C8051F020 Utilization in an Embedded Digital Design Project Course

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Abstract

In this paper, the utilization of the C8051F020 in an embedded digital design project course is presented. In the discussion that follows the digital design course sequence at our university is described. The key components of the project are then presented as they relate to the C8051F020. Next, an overview of the C8051F020 implementation in the Silicon Laboratories USB ToolStick concept is discussed. Finally, the results of an academic year’s implementation are presented.

Introduction

The digital design sequence in the electrical and computer engineering technology program at our institution consists of three courses aptly named Digital I, Digital II, and Digital III. The corresponding course numbers are ECET 1200, ECET 2210, and ECET 3220. In each course, an element of design is required of the student. In the freshman course, the students are required to complete a two week lab project towards the end of the semester. The project usually involves small scale discrete logic ICs and possibly programmable logic devices programmed using VHDL. In the second course of the digital design sequence, students are required to complete a minimum of two digital design projects. The first project is usually an elaborate state machine implemented in VHDL on a complex programmable logic device (CPLD). The second project is a small embedded design centered on a Silicon Laboratory C8051F330 microcontroller. The duration of each project is approximately four weeks. The third course in the digital sequence is the subject of this paper.

Digital III is an embedded design course centered about the Intel 8051 series of microcontrollers. Student groups are required to design, construct, test, and document an embedded system over the course of a semester. To most students in our program, the course project appears to be a daunting task. It is not uncommon for a student to postpone the required course until the semester of expected graduation. As a result, student project groups consist of credit hour laden juniors and seniors. As such, the course is very close to that which is considered a capstone course at many universities.

Course Description

ECET 3220 Digital III is a project based course scheduled for the last semester of the student’s junior year. The core device about which the system is designed is the 8051 microcontroller. The data entry to the microcontroller is through a standard 4x4 keypad. The system display is a
common parallel LCD. External memory should also be included. The student groups are required to research problems that might be solved by using embedded systems based on microcontrollers then present a proposal to the course instructor for approval. Once approved the students go about designing, procuring, testing, documenting, etc. while the instructor lectures on the following course topics:

- address decoding
- memory mapping
- interfacing
- interrupts
- serial communication
- analog to digital conversion
- digital to analog conversion
- advanced coding

The real learning experience comes from the lessons learned in the laboratory. Project management is the most important aspect of the course. Fortunately, the experience in the prerequisite digital course has prepared the students to somewhat methodically plan out and anticipate the time required to implement each subsystem of the design. Interfacing the subsystems and components is also a key lesson learned in the laboratory. Prior to the course, students have a vague idea of how to spot voltage and current issues in the design stage. The laboratory experience quickly reinforces this key concept. Prototyping, noise reduction, mechanical construction, budgeting, documentation, etc. all come into play during the project.

Until recently, an inhibiting factor to project success was how rapidly and how well the students could test 8051 source code as it relates to subsystem function and to the complete system design. In the recent past, 8051 variants from Intel, Atmel, Philips, and others, required brute force external programming, chip insertion testing, and reprogramming in order to flesh out source code problems. Many chip vendors have developed in-circuit emulators to expedite the process. The in-circuit emulator communicates with a personal computer to allow code debugging. However, many of the emulators use a microcontroller of the same product line but slightly different in specification from the intended microcontroller. The substitution in emulating microcontroller presents another set of possible problems such as variations in memory area, timing, port operation, etc. Recently, Silicon Laboratories has launched a development tool concept based on their 8051 variants which they market as the USB ToolStick.

**C8051F020 Development Platform Overview**

Of the 8051 family of microcontrollers used in this course to date, the Silicon Laboratories C8051F020 has been the most student friendly and economical. The USB ToolStick development system is marketed in the configuration shown in Figure 1. The ToolStick has a main module, the base adapter, which handles communication to the host computer through the USB port. It is also powered by the USB port. Inserted into the base adapter is a daughter card that contains the desired 8051 variant ². The default configuration is a daughter card based on the C8051F330. The C8051F330 is a 20 pin, small, entry level microcontroller insufficient for
complex embedded designs required for this course. The base adapter and daughter can be purchased for approximately $25 USD.

![Figure 1: Silicon Laboratories USB ToolStick](image1)

The C8051F020 microcontroller is a 100 pin enhanced version of the 8051 microcontroller. The students can purchase the C8051F020 daughter card for around $25 and is marketed under the TOOLSTICKUNIDC which refers to university daughter card (Figure 2). The port pins of the microcontroller are brought out to the eight pin jumpers shown on the right side of the board. Pushbutton, dip switches, LEDs, and a potentiometer are available on the board for student use. The prototyping area shown at the top of the board in not connected to the microcontroller.

![Figure 2: Silicon Laboratories C8051F020 Daughter Card](image2)

Another implementation that is more suited to this course is the university prototype board shown in Figure 3 which cost around $15. All of the microcontroller pins are brought out to the soldering pads located around the edges of the board. The kit includes linear pins to solder around the board. Students can then easily insert the board into their embedded design.
In order to use the University Prototype Board shown in Figure 3, an adapter is needed to connect the USB ToolStick base to the JTAG connector of the prototype board. The ToolStick Debug Adapter shown in Figure 4 is necessary to connect the base unit to the microcontroller prototype board. The flat ribbon cable brings out the JTAG and C2 debug interfaces to the target device’s in-system debug/programming circuitry. The debug adapter can also provide USB power to the target system up to 75 mA at 5 V.

The software for compiling the assembly or C code and subsequent emulation is available for free download on the Silicon Labs website, www.silabs.com/toolstick. The software is termed the Integrated Development Environment (IDE). As a package, the USB ToolStick replaces development systems that have cost several hundred dollars.
C8051F020 Specifications

The C8051F020 is a 100 pin, TQFP surface mount, enhanced version of the 8051 microcontroller. The block diagram is shown in Figure 5. The key specifications for the embedded design course are the operating voltage of 2.7 to 3.6 V, the size of the ROM and RAM, how many port pins are available and if they are bit or byte addressable, and what additional enhancements are present on the chip. The ROM is the full 64 kB of flash, in-system programmable memory of the standard 8051. In addition to the 256 bytes of internal RAM, another 4 kB is available on-chip. All standard 8051 ports are available and are 5 V tolerant. The ports can be configured as open-drain, weak pull-up, or as push-pull. An additional four ports are available beyond that of the standard 8051. Ports 0, 1, 2 … 7 yield 64 port input/output pins. The maximum system clock is 25 MHz with up to 25 MIPS throughput. Either an external oscillator or an internal programmable oscillator with a reduced range can be used for the system clock.

The C8051F020 is a system-on-a-chip whereby two analog-to-digital converters (12-bit and 8-bit) are present along with two 12-bit digital-to-analog converters. It has two comparators and one built-in temperature sensor. Five internal general purpose counter/timers are present. Two UARTs for serial communication are present along with I2C and SPI. Virtually all key components of a feedback control system reside on the chip allowing for a very capable embedded system.

![Figure 5: C8051F020 Architecture Block Diagram](courtesy of Silicon Labs.)
Results

The C8051F020 has been utilized for two semesters, one academic year, in the digital design course. A total of 15 projects and approximately 45 students have employed the C8051F020. Every project has met the minimum requirements for completion of the course while most have exceeded the course expectations.

The combination of the C8051F020 and the USB ToolStick platform has allowed the student groups to build each subsystem, test, and debug quickly throughout the semester. Problems were quickly identified allowing for solutions and work-arounds to be quickly implemented.

The rapid development allowed each student group in both semesters to identify strengths and weaknesses in the project team by the end of the fifth week or the first third of the semester. The group members would then assign tasks to each member to be completed between meetings followed by verification of performance at the next group meeting. If the task was not completed, the other team members would step in to help trouble-shoot and brainstorm for a solution. By the tenth week, the team members were confident of each person’s ability to complete the assigned task with minimal oversight. Most teams had the project essentially completed before the due date.

Conclusion

The utilization of the C8051F020 along with the USB ToolStick development platform has greatly enhanced the embedded design process for our project course. The microcontroller development system is relatively inexpensive and can be ordered by each student group. The easy availability and economy frees the students and the instructor from depending on school resources. The development system is comprehensive allowing student groups to work outside of posted laboratory hours. The integrated development software environment allows the students to rapidly test source code and debug errors quickly. Most importantly, the project success rate for the first academic year the C8051F020 has been in use in this course has been 100%.

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