Group 13 – S.H.E.M.S.
Smart Home Energy Monitoring System

Sponsored by Duke Energy and Texas Instruments

Alejandro Dirksen

Zaida Gonzalez

Marisa Vega

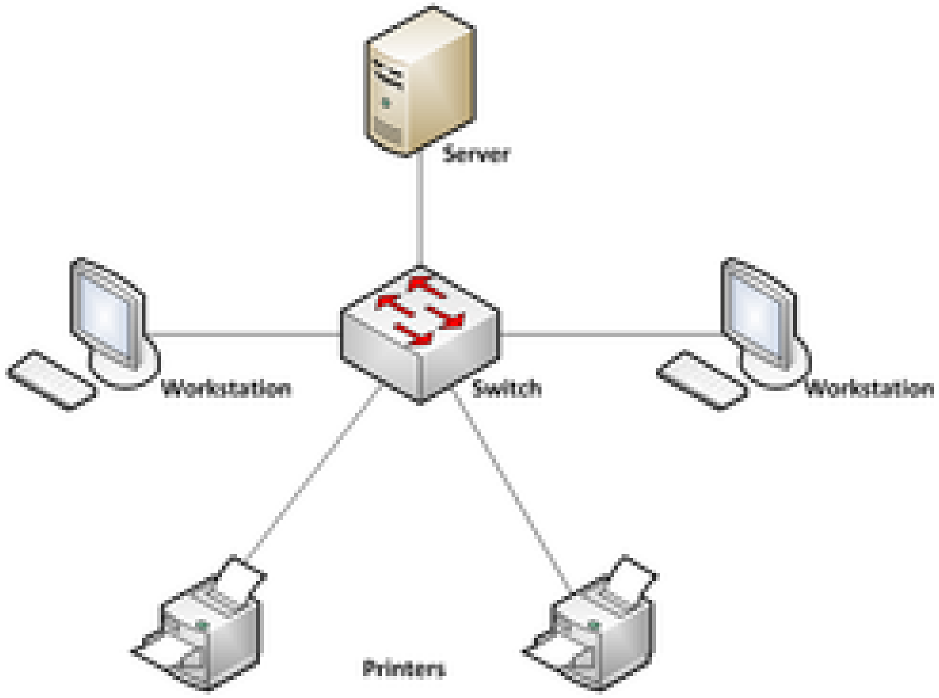
Wayne Rodenburg

Motivations and Goals

- Reduction of the high cost of energy and the control over power at all levels including standby power or phantom energy
- According to the Lawrence Berkeley National Laboratory, individual devices draw some power and they cannot be completely off unless they are unplug
- The goal of our project is to reduce the standby power to a negligible amount remotely and safely and provide visual means for a user to realize how much power the devices connected to the smart meter are actually drawing.

Objectives

- To measure current, voltage and power accurately and safely
- Give the users information about their usage in a detailed and uncomplicated manner



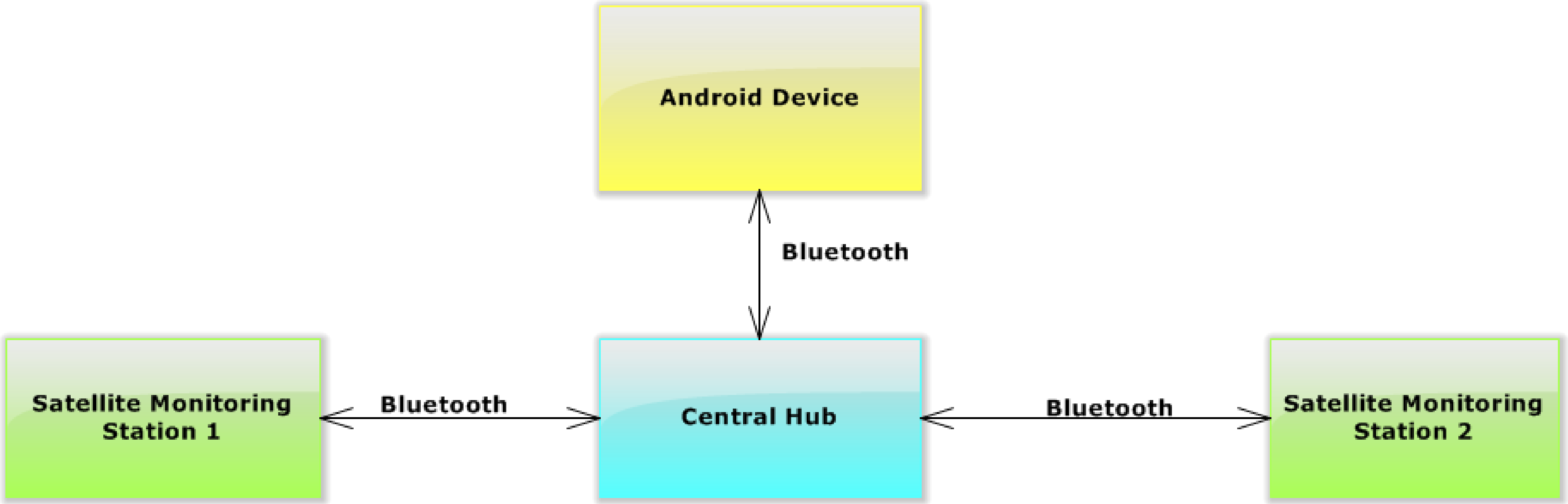
Central Hub Specifications

Feature	Value
Ultralow to low power consumption	Yes
Real time clock	Yes
Watchdog timer	Yes
UART	12C
CPU	16 bit
RAM	8 kB
Minimum CPU speed	16 MHz
High resolution timer	4 ns

Satellite Station Specifications

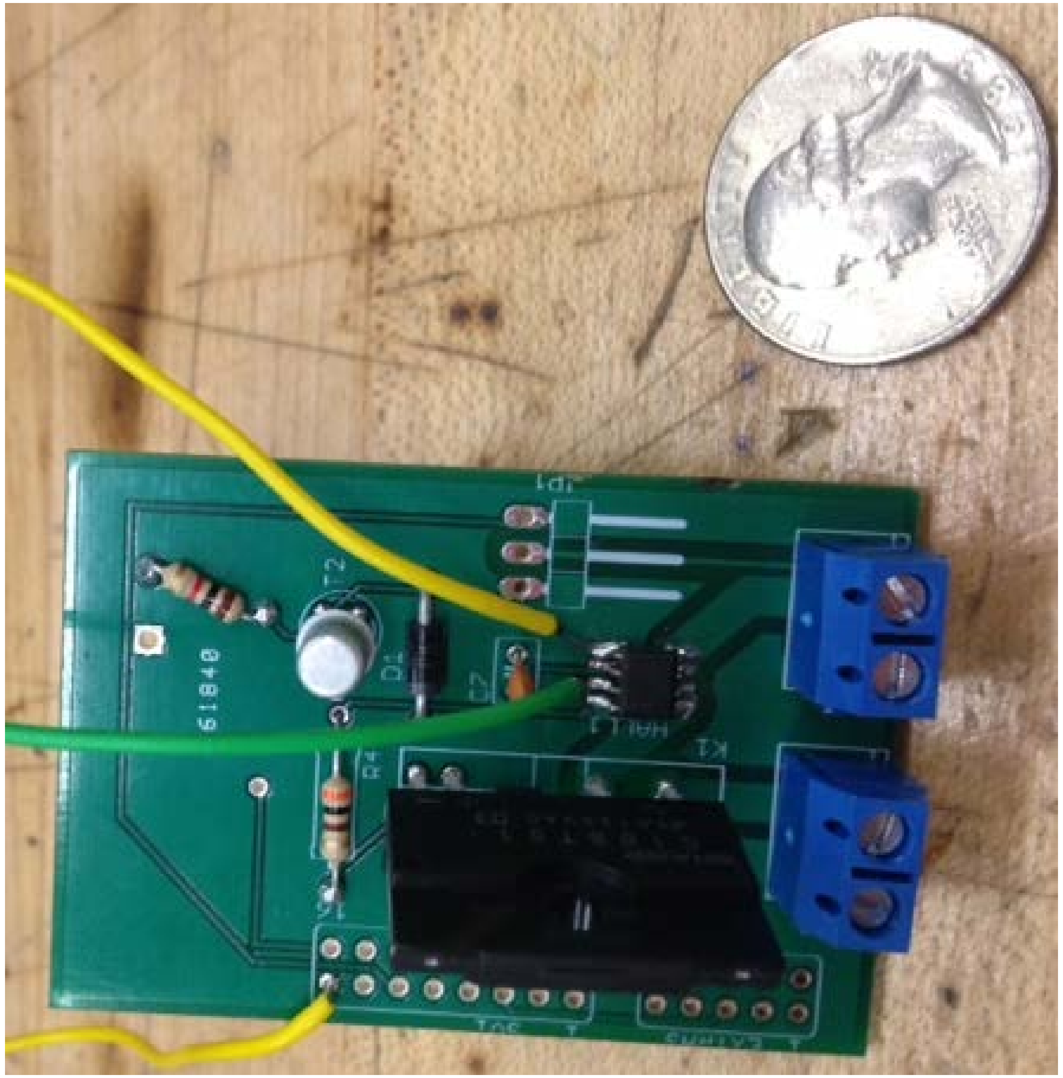
Feature	Value
Voltage	120VAC
Phase	Single Phase
Frequency	60 Hz
Max Current	8 amperes
Max Load	0.98 KVA
Connection	L5-30P with rear panel
Monitors	NONE
Outlets	(1) 5-15R, 120V
P Protection	Spike/Surge
OCP	Yes

Project overview



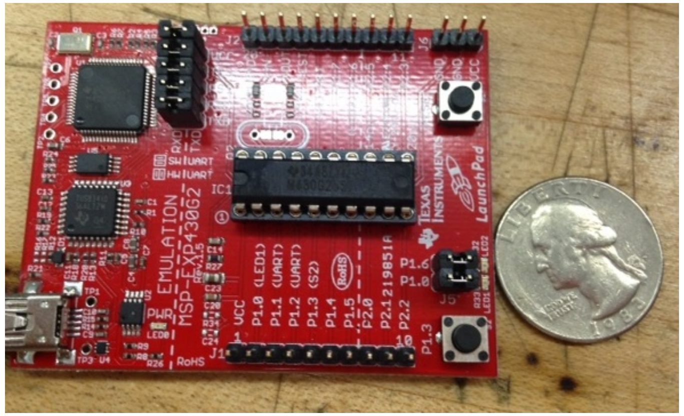
Parts of the Satellite Station

- Microcontroller
- Current Sensor
- Voltage Sensor
- Relay
- Plug
- Receptacle
- Power supply
  - AC/DC Converter (provide adequate voltages to each part in the circuit)



Key characteristics that we need when choosing a microcontroller

- Fast reliable data acquisition
- Low power consumption
- Applications that includes sensoring of analog signals and conversion of the same to digital to be transmitted to a host system for display
- Ultra low power settings
- N packaging allowing easy mounting of the MCU in the launch pad for flashing



Microcontroller comparison table

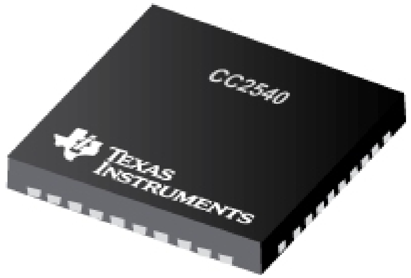
Manufacturer	Atmel	Microchip PIC	Freescale	Texas Instruments
Manufacturer part #	ATSAM4L52CA-AU	PiC32MX120F032B	SPC5601PEF0MLH6	MSP430G2553IN20
Image				
Availability	Immediate	In production	Available	Available
Unit price	$6.39	$1.71	$6.59	Free Samples
Packaging	TQFP	SSOP,SOIC	LQFP64	PDIP(N)
Series	SAM4L	PC132MX1	MPC564XA	MSP430
Core processor	ARMCortexM4	DMIPS16e	E200zoh	2 Series
Core Size	32 bits	32bits	32bits	16 bits
Speed	48MHz	50MHz	64MHz	16MHz
Connectivity	I2C,IrDA,LIN,SPI,UART/USART,USB	UART,SPI,I2C	CAN,LIN,SCI,SPI	I2C,IrDA,UART/USART,USB,SPI
Digital communication Peripherals	Brown-out detect/Reset DMA,I2S	-------------	DMA,PWM,WDT	Brown-out detect/reset, PWM
Comparator	1	3	1	1
Number of I/O	80	28	45	21
Program memory type	Flash	Flash	Flash	Flash
Program Memory size	128KB	32KB	192KB	128KB OR 256KB
RAM	32KB	8.192KB	12KB	8KB
Voltage Supply	1.68V-3.6V	2.3V-3.6V	3.3V-5V	-0.3V-3.9V
Oscillator	Internal	Internal	Internal	Internal
Operating Temperature	-40°C to 85°C	-40°C to 85°C	-40°C to 85°C	-40°C to 85°C
ADC channel	3	10	12	8
Watchdog	1	1	1	1

Microcontroller for the HUB: CC2540F256RHAT

- True Single chip BLE solution: can run both applications and BLE Protocol
- Includes Peripherals to interface with our LCD screen
- Enhanced 8051 MCU, in-system programmable flash memory
- 8KB ram and other powerful supporting features
- Very low power sleep modes available

6.3mm

x

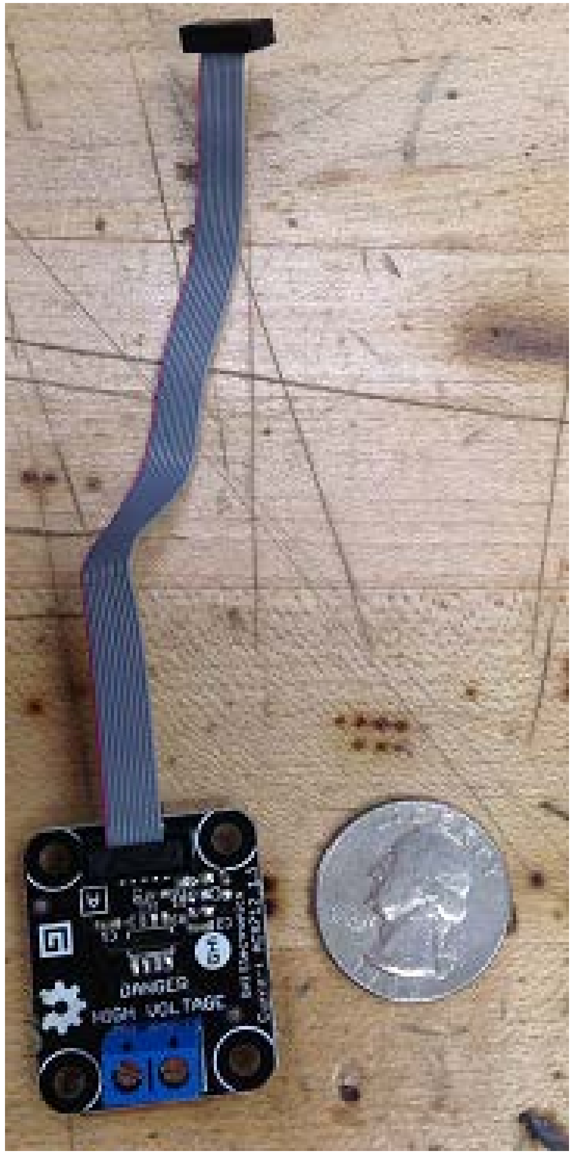


6.3mm

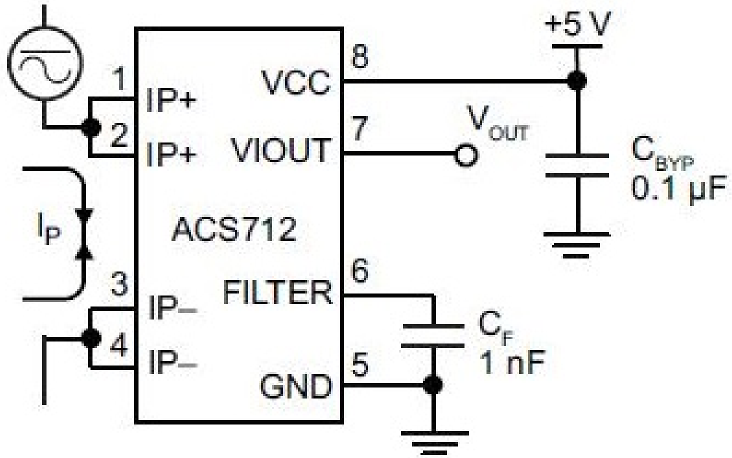
Types of Sensors

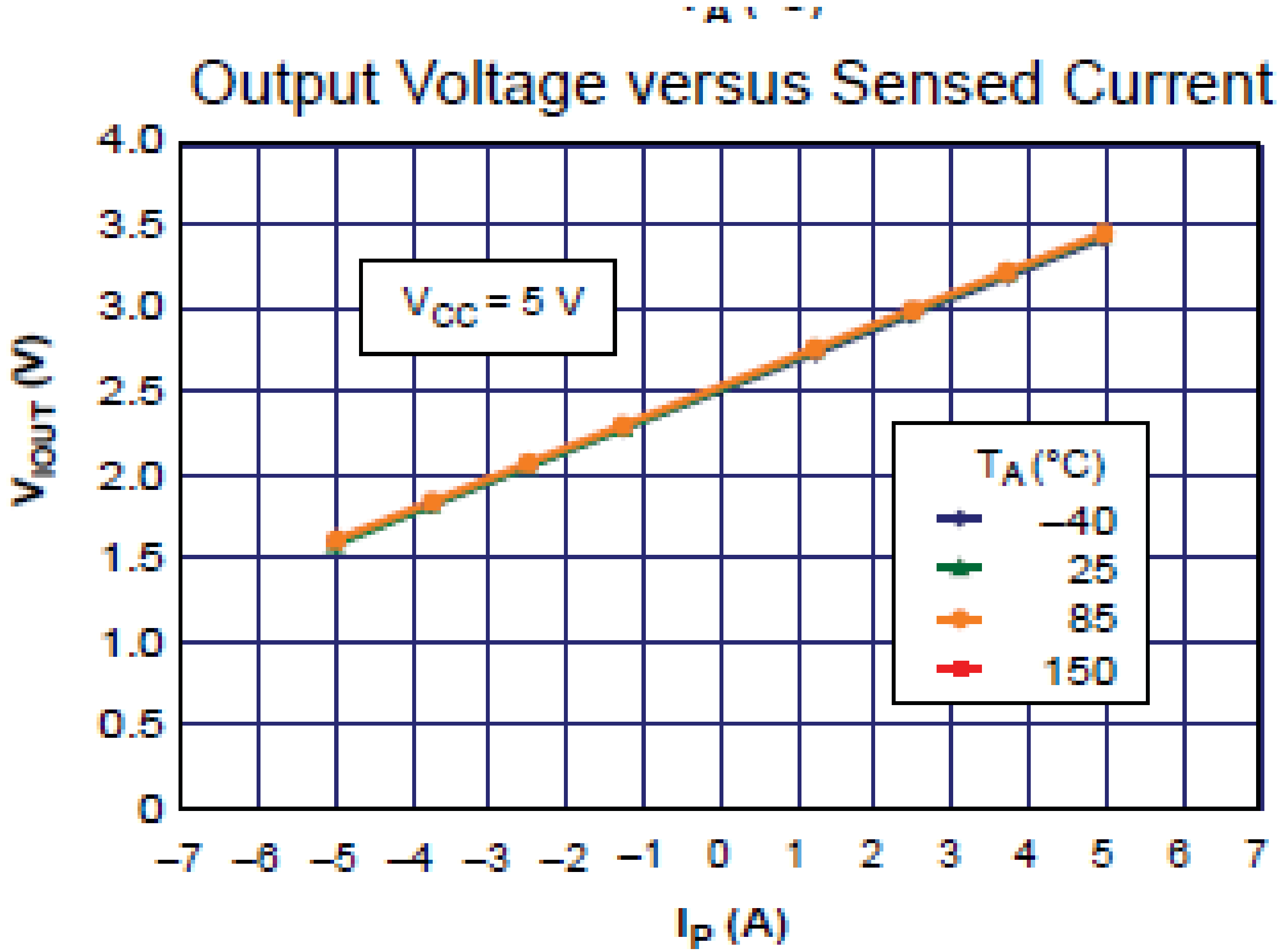
- Current Shunt Monitor
- Current Sense Amplifier
- Magnetic Current Sensor
- Current Transformer

- Our Choice: Current Hall Sensor
    - ACS712



Mechanism for the Current Hall Sensor ACS712





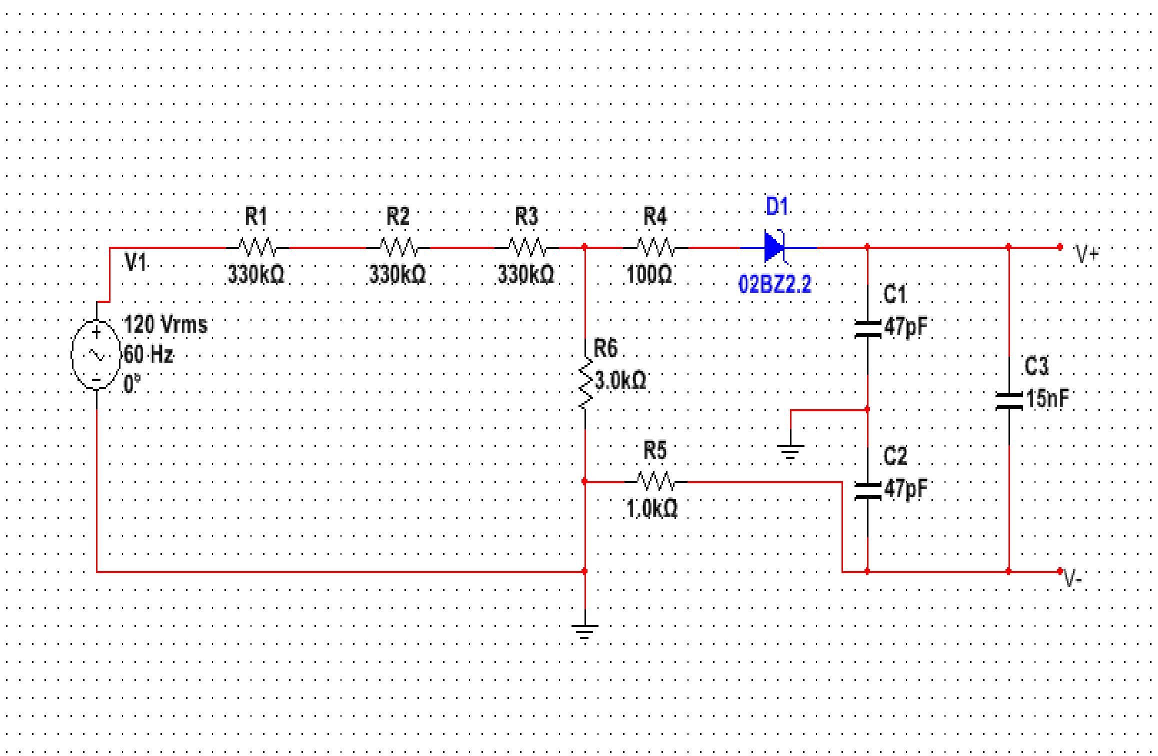
Output signal Vout varies linearly with the bidirectional AC primary sample current Ip

Key features for the ACS712 Current Sensor IC

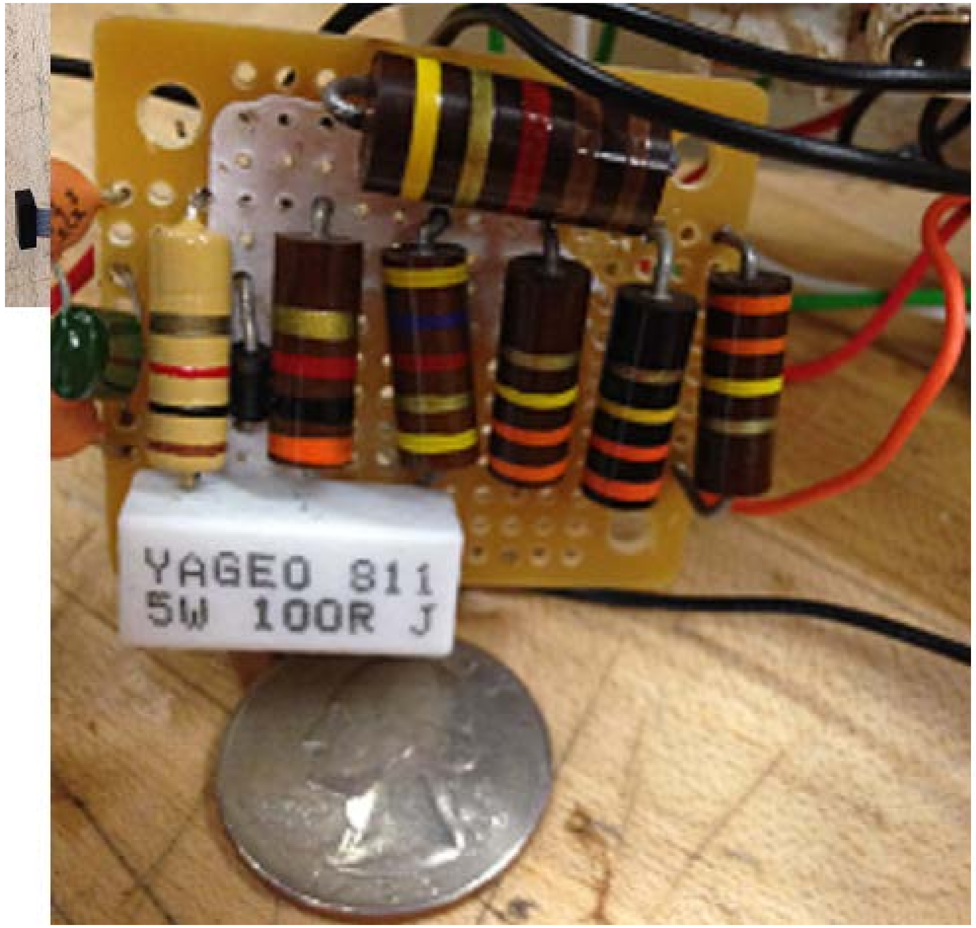
Feature	Value	Unit
Single Supply Operation	5	V
Output Sensitivity	185	mV/A
Minimum isolation voltage(from pin 1-4 to pins 5-8)	2.1	kVRMS
Bandwidth	80	kHz
Total output error	1.5	%
Internal conductor resistance	1.2	mΩ
Hysteresis	500	mV

Voltage Circuitry: Analog Front End for Voltage Inputs

Schematic for Voltage Circuitry

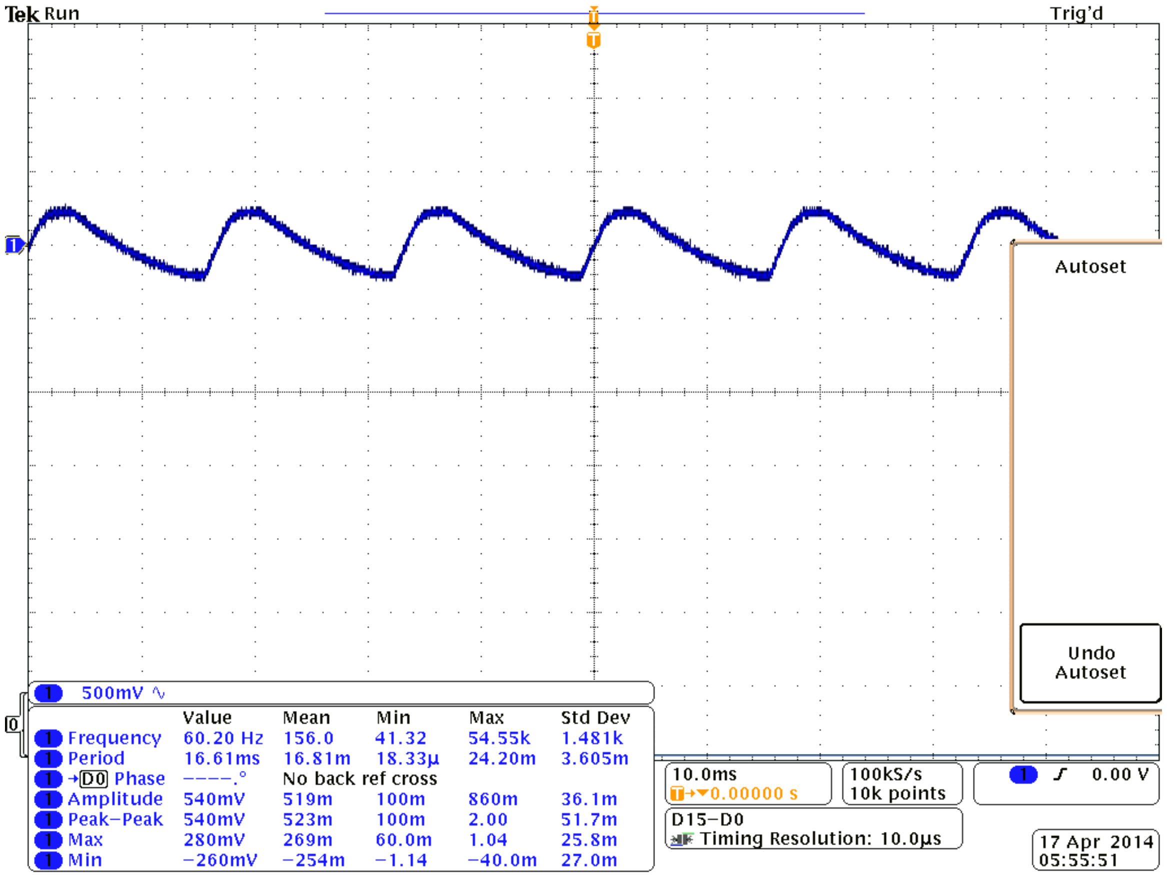


Actual Circuit as in the monitoring node

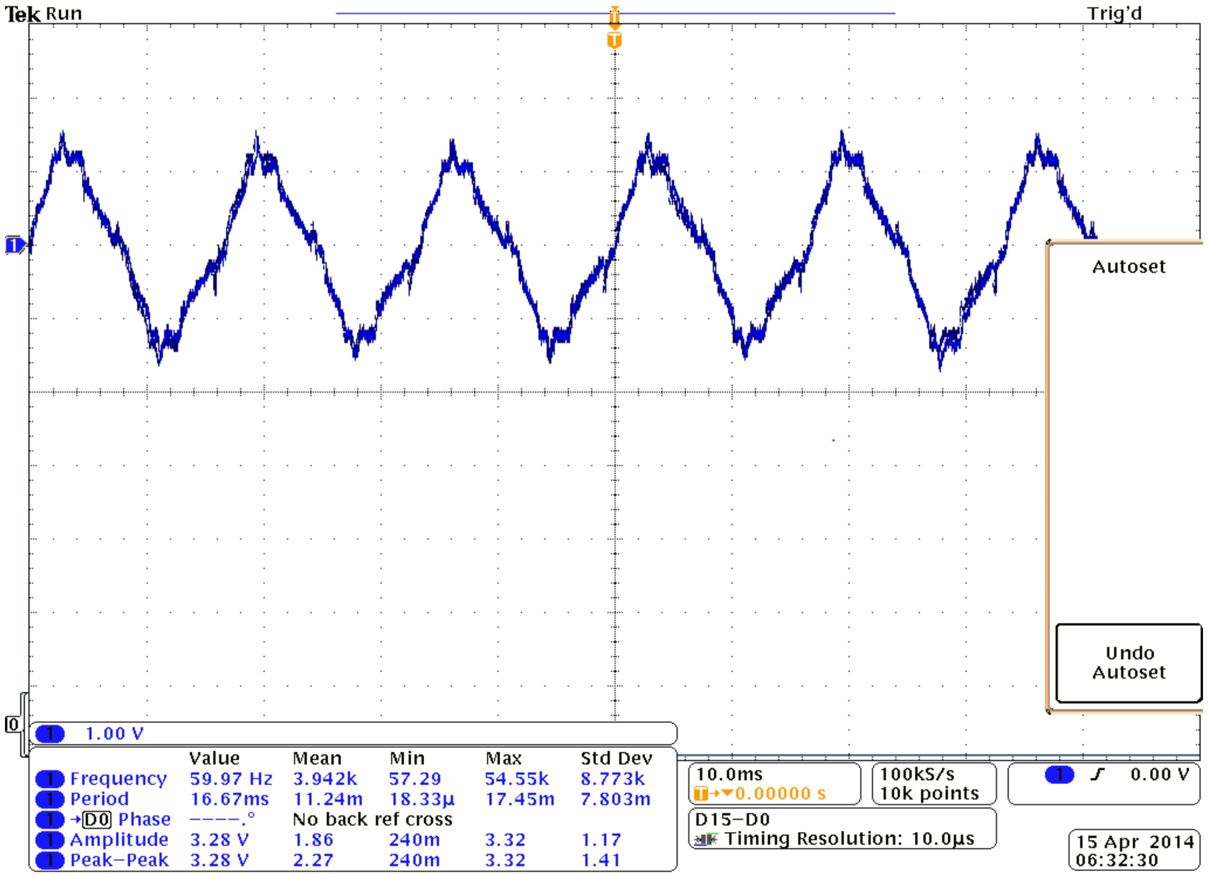


Measurements with the Oscilloscope

Voltage Circuitry



Current Sensor



Calculations for Voltage, Current, Power

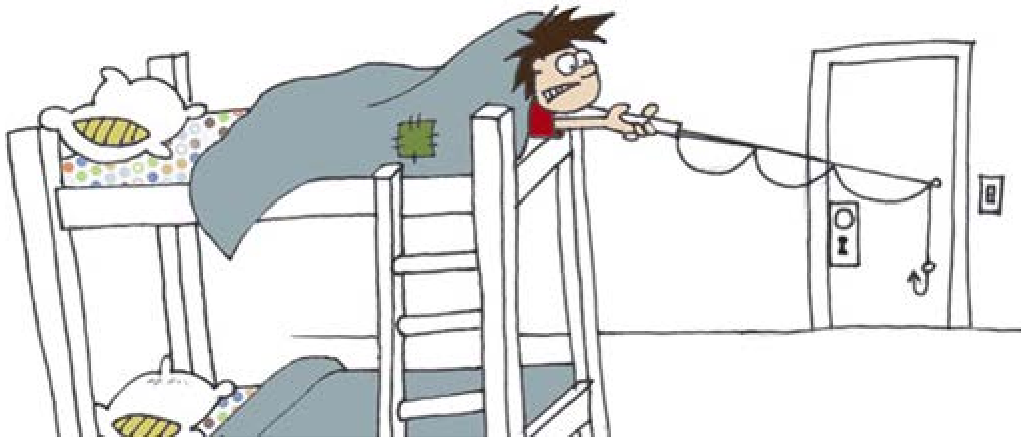
$$V_{RMS} = K_v * \sqrt{\frac{\sum_{n=1}^{Sample\ count} v^2(n)}{Sample\ count}}$$

$$P_{ACT} = K_p \sqrt{\frac{\sum_{n=1}^{Sample\ count} v(n) \times i(n)}{Sample\ count}}$$

$$I_{RMS} = K_i * \sqrt{\frac{\sum_{n=1}^{Sample\ count} i^2(n)}{Sample\ count}}$$

$$P_{REACT} = K_p \sqrt{\frac{\sum_{n=1}^{Sample\ count} v_{90}(n) \times i(n)}{Sample\ count}}$$

REMOTE SWITCH ON/OFF OR LOAD MANAGEMENT



A device that will control a circuit with a low power signal is necessary.

Options:

Electromechanical Relay, SS relay or Darlington Arrays

Our choice Solid State Relay

SS Relay

- No contact relay
- Activated by the control signal to control the load
- Faster response
- Highly reliable
- If large currents additional heat sink is required

Darlington Array

- IC’s capable of high voltage, high current
- Open collector output
- Free-wheeling clamping diode
- No need for diodes across relay
- IC has internal resistance

S108T01 Series

Description:

Solid State Relay(SSR) with integrated infrared emitting diode (IRED), Phototriac Detector and Main output Triac

Important Features:

Output Current, Ir(rms)<=8.0A

Non-zero crossing functionary

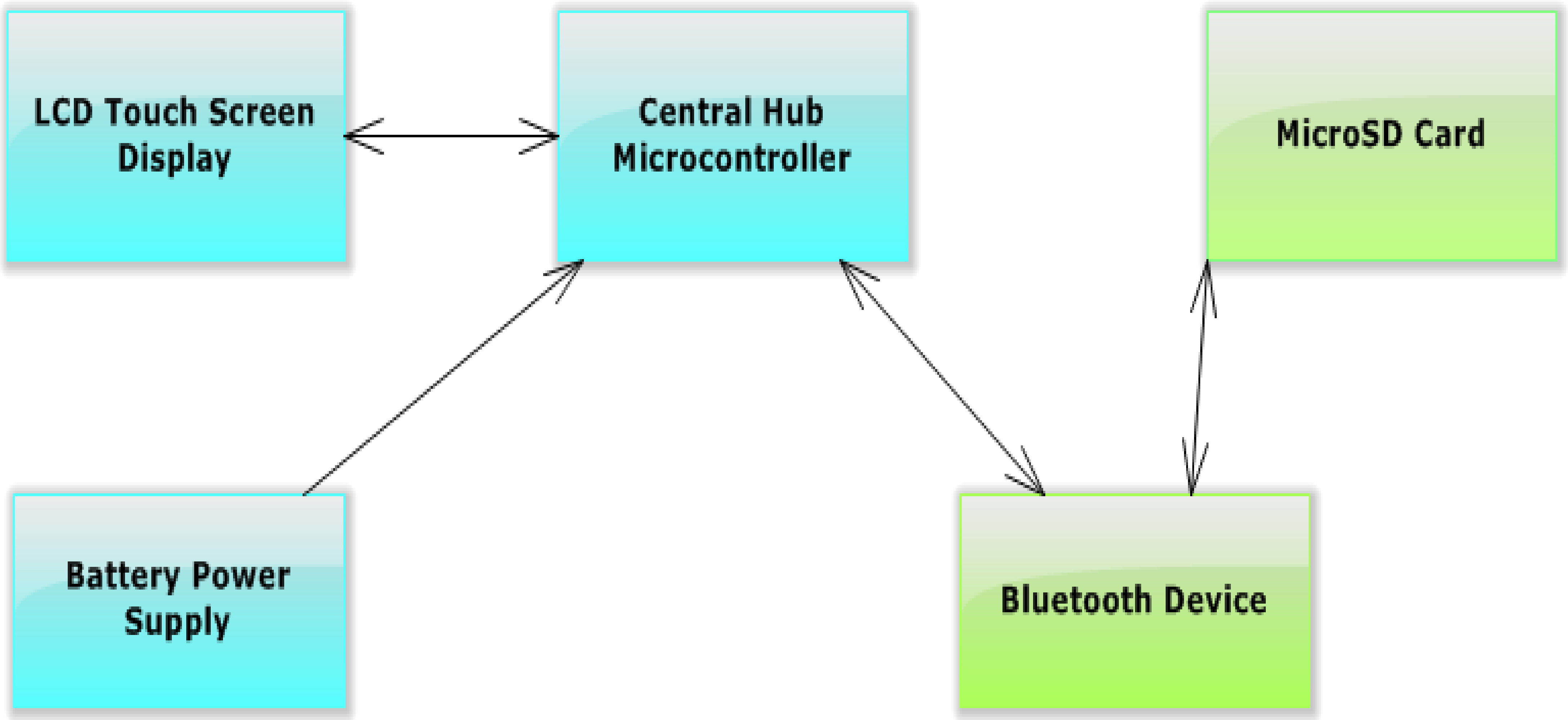
Ideally suited for controlling high voltage AC loads

3.0kV isolation (Viso(rms) from input to output

Applications:

Phase or power control

The Central Hub



LCD: Features and Specifications

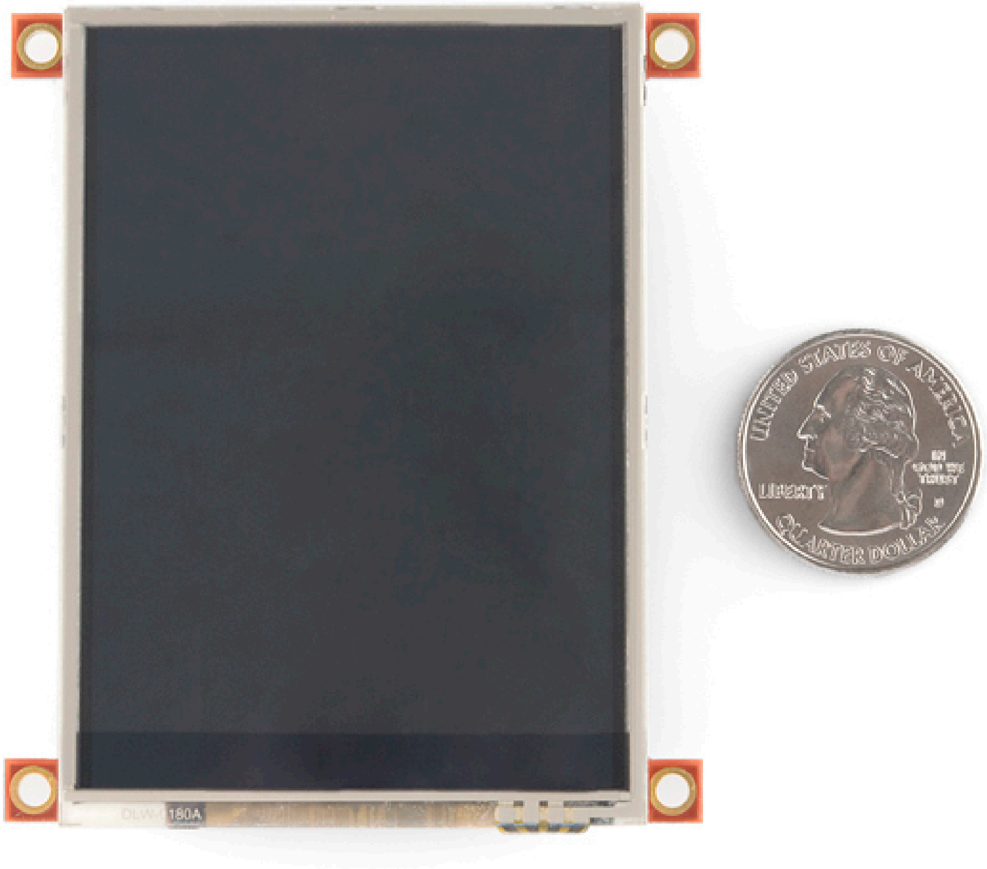
Serial TFT LCD - 3.2“ (Chosen)** ($84.95)	arLCD - 3.5" Touchscreen ($89.95)
Not Arduino	Arduino Compatible
4.0V to 5.5V range operation (single supply)	6 – 9V Operating Voltage
65K true to life colors, TFT screen with Integrated 4-Wire Resistive Touch Panel	Thin Film Transistor
320 x 240 Resolution	320 x 240 Resolution
Display full color images, animations, icons and video clips	65k colors
14KB of flash memory for user code storage and 14KB of SRAM for user variables, or 14KB shared user code and program variables	4MB Flash Memory
A 30 pin header for I/O expansion and future plug-in daughter boards	LCD Backlight

LCD

Technology chosen: Resistive LCD technology

Chosen: Serial TFT LCD - 3.2"

- Cost effective
- Sophisticated software makes it compatible with almost any application
- Range voltage is ideal
- More suitable for further expansion or additions if necessary
- The software used (4D Workshop) makes it really easy to code – Drag and put into the LCD interface



Bluetooth or Wi-Fi

Bluetooth	Wi-Fi
Pros:	**Pros:**
New Technology commonly used nowadays by many gadgets	Universally used
Very secure	Depending on the network the range can be very large
Low power	
Cons:	**Cons:**
Limited range	Signal strength could be an issue (need a good network)
	Needs more protection of user's personal data

Bluetooth

The decision was the Bluetooth

- It is more secure
- Can be connected with multiple devices
- Can be used with Android app
- Good for the group to familiarize and work with Bluetooth technology

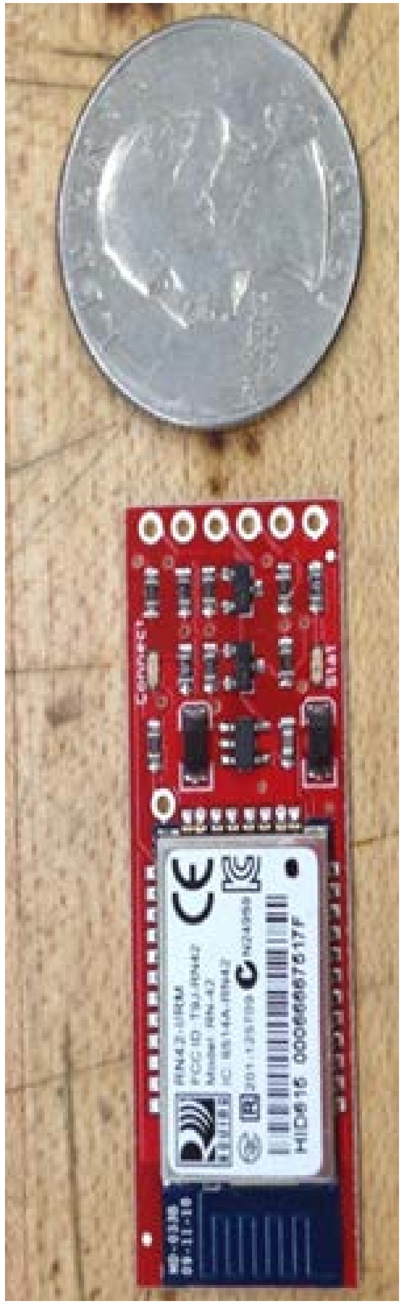
Bluetooth Parts: Features and Specifications

Bluetooth Mate Silver Module - RN-42 – from Sparkfun ($39.95)	**TI CC2564 (Free Samples)**	**TI CC2540F256 (Free Samples) – Development Kit ($100)**
Fully qualified Bluetooth module	Fully qualified Bluetooth module	RF transceiver/Bluetooth
FCC certified	Low Energy	Low Energy Technology
Compatible with Bluetooth modules that support SPP Built in antenna	Supply voltage range: -0.5 – 4.8 V RF inputs: 10 dbM	Programmable flash memory of 256 KB (and 8KB of SRAM)
Lower Power Consumption: 25 mA	Class 1.5 TX Power Up to +12 dBm	Low power: 15.8 mA avg for RX and 18.6 mA for TX
3.3V Operation Low power sleep mode	Shutdown current: 7 uA Deep sleep mode: 105 uA	Operating Voltage: 3V

Bluetooth Chosen

Bluetooth Mate Silver

- Low Power Consumption and voltage operation
- Good range – ideal for the project
- Cost effective – cheaper than the TI development kit
- Because the Bluetooth is separate from the microcontroller, no code is needed to make the connections
- All processes are encapsulated inside the Bluetooth – no code needs to be done
- It is compatible with the microprocessor chosen – MSP430
- It is easy to connect to the circuit – RF/TX connectors



Apple vs. Android

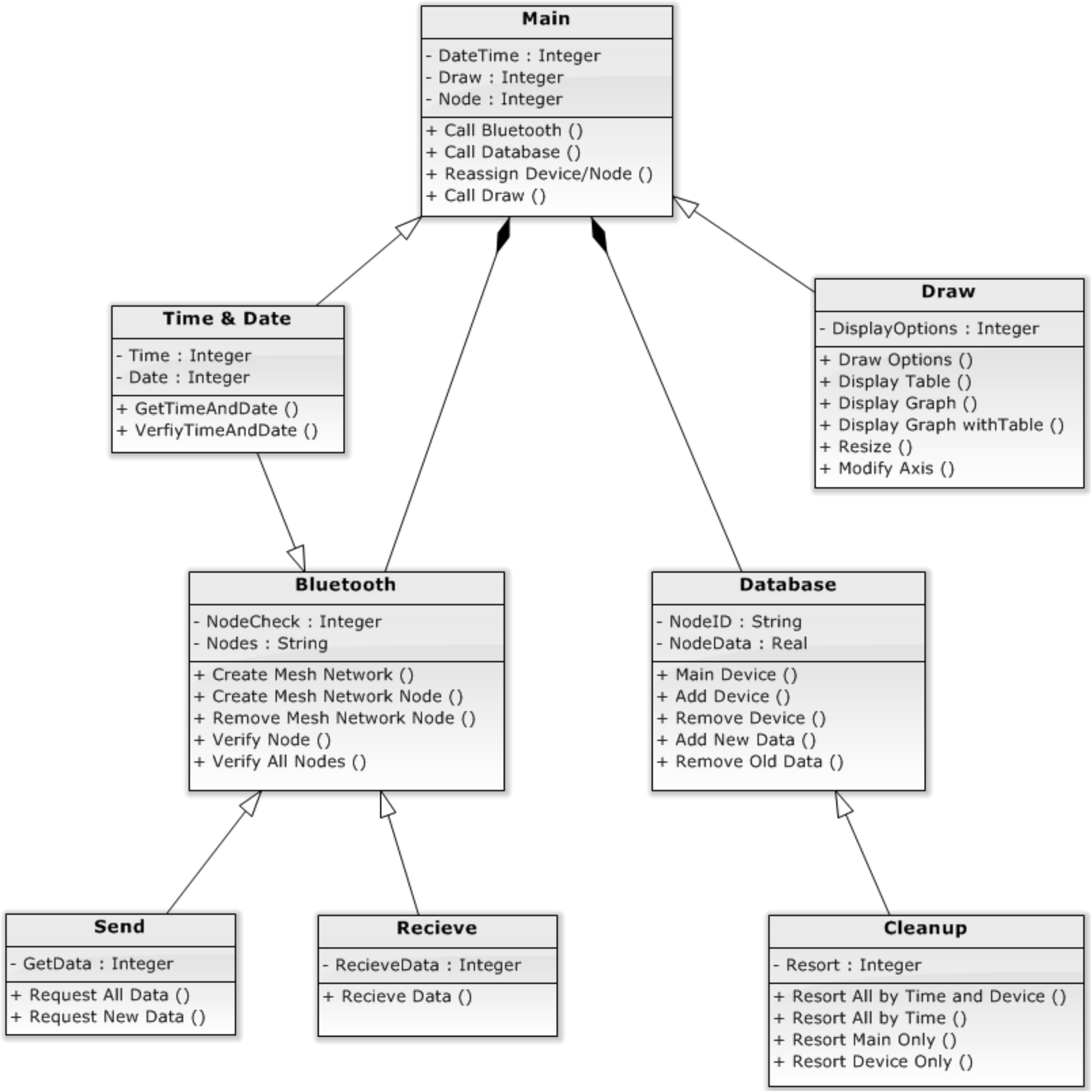
Options	Android	Apple
Cost	Free	$99 per year
Usage	Widely used Globally	Widely used in the US
Past Development With	Java coding	None at all
Hardware needed	Android device & any PC	Apple device and computer
Conclusion	We will use Android	We will not use Apple

>

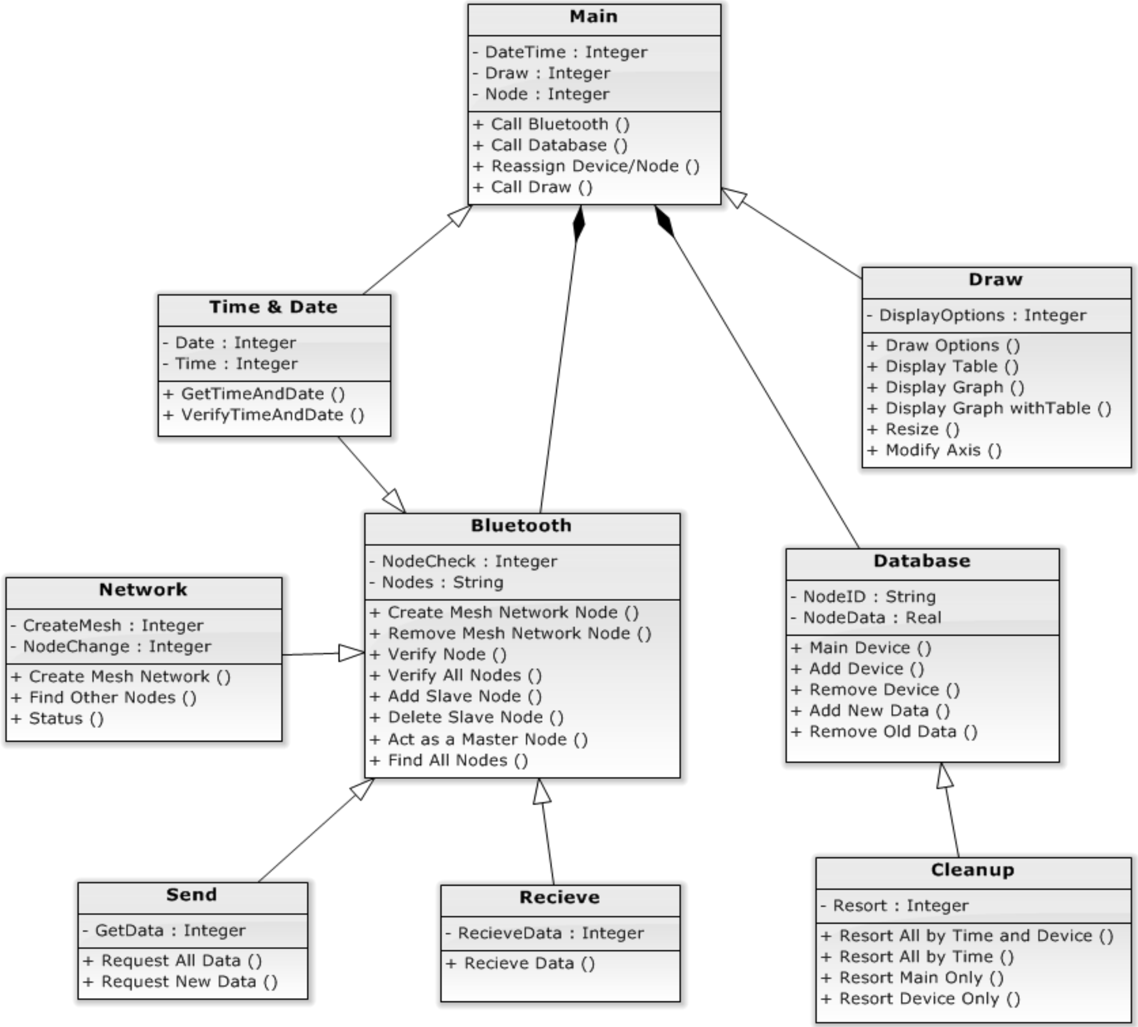
Android App Development

- Android device
- Bluetooth interactions
- Display the Data in a simple and nontechnical way
- Ideally we would like to use a SQLite database to store the information in
- If we use a SQLite database we will want to refactoring data

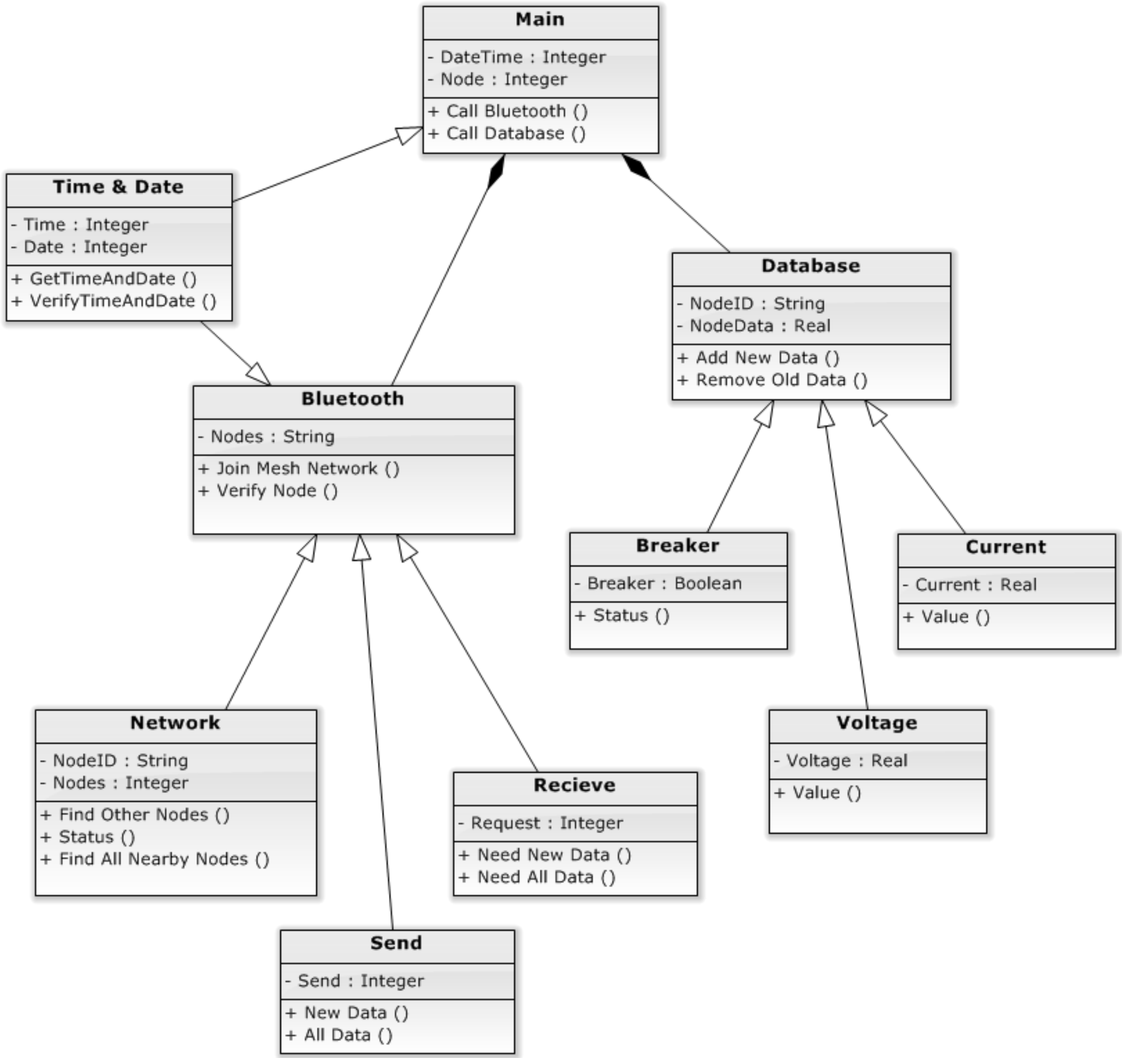
Android App Class Diagram



Central Hub Microcontroller Class Diagram



Satellite Microcontroller Class Diagram



Power supply for Central Hub

- Wall Outlet Vs Battery Powered

  -We decide on battery power

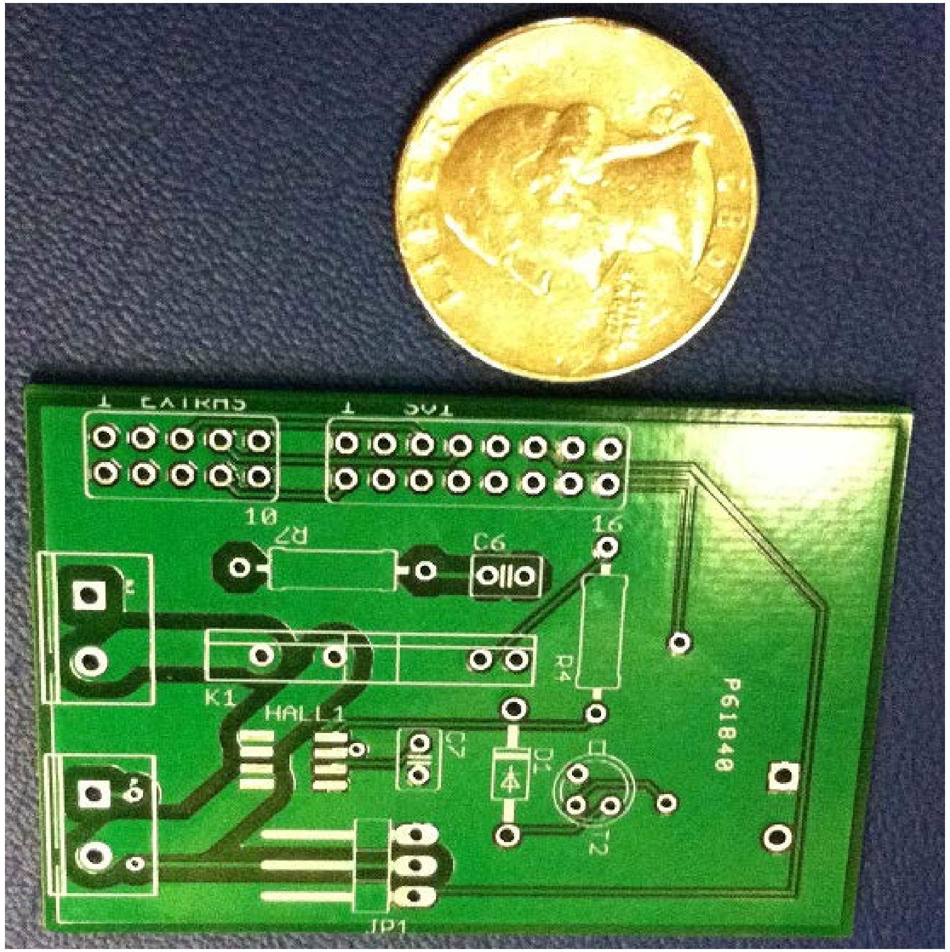
  -Portability

  -no need for ac/dc converter

  -voltage requirement of the devices

PCB Advanced circuits

- Currently done on 2 layers
- Most inexpensive for the quality they provide
- Very fast shipping



Division of Labor

Main Component	Subcomponents	Persons Responsible
Central Hub	LCD display	Zaida Gonzalez then Wayne Rodenburg
	Bluetooth Device	Zaida Gonzalez then Wayne Rodenburg
	Microcontroller	Wayne Rodenburg then everyone
	Circuit Board	Alejandro Dirksen then Marisa Vega
Individual Satellite Monitoring Stations	Bluetooth Devices	Zaida Gonzalez then Wayne Rodenburg
(Five in all)	CT Current Meters	Alejandro Dirksen then Marisa Vega
	Surge Protectors	Marisa Vega then Alejandro Dirksen
	Relays	Alejandro Dirksen then Marisa Vega
	Outlets	Marisa Vega then Alejandro Dirksen
	Microcontrollers	Alejandro Dirksen then everyone
	Circuit Boards	Marisa Vega then Alejandro Dirksen
Android Application	Android Application	Wayne Rodenburg then Zaida Gonzalez

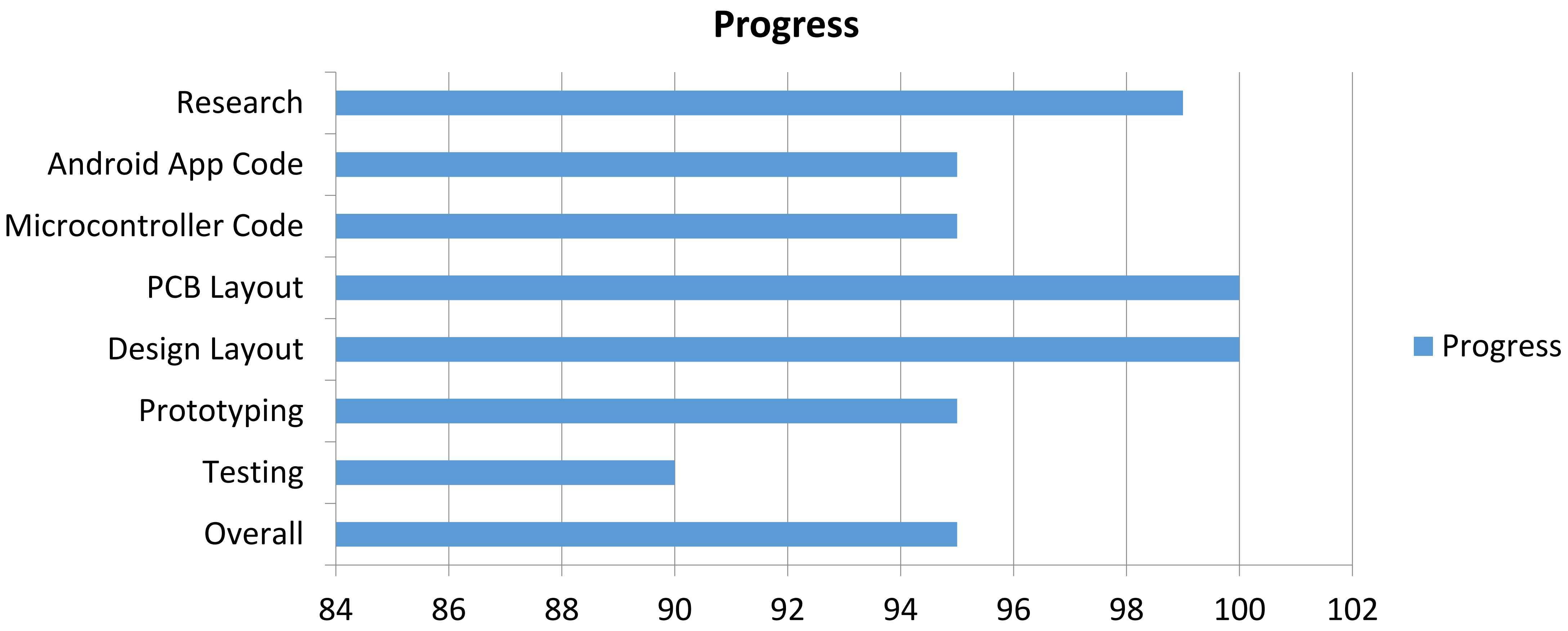
Budget

Item	Expected Cost	Actual Cost
LCD 1x	$ 150	$120
Outlet 2x	$ 10	$20
Relays 4x	$ 25	$20
Hall Effect Current Sensors 4x	$ 25	$120
Microcontrollers for the Stations & Hub	$ 150	$99
Wiring	$ 15	$0
Housing for the Hub 1x	$ 10	$10
Housing for the Stations 2x	$ 50	$20
Circuit Board 4x	$ 150	$216
Shipping and Handling	$ 200	$300
Board assembly and learning how to solder	$ 150	$20
Total amount	$ 1535	$945

Milestones

Milestone	Expected Time to Complete Each Milestone	Expected Start Dates & Expected Completion Dates
Form Group and Pick Project	1 week	August 19^{th} – September 9th
Research	6 months	September 2^{nd} – March 1st
Decide on Project Features	1 month	September 2^{nd} – October 1^{st}
Form a Design we all agree on	1 month	September 2^{nd} – October 1^{st}
Decide on parts we will use	5 months	September 9^{th} – February 1^{st}
Duke Energy Grant Proposal		Submit by October 18^{th}
Order the Parts	3 months	December 1^{st} – March 1^{st}
Meter Design	2 months	December 1^{st} – February 1^{st}
Plug Design	2 months	December 1^{st} – February 1^{st}
Relay Design	2 months	December 1^{st} – February 1^{st}
Surge Protector Design	2 months	December 1^{st} – February 1^{st}
Android Application	6 months	October 1^{st} – April 1^{st}
Android Testing	6 months	October 1^{st} – April 1^{st}
Circuit Board Design	3 months	November 1^{st} – February 1^{st}
Circuit Board Testing	4 months	November 1^{st} – March 1^{st}
Microcontroller Coding	5 months	November 1^{st} – April 1^{st}
Microcontroller Testing	5 months	November 1^{st} – April 1^{st}
Interface Testing	5 months	November 1^{st} – April 1^{st}
Senior Design 1 Paper Due		December 2^{nd} 2013
First Prototype	3 months	December 1^{st} – March 1^{st}
First Prototype Testing	3 months	December 1^{st} – March 1^{st}
Final Prototype	3 months	January 1^{st} – April 1^{st}
Final Prototype Testing	3 months	January 1^{st} – April 1^{st}
Senior Design Day Showcase		April 18^{th} 2014
Final Presentation		April 2014

Project Progress



Issues

- A few Android application bugs
- A few microcontroller code bugs
- Time constraints

Special Thanks

- Duke Energy for the grant money that funded much of our project
- TI for the contest money that helped us buy our development boards and all of the free samples and information that aided us
- Matt our lab TA for his help and insights
- Mr. David Douglas for his help in procuring some of the testing equipment we needed
- Dr. Samuel Richie our faculty advisor
- Professors Chatterjee, Abichar and Mikhael for taking time out of their busy schedules to sit as our senior design committee

Questions