AC 2008-2928: EVALUATING DEVELOPMENT BOARDS FOR LABORATORY BASED EMBEDDED MICROCONTROLLER COURSES: A FORMAL EVALUATION MATRIX

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Evaluating Development Boards for Laboratory Based Embedded Microcontroller Courses: A Formal Evaluation Matrix

Abstract:

With all the different development board options available for laboratory based embedded microcontroller courses, how do you know that you have selected the best option? As part of the effort to improve the curriculum in the Electrical and Computer Engineering Department at Purdue University, several different development boards were evaluated. To assist in this process and make the "best" choice, a formal evaluation matrix was developed to assess the various attributes of each option. The evaluation matrix and rationale for the criteria are explained in detail in this paper.

Introduction:

Evaluation matrixes are used in engineering fields to make comparisons between technologies on a daily basis. They allow decisions to be made based on priorities of the various engineering requirements for the application at hand. This technique can also be applied to development boards in an educational environment. More and more development boards are becoming available daily and it is difficult to know if we are using the right one.

Background:

Many universities utilize development boards as part of their engineering and technology courses. These boards allow the students to explore the current technology usually in a laboratory setting. In some instances, students also utilize these boards at home. At Purdue University, we actually require all of our students in both the freshman digital and sophomore microcontroller courses to purchase their own development boards. This was driven by years of students inadvertently damaging community boards that the university would supply for student use in the laboratory setting. Students would make honest mistakes as part of the learning process and ultimately damage an input or output pin on both microcontrollers and the CPLD's that were being used. The current student would not realize that this had occurred, or perhaps didn't want to admit that they broke something, so they would not notify the laboratory instructor of the failure. The next students would come into lab and immediately be at a disadvantage because they were given faulty hardware without knowing this had occurred. After several hours of wasted time, the laboratory instructor might find the damaged hardware and replace it for the student. More times that not, this broken hardware would be utilized in several laboratory meetings before the damage was located. This caused a significant problem for our students.

The solution to this problem was to require the students to purchase their own development boards. In this way, the students have control over the hardware and are responsible for ensuring the board is still operational at the start of each and every lab. This also allows the students to do outside work at home, since they have the development board. This also allows the students to be able to utilize these boards for other course projects and can significantly aid in capstone project courses.

Having the students buy their own development boards can significantly add cost to these courses. To ensure that the students are spending their money wisely, we have turned towards a decision matrix to help ensure that we are utilizing the best platform for these courses and the future courses that the students may take.

Analytical Hierarchy Process (AHP):

Analytical Hierarchy is a well known process of evaluating and making decisions based on requirements. The exact process to be under taken is beyond the scope of this article. However, the general steps are listed below:

Step #1 – Determine the selection criteria
Step #2 – Determine the criteria weightings
Step #3 – Identify and rate alternatives
Step #4 – Compute Scores for the alternatives
Step #5 – Review the decision

The Criteria:

The first step in the process was to determine the criteria for the boards. On the surface, this sounds like a simply step, but in reality, it was not. Significant time and effort was put into the determination of the criteria. There are multiple courses that can benefit from this decision, so all of them needed to be represented. In the end, the follow criteria were established for making the decision:

Table 1 – Criteria

Serviceability
Pedagogy
Reliability
Programming Support / Options
Processor Support (multiple?)
Operating Voltage
Cost
Design Control
Power Supply
Debugging Port
System Clock Options
Serial Port Connection
Features

Serviceability – It is (or may be) important that the boards are able to be repaired if and when something goes wrong. To this end, the packaging of the microcontroller needs to be considered. It is important to consider whether the microcontroller is a through-hole part mounted in a socket or is it surface mounted. If it is surface mounted, can it be replaced in the event something goes wrong?

Pedagogy – The educational value and cognitive loading effects of the board must be taken into account. Big and fancy development boards may offer a tremendous amount of features and look really "cool", but if these features diminish the student's understanding of the core technology, then they may be detrimental to the cause.

Reliability – One of the main goals of student owed development boards is to ensure that they have an operational development board for each and every laboratory meeting. To this end, a student built board such as one constructed on a proto-board may provide good pedagogy, but may not be operational for the first laboratory meeting or may fail later in the course. Any time spent attempting to fix the development board can take away from the student's time in the laboratory and ultimately influence their learning of the material.

Programming Support – Newer microcontrollers allow the parts to be programmed while they are located in the system. The options may include an external programmer or through a self-program mechanism. Short term and long term consideration should be taken in account. If the development board is utilized for other activities, these should be considered when deciding how the board will be programmed.

Processor Support – Another main goal of a student owed board is that the student can utilize the board in other courses. To this end, the initial processor selected either needs to be usable in these other courses or the development board may need to support multiple processors that will be useable in the other courses. A proper decision up front can save the students money in the long run.

Operating Voltage – More and more products are being developed that utilize embedded microcontrollers and processors that are operated on batteries. As part of this development, many microcontrollers are now being operated on 3-volt logic as opposed to 5-volt logic. Some are even being operated at 1.8 volts. These developments should be taken into consideration.

Cost – There is no doubt that obtaining a college degree is an expensive endeavor. However, consideration should be given to selecting an appropriate board at a reasonable cost.

Design Control – There is nothing more frustrating than selecting an appropriate development board only to have the manufacturer make a change that ultimately

forces a new development board to be selected. To this end, it may be necessary to have some type of design control over the development board that is ultimately chosen.

Power Supply – There are a multitude of options for supplying power to a development including bench top supplies, wall warts, batteries, and through a USB connection. If the students have access to a bench top power supply at home, then this category may not be important.

Debugging Port – The use on a debugging port such as a JTAG interface may be a requirement for either current or future work.

System Clock Options – Again, there are a multitude of options for providing the microcontroller with a system clock from external crystals and ceramic oscillators to internal oscillators. If an introductory course can utilize an internal oscillator, then the development platform may benefit from this decision.

Serial Port Connections – For years, RS232 serial port connections between development boards and PC's or MAC's were the norm. However, laptops with RS232 ports are almost impossible to find nowadays. Since many students utilize laptops at home, consideration must be given to the type of serial connection used. Recent trends have led to USB serial ports as the primary connection between boards.

Features – The supporting features of the development board may or may not be critical to the applications undertaken with them. For instance, many development boards contain switches or push buttons for inputs and LED's for output indicators. Some development boards include LCD's, Keypads, memory devices, etc. These extra features can drive the cost of the development board significantly higher than a plain version. If these extra features have potential uses, then a board with these features should be considered. Keep in mind that these extra features may have a negative impact on the student's ability to understand the basic function of the microcontroller. On the other hand, these extra features tend to make the students feel like they are getting their money's worth when purchasing the boards.

Ranking of the Criteria:

After the criteria were established, the relative importance of each item was determined by having the faculty vote on these items. The results of this are shown on the following page.

Table 2 – Importance of the Criteria

Relative Importance: 1 = Equal 3 = Moderate 5 = Strong 7 = Very Strong 9 = Extreme	Serviceability	Pedagogy	Reliability	Programming Support / Options	Processor Support (Multiple?)	Operating Voltage	Cost	Power Supply	Debugging Port	System Clock	Serial Port Connection	Features	**Weight**
Serviceability	1	1	1	3	3	3	5	7	7	7	7	7	0.1839
Pedagogy	1	1	1	3	3	3	5	7	7	7	7	7	0.1839
Reliability	1	1	1	3	3	3	5	7	7	7	7	7	0.1839
Programming Support / Options	1/3	1/3	1/3	1	1	1	5	7	7	7	7	7	0.1062
Processor Support (multiple?)	1/3	1/3	1/3	1	1	1	5	7	7	7	7	7	0.1062
Operating Voltage	1/3	1/3	1/3	1	1	1	5	5	7	7	7	7	0.1032
Cost	1/5	1/5	1/5	1/5	1/5	1/5	1	1	3	3	5	5	0.0381
Power Supply	1/7	1/7	1/7	1/7	1/7	1/5	1	1	1	1	1	1	0.0211
Debugging Port	1/7	1/7	1/7	1/7	1/7	1/7	1/3	1	1	1	1	1	0.0187
System Clock Options	1/7	1/7	1/7	1/7	1/7	1/7	1/3	1	1	1	1	1	0.0187
Serial Port Connection	1/7	1/7	1/7	1/7	1/7	1/7	1/5	1	1	1	1	1	0.0180
Features	1/7	1/7	1/7	1/7	1/7	1/7	1/5	1	1	1	1	1	0.0180

Identifying and Rating Alternatives:

The actual application of this technique varies greatly. A recent survey showed that the type of microcontroller utilized in introductory microcontroller courses varies greatly. A small sampling set includes Intel, Atmel, Microchip, and Freescale. A comprehensive survey of the available development boards for the Atmel family of AVR microcontrollers was performed.

Actual Evaluation:

Once the criteria had been ranked, the next step was to identify the possible choices. Each possible choice was then compared to the other possible choices in order to determine a comparative score. The table utilized to record these results is shown below. The actual scores and the development boards that were ranked have been omitted in an attempt to not show a bias towards one option or another.

Table 3 – Rating of Alternatives

1 = Does not meet criterion 5 = Partially meets criterion 9 = Completely meets criterion		Student Built on Protoboard	Sample Development Board #1	Sample Development Board #2
Reliability	0.1839			
Immediate - Guaranteed Functionality	0.5000	5	9	5
Long Term Functionality	0.5000	5	9	3
Serviceability	0.1839			
Through-hole with Socket	0.5000	9	9	9
Surface Mount	0.1000	1	1	1
Surface Mount with Socket	0.4000	9	1	1
Pedagogy	0.1839			
Layout	0.2500	9	9	9
Connections - clear and obvious	0.2500	9	5	9
Complexity	0.1250	9	3	9
Cognitive Load	0.1250	9	9	9
Usability	0.2500	5	9	9
Programming Options	0.1062			
Boot Loader (self programming)	0.1000	5	9	9
ISP	0.5000	9	9	9
Parallel	0.2000	9	1	9
JTAG	0.2000	9	9	5

Multiple Processors	0.1062			
Selection of appropriate devices	0.6000	9	1	9
Mega16,32,64, 8535	0.1000	9	9	9
Mega8515	0.1000	9	1	9
Mega8	0.1000	9	1	9
Tiny2313	0.0500	9	1	9
Tiny11, 12, 13	0.0500	9	1	9
Operating Voltage	0.1032			
3.3 Volt Logic	0.3000	9	1	9
5.0 Logic	0.5000	9	9	9
Multiple Voltages	0.2000	9	1	9
Cost	0.0381			
Board Cost	0.8000	9	5	5
Shipping Cost	0.2000	9	9	9
Power Supply	0.0211			
Traditional Supply	0.3000	9	9	9
Wall Wart	0.3000	9	9	9
USB Powered	0.3000	9	1	1
Battery Powered	0.1000	9	1	1
Debugging	0.0187			
Serial Port	0.5000	5	9	9
JTAG	0.4000	9	9	5
1-Wire	0.1000	9	1	9
System Clock	0.0187			
Crystal Oscillator	0.3000	9	9	9
Crystal	0.5000	9	9	9
RC Oscillator	0.2000	9	9	9
Serial Port	0.0180			
RS232	0.2000	5	9	9
USB	0.7000	5	1	1
Ethernet	0.1000	5	1	1
Features	0.0180			
LEDs	0.2000	1	9	9
Push Buttons	0.2000	1	1	9
Toggle Switches	0.2000	1	1	1
LCD	0.0500	1	1	1
Keypad	0.0500	1	1	1
Adjustable Power Supply	0.0500	1	1	9
Built-in Programmer	0.0500	1	1	9
7-Segment Displays	0.0500	1	1	1
SD/CF Memory Cards	0.0250	1	1	1
RS485/RS422 Drivers	0.0250	1	1	1
Optical Encoders	0.0250	1	1	1
Temperature/1-Wire Interface Connections	0.0250	1	1	1
Connection to External Devices	0.0500	9	9	9

Evaluation of the Results:

The process of evaluating the alternatives produces a single numerical value or score for of the evaluated development boards. The development board with the highest score would represent the best choice given the selection criteria. In the end, the user must review the decision to ensure the data is valid and makes sense.

Conclusions:

This process can be an effective method to make decisions in both industry and in academia. As a newer faculty member, it is sometime difficult to make changes to the current model without having strong evidence to support the changes. This is especially true when politics play a major role in the decisions that have been made in the past. Regardless of whether or not a formal matrix is utilized to make decisions, the criteria outlined in this paper should at least be considered when deciding on a platform for laboratory based courses.