Data acquisition systems sit on single-chip designs

John H. Day - January 25, 2000

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Vendors of analog-to-digital converters are stepping up their efforts to develop data acquisition systems-on-chip (SoC) that can rival the performance of standalone components, but it's not yet clear how well they've succeeded.

Analog Devices Inc. (Norwood, Mass.) offers the ADuC812, featuring dual 12-bit D/A converters, a 12-bit A/D, flash memory and 8051/8052 microcontroller cores, plus support circuitry and a selection of serial port configurations. The company also provides the AduC824, with two high-resolution (up to 24-bit) A/Ds, a temperature sensor, a programmable-gain amplifier, a 12-bit D/A, an 8-bit microcontroller, flash memory and random-access memory (RAM), as well as serial ports.

"We have succeeded in providing laboratory-quality measurement functionality within the ADuC824," said Tremont Miao, strategy manager for Analog Devices' MicroConverter product line. The part's accuracy ranges from 0.003 percent to 0.0015 percent of full scale.

Analog Devices and other vendors say they can reduce power requirements as well as costs and design time when they integrate functionality on a single chip that previously would have required multiple chips. But not all vendors are convinced that the time has come for precision analog to be integrated with digital circuitry.

Jerome E. Johnston, a staff systems engineer with the Crystal Products Division of Cirrus Logic Corp. (Austin, Texas), acknowledged that the market would like to move toward SoC solutions but said it's still uneconomical and unfeasible to combine high-precision analog on the same die with digital microcontrollers.

"The digital noise from the microcontroller typically degrades the analog performance of the converters," Johnston said. "As has been said many times, good digital is easy; good analog is not, especially in the presence of digital."

"Customers aren't willing to sacrifice performance for the sake of integration," said Lee Walter, strategic marketing manager at Signal Processing Technologies Inc. (SPT; Colorado Springs, Colo.). "Some customers, in fact, are willing to pay a premium to gain a couple of extra decibels in SFDR spurious free dynamic range or SNR signal-to-noise ratio. You lose something when you integrate analog and digital."
Walter said analog and digital could be integrated in midrange and low-end applications where higher noise levels can be tolerated, but not in "instrumentation-quality" devices.

SPT is focusing on low-power products, such as its SPT7935, which the company says is the first 12-bit, 20-Msample/second A/D designed to operate from a 3.3-volt power supply. In November, SPT brought out the 10-bit, 20-Msample/s SPT7851, which achieves 9.3 effective number of bits (ENOBs) of dynamic performance and a typical SFDR of 70 dB while consuming 79 milliwatts from a single 3-V supply.

"The high-performance edge of the marketplace will continue to be the home of discrete solutions because of the technical difficulties presented to the mixed-signal designer," said Chuck Traylor, product-marketing manager for National Semiconductor's Data Conversion Systems Product Group (Santa Clara, Calif.) "Off-the-shelf integrations microcontroller solutions with an A/D converter onboard typically have only a single channel. Our customers have highlighted a need for a standalone, small-footprint A/D converter that complements the ADC on the microcontroller but offers additional channels and, sometimes, enhanced specifications."

Traylor said discrete solutions are likely to prevail in lower-volume applications (less than one million units per year) but added, "As an application grows in volume, it quickly moves toward an integrated solution, and the time this takes is continuing to get shorter."

The Diversity Receiver Chip Set (DRCS) that National introduced last June for cellular basestation applications combines two digital variable gain amplifiers with two CLC5956 12-bit, 65-Msample/s A/Ds and a digital downconverter. It requires 5 V for the analog portion, but all of the I/O is at 3 V. This mixed-voltage style of design is becoming common in very high-performance systems, Traylor noted.

"System accuracy requirements can be difficult to meet with a low supply voltage," he said. "This is the trade-off that ADC designers face. Digital circuits get more efficient with increased integration and lower supply voltages, but ADCs and other analog circuits are more efficient with high supplies. As technology advances, the performance of our DRCS can be expected to migrate to all 3 V, followed by 3-V analog combined with 2.5-V digital.

"Supply voltages will continue to decrease as the fundamental limitations for the shrinking MOSFET force the industry to reduce supply to allow increased functionality per chip. The industry will continue to step down in voltages as the processors do," Traylor said.

In October, TelCom Semiconductor (Mountain View, Calif.), introduced the TC3401, said to be the first in a new family of sigma-delta A/Ds designed especially for low-power/battery-powered applications. According to Don Ashley, manager of advanced products marketing, the 16-bit sigma-delta converters can operate with low power consumption (250 microamps normal and 50 microamps standby) from supplies as low as 1.8 V. Because they are designed for use in battery-powered products, the devices include an MPU-reset output and a voltage supply bus monitor with power-fail output.
Precise measurements won’t be a problem with TelCom's new A/D converters, according to Ashley, who said an on-board oscillator allows the resolution and sample rate to be scaled, under microprocessor control, from 16 bits at up to eight conversions/second down to 10-bit resolution at 512 conversions/s. Future products may include multiple A/Ds and D/As, and a microcontroller with flash memory. "ADC vendors have to be careful when they select a microprocessor core to license and embed," Ashley noted. "Each core has its following, so adding a core can fragment a line. Also, vendors need to be aware of the software development tools available to support the cores they select."

Companies known more for their microcontroller expertise than their A/D acumen are entering the data-acquisition SoC market. Last March, Atmel Corp. (San Jose, Calif.), brought out the AT90S2333 and AT90S4433 8-bit RISC microcontrollers, with a 10-bit, six-channel A/D and with a respective 2 kbytes and 4 kbytes of flash memory.

The parts are available in 2.7-V and 5-V versions and are aimed at sensor-based applications requiring low power, high accuracy and "pinpoint resolution" in converting analog information into digital data, according to Jim Panfil, Atmel's director of microcontroller marketing.

Atmel's successive approximation register (SAR) A/Ds offer 0.5 LSB accuracy. That's four times greater than the resolution and accuracy provided by most embedded A/D converters, which typically offer 8-bit resolution with 6-bit accuracy, Panfil said.

In August, microcontroller vendor Microchip Technology (Chandler, Ariz.) introduced the four-member MCP320X family of 12-bit SAR ADCs for embedded control applications. A month later, it launched the PIC16C717, PIC16C770 and PIC16C771-8-bit microcontrollers in 20-pin packages that integrate a 10- or 12-bit A/D, capture/compare/pulsewidth-modulation and an on-chip voltage reference.

The MCP320X ADCs are available in single, dual, quad and eight-channel versions and feature 100-ksample/s throughput, 400-microamps active and 500-nanoamp standby current, a 2.7-5.5V supply voltage range, and maximum differential non-linearity and integral non-linearity of plus/minus 1 LSB at 100 ksamples/s.

The PIC16C717 and PIC16C770 both feature 2k x 14 bits of one-time programmable (OTP) program memory and integrate a six-channel 10-bit and 12-bit A/D, respectively. The PIC16C771 has 4 kbits of OTP and a six-channel, 12-bit A/D. All three devices contain 256 bytes of user RAM and have 5-Mips performance at 20 MHz, 16 I/O pins, 4 MHz internal clock oscillator, high-performance communication capability via I2C/SPI interfaces, a 16-bit timer, two 8-bit timers, a watchdog timer, and a 2.5- to 5.5-V operating voltage range.

Nathan John, Microchip Technology's product marketing manager for PICmicro products, said the integrated A/Ds in the PIC16C7xx family provide a level of resolution previously requiring a standalone converter. "This gives designers the ability to detect smaller signal changes, which is important when interfacing with a wide variety of sensors," he said. "No external circuitry is required for high-precision measurement of analog signals."
Eschews controller-centric

Cirrus' Johnston is unimpressed by controller-centric data-acquisition SoCs. "They typically use general-purpose ADCs that aren't aimed at high-precision measurement applications," he said.

By contrast, Cirrus' CS553x family is designed especially to provide high-precision measurement of low-level signals, and it integrates a low-noise, low-drift amplifier. Johnston said CS553x parts provide better than 21-bit performance on a 100-millivolt signal at 7.5-Hz throughput. "Users would have to attach an external amplifier to other devices to get similar performance," he contended, "and even then, trade-offs would have to be taken into account."

Johnston said users who want to digitize signals greater than 1 V and don't require accuracy, which he defined as precision of 16-bits or better, can get by with a microcontroller and low-performance A/D combo.

There is a customer-driven trend toward higher integration, but not necessarily toward integration of a controller and memory with an A/D converter, according to John Brown, strategic marketing manager for Linear Products at Burr-Brown Corp. (Tucson, Ariz.).

"The objective of integration is to reduce size and simultaneously increase functionality," he said, citing the new ADS7870, which consists of a four-channel differential/eight-channel single-ended multiplexer (mux), a programmable gain instrumentation amplifier (PGIA), a 52-ksample/s 12-bit SAR A/D converter and an on-chip voltage reference. Brown said the PGIA eases the burden on system microprocessors and gives the ADS7870 a 16-bit dynamic range.

The ADS7870 also provides digital I/O via an easily isolated output serial port that supports digital communication without the need for additional optocouplers. It can work with a supply voltage of 2.7 V, and when its 1-kHz clock is slowed it requires only 1.5 mW of power. It's manufactured on a small-geometry CMOS process and is packaged in a low-profile SSOP-28.

According to National's Traylor, the need for integration is often driven by board space constraints, and National and others are focusing on high-performance A/Ds in small packages. "Miniature packages enable standalone functions that optimize performance in the smallest possible board space," he said.

Last February, Linear Technology Corp. (Milpitas, Calif.) unveiled the LTC2400, which product-marketing manager Todd Nelson said was the smallest 24-bit A/D yet, in an SO-8 one-quarter the size of competing parts, and the most accurate, with total unadjusted error of less than 10 parts per million.

Nelson said it operates without the external crystals, software and additional circuitry other high-resolution converters require. He claimed it is the only high-resolution A/D to include an on-chip oscillator, pin-selectable 50-Hz/60-Hz notch frequency filter and fourth-order sync filter. It works with from 2.7 V to 5.5 V, consuming 200 microamps during conversion, 20 microamps during shutdown.
A/D converter vendors

contend constantly with power, size and performance trade-offs, according to Chris Mostoller, technical business manager for Maxim Integrated Products (Sunnyvale, Calif.) "Providing a part with the greatest accuracy may result in power that is too high for an application," he said. "If we make a part faster than an application requires, power dissipation becomes a problem. It's important from a business standpoint to assess the current and future needs of the market and design parts that provide the best solutions."

18-bit A/Ds roll

Last February Maxim introduced the MAX1400 and MAX1402 18-bit A/Ds, with guaranteed 16-bit performance (.0015 percent INL) at 480 samples/s. They combine a switching network, programmable gain amplifier, two buffers, a system-offset-correction D/A converter, internal oscillator, on-chip digital filter, modulator and bidirectional serial interface in a 28-pin shrink small-outline package. Mostoller said the MAX-1400 and MAX1402 perform coarse measurements 10 times faster than alternatives at conversion rates as high as 4,800 samples/s, while still maintaining 12-bit performance (.024 percent INL).

The MAX1400 and MAX1402 operate from a 5-V analog supply and a 3- or 5-V digital supply. Power consumption is 1.5 mW for both parts and drops to less than 50 microW in shutdown.

In April, Maxim introduced the MAX1401 and MAX1403, 18-bit A/Ds with performance and power consumption identical to that of the MAX1400 and MAX1402 but with the ability to operate from 3-V analog and 3-V digital supplies.

Russell Jordan, strategic marketing manager for data converters at Texas Instruments, (Dallas), said the company is about to launch a range of low-power products. Among the first to surface will be the TLV1508 and TLV1504, 10-bit CMOS SAR A/D converters able to operate from a single 2.7-V to 5.5-V power supply. Like other converter products from TI, the TLV1508 and TLV1504 are designed for easy interface with the company's digital signal processors. They integrate an analog multiplexer as well as a conversion clock and reference, and they include power-saving features that include software/hardware auto power-down modes and programmable conversion speeds.

There is an argument that integration is bad, said Analog Devices' Miao. "You can keep sensitive analog circuits separate from noisy digital circuits if each is on a separate chip. But digital technology is moving toward integration, and so must analog.

"We've been able to marry the two successfully, and that gives us a lead, but it doesn't create a barrier," Miao continued. "Other vendors will be able to do what we've done. Low-performance ADCs on micros have been around for years, but there's a definite trend toward high-performance technology."

Intersil Corp. (Melbourne, Fla.) offers the HI5630, a triple 8-bit, 95-Msample/s CMOS A/D converters for digitizing RGB graphics from PCs and VCRs. It features a pipeline architecture and an input
stage that enables it to accept single-ended or fully differential input configurations.

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