

ECE 480 Design Team 3 Proposal

Power-over-Ethernet for Wireless Home Automation Sponsored by Texas Instruments

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Executive Summary

With steady increases in energy costs and the demand for low power devices on the rise, engineers are now looking to tackle the situation with new innovative approaches. Texas Instruments Inc. has proposed a design to implement a Power over Ethernet (PoE) enabled gateway to low-power monitoring devices. PoE is an effective mechanism to safely transfer power and data over long distances within the same cable simultaneously. The intended application for this would be to power monitoring devices that interact with wireless sensors within range. The use of low power wireless protocols is essential in maintaining efficient energy usage within all nodes of the network. These sensors could be of any application desired by the user, including monitoring devices used for building control, homeland security, medical instruments and agriculture. Using parts and packages from TI, the prototype provides an effective means for monitoring sensor activity as well as maintaining low cost and low power.

Table of Contents

1. Introduction.....	3
2. Background	5
3. Design Specifications.....	6
4. FAST Diagram.....	9
5. Ranking of Conceptual Designs.....	10
6. Proposed Design Solution.....	11
7. Team Member Roles.....	13
8. Risk Analysis.....	15
9. Budget.....	15
10. Proposed Schedule.....	16
11. References.....	18

1. Introduction

Power over Ethernet (PoE) is an efficient concept for low power applications. The technology utilizes Ethernet to both power devices and transmit data on one cable. The technology is similar to Universal Serial Bus (USB) in which phones can both be charged and transmit data to a computer simultaneously. An effective implementation of this technology would be for using wireless transmission to monitor sensor information on a periodic basis. The advantage of this system is having the convenience of low-cost implementation and not requiring an AC power source.

In the modern world of wireless data transmission there is a growing demand for the use of sensors in many applications ranging from industrial to commercial markets. Wireless sensors are commonly used to monitor various environmental conditions. Using low-cost routing protocols such as Berkeley IP (BLIP) and Lightweight TCP/IP Stack (lwIP), our team will integrate sensors with a gateway. The team will develop a web based server to periodically monitor and control all connected sensors within the network. The gateway is remotely accessed through the Internet.

ECE 480 design team 3 will design and develop a PoE gateway that will use wireless protocols 6LoWPAN and Zigbee allowing efficient communication within the network. By using the Stellaris LM3S8962 evaluation board as a starting point, we will incorporate wireless communication which will serve as a gateway for our sensors. This approach will provide extendibility both in hardware and software aspects; for example the interfacing of Bluetooth provides multiple ways of communication. Also, the ad-hoc wireless setup will allow detection of additional sensors with minimal network

reconfiguration. This project will demonstrate multiple features of Texas Instruments' analog, RF, and software technologies in an area of high industry demand.

2. Background

In the fall of 2009 Texas Instruments made a unique opportunity available to our ECE 480 design team. The task would be designing and developing a low-cost Ethernet-to-wireless gateway that can be deployed wherever an Ethernet port can be located. The project is new to MSU and the team has the opportunity to be creative with the project and design it from top to bottom. Although the customer has some constraints to the project including time, cost, power and performance (rate and range, inter protocol bridging efficiency and size), the project is open-ended and can be designed to exceed customer expectations. The customer has mentioned that upon completion of the project it could be integrated with other analog, RF and computing technologies from TI.

Although, the design specification of the project will be up to the team, TI management suggested that the team could take advantage of the existing TI hardware parts like the ARM Cortex-M3 based microcontroller. Software will be developed using open source StellarisWare software package provided by Luminary Micro. Upon completion of the basic customer requirements, time allowing, the team will introduced other RF components that could be used in the design, such as Bluetooth. The customer has also requested that the gateway that the team builds have its own web server in order for easy management from the LAN.

We envision that the system will be used as a platform to organize and utilize information that is gathered between different sub-systems (i.e. sensors and web server). In order to gather all this information and integrate them all with no interference, a challenging design must be considered. The team has come up with a plan that will effectively produce the best option to integrate all these sub-systems in which we produce

the design in an incremental process.

3. Design Specifications

The Stellaris LM3S8962 Evaluation board in Figure 1 contains an embedded microcontroller and multiple integrated components useful in our low-power implementation. The interface shown in Figure 2 shows the availability of a 10/100 Ethernet controller and USB interface which provides for power and debugging respectively. This evaluation kit will be an initial implementation of our design; it will be used to determine the design and functionality of our PoE. With this feature working, the board will be extended for wireless communication. This kit also contains an embedded web-server for initial testing of our inter-network communication. With support of C code, the LM3S8962 is an ideal starter step to establish the basis of our project design. Figure 3 shows a typical application of both the TI TPS2384 power sourcing equipment chip and the TI TPS2375 Power over Ethernet power device (PD). This is one of the key elements in our design and will allow us to apply power to the four unused wires in a RJ-45 Ethernet cable. The TPS2375 PoE PD will sense the voltage on the line and recognize that it can receive power.

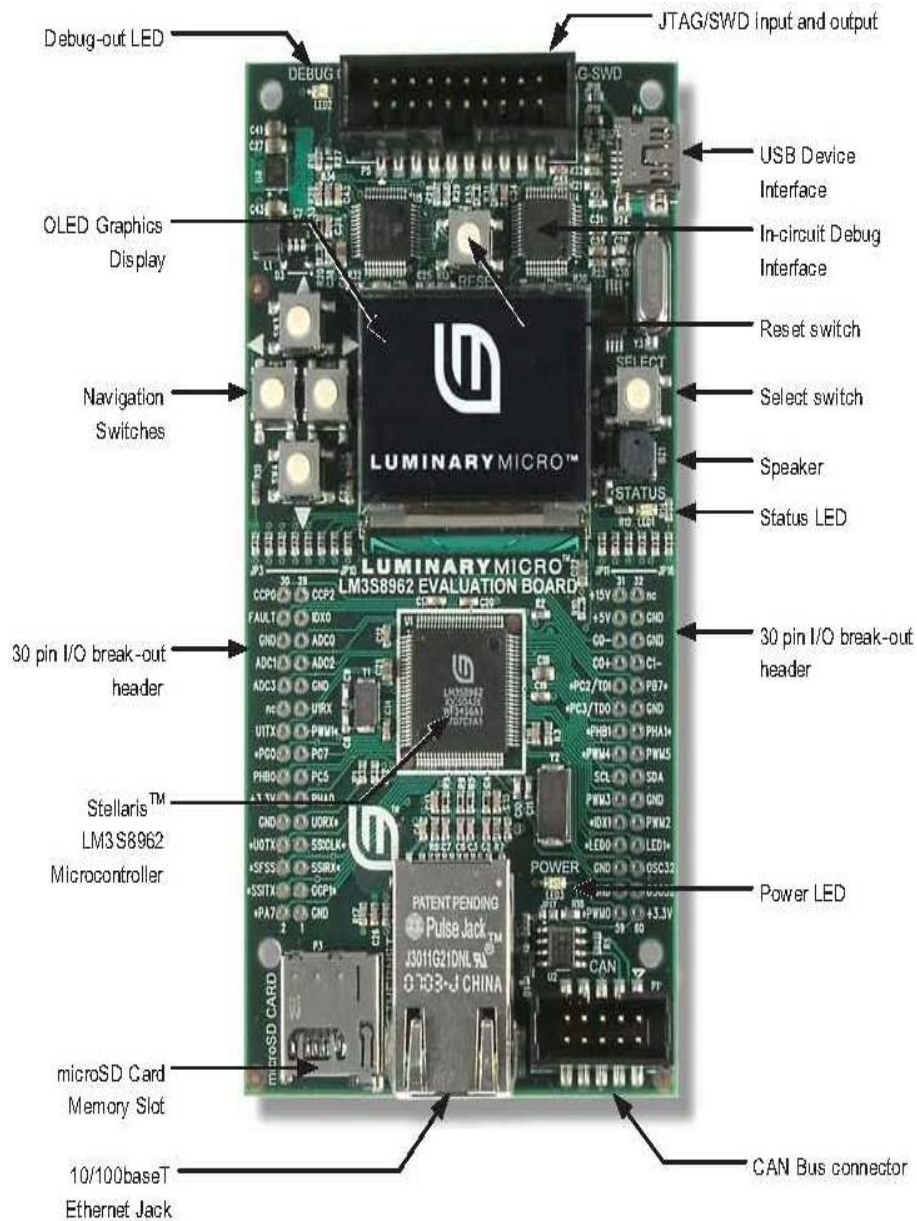


Figure 1. Stellaris LM3S8962 Evaluation Board

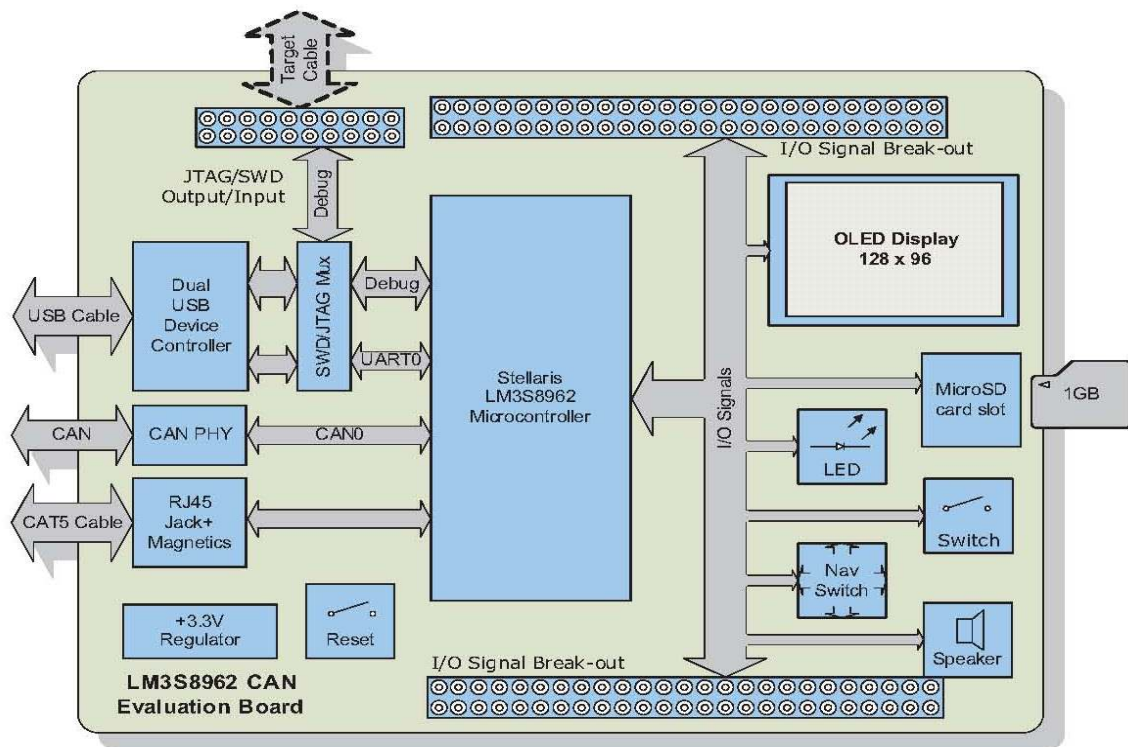


Figure 2. Stellaris LM3S8962 Evaluation Board Block Diagram

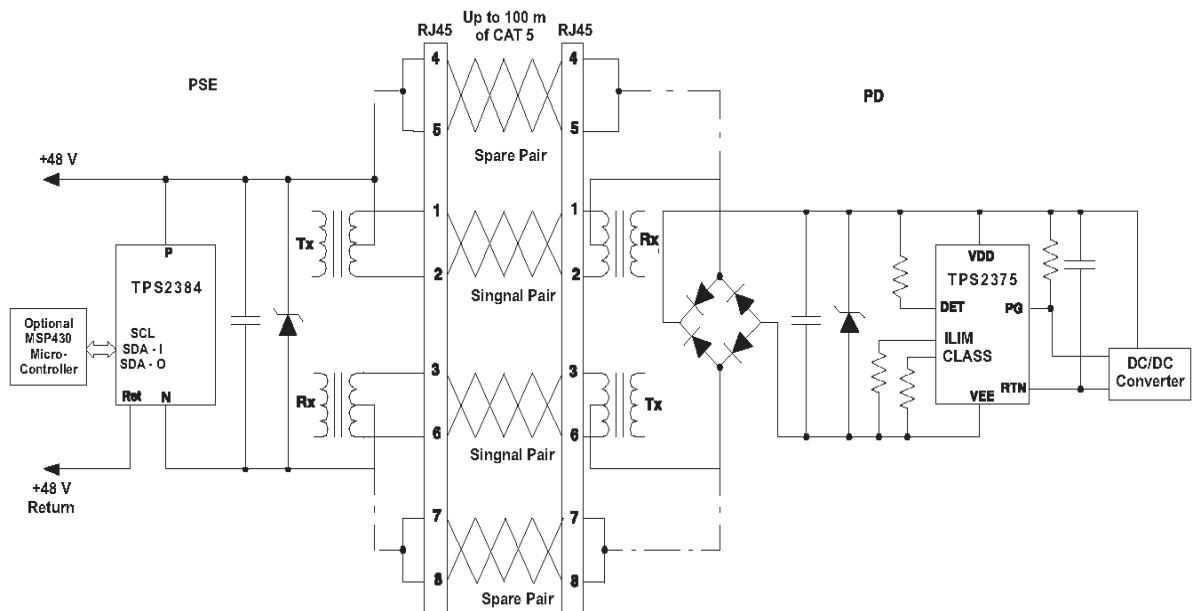


Figure 3. Typical application of TPS2384 PSE with TPS2375 PoE PD

4. FAST Diagram

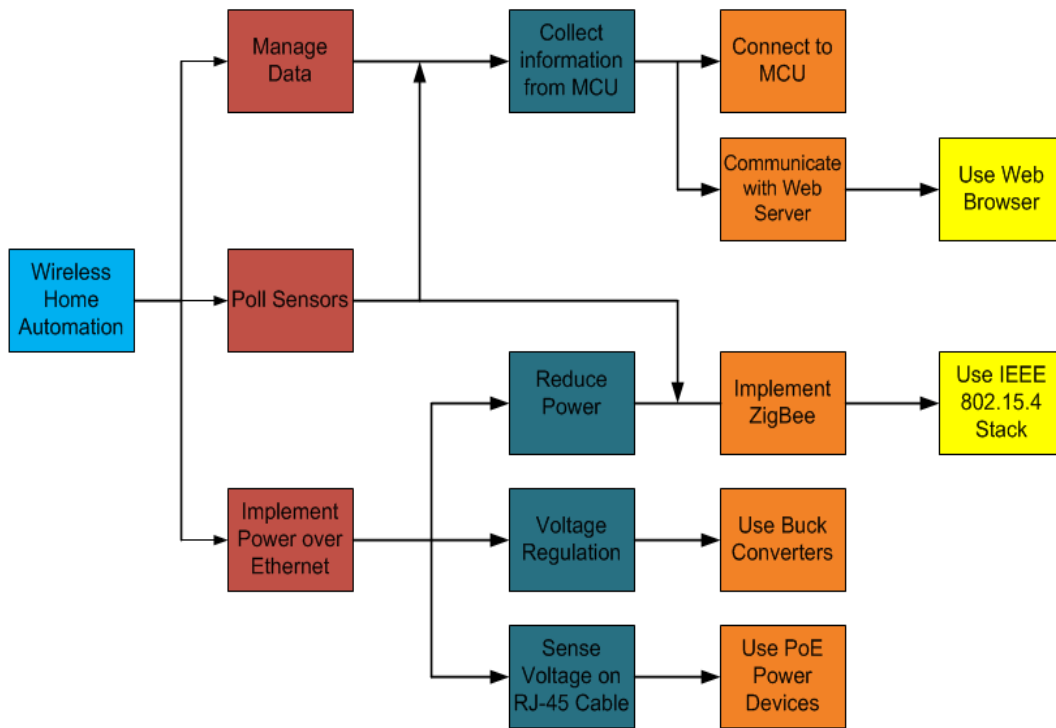


Figure 4. Wireless Home Automation FAST diagram

Our teams FAST (Function Analysis System Technique) diagram can be seen in Figure 4 above. The purpose of the diagram is provide a complete understanding of why we are designing the project and what functions go along with the creation. The diagrams logic is read left to right, with the leftmost object being our basic function and the rest being secondary. There are three main secondary functions involved in completing our design task: managing all data from the microcontroller; polling the sensors so that status information and communication can be performed; and finally

implementing Power over Ethernet to power our devices. As you continue to move further right, you can see how and why these functions are being performed.

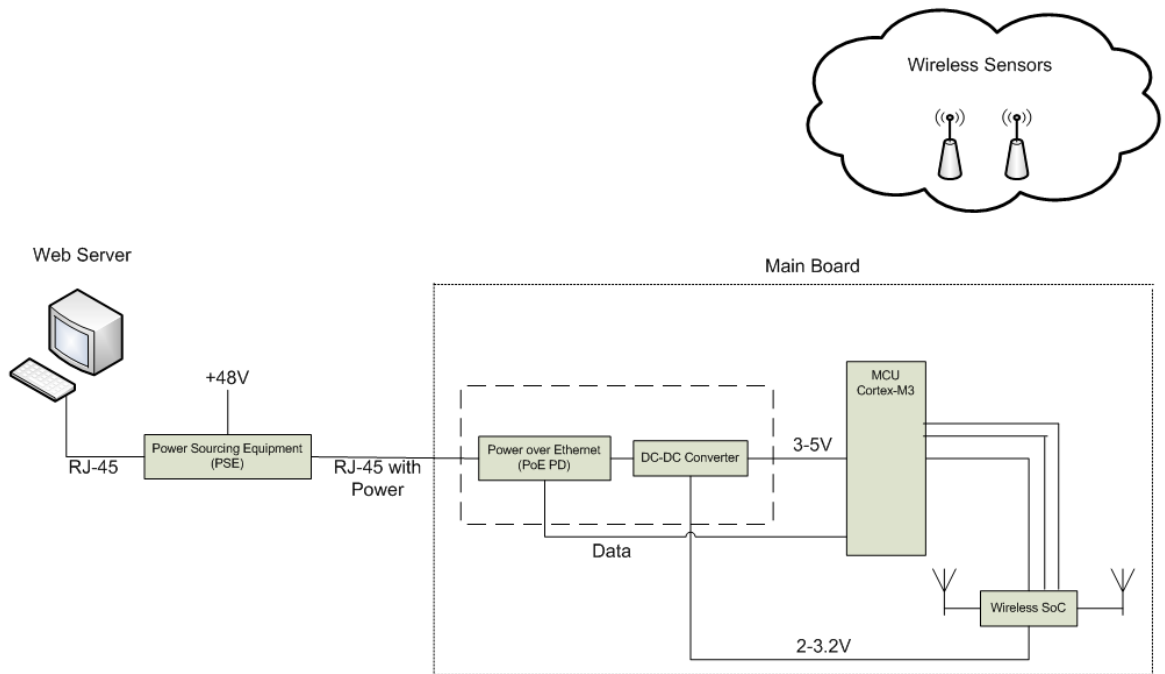
5. Ranking of Conceptual Design

Design Criteria	Weight	Power over Ethernet	Radio Communication	Web Server
Performance	5	4	5	5
Cost	5	5	5	4
Expandability	4	2	5	4
Power	4	5	5	3
Robustness	3	4	4	2
Size	3	3	4	1
	Total	94	114	82

Texas Instruments has addressed that in designing the project, a few constraints should be met. These include but are not limited to time, cost, performance, power, expandability, size, and robustness. To deal with time constraint, our team has created a schedule of when certain parts of the project must be completed. This allows us to satisfy all desired requirements by design day and allows buffer time in case of unexpected failures or issues with the project. Along with time comes cost. Cost can become an issue with a \$500 budget, however many of the parts for our project will be distributed directly from Texas Instruments or its subsidiary Luminary Micro. Nonetheless, we want to address the issue of keeping production cost down so that our design can be realizable in the market. Performance is by far the most vital design criteria that we would like to meet. Performance includes but is not limited to range and efficiency of our wireless signal and inter-protocol bridging efficiency. Without an efficient wireless and wired

signal, both communication between web server to circuit and sensor to circuit will be poor or non-existent and the final design will be useless. Power consumption is also critical to our design. All of the parts should be low-wattage to work under our power over Ethernet hardware power rating. Size and robustness are fairly obvious constraints as we want the design to both be stable and compact. In terms of expandability, we hope for our design to be accommodating to different wireless protocols such as Bluetooth and the addition of new hardware if the consumer deems it necessary.

6. Proposed Design Solution



Parts in Diagram:
PSE – TPS2384
PoE PD + DC/DC – TPS2375/77-1
MCU – LM-3S8962
Wireless SoC – CC2430/F128

Figure 5. Block diagram of proposed design solution

Our teams proposed design solution consists of four main components provided by Texas Instruments. The first component is the TPS2384, which is the Power Sourcing Equipment chip. This module is critical to our design as it allows us to use a 48 V power supply to deliver up to 15W of power over the RJ-45 Ethernet cable. Since there are four unused wires on every Ethernet cable, the voltage will be applied to those lines. The PSE along with the Power over Ethernet Power Device (PoE PD for short) must be in constant interaction with each other. The PSE will continuously probe and detect if a PoE PD is present. If it is, the PSE will both power the PD and will shutdown power to the Ethernet cable if the PD ever becomes disconnected.

The next important pieces of hardware which will be built are the DC-DC converters. These will be used to step down voltage from the Ethernet cable coming from the PD. In our design, we require two such converters. One will be used to step-down the voltage to 3-5V for the microcontroller, and another will be used for the wireless SoC to step-down to around 2-3.2V.

The wireless SoC consists of the TI2430/F128 module shown in figure 6. The module consists of two external antennas that will broadcast the wireless ZigBee signal to interact with any wireless sensors in the network. The SoC also will constantly interact with the microcontroller so that all data collected from the sensors can be logged and managed. This data will then subsequently be transmitted to our web server, enabling us to easily manage the system and check on the status of the sensors locally or remotely.

Finally, one of the most vital pieces of hardware to our design, the LM3S8962 microcontroller, is produced by TI's subsidiary Luminary Micro. This is the heart of our design and will do most of the processing and data management. As mentioned above, it

will also be in constant communication with the wireless SoC chip and the web server for easy management. The microcontroller will also require the most amount of coding because of these tasks.



Figure 6. TI2430/F128 Evaluation Module

7. Team Member Roles

David DeLuca - Lab Coordinator

David will be working on development and coding aspects of the web server required for the project. This will involve extended use of the StellarisWare software provided by LuminaryMicro and all coding will be based on the C++ language. David will also be responsible for working on and co-designing the radio required to send wireless signal from the main board to the any sensors connected in the network. He is responsible for ordering and providing the team with any parts or materials required for the project as well as keeping laboratory space clean and orderly.

Hassan Abdullahi - Presentation Prep

Hassan is responsible for all hardware design of the project. Hassan will be working on the design and development of the radio and all wireless antennas needed for the project. This includes but not limited to the implementation of the radio on the Stellaris Board and the EM connectors modules. Hassan's role for the team is also to coordinate the preparation of all presentations (oral and poster) and maintaining portfolios for the team.

Sasang Balachandran - Document Prep

Sasang will be responsible for the wireless communication between sensor and gateway. The main aspects include configuring Zigbee protocols within the network and configuring sensors to work with the gateway. In addition to this, Sasang will be working on the programming of the MCU implemented in the design of the board. Most of the programming/simulating will be done in collaboration with David. In a non-technical aspect, Sasang will be in charge of all the document preparation for the teams' proposals and reports throughout the design process.

Kang Hu Lee - Webmaster

Kang takes part in implementing BLIP and LWIP sensor protocols into the gateway. This involves not only making use of wireless communication but also adding some other protocols such as Bluetooth for short distance. Kang also will be working closely with Karthik to specify Power over Ethernet implementation in detail. Kang's non-technical role in the team is webmaster, developing and maintaining the team webpage.

Karthik Hemmanur - Manager

Karthik will be responsible for the design of the Power over Ethernet part of the device, and also co-ordinate with Sasang with wireless communications design. In addition to these, Karthik will also be working on regulations for bridging connections between the device and sensors. Karthik will be also responsible for team management, and also maintain the Gantt Chart.

8. Risk Analysis

According to the IEEE 802.3af PoE standard, 15.4 Watts of power and a minimum of 44VDC power and 350mA is provided to each device. Since we will be working with such high current devices, we must take appropriate precautions to avoid any electrical hazards. However, our main hazard will come from using the 48V power supply to apply power to the PSE which will apply power to the RJ-45 cable. Using basic lab skills and prudent judgment, our group should not run in to any issues.

9. Budget

As mentioned in the ranking of conceptual design, most of the parts required for our design will be provided via our sponsor Texas Instruments. This will allow for our \$500 dollar budget to be used on performance or any odds or ends that cannot be provided by TI. Currently, the only costs will be of the wireless sensors used and small electrical components such as resistors, capacitors, and diodes.

10. Proposed Schedule

Week	Tasks
Week 1 - 9/02/09 - 9/04/09	• First team meeting • Schedule first conference call with sponsor • Schedule weekly meeting time with facilitator • Discussion of project, brainstorm ideas
Week 2 - 9/07/09 - 9/11/09	• Research software and hardware aspects of project • Begin documentation in lab notebooks
Week 3 - 9/14/09 - 9/18/09	• Request of development kits and schematics from sponsor • Begin writing of pre-proposal document
Week 4 - 9/21/09 - 9/25/09	• Submit Voice of Customer assignment • Submit Pre-proposal assignment
Week 5 - 9/28/09 - 10/02/09	• Practice oral presentation with facilitator • Begin working on hardware design ideas
Week 6 - 10/05/09 - 10/9/09	• Work on FAST diagram • Submit final proposal assignment • Request/order hardware as required according to design specifications • Oral presentation to class 10/07/09
Week 7 - 10/12/09 - 10/16/09	• Submit design day program pages • Begin coding web server and microcontroller
Week 8 - 10/19/09 - 10/23/09	• Work on Gantt chart • Begin preparation for first demo and progress report • Work on demo 1
Week 9 - 10/26/09 - 10/30/09	• Submit progress report 1, demo 1, and project notebooks • Work on technical lectures
Week 10 - 11/02/09 - 11/06/09	• Present student technical lecture on 11/02/09 in 2250EB
Week 11 - 11/09/09 - 11/13/09	• Application notes due

	• Isolate issues in design
Week 12 - 11/16/09 - 11/20/09	• Submit progress report 2, demo 2 • Continue programming web server
Week 13 - 11/23/09 - 11/27/09	• Submit design issues paper by 11/25/09 • Work on final report
Week 14 - 11/30/09 - 12/04/09	• Work out final design, test for proper functionality • Finish poster for design day • Finalize final report • Professional self-assessment paper
Week 15 - 12/07/09 - 12/11/09	• Design Day • Submit notebooks • Submit final report

11. References

[1] StellarisWare, Firmware Development Package. [Online]. Austin, TX. Luminary Micro, 2009.

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