The Precision32 Family of Mixed-Signal MCUs

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This paper describes Silicon Labs' new Precision32™ microcontrollers, the company's first 32-bit MCUs. In addition to the ARM-compatible CPU, the chips integrate USB and a set of analog components along with the usual flash memory, SRAM, timers, and serial interfaces. This paper is sponsored by Silicon Labs, but all opinions and analysis are those of the author.

Silicon Labs Knows Microcontrollers

Most people know Silicon Labs for its analog and mixed-signal technology. The company has core expertise in integrating high-performance analog peripherals with digital circuits in CMOS. This expertise is embodied in a number of IP blocks such as analog-to-digital converters (ADCs) and digital-to-analog converters (DACs), digital isolation, digital phase-locked loops, USB, RF, and sensors. The company integrates these blocks to create products for specific applications, including SLICs and DAAs for voice-over-IP (VoIP) equipment, FM/AM radio receivers and transmitters, silicon TV tuners, capacitive touch sensors, USB bridges, and programmable timing devices.

Less well known is that Silicon Labs has a long history in the microcontroller (MCU) market. This experience dates back to 1999, when a company called Cygnal Integrated Products began work on a line of mixed-signal MCUs. By the time Silicon Labs acquired Cygnal in 2003, the company had released more than 50 versions of its 8-bit MCU. The company developed a pipelined 8051-compatible CPU that operates at up to 100MHz. In addition to the speedy CPU, these microcontrollers included ADCs, DACs, oscillators, voltage regulators, and other analog functions.

Since the acquisition, Silicon Labs has continued to invest in microcontrollers, broadening the product line and integrating technologies from its diverse analog portfolio. Many versions include RF, USB, and other communications interfaces. The company also used its analog expertise to reduce the power consumption of its MCUs, both when active and when dormant.

Today, Silicon Labs offers mixed-signal 8-bit microcontrollers in packages as small as 2mm square. These chips are popular in a range of industrial, embedded, consumer, and communications applications, particularly where small footprint, analog performance, and low power are required.

Precision32 MCUs Muscle Up with ARM

Extending its microcontroller lineup, Silicon Labs recently introduced the first products in a new family of 32-bit MCUs. The new Precision32 products include an ARM CPU, taking advantage of the ecosystem of software and tools available for the ARM architecture. ARM is the most popular instruction set in the industry, both in the number of vendors and in units shipped per year. Much of this success comes from the cell-phone market, but ARM is quickly becoming the leader in 32-bit MCU shipments as well.

Silicon Labs' Precision32 family uses an ARM Cortex-M3 CPU running at speeds of up to 80MHz. Although this clock speed is no faster than that of Silicon Labs' 8-bit MCUs, ARM's 32-bit architecture is better suited to modern compiled software and other code that uses 16-bit or 32-bit data. Cortex-M3 supports ARM's Thumb2 mode, which reduces code size by compressing instructions to 16 bits whenever possible. As a result, the code size for the ARM CPU is similar to or even less than that of an 8051 or other 8-bit instruction set.

The Precision32 products combine the Cortex-M3 CPU with a variety of analog components, many of which are held in common with those used in the company's 8-bit MCUs. These components include two 12-bit ADCs, two 10-bit DACs, an oscillator, a regulator, and a 16-channel touch sensor. The products also include flash memory, timers, counters, and serial interfaces, as Figure 1 shows.

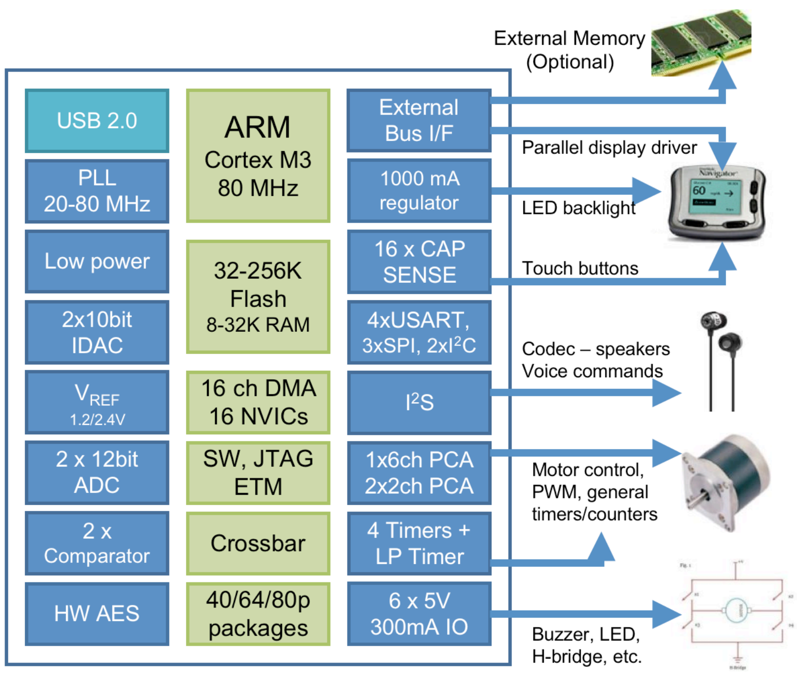

Figure 1. Block diagram of Precision32 microcontroller. The new Silicon Labs MCU combines a Cortex-M3 CPU, flash memory, and a variety of analog interfaces.

The initial Precision32 products come in two basic types: with USB and without USB. The former supports USB 2.0 at full speed (12Mbps) but not high speed. Each of these types is available with flash-memory configurations ranging from 32KB to 256KB. The company offers a variety of leaded and leadless package options: a 6mm QFN-40 for minimum size, a QFN-64 or QFP-64, and a TQFP-80 or LGA-92 for maximum I/O configurations. Note that even the small 6mm version supports the full 256KB of memory. Altogether, the company is launching 32 different product variations. All of the initial products are already sampling, with production volumes expected in 2Q12.

Reducing System Cost

The Precision32 MCU's high level of analog integration reduces system cost by eliminating the need for several external components. For example, most MCUs require an external crystal oscillator operating at a relatively high speed such as 8MHz. This crystal costs around 10 cents. A Precision32 MCU can operate its USB port with no external crystal, using only its internal oscillator and PLL. The internal oscillator uses a clock-recovery technique to operate at a precision of 1.5% over PVT (process, voltage, and temperature), which is within the tolerances of the USB specification. A second internal oscillator generates the 80MHz CPU clock (also to 1.5% PVT) using either the USB clock (crystalless) or an inexpensive 32kHz crystal.

Similarly, the internal voltage regulator eliminates an external regulator, which can cost around 15 cents. This regulator allows the Silicon Labs chip to operate directly from a 5V supply, if necessary; it can even be powered directly from USB. The regulator can also drive an output rail at a programmable voltage, enabling the MCU to provide power to additional ICs while still avoiding the need for an external regulator. Alternatively, this output can act as a constant current source to drive the backlight on an LED display. A separate LED-backlight controller can cost 30 cents.

The MCU also provides six high-drive output pins that can each sink 300mA or source 150mA—enough to directly drive power MOSFETs, high-power LEDs, buzzers, and similar components. Because an external high-drive transistor can add 4 cents to the system cost, these outputs can save the designer up to 24 cents total. In addition, the chip can connect directly to up to 16 capacitive touch sensors. These types of sensors are increasingly used in consumer and other equipment to avoid mechanical buttons, which are more expensive and can fail. An external touch controller can cost up to 50 cents.

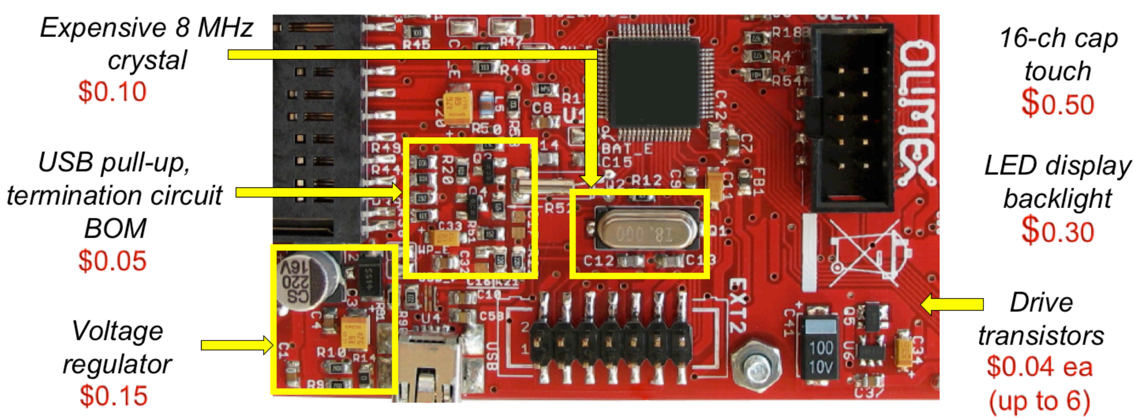

Figure 2. Cost savings from integrated analog components. This photo shows how many of the external components in a typical MCU-based design can be eliminated using the highly integrated Precision32 chip.

For systems with USB, the chip integrates a complete USB PHY and analog front end, interfacing directly to the USB connector. Most other MCUs require an external USB pull-up resistor and termination circuit, adding several small components with a total cost of about 5 cents. The total cost of the components saved using Precision32 MCUs can be as high as $1.34. Of course, many systems will not require an LED backlight or a touch controller, reducing the savings, but most designs will save at least 30 cents. As Figure 2 shows, eliminating this external circuitry also reduces board area.

Reducing Power

Silicon Labs engineered the Precision32 MCU for low power in both active and sleep modes, paying particular attention to the Cortex-M3 CPU. In active mode, the entire chip can operate at just 22mA at 80MHz, or 0.28mA/MHz. This level bests that of most competing MCUs, although some of Freescale's newest Kinetis MCUs can also operate at 0.25mA/MHz at up to 72MHz. The Precision32 MCU's sleep-mode current is more impressive: just 0.35µA with RTC enabled, the lowest in the industry.

The company also focused on reducing system power, since many MCU applications are powered by batteries or through the limited levels of the USB specification. For starters, integrating the analog components noted above, such as the oscillator and USB termination, reduces the overall system power by shortening signal paths and moving them on chip.

Furthermore, the on-chip oscillator enables the CPU to operate at virtually any desired frequency; with an 8MHz external crystal, an MCU must operate at an exact multiple of 8MHz. For the same reason, Silicon Labs allows the CPU and USB frequencies to be set independently rather than at a fixed ratio. This flexibility allows the system designer to fine-tune the CPU frequency to deliver the required performance while operating at the minimum speed and power.

Reducing Design Time

Drawing on its experience with 8-bit MCUs, Silicon Labs built a flexible I/O system into the Precision32 design. The chip includes two crossbars that can link any internal I/O function to a wide range of pins, as Figure 3 illustrates. In this TQFP-80 example, Crossbar 1 connects to pins 9 through 40, excluding only 28 and 29, which are power and ground pins. Crossbar 1 supports 14 different internal functions, including various serial ports, timers, and comparators; any of these functions can connect to any of the external pins that the crossbar serves. Some of these pins can also be mapped to ADC inputs or 5V-tolerant outputs.

This flexibility provides several benefits to the system designer. The designer can arrange the pinout of the chip to simplify board design, placing a group of output pins next to the chip that they connect to, for example. In some cases, this approach can even save cost by allowing the use of a PCB with fewer routing layers. Furthermore, pinout changes can be made easily to accommodate last-minute board modifications.

This approach provides great flexibility when choosing which functions to connect to pins and which ones to leave unconnected. This flexibility is particularly important when using smaller packages with fewer I/O pins. Most other MCUs provide some configurability but may support only one or two functions per pin, limiting the number of options and creating potential pin conflicts.

So much configurability can be confusing, but Silicon Labs provides a software tool to simplify the configuration. The Application Builder (AppBuilder) tool offers a graphical interface that allows designers to drag-and-drop functions to pins. Once the configuration is complete, the tool generates the boot code required to load this configuration into the MCU. This tool works with commercial IDEs including Keil and IAR as well as the popular Eclipse, which Silicon Labs has modified to support Precision32 products.

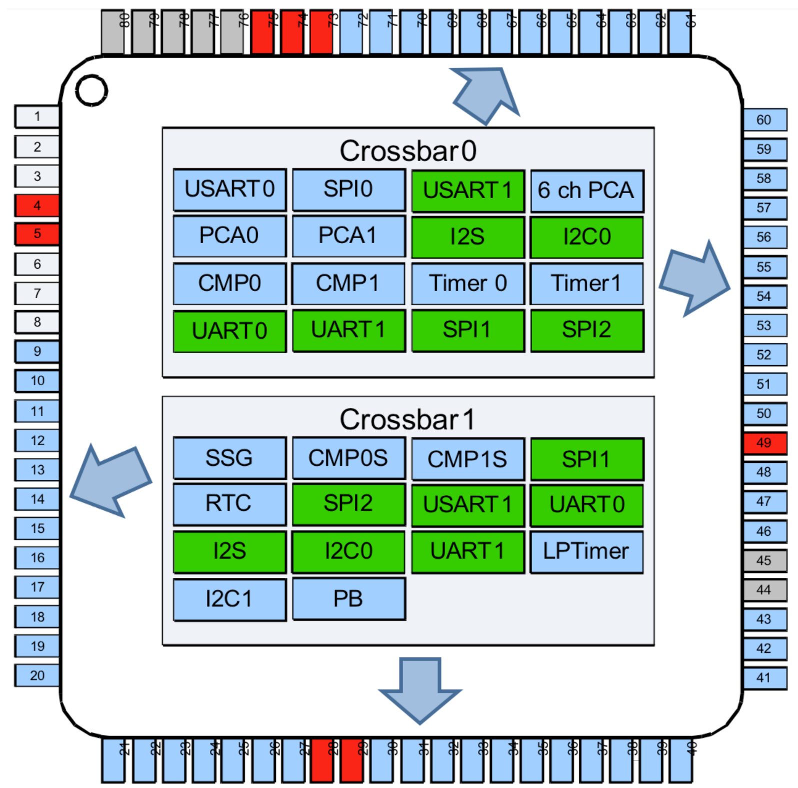

Figure 3. Precision32 I/O crossbar. The Silicon Labs MCU includes two internal crossbars that enable any I/O function to connect to a wide range of pins.

Industry-Leading Low Power

With several vendors offering ARM-based 32-bit microcontrollers, Silicon Labs needs some special capabilities to stand out from the pack. As Table 1 shows, competitors include Freescale's new Kinetis products, STMicroelectronics' STM32 line, and Texas Instruments' Stellaris. Other vendors such as Atmel, EnergyMicro, and NXP also play in this market, but we have focused on the market leaders. To facilitate comparisons with other vendors' broad product lines, we have tried to select models with similar CPU speed and memory capacity as well as a USB port.

Freescale's Kinetis provides stiff competition. Its Cortex-M4 CPU is similar to the M3 but includes a DSP and optional FPU. In the K20 version, the CPU can achieve 100MHz, although the new low-power version is limited to 72MHz. In this low-power mode, the new Kinetis K20 can match the Precision32 MCU's operating current while operating only slightly slower than the Silicon Labs device. In sleep mode, however, Kinetis draws 4.0µA—more than 10 times the current that the Precision32 MCU uses.

Kinetis matches most of the analog capabilities of the Precision32 MCU and even offers greater resolution on the ADC and DAC. Precison32 offers some advantages over Kinetis, however, including smaller packages on the low end. A bigger concern is that Kinetis is behind schedule, and the low-power versions are not yet sampling (they are due to sample by the end of 1Q12). Furthermore, the Freescale chip's extra features, such as the DSP and FPU, will increase die size and thus could drive up its price.

	Silicon Labs Precison32	Freescale Kinetis K20DX	ST STM32F10x	TI Stellaris 3000
CPU Type	Cortex-M3	Cortex-M4	Cortex-M3	Cortex-M3
CPU Speed (max)	80MHz	72MHz*	72MHz	50MHz
Internal Flash (max)	256KB	256KB	1MB	256KB
Internal RAM (max)	32KB	64KB	96KB	64KB
Pin Count	40, 64, 80	64 to 144	36, 64, 100, 144	64, 100
Package Size (min)	6mm	9mm	10mm†	10mm
Active Current (/MHz)	0.28mA	0.25mA	0.39mA	1.00mA
Sleep Current	0.35µA	4.0µA	1.90µA‡	18µA
ADC Resolution	2×12 bits	2×16 bits	2×12 bits	1×10 bits
DAC Resolution	1×10 bits	1×12 bits	2×12 bits	None
USB Speed	Full speed	Full speed	Full speed	Full speed
Capacitive Sense	16 channels	16 channels	None	None
Other Analog	Oscillator, regulator high-drive I/O	Oscillator, regulator	Oscillator	Oscillator, regulator
Availability	Samples 4Q11	Samples due 1Q12	Production	Production

Table 1. Comparison of Precision32 MCU and leading competitors. *Also available at 100MHz with higher power; †also available in 6mm QFP-36 with 128KB flash memory, 20KB SRAM, and no DAC; ‡using battery only, current is 4.0µA when using V_{DD}. (Source: vendors)

ST offers a broad range of ARM-based MCUs, but the STM32F10x is the best match with its 72MHz Cortex-M3 CPU and full-speed USB interface. ST is the only competitor that can match the small size of the Precision32 family's 6mm package. ST's 6mm package, however, limits the amount of flash and SRAM to about half of what Silicon Labs offers in that form factor; the small package also prohibits use of the DAC. The full-featured version requires a 10mm package.

The STM32F10x burns about 50% more power than the Precision32 MCU at the same clock speed. In sleep mode, the difference is more like 5x. ST offers an "ultra low power" version of the processor that is rated at 0.23mA/MHz and 0.27µA sleep current; these figures are slightly better than Silicon Labs's, but ST's ultra-low-power device is limited to 32MHz CPU speed, 128KB of flash memory, and 16KB of SRAM, helping to keep its power down.

For TI's Stellaris, we have selected the 3000 series for this comparison. In these products, TI limits the Cortex-M3 CPU to 50MHz—considerably slower than the Precision32 CPU. To get an 80MHz CPU, one must use the more expensive 5000 series, which targets automotive applications. The Stellaris 3000 uses a bigger package than the Precision32 MCU, burns more power, has limited ADC resolution, and has no DAC at all.

The Precision32 family offers some unique features that distinguish it from all of these competitors. The chip's I/O crossbar provides design flexibility that is unmatched in other MCUs. The high-drive outputs and LED backlight capability are unusual and potentially cost-saving features. Other leading MCUs do not offer capacitive touch interfaces, although Kinetis will have this capability when it samples.

Standing Out From the Crowd

Although Silicon Labs does not offer the broadest portfolio of 32-bit MCUs, the initial Precision32 devices are a good fit for many end applications. For industrial purposes such as motor control and monitoring, the chip's 5V-tolerant inputs and high-drive outputs are particularly useful. Battery-operated devices such as blood-glucose monitors, GPS tracking systems, sensor controllers, and thermostats can benefit from the MCU's low power consumption. Barcode scanners, card readers, and other peripheral devices need the highly integrated USB interface. The 6mm package will help meet the form-factor requirements of 10Gbps optical transceivers.

The chip's uniquely flexible pinout is an important advantage for almost any design. It can reduce design time and allow last-minute changes, getting the product to market sooner. This approach also allows more designers to use smaller packages and pin counts, since the pins can be arranged to support almost any peripheral combination.

Silicon Labs applied its characteristic analog expertise to its new 32-bit MCUs, giving them an array of features such as precision oscillators, voltage regulators, high-drive outputs, and capacitive touch interfaces. Although some competitors have some of these features, none can match this entire package. Even in functions that competitors offer, such as analog-to-digital converters, Silicon Labs often excels in precision and voltage range.

The company engineered its new MCUs with by far the lowest sleep power among competitive products: they draw just 0.35µA, less than a third that of the nearest competitor. Its active power (mA/MHz) is also the industry's lowest for MCUs in its class. The processor provides several power modes and clocking options to help designers minimize power.

With its new line of 32-bit microcontrollers, Silicon Labs is expanding from the 8-bit world into the crowded realm of ARM-compatible MCUs. To stand out from the crowd, the new Precision32 products offer low power, flexible I/O, and analog integration. These features make them well suited to a range of industrial, medical, communications, and consumer applications. Designers used to working with the big microcontroller suppliers should take a look at this new player in the 32-bit market.

Linley Gwennap is founder and principal analyst of The Linley Group and editor-in-chief of Microprocessor Report. *The Linley Group offers the most comprehensive analysis of the microprocessor industry. We analyze not only the business strategy but also the technology inside all the announced products. Our in-depth reports cover topics including embedded processors, mobile processors, network processors, and Ethernet chips. For more information, see our web site at www.linleygroup.com.*