ECE 4890 Spring 2011: Design Project RFPs

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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: Machine Shop Assistant Robot

Introduction

The University of Colorado at Colorado Springs has a machine shop in the new Science and Engineering Building that is heavily used by cross-functional departments within the college. New students are constantly in the facility, so a tremendous amount of training and hands-on instruction occurs every semester in the facility.

Unfortunately, the layout of the machine shop is ideal for students already proficient in using the equipment but is not ideal for instruction. Machines are located close to each other, and it is difficult for machine shop instructors to give a “bird’s eye view” of smaller devices when trying to give instruction.

Ideally, a robotic camera system could be installed in the machine shop to be used for instruction as well giving tours to prospective students. There are a few requirements of this system:

- It must provide video output to VGA format for connection to a laptop projector.
- It must be located above the machine shop tools so that it can look down a machine in use.
- The video camera itself must include panning, zooming, and tilt capability.
- The camera needs to be mounted to a cart of some sort that could run a track, providing visibility to a majority of the tools in the shop.
- The cart must be controlled wirelessly from a controller.
- There are numerous other goals that are optional but would make the system all the more valuable.

Product

The team taking on this task would produce and install a robotic camera system in the machine shop located in the new Science and Engineering Building. Major components include:

- A Track System
- A Cart
- A Mobile Video Camera
- A Wireless Controller that moves the cart and adjusts the video camera

Since the system will be used at UCCS, the student team must also provide full schematic documentation and functional description for later maintenance and expansion.

Requirements

The team taking on this task will be required to solve numerous, difficult engineering tasks, including:

- Building and designing a track that either distributes power to the cart OR a rechargeable battery system that returns to a “home” position on the track
- Developing a wireless controller to allow the machine shop instructor a simple way to control and monitor the camera
- Selecting a video camera that is fairly full-featured (pan, zoom, VGA output drive, etc).
- Integrating a complex system into a final, working solution that can view all of the fixed machine tooling assets in the working area

Stretch Goals

There are three stretch goals for this project, including:

- The ability for the machine shop instructor to remove the cart from the track and zoom very far in on some particular subject matter, then simply replace it on the cart
- Audio and Video recording of machine shop sessions for students who could not attend or for later use
- The design of a system that could be expanded to take on more of the machine shop

Constraints

Since the machine shop is in use, students will have to schedule time slots with the machine shop instructor for when they can test the device.

A budget, to be provided by the machine shop instructor, is not yet currently available. Students will have to choose materials wisely to stay within this budget.

Areas of Engineering

- Wireless Video
- Wireless Data Protocols

- Embedded Systems Design
- Motor, Robotic, and Control Systems Design
- Integration of Electrical Devices with Mechanical Systems

What the Student Gains

This is an excellent project that combines hardware, software, firmware, and even robotic design into a practical system of great value to the university while providing practical experience to the student.

Project 2: Digital Family Radio

Introduction

The FM, UHF *Family Radio Service* (FRS) is an improved *walkie talkie* radio system introduced in the mid-1990's by Radio Shack, and has become popular worldwide (source Wikipedia). Since that time, cell-phones and cordless phones have adopted digital communication techniques noted for lower-power, lower-cost, higher quality audio, and a more robust RF link (less susceptible to interference). We seeking an implementation of a *Digital Family Radio*, also with similar benefits, and which utilizes the 2.4 GHz ISM band.

Low-cost (<$1), low-power (13.5mA on/ 1uA standby, 1.5V), 2.4 GHz radio ICs now exist with data-rates capable of handling high-end audio (1-2Mbps). Assuming 1-10% duty cycle, a single AAA battery could last one month to one year or more. Higher quality applications could be envisioned including a streaming MP3 receiver/Internet radio, or two-way communication devices such as a cordless headset for cell phones or a Skype phone.

Product

The product shall be a 2.4 GHz Family Radio capable of communicating between two adjacent offices with programmable audio quality/power consumption. The power consumption and link quality can depend on several factors including range, audio sample-rate, and channel congestion. Theoretically a high-quality 128 kbps audio sample rate can be supported; however, power consumption would be high while range would be low. Lower sample rates would have lower quality audio, but power consumption would be lower and range higher.

Requirements

- Hardware:
  - The "shell" of a commercially available family radio can be used including the speaker, microphone, and controls. All of the electronics shall be replaced with this new design.
  - The radio link shall use the EM9201/2 RFIC and EM6819 microcontroller. A simple PCB or chip antenna can be used.
  - Choices of audio circuits are up to the design team, with emphasis on low-cost, low-power. Trade-offs shall be presented.
- Features:

  - Several audio sample rates shall be supported.
  - Audio should be buffered for continuous audio playback.
  - The RF channel and address shall be selectable.
- Analyses:
  - Analysis of signal quality and power consumption versus FSR shall be presented, at various data-rates.
  - The bill-of-materials for the electronics must be minimized, and priced in 100k quantities.

Stretch Goals

- Optimization of low power modes: While not transmitting or receiving the unit shall be in a low-power state
- Optimization of data-rate: If the signal becomes weak or packet loss is high, a lower sample rate could be automatically chosen.
- Support a stereo link with stereo headphones and a stereo microphone input
- An article on the design can be written and submitted for publication to a suitable technical journal such as EDN.

Constraints

- Must use the EM9201/2 RFIC and EM6819 microcontroller
- Total solution to fit inside a family radio shell
- Must be "clean" and presentable to potential customers

Application

The family radio will be used as a demonstrator to potential customers to show high-quality audio streaming over the EM9201/2 platform. It may also be used at trade-shows, etc. for the same purpose.

Areas of Engineering

- Digital Wireless Communication
- Low-Power Electronics (RF and Audio)
- Embedded Software

What the Student Gains

Hardware and embedded software design skills, consumer product optimization based on lowest power consumption and cost, high quality audio and RF design experience. Technical writing if the student team desires.

Project 3: 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 4: 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.

Project 5: Leaf Sensor™ Base Station Product 2010

Introduction

There is a need to address the specific integration of the wireless leaf sensor to a directional antenna. By interfacing a wireless leaf sensor module to a leaf and transmitting the data over long distances to a USB access point, the end user would be able retrieve leaf moisture data from a number of modes in a field.

Product

The product will be to develop an antenna base station using a long range directional antenna. The base station will receive data signals from a number of wireless leaf sensor modules in the field.

Application:

This Wireless Leaf Sensor base station is targeted to commercial farms in remote areas on a large scale.

Areas of Engineering

- Low power one-way 2.4 GHz short range wireless link - at least 15 mile range.
- Real time embedded software.

Student Solution

The student solution will include a complete prototype receiver base station. Battery life estimates will be required, and at least 90 days of growing must be supported. The ability to receive and parse numerous leaf sensor modes and battery life is critical.

Project 6: Leaf Sensor™ GUI Product 2010

Introduction

There is a need to address provide the end user with a graphical interface to interpret the data from numerous wireless leaf sensors in the field. The GUI allows the end user would be able retrieve leaf moisture data from a number of modes in a field and distinguish the modules/data from each other.

Product

The product will be to develop a GUI to parse data signals from a number of wireless leaf sensor modules in the field into a easy to use stand alone software tool.

Application

This Wireless Leaf Sensor GUI is targeted to consumers and commercial farms.

Areas of Engineering

- Low power one-way 2.4 GHz short range wireless link - at least 15 mile range.
- Computer Programming
- Real time software

Student Solution

The student solution will include a complete prototype of the GUI. The GUI will be user friendly; easy to understand and have real-time i/o features. The ability to parse numerous leaf sensor module and data is to a cvs file for used in Microsoft Excel is crucial.

Project 7: Leaf Sensor™ Wireless Module Product 2010

Introduction

There is a need to address the ability of the wireless leaf sensor module to receive data commands from the wireless base station. The Leaf Sensor™ Wireless Module developed in 2009 by Matt and Zane will be upgraded to receive and transmit data to the wireless base station

Product

The product, a next generation wireless leaf sensor module, will be consistent with the Leaf Sensor™ Wireless Module developed in 2009. The device will transmit leaf moisture data and be able to receive specific commands from the wireless base station. The base will be able distinguish module data from other units in the field.

Application

This second generation Wireless Leaf Sensor Module is targeted to consumers and commercial farms.

Areas of Engineering

- Low power one-way 2.4 GHz short range wireless link - at least 15 mile range.
- Assemble Language Program
- Real time software

Student Solution

The student solution will include a complete prototype of leaf sensor module including schematics and code. The device will be user able to transmit leaf moisture data and receive commands from the wireless base station. The ability of a wireless module to receive a specific commands and maintain battery-life for 90-days is crucial.

Project 8: Real-Time Audio Pitch Shifting

Introduction

This project involves streaming audio to a USB hosted FPGA board and performing frequency scaling (pitch shifting) on the streamed audio. A DSP algorithm needs to be designed that will scale down the frequencies between 4kHz – 20kHz to the 20Hz – 4kHz 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

The project will involve the design and implementation of the following:

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. A 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.

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 include, but not limited to, accessibility, audio effects, etc.

Project 9: Super Cheap Sound Signal Processor (SCSSP)

Introduction

We need to acquire analog signals, process them digitally, and output the processed signals in analog form. Sound simple? Well, here's the bad news for the Class of 2010 - by now, everything simple in electronics has been done. When you graduate, there are only the tough projects left. So here are some challenges that make this project a little tricky.

Product Description

1. You need to achieve this design with a BOM of less than $7, or at least that's your goal. (BOM, or Bill of Materials, is the list of parts and we colloquially also refer to it as the cost of the bare parts, before adding labor.)
2. The circuit needs to fit on 1 square inch of printed circuit board. You may use as many as 6 layers on the PCB, but watch those PCB costs. You can mount parts on both sides of the PCB. Again, 1 square inch is a goal, but if it's 1.5 square inches, we probably won't fire you.
3. Did we forget to mention that we want a battery charger circuit thrown in, so we can use rechargeable batteries such as Li-Ion? And we'll want to use a small battery, so battery life is important, but we won't put a number on that spec. We might also want to use a single Alkaline battery so we can keep our options open. That means that you'll need voltage regulators to be able to use a range of input voltages. If it's really inconvenient to add that single Alkaline capability, let us know.
4. One more thing - the signal processing needs to be low noise, better than 80 dB SNR. If the battery charger is noisy, we don't mind if it affects the analog signal processing since we won't charge the batteries when processing analog signals. However, we will need to regulate the circuit voltages to run the circuit, so using low-noise voltage regulators is important. The input signals are 0.5 V p-p, with a frequency range of 1 Hz - 10 kHz, but we're only interested in processing a band from 20 Hz - 2000 Hz. So you will be able to filter quite a bit of noise.
5. It might also be nice to be able to output the filtered signal in digital format via an SPI port. We'd like the digital output to be 16 bits at a common sampling rate like 8000 Hz, 11025 Hz, 44100 Hz, etc. Just pick one that works for you. If you go too low, you'll affect SNR, and if you go too high, it'll be difficult to do the signal processing in software on a low cost processor.
6. We're partial to the Texas Instruments MSP430 family, so please use one of their micro-controllers to implement the project. They're low cost, use very little power, and they have instructions that will help with the filtering.
7. Signal Processing - We want to do fairly basic digital filtering and be able to select filters with external control keys:
   a.) Filter A: 20Hz – 200Hz
   b.) Filter B: 20Hz – 1000Hz

c.) Filter C: 80Hz – 500Hz

d.) Filter D: 120Hz – 1000Hz

e.) Filter E: 150Hz – 2000Hz

All filters are ±1.5dB, and we don't want them to ring too much. We don't mind if the roll-off is quite gradual, say, 40dB per decade, with stopband attenuation of about 20 – 30dB, but the more the better. Normally, digital filter design is a pretty easy process - throw it into Matlab and get the results. But when you're trying to do it in a low-cost chip with limited math capability, you won't have the luxury of doing some 100-tap FIR filter. So it may be challenging to make these filters run in real time. You also have to watch finite word length noise problems.

– Input impedance - the analog input impedance should be more than 2K Ohm - not very problematic.

– Output - the analog output needs to be able to drive small headphones with 16 Ohm impedance without clipping.

So we expect to need a voltage range of about 2V p-p. Almost forgot – we want to be able to adjust the output signal level, either with key inputs to the MSP430, or a digital pot with up-down controls, as long as it's not too expensive.

– Testing - We will test the quality of the signal processing, SNR and circuit performance by listening to the signals we inject as tests.

The human ear is far more sensitive to noise than an oscilloscope display. We recommend that you test your circuits the same way. We will provide headphones that will reproduce some pretty low level noise clearly. You'll be able to hear a bad voltage regulator for instance. We'll also provide the audio source that we want you to use for testing.

6. All this has to be done according to your academic schedule. No project has unlimited deadlines. In the real world you're about to enter, not only are the simple problems gone, the world just ran out of money! Good Luck out there.

Project 10: Radio Station WWVB Time Code Decoder and Time Base PLL

Introduction

Radio station WWVB operated by NIST (http://tf.nist.gov/stations/wwvb.htm) and located near Fort Collins, Colorado continuously transmits time and frequency signals at 60 kHz. The time code consists of an AM modulated bit stream transmitted at a rate of 1 bps (60 bits per minute) and is synchronized with the carrier. The 60 KHz carrier itself is slaved to an atomic clock and has an uncertainty of 1 part in 10^{12}. The scope of this project is to build a 60 kHz radio receiver that can receive the 60 kHz carrier, demodulate the time code, and using a PLL slave a local 10 MHz VCXO to the incoming carrier to create a precision local time base suitable for instrumentation.

Product

A receiving tuned-loop antenna with an integrated JFET or op-amp pre-amp should be used to receive the incoming 60 kHz carrier. After filtering, the signal should be fed to an AM demodulator to recover the time-code bit stream, and also to a limiting amplifier to recover the carrier. A programmable microcontroller, such as the MSP430 from Texas Instruments, is used to decode the bit stream and monitor/manage the PLL. The VCXO can easily be constructed using the CDCE913 or similar device, also available from Texas Instruments. A temperature sensor and precision DAC are used to control the VCXO and close the PLL loop such that if the radio signal is lost, the VCXO can continue to operate with minimal loss of precision for a short period of time.

The current time and date must be available over either an RS232 or USB serial port. USB is preferred. The 10 MHz precision time base must be adequately buffered, amplified, and filtered to create an AC-coupled 1 V_{pp} sine wave output available on a 50 Ohm BNC connector suitable for connection to external test equipment such as RF signal generators, spectrum analyzers, etc.

Application

This device will be used as a local time base for laboratory test equipment. The USB interface will allow a computer to connect and read the current time and monitor that status of the PLL.

Areas of Engineering

- Tuned Loop Antenna
- Fixed frequency analog PLL Design
- MCU programming, digital PLL design
- Linear Amplifier, filter design
- AM Demodulation

Student Solution

A remote receiving loop antenna with integrated pre-amp connected through coax to a local PCB containing the MCU, PLL, crystal time base, and interface (RS232, or USB) circuitry. The precision of the PLL solution should be demonstrated by measurement against a known good laboratory time base.