Creating a Curriculum Linkage between Digital Electronics and Embedded Microcontrollers through Interconnected Development Boards

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Abstract

In the Electrical and Computer Engineering Technology Department at Purdue University, students are required to purchase two development boards: 1 – an Altera DE1 development and education board for digital electronic courses, and 2 – an Atmel ATmega development board for embedded microcontroller courses. The requirement to purchase these boards not only allows the students to work at home but also brings other benefits. To get the most out of these boards, the department supplies the students in the introductory embedded microcontroller course the equipment necessary to connect the two development boards together. This allows the two subject matters to be blended and creates a curriculum linkage. The interconnection allows the students to expand their digital knowledge by utilizing the DE1 development to replace the laboratory peripherals normally available to the students during their scheduled laboratory sessions. This process allows the students to revisit the topics studied during their earlier digital courses at a higher level and thus, creates a spiral education thread. The standard DE1 development board provides the student with lights (led's), slide switches, push buttons, seven segment displays, memory components, serial communication level shifters, removable storage media access, just to mention a few features. With the addition of a few extra components totally about $15, the students can add a keypad and stepper motor to the DE1 development board giving them an entire laboratory set of peripheral boards at home. This allows the students unlimited access to the resources required to complete most projects in the embedded microcontroller sequence. Having the hardware at home also empowers the students to explore the technology at a much deeper level. This paper covers the details of the interconnection and benefits of linking these development boards in depth.

Introduction

Many technology students learn through hands-on experiences. In order to facilitate these hands-on experiences, the Department of Electrical and Computer Engineering Technology at Purdue University requires that the students enrolled in freshman digital electronics and sophomores enrolled in embedded microcontroller courses to purchase development boards. The requirement to have the students purchase the development boards has been an evolutionary process.

Background

In the beginning, the department provided a set of community development boards for each laboratory environment. It was very common for a development board to be accidentally damaged during a normal laboratory exercise. In these instances, the student may not even know that they have damaged the development board. Therefore, the damage is never reported to the laboratory instructor and the "bad" hardware is placed back into the community supply. The next student that attempts to utilize the damaged development board has no way of knowing that it is damaged. This student may waste hours of laboratory time before realizing that the hardware is damaged if they realize it at all. This situation is detrimental to the learning experiences of the students in these courses.

As a possible solution to overcome this situation, the department instituted a requirement for students in the sophomore embedded microcontroller course to purchase their own development board. This requirement proved to be a successful solution to overcoming damaged community hardware. After the success from the microcontroller course, the digital electronics courses followed suite and instituted a similar requirement that the students purchase their own digital electronics development board. In addition to solving the problem of damaged hardware, the requirement to purchase the development board created a situation where the students could work from home.

Digital Development Board

The Altera DE1 development and education board from Terasic is the current development board of choice for the digital electronics courses. The department had previously centralized around the Altera family of programmable logic devices. This particular development board provides the students with a wide array of components for experimentation. For initial experiments, the DE1 board includes pushbuttons and toggle like switches for input devices along with LED's and 7-segment displays for simple output devices. In addition to the simple input and output devices listed above, the board contains more complex components such as memory components including RAM, Flash memory and a SD Card slot, RS232 and PS2 interface connections, along with VGA and audio connections. The board also includes two expansion headers that can be utilized to connect to external circuitry or other development boards. See the image on the following page for an overview of the Altera DE1 development board.

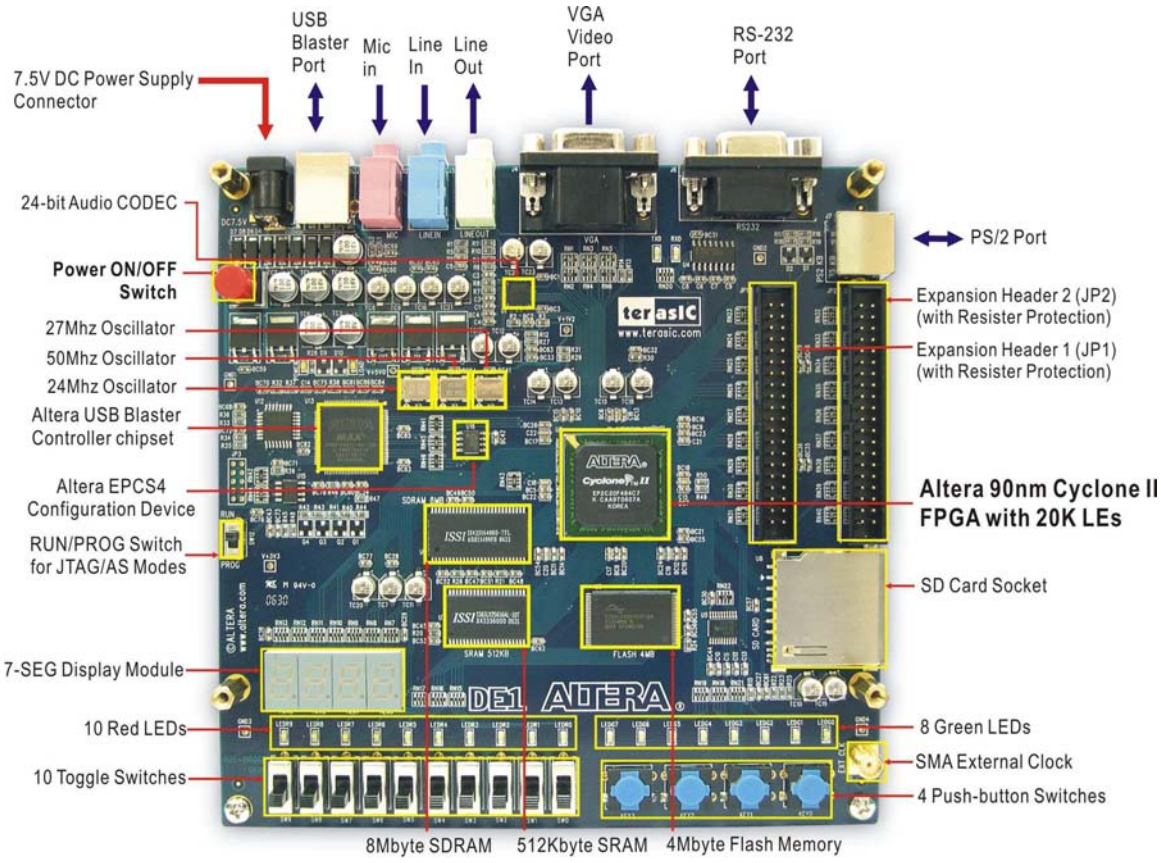

Figure 1 – Altera DE1 Development and Education Board
Image from http://users.ece.gatech.edu/~hamblen/DE1/DE1.JPG

Embedded Microcontroller Development Board

The ATmega Development board from PRIIO is the current development board of choice for the embedded microcontroller courses (see figure 2 on the next page). The department had previously centralized around the Atmel AVR family of microcontrollers. This particular development board provides the user an 8-bit microcontroller with 0.1" input/output (I/O) headers for connection to specialized peripheral boards. In addition to the I/O headers, the development board provides both a RS232 and USB serial connection. The board was designed to minimize on-board hardware and force the students to make external connections to the hardware required to complete the individual laboratory experiments.

The department still supplies a community set of peripheral boards including a lights & switches board, a keypad board, a 7-segment display board, a LCD board, a stepper motor board, a DC motor board, a synchronous serial board and a slide potentiometer board. These boards allow the students to create a wide variety of projects during the laboratory portion of the course (see figures 3 through 6 on the following page for examples of the available development boards). **These peripheral boards are only available to the students during their normal laboratory sessions.**

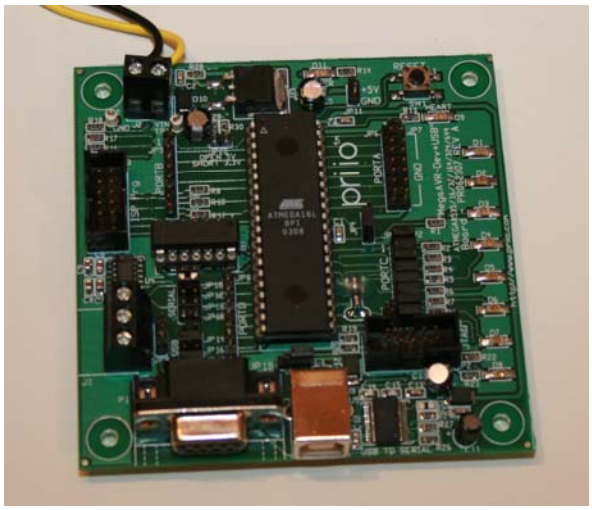

Figure 2 – ATmegaAVR Development Board

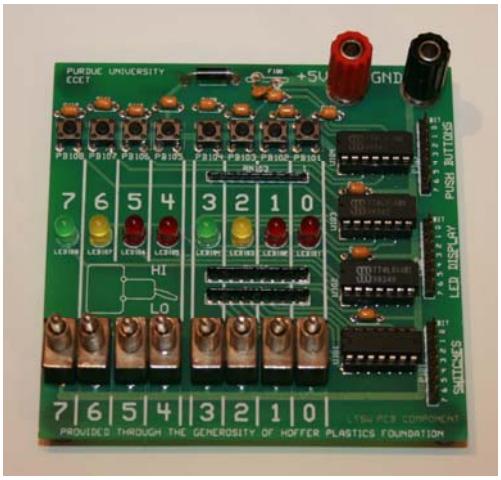

Figure 3 – Lights & Switches Board

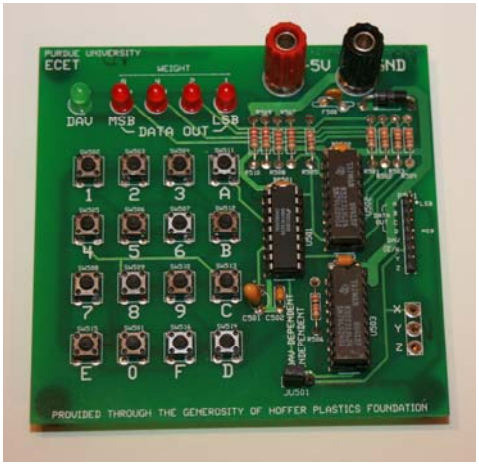

Figure 4 – Keypad Board

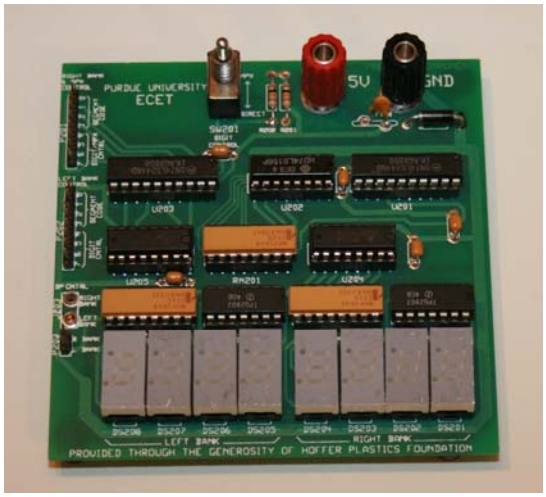

Figure 5 – 7-Segment Display Board

Figure 6 – Stepper Motor Board

Jumper Wires

To make the physical connections between the laboratory peripheral boards and the microcontroller development board, the students purchase a parts kit that provides all the materials necessary to build jumper wires. The students build the appropriate cables during their first laboratory exercise and then reuse them throughout their entire academic career. The image below shows a typical interface cable constructed by a student.

Figure 7 – Typical Microcontroller Interface Cable

The image shown below is a typical connection between the Atmel AVR development board and the standard lights & switches board utilized in the laboratory environment.

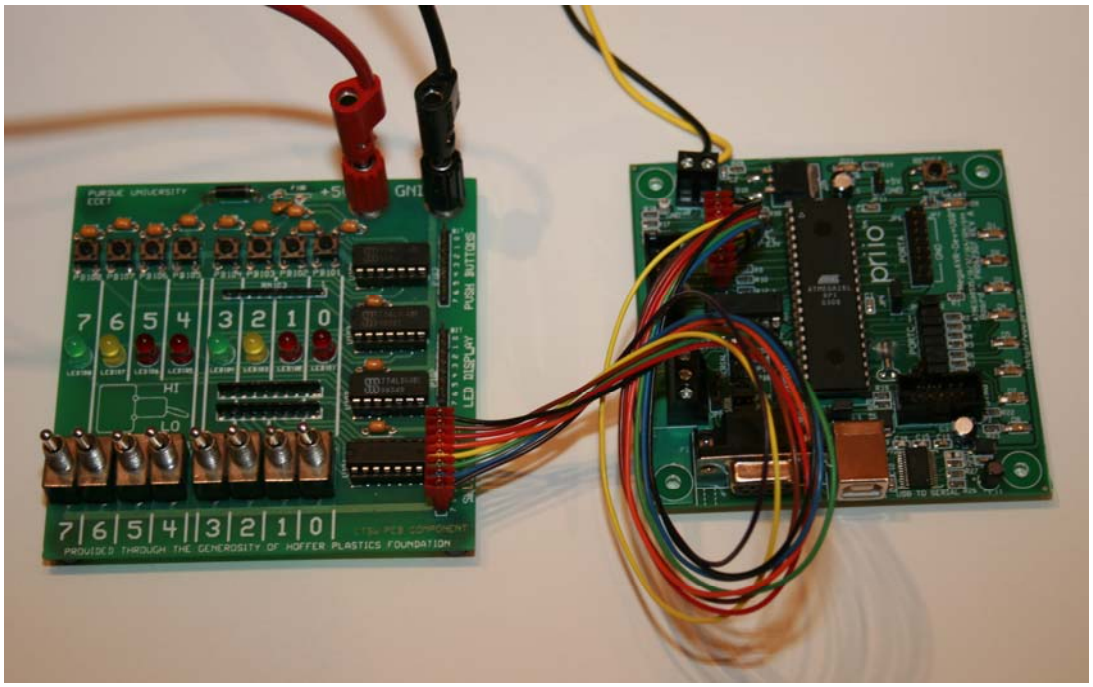

Figure 8 – Atmel AVR Delevelopment Board Connected to Lights & Switches Board

Working From Home

The department provides additional connectors and ribbon cable to make special jumper wires to allow the Altera DE1 development board to the Atmel AVR development board as shown in figure 9. The connection of these two development boards opens many doors to the students including the ability to work from home.

Figure 9 – Altera DE1 Interface Cable

The connection between the two development boards gives the Atmel AVR development board access to the LED's and switches present on the Altera DE1 development effectively replacing the department's light & switches board. The lights & switches board is the only peripheral board required to complete the first five laboratory experiments. Having a lights & switches board at home provides an opportunity for struggling students to gain additional time to work on laboratory experiments at home or during open laboratory hours when the community laboratory hardware boards are not available. Having unlimited access to the hardware required to complete the laboratory experiments is a major advantage for the students.

Connecting the Atmel development board to the Altera DE1 development board is only one piece of the puzzle (see figure 10 on the next page). In order for the students to utilize the lights & switches on the Altera DE1 development board, the students must program the Altera FPGA to map the appropriate pins that connect to the lights & switches to the proper pins of the general purpose expansion header. The programming of the Altera FPGA forces the students to revisit prior course information and apply it to the new problem at hand.

The next opportunity for the students to utilize their Altera DE1 board is to encode data from a keypad. The students enrolled in the microcontroller course are introductory students and scanning a keypad with the microcontroller is beyond the scope of this course. Instead of scanning the keypad with the microcontroller, the students read values from a keypad peripheral that includes a keypad encoder IC. The students can utilize the Altera FPGA to accomplish the same keypad encoding.

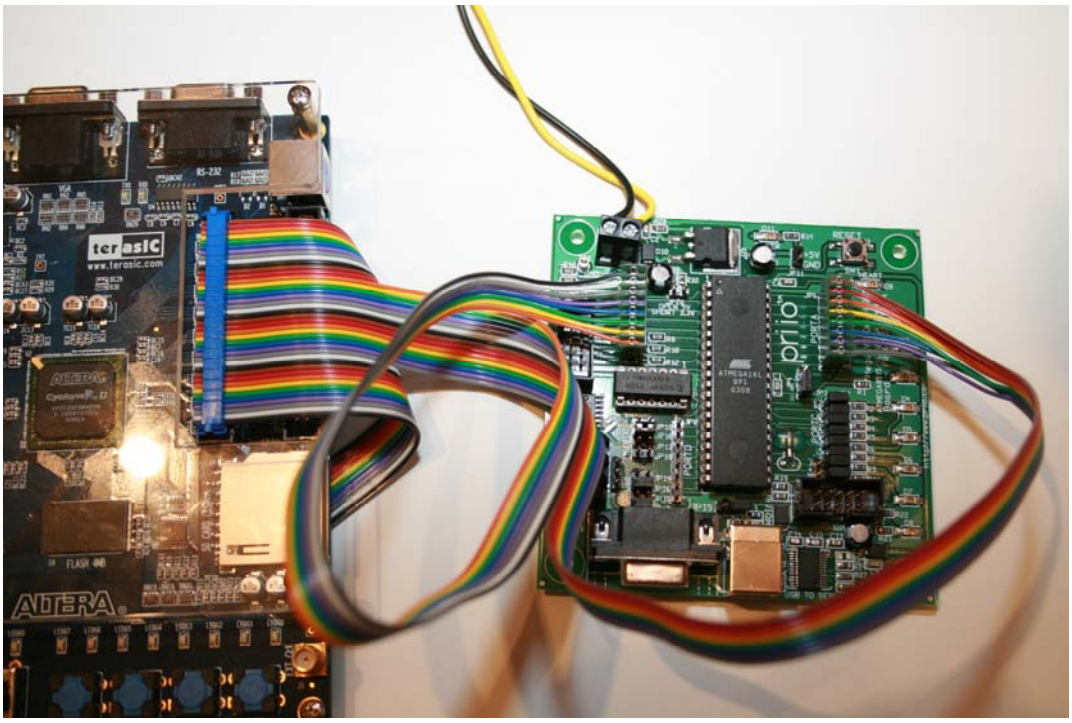

Figure 10 - Altera DE1 Board connected to the Atmel AVR Development Board

Two additional opportunities to utilize the Altera FPGA involve multiplexing the 7-segment displays on the board and also utilizing the FPGA to create a stepper motor controller chip.

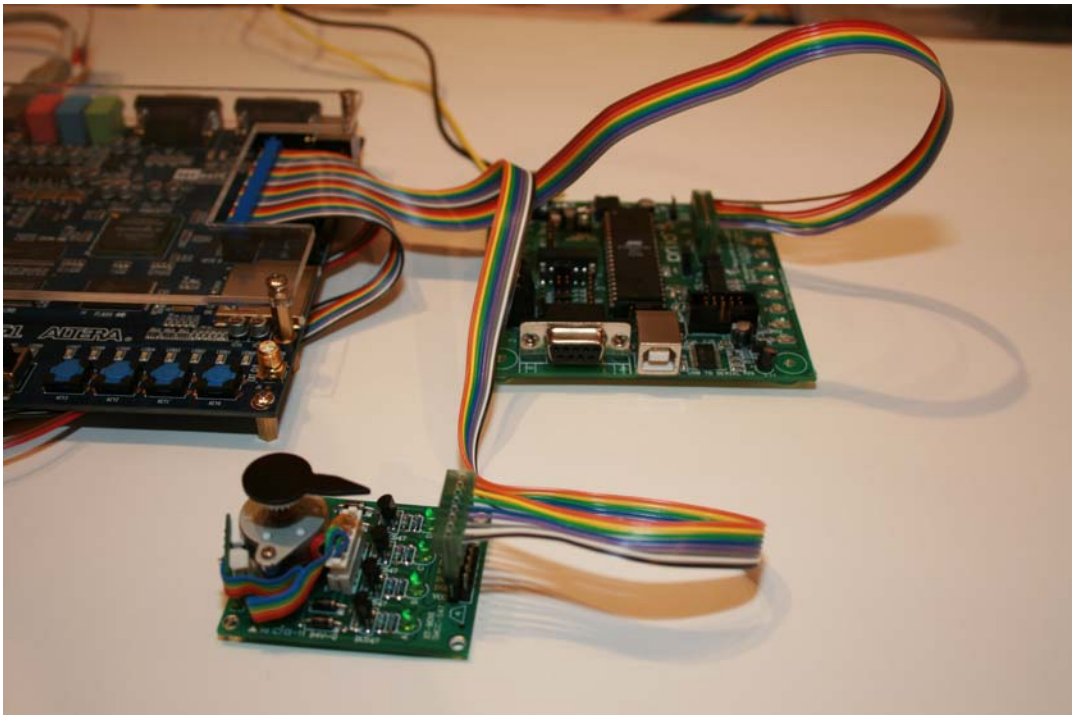

Figure 11 - Atmel AVR Development Board Connected to Stepper Motor through the Altera DE1 Board

Creating a Spiral Thread

Mapping of the lights & switches to the general purpose connection header of the Altera DE1 development board is a somewhat straight forward activity. This exercise forces the students to go back and remember or lookup previous course information. However, this is not the end goal. The real learning starts when the students start working on decoding a keypad using the FPGA. Now the students must take previous course information and expand on it to accomplish the given task. Revisiting previous course information at a higher level is the foundation of creating a curriculum spiral. This spiral is reinforced more when the students multiplex the 7-segment displays to create the appropriate functionality required to mimic the 7-segment laboratory peripheral board from the microcontroller laboratory. Additional reinforcement occurs when the students create the FPGA design to create a stepper motor driver circuit.

Additional Hardware

There are an additional two peripheral boards required during the introductory microcontroller course. These boards include a serial LCD and a DC motor peripheral board that is controlled through a pulse width modulated signal. These additional boards do not require the use of the Altera DE1 development board and can by purchased from online sources.

Conclusion

Connecting the Altera DE1 development board to the Atmel AVR development board provides the students the resources to create functionally equivalent peripheral boards to the ones provided by the department for laboratory experimentation. Having equivalent peripheral boards allows the students to work on laboratory experiments outside of their normally scheduled laboratory meetings. This provides the students the ability to explore the technology at a deeper level or to work on concepts that the student may have struggled with during an original assignment. In order for the students to utilize the Altera DE1 development board, they must revisit previous course material and apply it at a higher level. Revisiting the material deepens the student's understanding of the material and creates a linkage between the digital electronics courses and the introductory microcontroller course.