

# ECE 4890 Fall 2011: Design Project RFPs

*Revised 11/10/2011*

## Introduction

This document contains inputs received from the outside sponsors, faculty members, and other interested parties, with regard to senior design project ideas. The names of the submitters is available by request. When you have formed a possible design team, request project contact information from Dr. Wickert, and proceed to interview the submitter/customer for more details, and perhaps the formation of a preliminary requirements specification.

As more RFPs are submitted to me, they will be integrated into this document. Check back for additions and changes.

## RFPs

### **Project 1: Development of High Performance, Low-Power Compute Platform for Commodity Communications Devices**

#### Introduction

Currently barcode scanning and data capture for shipment and warehousing operations is performed on PDA-based Barcode scanning hardware. The hardware typically provides barcode scanning, wireless communications, and PDA capabilities using a Windows Mobile platform. Due to Microsoft certification requirements and the speed of change in operating system versions, hardware vendors continually provide new software installations. To keep up with the requirements, vendors often provide new operating system images and new versions of hardware to be purchased by the client business. This adds cost to the client and often requires continuous upgrade and modification to the custom business applications that run on the system.

Linux is capable of running on these platforms, and can be controlled by the owning business, not the hardware vendor or Microsoft. Using an embedded Linux installation on a PDA-based Barcode scanner will extend the usable life of the device beyond that typically experienced using Windows Mobile platforms, as well as reduce the software maintenance overhead required.

#### Product

The output of this project will be a generic Linux compute platform capable of scanning barcodes, capturing data input, and transmitting data to a server. The product created would be Linux-based barcode scanning and data capture handheld platform.

#### Requirements

- Create a development environment for the ARM processor with the CN3e device
- Create an embedded Linux installation on the CN3e device
- Provide a basic X-window system and QT GUI support

- Enable access and control of the 802.11 radio
- Enable access to the SD card
- Enable access to the touch screen
- Enable access to the keyboard
- Enable access and control of the barcode scanner
- Enable access and control of the audio speaker
- Bluetooth radio fully enabled and controllable through BlueZ software package.

### Constraints

- The system must be based on an Intermec CN3e device.
- The system must be able to capture Code39, Code128, Interleaved-2of5, code93, Codabar and PDF417 barcode symbologies.

### Application

An Embedded Linux handheld barcode scanning platform

### Areas of Engineering

- Embedded OS development
- Linux Development

### What the Student Gains

The student will gain experience creating an embedded Linux platform that deals with barcode scanning, data input and display, wireless communication, and specialized hardware.

## **Project 2: Wireless Leaf Sensor Data Relay Station**

Wireless leaf sensors are used to collect plant moisture information over a growing area. This data needs to be aggregated at a relay station and then sent to a base station for further analysis and decision making. The focus of this project is the design and fabrication of a proof-of-concept data relay station which uses a directional antennas to form interconnection radio links. All RF links will employ Texas Instruments (TI) CC2500 family 2.4 GHz radio chips. Directional antennas are employed by the relay station to increase the range to the base station and to increase the range to the sensor stations. The base station may also be equipped with a directional antenna to further increase the range of the base station to relay station link.

### Product

A 2.4 GHz proof-of-concept (POC) system based on the Texas Instruments MSP430 and CC2500 transceiver devices ([EZ430-RF2500 development kit](#)) will be assembled. The EZ430-RF2500 kit provides a USB dongle which will serve as the base station. The directional antenna(s) will be based on TI application note DNO34 (<http://www.ti.com/lit/an/swra350/swra350.pdf>). At present the POC only needs to communicate with the base station. Sensors local to the relay stations, e.g., temperature and humidity, will serve as payload data to sent to the base station. Packaging of the POC is very important. A conformal weather proof housing is needed for the electronics and

the directional antenna. The POC must be battery powered with an expected lifetime of 90 days between battery replacement. A custom PCB will be needed for the complete POC, including the planar PCB Yagi antenna.

The PC to which the USB dongle is connected, will use serial communications to display the radios received signal strength indication (RSSI) from the relay station and the sensor data. A GUI application will be developed using [Real Studio](#) for Windows™.

### Areas of Engineering

- Electronic circuit design, baseband analog, RF analog, and digital
- RF PCB design, layout, and fabrication
- Microprocessor systems, programming and interfacing
- Simple PC GUI development using serial port communications

### Student Solution

The student solution will include a packaged POC relation station. Battery life estimates will be required, and at least 90 days of growing must be supported. Battery life is critical. Using the simulated antenna gain, approximate free-space path loss, and the transmitter and receiver operating conditions (transmit power and receiver sensitivity), calculations will be provided to predict the transmission range in meters with a packet error probability of  $1E-2$ . This will be followed by field measurements. As a stretch goal a second directional antenna will be placed at the base station node, and the range calculations and measurements repeated.

## **Project 3: Fireworks Launch Control**

### Introduction:

The system used to shoot fireworks by the Gunnison fireworks team is outdated and inefficient for the current shows that it is being used for. The current set-up includes tedious wiring to awkwardly sized and spaced rails. Shots can only be fired in tandem if connected to the same position on the same rail. This creates a spider web of wiring that is hazardous for team members and makes it very difficult to trace down any continuity issues. Each rail is then connected to a 12 rail limited junction box. The junction box connects to a firing panel that requires a dial to select a rail, and switches to select an individual mortar tube. The dial and switch system is difficult to use in the dark. The dial and switch system also causes issues when trying fire shots in tandem that are physically separated for choreography purposes. Individual cues on the dial and switch system do not always fire when selected. This creates a potentially dangerous situation for team members and disrupts the choreography of the show.

A new, more ideal system is proposed to eliminate these problems with a new, modernized electronic firing system. Hardware should be revamped or recreated to fit the existing rack and tube system and optimize available components. The tubes, racks and magazines will not change. The firing panel should be replaced with a GUI that can control everything.

Product:

The product developed for this project will include a software GUI to fire individual and specific fireworks in a given time and order, and include associated hardware as necessary.

Requirements:

- Rails:
  - Sized to fit individual racks with a set number of spaces for each rack type
  - Able to be put in any order
  - Have individual power supplies
- Power Supplies:
  - Must be detached from power grid
  - Must supply sufficient power to fire entire rail
  - Must be easily replaceable between shows
- Junction Box:
  - Will be eliminated in the interest of expandability
  - An unlimited number of rails should be able to be included
  - Firing Panel
  - Will be converted to a GUI interface
- Multiple Systems:
  - Will need rail systems for multiple firing locations
  - Multiple locations should be controlled from one GUI if possible
- Mortar Tubes:
  - Mortar tubes must be individually addressable
  - Multiple mortar tubes must be able to fire at the same time or individually as desired
- GUI:
  - Pre-programmable to fire specific mortar tubes at specific times
  - Description of the contents of the mortar tube
  - Manual override, re-fire features
  - Includes modes for continuity check and firing
  - Requires two actions for security before firing
- Continuity Check:

- Very low power to make sure circuit is complete, but will not cause ignition of firework.
- Stretch Goal – Wireless Communication
  - Short range
  - Secure
  - Must reach multiple firing locations

Terminology:

**Rail** – Collection of audio style plug-ins where e-matches connect.

**Ematch** – Electronic ignition device commonly used to ignite fireworks with an electronic firing system.

**Rack** – Metal or wood stands that hold mortar tubes for stability. Racks hold different numbers of mortar tubes based on the size of the mortar tube.

**Mortar tube** - HDPE plastic tube, closed on one end that hold an individual firework.

**Magazine** – collection of racks secured together for stability.

**Rail Cable** – Cable between rail and junction box.

**Firing Cable** – Cable between junction box and firing panel.

**Junction Box** – Rail cables connect into; single firing cable coming out.

**Firing Panel** – Rail and position selector and firing mechanism.

**Firing Location** – Physical location of magazines based on fireworks regulations of required distance from audience and choreography requirements.

## **Project 4: Autonomous Robot 2.0**

### Introduction

There is a need for an autonomous robot to securely transport and deliver climate controlled items to pre-determined points in a pre-mapped single level building, with a small number of moving obstacles. Building off the incomplete robot from a Spring 2011 Senior Design team (Version 1.0), students will evaluate and validate the working parts of Version 1.0.

### Product

The product will be an autonomous, ground based robot capable of obstacle avoidance and navigating a pre-mapped area holding a cargo weighing 6 lbs.

### Application

Autonomous delivery of climate controlled items has a variety of applications in medicine, food service and manufacturing. This project will develop a prototype of such a robot that will, for demonstration purposes, deliver ice cream treats between offices at MITRE.

### Areas of Engineering

- Ubiquitous Computing
- Basic Robotics
- Embedded Device Programming
- Low Power Wireless Communication
- Novel User Interface Design and Development
- Autonomous navigation
- Feedback control

### Student Solution

The student solution will include a complete, functional prototype that will deliver sustenance to the engineers at the MITRE Colorado Springs facility on a regular basis.

### What the Student Gains

The student gets to apply a variety of engineering disciplines to solve a fun and challenging problem.

### Requirements

- Deliverers cargo between two points
- Needs to keep cargo cool in transit
- Carries 6 lbs. of cargo
- Wireless tasking
- Basic obstacle handling, capable of avoiding a person walking
- Non-evasive navigation
- Manufacture quality packaging
- Delivery notification when destination reached (audible)
- Automatic tracking of the inventory
- Provide a web site based human interface for tasking/status notification of signal and battery life strength
- Battery life/operation will last a minimum of 90 minutes
- A delivery queue with a max queue of five requests
- A wireless range of 100 ft

### Stretch Requirements

- Returning to a base station for charging of the battery
- Flair (plays ice-cream truck music and has appropriate decoration) with wireless mute button
- LED scrolled display

### Constraints

- Must be able to fit through doorways and maneuver in hallways at MITRE Colorado Springs, specific dimensions to be gathered by team during site survey

### Assumptions

- Will be deployed within a single level building,
- No weather proofing, etc. necessary
- Will not need to open closed doors
- No delivery speed requirement

## **Project 5: Development of Control System for Reactive Ion Etcher**

### Introduction

A reactive ion etcher (RIE) is a tool that uses a controlled plasma, created using an RF power generator, to etch various materials in a controlled, anisotropic fashion. Due to the consistently repeatable etch profiles they can provide, RIEs see widespread use in the semiconductor industry for a multitude of different applications. Most modern integrated circuits depend on RIE as an integral part of the processing procedure; RIE allows much greater control over etch dimensions than the historically favored wet etch processes, allowing for the creation of much smaller features. The highly three-dimensional structures of modern silicon sensors and MEMS devices would be nearly impossible to create without RIE. IAL uses RIE in support of integrated circuit failure analysis – once a device has failed in the field, we can dismantle it and find the root cause of failure, potentially allowing design and process engineers to identify a device’s weaknesses and take steps to improve upon it.

Though many RIEs used in industry already have integrated control systems that allow for precise monitoring and automated control of a whole gamut of parameters – reactant gas flow, etch chamber pressure, and RF power, to name a few – our RIE is a very basic model, and many of the parameters that constitute an etch “recipe” are controlled manually. Unfortunately, the greater the degree of manual control involved in a process, the less repeatable the process becomes. The goal of this project is to create a control system that is capable of automating the RIE process with a relatively high degree of repeatability, to ensure that any etch recipe that is developed can be used continually and reliably.

### Product

The final product will be a system that can interface with a Technics RIE 800 that is capable of interfacing with the RIE’s sensors, valves, and integrated logic in order to allow the automation of the etching process.

### Requirements

1. Any system built must be able to interface with the precision sensors and actuators already built in to the system. These include vacuum transducers, mass flow controllers, flowmeters, radio frequency power supplies, and others. Access will be provided to the tool and the equipment owner in order to determine the number of I/Os that will be necessary, and the precision

to which they must be held.

2. The control system must be able to hold a number of etch profiles in nonvolatile memory, and have a provision for inputting new etch profiles on the fly. The constituent elements of an etch profile are:
  - a.) Tetrafluoromethane (CF<sub>4</sub>) gas flow
  - b.) Oxygen (O<sub>2</sub>) gas flow
  - c.) RF Power
  - d.) Etch time
  - e.) Chamber pressure
  - f.) Chamber temperature (monitored only)
7. Though the gasses we use in our process are fairly harmless, many RIE processes use extremely dangerous gasses – for example, chlorine gas is often used in an RIE in order to etch metals. Any system designed should take this fact into account, and provide a robust safety interlock that will prevent harmful gasses from being pumped into the atmosphere accidentally.
8. In the same vein, the vast majority of parts that we process in the RIE are one-of-a-kind failures. Equipment failure is an unfortunate, yet inevitable fact of life; however, most customers do not take kindly to being told that their part was destroyed as a result of an equipment malfunction. Therefore, the RIE controller should be constructed with a “fail-safe” mechanism that shuts down the etching process gracefully, in the event of a malfunction (for example, the controller might disable the power supply if the measured RF power output deviates more than 10% from its set point).
9. On the subject of RF power – the RIE utilizes a 13.56MHz RF generator, with power output of up to 300W. This generator is hidden in the internal workings of the RIE and therefore well shielded from the outside world... but, since the RIE controller will have to interface to the RIE as well, it will be necessary to ensure the controller can reject any of the 13.56MHz signal that it may couple to. Also worth considering is whether the controller will need to adjust the impedance matching network internal to the power supply (to minimize reflected power) or whether the power supply already has an integrated controller for this purpose.
10. A high degree of automation is one of the primary goals of this project; therefore, the control system must be able to step through the various stages of the etching process (vacuum evacuation, gas injection, plasma ignition through the use of the RF power supply, chamber evacuation and purge) with a minimal amount of user interaction. Ideally, the user will be able to select a recipe from memory, hit a “start” button, and walk away.
11. The user interface for the device must be simple to use; as it stands currently, the system is operated mostly under engineering control, which drives up our costs. Any operator or technician should be able to use the interface to choose an etch recipe and run the process, given a reasonable amount of time and training.
12. Depending on the design proposed, we may require that the system be built onto a custom PCB as a way to increase reliability and extend the lifespan of the system. This may depend on the complexity of the design and methodology used to interface with the RIE.
13. In order to prove the robustness of the control system, a statistical analysis of the results shall

be performed over several days, using a group of “identical” devices, and using several operators to establish a baseline of repeatability and statistical process control. If not attained, an analysis of other possible variables that were not accounted in the original design will be reviewed, the proper engineering changes implemented, and the statistical analysis repeated.

### Areas of Engineering

- Embedded system design
- PCB design and layout
- Statistical analysis and process control

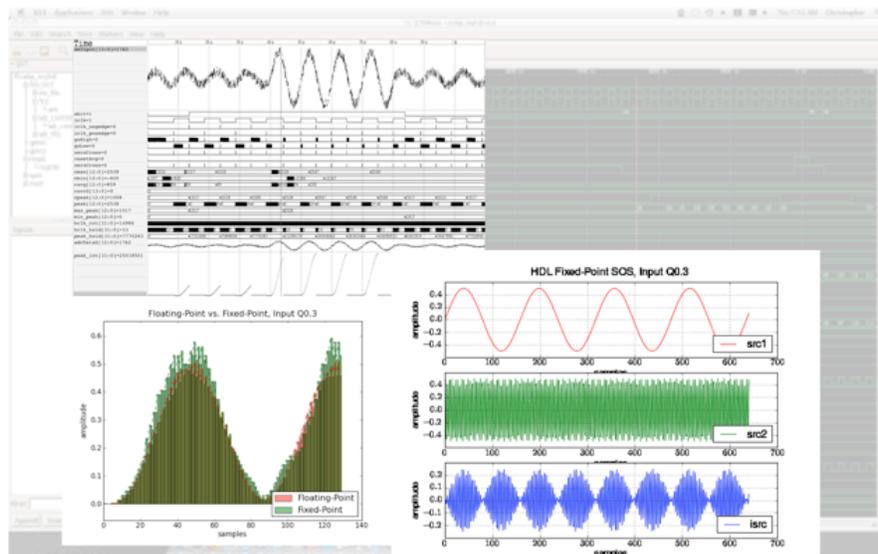
## **Project 6: Real-Time Audio Pitch Shifting**

### Introduction

This project involves performing DSP functions on an FPGA development board and implementing frequency scaling (pitch shifting) on streamed audio (real-time). A DSP algorithm needs to be designed that will scale down the frequencies between 4k – 20k to the 20 – 4k range. The algorithm needs to minimize harmonic distortion and aliasing. The algorithm needs to be designed such that it can be implemented on a general purpose FPGA.

### Project Description

1. DSP frequency scaling (pitch shifting) algorithm that minimizes harmonic distortion and aliasing and is also suitable for FPGA implementation.
2. FPGA implementation of the frequency scaling algorithm. A framework will be provided to interface to the hardware.
3. PC application to stream audio data to the FPGA board (framework provided). Also integrated into the application should be algorithm analysis to quantify the real-time algorithm [optional].



### Project Support

A USB FPGA Audio board will be provided and the students need to design and implement the previously described system. The basic framework for interfacing to the hardware and USB will also be provided. This project can be used in a real-world applications that includes but not limited to, accessibility, audio effects, etc.

In addition, a design contest will be held in the Fall of 2011. The above project will also be the design topic for the contest. Students can submit their designs for a chance to win a development board and a \$100 Amazon gift card. The contest will be announced in late September. More information and a framework will be provided to get started. See the last design contest for an example. See [www.dsptronics.com](http://www.dsptronics.com) for previous contest information. The Fall 2011 contest information will be posted late September.

### **Project 7: Verilog Linting Tool**

A linting tool is a tool that checks that a verilog design can be synthesized, simulated, tested, and adheres to company specified coding guidelines. A verilog design that is synthesizable can be translated to gates and implemented in an ASIC or FPGA. Testbenches are typically not synthesizable.

An example of a commercial linting tool is Synopsys's Leda RTL Checker. Details on Leda can be found at <http://www.synopsys.com/tools/verification/functionalverification/pages/leda.aspx>. UCCS has Leda installed on the Linux server LATS2.

### Project Need

Students in the ECE 4242/5242 Advanced Digital Design Methodology course often find that their coding style is not synthesizable and does not adhere to coding guidelines like number of comments, usage of the compiler directive. ``default_nettype none`, etc. When they take a follow on course to ECE 4242/5242 like 4200 Advanced Digital Design Methodology lab or 4211/5211 Rapid Prototyping with FPGA's they often find that their designs have to be completely rewritten to be synthesizable. It is desired to provide this feedback earlier in the ECE 4242/5242 class.

### Project Description

This project involves creating a linting tool to check for synthesizability and adherence to coding guidelines. The tool should be able to be used on a windows based PC using only a minimum of freely available software. Portability to a Linux based OS would be a plus. The tool is intended to be installed on any machine that students create their design on. This could be a personal PC, RATS, or the machines in EN229 or EN233. A web-based tool might be a good solution.

There are 3 main tasks to this project:

1. Create the linting tool
2. Create test cases for the linting tool. These test cases will be written in verilog and will contain code that should pass or fail when the linting tool is run on them as well as expected output.
3. Create a testing environment that will run the test cases created in 2 and compare the output (i.e. warnings/errors) of the linting tool against expected output.

### Team Makeup

The team should be made up of at least 1 computer engineer with strong software skills. A team of size 2 is appropriate. The team members need to have earned a B or better in ECE 4242 and should preferably be taking or have taken 4200 and/or 4211/5211.

## **Project 8: A Club-Mounted Golfer's Swing Analyzer with Wireless Display**

### Introduction

Golfer's who take the game seriously are always looking for ways to improve their game. Golfer's who are on top of their game, want to stay there. A club-mounted swing analyzer has been developed, but is in need of product enhancement. The objective of this project is add a wireless data link to the existing product so that swing velocity profiles can be displayed on a PC graphical user interface, in near real-time. The golfer can then see if his or her swing is *up to par* (pun intended).

*Personal best* profiles and selected pro-golfer profiles will also be available for comparison. In this way the golfer can keep track of their swing history and experiment with different techniques to hopefully improve on their game.

### Product

The end result of this project will be a proof of concept demo system which utilizes the Texas Instruments (TI) eZ430-Chronos Quick Start to wirelessly transfer golf swing velocity profiles to a PC graphical display. The existing product will also need to be ported to the CC430 family, which is the microcontroller + radio chip combination utilized in the eZ430 Chronos kit. On the PC host a software application will be written which post processes the club swing acceleration data into a velocity profile, plots the data, and allows for further analysis of the data

### Application

Provide amateur and pro-golfers with a reliable tool for perfecting their swing. In a future, beyond this project development, the wireless graphical display and software application will be posted to one or more popular smart phones. The solution will then be truly portable, allowing the golfer to compare their swing velocity profile to a database, anywhere on the course.

### Areas of Engineering

- Embedded systems design
- Graphical user interface software application development
- PCB design involving RF, analog, and digital circuit component layout
- Communications protocols at various levels and on more than one platform

### What the Student Gains

Experience with embedded systems and wireless development tools, experience with PCB design, practical GUI design and software application development.