S.H.A.P.E.R.

Smart Home Automated Power Expense Regulator

Group 18

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Sponsored by: Boeing and Leidos

Agenda

- Project description
- I/O hardware components
- Hardware interaction & power consumption
- Software development
- Mobile application
- Administrative content

Motivation

- Waste of electricity and power
- People not well informed about power consumption habits
- Living in a ‘smart’ world/society
- ‘Smart’ house concept not available to the average consumer
- Can be implemented at a more reasonable price
- Ford Model T concept

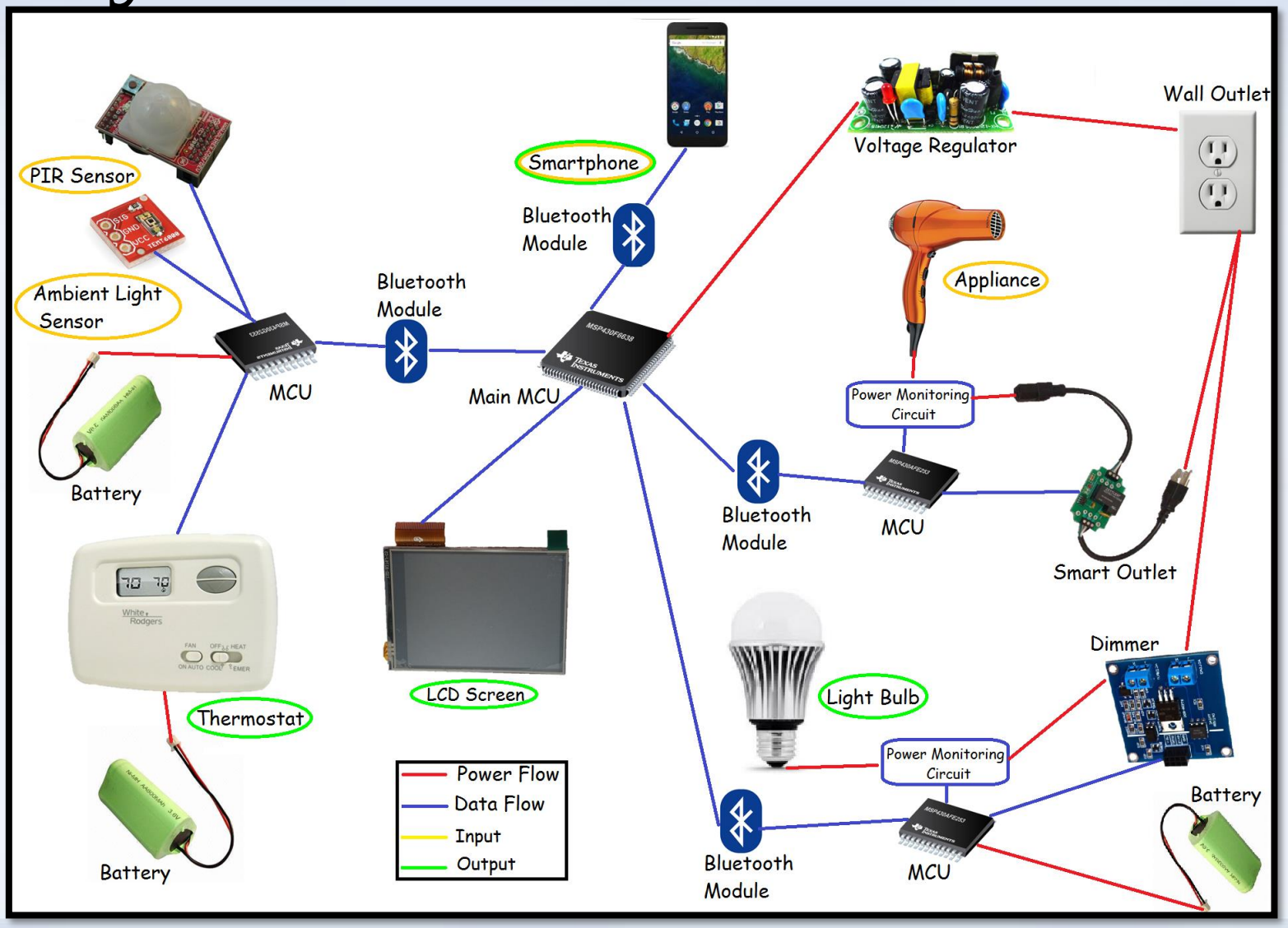
Objectives

- Create an affordable home system that can interact with the user
- Alter the lighting and AC systems
- Measure the power consumed
- Display it in an LCD screen and in an Android application
- Record the data obtained from the system in a historic interface
- Get the user’s power consumption habits into “shape”

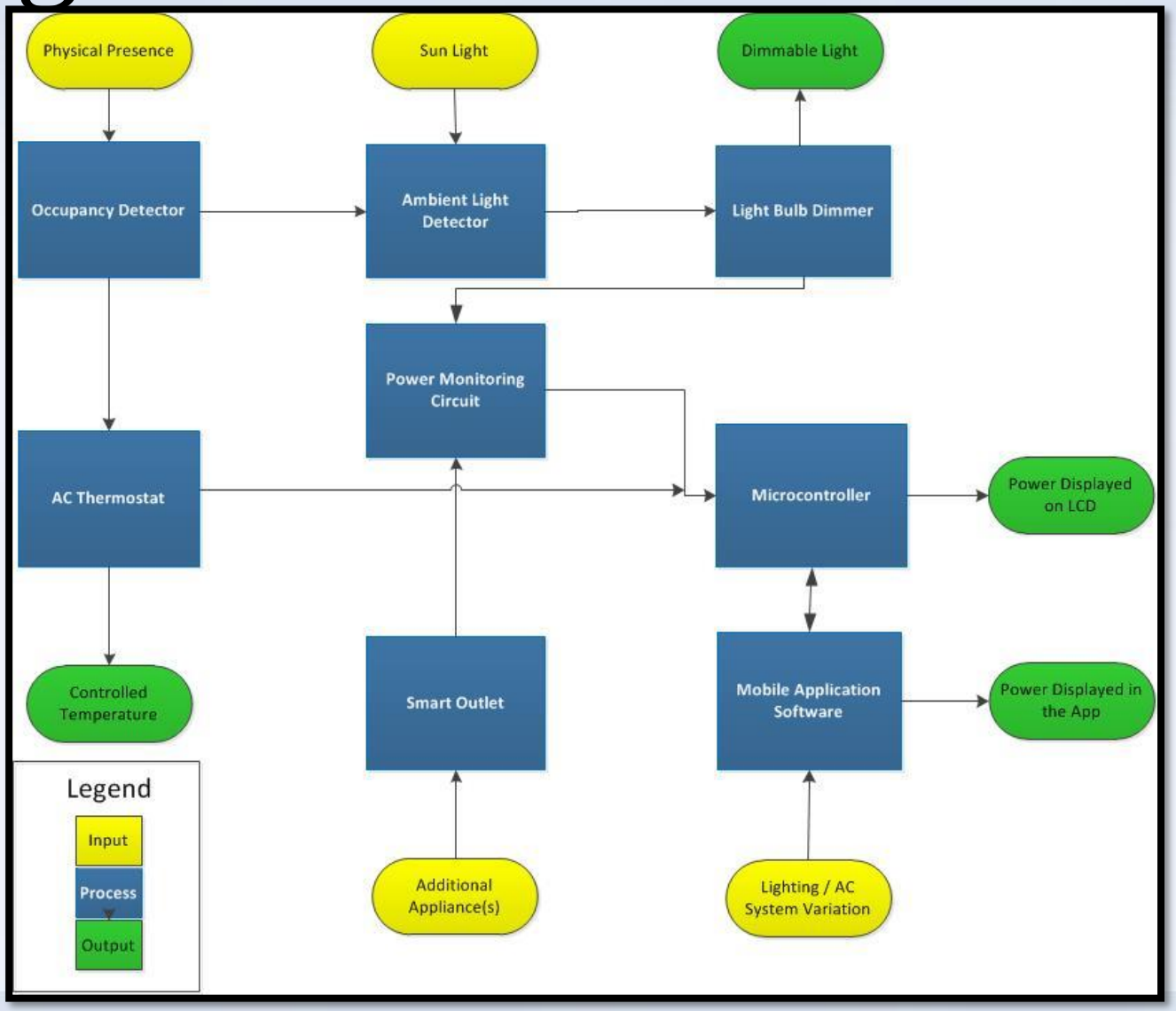
Design Goals

- Low power consumption
- Small footprint components
- Wireless connectivity
- Optimal computational speed
- User-friendly interface
- Adequate storage space for obtaining data from inputs

System Layout



System Diagram

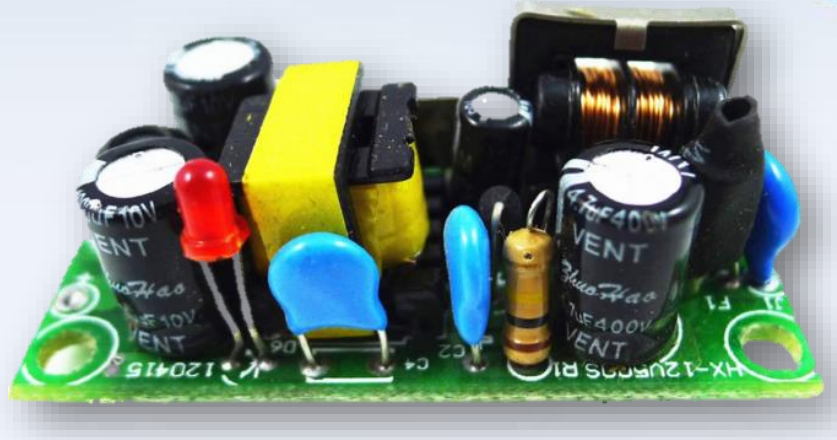


I/O Hardware Components

Voltage Regulator

Purpose: Supplies Power to the circuit from the wall outlet. Obtains 120VAC as an input and output 5 VDC.

GERI AC to DC Power Module Supply



Features:

- Converts mains electricity AC power to low DC power
- Over Temperature Protection
- Over Current Protection
- Over Voltage Protection
- Short Circuit Protection

Parameter	Specification
Dimensions	50mm x 25mm x 17mm
Input Voltage	86VAC to 265VAC
Output Voltage	5VDC
Output Current	1 A
Price/ Vendor	$7.20/ Amazon

Ambient Light Sensor

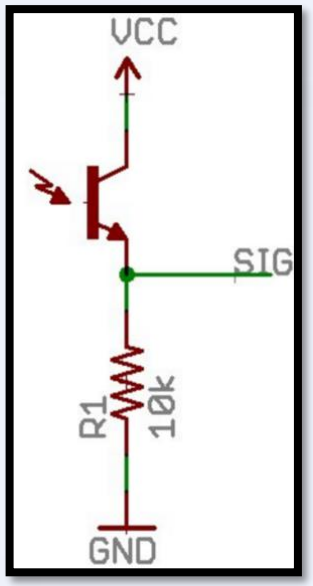
Purpose: Detect the amount of light in the area. If there is someone in the room determine if its day or night.

Sparkfun TEMT6000 Ambient Light Sensor

Features:

- Small size
- Light weight
- More light = More voltage on signal pin
- Acts like a transistor

Challenge: first model was hard to prototype
Solution: bought a new one ☺



Parameter	Specification
Dimensions	4mm x 2mm x 0.45mm
Supply Voltage	3.3V - 5V
Price/ Vendor	$7.95/ Amazon

PIR Motion Sensor

Purpose: Sense if there is someone in the room and communicate with the central hub via Bluetooth.

OLIMEX PIR Sensor with MSP 430 Microcontroller

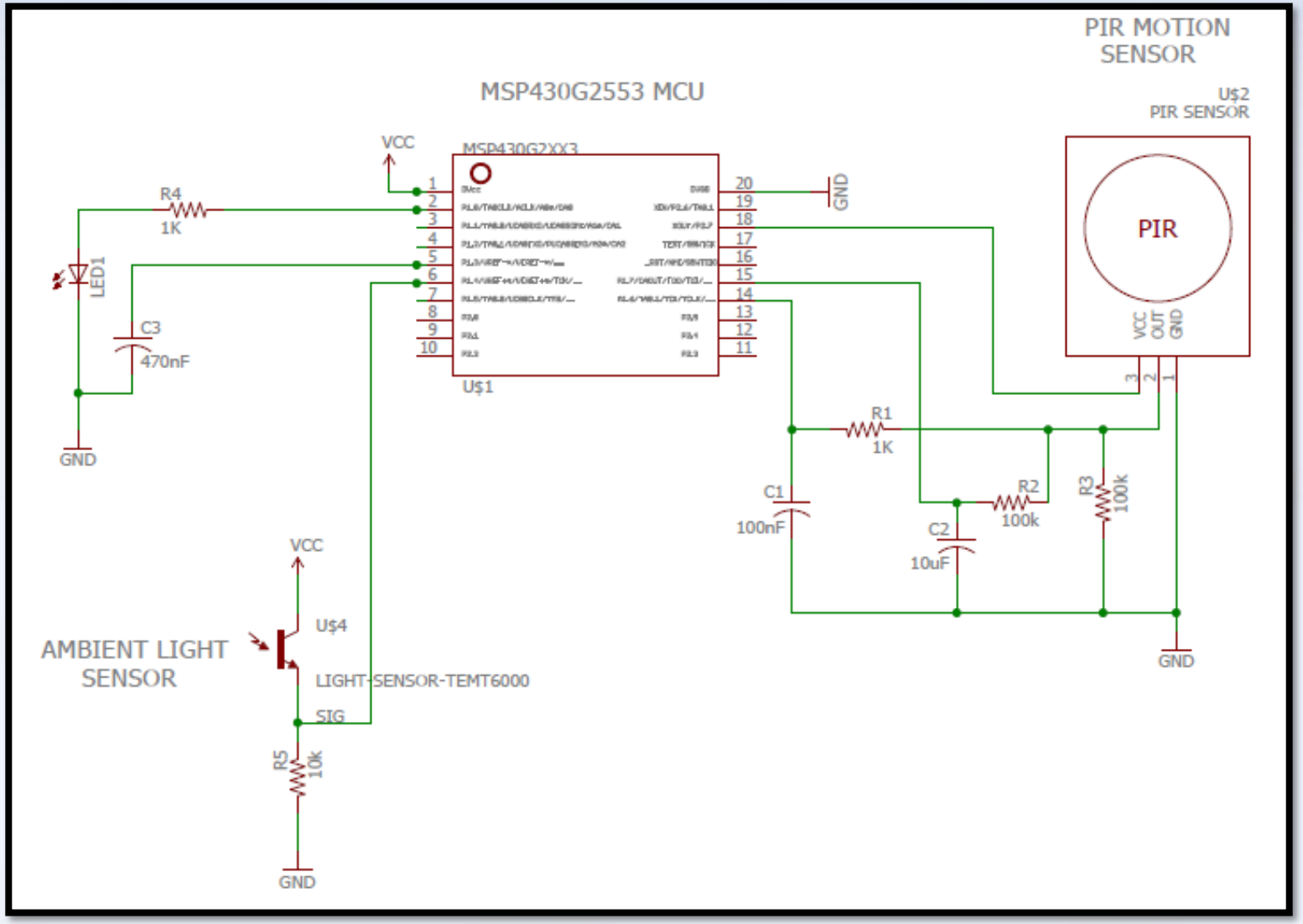
Features:

- MSP 430F2013 Microcontroller
- Low Power PIR Sensor
- Status LED
- Battery Holder
- JTAG Connector
- Serial Peripheral Interface

Parameter	Specification
Dimensions	43mm x 26mm x 20mm
Supply Voltage	1.8V to 3.6V
Memory	256KB
RAM	2KB
Price/ Vendor	$18.32/ Olimex

Challenge: design to be updated, not enough pins in MCU
Solution: New sensors board being designed

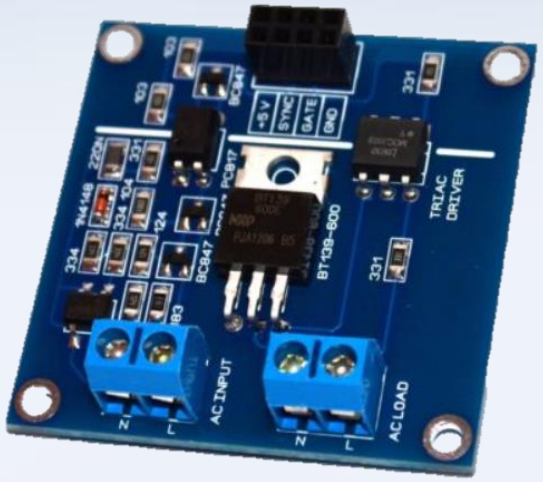
Sensors Board Schematic



AC Light Dimmer Module

Purpose: Control the amount of light being emitted by the lightbulb base on input from sensors.

Krida Electronics AC LED Bulb Dimmer Controller



Features:

- Allows programming of the intensity for AC LED dimmable bulbs
- Contains a Triac triggering coupled
- Zero-cross detection mechanism
- Auto-detects if 50Hz or 60 Hz

Parameter	Specification
Dimensions	50mm x 50mm
Device Voltage	5VDC
Working Voltage	110VAC to 240VAC
Price	$18.95

Challenge: Requires 5 volts to work, MCU supplies 3.3V
Solution: Researching if MCU output can be stepped up

AC Thermostat

Purpose: Vary the temperature in the house.

White Rogers 1F79-111 Digital Thermostat

Features:

- Battery Powered
- Temperature Sensor
- Displays current and desired temperature
- Temperature can be changed by using the buttons
- Modification of the circuit structure so the temperature displayed can be controlled by the microcontroller

Parameter	Specification
Dimensions	5.1” x 3.7” x 1.1”
Batteries	2 AAA
Voltage	3 V
Price/ Vendor	$18.99/ BasketCode

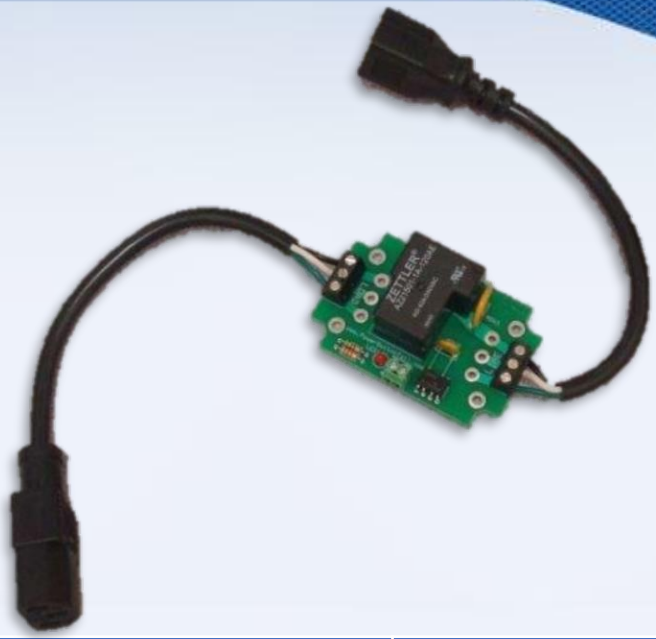
Challenge: Controlling unit with the microcontroller
Solution: Researching if a 2 channel selector can be used

Smart Outlet

Purpose:
Control the current flow from the outlet to an appliance

Power Switch Tail II

Features:
- Inserts between power source and corded devices
- Connects directly to I/O pins of MCU
- Switching by relay contact configuration
- Safe to utilize
- LED indicates when DC side is energized



Parameter	Specification
Switching Capacity	15 amps @ 120VAC
Input Voltage	3VDC – 12VDC
Life Expectancy	100,000 operations
Price/ Vendor	$26.99/ PST website

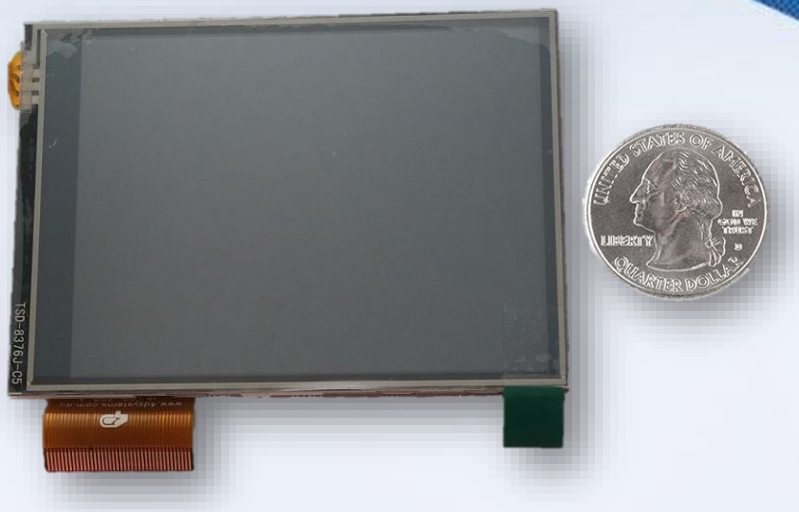
LCD Screen

Purpose: Display the power consumed by the system

4DLCD-32QA LCD

Features:

- TFT 3.2” Display
- Viewing Area of 47.87 mm x 63.84 mm
- 65K true to life colors
- Integrated LCD Driver
- Touchscreen (Optional)



Parameter	Specification
Dimensions	55.04mm x 77.70mm
Device Voltage	2.5V to 3.3V
Typical Power	30mV
Price/ Vendor	$30.00/ DigiKey

Hardware Interaction & Power Monitoring

Bluetooth Module

Purpose:

Establish communication with:

- Sensor nodes
- Dimmer system
- Thermostat
- Power monitoring nodes
- Mobile application

Desired Features:

Characteristics	Desired Value
Version	v4.0 or higher
Tx and Rx	Yes
Low Power Consumption	Yes
Serial Port	UART

Bluetooth Module

CC2564MODA- Bluetooth

Features:

- CC2564 Bluetooth Controller
- Integrated antenna ready for applications
- Low power consumption for different modes
- Physical Interface is UART
- Up to 7 Active Devices

Parameter	Specification
Dimensions	7mm x 14mm x 1.4mm
Bluetooth Version	v4.1
Device Voltage	2.2V to 4.8V
Frequency	2.4GHz
Current Rx and Tx	112.5mA
Price/ Vendor	$13.10/ DigiKey

Main Hub Microcontroller

Purpose:

Receive information from PIR motion sensor and ambient light sensor in order to control the dimmable lighting system and thermostat.

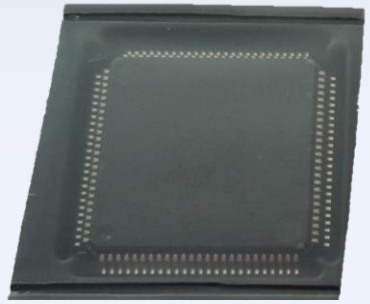
Communicate with power monitoring nodes to send it to the LCD display for the user to read.

Desired Features:

Characteristics	Desired Value
CPU Size	16-Bit
Storage	≥ 64KB
Maximum Speed	≥ 16MHz
Power Consumption	Ultra-Low to Low
Serial Communication Interface	I^2C
Serial Port	UART
Watchdog Timer	Included

Main Hub Microcontroller

MSP430FR6989 Microcontroller



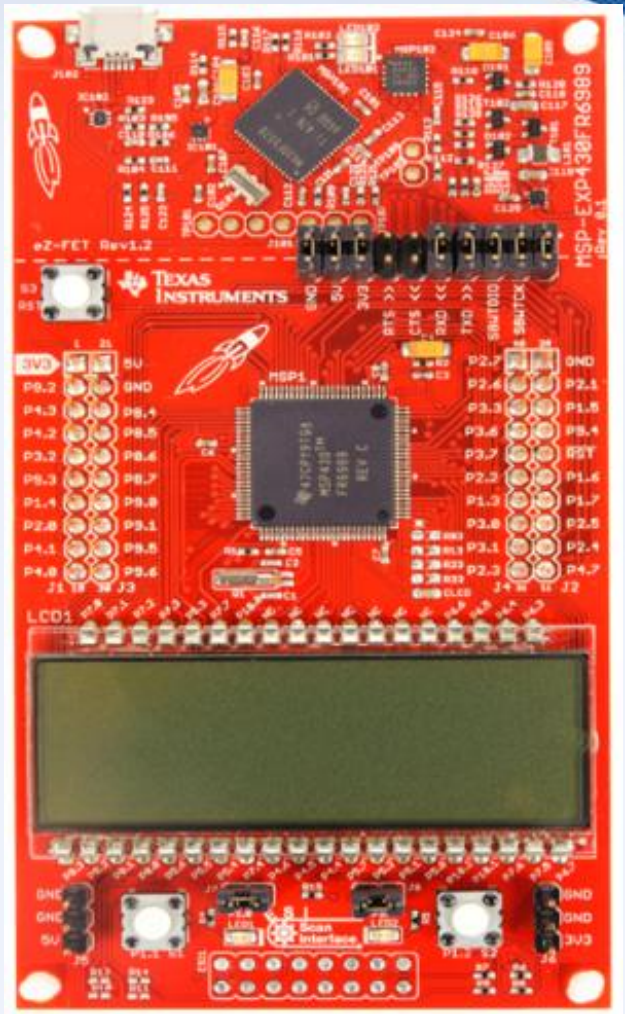
Features:

- 16-Bit RISC Architecture
- Optimized Ultra-Low Power Modes
- Multiple number of GPIOs
- Multiple communication interfaces (i.e. I^2C,SPI, UART) which allow an easy connection with the rest of the components
- Integrated LCD Driver
- Free Code Composer Studio IDE

Parameter	Specification
Dimensions	14mm x 14mm
Device Voltage	1.8V to 3.6V
Nonvolatile Memory	128KB
Maximum Speed	16MHz
Price/ Vendor	$10.13/ TI

Development LaunchPad

MSP-EXP430FR6989 Launchpad



Features:

- MSP430FR6989 Microcontroller
- Segmented LCD
- Software Examples available

Power Monitoring Diagram

Purpose:

Measure current and voltage values over a certain frequency range and period of time.
Calculate power consumption using the information previously obtained.
Send power calculation per appliance to the main hub via Bluetooth.

Approach:

- Implement a voltage divider circuit and connect its output to one of the A/D input from the MCU in order to measure the voltage
- Use current sensors in order to measure input current.
- Include anti-aliasing filters.

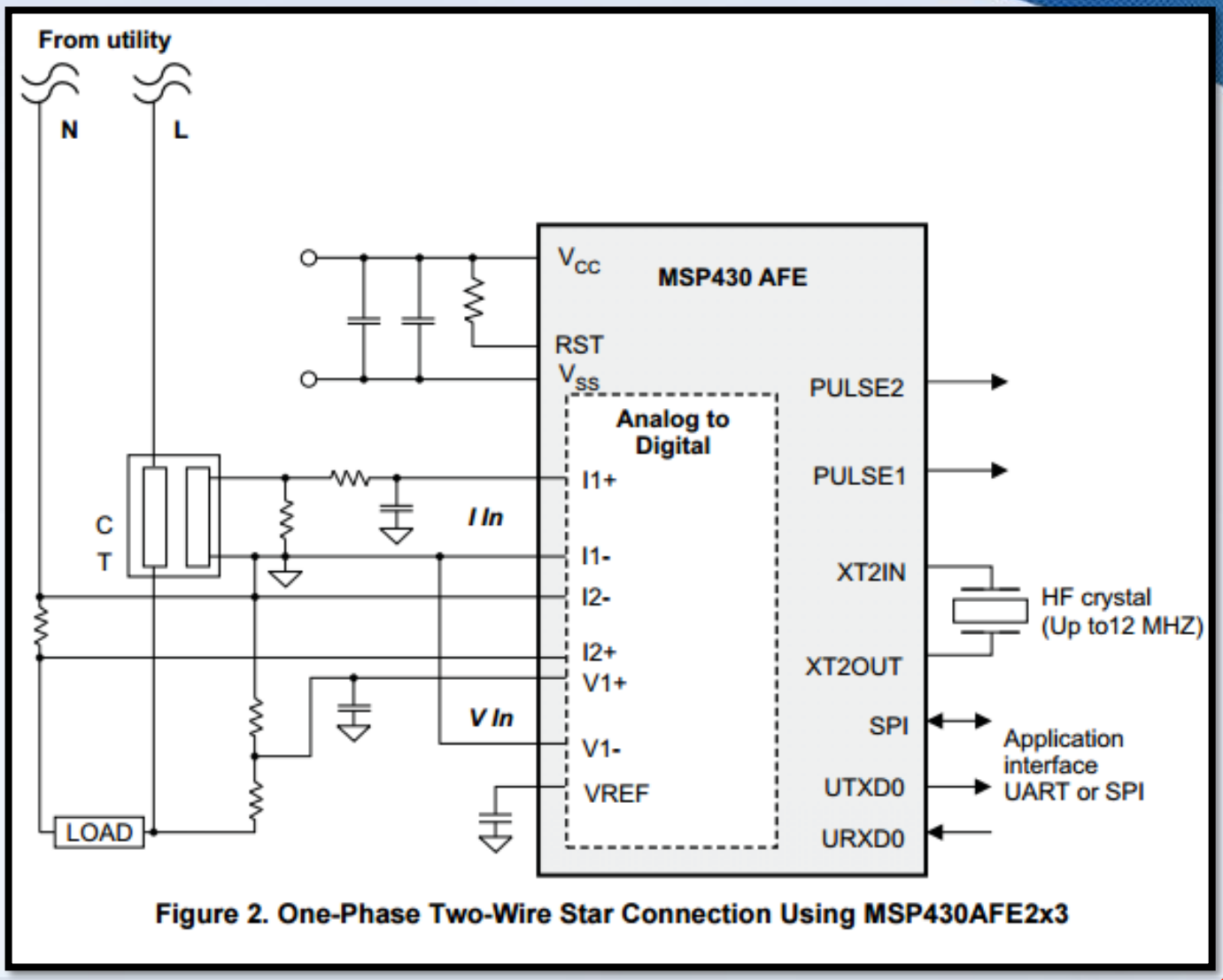
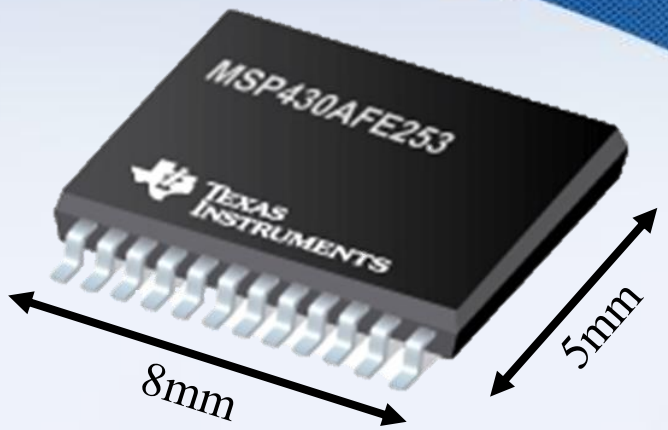


Figure 2. One-Phase Two-Wire Star Connection Using MSP430AFE2x3

Monitoring Nodes MCU

Purpose:

Simultaneously and independently obtain samples of current and voltage data at a given frequency rate
and keep track of the information accumulated over a time frame.
Being able to save the different sample data (i.e. voltage, current, etc.) in different registers



MSP430AFE253IPWR Microcontroller

Features:

- 16-Bit RISC Architecture
- Ultra-Low Power Consumption for Active, Standby and Off Modes
- Integrated three independent 24-bit sigma-delta A/D converters
- 16-Bit x 16-Bit Hardware Multiplier
- Serial Communication UART

Parameter	Specification
Dimensions	5mm x 8mm
Device Voltage	1.8V to 3.6V
Nonvolatile Memory	16KB
Maximum Speed	12MHz
Price/ Vendor	$4.95/ TI

Software Development

Software Design

- Code Composer
  - Will be using RISC architecture
  - Great documentation and datasheets
  - Simplified user interface
  - Intelligent learning tools
  - Verify power devices are initialized before system starts
  - System will execute operations based on priority of tasks

Software Design

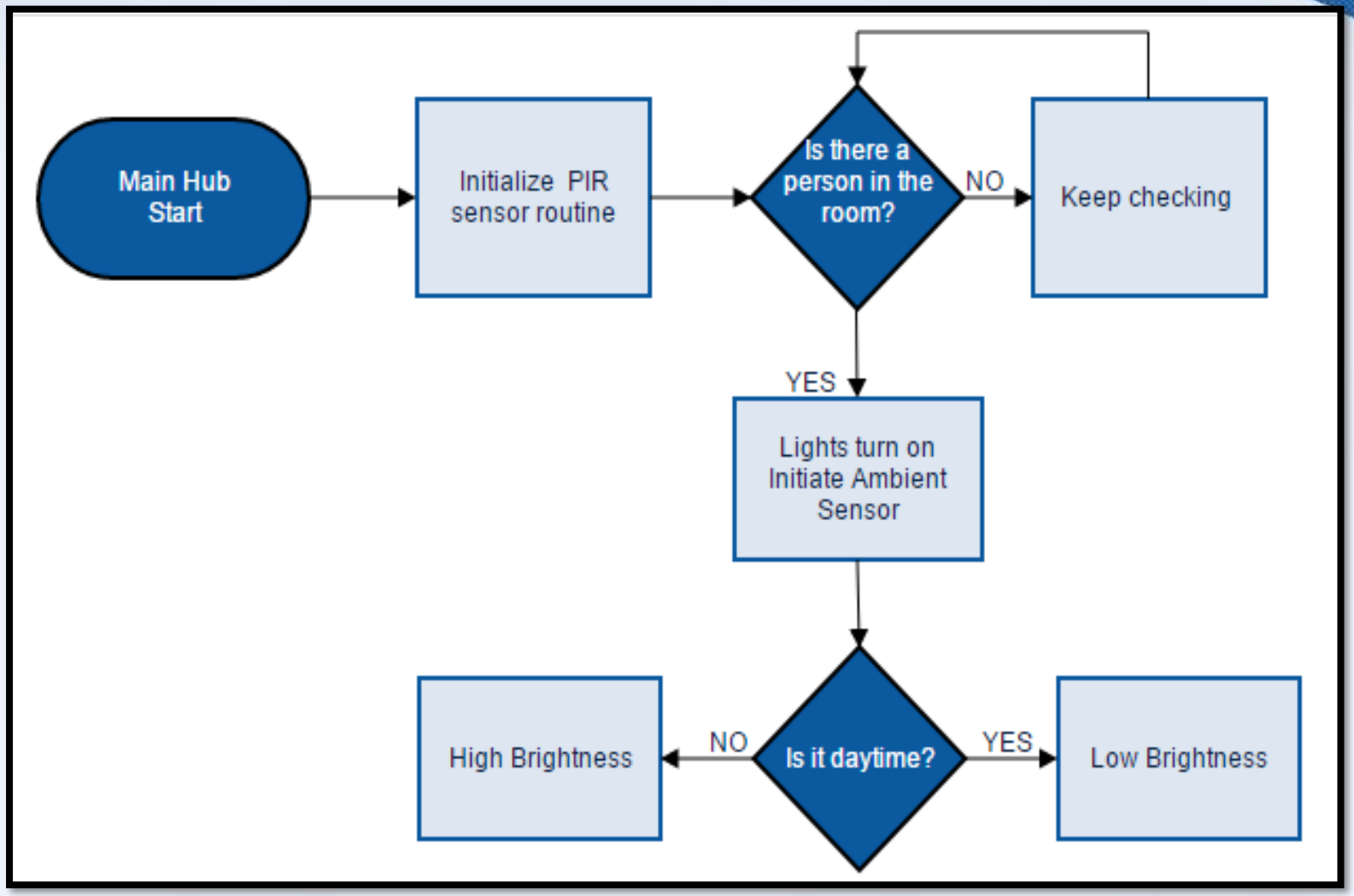
- Code Composer v6

Programming Languages	C	Assembly	C++
Pros	• Widely used • Built-in functionality • Compile time fairly reasonable	• Direct access to bios • Manipulate registers directly • Low memory usage	• Low memory usage • Higher level than C • Nice exception handling
Cons	• Uses more memory • Can be difficult to learn • Allows for more bugs	• Increased lines of code • Not always portable	• Slower compilation time • Convoluted error messages

Lighting Control Routine

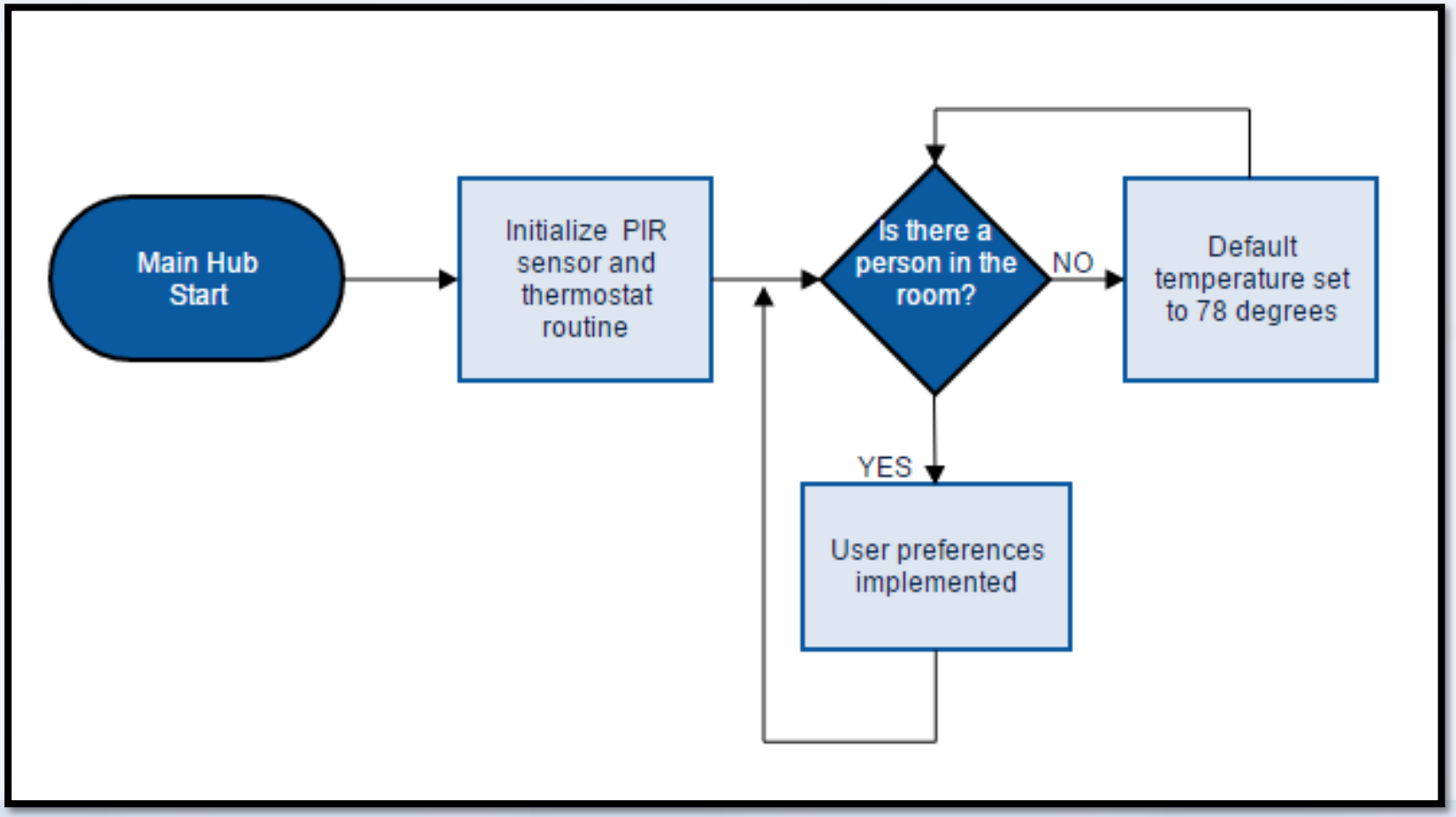
- Both PIR and Ambient sensor will be working in tandem
- Ambient sensor converts voltage change into data bits

Description	PIR	Ambient Light
Off	0	X
Off	0	X
High	1	0
Low	1	1



Thermostat Design Logic

- User temperature preferences encoded in MCU
- Temperature default setting for power conservation

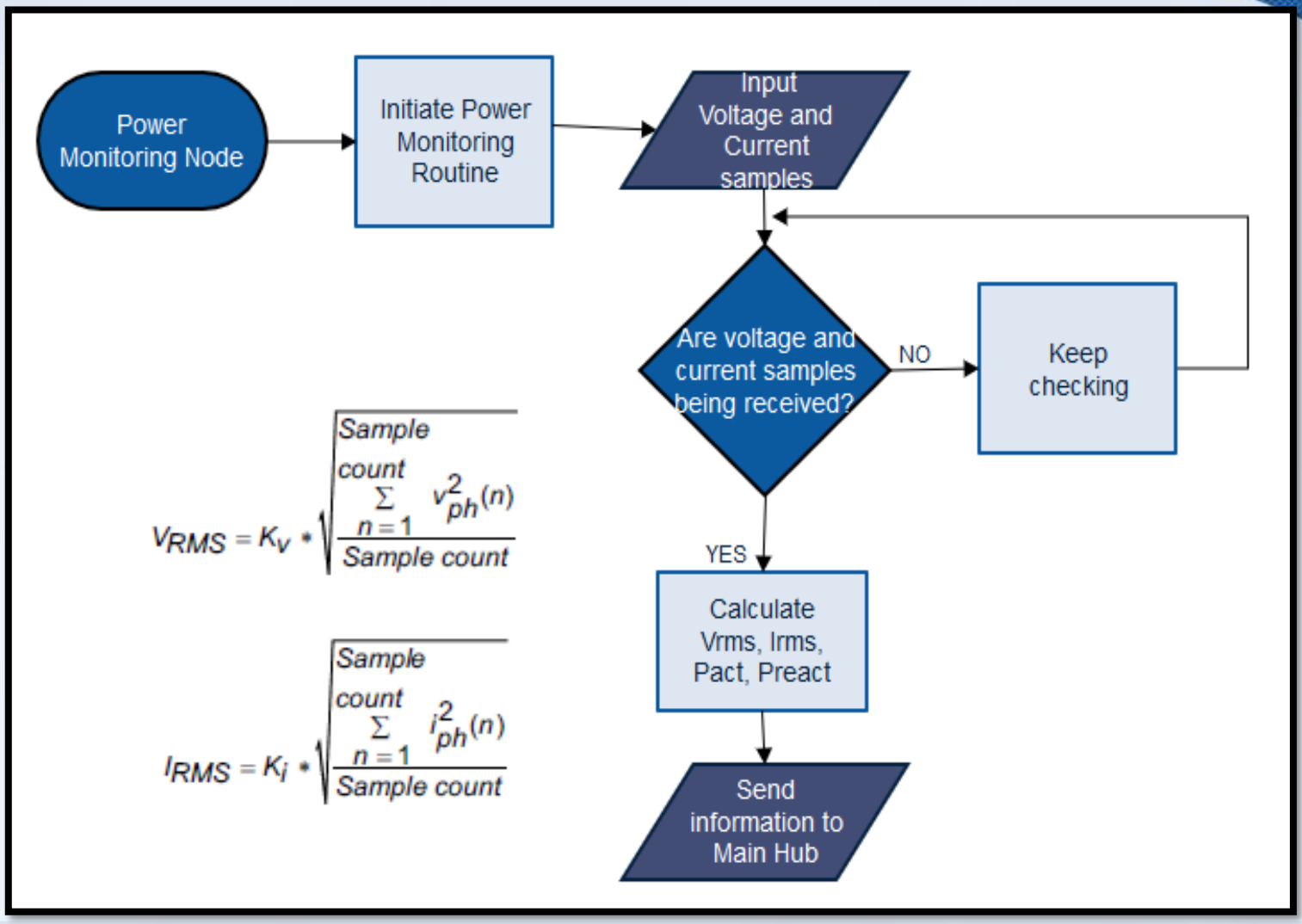


Power Monitoring Diagram

- Display power consumption to user via LCD
- Utilize Vrms and Irms to calculate real power

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

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



Mobile Application

Android vs iOS

Benchmark	Android	iOS
Global share of market	81.5%	14.8%
Applications available in market	600,000 from Google play.	700,000 from the Apple app store.
Programed using	Developers will be able to program using C, C++ and Java.	Developers will program mostly using Objective-C.
Development costs	It is free to develop with a onetime $25 charge to publish.	It is $99 per year to develop and publish.
Availability	Variety of devices will support this OS.	Limited to apple products
Customizability	Very customizable to fit developers need.	Not very customizable at all.

IDE

- Android Studio Features:
  - Bring organization to our design using packages, project files, tests, and productions.
  - Dynamic layout preview that will ease creation
  - Annotate parts of the code such as returns, variables, parameters.
  - Memory and CPU monitoring tools
  - Lint and other IDE inspections to check for bugs

Mobile Login Screen

Purpose: Makes it so that only S.H.A.P.E.R user will access the application

Features:

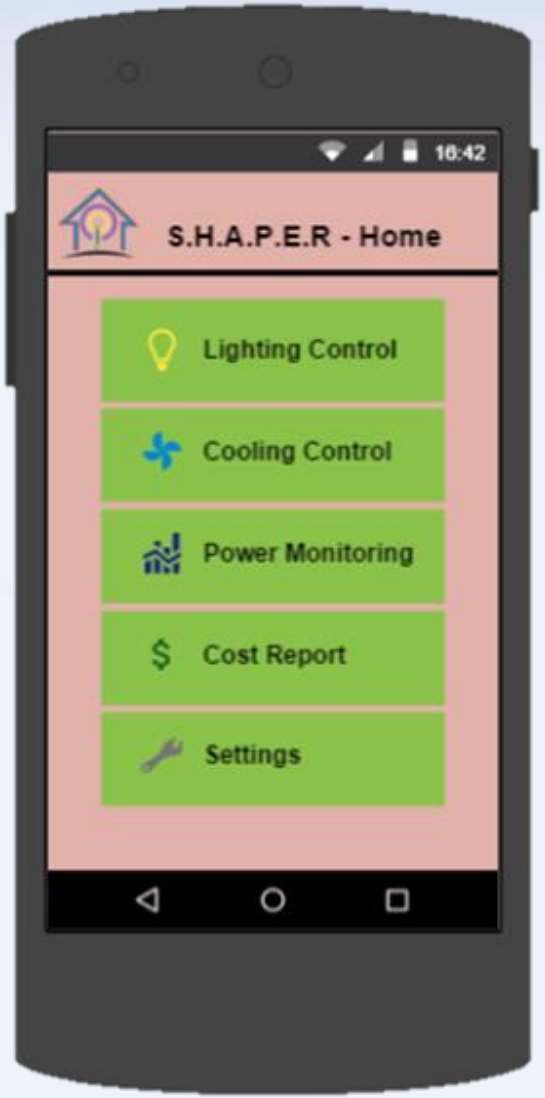
- Added security to the system
- Be the users introduction to the application.

Mobile Home Screen

Purpose: Gateway to other sections of the application.

Features:

- Utilizes universal usability.
- Colors and symbols to optimize the intuitiveness of the application
- Customizable in settings by the user

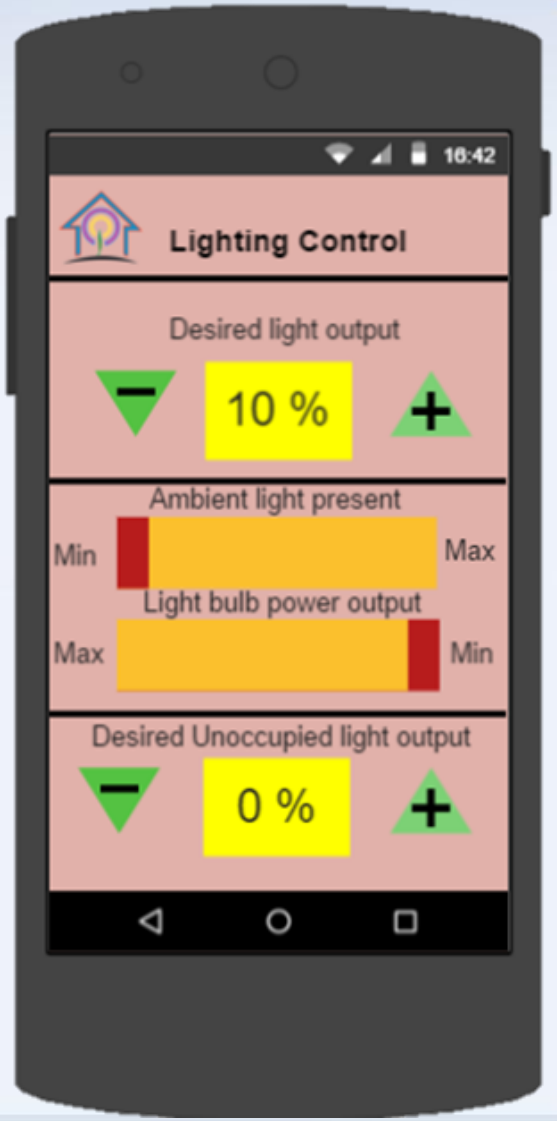


Lighting Control

Purpose: Give the user full control of the dimmable lighting system.

Features:

- Able to set desired light output when room is unoccupied.
- Monitor how much ambient light is in the environment.
- Manually control lighting settings.

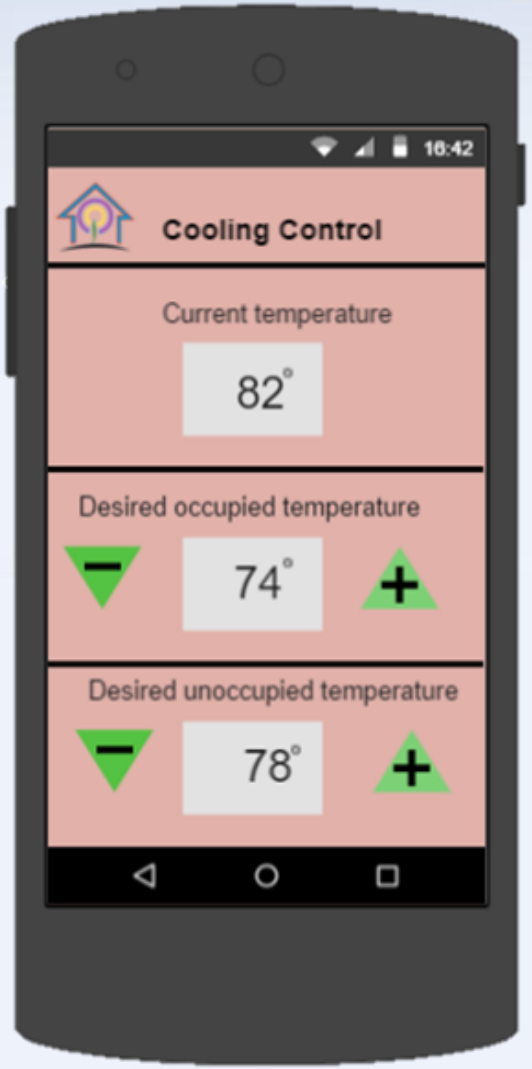


Cooling Control

Purpose: Give the user the ability to monitor and control thermostat settings.

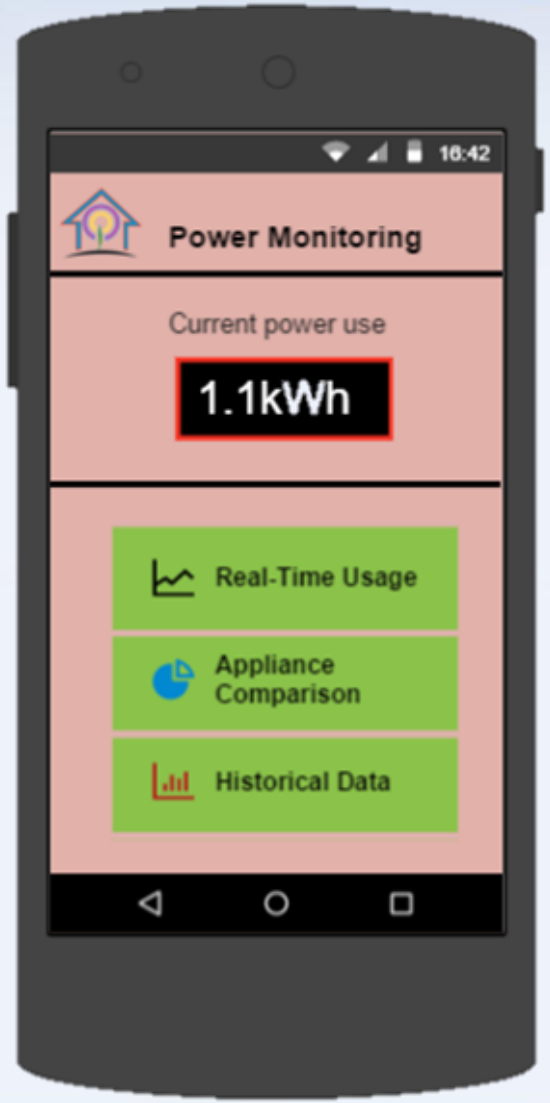
Features:

- View of current temperature in the environment.
- Ability to modify occupied temperature.
- Ability to modify unoccupied temperature to conserve power.



Power Monitoring

Purpose: Allow user to observe information about their power usage.



Features:

- Observe the current power being utilized
- View real time power consumption in the form of a line graph
- See how the power is being divided per appliance
- Bar graph representation of power use over time

Administrative Content

Division Of Work

	Main Hub Hardware	Power Consumption Hardware	Mobile Application	Software Development
Juan Aleman	**Primary**	Secondary		
Maria Alfonso	Secondary	**Primary**		
Gregory Pierre			**Primary**	Secondary
Francine Vassell			Secondary	**Primary**

Budget

Part	Projected Cost per unit (USD)	Projected Quantity	Projected Total Cost	Actual Cost per unit (USD)	Quantity	Total Cost (including Shipping)
LED Dimmable Light Bulb	17.49	3	52.47	3.49	4	13.99
Thermostat	65.73	1	65.73	18.98	1	28.98
Motion Sensor	10.99	4	43.96	7.95	1	7.95
Bluetooth Module	29.99	1	29.99	13.10	4	59.40
Capacitors	0.10	30	3.00	0.10	30	3.00
Resistors	0.05	50	2.50	0.05	50	2.50
Microcontroller	0.99	5	4.95	10.13/ 4.95	1/3	31.98
Development Board	29.99	1	29.99	19.99	1	19.99
LCD Screen	$50.00	1	50.00	30.00	1	30.00
Dimmer	N/A	N/A	N/A	18.95	1	23.90
Power Switch Tail	N/A	N/A	N/A	19.99	1	26.89
Outlet	1.99	2	3.98	To be Acquired	To be Acquired	To be Acquired
DC – DC Voltage Regulator	1.99	5	9.95	To be Acquired	To be Acquired	To be Acquired
Printed Circuit Board	99.99	3	299.97	To be Acquired	To be Acquired	To be Acquired
Lead Acid Battery	119.99	1	119.99	TBD	TBD	TBD
Power Inverter	39.99	1	39.99	TBD	TBD	TBD
Charge Controller	69.99	1	69.99	TBD	TBD	TBD
Wireless Router	49.99	1	49.99	TBD	TBD	TBD
Hard Disk Drive	69.99	69.99	69.99	TBD	TBD	TBD
RF Tx/Rx	4.99	4	19.96	TBD	TBD	TBD
Total			966.40			248.58

Current Progress

Difficulties

- Obtain smooth wireless connection
- Implementing the thermostat
- Creating Schematic and designing PCB in Eagle Cad
- Shipping time constraints

Plan for Completion

- Power monitoring implementation
- Finish designing sensors board
- Finalizing our prototypes
- Completing the testing phase
- Look into publishing our design on the market

Sponsors

Special THANKS to Boeing and Leidos
for their generous contribution of $899.00 for the development of our project

Thank you!

Questions?