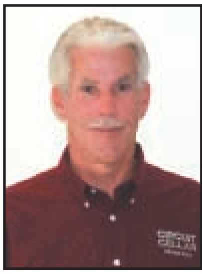
CIRCUIT CELLAR®
THE MAGAZINE FOR COMPUTER APPLICATIONS





SILICON UPDATE

by Tom Cantrell

# Something Old, Something New

*Naysayers are eulogizing the dearly beloved 8-bit microcontroller. Once again, Tom says not so fast. A new generation of chips proves there's still a long life ahead for the 8-bit MCU.*

"The 8 bit market is dead." It must have been more than 20 years ago, only a few years after the party had started, that naysayers began to proclaim it was over. And like clockwork in the intervening years, some pundit has felt the need to prematurely eulogize our beloved 8-bit microcontrollers. Of course, it's a bit hard to claim that a 10-million-plus-units-a-day market is actually "dead," so the latest trend is to claim that it's "dying" by virtue of an ostensibly negative growth rate (see Figure 1).

I don't believe the market for entry-level microcontrollers is either dead or dying, and I'm not alone. In-Stat, which is no lightweight when it comes to fortune telling, recently put out a press release with the headline: "Strong Growth to Continue for MCU Market."[1] Analyst Max Baron notes that the number of 8-bit microcontroller applications with positive double-digit growth rates exceeds those with negative double-digit rates by a factor of five to one. *Circuit Cellar*'s own reader survey, a notably trustworthy source of trend information, shows that 8-bit microcontrollers remain the single most widely used component, with design-ins by fully two-thirds of the survey respondents. Yes, the lead is shrinking, but 8-bit microcontrollers remain numero uno, as they have all along.

While I'm on the subject, one thing that has always bugged me about market statistics is the attempt to pigeonhole chips into 8 and 16 bit categories. Perhaps it made sense at one time. At this point, however, I feel the distinction is not only more ambiguous than ever, but it's rather unnecessary and even borders on misleading.

The problem has always been the "bitness" you're talking about. ALU width, data bus pins, or programmer's model? You're telling me a Texas Instruments MSP430 (16-bit ALU) doesn't compete directly with 8-bit microcontrollers? What, besides ALU width, is really the compelling difference between an HC11 (8-bit ALU) and an HC12 (16-bit ALU)? Shouldn't Renesas call their high-end H8 with a 16-bit ALU an H16?

To my mind, the meaningful differentiation between microcontrollers has more to do with the 64-KB-ness of the address space. Taking advantage of a variety of hacks, designers long ago figured out ways to hook more memory to 64-KB chips. The high (some would say low) point of the concept was the original IBM PC in which an 8088 chip (8-bit bus, 16-bit ALU, and 20-bit (kind of) address space) managed to shoulder 640 KB of RAM by breaking it into 64-KB segments.

Whether you're a market analyst or a designer, I think it makes more sense to group all 8- and 16-bit chips together in the 64-KB camp with the understanding that it's possible, and sometimes even makes sense, to tack on more memory. With that off my chest, here's a roundup of the latest and greatest 8/16-bit, do-it-all microcontrollers.

## PIC & CHOOSE

Talk about a rags-to-riches story. Back in the 1970s, a company called General Instruments had pretensions to build a minicomputer on a chip (the CP1600) for which the PIC was designed as an add-on "Peripheral Interface Controller" support chip. To make a long story short, GI's grand plan, and ultimately the entire minicomputer market, went down in flames.

By the mid-1980s, GI was further laid low by travails in the first-generation video game business. (Remember Atari?) GI decided to call it quits and sold off the smoking rubble of its IC business, including the PIC, to some outside investors, and Microchip was born.

Now, some 4 billion units later, the PIC stands as a shining example of free enterprise and creative destruction at work. What was once a failed chip from a failed company has clawed its way to the top. Don't you just love this business?

The PIC saga continues with Microchip's recent introduction of the 16-bit PIC24 lineup, a version of their dsPIC parts minus

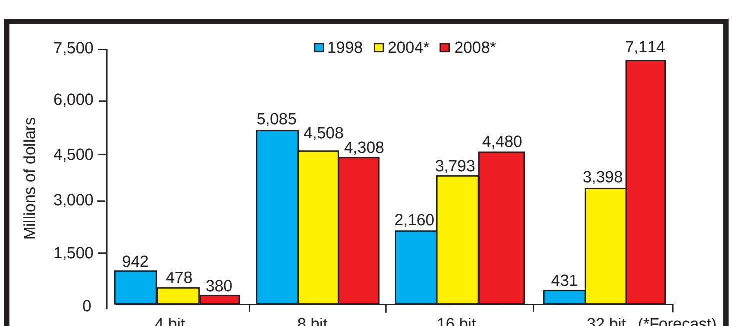



**Figure 1**—*Even the most jaded pundit would have to agree that the 8 bit market certainly isn't dead (like the 4 bit market). Dollar-based forecasts tend to disguise decent unit shipments by virtue of declining ASP assumptions (which themselves may be somewhat suspect). Furthermore, combining the 8 and 16 bit numbers yields another, perhaps more useful, perspective. (Source: WSTC IC Insights)*

**Photo 1—***Success in the MCU mass market calls for more than a good chip. Microchip carries that lesson learned long ago forward with their $130 Explorer 16 evaluation board, which supports all the members of the dsPIC and new PIC24 families.*

the DSP stuff (see Photo 1). With 20 to 40 MIPS on tap and a kitchen sink's worth of built-in peripherals, it bears little resemblance to the stripped-down versions of yore. Keeping up with the Joneses is a must in the MCU business. You either grow or you die.

## BATWINGS FOREVER

Leveraging a lead starting with their dawn-of-silicon MC6800 8-bit microprocessor, Motorola's MC68s (the 6801, 6805, 6808, etc.) have been top contenders in the MCU market from day one.

Although it isn't a riches-to-rags story (the MC68s remain in the top ranks to this day), I feel as though the embedded lineup was ill-served by the wavering focus associated with the Byzantine organization chart at Motorola and the upheaval during the subsequent spinout into Freescale. It's not that they've done poorly, but could they have done better?

But now that the Freescale spinout has settled down, my recent discussions with the company have led me to believe they get it once again. Notably, the folks I've talked to have expressed great enthusiasm over a renewed commitment and focus on the MCU business.

Talk and press releases are cheap, but Freescale is putting their silicon where their mouth is with the new less-is-more MC9S08QG parts (see Photo 2). Notably, the new chips allow Freescale to compete in the low-pin-count (8- and 16-pin parts in a variety of packages) and low-price (less than $1) space. They aren't the least expensive parts around, but I was impressed by the value I found looking under the hood.

For instance, there are a lot of flash memory MCUs and a lot that run at low voltages, but how many can self-program their flash memory over the entire voltage (1.8 to 3.6 V) and temperature (–40° to 125°C) range? Furthermore, flash memory programming is as fast as 20 µs per byte, which addresses a common production line complaint and enables psuedo-EEPROM emulation.

Ditto on the internal clock reference. Lots of chips have them, but few can maintain 2% accuracy across voltage and temperature like the MC9S08QG. Ten-bit ADCs are a dime a dozen, but most of those found on an entry-level MCU are slower than the MC9S08QG's 2.5-µs (400-kHz) converter. The chip also has an automatic window Compare mode that will only interrupt the MCU when the analog input hits a range of interest. An on-chip temperature sensor and a voltage reference further boost the MC9S08QG's analog capabilities.

Every pin counts when you have only eight or 16 to play with. The MC9S08 extends the single-pin debug feature found on other chips with an eight-entry, bus-activity FIFO. The FIFO provides a measure of real-time trace capability not found on simpler Background Debug mode (BDM) and serial monitor debug schemes.

And, of course, there are plenty of low-cost demonstration and development kits, notably packaged with the industrial-strength Metrowerks CodeWarrior IDE. By virtue of the small amount of memory on the MC9S08QG chips (4 and 8 KB versions), what might otherwise be a $2,000 purchase order disappears because the code limitation on the CodeWarrior free evaluation version is 16 KB.

## '51 FLAVORS

Joining the PIC24 and MC68s, the '51 rounds out the historic "Big Three" MCUs. However, unlike the other two, the '51 is notably unique by virtue of its de facto open architecture, which is somewhat ironic given the zeal with which the original inventor Intel typically guards their intellectual property family jewels. There may be no free lunch, but the '51 is a design free for the taking with literally dozens of suppliers on the bandwagon.

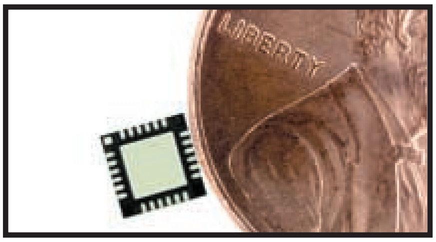


**Photo 3—***It's a small world after all, as demonstrated by the ever-shrinking MCU. In this case, it's a mere 4 mm × 4 mm for the latest flash '51s from Silicon Laboratories.*

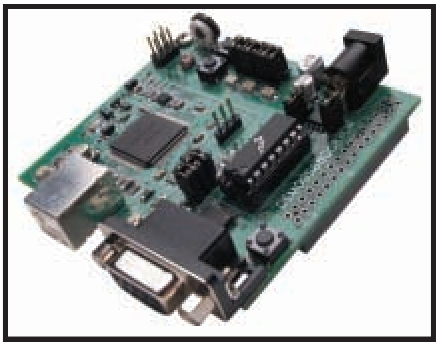


**Photo 2—***Competitors in the top tier don't have the luxury of choosing to serve only select markets. Strength across the board is a must. Freescale is responding with a new line of low-pin-count parts (16-pin shown here) that offer good value for a bargain price.*

That's good for customers because it means that some company somewhere around the world announces a new '51 flavor on practically a daily basis. Let's take a look at the latest three crowding my in-basket.

Silicon Labs is carrying the mixed-signal '51 torch they inherited with their Cygnal acquisition to new highs—er, better make that new lows, at least when it comes to the scarce PCB real estate available in ever-downsizing gadgets.

Silicon's new C8051F316/F317 microchips include a lot of goodies, starting with a 25-MIPS peak (maybe 10 MIPS sustained) pipelined '51 core, a precise (2%) on-chip oscillator, and all the usual digital I/O suspects (a UART, $I^2C$, a SPI, five 16-bit timer/counters, a watchdog timer, etc.).

Reflecting Silicon's analog focus and know-how, the C8051F316 includes a fast (up to 200 ksps) 10-bit ADC with up to 13 multiplexed inputs, an on-chip reference voltage, and a temperature sensor. In addition, both the C8051F316 and C8051F317 include a couple of analog comparators with programmable hysteresis that are configurable to generate an interrupt or reset. With all that and more, a full 24 pins of I/O functionality are crammed into a package that's a mere 4 mm on a side (see Photo 3).

Let's see. Compared to the '51 of 25 years ago, you're getting probably 20× the performance in a package about one-fiftieth the size of the original's 40-pin DIP. In other words, you're enjoying about a 1,000× improvement in terms of functionality and board space.

The mixed-signal stakes are also attracting new players with new chips to the table, such as Sensors Platforms with the SSP1492. The company may be new to you, but this chip traces it's analog roots to the proven design used by Precision Navigation as the signal processing brains of their Wayfinder magnetometer-based digital compasses. It's has signal-conditioning capability suitable for use with a wide variety of existing and emerging sensors (see Figure 2).

The '51 core, familiar to all, is a natural for applications where the I/O functionality is the tail that wags the dog. And one of the hottest topics on the I/O front is embedded wireless, with the emerging ZigBee standard generating a lot of buzz.

It's no surprise then to see that one of the first truly single-chip ZigBee solutions, the Chipcon CC2430, is based on the combination of their earlier CC2420 IEEE 802.15.4 2.4-GHz radio and a high-speed '51 core. Versions of the chip come with 32- to 128-KB flash memory and 8-KB SRAM to accommodate the range of networking complexity (reduced- and full-function devices) encompassed by the standards.

The '2430 packs a lot of punch in its 7 mm × 7 mm 48-pin QLP48 package. Along with hardware support for the radio network (e.g., AES encryption/decryption, random number generator, AGC, and RSSI), there's plenty of application processing and I/O goodies (e.g., DMA, UARTs, an eight-channel ADC with up to 14 bits of resolution, and an on-chip temperature sensor).

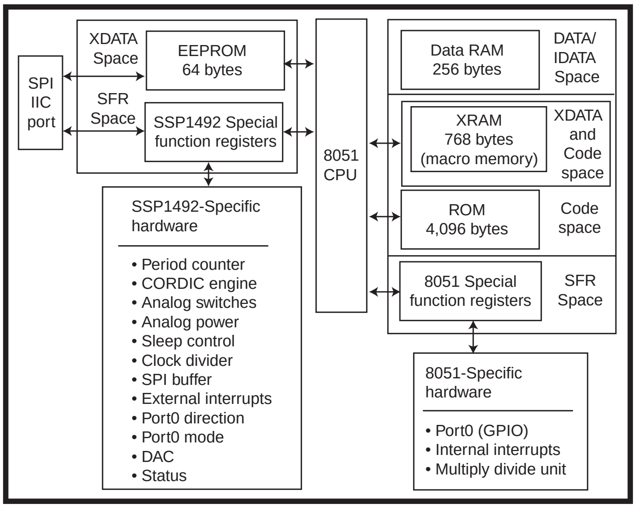



**Figure 2—***MCUs, such as the '51-based SSP1492 from Sensor Platforms, continue to integrate the analog functionality required to serve the growing markets for smart sensors of all sorts.*

Given the aggressive battery life goals at the heart of embedded wireless applications, Chipcon clearly devoted a lot of their design effort to reducing power consumption. The basic concept of ZigBee is to minimize the duty cycle of radio activity because power consumption during Tx and Rx (typically 25 mA) can be cut only so far. The secret to Chipcon's success is slashing standby power (less than 1 µA) and reducing the time (and thus energy) spent waking up.

## CHIP WITH NINE LIVES

Zilog is a company that's had more ups and downs than a rollercoaster. Most companies start private and then go public, but few do it two times. (Or three? I've lost count.)

Despite all the corporate machinations, descendants of the original circa-1970s Z8 continue to keep their heads above water in the market. It was a competitive part way back when, and the latest incarnations remain competitive today.

Generic microcontroller markets are pretty crowded, so most suppliers' expansion strategies rely on application-oriented designs aimed at specific vertical markets. In Zilog's case, the new Z8 Encore! MC versions target motor control, an ever-growing business with something on the order of 6 billion electric motors shipping each year. With features like fast ADC, an on-chip op-amp, and unique soft-start and direction reversal algorithms, the MC is particularly well suited to serve fast-growing brushless DC (BLDC) motor applications.

## SWEETER SIXTEEN

The Texas Instruments MSP430 is another MCU with roots that go way back. But until recently, Texas Instruments marketeers held it in suspended animation as a best-kept secret serving only a relatively narrow base of focus accounts.

That all changed a few years back when Texas Instruments threw a coming-out party to introduce the chip to the mainstream MCU market. Likely the strategy had some doubters within Texas Instruments, or they would have done it earlier. Needless to say, any doubts have been erased by the subsequent enthusiastic reception for the MSP430.

The MSP430 takeoff was due to a combination of competitive performance (16-bit ALU), aggressive pricing, and a very low-power consumption (see Photo 4). Not resting on their laurels, Texas Instruments is introducing a second wave of parts, the MSP430F20*xx* line, which further highlights these advantages with twice the performance (16 versus 8 MIPS), small packages, standby power as low as 500 nA, and sub-$1 pricing.

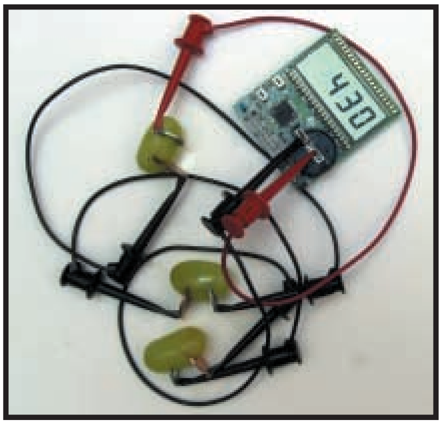


**Photo 4—***I've heard of ground loops, but fruit loops? Low-power is all the rage, which is one factor behind the sudden popularity of Texas Instrument's come-from-behind MSP430.*

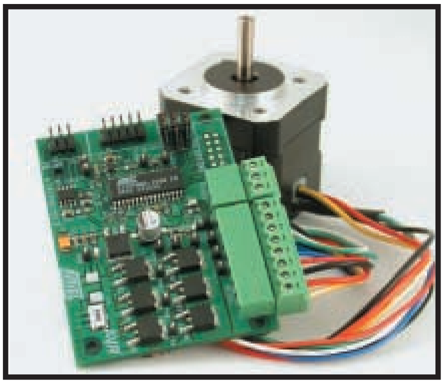


**Photo 5—***Zilog and Atmel are the latest to jump on the motor control bandwagon. Shown here is the Atmel ATAVRMC100 evaluation kit targeting sensor and sensorless brushless DC motor applications.*

## NEW CHIPS ON THE BLOCK

So far, every chip that I've discussed has ancestry that goes back at least 20 years. Given the double-time pace of the march of silicon, the staying power of these popular MCUs is remarkable. It's no mystery. Thanks to Moore's law, under-the-hood hop-ups have allowed these old designs to keep pace with designers' needs. Furthermore, the lean-and-mean philosophy that was a necessity way back when remains a virtue in today's cost-conscious environment.

Until relatively recently, it was a fact that these elder architectures completely dominated the MCU business. The prospects for a newcomer attempting to join the inner circle were daunting to say the least. But market statistics, *Circuit Cellar* reader surveys, and my own intuition indicate that the situation is changing. In short, some newer MCU architectures are finally making their marks.

The Renesas H8, which is the oldest of the new kids on the block, stands out as the leading Japanese challenger to the historic leaders. Technically speaking, the H8 is a relatively modern architecture unburdened by the antique architectural quirks that haunt the elder chips. Nevertheless, making a dent hasn't been easy. There have been a variety of challenges (memory chip mentality, legal issues, spinouts, and mergers) along the way. But they stuck with it through thick and thin, finally earning some well-deserved payback with a growing market share and acceptance by designers worldwide.

Another newcomer is Cypress Semiconductor's PSoC. In terms of the overall market, the PSoC is still just a blip. But Cypress has gotten out of the blocks quickly and has gained a surprising amount of traction in a relatively short amount of time.

The PSoC's advantage has little to do with the middle-of-the-road processor core itself. Rather, the chip's innovative analog-capable, programmable logic, easy-to-use roll-your-own-SoC tools, and an attractive price set it apart.

The PSoC isn't especially pretentious, but it excels when it comes to cost-sensitive, blue-collar applications. By virtue of its ability to programmably accommodate both digital and analog integration, a PSoC can often squeeze the typical "few chips" design into even fewer chips.

But my award for Rookie of the Year (OK, Rookie of the Decade) has to go to the Atmel AVR. From a technical perspective, Atmel got the recipe right with their combination of modern concepts (e.g., RISC and flash memory) and tradition (e.g., I/O integration and popular tools), the latter exploiting technology and relationships developed over the years in their prior (and still ongoing) '51 business.

At this point, the breadth of the AVR portfolio gives it an advantage. If you check Atmel's web site, you'll find something on the order of 50 different part types, and that's not counting package variations. They cover the range from Tiny AVRs in eight-pin packages with 1 KB of flash memory to "Mega" versions with 100 pins and up to 256 KB of flash memory. Furthermore, there is a range of vertical market parts with features targeting automotive, lighting, LCD, battery charger, and motor control applications (see Photo 5). And the list goes on.

Beyond the ones and zeros, credit for Atmel's success also goes to savvy and sustained marketing, which over time has established a healthy ecosystem of high-quality and low-cost tools from both Atmel and third-party supporters.

The bottom line is that the Big Three (PIC, '51, and '68) is now the Big Four, with the AVR muscling it's way into the top tier. Given the historical dominance of the old-timers, that's quite an achievement.

## LIVE FOR TODAY

The importance of these successful newcomers goes beyond simply offering designers more and better options. Along with the ongoing success of the old-timers, new chips from new players are also proof that the market for mini-me MCUs is far from dead.

But aren't the markets saturated? How many more little MCU-based gadgets does the world need? To that I say, never count out the imagination of designers and the whimsy of customers. Recall that when the microprocessor was invented, many people had doubts. After all, the market for computers was at that time measured in hundreds, leading the less enlightened to pooh-pooh prospects for a computer-on-a-chip.

Gordon Moore incorrectly predicted an end to his own law so many times that he quit doing it. There's a lesson in that for those who predict an end to entry-level MCUs, not to mention those who have been predicting it for 20 years. It ain't over until it's over—and it ain't over!

*Tom Cantrell has been working on chip, board, and systems design and marketing for several years. You may reach him by e-mail at tom.cantrell@circuitcellar.com.*

## REFERENCE

[1] In-Stat, "Strong Growth to Continue for MCU Market," 2005, www.instat.com/press.asp?ID=1445&sku=IN0502457SI.

## SOURCES

**AVR Microcontroller**
Atmel Corp.
www.atmel.com

**CC2430 Single-chip ZigBee module**
Chipcon
www.chipcon.com

**MC9S08QG Microcontroller**
Freescale Semiconductor, Inc.
www.freescale.com

**PIC24 Microcontroller**
Microchip Technology, Inc.
www.microchip.com

**H8 Microcontroller**
Renesas Technology Corp.
www.renesas.com

**SSP1492 Sensor interface MCU**
Sensor Platforms, Inc.
www.sensorplatforms.com

**C8051F316/17 Microcontrollers**
Silicon Laboratories, Inc.
www.siliconlabs.com

**MSP430F20*xx* Microcontrollers**
Texas Instruments, Inc.
www.ti.com

**Z8 Encore! microcontroller**
Zilog
www.zilog.com