet and evaluation samples, contact your local Linear Technology sales office.

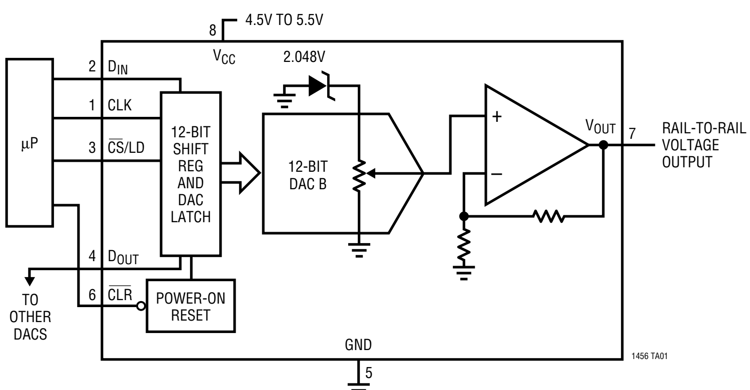

Figure 1. The LTC1456 Includes a CLR Pin to Reset the DAC to Zero

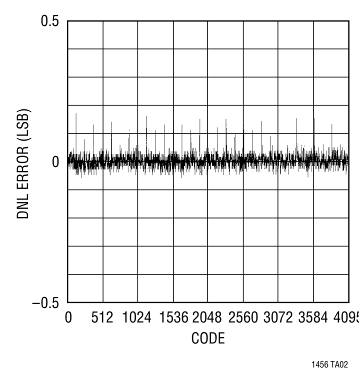

Figure 2. Differential Nonlinearity is Typically Less Than 0.2LSB

Ultrasmall 1V 600kHz Boost Switcher Maintains Constant Frequency Even at Low Load Current

The LT1307B fixed frequency PWM switching regulator is a new version of the LT1307 micropower single cell step-up converter, introduced in the August issue of *Linear Technology Chronicle*. The devices are similar except the LT1307B has its low power Burst Mode™ operation disabled. This allows 600kHz constant frequency switching from 1% to 100% of the load current range. Maintaining constant frequency even at greatly reduced load current can be essential for keeping noise out of the sensitive 455kHz IF band, important for pager and other wireless applications.

The LT1307B delivers up to 75mA of output current at 3.3V from a single alkaline cell. As shown in Figure 1, it provides over 75% efficiency from 1V to 1.5V at 40mA and efficiency is over 80% from 1.5V to 3.3V at 50mA. The operating quiescent current is only 70µA. The device contains a low-battery detector with a 200mV reference

Burst Mode is a trademark of Linear Technology Corporation.

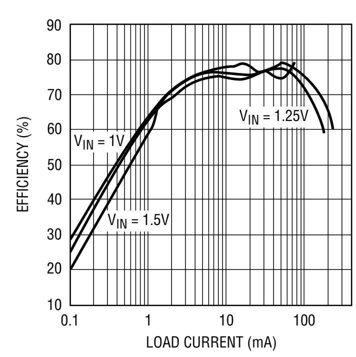

Figure 1. LT1307B Single Cell to 3.3V Converter Efficiency

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Application of the Month

Op Amp Selection Guide for Optimum Noise Performance

The amount of noise an op amp circuit will produce is determined by the device used, the total resistance in the circuit, the bandwidth of the measurement, the temperature of the circuit and the gain of the circuit. A convenient figure of merit for the noise performance of an op amp is the spectral density or spot noise. This is obtained by normalizing the measurement to a unit of bandwidth. Here the unit is 1Hz and the noise is reported as "$nV/\sqrt{Hz}$." The noise in a particular application bandwidth can be calculated by multiplying the spot noise by the square root of the application bandwidth.

Some other simplifications are made to facilitate comparison. For instance, the noise is referred to the input of the circuit so that the effect of the circuit gain, which will vary with application, does not confuse the issue. Also, the calculations assume a temperature of 27°C or 300°K.

The formula used to calculate the spot noise and the schematic of the circuit used are shown in Figure 1. Figures 2 through 4 plot the spot noise of selected op amps vs the equivalent source resistance. The first two plots show precision op amps intended for low frequency applications, whereas the last plot shows high speed voltage-feedback op amps. There are two plots for the low frequency op amps because at very low frequencies (less than about 200Hz) an additional noise mechanism, which is inversely proportional to frequency, becomes important. This is called 1/f or flicker noise. Figure 2 shows slightly higher levels of noise due to this contribution.

Studying the formula and the plots leads to several conclusions. The values of the resistors used should be as small as possible to minimize noise, but since the feedback resistor is a load on the output of the op amp, it must not be too small. For a small equivalent source resistance, the voltage noise dominates. As the resistance increases, the resistor noise becomes most important. When the source resistance is greater than 100k, the current noise dominates because the contribution of the current noise is proportional to R_{eq}, whereas the resistor noise is proportional to the $\sqrt{R_{eq}}$.

For low frequency applications and a source resistance greater than 100k, the LT1169 JFET input op amp is the obvious choice. Not only does the LT1169 have an extremely low current noise of $0.8fA/\sqrt{Hz}$, it also has a very low voltage noise of $6nV/\sqrt{Hz}$. The LT1169 also has excellent DC specifications, with a very low input bias current of 3pA (typical), which is maintained over the input common mode range and a high gain of 120dB.

High speed op amps, here defined by slew rates greater than 100V/µs, are plotted in Figure 4. These op amps come in a wider range of speeds than the precision op amps plotted in Figures 2 and 3. The faster parts will generally have slightly more spot noise, but because they will most likely be selected on the basis of speed, a selection of parts is plotted. For example, the LT1354–LT1363 (these are single op amps; duals and quads are available) are close in noise performance and consequently cluster close together on the plot, but have a speed range of 12MHz GBW to 70MHz GBW.
The same information is presented in tabular form in Table 1.

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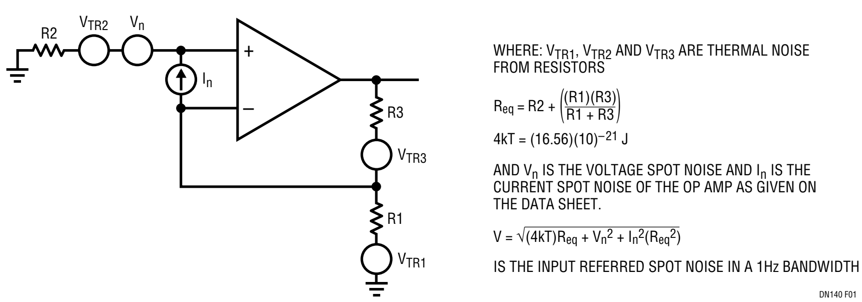

Figure 1. Noise Calculation Schematic Diagram

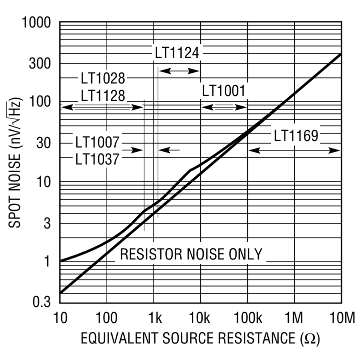

Figure 2. 10Hz Spot Noise vs Equivalent Source Resistance

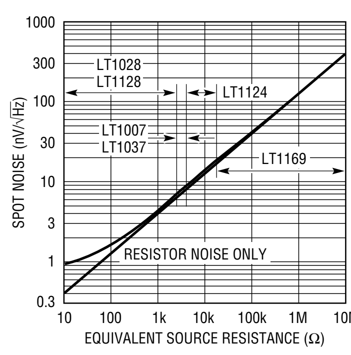

Figure 3. 1Hz Spot Noise vs Equivalent Source Resistance

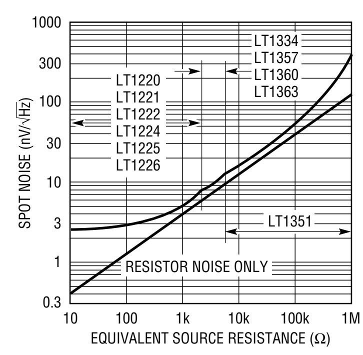

Figure 4. 10Hz Spot Noise vs Equivalent Source Resistance (High Speed Amplifiers)

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Table 1. Best Op Amp for Lowest Noise vs Source Resistance

	BEST OP AMP		
SOURCE R (R_{eq})	**10Hz PRECISION**	**1000Hz PRECISION**	**10kHz HIGH SPEED**
0Ω to 500Ω	LT1028, LT1115, LT1128	LT1028, LT1115, LT1128	LT1220/21/22/24/25/26
500Ω to 1.5k	LT1007, LT1037	LT1028, LT1115, LT1128	LT1220/21/22/24/25/26
1.5k to 3k	LT1124/25/26/27	LT1028, LT1115, LT1128	LT1220/21/22/24/25/26
3k to 5k	LT1124/25/26/27	LT1007, LT1037	LT1220/21/22/24/25/26
5k to 10k	LT1124/25/26/27	LT1124/25/26/27	LT1354/57/60/63
10k to 20k	LT1001/02	LT1113, LT1124/25/26/27	LT1354/57/60/63
20k to 100k	LT1001/02	LT1055/56/57/58, LT1113, LT1169	LT1351
100k to 1M	LT1022, LT1055/56/57/58, LT1113, LT1122, LT1169	LT1022, LT1055/56/57/58, LT1113 LT1122, LT1169, LT1457	LT1351
1M to 10M	LT1022, LT1055/56/57/58, LT1113, LT1122, LT1169	LT1022, LT1055/56/57/58, LT1113 LT1122, LT1169, LT1457	

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and shut down to less than 5µA quiescent current.

The fixed 600kHz frequency allows the use of very small, inexpensive output capacitors. New ceramic surface mount capacitors are available which provide good results, with 10µF usable in most cases. Inductor size and cost are also reduced. For most applications, a 10µH surface mount inductor works well.

Figure 2 shows the LT1307B in the SO-8 and MS8 surface mount packages. The SO-8 is offered in both commercial and industrial temperature versions. The MSOP and the LT1307B's other features make it the smallest solution available for boost regulation. For a data sheet and evaluation samples, contact your local Linear Technology sales office.

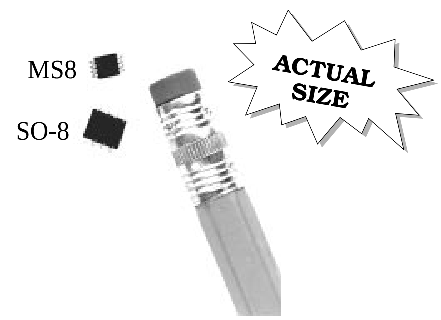
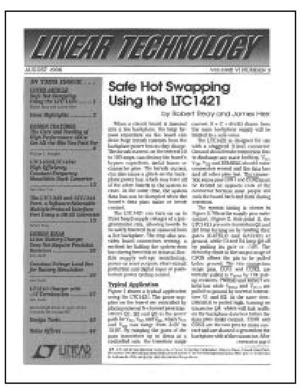


Figure 2. The LT1307B is Offered in SO-8 and MS8 Packages

Linear Technology, The Magazine, is Free

Linear Technology Corporation publishes detailed information about new products and applications in a magazine called *Linear Technology*. It's written by LTC's design and applications engineers on a quarterly basis and is free to all who request it. Each issue typically contains five or six *Design Features* as well as several application oriented *Design Ideas* articles. It concludes with a *New Device Cameos* section—a quick look at the most recently released LTC products.

A reply card is inserted in each magazine for ordering data sheets, *LinearView*™ CD-ROM (a catalog of over 8,000 pages on all our products, application notes, design notes plus more) and new releases of applications on disk such as the SwitcherCAD™ program.



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