ECE Senior Design Project Proposal

For

An “Anywhere” Microprocessor Laboratory

September 30, 2003 Rev. 4

Sponsor: Dr. Richard W. Wall

Student Design Team

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Approved for Design

Dr. Richard W. Wall, Instructor/Sponsor

Proposal Table of Contents

I. Abstract

The vision of our customer is to upgrade the current University of Idaho microcontroller laboratory with a modern processor, which will reduce department operating costs by requiring less support instrumentation. Student time and location constraints will be minimized, making it possible to offer laboratory based distance education classes using Engineering Outreach or compressed video to support undergraduates in Idaho Falls.

This proposal is for designing a new development platform that is low-cost and uses a modern microprocessor. To allow use of the system outside of a laboratory environment the system that will have its own instrumentation, therefore only requiring a PC for working on projects and experiments. This system will be less complex than the system its predecessor so technical support will be easier to provide. It is possible that a user could learn to use the system with just the use of a tutorial, thus requiring very little instruction in the laboratory. Given these characteristics the goal is to have the cost of the development system be low enough to make it affordable for students to purchase.

The merits and success of the proposed laboratory platform will be evaluated over both the short and long terms. The short-term metrics will be cost and educational merit as assessed by student surveys and our peer reviews. The experiments we develop with this system will demonstrate the proper operation of the project. The long-term assessment will be provided by student course evaluations using questions specifically formulated for these purposes.

II. Background and Problem Definition

a. Problem Description:

The ECE340 microcontroller course teaches critical skills for computer and electrical engineers. Student evaluations over the past 12 years show that students find the laboratory projects time consuming but invaluable to mastering the skills needed for designing embedded computer systems. The current ECE340 course is required for computer engineering majors alone though some electrical engineering students also enroll. Annual enrollment ranges from 30 to 40.

The faculty adopted a curriculum where both electrical and computer engineering undergraduates are now required to take a course in microcontrollers engineering design. Under the new curriculum, the laboratory will now need to accommodate approximately 60 to 70 students per year. In addition to the on-campus students, the ECE department has students in Idaho Falls, and Coeur d'Alene. The microprocessor that our course is centered on is no longer in production, which means our microcontroller laboratory can no longer be supported. The laboratory, which has been operating near capacity, will be inadequate next semester.

Outdated processors and facilities (development tools and instrumentation), in addition to the demand on instructor time, are all factors contributing to the need for an updated microcontroller laboratory. Offering the course each semester has temporarily solved the space issue, but this short-term solution is at the expense of instructor time. Due to the complexity of the suite of development tools, TA's offer only limited laboratory assistance unless they have taken the existing microcontrollers course.

b. Previous Work:

The original microcontroller course and laboratory were developed by our customer, Dr. Richard Wall in 1990 and have had significant improvements over the past 13 years through industrial grants and in-house designs. The microcontroller development platform for the laboratory has evolved allowing students to perform a suite of experiments that teach critical skills. The cost of the present development platform is over $7,500 per station.

III. Description of Work

a. Project Definition:

Our project involves an almost complete redesign of the current system. The one connection between the two systems is that the new microcontroller board will support all the current functionality.

b. Objectives:

This project will involve researching the following:

- which new microcontroller to use
- which components will be used to implement the desired functionalities
- which components will be implemented using software rather than hardware, if any
- PCB design and layout

The following decisions will need to be made:

- deciding what new features to add to the system
- determine how much upgrading of old features should take place, if any

The following testing will be required:

- writing software to prove that the concepts behind the old lab experiments are able to be duplicated on the new system
- writing software to prove that all new features are functional and perform within specifications

c. Specifications:

The following specifications have been compiled through meetings with our customer, Dr. Richard W. Wall, through review of the previous system, and via research into available components:

1. Rabbit microcontroller

2. Power supply requirements
   a. Voltage: 9 to 15V AC or DC
   b. Current: 1A minimum

3. Provision for 12V DC supply for DC motor control

4. LED to indicate power is on

5. Hardware reset switch

6. At least four switches
   a. at least 2 push button, momentary contact switches which will invoke external interrupts to the microcontroller
   b. at least 2 3-terminal switches such that the center terminal makes up with one outside pin in one position and the other outside pin in the other position

7. Slave module connectors
    a. Pre-wired to permit installation of a second Rabbit processor or other external device (FPGA)

8. At least four debugging LED for indication only, along with instrumentation pins for connecting electronic measurement devices.

9. Headers for breaking out at least 8 I/O pins
    a. 5V @ 6.8mA maximum for output and input.
    b. break out unused parallel ports for simple I/O or future expansion good

10. Stepper motor control
    a. 4, 5, and 6 pin header interface with pin descriptions
        i. Stepper motors outputs have to handle up to 15V at 0.5A
        ii. Instrumentation pins for monitoring outputs with measurement equipment.
11. Character LCD Interface
    a. 14 and 16 pin interfaces with 4 and 8 bit data bus capability allowing for 14/16 pin inline and 14/16 pin dual row interfaces.

12. DC motor interface
    a. Uses on-board PWM converter with power driver
    b. Analog input
        i. At least three analog inputs connected to on-board rheostat for speed control.
        ii. Sampling rate > 100kS/sec
        iii. Resolution > 10 bit
    c. Digital feedback
        i. Digital input from off board sensor that generates TTL compatible signals and/or zero crossing detector for AC signals.

13. Two RS232 Serial connections
    a. one DCE
    b. one DTE

14. Memory mapped I/O expansion to provide 8 bits of bidirectional digital communication that is TTL compatible.
    a. Requirements
        i. Address decoder
            1. 2 address lines
        ii. Read line
        iii. Write line
        iv. Isolate digital I/O bus from CPU bus
            1. Digital output – transparent octal digital latch
            2. Digital input – Tri-state octal bus drivers

15. Interface to a 64x128 graphical LCD
    a. Uses I/O expansion for CPU
    b. We may be able to combine the graphical and character LCD functionality into to one unit
    c. We may be able to run both LCDs off of common control lines

16. I^{2}C bus
    a. On board:
        i. Dallas Semiconductor DS1629 Time and temperature chip or equivalent.
        ii. Battery backup via coin battery on board
        iii. Microchip 24LC256 serial EEPROM or equivalent
        iv. I^{2}C Serial to digital I/O (Texas Instruments PCF8574A) or equivalent) with I/O connector including power and ground.
    b. Off board:
        i. 4 pin interface with pin descriptions
            1. Pin 1: 5V Power @ 250ma
            2. Pin 2: Power ground
            3. Pin 3: I^{2}C Serial Clock (Master clock from Rabbit processor)
            4. Pin 4: I^{2}C Serial Data I/O (Direct connect to Rabbit processor)
17. SPI Bus
    a. On board:
        i. CAN interface
            1. Microchip MCP 2515 SPI CAN Controller, or equivalent
            2. Microchip MCP 2551 High Speed CAN transceiver, or equivalent
            3. Off board connector pin definitions
                a. Pin 1. Power Ground
                b. Pin 2. CAN High signal
                c. Pin 3. CAN Lo Signal

    b. Off board:
        i. 8 Pin connector
            1. Pin 1: 5V Power @ 250 ma
            2. Pin 2: Power ground
            3. Pin 3: SPI CLOCK
            4. Pin 4: SPI MOSI (Master output – slave input)
            5. Pin 5: SPI MISO (Master input – slave output)
            6. Pin 3 CS 1 ((connection to memory expansion for SPI device select)
            7. Pin 4 CS 2 ((connection to memory expansion for SPI device select)

8. Pin 4 CS 3 ((connection to memory expansion for SPI device select)

d. Deliverables:

There are two phases for this project. The first phase will be completed at the beginning of December 2003, and the second phase will be completed in May 2004. December deliverables for this project include a working prototype, all code, documentation, data sheets for the project, bill of materials, schematics, user's manual, technical manual, and a project report. Deliverables for the month of May will include, but will not be limited to, a working, completed project board, all final code and documentation as above, a project presentation, and a project demonstration for public display. Delivered code will consist of a number of C and assembly program files demonstrating that the new system duplicates the principles of previous laboratory experiments, and proves that the new features added to the system have the correct functionality. The project report and technical documents will be detailed enough to facilitate reproduction of the system with no prior knowledge of this project.

e. Constraints:

This project has many constraints, which limit the project's range of solutions. Financially, we are restricted to a budget of \$2450 that must cover all project expenses. We must design a system that can be mass-produced and be available to consumers (most likely students of University of Idaho's microcontrollers courses) for less than \$250 per unit. This must include all the necessary software and components to have a fully working laboratory system anywhere with a PC. Further constraints include the specific components, or particular component families, that our customer requested that we us in the project.

IV. Strategy

a. Description of technical approach:

The approach we will take toward this project will be, first, to detail the required operations of the project platform. These operations will be from the perspective of the platform's users. Second, we will describe the underlying functions of the system necessary to carry out these operations. Finally, modularizing will aid in the testing of the separate parts of the system.

b. Block Diagrams:

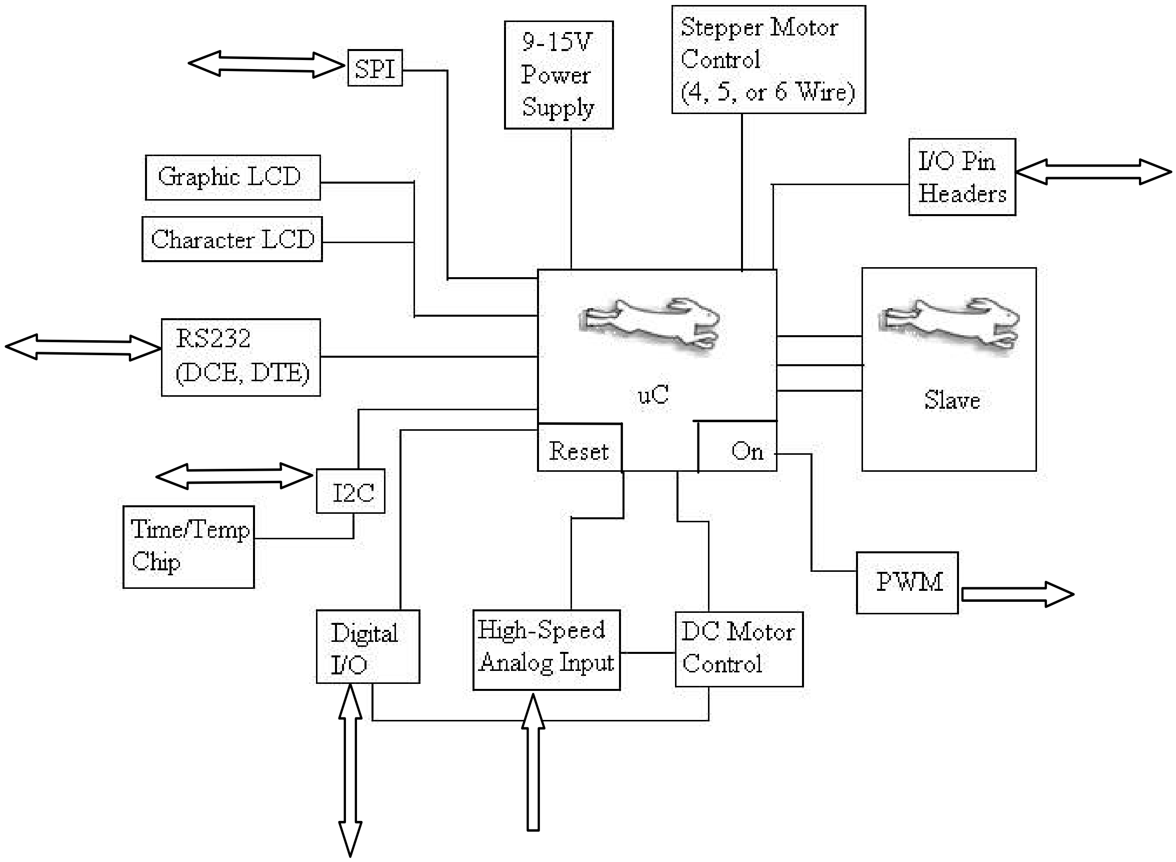


Figure 1. System Block Diagram

c. Constraint Mitigation:

To not deplete our limited financial resources, our design efforts will strive to use components and processes that provide as much functionality per unit cost.

i. Environmental:

In an effort to reduce the environmental impact of non-recyclable, solid waste, our goal is to realize a 15-year design life within our proposed system.

ii. Sustainability:

The new system will be more easily built and be maintained by using common and more readily available parts, as opposed to more specialized and costly ones. Component sources of will be documented for ease of reorder and replacement. ICs and other components will be soldered onto the PCB to prevent theft and minimize tampering. It may be possible to have the IEEE student store stock replacement components for the duration of the design to ensure reparability.

iii. Manufacturing:

The PCBs will need to be fabricated by an outside firm, and either another outside firm or an in-house shop will solder the parts on. We will provide assembly instructions that show where parts are to be installed on the PCB, such that anyone with basic soldering experience can assemble the system. With these instructions it will be possible to distribute the system as an unassembled kit.

iv. Health and Safety:

To minimize health and safety concerns we are designing the system such that when every component is working at full potential at once, the system will operate at a low maximum voltage of 15 volts and a low maximum current of about 1 amp. Even though the majority of the components and connections will be exposed to human contact, there will be very little risk of injury. The system is not intended for use in mission critical applications where humans could be at risk in event of system failure.

v. Social, Political, and/or Regulatory issues:

Licenses for the Dynamic C software must be acquired to allow redistribution of the software for educational purposes. Should we decide to expand the system's distribution beyond the University of Idaho, whereas a profit may be accrued, more research will have to be conducted regarding the legalities of maintaining copyrights and managing royalties.

d. Resources

i. Personnel:

Our team consists of two members, Andrew Huska and Lee Newbill. Both are Senior Computer Engineering students at the University of Idaho.

1. Team Leader

Andrew is the designated team leader, which entails being the primary person of contact in the group.

2. Areas of Responsibility

Andrew will be primarily responsible for analog related components in the system. These components include the power supply, DC motor control, high-speed analog input, and pulse width modulator. Lee will primarily handle digital functions such as serial communications, SPI, I2C, and the stepper motor control. To further our education, both team members will provide assistance to each other for all responsibilities.

3. Formal Meeting Schedule:

Our formal meeting schedule is limited to Tuesdays and Thursdays in class. Other meeting times are as needed, but often occur before the above classes, and most evenings Sunday through Thursday.

ii. Major Expenses and Unique Equipment:

Major expense items will be the development software tools, the microcontroller core module, and the components to populate the PCB. There are many other cost items, but separately they are of much lower cost magnitude. Oscilloscopes, digital logic analyzers, and multimeters will be employed in the testing of our project, but we will not need any other unique equipment that is not already available in our design laboratory.

iv. Budget Summary:

Source of Funds:	
External Grant	$2200
University of Idaho Electrical and Computer Engineering Development Account	$250
Total Project Funds	$2450

e. Evaluation:

Like any project, this project will be subject to validation and verification of its design specifications.

i. Strategy for validation and verification:

To properly test the operational specifications of the project, the customer has required that we supply C and assembly code programs to show that the new system can repeat all of the principles behind the previous laboratory experiments. The customer has also requested that we write programs to demonstrate that all of the new features work properly.

ii. Mechanisms for evaluating quality:

Not only will this testing show the correct operation of the individual functions, it will demonstrate that the functions can be used together successfully.

To prove the electrical specifications, we will show that our system can deliver the current and voltage required to the output ports, and that it can accept the required current and voltage input.

V. Plan of Action

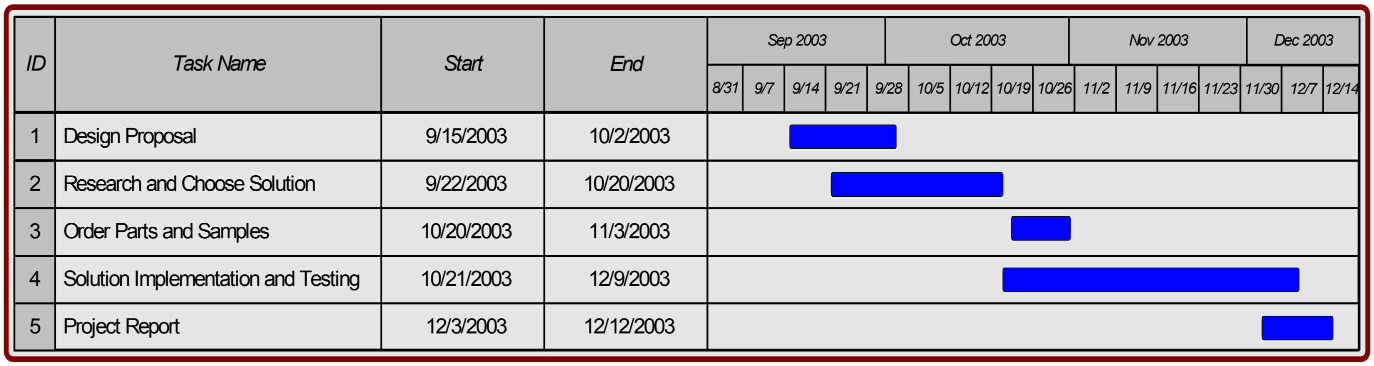
a. Task List:

- Research the most applicable and cost effective parts for each of the project's functions. – Andy & Lee, complete by 10/1/03
- Choose best solution and create system design. – Andy & Lee, complete by 10/21/03
- Order a small number of each part for use in experimentation and testing. (Engineering sample parts may be available at no cost, in some cases.) – Lee, complete by 11/3/03
- Create a circuit design for each individual function of the project, detailing the interaction between the components. – Andy, complete by 11/3/03
- Lay out circuit designs and test them using the actual components. – Lee, complete by 11/3/03
- Use a software tool to design a printed circuit board (PCB) layout of the system and its parts. – Andy and Lee, complete by 11/10/03
- Send the PCB design for fabrication. – Lee, complete by 11/17/03
- Test the interaction between the functions and verify that the overall functionality of the system works correctly. – Andy & Lee, complete by 12/1/03
- Solder the parts onto the PCB and test prototype. – Andy and Lee, complete by 12/8/03
- Write project report. – Andy and Lee, complete by 12/13/03

b. Milestones and Critical Dates:

- Design Proposal – October 2, 2003
- Design Review – October 21, 2003
- Working Model – December 9, 2003
- Project Report – December 13, 2003

c. GANTT and PERT Charts:



ID	Task Name	Start	End
1	Design Proposal	9/15/2003	10/2/2003
2	Research and Choose Solution	9/22/2003	10/20/2003
3	Order Parts and Samples	10/20/2003	11/3/2003
4	Solution Implementation and Testing	10/21/2003	12/9/2003
5	Project Report	12/3/2003	12/12/2003

Figure 2. GANTT Chart

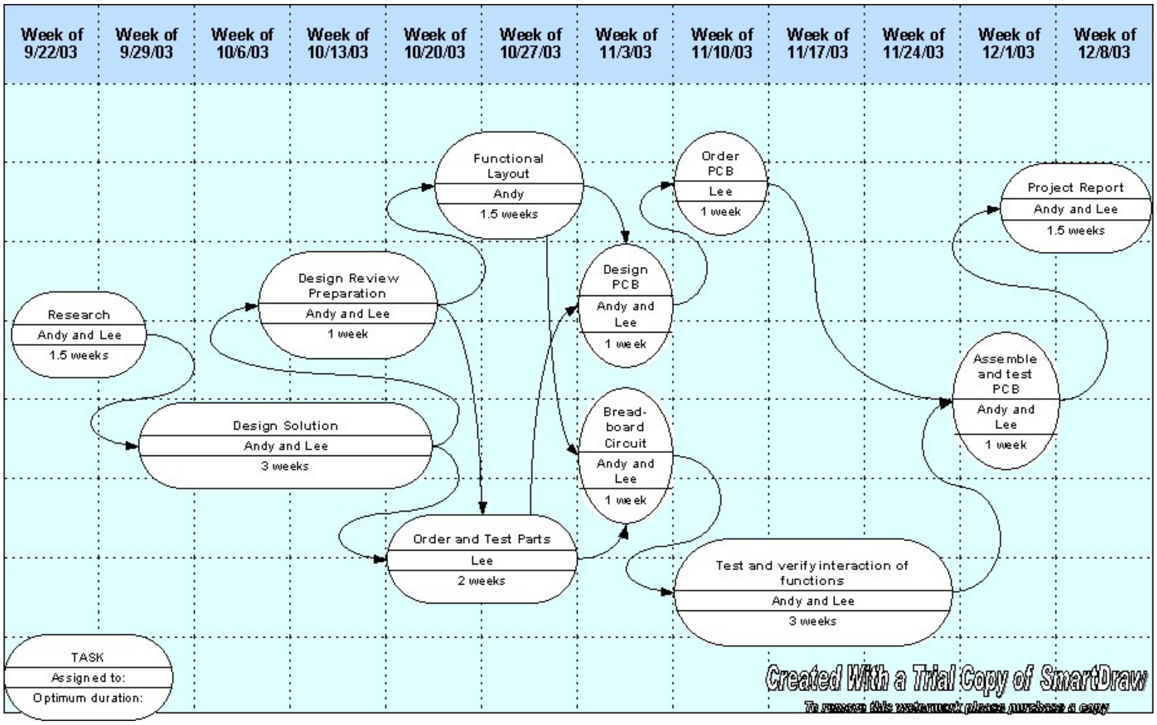


Figure 3. PERT Chart

VI. Budget

Our customer has given us a definite budget of $2450 that must cover all costs associated with the project. Items we will need to purchase for this project include:

a. Purchase Items:	
Development Kit, which includes microcontroller, software development system, basic test platform/prototyping board, documentation, serial cable for programming and debugging, and power adapter, 1kit	$239-349
Microcontroller core module, each	$49-89
Documentation binding, per manual	$20
Presentation materials	$50
b. Fabrication expenses:	
PCB Components, 1 board	<=$100
PCB Production, 2 boards	>=$38
NRE prototype fee	$150
c. Ancillary Expenses:	
No travel should be required.	$0
No long distance calls should be needed.	$0
Shipping and Handling: 5-10% of total ordered parts	$34-88
Total expenses:	$680-880

VI. Reports

a. Weekly Progress Reports:

Throughout the course of the project, we will be submitting a number of progress reports to our customer, Dr. Wall, on a biweekly basis. These progress reports will be e-mailed every other Tuesday informing him of work completed during the last period and work to be performed in the next two weeks.

b. Technical Reports:

We will also be delivering a major project report in December describing our prototype. Major reports will also be sent in March and in May, detailing our progress to date.

c. User's Guide:

A user's guide will be submitted to the customer that contains descriptions of all the operational aspects of the system.

d. Design and Maintenance Manual:

Finally, we will deliver a design and maintenance manual laying out the theory behind the project, detailing the construction of the system, describing the testing performed, and showing the methods used to test the system. We will also include instructions on how to assemble the system from its individual components.

VIII. Testing

In addition to the steps taken to evaluate the functionality of the system, we will verify that the system can handle any foreseeable use. To prove the electrical specifications, we will show that our system can deliver the current and voltage required at the output ports, and that it can accept, without malfunction, the required current and voltage input. The system should be able to operate at maximum rated load without adverse effects. It may also be necessary to show that our system can handle overloading without failure.