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8051 Embedded Design during Trying Times

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Abstract

Engineering design early in a student's course sequence captivates the student's interest in engineering. However, in recent times, it has been necessary to shift from in person instruction to online only instruction. Additionally, as the economy has been disrupted by supply chain issues, electronic parts availability has been unpredictable. Maintaining an embedded design project in an online only sophomore course has been a challenging experience. In this paper, an embedded design project in an online only sophomore course is presented. The design project is based on the EFM8BB1 from Silicon Laboratories. The EFM8BB1 is an 8051 series microcontroller that is self-contained, economical, and very student friendly. What follows is a discussion of the sophomore course, an overview of the EFM8BB1, and an example of the project design based on the EFM8BB1.

1. Introduction

The sophomore course referred to in this paper is the second course of the digital design sequence in the electrical engineering technology program at Kennesaw State University. Kennesaw State University was founded in 1963 as part of the University System of Georgia. In 2015, Kennesaw State merged with Southern Polytechnic State University. Throughout the history of Southern Polytechnic, the institution has responded to the applied engineering and technology needs of the state and region. In virtually every course, an element of design is required of the student. In the second course of the digital design sequence, students learn the architecture of the Intel 8051, learn assembly language, and then apply the knowledge in a design project.

The final project is where the student is expected to apply the lessons learned in the course. In designing a small embedded system, skills such as project management, interfacing components and troubleshooting are demonstrated. The embedded design centers on a microcontroller of the Intel 8051 family. The design must consist of a combination of sensor, actuator, analog-to-digital converter, digital-to-analog converter, and some small system to control. The proposal and review process goes through a couple of iterations until a project is agreed upon. It is then the responsibility of the student to acquire needed materials, construct the prototype, and present the results in class presentations. The students have about four weeks to complete the design. For most students, this project ends the semester.

Throughout the years, the Intel microcontroller used in this course has changed based on availability and programming platforms. The variations used have been the Philips 87C750 with CEIBO DS-750 emulator, the P87LPC760 with the EB-76x emulator, the Silicon Laboratories C8051F330 with the USB ToolStick, and the Silicon Laboratories C8051F360 on a custom designed break out board. Prior to the 2020 COVID-19 pandemic, we had designed a custom printed circuit board (PCB) around the 'F360 that our school's technicians used a surface-mount technology component placement system (commonly referred to as a pick-and-place machine) to fabricate. The 'F360 PCB board connected to the Silicon Laboratories ToolStick Debug Adapter and was programed with the Simplicity Studio software. At the beginning of the semester, each student was given an ‘F360 PCB. The students were then expected to order the Debug Adapter and download the free software. Fortunately for Spring Semester 2020, the course was already underway and near completion by the time the University System of Georgia went into lock down due to the COVID-19 virus. The students had already begun the final project so supply chain issues were not a factor. The biggest issue was communication with students. Fortunately, the University System of Georgia had been phasing into use a system referred to as D2L (or Desire2Learn) for distance learning education. The transition from face-to-face to distance learning went quite smoothly and occurred just after Spring Break. The issue of being online was the speed of communication. The inherent asynchronous nature of distance learning slowed communication down considerably. The following semester, Summer 2020, however, was another matter.

In Summer semester 2020, the University System of Georgia went entirely online. Manufacturing our own microcontroller PCB boards and distributing them to students was impossible. Another readily available 8051 Intel based microcontroller needed to be selected. The microcontroller needed be available from more than one national parts distributor. The microcontroller needed to be cheap. The microcontroller needed to have at least two ports. The best choice was the Silicon Labs EFM8BB1LCK microcontroller at the MSRP of $6.25.

2. Overview of Silicon Labs EFM8BB1 Microcontroller

Of the 8051 family of microcontrollers used in the course to date, the Silicon Laboratories platforms have been the most student friendly and the most economical. The EFM8BB1 Busy Bee microcontroller development board is shown in Figure 1. The development board has the EFM8BB1 MCU, the ToolStick debugger which handles C2 communication to the host computer through the USB Micro-B port, breakout headers, a reset push button, a user push button, and a user LED. Each section of the board is called out in Figure 2. The board is powered by the USB port. The students can purchase the EFM8BB1LCK development board from several vendors such as DigiKey and Mouser. The initial MSRP in summer 2020 at the beginning of the pandemic was $6.65 at Mouser with 58 in stock. The current MSRP is $18.53 at Mouser with 151 in stock and $20.54 at DigiKey with 157 in stock. 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/developers/simplicity-studio. The software is termed the Integrated Development Environment (IDE). As a package, the EFM8BB1LCK has replaced development systems that have cost several hundred dollars.

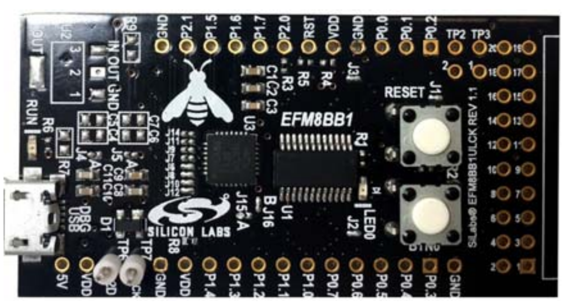

Figure 1: Silicon Laboratories EFM8BB1 (courtesy of Silicon Labs.) [1]

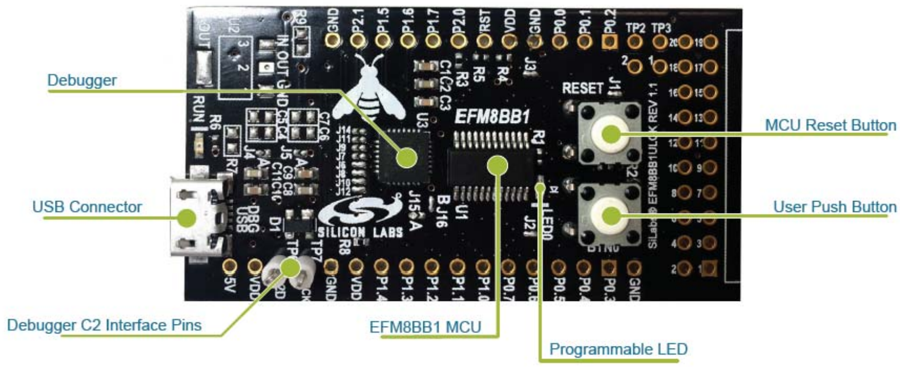

Figure 2: EFM8BB1LCK Hardware Layout (courtesy of Silicon Labs.) [1]

The section of the development board is highlighted in Figure 2. The microcontroller is the 4 mm x 9 mm 24 pin QSOP IC located at the center of the board. Each of the pins is accessible in the solder pad area shown at the top and bottom edges of the board. Should full in-circuit emulation be desired, 2.54 mm spaced male header pins can be soldered to the pads. The pins can then be inserted into a bread board. However, the width of the development board only allows a single tie point for each pin. Additional consideration is required for the pins RST and P2.0 which are used for C2 communication with the debug adapter. Port pin P1.4 is connected to an LED0. The LED provides a simple output for code development or demonstration. Port pin P0.2 is connected to Push Button 0 (BTN0). From a student standpoint, most designs can be implemented using the two eight bit ports P0 and P1 and VDD and GND. The supply voltage VDD is regulated from the 5V of the USB to 3.3V. The microcontroller pins are 5V tolerant.

The actual part number of the microcontroller is the EFM8BB10F8G-A-QSOP24. The key features of the microcontroller are an 8-bit pipelined C8051 core with a 25 MHz maximum operating frequency. It has up to 18 multifunction, 5 V tolerant I/O pins. It has one 12-bit analog to digital converter (ADC). It has two low-current analog comparators. It has an integrated temperature sensor. It has four 16-bit timers. It has UART, SPI, and SMBus/I2C communication protocols. It has a priority crossbar for flexible pin mapping [2]. Essentially, it has all the features necessary for 8051 instruction with up to 8 kB program memory and up to 512 bytes of RAM.

3. Embedded Design Project

The laboratory instruction of the course shifted to online only in summer 2020. As previously discussed, plenty of EFM8BB1LCK Busy Bee development boards were available for students to order for delivery to their home. The additional parts of resistors, push buttons, LEDs, seven segment displays, wires, etc. are common parts in great supply. Most students had these parts from the freshman digital course. The eight laboratory assignments written for the previous microcontroller, the C8051F360 with the Debug Adapter, had to be rewritten quickly for the EFM8BB1 and the newer Simplicity Studio IDE software. Each lab was rewritten so the student would be guided step by step, with detailed screen captures of the software. This allowed the student to work on each lab asynchronously, reducing the number of questions and delays normally experienced in a face-to-face lab session. The eighth lab provides the student with a basic template of an embedded assembly program interfacing to a seven segment display with a look up table. Porting the lab to the EFM8BB1 required minor changes with the exception of including more detailed instructions. Once the eighth lab was completed, the student was ready to program the assembly language instructions of an embedded project.

Prior to the COVID-19 pandemic, students in this course would propose to the instructor an embedded project based on the Intel 8051 family of microcontrollers programmed in assembly. Examples of projects are an “automated beverage server” and a “mini basket ball game controller” [3]. The automated beverage server consisted of toy remote car with a platform holding the beverages. The car was controlled by the microcontroller. The mini-basket ball game controller was a toy modified so that the microcontroller would keep score. Toys are very inexpensive platforms to build embedded control systems around. All of the mechanical aspects are already in place. Some of the electronics such as power transistors are also available. The student can reverse engineer the digital control lines to the H bridge transistor arrays. By monitoring the voltage levels on the lines as the vehicle is signaled to go forward, reverse, left, and right, the students can create a table of required logic signals on those lines. The student can then cut the trace and solder to those points their own control lines. The EFM8BB1 along with other logic can serve as the new controller to the toy car. Unfortunately, during the COVID-19 lockdown, having such an open ended project was not possible.

Beginning summer 2020, when the course went online only, it was decided to constrain the embedded project to just controlling an R/C car with the microcontroller. Toy cars were readily available for online order from retailers like Walmart and Target. Each student was required to select an inexpensive R/C car in the $10 to $20 dollar range. It was encouraged that students work online in groups of two by each student purchasing the same car. The students could use the D2L distance learning platform, Microsoft Teams, or Zoom to communicate ideas on how to control the car. Furthermore, retailers like Walmart had the additional tools of a cheap soldering iron and cheap multimeter that students could order to complete the project. Also, it was determined quite quickly that controlling the car through the transmitter was the most efficient method given the variety of toy designs currently available. That Summer 2020 semester, eight projects groups attempted the embedded project entirely online. Seven groups performed at the A level. The remaining group performed at the B level.

4. Conclusion

The embedded design process can be taught online at the sophomore level even in these trying times. The key to teaching design online is to step the students through the design process in great detail. Questions that can be answered in person in seconds takes minutes and hours online. Writing the lab assignments to guide the student step by step with detailed screen captures reduces the number of questions and allows the student to progress quickly. Choosing a platform that is inexpensive and readily available from multiple vendors is imperative. Constraining the project to a widely available and inexpensive platform like the EFM8BB1 and a toy R/C car avoids supply chain issues. The student learns project management skills, interfacing skills, documentation skills, and the actual lecture material of the textbook by presenting the material online in great detail. The EFM8BB1LCK from Silicon Laboratories offers an excellent design platform to accomplish the embedded design online. The development board is economical, in great supply, and conducive to online learning.

6. Acknowledgements

The author would like to thank Silicon Labs for past generous support of laboratory equipment and site licenses for software.

7. References

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[2] Silicon Laboratories, *EFM8 Busy Bee Family EFM8BB1 Data Sheet*, Rev. 1.6 03/2017

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