Using 8-bit 8051s in a 32-bit World

By Bill Finch, senior VP, CAST, Inc.

Recent engineering headlines focus on exciting uses of 32-bit processors like the dual ARM Cortex-A9s in Apple's iPad 2,A5 chip or NVIDIA® Tegra™ 2 in the Motorola Zoom and other Android tablets. But there's an unsung hero who still has a role to play in today's mobile, feature-happy world: the 8-bit 8051 microcontroller.

Respectable History

Intel introduced the MCS-51 single-chip microcontroller in 1980. Its architecture included many critical functions in one package, including CPU, memory, interfaces, interrupts and timers.

Through the '80s and '90s, several vendors went on to offer MCS-51 compatible variants—often running faster or including more functions than the original—and they served as the brains for a wide variety of successful products.

Today, 8051s are still available as discrete parts, but they're mostly used as IP cores. Available in soft high-level language source code or firm FPGA netlist formats, these cores are typically integrated within large embedded systems. But why would you use one?

Today's Surprising 8051 Capabilities

Modern 8051 cores are faster and have more benefits than you might think.（Details in the following examples are based on the 8051 IP family provided by CAST, Inc.）

High-speed performance

Architectural design improvements have significantly increased 8051 performance while retaining compatibility with the original MCS®51 instruction set.

The original Intel 8051 ran at 12 clock cycles per machine cycle, and most instructions executed in one or two machine cycles. A typical maximum clock frequency of 12 MHz meant these old 8051s could execute one million single-cycle instructions, or 500,000 two-cycle instructions, per second.

In contrast, enhanced 8051 cores now run at one clock cycle per machine cycle, and have clock frequencies of up to 450 MHz. That means 8051s can now execute 450 million instructions per cycle.

8-bits + Flexibility = Just Enough

While you wouldn't limit main system buses, memory connections, and other high-speed interfaces

to 8 bits, there are many command and control functions in advanced SoCs for which an 8-bit channel is more than adequate.

Additions to the original's many built-in functions also boost the controller's capabilities, and a good configurable 8051 core makes it easy to include exactly what you need for a specific use（and no more）. See Figure A for one example of the functions and options available for an 8051 IP core.

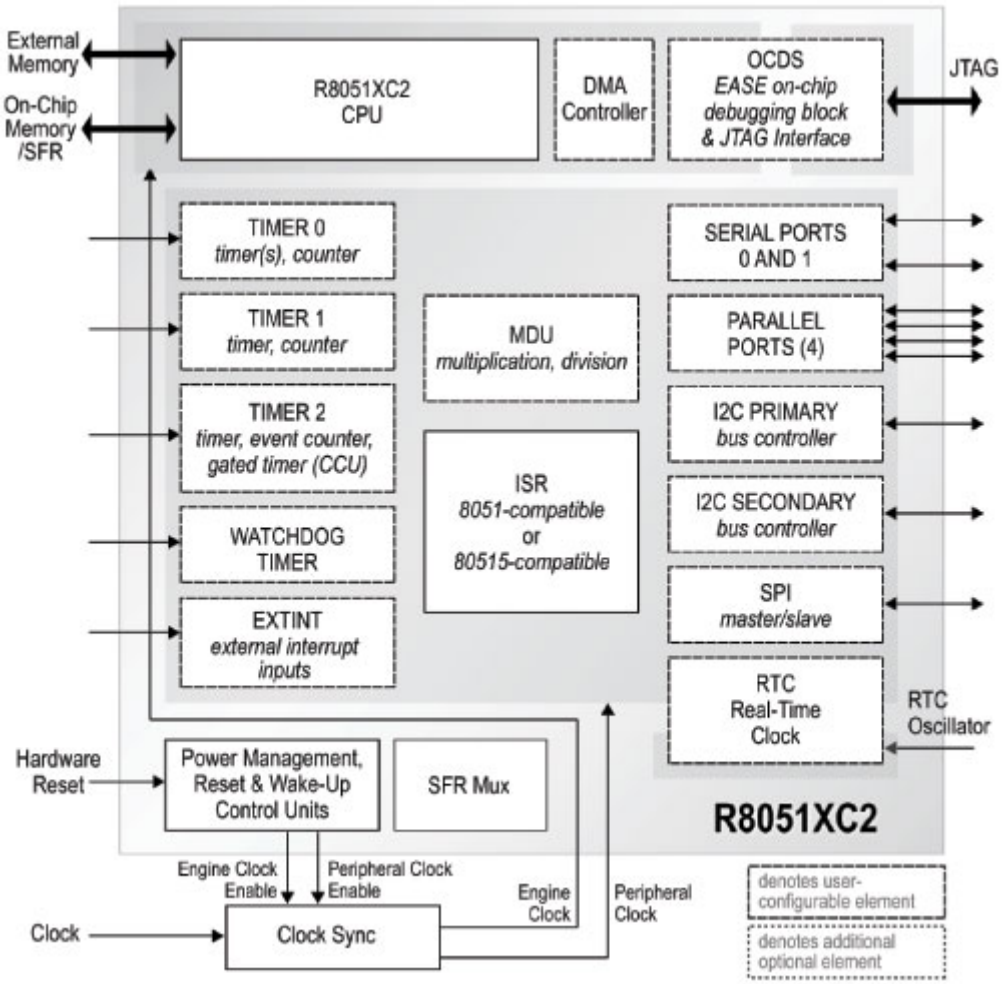

Figure A. Functional blocks available in a fully-configurable 8051IP Core.
（Courtesy of CAST, Inc.）

Small and power saving

Even the lean 32-bit processors targeted at the embedded controller market—such as the ARM® Cortex™-M0—lose to 8051s when you examine their consumption of resources.

Consider area. The fully-featured version of the R8051XC2 core shown in Figure A requires just the same 12,000 gates（in a TSMC 90 nm process ASIC）as a plain Cortex-M0. But by eliminating unneeded options and stepping down to a smaller core（the T8051）, that area usage drops to as low as 2,200 gates.

The differences are also significant for power. Specs for the Cortex-M0 rate it at 0.085 mW/MHz, while an 8051 variant comparably fitted with a multiple division unit uses less than half as much power, just 0.031 mW/MHz.

Very attractive costs

Excellent, silicon-proven, 8051 IP cores are available for a few tens of thousands of dollars, and with no royalty whatsoever. No 32-bit processor licensing comes close to this low cost or attractive business model.

Easy development

One of the biggest benefits to using an 8051 is the huge established ecosystem and programming heritage that make 8051 development easier than that for any other MCU. ARM's Keil group, for example, provides the excellent µVision IDE C51 tool set, with support for a huge number of 8051 implementations.

Complementing these tools are the complete packages and built-in debug capabilities from IP vendors like CAST. The array of integrated peripheral options, unique on-chip debug module, and documentation and support services polished through hundreds of previously successful 8051 customers make such an 8051 package a safe choice.

Numerous SoC Applications

Conclusions about the 8051 market in a 2008 ARM-authored report still hold true today. 8051s are especially useful as:

- Dashboard-like controllers managing the functions of and passing data through systems of a few million gates, and
- Analog sensing and control chips, where the 8051 accepts analog sensor data through its embedded peripherals, and decides what should be done based on that data.

RF connectivity systems—such as Zigbee, 2.4 GHz connectivity and UHF transmitter/receiver chips—are general examples of the latter, where an 8051 controls a digital modem and RxTx signals, and gives access to the system via UARTs, I2c, GPIO, or interrupts（see Figure B）.

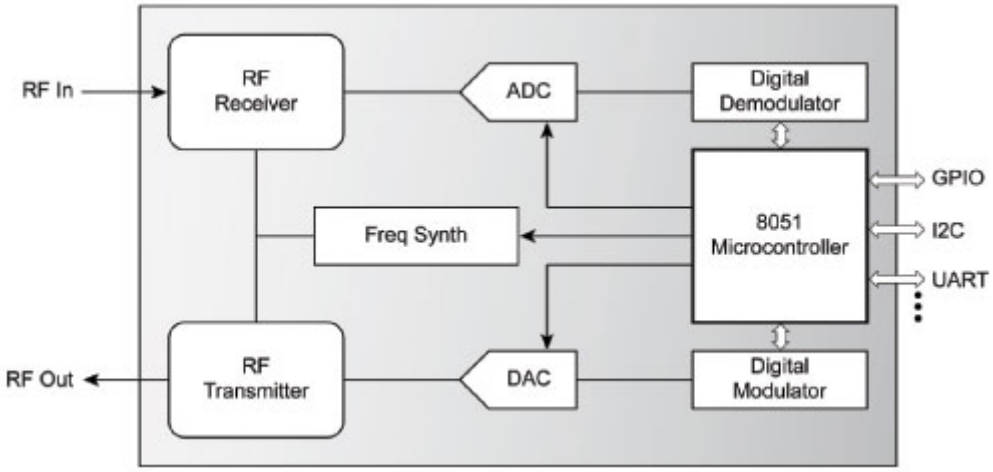

Figure B. General RF system using an 8051 microcontroller.
（Courtesy of CAST, Inc.）

IP subsystems now available make 8051s even easier to use for particular functions. For example, pre-integrated IP packages make adding USB or Ethernet functions almost a plug-in process.

Conclusions

8051 microcontrollers no longer get the spotlight, but they're still used in products ranging from USB thumb drives to washing machines to complex wireless communication SoCs. Basic 32-bit processors like ARM's Cortex-M0 are one way to go, but your system is likely to be smaller, use less power, and function just fine with any of the excellent 8051 IP core solutions available today.

Beginning with a BSEE from Purdue University, Mr. Finch has held a variety of engineering, sales and executive positions with companies including GenRad, Inc., Boreas, Inc., SemiTest, Inc. and the Brown and Sharp Manufacturing Company. His diverse areas of experience include microprocessor test, superconductivity research, semiconductor metrology tools and defect analysis for the flat panel and semiconductor industries. Since joining CAST in 2001, Bill has helped shaped the evolving IP business with innovative product ideas and new licensing practices