Linear Technology Chronicle

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# Product of the Month

## No Latency ΔΣ™ Multiplexed 24-Bit ADC—LTC2408

The **LTC®2408** is an 8-channel, micropower, 24-bit analog-to-digital converter, combining the high performance LTC2400 with an 8-channel analog input multiplexer. The unique features of the LTC2408, including exceptional noise performance, accurate full-scale and single cycle settling time, allow measurement of signals ranging from microvolts on one channel to volts on the next with no overhead associated with the input multiplexer.

The exceptional noise performance of the LTC2408 (1.5μ$V_{RMS}$) corresponds to a resolution of 21.6 bits for a 5V input range. Low level input signals within a 100mV range achieve better than 16-bit resolution without the use of a PGA. Competitive delta-sigma ADCs are significantly noisier than the LTC2408, requiring a PGA in order to improve noise performance for low level input voltages. The LTC2408 offers several significant advantages over converters that require a PGA. One is the ability to measure small signals (microvolts) superimposed upon large DC voltages (volts). For example, a 100mV signal sitting on 2V (2V to 2.1V) can be measured with the same accuracy and noise performance as a 100mV signal sitting on ground (0V to 0.1V). Conversely, a converter operating with a PGA gain of 50 is limited to an input range of 0V to 0.1V with a 5V reference. It cannot digitize any signal larger than 100mV.

A second advantage the LTC2408 offers is exceptional accuracy. The LTC2408 provides offset error of less than 1ppm, offset drift less than 0.01ppm/°C, full-scale error less than 4ppm, full-scale drift less than 0.02ppm and integral nonlinearity of less than 4ppm. Since the total unadjusted error is less than 10ppm, the absolute accuracy of any input voltage within the 0V to 5V range is within 10ppm. Alternatively, systems using PGAs exhibit full-scale errors limited by the matching of internal components. The user is burdened with the removal of these errors, usually by placing the device into a system calibration mode. For multichannel systems, this means full-scale and offset calibrations for each channel. The LTC2408 does not require any system calibration. The offset and full-scale are transparently calibrated during each conversion cycle.

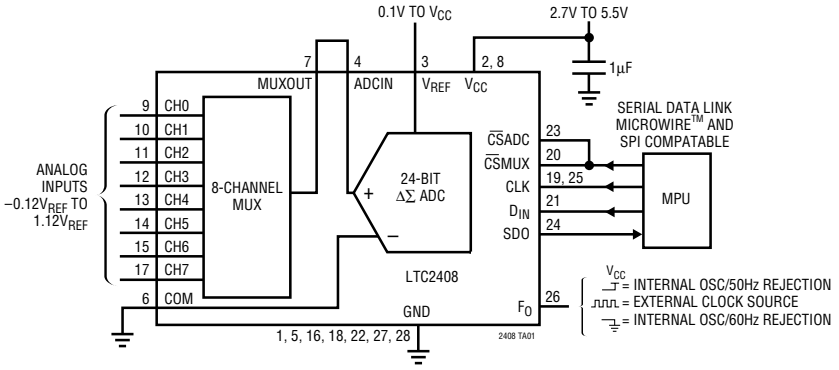


**Figure 1. LTC2408 Block Diagram**

The LTC2408 accepts any external reference voltage from 0.1V to $V_{CC}$. With its extended input conversion range of –12.5% to 112.5% of $V_{REF}$, the LTC2408 can consistently resolve low level signals in the microvolt range, regardless of the fixed DC level (0V to $V_{REF}$).

One advantage delta-sigma converter architectures offer over conventional ADCs is on-chip digital filtering. For low frequency applications, this filtering is typically designed to provide rejection of line frequencies at 50Hz or 60Hz and their harmonics. The disadvantage of conventional digital filters, prior to the release of the LTC2408, was the associated filter settling times. If the input signal changed abruptly, the conversion result was invalid for the following 3 or 4 conversion cycles, making multiplexing extremely difficult. The LTC2408's result is valid for every conversion, making multiplexing easy. With no filter settling time and no latency, there is a one-to-one correspondence between the conversion result and the applied input signal.

The LTC2408 is the simplest and smallest overall solution for a 24-bit A/D converter, making it ideal for high resolution applications such as DVMs, weight scales, industrial process control, temperature measurement and complete system monitoring.

## Inside This Issue:

# Highly Efficient and Tiny Low Input Voltage Boost Converters—LT1949, LT1308A/LT1308B and LT1615

Four wide input voltage range, high output voltage, step-up switching regulators are new from Linear Technology (Figure 1). The **LT®1949** and **LT1308B** operate at a fixed 600kHz for very low ripple. The **LT1615** operates with a 400ns fixed off-time and the **LT1308A** has built-in Burst Mode™ operation for high efficiency even at low load currents.

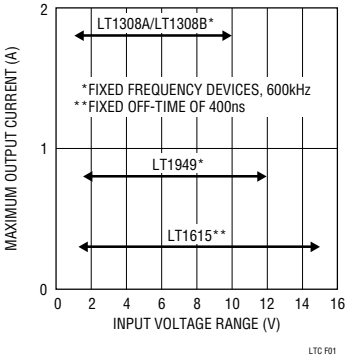


**Figure 1. Low Dropout Voltage, High Frequency Boost Converters**

## 600kHz Fixed Frequency 1A Boost Converter, 1.5V to 10V Input

The **LT1949** is a PWM DC/DC converter that operates with an input voltage range from 1.5V to 10V. It incorporates a 1A, 30V internal switch and is capable of producing two watts of power at output voltages up to 28V. To benefit noise-sensitive systems, the LT1949 maintains constant frequency PWM operation under all loads for very low output ripple that is easy to filter. Its 600kHz operation allows the use of small, low profile capacitors and inductors. The LT1949 is available in a fused lead, 8-pin MSOP package that saves board space.

The low output ripple minimizes noise that causes inconsistent illumination when powering large thin film transistor (TFT) LCD panels. The LT1949 is also ideal for other space-confined systems, such as GPS receivers, diagnostic medical instrumentation and other portable equipment, as well as board level applications operating off 3.3V or 5V power rails.

Figure 2 shows the LT1949 configured as a 3.3V to 10V step-up converter. Efficiency reaches 87% (Figure 3). The LT1949's quiescent current is 25µA in shutdown and 4.5mA while operating. Its internal NPN power switch handles an 800mA load with a voltage drop of just 410mV. An external compensation pin gives the user the ability to optimize feedback loop performance, permitting the use of small, low ESR ceramic capacitors.

The LT1949 contains an internal low-battery detector with a 200mV reference that stays alive when the device goes into shutdown. It is a pin-compatible higher current upgrade to the LT1317B boost converter (700mA internal switch).

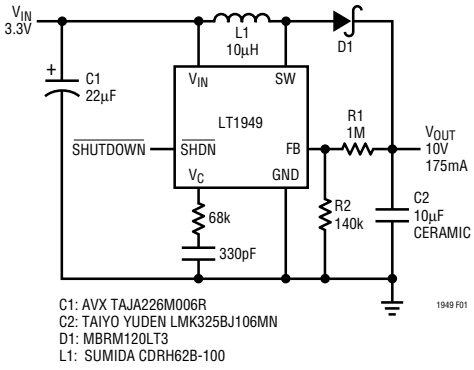


**Figure 2. 3.3V to 10V/175mA DC/DC Converter**

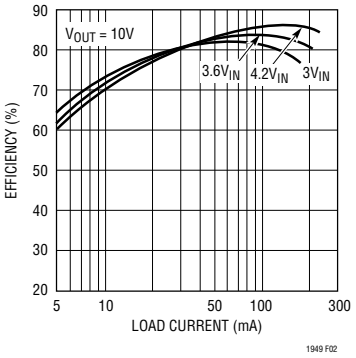


**Figure 3. Efficiency of Circuit in Figure 2**

## 600kHz Boost Switchers in SO-8 Deliver 5W from Single Li-Ion Cell, 1V to 10V Input

The **LT1308A/LT1308B** are 600kHz fixed frequency PWM switching regulators that incorporate a 36V power switch capable of handling a 2A peak current and a low-battery detector with a 200mV reference. These devices are improved versions of the LT1308. Both versions operate with an input voltage from 1V to 10V and deliver 5V at a load current of up to 1A (Figure 4) from a single Li-Ion cell or 12V at 300mA from a 3.3V supply. High efficiency is maintained over a load range of 1mA to 1A (Figure 5) by Burst Mode operation in the LT1308A. The LT1308A's no-load quiescent current is 140µA and both versions shut down to less than 1µA.

The LT1308B's constant frequency 600kHz operation keeps switching noise low and away from sensitive 455kHz IF frequencies, important for wireless applications. Both versions are well-suited for applications of a low duty cycle pulsed nature, such as two-way pagers, cell phones, camera flash units, latching relay energizers and handheld printers.

Fixed 600kHz current mode operation allows the use of very small components. A 10µF ceramic bypass capacitor is the only

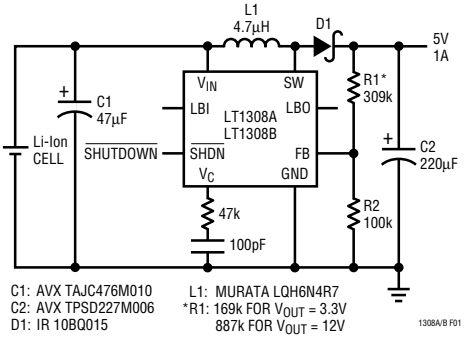


**Figure 4. Single Li-Ion Cell to 5V/1A Converter with the LT1308A or LT1308B**

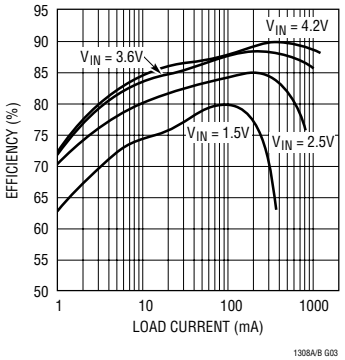


**Figure 5. Efficiency of Figure 4 Using the LT1308A**

*Continued on page 4*

# Application of the Month

## Pin-Compatible, Micropower 12-Bit, 14-Bit and 16-Bit DACs Provide Flexible Board Design—LTC1658/LTC1659 and LTC1448

A family of low power 12-bit, 14-bit and 16-bit DACs provides flexible designs for digital control loops and other systems requiring low power, low cost, small size and rail-to-rail voltage outputs. The 12-bit LTC1659 is a single DAC in 8-pin MSOP and SO packages that draws only 250µA from 3V or 5V supplies. The LTC1448 is a dual 12-bit DAC in an SO-8 package that draws 450µA, also from 3V or 5V supplies.

In a control loop application (Figure 1), the REF pin may be connected to a voltage less than $V_{CC}$ or the pins can be tied together as shown to obtain absolute accuracy and a full-scale output. The LTC1258 (6.5µA maximum quiescent current) and LT1460 are precision references in 8-pin MSOP and SOT-23 packages that offer low power and small size. In this configuration, the LTC1659 has a wide output swing of 0V to 5V or 0V to 3V. The LTC1448 can be substituted when dual DACs are required.

In the same MSOP package and pinout as the LTC1659, the LTC1658 provides 14-bit performance at very low power (270µA supply current) on 3V or 5V supply voltages. One compact board design can thus support 12-bit and 14-bit applications.

For additional flexibility that includes a 16-bit option, use the 12-bit LTC1659 in the SO-8 package. The 14-bit LTC1658 and the 16-bit LTC1655L (600µA), both available in SO-8, fit the same layout and can be used in 3V or 5V supply systems.

Each of these converters achieves 1LSB or better maximum DNL and includes a 3-wire cascadable serial interface. For more information, see the February, 1999, issue of *Linear Technology* magazine.

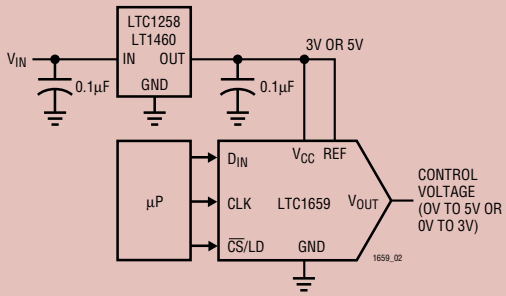


**Figure 1. 12-Bit DAC with Side Output Swing is Tiny and Very Low Power, May Be Upgraded to 14-Bit or 16-Bit Pin Compatible DAC**

## A 1.1MHz Over-The-Top Rail-to-Rail Op Amp—LT1637

The **LT1637** provides a unique and versatile combination of micropower, precision and durability. Drawing only 250µA supply current in normal operation, the LT1637 is ideal for battery-operated, low power applications and portable instruments. The LT1637 offers excellent DC and noise specifications, with a maximum offset voltage of 350µV, maximum input bias current of 50nA and a typical input voltage noise of $27nV/\sqrt{Hz}$. In shutdown mode, the op amp draws only 12µA of current and places the output in high impedance mode for easy multiplexing. At a typical gain bandwidth of 1.1MHz and slew rate of 0.4V/µs, the LT1637 provides an excellent speed-to-power ratio.

The true rail-to-rail input and output of the LT1637 maximizes the dynamic range of operation for the amplifier. This is especially useful for low voltage, single supply applications powered by batteries, giving maximum signal swing from limited supply voltages. Over-The-Top operation allows for common mode inputs of up to 44V, independent of the positive supply. This feature is extremely important for applications such as high side current sensing or monitoring voltages above the supply rails.

The LT1637 provides tremendous durability, offering a wide supply range and built-in input overvoltage protection features. The supply voltage range extends from 2.7V to 44V, with an input stage designed to take common mode voltages above the positive supply rail (up to 44V above the negative rail). Input voltages can also fall 22V below the negative supply rail without harm to the op amp. The LT1637 is protected against reverse supply voltages up to 25V. These protection features make the LT1637 a good choice for applications in high voltage industrial control systems.

The LT1637 is now available in the 8-lead small outline package and in the 8-lead micro-SO package (MSOP).

*DC/DC Converters from page 2*

input capacitance required when operating from a low impedance source such as a NiCd or NiMH battery. Low-battery detector accuracy of the LT1308A and LT1308B is ±2%. The 36V switch rating allows up to 34V outputs in boost mode and high input and output voltages in SEPIC circuits.

A common requirement for GSM terminals is an efficient, compact converter that develops 5V from a single Li-Ion cell to power the RF amplifier. The LT1308B performs this function with few external components, with efficiency that reaches 90%. Transient response of a 0A to 1A load step with typical GSM profiling produces a voltage droop of only 200mV.

Power supplies for digital cameras must be small and efficient while generating several voltages free of low frequency noise, so that post filtering can be done easily. A single LT1308A, along with an inexpensive transformer in a coupled-flyback scheme, generates 3.3V/200mA, 5V/200mA, 18V/10mA and –10V/10mA from a pair of AA or AAA cells.

The LT1308A and LT1308B are offered in an SO-8 package and are pin compatible with the LT1307A and LT1307B which have a 600mA switching current capability. This permits the same board design to support two different power levels.

## Versatile SOT-23 Boost Switching Regulator for 1.2V to 15V Input

The **LT1615** is a micropower step-up DC/DC converter in a 5-lead SOT-23 package. With an input voltage range from 1.2V to 15V, this converter is ideal for a wide range of applications and input sources. The LT1615 features typical quiescent current of 20µA with no load, which further reduces to 0.5µA in shutdown. The LT1615 uses a current limited, fixed off-time control scheme that helps achieve high efficiency over a broad range of load currents. Its short off-time of 400ns permits the use of tiny, low profile inductors and capacitors to minimize the overall system footprint and cost (Figure 6).

The LT1615 includes an internal 36V switch that allows the device to generate output voltages of up to 34V without the use of costly transformers. This makes the LT1615 attractive for applications such as LCD biasing which need a high output voltage at a relatively low current. The converter in Figure 7 demonstrates the input and output voltage range of the LT1615. A 33V output is generated from a wide range input voltage using a simple boost topology. A small 1µF ceramic capacitor is all that is needed at the output. The circuit can deliver up to 1.32W (40mA at 33V) of power from an input of 2.5V to 4.2V with an efficiency of 85%, all from a tiny SOT-23 package.

A typical requirement is for a 15V output at 15mA from a single Li-Ion cell. Using the circuit in Figure 7 with different resistor values, efficiency for this LT1615 converter reaches 82% and exceeds 70% even as the battery voltage drops to 2.5V and for load currents under 1mA.

A dual-output converter, with 20V and –20V outputs, for example, may also be generated by the LT1615 with efficiency reaching 77% from a single Li-Ion cell

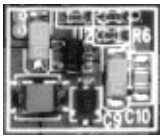

**Figure 6. High Frequency and SOT Package Allow a Very Small Circuit (Shown 150% of Actual Size)**

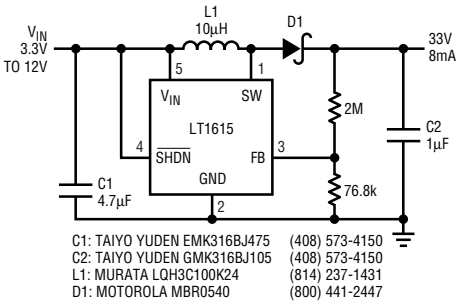


**Figure 7. 1-Cell Li-Ion to 33V Converter for LCD Bias**

(Figure 8). The addition of a diode and capacitor to this circuit allows both outputs to be disconnected from the input in shutdown. (See data sheet.)

Another popular application is a single-cell Li-Ion battery to a 3.3V output using a SEPIC (single-ended primary inductance converter) topology. A simple SEPIC circuit using the LT1615 will provide 100mA with a typical efficiency of 70% using two small 10µH inductors or a single, dual-winding inductor.

No other IC solution offers the high output voltage, high efficiency and very small size of the LT1615.

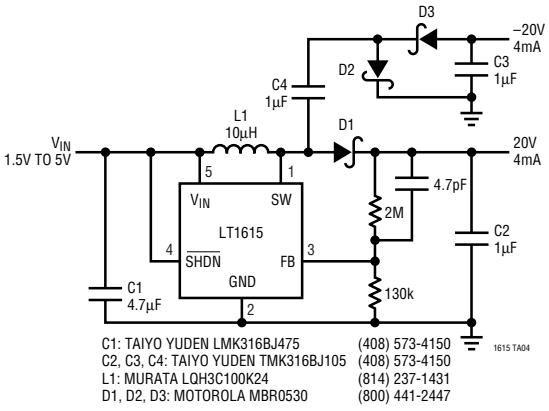


**Figure 8. ±20V Dual Output Converter Provides 8mA Output From 1.5V Input**

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