Linear Technology Chronicle

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Product of the Month

LTC1412: 12-Bit, 3Msps ADC—Speed, Performance, Low Power, No Pipeline Delay

A new 12-bit 3Msps ADC brings unparalleled levels of performance and ease of use to circuit designers. Excellent dynamic specifications enable high speed modem designs with cleaner signals over greater distances. Low noise and high DC performance fit it for CCD imaging. No pipeline delay facilitates servo-loop and motor control, DSP, sampling systems and multiplexed data acquisition. Low power and small package size make it easy for everyone to live with.

SAR Architecture, Clean and Simple

The **LTC®1412**'s successive approximation (SAR) design avoids the many problems found in pipelined and subranging ADCs in the Msps speed range. These problems include compromised AC and DC performance, general operational misbehavior and cumbersome analog support circuitry. Other pipeline drawbacks are poor noise and SNR, pipeline delay (latency), no three-state outputs, poor frequency domain performance and large package and power dissipation.

Conversion data is present at the LTC1412's three-state outputs 300ns after the conversion begins. Inputs can be multiplexed. The new LTC1412 is the only clean, simple-to-use alternative faster than 1.25Msps.

Cleaner Behavior and Superior Linearity

The LTC1412 depends solely on capacitor matching for accuracy. This results in typical 0.25LSB INL and DNL (Figures 1 and 2) that have nearly zero drift with time, temperature, supply voltage or reference voltage. There is virtually no potential for sparkle codes to which pipelined ADCs are susceptible.

Lower Noise

Pipelined ADCs add noise to their conversion because they resample the input signal as the conversion moves through the converter. The LTC1412 has nearly perfect noise performance because its single sample-and-hold and single-pass conversion add almost no noise. Its 73dB (typical) SNR at 3Msps is within 1dB of the theoretical quantization noise. The LTC1412 also has premier distortion performance of 80dB at its Nyquist frequency.

Simple Input and Reference Circuitry

The LTC1412's high impedance, differential input sample-and-hold eliminates the level shifting, complementary differential input or transformers typically used in single supply ADCs. The internal reference does away with the multiple reference pins, multiple bypassing caps and fast reference buffer amps commonly used with pipeline converters. The LTC1412 reference allows slow and fast span adjustments and maintains linearity over a 2:1 reference voltage range.

The unique sample-and-hold circuit provides a wide, 40MHz full-power input bandwidth that allows the circuit to undersample signals far above the converter's Nyquist frequency and preserve their fidelity. The common mode rejection of 60dB is especially useful for suppressing the perturbating effects of common mode noise and ground loops.

Size and Power Efficiency

The LTC1412's simple, efficient architecture and low power dissipation (150mW) allow small 28-lead SSOP packaging. Thus, the LTC1412 offers the smallest footprint among 3Msps, parallel-output ADCs plus generally fewer external components (see Figure 3).

Continued on page 2

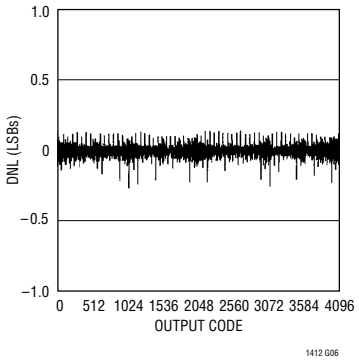

Figure 1. Differential Nonlinearity vs Output Code

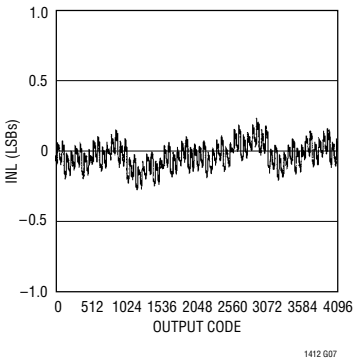

Figure 2. Integral Nonlinearity vs Output Code

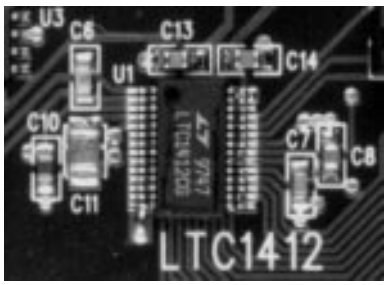

Figure 3. Complete 3Msps 12-Bit ADC System (175% of Actual Size)

Inside This Issue:

New LT1167: Industrial-Strength Instrumentation Amplifier, Single Resistor Sets Gain

The **LT®1167** is the next generation instrumentation amplifier. Gain from 1 to 10,000 is set with a single external resistor. It has improved performance and features over other monolithic instrumentation amps and has improvements over multiple op amp solutions. The LT1167 combines excellent DC precision with industrial-quality fault protection. The pinout and gain equation are compatible with other monolithic instrumentation amps, allowing easy upgrade for existing products.

4kV ESD Input Protection

Instrumentation amplifiers are subjected to hostile environments, connected to sensors and input lines that experience voltage and current transients and ESD. The LT1167 is designed with low leakage internal protection diodes from each input to the supplies. These diodes have a current rating of 20mA and protect the IC when the input voltage exceeds the supply rails.

Because of the ultralow 350pA bias current of the LT1167, high value resistors in series with the inputs do not degrade V_{OS}. For example, 10% tolerance 100k resistors add only 5µV of offset to the LT1167. With 20k resistors, the LT1167 can handle both ±400VDC input faults and ESD spikes over 4kV. This meets the IEC 1004-2 level 2 European standard. Higher value resistors can be used for higher voltage protection.

Industry Best DC Performance

The LT1167 input bias current is comparable to that of a JFET input stage at room temperature. However, I_B for the LT1167 does not double for every 10°C rise as do JFET types. At 85°C, it is still less than 1nA.

The LT1167 is trimmed to meet critical DC parameters over a wide range of operating conditions. Input-referred offset voltage is only 15µV at 25°C and 40µV over the industrial temperature range (typical values). Common Mode Rejection Ratio (CMRR) is a minimum of 90dB and 106dB at gains of 1 and 10. Power Supply Rejection Ratio (PSRR) is guaranteed at 109dB and 125dB. CMRR and PSRR are tested and guaranteed over temperature. Competing devices are not specified over temperature.

Single Gain-Set Resistor, Low Gain Nonlinearity

Gain is easily set with a single external resistor. No expensive matched resistor arrays are needed. Gain error is trimmed to a very low 0.04% worst-case over temperature (at a gain of 1). The system gain accuracy is determined by the tolerance of the external resistor.

The low gain error is maintained over the output voltage range. Since gain nonlinearity (GNL) cannot be trimmed, the LT1167 was designed to cancel gain errors due to die stress and thermal gradients. Gain error and GNL over temperature are fully specified for the LT1167.

Gain nonlinearity can contribute significant system error, especially at higher gains and larger loads. Figure 1 shows the GNL of a competitive device into a 1kΩ load at a gain of 1000. The LT1167 exhibits the greatly improved GNL as shown in Figure 2.

Ideal for Many Applications

The ability to operate at ±3V on 0.9mA makes the LT1167 ideal for battery-powered systems. Its low current noise and low voltage noise make it ideal for ECG monitors that have megohm source impedances. The LT1167's ruggedness, accuracy, wide supply voltage range, ease of use and small size make it suitable for a broad range of precision data acquisition, medical instrumentation, industrial measurement and process control and flow control applications. Contact your local Linear Technology sales office for a data sheet and evaluation samples. For more information, visit our web site at **www.linear-tech.com**.

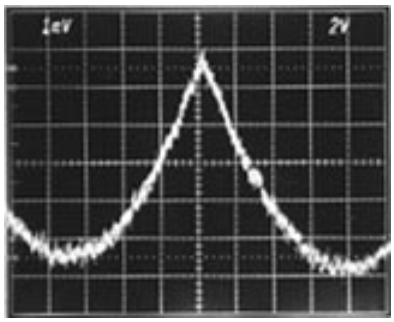

Figure 1. Gain Nonlinearity of a Previous Generation Instrumentation Amp: R_L = 1k; V_O = ±10V

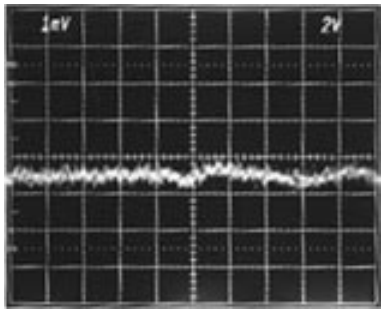

Figure 2. LT1167 Gain Nonlinearity: R_L = 1k; V_O = ±10V

LTC1412 from page 1

High Speed, High Resolution Applications

The LTC1412 is designed for applications such as telecom digital-data transmission, wide bandwidth multichannel data acquisition and baseband signal recovery through undersampling. Its simple parallel interface and conversion start signal make it easy to use in DSP-based designs.

Now there is a clean 12-bit, 3Msps ADC alternative: the LTC1412. It does everything a pipelined ADC does, and better, but without the drawbacks. For a data sheet and evaluation samples, contact your local Linear Technology sales office. For more information, visit our web site at **www.linear-tech.com**.

Application of the Month

Battery-Powered Buck-Boost Converter Requires No Magnetics

One of the problems that designers of portable equipment face is generating a regulated voltage that is between the charged and discharged voltage of a battery pack. As an example, when generating a 3.3V output from a 3-cell battery pack, the regulator input voltage changes from about 4.5V at full charge to about 2.7V when discharged. At full charge, the regulator must step down the input voltage, and when the battery voltage drops below 3.3V, the regulator must step up the voltage. The same problem occurs when a 5V output is required from a 4-cell input voltage that varies from about 3.6V to 6V. Ordinarily, a flyback or SEPIC configuration is required to solve this problem.

The LTC1515 switched-capacitor DC/DC converter can provide this buck-boost function for load currents up to 50mA with only three external capacitors. The circuit shown in Figure 1 will provide a regulated 3.3V output from a 3-cell input or a 5V output from a 4-cell input. Connecting the 5/3 pin to V_{IN} will program the output to 5V, whereas grounding the 5/3 pin programs the output to 3.3V.

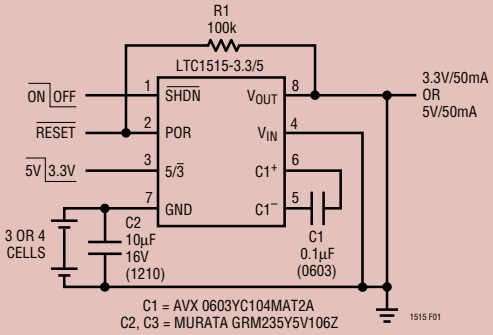

Figure 1. Battery-Powered Buck-Boost Converter

The absence of bulky magnetics provides another benefit; this circuit requires only 0.07 square inches of board space in those applications where components can be mounted on both sides of the board. The addition of R1 provides a power-on reset flag that goes high 200ms after the output reaches 93.5% of its programmed value. The $\overline{SHDN}$ pin allows the output to be turned on or off with a 3V logic signal.

LTC1710: SMBus Compatible High Side Switches

Two 0.4Ω Switches in MSOP-8

The **LTC1710** High Side SMBus dual switch is a complete solution for supplying power to portable equipment peripherals. Two high side 0.4Ω N-channel MOSFET switches, with 300mA capability and independent drains, are included in the tiny MSOP-8 package. The circuit is fully compatible with SMBus and I²C™ prototcols. With ultralow standby current (14µA), the LTC1710 is a perfect fit for handheld electronics and other space-constrained applications.

Internal Charge Pumps and Capacitors

To fully enhance the power switches, the LTC1710 uses a charge pump tripler to boost and regulate the gate drive of each switch (Figure 1). Running at about 300kHz, each charge pump is programmed to supply a ramped voltage to the gate of each switch, so that it turns on smoothly, avoiding large current spikes into the load. The charge pump capacitors are integrated on the IC.

Independent Voltage Control; Fault Protection

The drains of the two switches are independent of each other. As a result, SMBus peripherals requiring different input voltages can be simultaneously switched by the LTC1710 (see Figure 1). If too much output current is sourced, an internal thermal shutdown circuit protects the system by turning off both switches.

A power-on reset signal ensures that the LTC1710 starts up with both switches off. The POR signal inhibits operation until about 300µs after V_{CC} crosses the undervoltage lockout threshold. The system includes some hysteresis and delay to avoid nuisance resets.

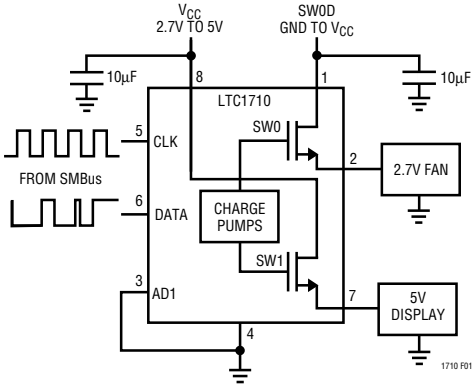

Figure 1. The LTC1710 Switches Two SMBus Peripherals with Different Input Voltages

Three-State Programmable Address Input

The SMBus is a serial bus interface that uses only two bus lines, DATA and CLK, to control low power peripheral devices in portable equipment. The LTC1710 operates over an input voltage range of 2.7V to 5.5V and maintains the SMBus specified 0.6V V_{IL} and 1.4V V_{IH} thresholds throughout.

To identify itself on the SMBus, the LTC1710 has a three-state programmable address pin that can be tied to V_{CC}, to ground or to $V_{CC}/2$ with the help of two 1M resistors. Thus, a total of six switches may be controlled on the same bus. The format of the address places the LTC1710 directly in the reserved address range for power-plane switching.

The LTC1710 features a double-buffered output. The Stop signal can be used to synchronize the output executions of several differently-addressed peripherals whose data were loaded at different times.

Compact, Complete Power Management

With two built-in 0.4Ω power switches in an MSOP-8 or SO-8 package and low standby current, the LTC1710 is an ideal solution for delivering up to 300mA to SMBus peripherals in complex portable equipment. For a data sheet and evaluation samples, contact your local Linear Technology sales office. For more information, visit our web site at **www.linear-tech.com**.

I²C is a trademark of Philips Electronics N.V.

15kV ESD Protected RS232 Transceivers—LT1780/LT1781

The **LT1780** and **LT1781** are dual RS232 transceivers that provide ESD protection compliant with the International Electrotechnical Commission's 1000-4-2 (Level 4) specification. The circuits operate from a single 5V supply and the LT1780 offers a low power shutdown mode.

Each device includes two drivers and two receivers. This configuration provides the basic RS232 signals used in industrial, instrumentation and medical applications.

ESD Protection

These transceivers are designed for equipment with serial ports that may not be protected from the environment. Therefore the driver outputs and receiver inputs include ESD protection structures. The LT1780 and LT1781 meet the stringent European standards:

IEC 1000-4-2: 15kV Air Gap Discharge Method
IEC 1000-4-2: 8kV Contact Discharge Method

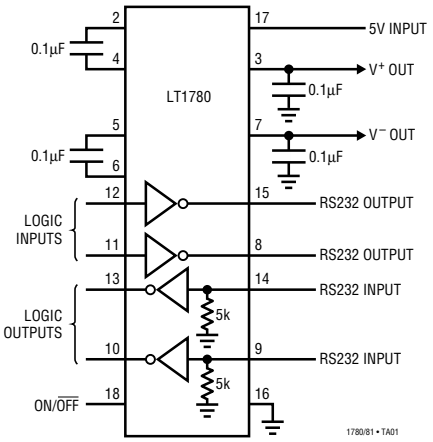

Figure 1. LT1780 in Single Supply Application

Compliance with the IEC ESD requirements shortens the qualification process for sale into European markets. The driver outputs are also protected from overload and shorts up to ±30V.

Single Supply, Low Power and Fast

The LT1780/LT1781 generate the RS232 bias voltages internally. The internal charge pump requires only four small 0.1µF capacitors. The LT1780 has a shutdown mode for power savings in battery-operated applications while the LT1781 is in an industry standard footprint. In shutdown, the LT1780 current drain drops to just 1µA.

The LT1780/LT1781 operate at 250kBaud for high speed RS232 applications. The low power and dual transceiver configuration make these devices ideal for portable instruments that communicate through an RS232 interface to the host computer. Contact your local Linear Technology sales office for a data sheet and evaluation samples. For more information, visit our web site at **www.linear-tech.com**.

LTC1542: Micropower Op Amp and Comparator

The **LTC1542** combines a micropower amplifier and comparator in one miniature 8-pin package (MSOP or SO). This circuit has very low input offset voltage and low standby current. The outputs swing rail-to-rail. These features are useful for battery-powered applications such as cellular phones, keyless entry systems and remote controllers where precision sensing and low power consumption are required.

The circuit operates from a single 2.5V to 12.6V or dual ±1.25V to ±6.3V supply with a typical supply current of 5µA. Both the op amp and the comparator have a common mode input voltage range that extends from the negative supply to within 1.3V of the positive supply. The input current is 10pA typically for both op amp and comparator.

The Op Amp

The input offset voltage of the op amp is a very low 700µV maximum. The input bias current is 1nA maximum over the extended temperature range.

The op amp is internally compensated to be unity-gain stable with typical gain-bandwidth of 12kHz and slew rate of 8V/ms. Unlike other micropower CMOS op amps, the LTC1542 maintains stability in unity-gain configuration even while driving heavy capacitive loads of up to 1000pF.

The Comparator

The comparator has a high impedance differential input stage. The CMOS output stage can swing from rail to rail and source up to 20mA. The output stage has been designed to eliminate the power supply glitches that normally occur when the output changes logic state. In addition, ±3mV of internal hysteresis ensures clean output switching, even with slow moving input signals.

The Family

The LTC1542 is the newest member of the micropower building block family of useful combinations of analog functions (see Table 1).

Table 1. Micropower Building Block Family

	Op Amp	Comparator	Reference
LTC1542	✓	✓	
LTC1541	✓	✓	1.2V
LTC1540		✓	1.182V
LT1635	✓		0.2V

The LTC1542 is a much improved design, pin-compatible to existing circuits. Try it in your battery- or solar-powered system, local area detectors and alarms, infrared receivers or smoke detectors and safety sensors. Contact your local Linear Technology sales office for a data sheet and evaluation samples. For more information, visit our web site at **www.linear-tech.com**.

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