Baskin School of Engineering

Corporate Sponsored
SENIOR PROJECTS PROGRAM

PARTNER’S DAY
May 31, 2012
Introduction

We are pleased to provide this brochure to you highlighting our inaugural Corporate Sponsored Senior Project Program! Our students have worked very hard during their time at UC Santa Cruz earning their engineering degree and fulfilling this capstone design sequence.

Our students who have participated in this Corporate Sponsored program have been provided with a unique opportunity to experience working on real-world projects that involve design, budgets, deadlines, teamwork and reviews with their team mentor. They have come away with a new sense of professionalism and pride in their work, learning new skills that may have been challenging, entrepreneurship and implications of intellectual property.

Throughout this academic year, the students have interacted with their teams, made visits to their corporate sponsor's worksite, solved problems that came up along the way.

We take great pride in what the students have accomplished. We are very grateful to our corporate sponsors for their willingness to participate in this year-long program, mentor our students and provide them with challenging projects to work on.

Arthur P. Ramirez
Dean
Baskin School of Engineering
We would like to acknowledge and thank the faculty and staff who have been instrumental in developing and moving this inaugural program forward:

**Senior Design Faculty (Corporate Sponsored Senior Project Program) 2011-12**

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- Dave Meek—Baskin Engineering Lab Support
- Jeff Duncan—Baskin Engineering Lab Support
- Christian Monnet, Baskin Engineering Lab Support
Sponsors

Thank you to our sponsors for your generous support of our inaugural Corporate Sponsored Senior Project Program. Your time, experience and financial support were beneficial to our students and the success of their Senior Design Projects.

Applied Materials
CITRIS
Corning
eBay
Google
Los Alamos National Lab
Oracle
Plantronics
Raytheon Applied Signal Technology
Texas Instruments
Reducing Costs of Solid State Lighting
Ryan Baker, Julian Dahan, Russell Petersen, and Craig Sloan
JACK BASKIN SCHOOL OF ENGINEERING
Senior Design Capstone

Abstract
Typical LED light bulbs in today’s market can range in cost up to $60. We analyzed various behaviors and characteristics of several LED bulbs, and disassembled them into base components in order to assess what drives this high cost. The LED bulb brands investigated included GE, Feit, Samsung, Philips, Sylvania, and Utilitech. Each bulb was assessed by its heat and power behavior, in addition to its light characteristics. Driver circuit and LED analyses was also performed. Additionally, a focus group was held to investigate the general consumer response of the aesthetic nature of each LED bulbs’ light.

Focus Group
Two focus groups were conducted to gain an understanding of how LED bulbs appealed qualitatively to individuals.

Exploded View

Light Bulb Thermal Trends
To measure the thermal behavior of each LED bulb, we used an infrared thermometer to monitor the temperature of the heat sink. For each bulb, temperatures trends were measured over a period of one hour. LED bulbs tend to take longer to reach a steady peak temperature compared to incandescent and CFLs, however they maintain much lower overall temperatures and are often safe to handle after being powered on.

Light Characteristics
A compact array spectrometer was our main instrument in determining light characteristics of the LED bulbs. Radiant flux data was compiled into a spectral power distributions (SPD) chart for each bulb as well as a CFL and incandescent. The normalized plot shows the relative brightness of each bulb in the visible spectrum.

Cost Breakdown
The left graph shows the cost percentages of each major component in our bulb. The right graph shows the cost breakdown for a typical $40 retail 60W bulb.

Acknowledgements
This project was sponsored by Applied Materials. We would like to thank Dr. Mingwei Zhu, Dr. David Kyser, David Munday, Dr. Patrick Mantey, Stephen Petersen, PE and Dr. Gabriel Elkaim.
Current energy monitoring products, such as Kill-A-Watts and PG&E Smart Meters, allow users to see energy usage of appliances. However, these devices do not allow remote viewing or real-time viewing of the data. The Smart Home Energy Monitoring Project (SHEMP) team has built devices capable of monitoring the same power usage, but can also send the data wirelessly to a central server where a user can see real-time data and control the device from anywhere in the world.

Since the SHEMP devices use sensors to measure current and voltage waveforms to calculate wattage, these devices can also send those waveforms to the server for scientific analysis. Optional external acoustic, temperature, and light sensors have also been implemented which allow additional monitoring of the home for comparing environmental influence to power usage.

There are many applications of the SHEMP device, from just learning your own power use, to noninvasively monitoring an elderly relative, and even to recording anywhere in the world.

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The SHEMP system allows users to be notified via email or SMS when a device uses too much energy or they move into the next pricing tier. These devices can also send those waveforms to the server for scientific analysis. Optional external acoustic, temperature, and light sensors have also been implemented which allow additional monitoring of the home for comparing environmental influence to power usage.

There are many applications of the SHEMP device, from just learning your own power use, to noninvasively monitoring an elderly relative, and even to recording anywhere in the world.

With the data collected, the user is able to view graphs at any arbitrary time interval. Here, we show several months of energy use for a fridge. During the winter, the fridge does not have to try as hard, and uses little energy. As the months get hotter, the fridge has to fight more to keep its contents cool, and uses more energy on average. But what about on a smaller scale?

If you simply click and drag, the graph will zoom in. If you then click “Refresh Data”, the interface will reload higher resolution data for the time interval you are zoomed to. Here, we can see that the fridge does not use a constant amount of energy, but instead has cycles of being on and being off. Looking at this graph, you may become interested in those spikes.

Zooming in more, we can see the waveform. The SHEMP device records current and voltage at 60Hz, so we have more than enough to recreate the 60Hz wave from the power grid. Here, you can see that as the fridge turns on, it draws over 1 amp as it starts up the compressor motor. Very quickly this settles down and the energy use levels off.

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Glass Microphone

Ethan Papp      Jeff Bertalotto  Brian McNally  Tyler Couto

JACK BASKIN SCHOOL OF ENGINEERING
Senior Design Capstone

Abstract

For our capstone project, we were tasked to build a glass microphone, that is, a microphone that uses glass to capture the vibrations of sound and convert them into electrical signals which can be amplified, processed and transformed to loud speakers or other devices.

Our approach consisted of an exploration phase in which we experimented with three different methods. We explored a capacitive approach, in which the changing distance between two capacitive plates creates a change in voltage, an infrared laser (IR) approach, in which a laser incident on the glass reflects onto a IR sensor creating a voltage, and a piezoelectric approach, in which a piezoelectric crystal is securely bonded to the glass.

After considering these three approaches, the piezoelectric method was chosen, because it is inexpensive and naturally produces good-quality results. This made honing the signal quality straightforward.

We overcame several hurdles during the project including minimizing electrical noise and overtones produced by the glass. Our final product is comparable to and surpasses the sound-quality of a standard computer microphone.

Infrared Laser Method:

Infrared sensors are used in sound capture by creating a change in voltage, as the vibrations of glass reflect through the sensor. The distance between the two plates is measured, and the voltage created from the distortion is also proportional to the vibration in the glass.

Therefore, if the glass is vibrating due to audible sounds, the voltage produced oscillates in the same way that the sound vibrates the air, and the sound can be effectively captured and reproduced.

Future work could also include modifications to our design to obtain a more directional microphone as currently, our microphone accepts sound from every direction.

To reduce power consumption, we decided to use a differential amplifier to remove common mode noise. The differential amplifier not only removed the white noise, but also most of the 60 Hz. Two graphs are shown below displaying an FFT of a recording before and after the differential amplifier. Notice the prominence of 60 Hz and its harmonics on the early microphone and how much we were able to reduce using the final microphone.

Future work could also include modifications to our design to obtain a more directional microphone as currently, our microphone accepts sound from every direction.

Conclusion and Future Work

Over the past twenty weeks, our team has designed and built a glass microphone. Comparable in quality to standard PC microphones, our microphone could be available for purchase as a standalone device.

In the future, we could integrate the microphone into anything that's made from a pane of glass. Tables, windshields, mirrors, televisions, smart phones, and computer monitors could all potentially become microphones. In addition, we could integrate the capability of our glass microphone into glass speakers which are already commercially available. Using digital techniques it should be possible to use the same piece of glass to capture and produce sound simultaneously.

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Acknowledgements

- Thanks to Yorkshire Hospitals NHS Foundation Trust for providing us with hospital experience.
- Thanks to Mr. David Musgrove for providing us with lab experience.
- Thanks to Mike Elsner from the UCSC Electronic Music Department for allowing us to use the recording equipment and the computer in the lab.
- Thanks to Kamil Zielinski for providing us with lab space.
- Thanks to safety and procurement department.
- Thanks to everyone else who helped and supported us.

INFRARED LASER METHOD:

In this method, an infrared laser reflects off a vibrating sheet of glass onto an infrared sensor. The change in location of the laser on the sensor translates into a change in voltage. This change in voltage is proportional to the vibrations of the glass.

In order to capture the vibrations of the glass, the voltage is amplified and converted into electrical signals which can be amplified, processed and transformed to loud speakers or other devices.

Theory of Operation

Piezoelectric materials have an interesting property. They produce a voltage across their two sides when deformed. As the glass vibrates due to sound incident on its plane, the piezo deforms with this vibration. Since the deformation of the piezo is proportional to the vibration in the glass, the voltage created from this distortion is also proportional to the vibration in the glass.

Therefore, if the glass is vibrating due to audible sounds, the voltage produced oscillates in the same way that the sound vibrates the air, and the sound can be effectively captured and reproduced.

Final Design

SPECIFICATIONS:
- Total Cost per Microphone: $60.48
- Rated Voltage: 15 – 35 V (Min – Max)
- Glass Dimensions: 10.9" x 6.7" x 0.043" (1.1mm)
- Frequency Range: 20 Hz – 20 kHz
- Design Dimensions: 9.75"H x 9.25"W x 6.25"D

Future work could also include modifications to our design to obtain a more directional microphone as currently, our microphone accepts sound from every direction.

Design and Test

Our main goal was to make sure the glass resonated optimally. We experimented with different sizes and thicknesses of glass in combination with the way the glass was mounted to the wall, as well as testing different locations, sizes, and number ofplates.

There were three major hurdles that we dealt with. Noise consisting of 60 Hz and its harmonics was overwhelming in early recordings. White noise was too loud, and the resonance of the glass caused audible and annoying overtones in recordings.

We tried several approaches to get rid of the 60 Hz hum. The first thing we tried was to use a notch filter. While this eliminated the 60 Hz, the harmonics of the noise remained and our low frequency response suffered. We also tried digital signal processing (DSP) techniques, specifically a digital comb filter, which nixed out 60 Hz and its harmonics. Using a very fine comb filter over a sufficient frequency range yielded good results, however, we were not convinced that we needed to use digital techniques.

We considered a few different approaches to eliminate white noise. We looked into a DSP approach for noise cancelling using the spectral characteristic of the noise and removing that from the real-time audio signal. We also looked into using a differential amplifier to remove common mode noise. The differential amplifier not only removed the white noise, but also most of the 60 Hz. Two graphs are shown below displaying an FFT of a recording before and after the differential amplifier. Notice the prominence of 60 Hz and its harmonics on the early microphone and how much we were able to reduce using the final microphone.

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Acknowledgements

- Thanks to Mike Elsner for helping us understand the basics of DSP.
- Thanks to Zachi Baharav and Jeff King from CORNING for sponsorship and providing glass as well as relevant expertise.
- Thanks to Pat Mantey for taking time to explain the basics of DSP.
- Thanks to everyone else who helped and supported us.

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Abstract

The Goal of this project is to exfoliate the recently discovered material, graphene, on to Corning’s Eagle XG glass, and determine how the interfacial interactions between the graphene and glass affect the properties of graphene. The graphene has been produced by means of a process known as ‘micromechanical exfoliation’ or ‘the scotch tape method’. We are studying the properties of graphene by first fabricating devices with non-traditional photolithography techniques that use graphene’s ability to quench fluorescence. We will then compare the results of transport properties recorded for graphene on glass with that of graphene on SiO₂, which is well understood, in order to reduce any error.

What is Graphene?

Graphene (shown above) is a single atomic layer of Carbon in honeycomb like crystal structure that can be considered the basic building block for other Carbon allotropes including Graphite, Carbon Nanotubes, and Fullerines.

Making Graphene

The process of Micromechanical exfoliation involves cleaving layers of graphene from highly oriented paralytic graphite (HOPG) and rubbing them onto our desired substrate within an inert atmosphere. This process produces flakes of graphene that are on the order of tens of microns laterally.

Making Graphene Devices

Graphene Devices are standardly made using methods of electron beam lithography. But because of lack of resources and time, we are attempting to make graphene devices with a technique that is much simpler and allows for custom electrical contacts for each flake. In this method we are also able to see individual graphene flakes much easier than any other method by using graphene’s ability to quench fluorescence. The image on the left shows graphene and small graphitic flakes covered by a photoresist, which was excited to fluoresce with and imaging laser. The thinner the flake results in less quenching of the fluorescence, allowing for us to identify the graphene. Once we have identified the graphene, we will then use a write laser with a shorter wavelength to etch a electrode pattern into the photo resist over the graphene, on which we can then deposit metal to create electrical contacts.

Predicted Substrate Effects

The two dimensional nature of graphene makes its properties vulnerable to be influenced by the substrate on which it is supported and the atmosphere in which it’s immersed. It has been seen that semiconductors in contact with glasses containing alkali atoms, become p-doped. The glass on which we are exfoliating graphene has a very small concentration of alkali atoms (~ .01% by wt.), however this small concentration may still contribute holes to graphene because of graphene’s susceptibility to substrate effects. We will examine carrier concentrations along with other electrical transport properties once we have successfully made devices.

Keep in Mind…

It is important to keep in mind that water, even at the concentrations found in air, also contributes to hole doping in graphene. We are also using an alkali solution to develop the photoresist in our device fabrication process, which can be another source of hole doping. To distinguish the effects of the glass substrate from that due to atmosphere and fabrication processes, we will create identical devices on SiO₂ substrates, which are well studied, to compare our results too as a control.
The Mantis Video project was designed to provide a framework for eBay Research Labs to facilitate the study of how people approach video commerce and streamline their computer vision research.

By utilizing cloud services and agile development techniques, combined with the power of modern mobile devices, we were able to deliver a fully integrated system for the creation and viewing of HD video content within eBay auctions.

This poster showcases the various technologies and software engineering techniques we used in our solution.

**Overview**

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**Software Engineering**

"The only constant in software development is change". This is an oft quoted phrase which is true in many respects. How do software engineers prepare for it? In the face of changing feature requirements, we note the effectiveness of several techniques which allowed us to adapt quickly.

First, we used software design patterns to give a common language to describe the plethora of systems which comprised our applications. Software design patterns are templates for frequently used solutions to various engineering problems. They do not comprise an actual solution, but when adapted to a system, they explain purpose and underlying relationships within the code. For example, we used the “observer” pattern (within model-view-controller) frequently when building applications with an interface and dataset behind the interface (graphical or otherwise). In many cases we found that following these patterns reduced the complexity of the systems when honing them to their most needed components, and also increased code reuse by adapting similar systems to each other.

**Project Anatomy**

- **Mantis Video**
  - Mantis video is the mobile application component of our project. We went through many iterations, and conducted extensive testing to find a design that worked. We utilized the Android SDK to build this software. It features a model, view, controller (MVC) design methodology and takes advantage of many different design patterns.

- **Amazon S3**
  - Cloud file service for storing and serving videos and images.

- **GitHub**
  - Popular source control hosting service, chosen for asynchronous development support as well as easy management of multiple projects/teams.

- **Django**
  - Framework for web applications. Particularly useful features include the object-relational mapping, templating system, and unit testing framework.

- **Google Logging**
  - Logging system.

- **Heroku**
  - Used for web application hosting and easy continuous integration and deployment of latest development.

- **PostgreSQL**
  - Database used for storing listing metadata.

- **Django Builds**
  - Framework for web applications. Particularly useful features include the object-relational mapping, templating system, and unit testing framework.

We also used cloud based services to manage various aspects of our application. We could have created the back end using our own servers and creating our own build paths, but we very quickly noticed that even in situations where some of this was managed for us (Amazon EC2), there was too much time spent on reconfiguration (especially when scaling). We then decided to move our application hosting to Heroku, as Heroku specifically is designed for web application deployment. It removed many of the barriers towards being able to deliver a functional web application.

The only downfall with moving to Heroku was the increased cost, but our budget for the project was sufficient to cover it. Heroku helped us focus on developing the application, not building the server architecture to manage it. The same goes for using Amazon S3 – we did not have to spend a significant amount of time developing a file server to host all of our video and images, so we could reinvest that time into making our application better.

Lastly, automated testing frameworks allowed us to make seemingly large and dangerous changes to the codebase while having confidence that they would work. Every time a change was made to the Django application we would write unit tests to test that change and run them alongside all the tests we had written before. Thus, as we added more and more features to the system, we would have a test suite for almost all of the features. Since we could run these tests after every change, we could not only have confidence in the new features in of themselves, but we also see if there were any problems introduced elsewhere. Although this system did not catch every issue, it would give us reasonable information to see if a build was ready for use. Automated testing allowed us to quickly diagnose glaring engineering issues.

It was software engineering techniques such as these that allowed us to adapt to dynamic customer requirements and deliver under pressure.
What is Puzzle Defenders?

Puzzle Defenders is an HTML5 Game that is sponsored by Google. It is a 2D puzzle game where your matches on the board create attacks or shields.

**Creating a Shield:**
- Match 3 or more orbs of the same color in a vertical line.
- The goal of the game is to destroy your opponent's resources while at the same time defending your own. Unlike most puzzle games, you don't lose when your board fills up.
- You need to make a match of three or more of the same color in order to create a shield.
- Play Online or Locally with your friends.

**Creating an Attack:**
- Match 3 or more orbs of the same color in a horizontal line.
- These fairies will stop in front of the resources in the center of the board to absorb incoming attacks.
- Each character has a powerful spell that can change the tide of the game.

Basic Gameplay

**Goal of the Game:** Destroy the Opponents Resources, while guarding your own.

**Creating an Attack:**
- Match 3 or more orbs of the same color in a horizontal line.
- These fairies will attack the resources in the row they were created.
- They will all attack in front of the resources in the center of the board to absorb incoming attacks.

**Creating a Shield:**
- Match 3 or more orbs of the same color in a vertical line.
- These fairies will stop in front of your resources.
- They will all attack in front of the resources in the center of the board to absorb incoming attacks.

**Using Spells:**
- Each character has a special spell that can change the tide of the game.
- Spell orbs activate when they complete a match of 3 with any orb of the same color.
- When the match is activated, the spell will be triggered.

Advantages:
- Refresh is the compile, so iteration upon a build is fast.
- No installation required to use, beyond the web browser.
- Javascript console has flexible debug.
- Easy to distribute product. Very flexible. So platform isn’t as big of an issue if we want to expand.
- Learning initial code base is fast since it’s a mixture of HTML and Javascript. Allows for people from either background to get on the ground running.

Disadvantages:
- Lack of security makes it hard to keep code base private.
- Drawing objects to the canvas can be hard because graphic manipulation has to be made from scratch.
- Audio is lacking on HTML5, no tools to use.
- Lack of libraries makes it hard to find proven code.
- Limited Font Selection hampers User Interface development.
- Lack of up to date documentation and support. Slows start of production if this is needed.
- Lack of proprietary engines means that most code has to be made from scratch.

Working with HTML5 on Chrome

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MongoDB

Advantages:
1. Utilizes a non-SQL database, easy to add things whenever you want. No schema needed.
2. Unique IDs for every entry. Made it easier to keep track of objects.

Disadvantages:
1. Not very compatible with NodeJS.
2. Takes too long to connect with server.
3. Not much documentation for MongoDB was available for this situation.
4. Documented well.

NodeJS

**Advantages**
1. Once connection is established, it’s easy to use.
2. Imperceptible lag time.
3. Maintains multiple connections easily.
4. Documented well.

**Disadvantages**
1. Hard to set up the initial connection.
2. Heroku doesn’t fully support NodeJS.
3. Lots of out of date documentation.

Reception

- We’ve had at least 57 people play the game during the UCSC Playtest Fest.
- Response has generally been very positive.
- According to our survey:
  - 55.4% of the people rated the game as a 5/5, based on how much fun they had.
  - 33.9% of the people slightly disagreed that the games lasted too long.
  - 43.6% of the people slightly agreed that a tutorial would be nice to have.
  - 56.4% of people strongly agreed that the controls were easy and intuitive to use.

Conclusions

- It’s completely viable to make a game in HTML5 with NodeJS for networking.
- This set up provides flexibility and allows for fast iteration throughout the entire product.
- Main problem is that all of these are fairly new or undergoing heavy iteration. This leads to:
  - Out of date documentation.
  - Lack of documentation.
  - This makes starting up on this platform to be difficult with a steeper learning curve since most things have to be made from scratch.

Team

1. Jameka March – Project Lead
2. Ryan Cook – Engineering Lead
3. Gabriel Rivers – Producer
4. Wesley House – QA Lead
5. Te Wan Kim – Gameplay Programmer/Music Liaison
6. Bradley Monajjemi – Gameplay Programmer
7. Leng Lu – Database Programmer
8. Umii Hoshijima – Composer
9. Jacob Perrell – Composer
10. Jake Brightside – Composer
12. Ryan Beck – Art Coordinator
13. Britteny Sugar – Artist
14. Kirsten Anderson – Artist
15. Amanda Lee – Artist
16. Edith Pautman – Artist
**Blackbox Requirements**

- Security
  - Encryption
  - Authentication
- Usability
  - Command Line History
  - Output and Input clear
- Scheduling
  - Integration with existing scheduling tools
  - Separate FIFO threaded scheduler available as well

**Usability**

Blackbox is being built for people who are very comfortable working in a Unix shell. This means we have very different definitions of what Usability is, compared to more mainstream apps.

To keep everything Unix style:

- Incorporates the readline library
  - Provides in-line deletion, insertion and command history, with just the cursor keys
  - Imitates bash, intuitive to Unix people
- Incorporates ncurses library
  - Allows us to redraw the command line, to better display information
  - Think Vim or Emacs style windows, familiar to users of Unix
- Single Login Step
  - Using munge and SSL, the user only has to authenticate once per session

**What is Blackbox?**

Blackbox is a project started by LANL, to streamline the manipulation of large data sets between computation clusters and long term archival storage. Their current interface is difficult to work with, and frustrating for researchers. Since supercomputer time is expensive, and data sets are exabytes in size, this becomes a critical issue.

**Abstraction of Complex Interfaces**

The real benefit of Blackbox, is that it abstracts away the nitty-gritty details of operating a complex network of super computers and long term storage. Users may log in from anywhere, manipulate files in a way familiar to them (Unix style), and then log off, their session secure and encrypted. No need to invoke and bargain with arcane and complex machines.

**Security**

LANL is a top secret facility: not even cell phones are allowed on their campus. Security is the most important consideration on our list.

- Server and Client communication is encrypted with SSL
- No eavesdropping
- Users are authenticated with munged tickets
  - This is where file permissions are verified
- Potential to expand, and support alternative security, like Kerberos

In the end LANL may opt to disallow remote access via Blackbox, but even local users will benefit from using Blackbox, because of it’s focus on usability

**SLURM**

SLURM (Simple Linux Utility for Resource Management) is a widely used open-source tool for scheduling jobs on clustered systems. It works on both network clusters, and supercomputers.

- Divides jobs into job steps, and spreads them across the cluster
- Prioritizes jobs, for efficient time usage

**Thrift**

Thrift is an open-source framework for simplifying secure network connections, and serializing data communication.

- Makes it easy to setup a server-client connection
- Defines serializable objects. In our case, file commands.
Exploring Energy Efficient Multiplication in Hardware

Colleen Clare, Namwoo Melosh, Peter Murphy

JACK BASKIN SCHOOL OF ENGINEERING
Senior Design Capstone

Abstract
With an understanding of a proprietary number format used by Oracle, referred to as Oracle Numbers (ONs), the Oracle Hardware design team created two designs to perform multiplication in synthesizable Verilog for an Application Specific Integrated Circuit (ASIC). After testing the designs for accurate Oracle number manipulation, the UCSB Senior Design Team analyzed the power, area, latency and performance to determine the most energy efficient multiplication implementation.

Background
Oracle Number Format
Oracle Numbers (ON) are a proprietary format for variable-length, floating point numbers used in the Oracle Database. The ON format is composed of an exponent byte followed by twenty Oracle Digits (OD). The exponent byte encodes the sign and exponent of the ON. When the most significant bit (MSb) of the exponent byte is set, the ON is negative, and when the MSb is not set, the ON is positive and the exponent bits are inverted. Finally, an offset is subtracted to determine the binary exponent ranging from [-43, 63]. Similarly, ODs are decoded based upon the sign bit. If positive, one is subtracted from each OD; else each OD is subtracted from 101 and a trailing 102 is appended for sorting purposes.

ON: Length EXP 001 002 003 004
5 60 89 67 45 102

EXP: Byte

00110001 00000000 89 67 45 102

Figure 1. Decoding for ON Format

Binary Coded Decimal (BCD)
Binary Coded Decimal (BCD) reformats decimal digits on a nibble. BCD is explored as an alternative due to simple multiplication through shifts in hardware.

Multiplication by 5

x5:
1. Start in 4221, 2. Work from least significant, 3. Answer in 5422

Figure 2. BCD-4221 Multiplication by 5 [14]

Results
Power and Area Analysis for BCD and Binary to determine optimizations and the least energy per multiply.

Relative Performance Improvement to Oracle's Official Implementation

<table>
<thead>
<tr>
<th>Implementation</th>
<th>BCD</th>
<th>BCD</th>
<th>BCD</th>
<th>BCD</th>
</tr>
</thead>
<tbody>
<tr>
<td>EXP 001 002 003 004</td>
<td>1.67</td>
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<td>1.67</td>
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<td>1.67</td>
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</tr>
</tbody>
</table>

Figure 3. Top Level Diagram for BCD Design

Figure 4. Top Level Diagram for Binary Design

Software vs. Hardware Efficiency Performing 100 Multiplications

<table>
<thead>
<tr>
<th>Implementation</th>
<th>Software</th>
<th>Hardware</th>
</tr>
</thead>
<tbody>
<tr>
<td>EXP 001 002 003 004</td>
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<td>1.67</td>
</tr>
<tr>
<td>EXP 001 002 003 004</td>
<td>1.67</td>
<td>1.67</td>
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</tbody>
</table>

Figure 5. Relative Timing Performance Comparison with Oracle’s Current Implementations.

Figure 6. Energy Comparison of 100 Multiplications of Software vs. Hardware Efficiency

Total Area at Different Frequencies

<table>
<thead>
<tr>
<th>Frequency (MHz)</th>
<th>BCD</th>
<th>BCD</th>
<th>BCD</th>
<th>BCD</th>
</tr>
</thead>
<tbody>
<tr>
<td>200 MHz</td>
<td>100</td>
<td>100</td>
<td>100</td>
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<tr>
<td>300 MHz</td>
<td>100</td>
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<tr>
<td>400 MHz</td>
<td>100</td>
<td>100</td>
<td>100</td>
<td>100</td>
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<tr>
<td>500 MHz</td>
<td>100</td>
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</tr>
</tbody>
</table>

Figure 7. Total Area of the BCD and Binary Designs synthesized at different frequencies.

Energy Per Multiply vs. Frequency

<table>
<thead>
<tr>
<th>Frequency (MHz)</th>
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<tr>
<td>500 MHz</td>
<td>100</td>
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</tr>
</tbody>
</table>

Figure 8. Energy per Multiplication at different frequencies for the BCD and the Binary Designs Synthesized.

Conclusion
The higher latency Binary Design consumed less power than the lower latency of the BCD Design. The Partial Product Generation (PPG) for BCD Design was unexpectedly slow and had a high power consumption because a significant number of flops were needed to store multiples of an entire twenty digit ON. The BCD Design has 30% fewer stages than the Binary Design, but due to higher parallelization more flops are required at each stage trading power for latency. The longer critical delay path in the Binary Design requires more staging, but fewer flops are required for each stage. Each design has the same throughput and operates at the same clock frequency to provide an ON product each clock cycle after the initial latency.

When compared with the vector multiplication from Oracle’s current software implementation, the custom hardware is about 7,000 times more energy efficient and 66 times faster. Compared to the ONAT computation implementation for vector multiplication, by the Oracle Software Senior Design Team, the custom hardware was 3900 times more energy efficient and 34 times faster. Custom hardware provides significant improvement of performance using lower energy per operation, but area must be allocated on the chip for this custom hardware.

Future Applications
ASIC custom hardware for ON multiplication can also be applied to ON division. Custom hardware can be used in other future projects to improve the efficiency of Oracle’s software subroutines. Each design can be optimized to reduce area and power to maximize efficiency.

Acknowledgements
We would like to thank our sponsor, Oracle and the Jack Baskin School of Engineering for providing us with the opportunity to work on this project. We would also like to thank our teaching fellow, David Munday, our professor, Patrick Manley and the Oracle mentor, Hesam Fathi Moghamad for guiding and offering key insight throughout the project. We would also like to thank the following individuals: Jo Ebergen, Brian Gold, Jose Renau, Matthew Guthaus, Rigo Dioschea, Elhaz Ebrahim, and the Oracle Software Senior Design Team for their support.

References
Accelerating the Oracle Database for Analytic Workloads

Ariel Anders, Nathan Pemberton, and Lincoln Thurlow

JACK BASKIN SCHOOL OF ENGINEERING
Senior Design Capstone

Introduction

The Oracle Software Senior Design team’s objective is to improve the performance of Oracle Number arithmetic operations: addition, subtraction, multiplication, and division. This is achieved by temporarily converting to a new format called ONAT.

Overview

Oracle database systems store numbers in base-100 representation with up to 38 decimal digits of precision. We’ve created an alternative format called Oracle Native (ONAT) which combines the base-100 digit into base-100^4 (8 decimal digits) MegaDigits which are stored in 2 128-bit vectors.

Oracle Number (ON) Format

<table>
<thead>
<tr>
<th>ON Format</th>
<th>ONAT Format</th>
</tr>
</thead>
<tbody>
<tr>
<td>Oracle Number Format</td>
<td>Separate Sign and Exponent bytes</td>
</tr>
<tr>
<td>Variable Length</td>
<td>Each Mega Digit stores up to 8 decimal digits in 32-bits</td>
</tr>
<tr>
<td>Each digit stores 2 decimal digits in 1 byte</td>
<td></td>
</tr>
</tbody>
</table>

ONAT Format

Add Resultant Pair

Perform Carry Routine

Convert ONAT back to ON representation

Arithmetic Function Example

Multiplication – Base Case

- Compute partial products
- Sum partial products
- Perform the sequential (expensive) carry routine

Multiplication – ONAT Optimization

- Takes advantage of modern 64 and 32-bit processors
- Fewer partial products mean fewer multiplies and carries

Results

After only 3 arithmetic operations, the relative speed of ONAT operations has paid for the cost of conversion. As the number of operations between converts increases, the performance quickly approaches the limit of 2.5x faster (for large operands).

Performance Testing

- Load Oracle Numbers into memory in the C Harness and wait for signal.
- Attach Linux Perf and signal the C harness to begin the arithmetic operations.
- Record performance data and parse using a Python script.
- The performance was analyzed using 4 data sets.
  - Small (1-2 decimal digits)
  - Medium (20-24 decimal digits)
  - Large (40 decimal digits)

Conclusion

The performance of arithmetic operations is critical to meeting the demand for big data analytics. With a performance advantage of up to 2.5x, the ONAT format offers a competitive edge to the Oracle Database.

Acknowledgements

Advisors:
- Brian Gold (Oracle)
- Pat Mantey (UCSC)
- David Munday (UCSC)

Special Thanks to:
- Andrea Di Blas
- Jo Ebergen
- Jose Renau
Plantronics Human Energy Monitoring and Interface
David Bulnes, Ryan Conway, Vincent Harn, Charles Morales, Christopher Nagy

Objective
• Investigate the feasibility of harvesting energy from human body movements to charge or extend the battery life of a headset

Goals
• Design and develop modules that will measure movements at the head, wrist, and ankles
• Use the modules to collect data during daily activities over an 8-hour workday
• Analyze the gathered data to assess the feasibility of energy harvesting
• Create a user interface that presents data sets and graphs

Data Visualization
• A web-based user interface is used to visualize the data

Hardware
• Microchip PIC24F microcontroller
• 2GB MicroSD storage
• Mini-USB port for debugging and real-time data output
• Expansion port for future upgrades

Sensors
• Accelerometer
• Magnetometer
• Gyroscope

Photos
Head
2x Wrist
2x ankle
Cellphone usage in California prisons has become very prevalent. Our system detects idle cell phones. We built an integrated system detecting motion, metal cell phones, and cell phone radiated RF energy.

Abstract

We had many approaches to this issue:

- **ELECTROMAGNETIC RADIATION**
- **STIMULATED EMISSIONS**
- **DIRECTION FINDER**
- **PULSE INDUCTION**
- **WHITE NOISE**
- **MICROCELL**

Results and Design

- To ensure detection and reduce false alarms:
  - Motion Sensor detects you walking through door
  - Microcell causes phone to transmit
  - Power Detector detects the transmitted energy
  - Metal detector detects metal in phone
  - Outputs:
    - Green LED = Motion
    - Yellow LED = Metal
    - Red LED = RF Energy
    - Red LED + Yellow LED = Sound

Sherlock Project Block Diagram

Acknowledgements

We’d like to thank Raytheon Applied Signal Technology and our sponsor Michael Ready for all his help. We’d also like to thank Patrick Manney, Stephen Petersen, and David Munday for their guidance.

Additionally we thank Daryl Beetner and Carl Moreland.

Experiments

We had many approaches to this issue:

- **ELECTROMAGNETIC RADIATION**
  - We looked to see if the cellphone was emitting spurious emissions around its clock frequencies.
- **STIMULATED EMISSIONS**
  - We sent signals to the phone to see if it would emit back.
- **DIRECTION FINDER**
  - The Direction finder compares the phase between two dipole antennas. When a phone is introduced into the field it will cause a disruption of the channel.
- **PULSE INDUCTION**
  - This experiment is analogous to our metal detector, in which we send a pulse of energy with the same frequency of the cell phone, and analyze the transient response.
- **WHITE NOISE**
  - Similar to the Pulse experiment, except we send a continuous channel with a band of frequencies to another antenna and study any changes to the channel when a phone is introduced.
- **MICROCELL**
  - We are trying to cause the phone to transmit by introducing a microcell.
**Mission**

- Improve Rider’s Safety
- Unleash Artistic, Creative and Engineering Talents

**Project Hardware**

- **TI MSP430 LaunchPad Development Tool**
- **MSP430G2553 Microcontroller**
- **Capacitive Touch BoosterPack**
- **Electroluminescent Wire and Panel**
- **E2430-RF2500 MSP430 Wireless Development Tool**
- **MMA 7361 Triple Axis Accelerometer**

**Project Challenges**

- Allow cyclist to communicate turning intentions through the capacitive touch sensor.
- Signal turning intentions.
- Signal breaking and emergency situations.
- Adjust brightness to suit lighting conditions.
- Meeting baseline Design Functionality
- Visibility from 300 ft.
- Power time at least 6 hours.
- Synchronized helmet and garment signaling.
- Design fashionable and comfortable garment with the embedded system.
- Garment is attractive & comfortable to wear.
- Battery charging system is convenient and easy to use.
- Garment light weight 1-1.5 lb.
- Engineering a battery powered micro-controller based product from ground up.
- Integrated system components.
- Rigorous testing and prototyping.
- Reliable performance that does’t detract from user experience.
- Creating a valuable consumer project with positive social and economical impacts.
- Garment will be used to increase cyclist’s safety during dark hours.

**System Block Diagrams**

**Control System**

- Capacitive Touch Sensor
- LED Lights
- 3-Axis Accelerometer

**Garment System**

- Brightness Commands
- Turning Intentions
- LED Lights

**Helmet System**

- Brightness Commands
- Turning Intentions
- LED Lights

**Conclusion**

The Smart Illuminating Garment & Helmet Technology system provides controllable illumination to the wearer for increased visibility. In low light situations it should reduce accidents involving cyclists, and vehicles that occur due to little to no visibility of the cyclist. Turn signaling will help others identify the cyclist’s intentions and further reduce accidents.

**Future**

While this project is embedded on a jacket and helmet, this system can be adapted for any situation that requires controllable lights. It could be used on roadside workers’ vests, on other garments, and even in non-clothing applications. This system can also be expanded to support multiple lighting modules which can be addressed through a single control module. The module can also be expanded to control LEDs to provide flexibility in future lighting options.

**References**


**Acknowledgements**

Jian Zhang, Software Engineering Manager, Texas Instruments.

Sameh Sahar, Senior Strategic Marketing Manager, Texas Instruments.

Stephen Petersen & John Vesecky, University of California, Santa Cruz Electrical Engineering professors.

Ryan Heywood, Economics and Environmental Studies student & activist in cyclist’s community, University of California, Santa Cruz.
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