SAR ADCs Feature Speed, Low Power, Small Package Size and True Simultaneous Sampling

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Introduction

When it comes to quickly digitizing analog signals from a few hertz to a few megahertz, successive approximation register (SAR) ADCs are the best choice for a broad range of applications. Their fast response and low latency make SAR ADCs ideal for single channel or multichannel data acquisition.

Low power SAR ADCs are crucial as more designs migrate to lower supply voltages and tighter power budgets. Solution size is also a key requirement for designers needing a single snapshot of the input, as many low power SAR ADCs are used in portable or multichannel systems in which PCB space is limited. With designers trying to do more with less space, a small package becomes vital.

As package size shrinks, it makes sense to replace a parallel interface with a serial interface to reduce the number of data lines, which in turn reduces the size of both the SAR ADC and the microprocessor. Serial interfaces also reduce the headaches associated with routing many parallel data lines across a board. Linear Technology offers multiple families of fast SAR ADCs that combine speed, low power, small package size and simple serial interfaces.

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6-Channel Simultaneous Sampling ADCs

Motor control is one of many applications that benefit from simultaneous sampling SAR ADCs. In motor control circuits, the phase relationship of measured channels must be preserved, thus requiring simultaneous sampling ADCs with multiple sample-and-hold amplifiers (S/HA's). Data can be stored internally to be read out sequentially, with the phase relationship from the inputs intact. Without simultaneous sampling, control algorithms could incorrectly adjust the motor's torque or speed control, leading to vibrations and additional wear on the motor. Linear Technology has a growing family of low power simultaneous sampling ADCs that target motor control, servos, and general purpose AC power monitoring.

Linear Technology offers four low power, 6-channel simultaneous sampling ADCs, optimized for two fast sample rates (250ksps per channel and 100ksps) as well as two different resolutions (14 bits and 12 bits). All are pin- and software-compatible, making it easy to optimize designs for resolution, speed and cost. By using a 5mm × 5mm 32-pin QFN package, these ADCs achieve a solution size as much as six times smaller than comparable performance ADCs. A single 3V supply powers both the analog and digital circuitry, thus reducing power dissipation eliminating the need for higher voltage supplies.

Table 1. Simultaneous sampling ADCs from Linear Technology

Part Number	Resolution	Number of Channels	Sample Rate per channel	Power	Package	Input Voltage Range
LTC2351-14	14-Bit	6	250ksps	16.5mW	QFN-32 (5mm × 5mm)	±1.25V, 0V to 2.5V
LTC1408	14-Bit	6	100ksps	15mW	QFN-32 (5mm × 5mm)	±1.25V, 0V to 2.5V
LTC1407A	14-Bit	2	1.5Msps	14mW	MSOP-10	0V to 2.5V
LTC1407A-1	14-Bit	2	1.5Msps	14mW	MSOP-10	±1.25V
LTC2351-12	12-Bit	6	250ksps	16.5mW	QFN-32 (5mm × 5mm)	±1.25V, 0V to 2.5V
LTC1408-12	12-Bit	6	100ksps	15mW	QFN-32 (5mm × 5mm)	±1.25V, 0V to 2.5V
LTC1407	12-Bit	2	1.5Msps	14mW	MSOP-10	0V to 2.5V
LTC1407-1	12-Bit	2	1.5Msps	14mW	MSOP-10	±1.25V

Low Power ADCs Optimized for 250ksps–750ksps

The 14-bit LTC2351-14 is a 1.5Msps, low power SAR ADC with six simultaneously sampled differential input channels. It operates from a single 3V supply and features six independent sample-and-hold amplifiers and a single ADC. The single ADC with multiple S/HA's enables excellent range match (1mV) between channels and channel-to-channel skew (200ps). The six channels can monitor two separate motors, providing vital information about motor torque, speed, shaft position, and direction.

The versatile LTC2351-14 also suits other industrial monitoring applications such as 3-phase voltage monitoring to ensure line voltage compliance, 3-phase power monitoring of current and voltage, power factor correction, and data acquisition. These applications may require portability, and it is here that the LTC2351-14's low power and small size are most desirable. Power consumption is a mere 16.5mW, which extends battery life. The 3-wire serial interface means fewer pins than traditional parallel output devices, allowing the LTC2351-14 to fit in a 32-pin, 5mm × 5mm QFN package.

When the LTC2351-14 is not converting, the ADC offers two power saving modes. Power dissipation can be reduced to 4.5mW in nap mode with the internal 2.5V reference remaining active. Sleep mode further reduces

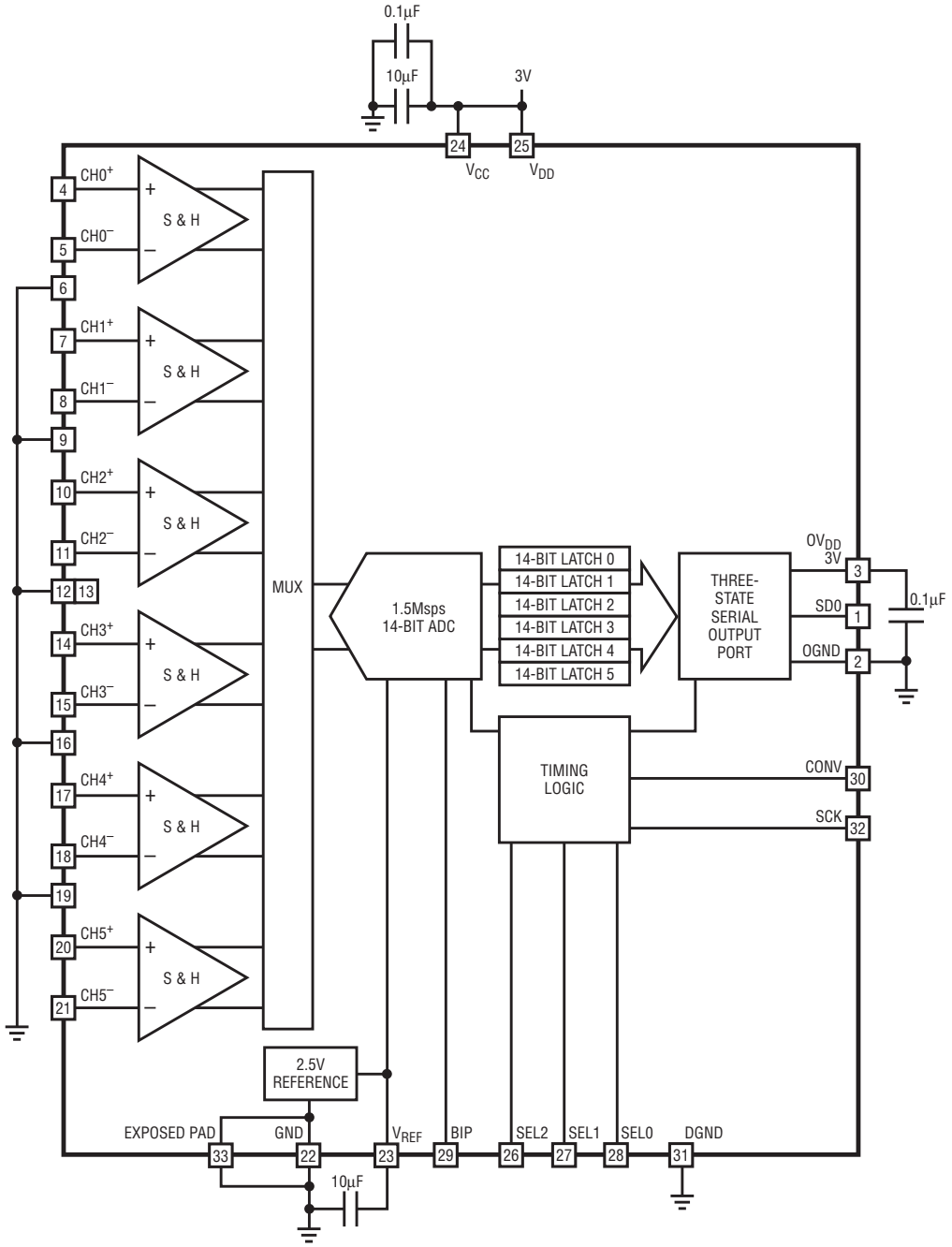

Figure 1. The LTC2351-14 includes six sample-and-hold amplifiers.

power consumption to 12µW, with all internal circuitry powered down, further extending battery life. Upon waking up from sleep mode, the internal reference settles within 2ms, and conversions resume thereafter within a single clock cycle.

Three input-select lines configure the number of differential inputs converted. Thus, higher speeds are possible as the number of channels converted decreases, from six differential inputs at 250ksps, two differential inputs at 750ksps, to one differential input at 1.5Msps. A bipolar/unipolar input line selects either a ±1.25V bipolar or a 0V to 2.5V unipolar input range. A 100kHz input signal yields a SINAD of 75dB and –90dB THD. The LTC2351-14's true differential inputs and 83dB common mode rejection make it ideal for minimizing common mode noise prevalent in harsh industrial environments. For lower resolution applications and performance-cost optimization, Linear Technology offers the pin- and software-compatible 12-bit LTC2351-12 ADC. The LTC2351-12 also simultaneously samples up to six differential channels, draws only 16.5mW of power and features 72dB SINAD.

Some simultaneous sampling ADCs are capable of measuring six channels, but use only two S/HA's, two ADCs, and two 3-to-1 multiplexers. In these competing ADCs, only two channels are simultaneously sampled. Multiple ADCs can mean mismatches from one ADC to the other within the package. INL could be within the maximum ratings, but bow in one polarity on one ADC and the opposite polarity on the second ADC. By integrating six S/HA's and a single ADC, the LTC2351-14 does not suffer the anomalies associated with multiple ADCs and is ideal for applications that require simultaneously sampling more than two channels.

Lower Sampling Rate ADCs with Improved AC Performance

Linear Technology also offers a second pair of 6-channel simultaneous sampling ADCs optimized for slower sampling rates. The 14-bit LTC1408 and 12-bit LTC1408-12 are optimized for output rates up to 100ksps/channel for all six channels, 300ksps for two channels, and 600ksps for one channel. The LTC1408 features improved AC performance (79dB SINAD at 300kHz, with an external reference). Like the LTC2351 family, both LTC1408 ADCs are low power (15mW), offered in a small 5mm × 5mm 32-pin QFN package, and include six sample-and-hold amplifiers. See Table 1 for a complete listing of these simultaneous sampling ADCs.

The LTC1408 and LTC2351-14 6-channel SAR ADCs are ideal for monitoring 3-phase voltages and currents, as shown in Figure 2. Attenuation networks externally reduce the voltage to within the selected bipolar/unipolar input ranges. While three analog inputs measure the voltage, the other three channels use signal conditioning and filtering to convert the currents. The six S/HA's keep the phase relationship between the voltages and currents intact and data can be read out through the serial interface. These ADCs also include a digital output supply voltage that can be set between the analog supply voltage down to 1.8V, making it possible to interface with 1.8V, 2.5V or 3V digital logic.

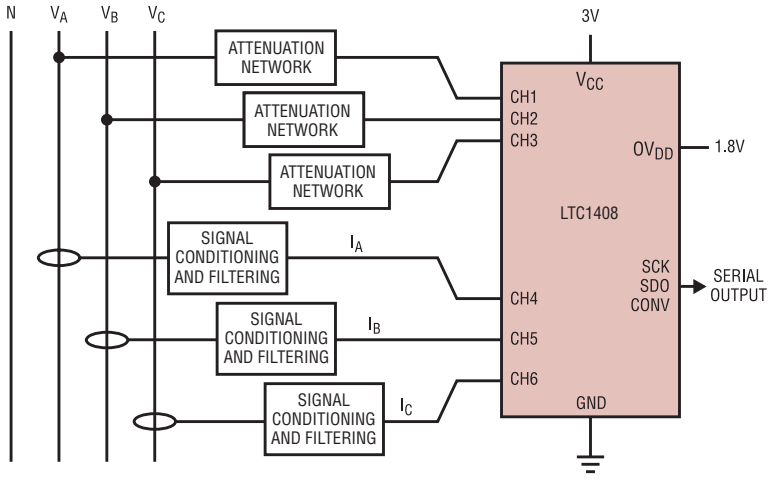

Figure 2. The LTC1408 is ideal for 3-phase power monitoring.

2-Channel Simultaneous Sampling ADCs

For applications such as encoders and communications requiring simultaneous sampling on only two channels at rates greater than 1Msps per channel, fast SAR ADCs again work very well. Linear Technology offers a pin- and software-compatible family of 14-bit and 12-bit, 2-channel, simultaneous sampling SAR ADCs.

Like the 6-channel simultaneous sampling ADCs, the 14-bit, 2-channel LTC1407A-1 is also optimized for low power and small package size, further extending battery life and reducing total solution area. The LTC1407A-1 is available in a 10-pin MSOP package and dissipates only 14mW. This small ADC measures two ±1.25V bipolar channels simultaneously at 1.5Msps per channel or a single channel at 3Msps. No competing ADCs of similar size can meet the speed and input frequency range of the LTC1407A-1.

The pin- and software-compatible LTC1407A is a 0V to 2.5V unipolar 14-bit ADC. Both the unipolar and bipolar LTC1407 ADCs perform well when measuring differential AC inputs, making it a good choice for communications applications. The LTC1407A-1 and LTC1407A achieve 76.3dB SINAD and –86dB THD with a 750kHz input frequency and an external 3.3V reference. SFDR is 86dB and intermodulation distortion is –82dB at the same input frequency.

For applications requiring less resolution, the 12-bit LTC1407-1 (bipolar) and 12-bit LTC1407 (unipolar) ADCs are available. All four LTC1407 ADCs include a 2.5V internal reference, nap

Table 2. Fast single-channel SAR ADCs from Linear Technology

Part Number	Resolution	Sample Rate	Package	Power	Input Voltage Range	I/O
LTC2355-14	14-Bit	3.5Msps	MSOP-10	18mW	0V to 2.5V	Serial
LTC2356-14	14-Bit	3.5Msps	MSOP-10	18mW	±1.25V	Serial
LTC1403A	14-Bit	2.8Msps	MSOP-10	14mW	0V to 2.5V	Serial
LTC1403A-1	14-Bit	2.8Msps	MSOP-10	14mW	±1.25V	Serial
LTC2355-12	12-Bit	3.5Msps	MSOP-10	18mW	0V to 2.5V	Serial
LTC2356-12	12-Bit	3.5Msps	MSOP-10	18mW	±1.25V	Serial
LTC1403	12-Bit	2.8Msps	MSOP-10	14mW	0V to 2.5V	Serial
LTC1403-1	12-Bit	2.8Msps	MSOP-10	14mW	±1.25V	Serial

(3.3mW) and sleep (6µW) power-down modes. Both families of 6-channel and 2-channel simultaneous sampling ADCs are detailed in Table 1.

Data Acquisition Systems

SAR ADCs also excel in data acquisition applications due to the ability to multiplex multiple channels with little or no data latency. Data acquisition requires the ability to monitor a wide array of analog signals in industrial settings, often including temperature, pressure, voltage, or load currents. For example, an industrial control design may use thermocouples to monitor temperature variations, pressure sensors to measure physical changes, or chemical sensors to detect various environmental settings. Data acquisition could mean monitoring a single channel or hundreds of channels.

Figure 3 shows an example of the analog signal chain for a multichannel data acquisition system. After being routed through a series of multiplexers and signal conditioning circuits, these signals can be digitized by a fast single-channel SAR ADC, such as the LTC2355-14. With a fast SAR ADC, multiplexers and amplifiers with high gain bandwidths are used to switch through the various data inputs. The LTC1391 is an 8-to-1 multiplexer used to switch the various analog signals on the front end of the system. The LT6241 is a precision amplifier that has low noise (550nV$_{P-P}$), 1pA bias current, 17MHz unity gain bandwidth, and provides a low impedance connection to the ADC.

High Speed Single-Channel SAR ADCs

Along with its growing family of simultaneous sampling ADCs, Linear Technology is also adding to its family of pin- and software-compatible high speed single-channel SAR ADCs. The 14-bit, 3.5Msps LTC2356-14 measures a single differential input and communicates via an SPI-compatible serial interface. This SAR ADC operates from a single 3.3V supply, draws only 18mW at the maximum conversion rate, and is available in a tiny 10-pin MSOP package. The combination of high speed, low

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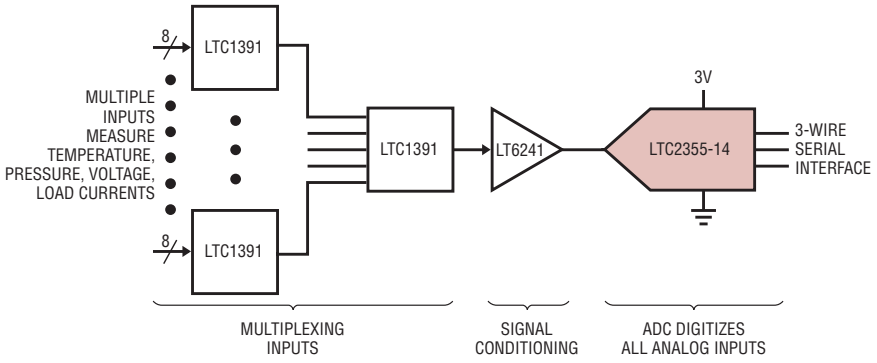

Figure 3. Industrial control data acquisition systems measure numerous signals with a single ADC.

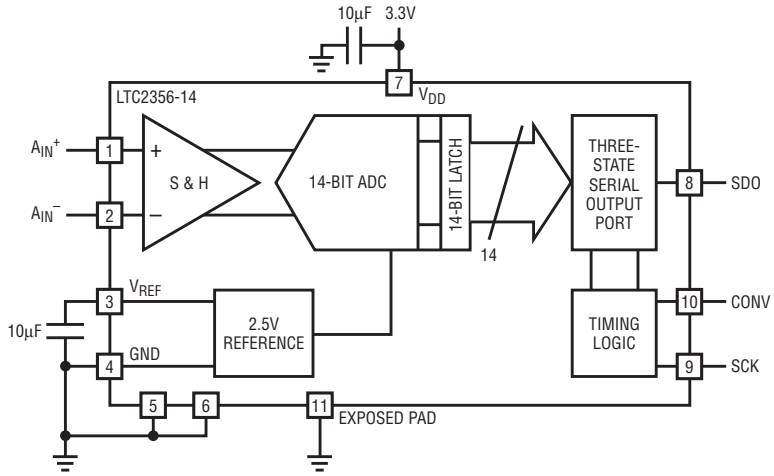

Figure 4. The LTC2356-14 single channel ADC is ideal for fast, low power applications.

Adjustable current limit is also built-in. The inductor current of LTC3610 is determined by measuring the voltage across the sense resistance between the PGND and SW pins, where $R_{DS(ON)}$ of the bottom MOSFET is about 6.5mΩ. The current limit is set by applying a voltage to the V_{RNG} pin, which sets the relative maximum voltage across the sense resistance. An external resistive divider from the internal bias, INTVCC, can be used to set the voltage of the V_{RNG} pin between 0.5V and 1V resulting in a typical current limit of 16A to 19A. Tying V_{RNG} to SGND defaults the current limit to 19A.

The LTC3610 also has soft-start and latch off functions enabled by the Run/SS pin. Pulling the Run/SS below 0.8V puts the LTC3610 into a low quiescent current shut down state, whereas releasing the pin allows a 1.2µA current source to charge up the external soft-start capacitor. When the voltage on Run/SS reaches 1.5V, the LTC3610 begins operating with an initial clamp on I_{TH} of approximately 0.9V. This prevents current overshoot during start up. As the soft-start capacitor charges, the I_{TH} clamp increases, allowing normal operation at full load current. If the output voltage falls below 75% of the regulated voltage, then a short-circuit fault is assumed. At this point, a 1.8µA current discharges capacitor C_{SS}. If the fault condition persists until Run/SS drops to 3.5V, the controller's overcurrent latch off turns off the MOSFETS until Run/SS is grounded and released. If latch off is not desired, a pull-up current source at Run/SS defeats this feature.

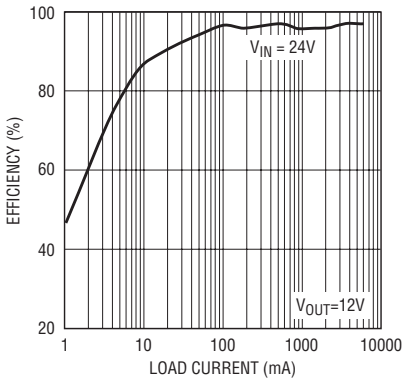

Figure 6. Efficiency vs load current for the circuit of Figure 4

Conclusion

Few synchronous monolithic DC/DC converters are versatile enough to use in low power portable devices such as notebook and palmtop computers, as well as high power industrial distributed power systems. The LTC3610's broad input and output ranges, efficiency greater than 90% and high current capability make it a superior alternative to many solutions requiring separate power switches.

LTC4067, continued from page 34

OUT voltage rises above the BAT voltage, the charge cycle restarts where it left off.

At any time, the user may monitor both instantaneous charge current and instantaneous USB current by observing the PROG pin and CLPROG pin voltages respectively.

Conclusion

The LTC4067 satisfies the needs of voltage sensitive battery operated devices, replacing as many as three separate devices. With accuracy better than ±0.4% on the battery float voltage, the LTC4067 is ideally suited for demanding high-precision applications. The LTC4067 offers both a power management strategy that complies with USB port specifications as well as providing an advanced battery charger. The LTC4067 also offers overvoltage protection up to 13V, to protect itself as well as system devices in the event that an incorrect wall adapter is attached.

LTC2355/56, continued from page 21

power, and small package makes the LTC2356-14 ideal for high speed, portable applications including data acquisition, communications, and medical instrumentation.

The LTC2356-14 achieves 72.3dB SINAD and –82dB SFDR with a 1.4MHz input frequency. While measuring ±1.25V bipolar inputs differentially, the LTC2356-14's 80dB common mode rejection ratio allows users to eliminate ground loops and common mode noise. When the ADC is not converting, power dissipation can be reduced to 4mW in nap mode, with the internal 2.5V reference remaining active, and 13µW with all analog circuitry powered down in sleep mode.

For applications requiring a unipolar measurement, the LTC2355-14 measures 0V to 2.5V input signals, but is otherwise identical to the LTC2356-14. For lower resolution applications, the LTC2356-12 and LTC2355-12 are pin- and software-compatible 12-bit versions of the LTC2356-14 and LTC2355-14.

The LTC2355-14/LTC2356-14/LTC2355-12/LTC2356-12 ADCs are pin- and software-compatible with the LTC1403 2.8Msps ADC family, allowing users to easily upgrade their design for a 25% faster sample rate. Table 2 details these fast single-channel unipolar and bipolar ADCs.

Summary

With PCB real estate getting tighter and designers always searching for lower power ICs, fast data acquisition can be a challenge. Linear Technology's families of simultaneous sampling ADCs and fast single-channel ADCs make it possible to optimize solution size, power and cost. The pin- and software-compatible families of 6-channel, 2-channel and single-channel ADCs offer flexibility to upgrade from 12-bit resolution to 14-bit resolution. Whatever your motor control, power monitoring, or data acquisition system requires, Linear Technology has a fast SAR ADC to do the job.