

ECE 4890 Fall 2010: 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: RFP: Development of High Performance, Low-Power Compute Platform for Commodity Communications Devices

Introduction

Currently a consumer may purchase a Linux-based server for around \$500. The servers typically require surge protected AC power along with special cooling if more than a few servers are located together. This is not only a size inefficient model, but also a power inefficient model. Contrast this situation with a mobile phone. The phone is typically a very small platform that has been optimized for low power and high efficiency, which runs from a battery. If a phone could be modified to support Linux server functionality then a new paradigm for computing could be created.

The Android mobile phone market is quickly becoming one of the largest consumer products in the world, thus driving costs to a minimal amount, typically around \$250. There are currently over 100 different Android models, most of which are based on an ASIC chipset from Qualcomm. The primary processor within the ASIC chipset is an ARM processor variant running a Linux kernel at 1GHz or more. Many phones contain a 16 or 32 GB FLASH memory ideal for a large file system. This situation provides an opportunity to determine if the low-cost phone platform can be modified into a low-power, high-performance, compute platform.

Product

The output of this project will be a generic Linux compute platform capable of downloading and executing generic Linux applications, not Android specific applications. The product created would be a low-cost, high-performance, low-power Linux platform.

Requirements

- Do a survey of Android phones - must be a Qualcomm chipset. Select 1 or 2 phones
- Qualcomm will acquire the phones and send them to the students

- The students will “root” the phone to gain admin privileges
- Create a development environment for the ARM processor with the Android phone
- Determine how to open a Linux shell to the phone’s operating system
- Port a basic Linux development environment to the phone such as gdb, oprofile, and busybox
- Enable access to the phones SD card file system
- Port the GNURadio framework to the platform

Stretch Goals

- Access the RF hardware on the phone and generate an RF waveform using GNURadio framework and the USRP hardware platform
- Access the graphics processor on the phone for use to accelerate the GNURadio algorithms

Constraints

- The system must be based on an Android phone containing a Qualcomm chipset

Application

High-performance, low-power, low-cost Linux compute platform

Areas of Engineering

- Embedded SW
- Linux Development
- RF/modem development if the stretch goals can be met

What the Student Gains

Linux development techniques, software programming techniques, software porting techniques, RF analysis techniques.

Project 2: Autonomous Robot

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.

Product

The product will be an autonomous, taskable, ground based robot capable of obstacle avoidance and navigating a pre-mapped area.

Requirements

- Needs to keep cargo cool in transit
- Carries 2.75 kg of cargo

- Empty warning, status indicator that determines when cargo container is empty
- Wireless tasking. Technology unimportant, recommended: SMS, ZigBee 802.15.4, 802.11a/b/g
- Wireless receipt when delivery completed
- Basic obstacle handling, capable of avoiding a person walking
- Provide a human interface for tasking/status notification. This could be anything, Web Site (embedded or otherwise), Cross-Platform GUI, SMS interface, etc.

Stretch Goals

- Return to base station for charging
- Delivery notification when destination reached (audible)
- Flair (plays ice-cream truck music and has appropriate decoration)
- Tracking of cargo status

Constraints

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

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 sandwiches between offices at MITRE.

Areas of Engineering

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

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 project.

Project 3: 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 4: A Compact Antenna for Mobile Applications

There is an increasing need for wideband or multiband antennas for wireless communication systems. Due to the tremendous increase in usage rate, the service providers are improving their systems with advanced technologies. The Advanced Wireless Services (AWS), recently licensed by FCC, provides a variety of wireless services including the broadband 3G mobile. Features including TV and satellite radio are being integrated into the mobile handheld devices. As the demand for wireless communications equipment grows, the antennas for this equipment are becoming more

important. These antennas require wide bandwidth, high efficiency, compactness in size, complete built-in mountability, and environmental isolation. The conventional technologies for these antennas are reaching their limit of improvement to meet the market requirements.

To respond to the above needs, senior design students will develop an improved antenna for wireless mobile applications. Candidates for wideband antenna include a planar monopole antenna, a planar inverted-F antenna, and a circular antenna. These antennas require thorough research and analysis to meet the design specifications.

Senior Design Tasks

- Design of 3~4 different types of wideband antenna employing HFSS
- Manufacture wideband antenna on a PCB
- Test antenna in an anechoic chamber environment

Application

Mobile communication and other portable electronics with wireless interfaces.

Areas of Engineering Required

- Electromagnetic theory
- RF/Microwave engineering
- Antenna engineering

What the Student Gains

Antenna design technique, HFSS simulation technique, network analyzer measurement technique, RF/microwave circuit analysis skills, antenna characteristic measurement technique using anechoic chamber, experience and knowledge of PCB fabrication skills.

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 nodes 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 ± 1.5 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 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 pro-

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.