ECE 4890 Spring 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: Novel Solar Tracking Charger Device

Introduction

With the advent of newer materials and higher production volumes, solar energy continues to serve as a viable form of alternative energy for certain applications. When designing a solar-based device, it is important to maximize the amount of energy collected by the solar panels. Many novel electrical and mechanical solutions have been created to address this issue and optimize the conversion of sunlight to electricity.

The goal of this project is to research the creation of a novel, solar-based, battery charging system. By combining modern embedded microelectronic sensor technology, such as GPS, magnetometers, and accelerometers, with a novel controls system approach, the project will investigate the feasibility and effectiveness of tracking sunlight based on global position and orientation, automatically adjusting itself to maximize energy conversion.

The scale of this project is kept to a minimum to conserve cost while proving out its core contribution, that of a new tracking approach and algorithm. Therefore, there is no minimum amount of power that must be generated by the solution. However, all major components of such a charging system (solar panel, charge controller, batteries, low-power servo for panel movement, etc.) must be represented in the final device.

A "must" deliverable includes the construction of a single unit that tracks sunlight based off of geolocation while minimizing energy spent accomplishing its task. "Want" deliverables to include automation and sourcing current for a specific application.

Project Description

Students will need to:

1. Work with a member of the ECE Faculty to define system architecture.

2. Create and optimize a control system to maximize energy transfer.
3. Physically construct and test the device.
4. Compare the device to traditional sun tracking systems.

Result

The final product should be a *proof-of-concept* solar charging device utilizing a unique algorithm involving geospatial data to maximize energy transfer.

Project 2: UCCS Workstation Test System

Introduction

The University of Colorado at Colorado Springs has an engineering lab located in ENGR 229 that is used for many undergraduate Electrical Engineering courses. The lab contains basic equipment needed to power up and characterize a wide number of circuits built across a variety of courses.

Unfortunately, the equipment in the lab is often stressed by students unfamiliar with their operation. The result is broken or malfunctioning equipment, which serves as a source of frustration to students in the lab. There is currently no auditing process to guarantee that a workstation is fully functional at the start, middle, or end of the semester.

A solution is needed to test each workstation and report on broken or malfunctioning equipment. This Workstation Test System must have the ability for any student at any experience level to be able to fully test the oscilloscope, multimeter, power supply, and function generator that exist at each station. When a workstation is deemed inoperative, the Workstation Test System report can be given to the ECE Department so that warranty work may be performed on the device. This will ultimately maximize the customer's experience (the student) while maximizing the university's investment in maintenance and warranty contracts.

A "must" deliverable includes the testing and diagnostic reporting on two of the four instruments. A "want" deliverable includes the testing and diagnostic reporting on the entire set of four instruments.

Project Description

Students will need to:

1. Work with a member of the ECE Faculty to define what needs to be tested and how.
2. Create a workflow for logically testing the instrumentation.
3. Decide on automated testing using GPIB, USB, etc. vs. manual testing (turning knobs).
4. Architect the entire *Workstation Test System* – choose connectors, whether or not the system is microcontroller based, form factor, etc.

Result

The final product should be a Workstation Test System that plugs into any workstation in the ENGR 229 Lab and reports back broken or malfunctioning equipment to its user. An operator's manual is also required that allows a technician of any skill-set to properly diagnose workstation problems.

Project 3: Verilog Simulation Model and Virtual LCD Screen

Introduction

This project involves creating a simulation model of the LCD controller on the Spartan 3E demo board used in the Rapid Prototyping (4211) course. A virtual LCD screen will also be created that will emulate the LCD on the Spartan 3E demo board.

Project Description

Many projects in the Rapid Prototyping with FPGA's course (4211/5211) involve usage of the LCD on the Spartan 3E board. The LCD is accessed via an LCD controller that is driven by the FPGA as seen in Figure 1.

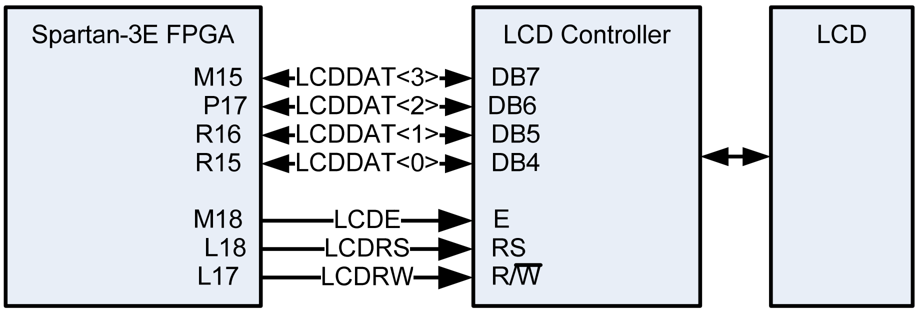

Figure 1: LCD Connections on Spartan 3E demo board

Unfortunately, no simulation model exists for this controller so students are forced to visually verify that their design implements the proper protocol to the LCD controller. It is desired to design a LCD controller model and virtual LCD screen so that students can be confident that their FPGA design is correct.

The LCD controller on the Spartan 3E board is the Sitronix ST7066U. It is functionally equivalent to the Samsung S6A0069X or KS0066U, Hitachi HD44780, or SMOS SED1278. The data sheet for this LCD controller is at `http://www.uccs.edu/~gtumbush/4211/LCD%20 Data%20sheet.pdf`. The simulation model will need to check for timing and protocol violations.

It is also desired to have the LCD controller simulation model interact with a virtual LCD screen. As the LCD controller receives instructions the virtual LCD screen will update appropriately. The TCL/TK language, supported by the Modelsim simulation tool, would be a good choice for implementing the virtual LCD screen.

The LCD controller will need to be verified with a self-checking testbench that verifies both correct and incorrect protocol. A high level depiction of the testing environment is in Figure 2.

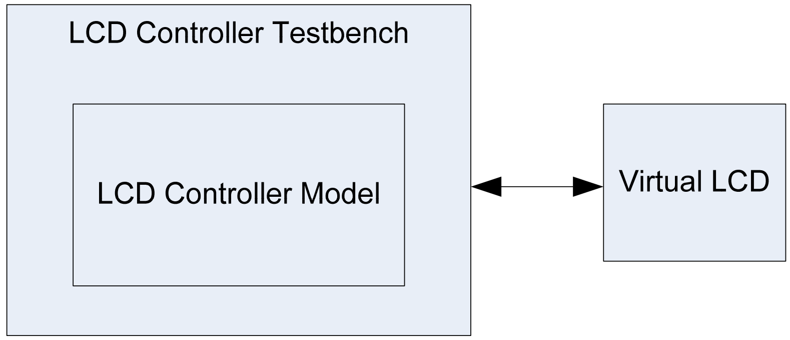

Figure 2: LCD Controller Testing Environment

Team Tasks

1. Create a verilog simulation model of the Sitronix ST7066U LCD controller.
2. Create a virtual LCD that updates according to commands sent to the LCD controller mode
3. Create a self-checking testbench that verifies both correct and incorrect protocol.

Project 4: 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 5: 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 6: 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 7: 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 8: 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.