EEE190: Senior Design

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Design Document

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Abstract

This document contains the featureset for our proposed smart electrical bicycle. Also contains descriptions of our features, the resources needed to implement them, and the estimated time required to develop the system.

Index Terms

Electrical Assist, FPGA, Electric Speed Controller, Bicycle.

I. Addressing the Societal Problem

THE commute provides an opportunity for office workers to work exercise into their otherwise sedentary and busy days. The advantage over a purely motorized vehicle is the requirement for the rider to provide power to some extent enabling physical activity. The responsive control system allows a user to set an exertion amount and tailors itself to the users wants.

II. Skill Sets

THERE will be a variety of different skills required to develop this system. Many of them are currently present in our group, however some will need to be learned and or refined. The most significant technological hurdles will lie within the exertion based control algorithm and the electronic speed control for the CPEs and EEEs respectively.

*a) **Mike Frith:*** Analog circuit design, lab testing. Schematic creation and referencing.

*b) **David Larribas:*** Experience with lighting and voltage conversion. Cycle commuter.

*c) **Devin Moore:*** Verilog and FPGA development ready. Experience with C++, C, and Java. Worked at bike shop from 2007 to 2010 and cycle commuted 2008 to 2010.

*d) **Ben Smith:*** Verilog, FPGA development, Experience with NIOS II C development. Worked at bike shops since 2004, still employed at the Bicycle Emporium. Cycle commuted from 2005 to 2008 along the American River Parkway.

III. ”Punch List”

THE ”punch list” is a listing of features to be implemented in the final product. These core features represent the bulk of work to be done in the project. They Fall into 5 basic categories

- Smart Assist
  - FPGA based control mechanism
  - Inclanation based speed control
  - Effort based speed control
- Motor and Motor Control
  - Commercial motor integrated into design
  - Custom build Electronic Speed Control
  - Motor data: temperature, voltage, current, rotation speed
- Power Distrobution
  - 5V subsystem for control components
  - Battery charging circuit
  - Battery monitoring: Charge, Voltage, Current
- Safety and Lighting
  - Function turn and brake light
- User interface and Controls
  - Bluetooth Android control application

A. Smart Assist

The amount of motor assist will be controllable in real time. This combined with a micro controller and sensors will allow motor response tailored to the users need. The motor will have four modes of operation.

- Constant effort via feedback loop (HRT or Torque)
  PI feedback control system based on exertion measurement
- Inclination based assistance
  Linear wattage response to change in gradient
- Constant speed mode
  PID based control based on speed sensor
- Constant Wattage mode
  Basic wattage setting with no digital control.

These modes offer the user a variety options that require the use of external sensors or not. The constant wattage mode will need to be selectable and controllable via physical buttons on the device. The rest of the modes will be controlled by the Android application over the bluetooth connection.

The motor must also turn off when the brakes are applied. There are a number of systems that detect the application of the brakes. The signal line from these sensors will be run into the FPGA to turn the motor output signal on and off.

To implement the NIOS II soft processor and other HDL entities we will use Alteras Quartus 13sp1 development environment. The actual programming of the Soft Processor will take place in a separate development environment called Nios II Software Build Tools for Eclipse Indigo. Development of the control system in expected to require significant effort. The MicroC RTOS will be implemented on the NIOS processor to handle task scheduling on the NIOS core.

*e) **Central Processor:*** We will be using the NIOS II soft processor implemented on an Altera Cyclone IV FPGA. During the breadboard phase

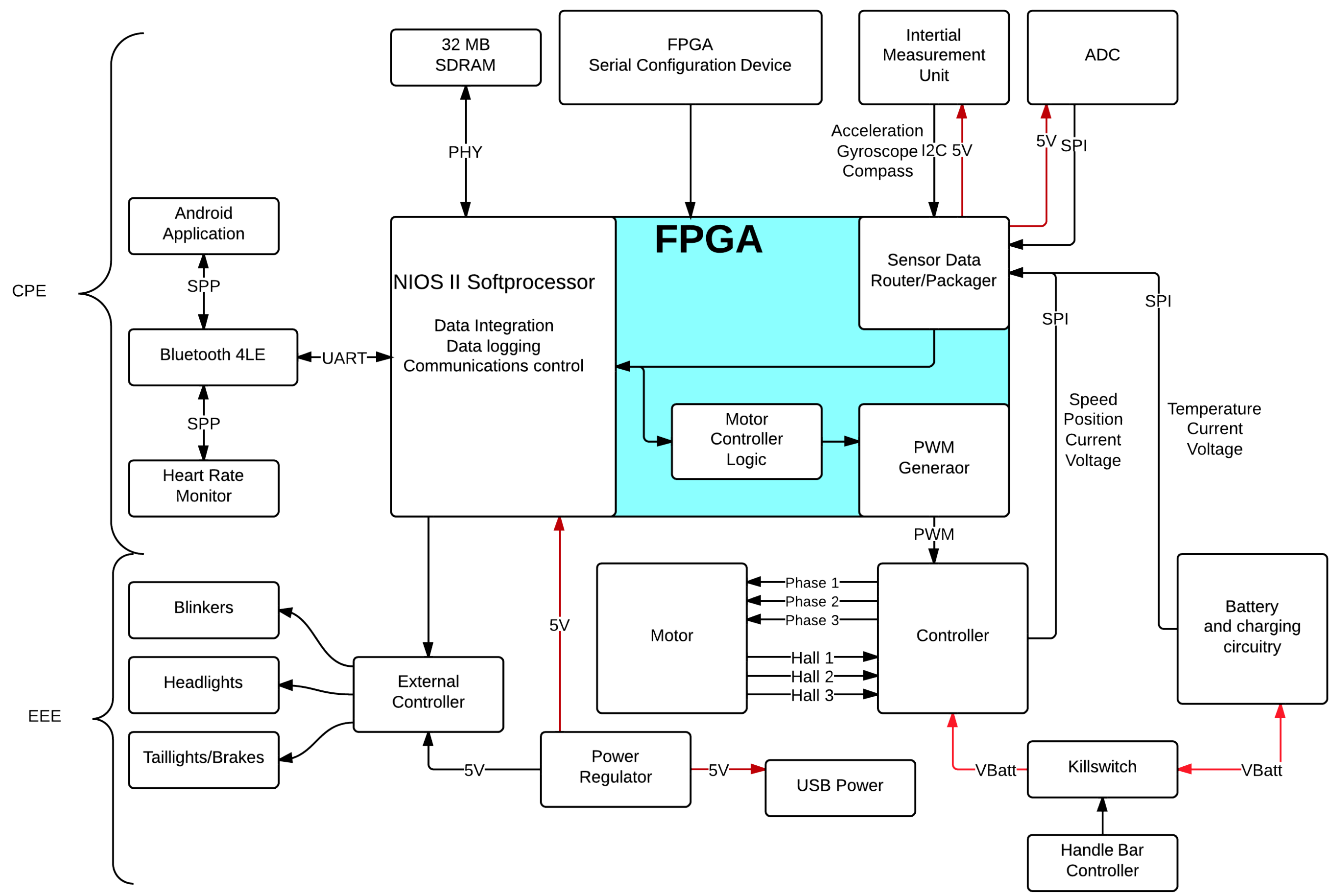

Fig. 1. Block diagram of control hardware

will use the Terasic DE0-Nano development board. This would mainly be used to communicate with peripherals through UART and Bluetooth. This would also package and store user data in a useful manner onto an SD card to be uploaded to PC or smart phone.

*f) **Heartrate Based Control:*** The Zephyr HxM uses the bluetooth SPP (slave) protocol to communicate. the RN-41 bluetooth module we plan to use can communicate with the heart rate strap operating in master mode. Adding this feature will allow motor torque to be varied in near real time automatically based on the users need. An example implementation would be to use the Android application UI to specify a heart rate ceiling. As the user approaches the ceiling value the output wattage of the motor is increased to provide assistance. The downside is a 10 to 20 second delay from increase in exertion and heart rate response. The benefit is we can provide a feedback system without having to implement the mechanically complicated torque measurements. [1]

*g) **Referenced control systems:*** An SOPC based Intelligent Bike The authors of this paper developed a system to monitor tire pressure and and gear selection the most novel portion of their implementation is the use of cellphone RF to indicate the presence of other riders. [2]

Applying Fuzzy Logic Control to an Electric Bicycle This paper details the Author's control system based on inclination. A control system was built around the rotational speed of the rear wheel. This system generated a PWM signal using a Programmable System On Chip. [3]

*h) **Qualifications for success:*** Smart control can be tested by isolating a control variable and manipulating it while recording the systems output data. The control algorithms are to be developed in a simulation environment and tested against generated data. A successful match between theoretical and experimental data will validate the systems performance.

Task	Labor Hours
SPI for ADC	16
I2C for IMU	25
NIOS II Core in Quartus	8
MicroC OS for NIOS II	8
Verilog PWM Generator	4
Verilog Motor Control	60
Verilog Sensor Parser	10

TABLE I: Estimated Time for smART Control

B. Motor and Motor Control

i) ***Motor Selection:*** Our motor shall be contained within the rear hub of the bicycle. Placing the motor in the rear will ensure the greatest traction while climbing. Rear mounting also attaches the motor to the sturdiest portion of the frame. We have chosen a brushless design due to their availability, durability, and reliability. Unlike a brushed DC motor, brushless designs dont have electrical contacts in the moving portion which can get contaminated or wear out. The motor will additionally have the traditional bicycle gearing attached.

j) ***Speed Controller:*** The motor shall be initially driven using an off the shelf electronic speed controller. This speed controller will accept a pulse width modulated signal generated by our master control unit and convert the the incoming signal to a 3 phase signal to power the motor.

We shall design our own ESC to control the motor using the same pwm signal, however we will be creating our own design to get more data out to the master control unit while incorporating a power supply to get power to our master control unit and auxiliary systems.

The electronic speed controller shall use a microprocessor to trigger 6 MOSFETS to conduct current to the motor windings. It shall process data to feed back to the control unit. Ideally we would like rotational speed, temperature, current, voltage, and torque data.

k) ***Qualifications for success:*** The motor will power the wheel to variable speed and power depending on the incoming signal, verified by an oscilloscope. The electronic speed controller shall detect wheel position and speed and control the motor to maintain a speed given an input signal.

Task	Labor Hours
Researching controllers	10
Installing controller	4
Controller Design	90
Motor Selection	8
Installing Motor	5
Testing	4

TABLE II: Estimated Time for Speed Controller

C. Power Distribution

l) ***USB power:*** This will be a hub that will supply power and operate the various external functions of the project including the lighting and sound. Additional slots will be added providing power for whatever USB device the user chooses. The main purpose for the extra slots are for charging a cell phone which the user would use to adjust settings. This hub would provide six female USB slots; four of these would be controlled by the FPGA and the other two would be always powered. The four controlled ports would be used for the lights and sound. The hub will take power from the battery and step down the voltage to 5V and limit the current to 700mA for each output. The hub will also supply the power to the FPGA.

m) ***Qualifications for success:*** The ports must all produce 5V and the designated ports must be activatable by the FPGA.

Task	Labor Hours
Power Hub Design	10
Hub Fabrication	14

TABLE III: Expected time for power distrobution system

D. Safety and Lighting

n) ***Motor Safety:*** A number of safety systems need to be considered in the development of the control algorithm. All operation modes must have a speed limit of 25 mph in accordance with state law. Accelerometer data can be utilized to ensure the rider is upright and disable the drive motor in the event of a fall for an added measure of safety.

A hard kill switch is to be between the battery and motor, this relay is to be held closed by the NIOS soft processor. The signal line is to be use a pulldown resistor to ensure the relay will open in the event of a software failure. A physical handlebar switch should be also attached to the motors kill system so the user can kill the motor without having to rely on the FPGA control system.

o) ***Battery Safety:*** The volatile lithium polymer will need to have it's operation monitored to deal with a number of conditions which can harm the battery or lead to catastrophic failure. A robust charging system will be needed to prevent the battery from harmful overcharge or undercharge conditions. Short circuit protection will be needed as lithium polymer batteries are specifically susceptible to damage from high current conditions. Temperature and charge control mechanisms can be built into the FPGA.

p) ***Lighting:*** The lighting will consist of a headlight, brake light, and front and rear blinkers. The headlight will illuminate the area in front of the bicycle in order to increase the riders visibility and perceptibility. The lighting must not interfere with a drivers ability to see and thus must not shine directly into a drivers eyes. LEDs will be the illuminator because of their small viewing angle which allows them to have a concentrated beam of light without the use of reflection and their low energy consumption. Some number of LEDs are to stay illuminated at all times the bike is in operation to increase visibility to drivers. The rest of the LEDs in the headlight, which will be used for illuminating the road in front of the rider, will be activated manually or through light detection to activate automatically in dark areas.

The blinkers will consist of lights mounted on the rear, and possible front, of either side of the bicycle. The left light flashes when the rider flips the toggle up and the right light flashes when the toggle is down to indicate which direction the rider intends to turn. Both lights remain off when the toggle is in the center position. Blinkers may be combined with the brake lights to reduce number of units.

The brake and tail light will be a red light or set of lights will be on at all times the vehicle is in operation at a reduced intensity. When the rider squeezes the braking lever, the brake lights will engage with full intensity to alert people behind that the rider is slowing down significantly or stopping.

This feature will not require any software to run and will only need simple hardware: resistors, LEDs, wires, switches and maybe some others if different modes are to be hardwired.

q) ***Qualifications for success:*** If the lights switch state when the user interacts with them through the physical controls or through the app, we know the module is working properly. Driving lights must turn on any time the vehicle is powered.

Task	**Labor Hours**
Design Schematics	4
Proto Wiring and Testing	2
Design Casings and Mount	3
Fabricate Lights	15
Fabricating Control Unit	3
FPGA Logic Module	1

TABLE IV: Estimated Time for Lighting and Safety

E. User Interface and Controls

r) ***Cell Phone Application:*** The cellphone application will primarily act as the riders dashboard. It will display the riders speed, heart rate, location, and state of the system including battery charge, rate of discharge, distance to empty estimation and power mode. The app is meant to be used from a cell phone mounted to the handlebars much like the commercially available gps systems. The application will communicate with the NIOS II through Bluetooth and store required data on the SD card.

The user will also be able to change the power mode and alter the system settings from the application. This should be the only interface to the system that the rider has to worry about, besides a physical kill switch in case a reset is required.

The implement this system we will use Nios II Software Build Tools for Eclipse Indigo to program the FPGAs Bluetooth utility and use the Eclipse IDE with built-in Android Developer Tools and Android SDK components for programming the cell phone application.

*s) **Handgrip Controls:*** It is important for the rider to have a physical way to shut off the system seperate from the cell phone application. This will be implemented with a switch next to the hand grip connected to a relay between the battery and the motor.

There will be a toggle for the blinkers on the same mount, so the rider can control them with their thumb. Any other simple controls will be housed here.

*t) **Qualifications for success:*** We can test the data comming into the FPGA with either an osciliscope or Signal Tap, and compare it to the incoming data and the outgoing comands on the cell phone. We will also check eaech of the files of stored data often to make sure there are no descrepencies, and the format is correct. Once we can communicate with the FPGA and are confident the data is accurate we will consier the section complete.

Task	**Labor Hours**
Application UI	8
Data Processing/Presentation	16
Data Storage Procedure	6
NIOS II Bluetooth	8
Cell Phone App Bluetooth	8

TABLE V: Estimated Time for Cell Phone Integration

IV. Estimated Costs

Part	**Cost in Dollars($)**	**Purpose**
DE0-Nano	100	Central Processor
9 DOF IMU	100	Orientation Sensors
Bluetooth	50	Communication
Electric Motor	150	Propulsion
Motor Controller	100	PWM to Motor
Battery	400	Power
BT4 Heart Rate	70	HR Monitering
Bicycle	FREE	Framework
Cell Phone	FREE	UI/Controls
Miscellaneous	75	Framework
TOTAL	1050	N/A
TOTAL +35%	1417	Room For Error

TABLE VI: Cost Estimation

References

[1] Zeypher. (2010, Mar.) Hxm bluetooth api guitde. [Online]. Available: http://www.zephyranywhere.com/media/pdf/HXM1_API_P-Bluetooth-HXM-API-Guide_20100722_V01.pdf

[2] C. I. . K. J. . V. A. . R. R. Prabhu, S. ; PARK Eng. Coll., "An sopc based intelligent bike," *Conference on Computer Modeling and Simulation*, vol. 4, 2010.

[3] B. C. Chi-Ying Liang, Wai-Hon Lin, "Applying fuzzy logic control," *An SOPC Based Intelligent Bike*, 2006.

Michael Frith

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Objective: A student position in Electrical Engineering.

Education

BS Electrical and Electronic Engineering • CSU Sacramento • GPA: CSUS 3.7 • Fall 2014
AS Mathematics • Sierra College • 2011
AS Natural Science • Sierra College • 2011

Relevant Courses

Electronics I and II*
Electronic Instrumentation
Introduction to Microprocessors
Signals and Systems
Network Analysis
Intro to Circuit Analysis
Electromechanical Conversion
Introduction to Logic Design
Engineering Statics and Dynamics
C Programming
Fabrication Techniques I
CIE Fundamentals-Mechatronics

** Fall 2013*

Knowledge & Skills

Electronics: Circuit Analysis • Schematic Creation and Use • Multi-Meter Usage • Oscilloscope • Soldering

Computer: Multisim • Psice • Mentor Graphics • Matlab • Mathematica • C Programming • Verilog (Quartus II) • Hardware • MS Office

Communications:

- Experience creating technical reports and documents.
- Able to create effective PowerPoint presentations.
- Experience speaking to large and small groups to explain complex concepts in simple language
- Extensive experience providing excellent customer service in high stress, high volume venues.
- American Sign Language

Project Experience

Linear DC Power Supply - Designed PCB from schematic; built and assembled chassis from sheet aluminum.

Work Experience

Student Intern *Miranda Technologies* 6/13 to 8/13
Leveraged an existing design to create a new product through component removal and code update. Wrote specification for signal level acceptance. Learned product processes such as ECOs, design review meetings.

Math Tutor *Sierra College Math Center* 8/11 to 12/11
Individualized tutoring from Algebra through Calculus and Physics classes.

Waiter and Expediter *Hacienda Del Rio* 7/07 to present
Provide excellent customer service and input to other servers and managers to continuously improve restaurant. Develop new product ideas and identify computer system improvements. As expediter- interface between wait staff, kitchen staff, and customers – facilitating continuously smooth food delivery. Identify and rectify any and all safety issues.

Personal Shopping Assistant *Best Buy* 3/04 to 6/07
Analyzed customer needs, and facilitated positive shopping experience. Led training of new and existing employees. Also responsible for customer support, effective display of product, and troubleshooting technical problems.

Professional Activities & Accomplishments

Member, IEEE Sacramento Valley Chapter
Member, Tau Beta Pi California Upsilon Chapeter
Obtained by being in top 12.5% of Junior Class.
Working 12 to 20 hours a week while carrying a full course load and maintaining a 3.7 CSUS and a 3.2 Overall GPA.

David J Larribas

(209)740-5993 dLarribas@gmail.com

OBJECTIVE: An internship in electrical engineering

PROJECT EXPERIENCE:

LED Stage Lighting

Designed and constructed LED light bulbs to be used as stage lighting for live performances. The bulbs were designed to be inexpensive, low powered, bright red, low heat and able to be screwed into a standard 120VAC light fixture. Designed the circuit to convert AC to DC and decrease voltage. Four bulbs were created in total and all were tested multiple times at live performances without failure.

SKILLS AND ABILITIES:

- Able to communicate effectively through multiple mediums with colleagues and customers
- Can work effectively in a group setting, but can also excel solo
- Can follow direction well
- Trustworthy worker with exemplary integrity and honesty
- Confident of abilities and not afraid to ask for help to insure the job is completed safely and correctly

Tools: PSpice, MATLAB, AutoCAD, JAVA, C Code, Digital Oscilloscope, Function Generator

WORK EXPERIENCE:

Promoter/Performing Musician — ***Self Employed*** — *6/07- 9/12*

Organized music events by contacting venue owners and musicians through phone or email. Kept a tight schedule during the night of performance. Manned and organized the merchandise stand and sold products to customers.

Pony Express Delivery Driver — ***PG&E*** — *6/09- 9/09*

Delivered mail between PG&E stations safely and in a timely manner.

EDUCATION:

In progress: **Bachelors of Science in Electrical Engineering**
California State University, Sacramento • GPA 3.5 • December 2014

Related Courses:

Electronics II*	Product Design*	Probability and Random Signal
Electronics I	C Code	Signals and Systems
Intro to Microprocessors*	Applied Electromagnetics	Electromechanical Conversions
Intro to Logic Design	Engineering Exonomics*	
Intro to Feedback Systems*	Network Analysis	**In Progress (Fall 2013)*

ACTIVITIES & ACCOMPLISHMENTS:

- Active Member, Mathematics Engineering Science Achievement (MESA)
- Academic Mentor, MESA. Working with a professional mentor to aid a student mentee
- Active Member, Society of Hispanic Professional Engineers (SHPE)
- Academic Committee and Star Member, SHPE
- Active Member of Tau Beta Pi Engineering Honor Society
- Tau Beta Pi - Cataloger
- Member of the Institute of Electrical and Electronics Engineers
- Dean's Honor List
- Boy Scouts of America

Devin Moore

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EDUCATION

In progress: Bachelor of Science, Computer Engineering, CSU-Sacramento, GPA: CSUS-3.93; Cumulative-3.06 (Expected Graduation: Spring 2014)

Transfer for B.S. Comp. Engineering, Santa Rosa Junior College

Related Courses

Programming Concepts 1 and 2(C++)	Computer Interfacing
Intro to Comp Architecture(x86 assembly)	Physics I & III
Circuit Analysis	Linear Algebra
Network Analysis	Discrete Math
System Programming (Unix/C)	Calc. I, II, & III
Logic Design	Differential Equations

KNOWLEDGE AND SKILLS

Programming Languages: C · C++ · x86 Assembly · Verilog · VHDL · HTML

Software: DevC++, Eclipse, Multisim, Matlab, Modelsim, Quartus, MS Office, OpenOffice

Equipment: Multiple brands of DMMs, oscilloscopes, function generators and power supplies. Experience with the Amani GTX and working with the Arduino Uno, Parallax Propeller, Digilent Analog Discovery, Microchip PICKit3, and Raspberry Pi this semester (Spring 2013).

Communication and Organization:

- Great public speaking and presentation skills
- Exceptional problem solving and analytical skills
- Excellent with multitasking
- Thrives with heavy workload or stressful environments
- Strong verbal and written communication skills

PROJECT EXPERIENCE

Spring 2013 Worked with two students to create a robot that could balance on two wheels. We used Quartus software and an Altera Cyclone 4 FPGA to implement PID controller and PWM output based on accelerometer data.

WORK EXPERIENCE

Food Service **Sonoma Valley Bagel and Deli** 04/05 -05/08

Working with a small team to prepare and sell products. Eventually became assistant manager, with tasks including scheduling, opening/closing store, deposits, and delegating tasks.

Mechanic/Sales **Windsor Bicycle Center** 05/08 -11/09

Working alone or with one or two others to build, repair, tune, and sell bicycles. Repairing and building helped exercise problem solving and analytical skills.

Barista **Starbucks** 11/09 -Present

Working closely with a team of diverse people in a very fast paced environment. The constant expectation of efficiency and teamwork has been very rewarding. Having the opportunity to learn to work well with so many different types of people has been invaluable.

Ben Smith

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Linked In: goo.gl/UJQGMY

Work Experience

Jun 2013 – Aug 2013

Engineering Intern at Miranda Technologies

Verilog Firmware Development

Debuged control firmware in System Verilog for Altera FPGA. System was experiencing unknown issue causing a failure with a particular controller module. Xilinx and Altera debugging tools were extensively used to isolate the bug in a chip control bus' arbitration system. Wrote fix for Veilog HDL that was integrated into code depository distributed to customers.

Mechanic, sales at Bicycle Emporium — Mar 2009 – Current
Boutique bicycle retail

Manager at River Rat Raft Rental — Jun 2008 – Mar 2008
Daily operations and payroll

Mechanic at River Rat Mountain Bike — Jun 2004 – Mar 2008
Bicycle retail

Sound Technician Underground Cafe — Jun 2005 – Jun 2009
Live sound and stage management

Projects

June 2013

Self balancing FPGA robot

PID control system based on Accelerometer

A FPGA based robot balanced itself on a single axis. PID control was very similar to inverted pendulum problem. The system received its feedback via I2C accelerometer.

June 2013

LED brake light design for Hornet Racing

PCB design and validation

Unstable voltage conditions necessitated the design of a constant current source to supply the brake LEDs with reliable power. The Altium EDA suite was used to design a PCB board with surface mount N-FETs and BJTs.

July 2013

Cereal Hack 3

Rapid prototyping competition

48 hour rapid development "hackathon" where sensor interface for Accelerometer, Gyroscope, and rotary encoder were developed. The filtered data was communicated though bluetooth to a host PC and used to create an on screen representation of the users movement. The project took second place when judged by a panel of local industry experts.

Engineering Skills

Programmable Logic	**Altera:** Signaltap, Quartus, Cyclone IV and V SoC, Stratix V NIOS II **Xilinx:** Chipscope, Spartan 6, ISE,
Microcontrollers	**Microchip:** PIC, MPASM, C MPLAB 8 and X **Atmel:** AVR
Laboratory Equipment	**Oscilloscope:** High speed serial integrity testing, Eye diagrams,
Circuit design	**EDA tools:** Altium, DX Designer serial integrity testing, Eye diagrams,

Education

2012 – Present	**Computer Engineering** Undergraduate *California State University, Sacramento* **GPA: 3.5**
Coursework	**Electronics:** Network Analysis, Electronics I, Microcontrollers **Software Engineering:** Algorithms I, Advanced Object Oriented Programming,

Awards

2013 **Second place at Cereal Hack 3**
The Hackerlab

2013 **Deans List**
California State University, Sacramento