

ECE 4890 Fall 2009: Design Project RFPs

Revised 11/13/2009

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: Low Cost UAV

Although the modern day SWAT team primarily focuses on training in close quarter environments, for teams like ours there is still the need to be prepared for situations that potentially arise in rural areas. When a tactical team searches for and or engages one or more suspects in a rural environment, having complete knowledge of what they are facing is key to the officer's survival and safe apprehension of the suspect(s). Without adequate knowledge of the situation, disaster can result—think Ruby Ridge, Texas Seven, or Waco. Since rural areas are predominantly the responsibility of small, local police forces, a cheap and reliable method of gaining situational awareness is needed for modern America's police forces.

Product:

Although a military UAV such as the predator would be ideal, this is obviously out of reach for every police force. Instead, a short range UAV with video capability would be financially obtainable for average police forces. Below is a list of requirements for such a UAV:

- Less than \$500
- Minimum 10 minute flight time
- Minimum 800 foot range between operator and UAV
- Inaudible at 50 feet
- Decent video quality, able to be viewed on currently fielded MDCs
- Operate in average wind and weather conditions

Application

This UAV would be used by local response teams to gather intelligence while on scene at their deployment location.

Project 2: Database Application for ABET Records Keeping

Introduction

The intent of this project is to develop a database application for records keeping by the Department of Electrical and Computer Engineering (ECE) faculty of the University of Colorado at Colorado Springs. This database will hold course assessment information that the department maintains on specific electrical and computer engineering and computer science courses, as part of the accreditation process by the Accreditation Board for Engineers and Technologists (ABET). This a software centric project which will be most appealing to computer engineers. The core set of requirements will be introduced in this RFP. More details will follow via one-on-one meetings with a team interested in pursuing this project.

Presently individual faculty maintain assessment records in PowerPoint™ (PPT) files on a course-by-course semester-by-semester format. The responsible faculty member holds a local copy of each PPT file, which is shared for peer review at the beginning and end of each semester. Sharing at present consists of moving file copies in and out of a PPT file repository that is organized by semester and year. When a semester is closed out, the faculty member updates his/her local PPT file copy for course xxxx_spyyyy.ppt/xxxx_fayyyy.ppt, and places it on the EAS file server under the ECE department common file folder, and then a subfolder denoting the term and year. A top level PPT file which holds a summary of the overall assessment information is then be manually created. There is much to dislike about the current process. For one thing, it is very labor intensive to move these files around by hand. The PPT files are graphics intensive, but do not need to be to convey the records keeping mission. Creating the top level summary document is also labor intensive, as it requires the author to open and close all of the individual files to extract just a few pieces of information. The assessment documents associated with a particular course are not *threaded*. If you want to see the assessment history of a particular course or generate a report of issues being dealt with for a particular course over time, manual access to individual PPT files is required, again very labor intensive.

Product Description

The finished product will be a database software application hosted on computing resources of the College of Engineering an Applied Sciences (EAS). The database application itself should be fully Web accessible from anywhere on campus, and with password protection, accessible from offsite locations, e.g., home. The records maintained on the specific ABET assessment courses, should be at minimum the same information contained in the present PPT solution. This new product should go beyond the capabilities of the existing solution, however. The fact that it is a database centric product, means that a variety of report generation capabilities shall be implemented. The reports themselves should be attractive when printed so that they are easy understand, i.e., an ABET visitor should be able to assess our assessment process and trends with regard to specific courses with ease. The reports themselves should be able to thread information about a particular course over time, or assessment information common to all courses should be viewable by semester, etc. Top level reports, currently required by the ABET assessment process, are of utmost importance. Other features and specific requirements will be added during the team interview with the customer.

The product should be maintainable, expandable, and robust with regard to data storage integrity. On-line help should be available describing how to use the product to enter data and how to gener-

ate various report types. A PDF users guide shall also be provided, and shall downloadable from the Web interface, in addition to HTML-based on-line help.

Areas of Engineering

- Software engineering
- Web-based technologies
- Database programming

What the Student Gains

In the end the student will gain experience in developing a turn-key Web-based software application, with very specific end-user requirements. The team will also learn how to craft the solution with very specific requirement, while at the same time be expandable with grow with future needs. The fact that the software solution is expandable also means that the student will learn what it means to write maintainable software.

Project 3: 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 ± 1.5 dB, 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 4: KADSP Signal Processing

Introduction

This is an advanced version of Super Cheap Sound Signal Processor (SCSSP), however we now want to substitute some *kick-ass* signal processing capability to our system. (That's what KA stands for in the title!) Cost and size are still an issue, but we'll have to give you a bit more space to play with and you'll probably prove this system without building circuit boards, resorting instead to a development board. If you'd like to build the hardware, we can explore that, but the chip we want you to use is not easy to work with from a mechanical point of view, so you may be better off with an evaluation board. More about that later.

In KADSP, we want you to develop an audio processing system with the same specifications as SCSSP, except that we'd like you to use the Texas Instrument TMS320C5505 Digital Signal Processor. This will provide you with far more DSP capability than a simple micro controller. This chip is quite amazing and you'll be able to have lots of fun with DSP horsepower. Since the TI DSP chip is packaged in a small BGA that is difficult to work with, you will be provided with an Evaluation Board to test out your system concept, so there's less hardware design than is SCSSP.

Simple? Not so fast – if you think that, you didn't read the warning to your generation. Since you'll have time on your hands not having to build hardware, we're going to give you some Matlab DSP design work. So you'll first do some DSP algorithm design, and then code it and run it on the DSP. The signals we work with have some interesting characteristics. The filtering we mentioned in SCSSP are trivial for a powerful DSP chip. So we're going to give you some unusual signal processing problems as well. We want you to look for certain *sound patterns* in our special audio signals and write code that can detect certain audio events or patterns and do some signal processing according to what the DSP is *hearing*. This kind of work requires some DSP skill, a good bit of software coding and debug skill and a good mind for problem-solving to create smart algorithms. You won't find canned software to build this kind of intelligence.

The kinds of patterns we want you to look for are secret at this point. So if you sign up for this project, we'll reveal what we want you to solve.

Project 5: Sound Radio

Introduction

There are many wireless protocols out there that do wonderful things – Bluetooth, Wifi, Zigbee and so on. But we have a problem that can't be solved by any of these. We need to send our special audio signals to multiple listeners in a small space. Bluetooth transmits point to point with a theoretical limit of 8 recipients. Wifi can stream, but it's not synchronous – different people might hear things at different times. Analog FM might work, but it may be too noisy or inadequate, but it is one candidate. Another is a digital radio chipset from Texas Instruments, the C2500 family. These are radio chips with micro controllers built in. So one can do radio transmission and reception and write code for the processor. There may be other candidates out there as well. You can survey the market as part of your project.

Technical Requirements

1. The system should be quite low cost. The transmitter BOM should be around \$20 and the receivers should cost about the same. Ideally we'd like to achieve half that cost.
2. We need to transmit audio in the frequency range 20Hz - 2000Hz. Wider bandwidth is nice if you can do it without adding too much white noise. A single channel (mono) is all we require. Stereo is cool but unnecessary.
3. SNR needs to be around 80dB. We might be able to live with a somewhat worse SNR and do some serious filtering as a second-best solution, but in the best-case system we'd like low noise.
4. The system should not be affected by TMDA, CDMA, Wifi, Bluetooth and all the other RF junk in a typical environment today. So you'll have to do some RF immunity testing - rather challenging. Oh, and your circuit is going to have to pass FCC requirements (as well as European standards).
5. Ideally, we'd like to be able to broadcast i.e. one transmitter and unlimited receivers. But if that's tricky, we'd like to have about 50 receivers. If that's too difficult, we'd still be able to use a system with 12 receivers at a time if we have to, but that limits our market opportunity.
6. The hardware should be small - less than 2 square inches, and run on a small battery for an hour. Ideally, we'd like to use a small rechargeable battery, but we'd like you to focus on the radio challenge, not the power supply. Just keep in mind our ultimate goal when you're considering power consumption.
7. The audio input signal can be digital, but it would be nice to be able to input an analog audio signal. On the receiver end, the same applies - digital is OK, but providing for analog is convenient. So it could be digital audio to digital audio, but we'd also like analog to analog.
8. Testing will be done using our special audio signals. These can be very challenging. We've tried many radios and not found any that really did the job. Oh, and just to make things more difficult, we don't want the radio design to interfere with our own analog audio circuits, so we may ask you to explore making our own circuit RF immune, or making sure your circuits don't clobber us with interference.

Project 6: Leaf Sensor™ Remote Wireless Product

Introduction

There is a need to eliminate hard wiring of Leaf Sensors to computers. By interfacing a wireless module to a leaf sensor and transmitting the data to a USB access point the end user would be able to place the leaf sensor on plants with range of a PC.

Product

A 2.4 GHz system based on the Texas Instruments MSP430 and CC2550 transmitter devices on a small discreet flex circuit that connects to a Leaf Sensor™. The Leaf Sensor™ output voltage and temperature is integrated into the transmitter. The MCU in the sensor will read the Leaf Sensor™ in question, and periodically send a one-way transmission to the USB access point. Each flex cir-

cuit will contain its own battery. Battery life is of paramount importance, so the advanced power management features of the MSP430 must be utilized.

Application

This Wireless Leaf Sensor-computer is a consumer product targeted at home gardeners and greenhouse growers.

Areas of Engineering

- Low power one-way 2.4 GHz short range wireless link - at least 3 meter range
- Low power MCU battery management
- Flex Circuit Design
- Real time embedded software

Student Solution

The student solution will include a complete prototype mounted to a Leaf Sensor™. Leaf Sensor™ transmitters need not be in custom plastics, but should be nearly the size of the final form factor. Battery life estimates will be required, and at least 90 days of growing must be supported. The low-mass of the flex circuit and battery is critical.

Project 7: All-On-The-Crank™ wireless Cadence and Speed Bicycle Cyclo-computer

Introduction

Both wired and wireless cyclo-computers are commonly available. Either way, these devices typically rely on a magnet mounted on either the crank or front wheel to activate a fixed mounted reed switch sensor found somewhere on the fork or frame. This two piece solution can be difficult to mount on high performance time trial or unique geometry bicycles, and can be unreliable as the sensor performance depends on the gap between the magnet and sensor. It is also aesthetically less pleasing.

Product

A 2.4 GHz system based on the MSP430 and CC2550 Transmitter devices that mount directly on the front axel of a bicycle and to the crank arm of the bicycle. The element sensing rotation of the wheel/crank is integrated into the transmitter rather than a magnet and reed switch setup. The sensor could be a variation of a mercury switch, a single axes accelerometer to detect the G vector direction, or some other suitable sensing element. The MCU in the sensor will count revolutions of the crank or axel in question, and periodically send a one-way transmission to the receiver/display unit. The receiver/display unit will receive the count updates from the speed and cadence sensors, compute velocity and RPM, and display the information to the bicyclist. There are (at least) 3 devices involved- a speed sensor to be mounted on an axel, a crank sensor to be mounted on a crank arm, and the wireless receiver/display to be mounted on the handlebars. Each sensor will contain its own battery, as will the receiver/display.

Battery life is of paramount importance, so the advanced power management features of the MSP430 must be utilized.

Application

This cyclo-computer is a consumer product targeted at serious, elite, and pro bicyclists and tri-athletes.

Areas of Engineering

- Low power one-way 2.4 GHz short range wireless link, 3 meter range.
- Low power MCU battery management.
- Sensor design.
- Real time embedded software.

Student Solution

The student solution will include a complete prototype mounted to a bicycle. The receiver and display need not be in final form factor, but should be mountable to the handlebars. The sensors/transmitters need not be in custom plastics, but should be nearly the size of the final form factor. Battery life estimates will be required, and at least 500 hours of cycling must be supported.

Project 8: 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.

Project 9: Amateur Rocketry Flight Data Logging Device Version II

Product

Amateur rocketry is enjoyed by enthusiasts worldwide. Individuals can invest as little as \$20.00 to achieve flights in excess of 800-meters or many thousands of dollars to achieve impressive heights while carrying payloads. In all cases, individuals build the rocket and can optimize its performance. Unfortunately, there appears to be no inexpensive, robust, light-weight payload that could be attached to these rockets which could record critical flight data.

The goal of this project is to improve upon the LeADER Project which is to be demonstrated by ECE 4899 students in Fall of 2009. LeADER is a custom PCB outfitted with an 8-bit microcontroller which can be placed inside of a 1" diameter rocket payload housing.

Application

Amateur rocketry enthusiasts are interested in recording key metrics on their flight, including total time of flight, height of the rocket above earth with respect to time, maximum height of flight, acceleration, velocity, and position. A recorder can be placed inside the rocket during its entire flight and record this critical information. Once recorded, the information would need to be transmitted to a computer for further analysis and logging. The recorder needs to be robust enough to record data reliably during flight and re-usable for later launches.

This project proposes several key improvements to LeADER, including:

- A Remote Trigger that initiates the launch sequence
- A 3D Gyro and Accelerometer System to improve flight data
- A barometric pressure sensor for accurately measuring height

- “Still” Imagery of the Rocket Captured During Flight
- Improved Software for Analyzing Flight Performance

There are several stretch goals for the project as well. If they are not implemented on this version, future Senior Design Teams may implement these features:

- RF Communication Link between the rocket and a laptop on the ground to transmit images and data “live” during flight.
- “Live” Imagery of the Rocket Captured During Flight (preferably color images)
- KML File Export Capability for 3D Plotting of Flight Trajectory with Google Earth
- “Find My Rocket” – a simple solution for finding lost rockets when they land

Senior Project End Solution

The ultimate goal of this Senior Design Project is to produce a recorder that profiles key rocket performance data during flight. That data may be downloaded offline to a computer upon retrieval, stored in an on-board SD/MMC Memory Card, or transmitted real-time to a laptop computer using an RF Communication Link. A custom rocket will need to be built for holding this payload, and multiple test flights using different rockets with different performance will have to take place. The team will work with the advisor to balance keeping costs of the recorder low while maximizing features.

It is expected that the team improve upon the LeADER Project and use it as the starting point.

Possible Areas of Engineering

- Electrical Engineering: Custom PCB Design, Firmware Development, Data Transmission, System Design, Sensor Integration, Component Selection
- Computer Engineering: Communication with the device, data logging, data storage, data analysis tools
- Rocket Construction and Modification
- Feature vs. Cost Analysis
- Comparing Solution vs. Existing Products

What The Student Gains

The students on this design team will gain practical experience in taking a full product from concept to reality. They will engage in everything from component selection to testing, from analog design to software design. The sponsor may choose to post information about the student team, the design process, and recorder.

Project 10: Project: Underground Cable Ampacity Calculations

The Pueblo Chemical Agent Pilot Plant (PCAPP) project is currently under construction East of Pueblo, Colorado at the Pueblo Chemical Depot (PCD). The PCAPP project engineering design team working for Bechtel National Inc. (BNI) has a need to determine the amperage of 90 degree centigrade rated power cable installed in underground conduit and duct banks. It is known that

temperature can adversely affect the amperage capability of a power cable system, and the PCAPP team wants to ensure design amperage requirements to installed equipment are achieved upon installation of the cable.

This senior design project involves collecting data from cable manufacturers (BNI to assist in identifying appropriate suppliers) and using the cable derating ampacity calculations found in the National Electric Code (NEC) to determine the effects of temperature, ground depth and duct bank configuration and loading on the cable's ampacity rating. Calculations will be performed on various cable types and sizes to be specified by BNI. Calculations to be electronically documented in a tabular form to allow for ease in reference when designing power system circuits and checking power cable installations in the field. Automating the process would enhance the results of the project.

Upon establishing this cable ampacity information, the UCCS team should attempt to contact EPRI (Electric Power Research Institute) and or an NRTL (Nationally Recognized Testing Laboratory) to obtain test data representative of the data and analysis done by the project team.

Project 11: Multi-node 802.15.4 Radio Based Network with Network/DC Performance Characteristics Based on SOS Embedded Operating System

- Participate/drive the porting of SOS to Atmel based (RF230) hardware
 - Develop build tools for ATmega1281 + ATRF230 systems
 - Realize the implementation of SOS on these systems
 - Develop a sample application on SOS and Atmel hardware
- Performance characteristics
 - Publish network related metrics
 - » Network latency > 50 node network
 - » Network collisions, re-try, failure...
 - Power saving techniques
 - » Sleep techniques and associated power consumption
 - Geographical/geometric coverage per node

The SOS OS is managed by UCLA and is an alternative to TinyOS. It is completely C based and my serve to bring low power wireless networks to realization.

Required hardware will be provided by Atmel, Colorado Springs. Additionally, appropriate software tools and consultation with Atmel engineers will be made available.