
ARDUINO FRIENDLY PSoC SHIELD

PRE-PROPOSAL

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DESIGN TEAM 1:

Cecilia Acosta
Brett Donlon
Matt Durak
Aaron Thompson
Nathan Ward

FACULTY FACILITATOR:

Dr. McGough

EXECUTIVE SUMMARY

The Programmable System on Chip (PSoC), made by Cypress Semiconductor, is a configurable piece of hardware which contains a CPU and programmable hardware. It is used by numerous companies to build embedded systems. Until recently Arduino was a hardware platform for hobbyists and students, but has recently been endorsed by Google as an Android Development Platform, Arduino includes a CPU and can be connected to one or more daughterboards, known as shields. The purpose of this design project is to provide a means to connect the PSoC to Arduino shields, in order to help Cypress penetrate the growing Arduino market with PSoC.

This project will involve connecting the physical pins of the PSoC to the standard Arduino shield pin layout. This will require soldering to physically connect the pins, as well as using the PSoC Creator software to configure the general purpose I/O ports to route to the Arduino pins. The next step will involve connecting the Arduino Ethernet shield to the PSoC and writing the firmware for the PSoC to interface with this card. Finally, a web server application will be developed to demonstrate the working PSoC and Ethernet shield. The team also plans to test other Arduino shields, time permitting. Also, the team expects to deliver a custom printed circuit board as the final prototype.

It is expected that this project will remain well under its \$500 budget, as only a small number of hardware components must be purchased. The greatest amount of work and risk will involve developing the software for this project. However, the team has set a reasonable schedule and expects to have the primary deliverables finished in time for Design Day.

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INTRODUCTION

The overall goal of this project is to have Cypress products, in this case the PSoC, be “Arduino-friendly”. This means that customers using Arduino products could be enticed to purchase PSoC without encountering any technical difficulty when interacting with the two components. The immediate goal of this project is to make PSoC 5 work with the Arduino Ethernet Shield at the very minimum. The project has the possibility of being extended to other Arduino shields as time allows. Lastly, there will be programming of the PSoC to perform the functions of a web server. PSoC Creator will also be used to make the virtual electronic components to interface with the shield.

Until recently the main audience using Arduino has been students and hobbyists. Recently, a fair number of companies have been prototyping with Arduino especially since Google has specified Arduino as the preferred Android development platform. By making PSoC “Arduino-friendly”, the chance of success in capturing the intended audience is increased. The functionality required by the customer is a working component in PSoC Creator and a piece of hardware which, together, will allow the PSoC to be used with Arduino shields. The product should be easy to use for anyone familiar with PSoC Creator and Arduino. Ideally, it will use the same API as Arduino, in order to ease the transition of the customers currently using Arduino. Likewise, the PSoC Creator component should be developed in a standard way, similar to existing components. Building a custom printed circuit board (PCB), would improve the aesthetics and packaging of the end product to the customer. There is an expectation that the product will be very reliable and require little to no maintenance. The customers can expect a light weight, easy to carry product at a low cost, very accessible and with the desired functionality.

The other customer of this product is Cypress itself. The needs of Cypress are primarily to create a product with which the end user will be satisfied. The final delivery date for Cypress will be on December 9, 2011. Cypress needs only one working prototype on that date. This prototype should demonstrate the final product, although it may not be the built to production quality at that time.

Some of the technical problems that may be encountered are within the design of the pin to pin connection between the Arduino Shield and the PSoC. Also, the memory capacity in the PSoC is very limited and will need to be used wisely to implement the web server without sacrificing its performance. This product will not present any environmental issues. It will be safe and use a relatively small amount of energy.

Currently the project scope does not extend further than being able to demonstrate that PSoC and the Arduino Ethernet shield work together. However the ultimate goal would be to create a board that will serve as a connector to all Arduino shields with PSoC 5. This goal may not be accomplished due to time and budget constraints. To test all the shields against the newly designed board, all other shields will need to be purchased, hence the budget problem. Other constraints that may be encountered have to do with the Arduino coding. It may not be possible to modify this code to work with the ARM and thus more time will need to be spent writing new code. These are the only foreseeable constraints.

BACKGROUND

A programmable system-on-chip (PSoC) is an integrated circuit made by Cypress Semiconductor. It includes a CPU subsystem, configurable analog and digital blocks, and programmable routing and interconnect. The programmable routing and interconnect allows one to route signals to selected pins. Configurable analog and digital blocks are the basis of the PSoC and can be combined to create custom functionality in the hardware. The CPU subsystem includes SRAM, EEPROM, flash memory, processors such as the ARM Cortex M-3 or 8051, internal oscillator, on-chip JTAG debugging, and communication with I2C, USB, and CAN 2.0 (Cypress Semiconductor Corporation, 2011). Overall, this product is configurable like an FPGA, but is used for similar applications as microcontrollers. This project will focus on the PSoC 5 family, which uses the ARM Cortex M-3 processor.

In order to develop for the PSoC 5, the software called PSoC Creator must be used (Cypress Semiconductor Corporation, 2011). PSoC Creator features a schematic design tool to configure the programmable blocks and the routing. This tool uses pre-designed “components” found in a catalog and supports user-created components. Components may be configured and also contain data sheets with more technical information. The Creator software also provides a way to assign pin connections between the physical pins and the component design. Lastly, the software includes a full IDE for writing C code to be compiled on the processor. PSoC Creator can then be used to program the device and debug the code on the device.

Arduino is an open-source microcontroller platform that is intended primarily for hobbyists as a way of building projects to interact with the world through sensors. It is open-sourced both in the software and the hardware, which means that the PCB layouts can be freely downloaded to build an Arduino board without buying a pre-assembled one. This allows for Arduino projects to be built with very little cost and has made the platform attractive to students and teachers. Furthermore, the Arduino has a standardized pin layout which allows a number of daughterboards, called “Shields” by Arduino, to be connected to the microcontroller. Some examples of Arduino shields are the Ethernet Shield, Motor Shield, XBee Shield, and Proto Shield (Mellis, 2009). For the purpose of this project, the focus will primarily be on the Ethernet Shield, with the Proto Shield as a means of physically connecting the PSoC to the Ethernet Shield. The Ethernet Shield, as the name implies, is a board based on the Wiznet W5100 Ethernet chip, which allows the Arduino to connect to the Internet. It provides the IP stack, which can work with TCP or UDP software. It also includes a microSD card reader (Fitzgerald, 2011). The Proto Shield is a device with the proper Arduino header pins designed to connect the Arduino to a breadboard or do other prototyping (Jimbo, 2010). It primarily provides a blank chip which can be connected to an Arduino or to another Arduino shield.

While the idea of using the Arduino and PSoC together is novel, there are a few similar ECE 480 design projects which have been done. There were teams in both fall 2009 and spring 2010 called *Power over Ethernet for Wireless Home Automation* and *Ethernet Integrity Analyzer (EIA)*, respectively. Both of these projects utilized the same processor (ARM Cortex M3) and Ethernet hardware, although it was hardware produced by TI. The design team in spring 2011 called *Zigbee component for PSoC Creator* also worked to interface the PSoC with another piece of hardware, this time a wireless component called the Zigbee. Cypress itself does not offer anything similar to the Arduino Ethernet Shield, so it is desirable to interface with this hardware in order to get the PSoC into the market where Arduino parts are commonly used.

The required functionality of the end product breaks down into three key areas. The first is to make the PSoC itself “Arduino-friendly”. This means that there must be some piece of hardware which

will interface the pins of the PSoC with the correct pins for an Arduino shield. At the very least, this must work with the Arduino Ethernet Shield, but it should work with any Arduino shield. Secondly, a component must be developed in the PSoC Creator, which will configure the necessary hardware on the PSoC to connect with Arduino parts. This will be a reusable library module to allow others to use the Arduino Shields with PSoC. The third part of the functionality is the software which will demonstrate the working design by controlling the Ethernet Shield with the PSoC. This can be subdivided into the firmware code for the ARM processor to interface with the Ethernet chip, and the application code which will read to and write from the SD card on the Ethernet board. The functionality of the application software is a demonstration, and not necessarily a full-featured production web server. The end product of this work will be a means of working with Arduino shields on the Cypress PSoC.

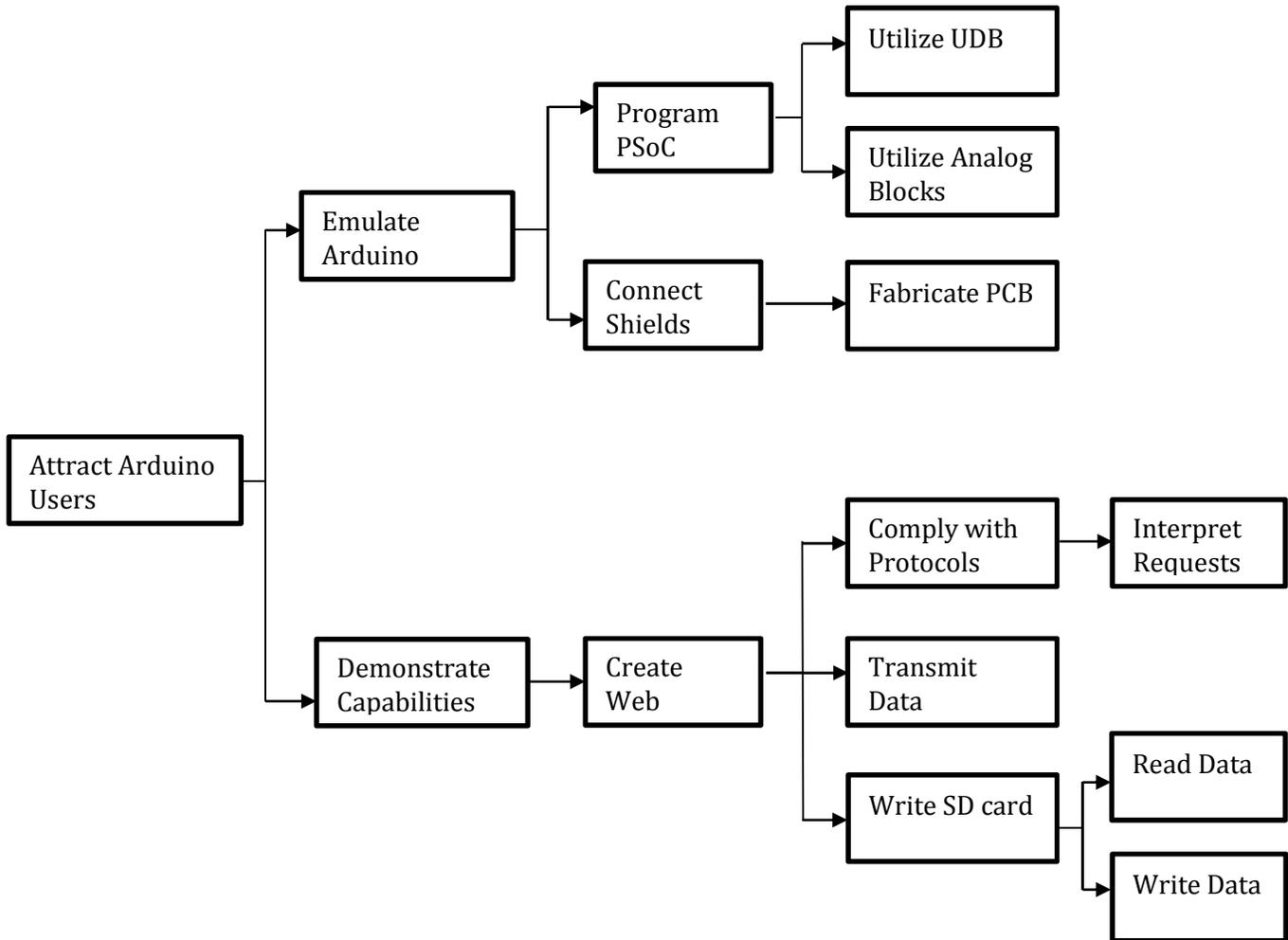
OBJECTIVES

The primary objective of this project is to make the PSoC “Arduino-friendly” meaning that as a result of this project, a consumer would be able to interchange an Arduino with a PSoC in any given shield, particularly in an Ethernet shield. To prove that the PSoC has been made compatible with this shield, a web server component will be created that will send and receive a message via the port on an Ethernet shield and save it on the SD card. This circuitry will be connected to the PSoC via some custom circuit based on the Proto Shield. At this moment, the project does not extend beyond this scope, which means the work will primarily consist of programming the PSoC to perform the functions of a web server. In addition, the “PSoC Creator” software will be used to make electronic components that will interface with the shield. Due to the ability of the PSoC to make virtual electronic components, the cost of this project should be minimal. The only required hardware will be the circuit based off of the inexpensive Proto Shield, which will interface the Arduino shield with the PSoC. Indeed, one of the feasible design criteria is that the solution be inexpensive, since Cypress is trying to capture the largest potential market. The goal is to prove that the PSoC can do everything an Arduino can and more.

The prime constraints on this project are cost and the adaptability of the design. The design must be easily changeable to suit the needs of the customer. It should also serve as an example, showing the capabilities of PSoC as compared to Arduino. If it is easy to get a project with an Arduino shield to function properly, the target audience will be eager to develop with this platform. Elucidating more on the cost aspect of the project, students and hobbyists typically do not have access to large sources of funding like that of a corporation. Therefore, it is desirable to implement more solutions via code rather than hardware in order to keep costs low. Concerning the adaptability of the design, the code of the web server ought to be similar to the way many hobbyists program the Arduino, through the use of readable, modular functions and libraries. If the web server's code is unnecessarily complicated or too rigid to add additional functionality, the usefulness of the web server will be compromised and the project's target audience will not be convinced that the PSoC will serve as a suitable design solution for their application. In order to appeal to this audience, the code should ideally serve as a general library for reuse. If it is limited to a specific communication protocol it should be modular enough to have additional functions added to it. This design constraint specifically applies to students and hobbyists who all have varied interests and depend upon building their applications with adaptable platforms. Although this design constraint applies to the targeted audience, it is not a necessity of the design, since the nature of this project as specified by Cypress is similar to a proof of concept. If this project can suitably work as well as an

Arduino in producing a web server with the Ethernet shield, users will come to view PSoC as a more powerful development platform than Arduino is viewed currently.

FAST DIAGRAM



CONCEPTUAL DESIGN DESCRIPTIONS

In order to satisfy the constraints requested by the customer, several potential designs have been proposed. The physical layout of the project depends on the stacking of three commercially available components: the PSoC on the bottom, then the Proto Shield, and then the Ethernet Shield. It will involve some soldering in order to adapt the PSoC to the Proto Shield and correctly connect the pins from the PSoC to the Arduino shield headers. The electronic connections between the PSoC and the Ethernet Shield will use the general purpose pins of the PSoC which can be configured in software using PSoC creator. If time allows, a custom PCB will be designed rather than building off

of the Proto Shield. Concerning the programming aspect of the project, the software will be made of modules which handle different aspects of communication via the Ethernet protocol. Some of the Ethernet IP layer is built into the Ethernet Shield, but added functionality such as the TCP or UDP transport layers will need to be implemented in code. Ideally, this code will be modified from the open source Arduino libraries, in order to reuse working code. The details of this system are still being developed, however this robust, hierarchical structure will serve as the basis of the system's software.

RANKING OF CONCEPTUAL DESIGNS

Engineering Criteria	Importance	Possible Hardware Solutions				Possible Software Solutions		Possible Software Demos	
		S1	S2	S3	S4	S5	S6	S7	S8
Cost	2	9	3	1	1				
Difficulty to Develop	2	9	9	1	3	1	3	9	3
User Friendly	5	1	3	3	9	3	9		
Aesthetics	4	1	3	9	9				
Impression	4							1	9
Totals		45	51	55	89	17	51	22	42
Normalized Totals:		3.461538	2.55	3.055556	6.357143	2.428571	4.29	3.666667	7

9 = Best, 1 = Worst

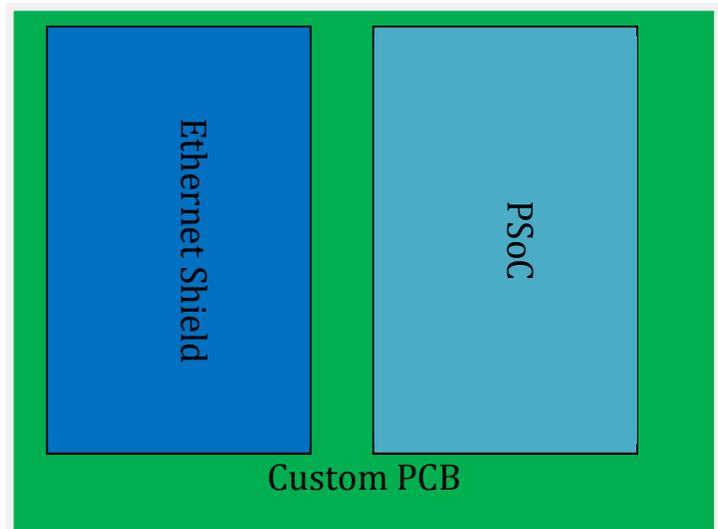
Hardware Component		
Connect PSoC to shield via protoshield	S1	This setup has already been completed
Connect PSoC to shield via a custom PCB (stacked) without enclosure	S2	Involves creation of a PCB similar to the protoshield
Connect PSoC to shield via a custom PCB (stacked) with enclosure	S3	Stacked design may prove difficult to mount due to irregular structure
Connect PSoC to shield via a custom PCB (side by side) with enclosure	S4	Placing the PSoC and shield side by side may be easier to mount
Software Component		
Create ethernet and SD software from scratch	S5	Allows for custom design, but involves more coding
Port ethernet and SD software from Arduino libraries	S6	Involves research and debugging of pre-made code, but platform independent code can be reused easily
Include demos from Arduino	S7	Demo code available and fairly platform-independent
Include custom demos	S8	Requires more research, may yield more impressive results

In our feasibility matrix, we compare several different solutions, arranged into 3 separate categories: hardware solutions, software solutions, and software demos. The various potential solutions presented here are rated by 5 different criteria deemed to be important by Cypress and by our own analysis. From this data the two categories, “cost” and “difficulty to develop”, were assigned the lowest weight among all of the criteria. Cost is not as important in the grand scheme of things, because of the platform that we are using. The PSoC utilizes virtual components to achieve much of its hardware functionality, such as for the implementation of the SPI. Because our project does not require the purchasing of expensive hardware components, the budget can be used for things that might not have been a priority otherwise, such as a custom PCB and protective packaging. Also our project is, at this point, very much a proof of concept that the PSoC can be “Arduino-Friendly”, the costs do not need to be optimized for mass-production as of yet. The “difficult to develop” criterion is not relatively important because in most cases, a development path that yields more impressive results may justify the extra work inherent in that path.

The other criteria that were deemed important were “User Friendly”, “Aesthetics”, and “Impression”. Making a user friendly device is by far the most important aspect of our project. Since we are trying to appeal to students, hobbyists, and the ever-growing Arduino market, our project aims to make development on PSoC as easy as development on the Arduino, the implications of this important criterion will become apparent later. “Aesthetics” and “Impression” are also important aspects of our project which deal with the general feelings a consumer will feel upon first observing our project. In our physical design and project demos we want potential users to be impressed upon viewing our completed system, encouraging them to use the PSoC for their own projects.

PROPOSED DESIGN SOLUTION

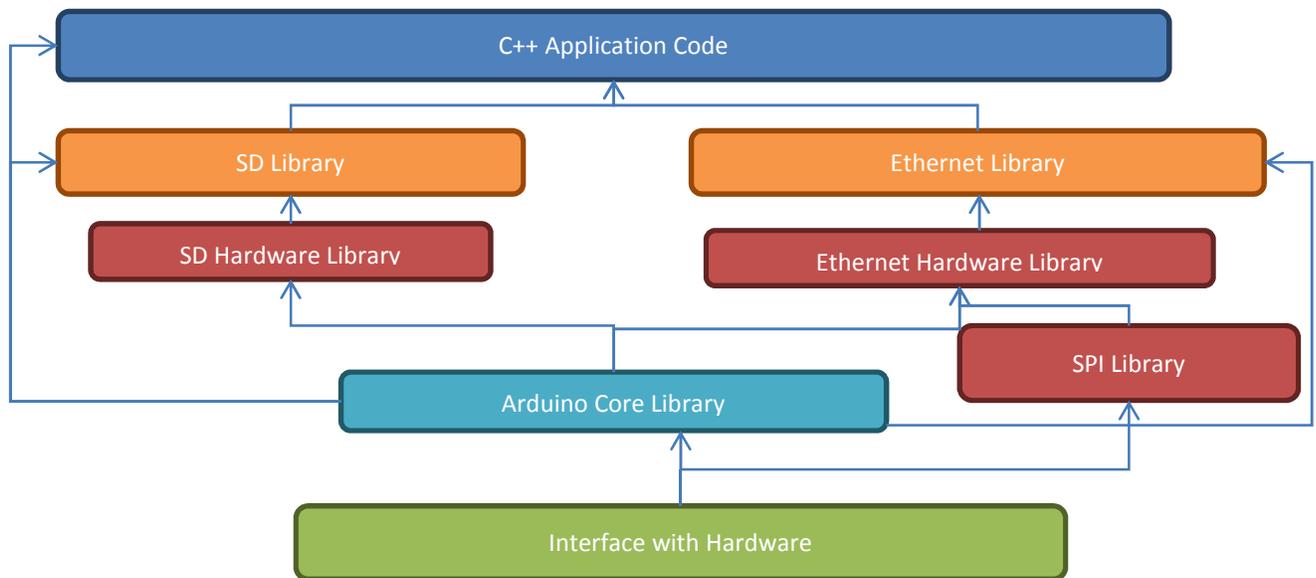
Our final design decision follows the summation of the criteria in the feasibility matrix. Concerning the hardware category, due to the fact that we made the weights of “cost” and “difficulty to design” relatively small, our final design will have a custom PCB and a protective enclosure. The PCB will not follow the same physical layout as the protoboard, rather it will be wide enough to accommodate the PSoC and the Ethernet Shield side-by-side. This will allow users to access and see all of the connections and informational LEDs on both the PSoC and the Ethernet Shield, and will allow for easier mounting within the packaging.



Our physical design will consist of a custom PCB which secures and connects the PSoC and Ethernet Shield.

Concerning our software category, our code will directly port the pre-made Arduino libraries (see figure on next page) for Ethernet and SD card interaction. Choosing this method will accomplish two things, firstly it will be easier for us to develop because the code is already written in the same language between both platforms, the only task for us to do is to simply modify the lower level resource calls specific to Arduino. Secondly, by simply porting already existing Arduino code, we provide a software environment that Arduino users are already used to.

As for the software demos we will design, we want our system to perform the basic tasks presented to us by Cypress, namely simple message transceiving between the SD card and a website or other method of internet messaging. However, we also want to make more complex demos that are beyond the scope of our presented task and the preexisting arduino demos such as the integration of our device with social media such as Facebook or Twitter. Our device could potentially send relevant data to a feed demonstrating how versatile the PSoC is for building custom applications.



The higher level application code for demos depends on the libraries ported from Arduino. The main task in coding this project arises from replacing resource calls to Arduino hardware with calls to the hardware provided by the PSoC, mainly the SPI hardware. Once this has been done, the higher level code largely stays the same because both platforms use C++.

RISK ANALYSIS

The risks associated with this project are based on the critical path which can be found in the following section on Project Management. The following table displays the tasks determined to potentially cause issues throughout the design and completion of the project. The risk was analyzed based on severity or impact and likelihood of that particular task being a problem.

Task	Description	Risk
Design and fabrication of PCB extends beyond delivery date	Major, Low Likelihood	Low (5)
Difficulty porting Arduino libraries to PSoC Creator Environment	Serious, Low Likelihood	Moderate (8)
Server application demo development issues	Serious, Low Likelihood	Moderate (8)

Near Certainty	5	10	15	20	25
Highly Likely	4	8	12	16	20
Likely	3	6	9	12	15
Low Likelihood	2	4	5	8	10
Extremely Improbable	1	2	3	4	6
	Minimal	Minor	Major	Serious	Catastr- ophic

Risk Legend	
Low (Green)	≤ 5
Moderate (Yellow)	$\geq 5, \leq 12$
High (Red)	≥ 12

PROJECT MANAGEMENT PLAN

Design team 1 is a diverse group containing three computer engineers (CPE) and two electrical engineers (EE). Aaron, Matt and Nathan are the CPE majors while Brett and Cecilia are the EE majors. The technical tasks have been broken up across discipline, giving each member a chance to contribute as well as learn from other disciplines. While all team members will attempt to work on various parts of the project, certain members have been identified as being responsible for various tasks. Cecilia and Brett will be tasked with the physical pin to pin connection between the Arduino Ethernet shield and the PSoC as well as PCB design. Brett will also work on power consumption analysis. Cecilia will also focus on designing packaging for the final prototype. Aaron, Brett, and Cecilia will work on connecting the PSoC to the Ethernet Shield using PSoC Creator to configure the pins. Nathan, Aaron, and Matt will have the task of building the Ethernet and SD card firmware for the PSoC, as well as writing application code for the web server. Nathan will perform debugging and integration of the code onto the PSoC. Roles may be subdivided further once more progress has been made as the team sees fit.

The PSoC-based web server using an Arduino Ethernet shield is a self-contained project. Most of the project can be done in the ECE lab using only a few external parts because the majority of the project will be computer programming code. The three major external components are the PSoC, Arduino Ethernet shield, and Arduino Proto Shield. The Arduino Ethernet shield and Proto Shield can be

purchased online from a number of various vendors. The PSoC hardware and software were provided by the project sponsor, Cypress.

The schedule will be divided into multiple miniature tasks and time lines. The pin connection between the PSoC and the Arduino Ethernet shield is the most critical because later tasks depend on it. This will be the first task to be completed. The next focus will be on how to use the Ethernet shield with the PSoC. Simultaneously, the ability to write to an SD card should be progressing toward completion. The final step, will be implementing the application code to demonstrate that the project is working. Once the basic and performance needs are completed, customization of the project can begin, including creating a custom PCB and testing other Arduino shields.

SCHEDULE:

Week 1: Course Introduction, Project Assignments Handed Out

Week 2: Team Planning and brain storming

Week 3: PSoC received, Shields ordered

Week 4: Familiarized with PSoC components, pre-proposal due

Week 5: Shields arrive (Tentative)

Week 6: Brochure Page due, Gantt chart due, Fast diagram due

Week 7: PSoC and Shields compatible and pin outs work, Practice oral presentation with facilitator

Week 8: Presentation, and Proposal Due

Week 9: Software completion, Progress report 1

Week 10: Test of IP address and web server, First project demonstration

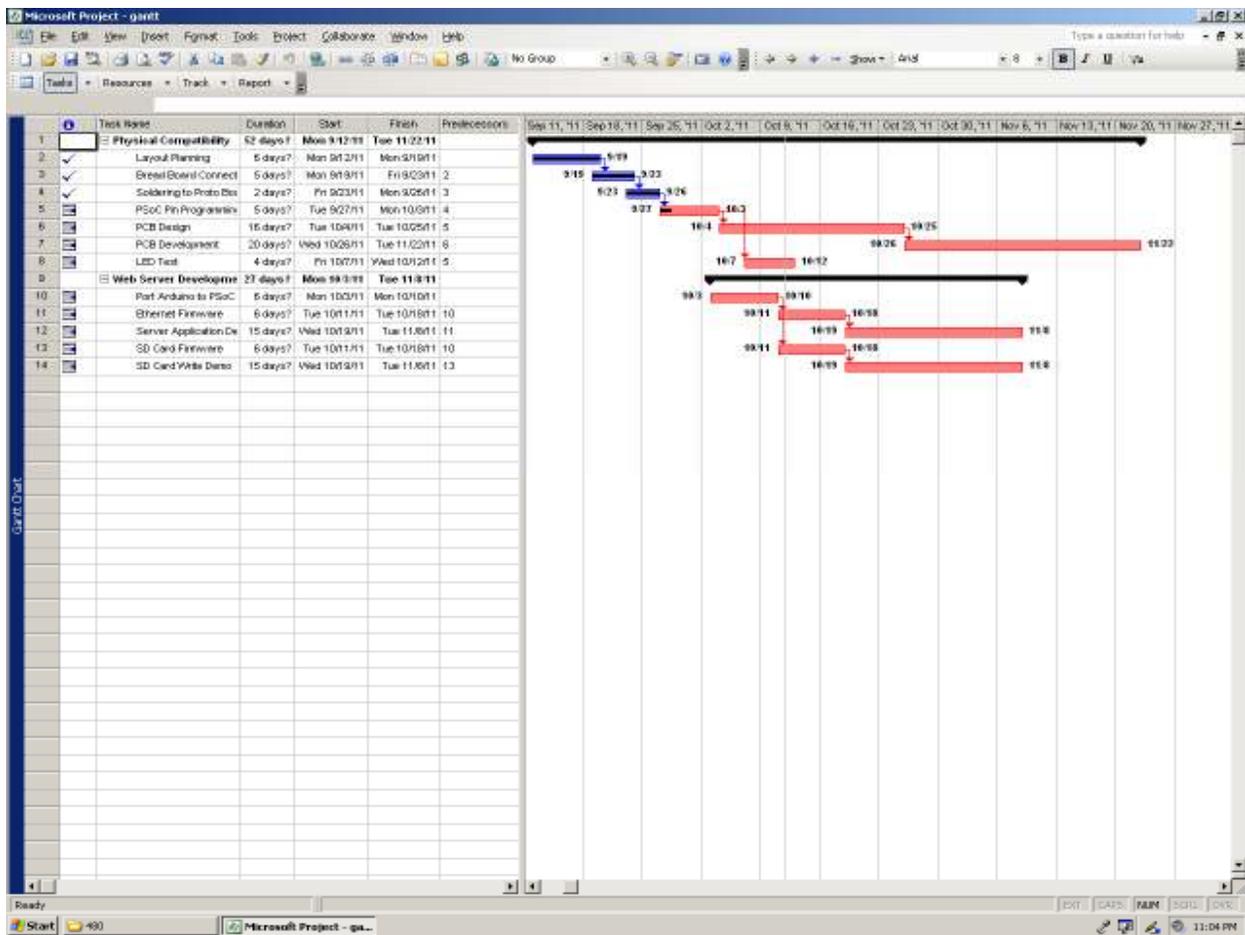
Week 11: Test of SD card write, Application notes due

Week 12: Test more shields, PCB design complete and submitted, Progress report 2 and demo due to facilitator

Week 13: Design Issues Paper due

Week 14: Professional self-assessment due, PCB return for testing and demonstration

Week 15: Design day



BUDGET

The proposed design solution will stay well under the allocated \$500 for this project. Due to the software nature of the project and the ability to program the PSoC, a minimal amount of external hardware needs to be purchased. The largest allocation goes to the fabrication of the custom printed circuit board. The breakdown of the proposed budget can be seen below.

Item	Cost
Arduino Ethernet Shield	\$46.72
Sparkfun Arduino ProtoShield Kit	\$20.51
PCB Fabrication (approximation)	\$70.00
Arduino Motor Shield	\$19.25

Additional Hardware (Headers, etc.)	\$5.00
Packaging (Approx.)	\$30.00
TOTAL:	\$191.48

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