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

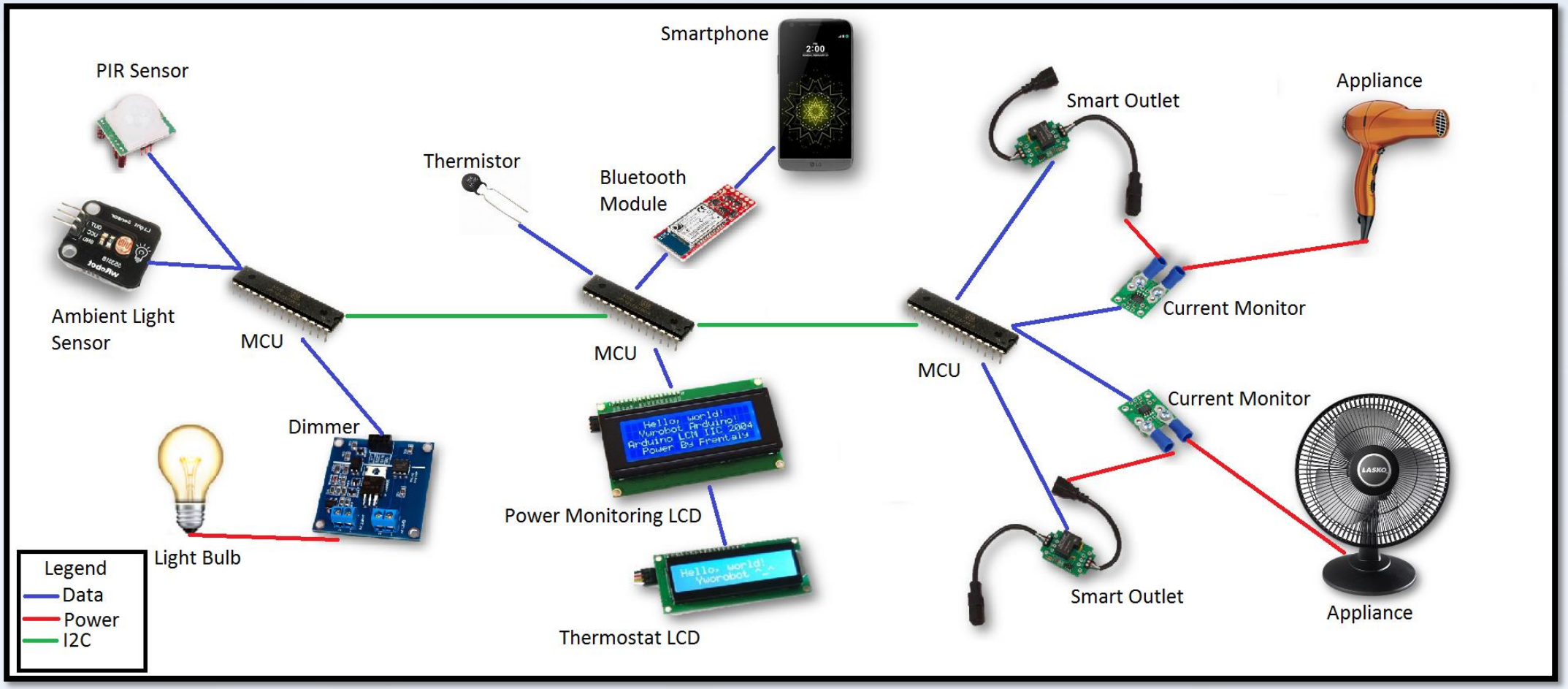
Objectives

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

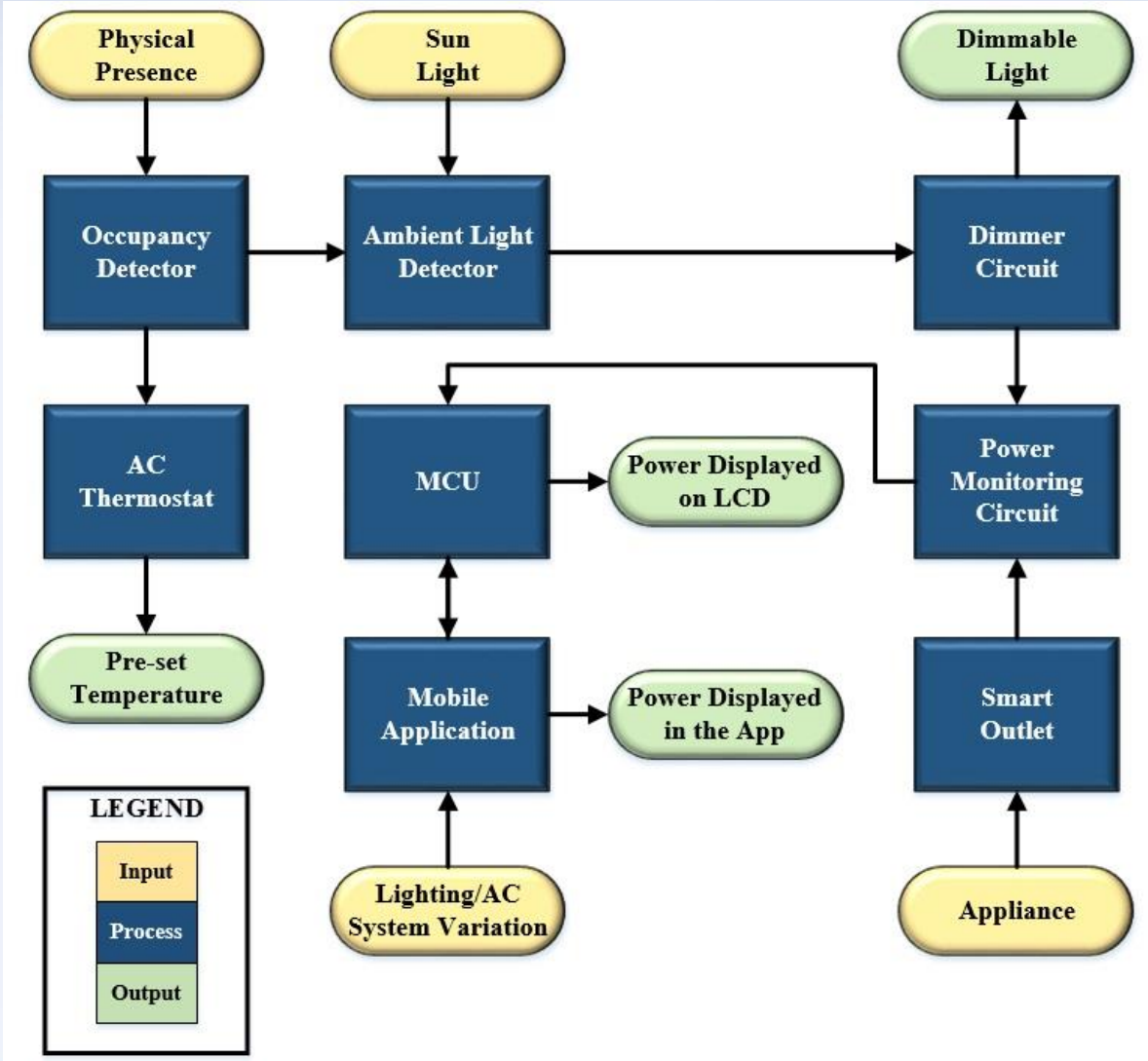
Design Goals

- Low power consumption
- Small footprint components
- Wireless connectivity
- Optimal computational speed
- User-friendly interface

System Layout



System Diagram

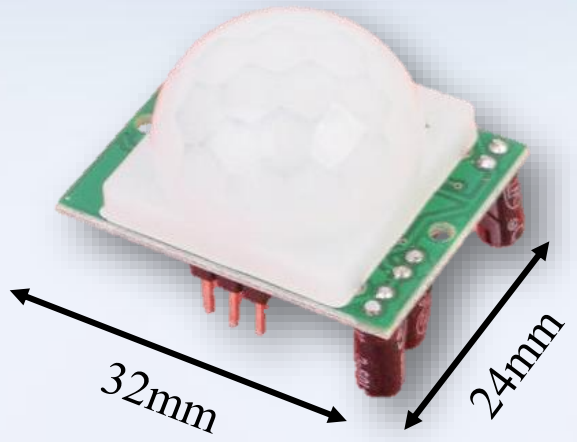


I/O Hardware Components

PIR Motion Sensor

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

PIR Sensor



Features:

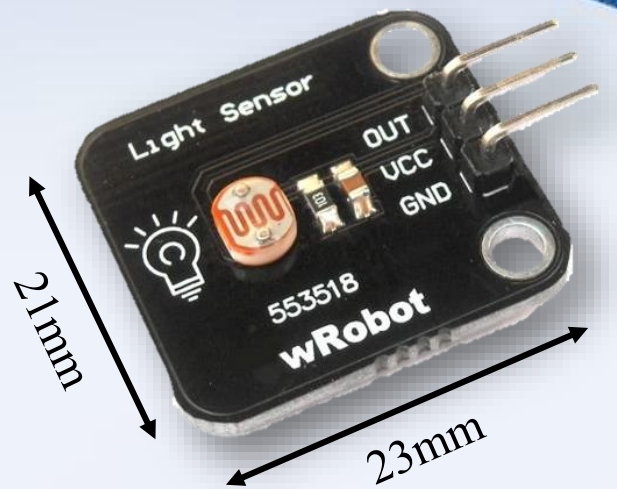
- Features probe LHI778/ High Sensitivity
- Sensing range: less than 120 degree cone angle of less than 7 meters
- Delay time: adjustable (0.3 seconds to 18 seconds)
- Level output: 3.3V, low 0V

Parameter	Specification
Dimensions	32mm x 24mm
Supply Voltage	5V to 20V
Price/ Vendor	$2.40/ Ebay

Ambient Light Sensor

Purpose: Detect the amount of light in the room in order to variate the dimming of the lighting system.

Phantom YoYo Ambient Light Sensor



Features:

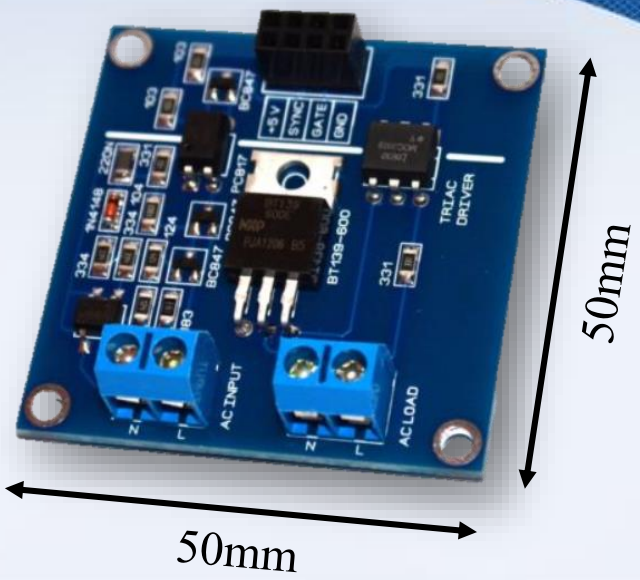
- Light weight
- Analog Interface
- Adjustable sensitivity/ Stable performance
- Adopt photoconductive resistance
- More light = More voltage on signal pin

Parameter	Specification
Dimensions	23mm x 21mm
Operating Voltage	5V
Price/ Vendor	$6.59/ Amazon

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/ Vendor	$18.95/ Ebay

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
Dimensions	50.8mm x 64mm
Switching Capacity	15 amps @ 120VAC
Input Voltage	3VDC – 12VDC
Life Expectancy	100,000 operations
Price/ Vendor	$26.99/ PST website

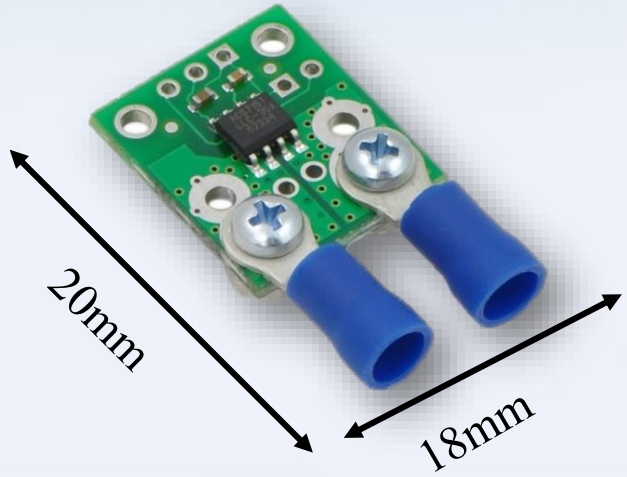
Current Monitor Sensors

Purpose: Monitors the amount of current flowing through both of the smart outlets

ACS714 Current Sensor

Features:

- Accepts a magnitude of up to 30 A
- Intended to be used in 5V systems
- Connects in between the Line wire
- Margin error of +/- 1.5%
- Convenient Size

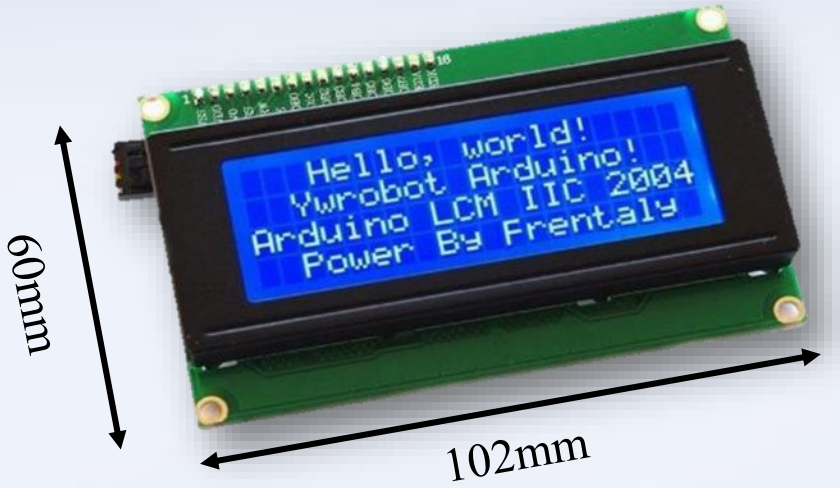


Parameter	Specification
Dimensions	18mm x 20mm
Weight	1.3g
Operating Voltage	5V
Price/ Vendor	$9.95 / ebay

LCD Screen used for Power Monitoring

Purpose: Display the power consumed by the system

Frentally® IIC/I2C/TWI 2004 Serial Blue Backlight LCD Module



Features:

- 20x4 LCD Display
- Potentiometer included to adjust the contrast
- I2C Interface allows to reduce IO ports usage
- Pin Definition: GND, VCC, SDA, SCL
- Backlight

Parameter	Specification
Dimensions	99mm x 56 mm
Operating Voltage	5V
Price/ Vendor	$10.75/ Amazon

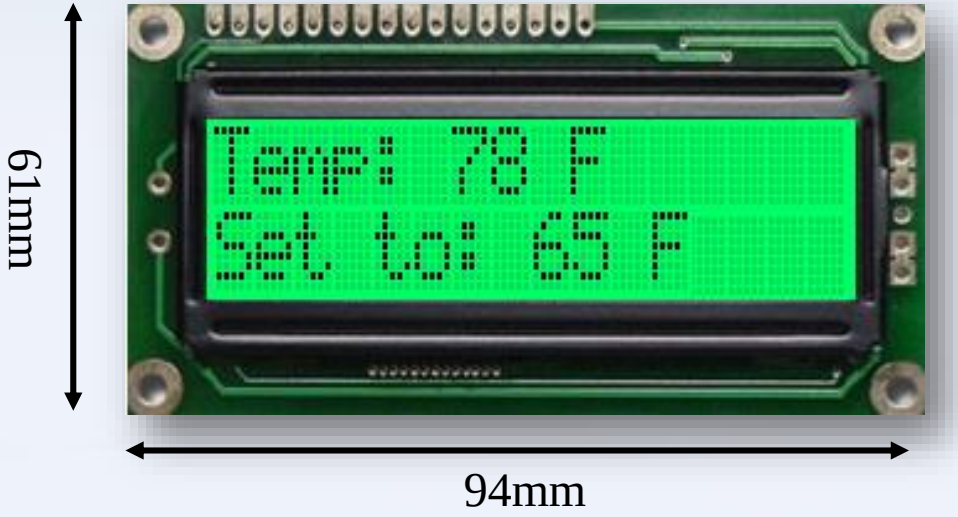
Simulated Thermostat

Purpose: Simulate a real thermostat in order to show the desire interaction with the rest of the circuit

Uxcell DC 16 x 2 Character Backlight LCD Display

Features:

- 16x2 LCD Display
- Backlight incorporated
- Used Thermistor to obtain temperature
- Potentiometer included to adjust the contrast
- Current Temperature at the top
- ‘Set to’ temperature at the bottom



LCD Parameter	Specification
Dimensions	82mm x 44mm
Operating Voltage	5V
Price/ Vendor	$8.79/ Amazon

Hardware Interaction

Microcontroller

Purpose:

- **Main Hub:**

Receive information from PIR motion sensor to control thermostat.
Communicate with power monitoring nodes in order to obtain the power being consumed per smart outlet and send such information to the LCD display for the user to view.

- **Sensors Station:**

Obtain PIR sensor information and send it to the main hub.
Control dimmable lighting system according to information obtained from sensors

- **Power Monitoring:**

Obtain samples of current data.
Calculate power being consumed by each appliance.

- **Simulated Thermostat**

Simulate the behavior of a thermostat once the information from the temperature sensor is received.
Vary the thermostat temperature according to the information obtained from the main hub and the mobile app.

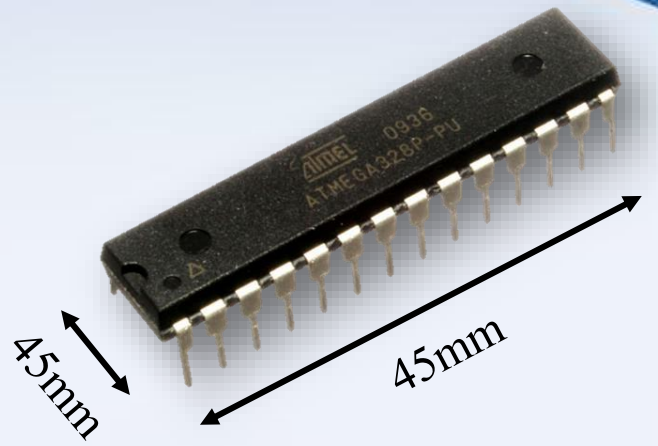
Microcontroller

Desired Features:

Characteristics	Desired Value
CPU Size	≥ 8-Bit
Storage	≥ 32KB
Maximum Speed	≥ 16MHz
Power Consumption	Ultra-Low to Low
Serial Communication Interface	I^2C
Serial Port	UART/USART
Watchdog Timer Included	Yes

Microcontroller

ATMEGA328P



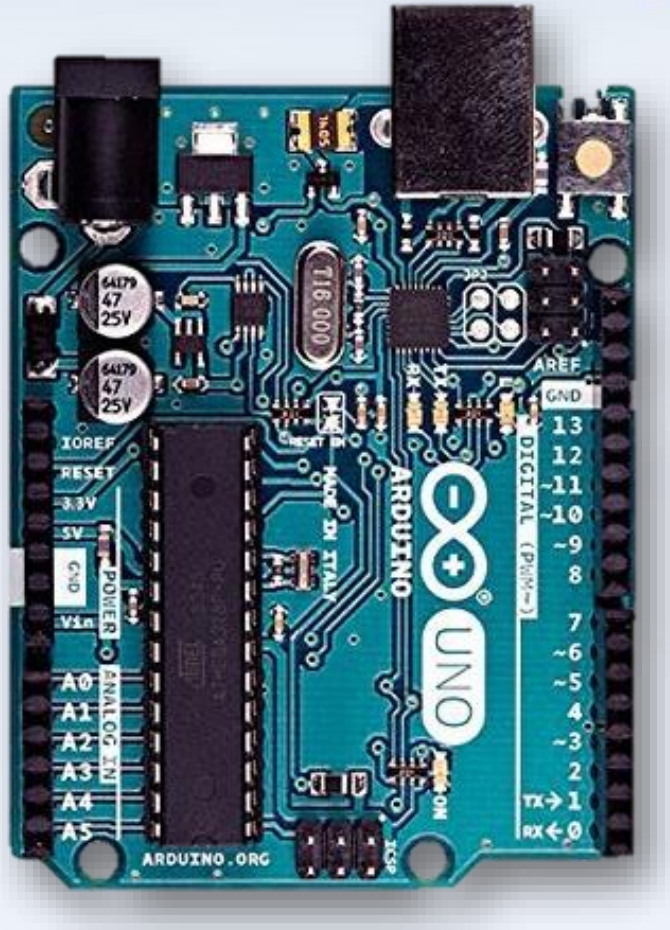
Features:

- 8-Bit AVR Architecture
- Low Power Modes
- 23 General purpose I/O lines
- Multiple communication interfaces (i.e. I^2C, SPI, UART) which allow an easy connection with the rest of the peripherals
- Free Arduino IDE

Parameter	Specification
Dimensions	14mm x 14mm
Device Voltage	1.8V to 5V
Nonvolatile Memory	32KB
Maximum Speed	20MHz
Price/ Vendor	$4.30/ Sparkfun

Development LaunchPad

Arduino UNO R3 Development Board



Features:

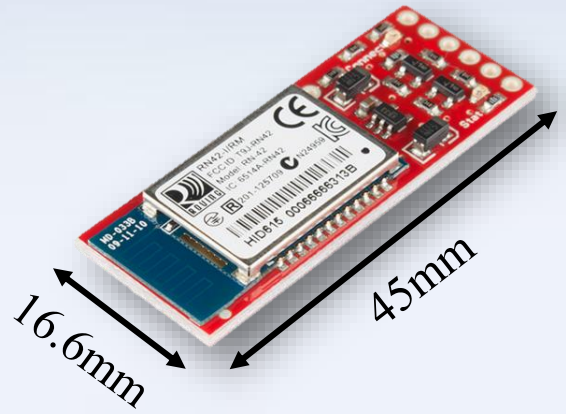
- ATMEGA328P Microcontroller
- Easy access to every available pin
- Easy to prototype
- Hardware and Software documentation available
- Software Examples available
- Extensive Support Community

Bluetooth Module used for App Purposes

Purpose:

Establish wireless communication with mobile application

BlueSMIRF Silver



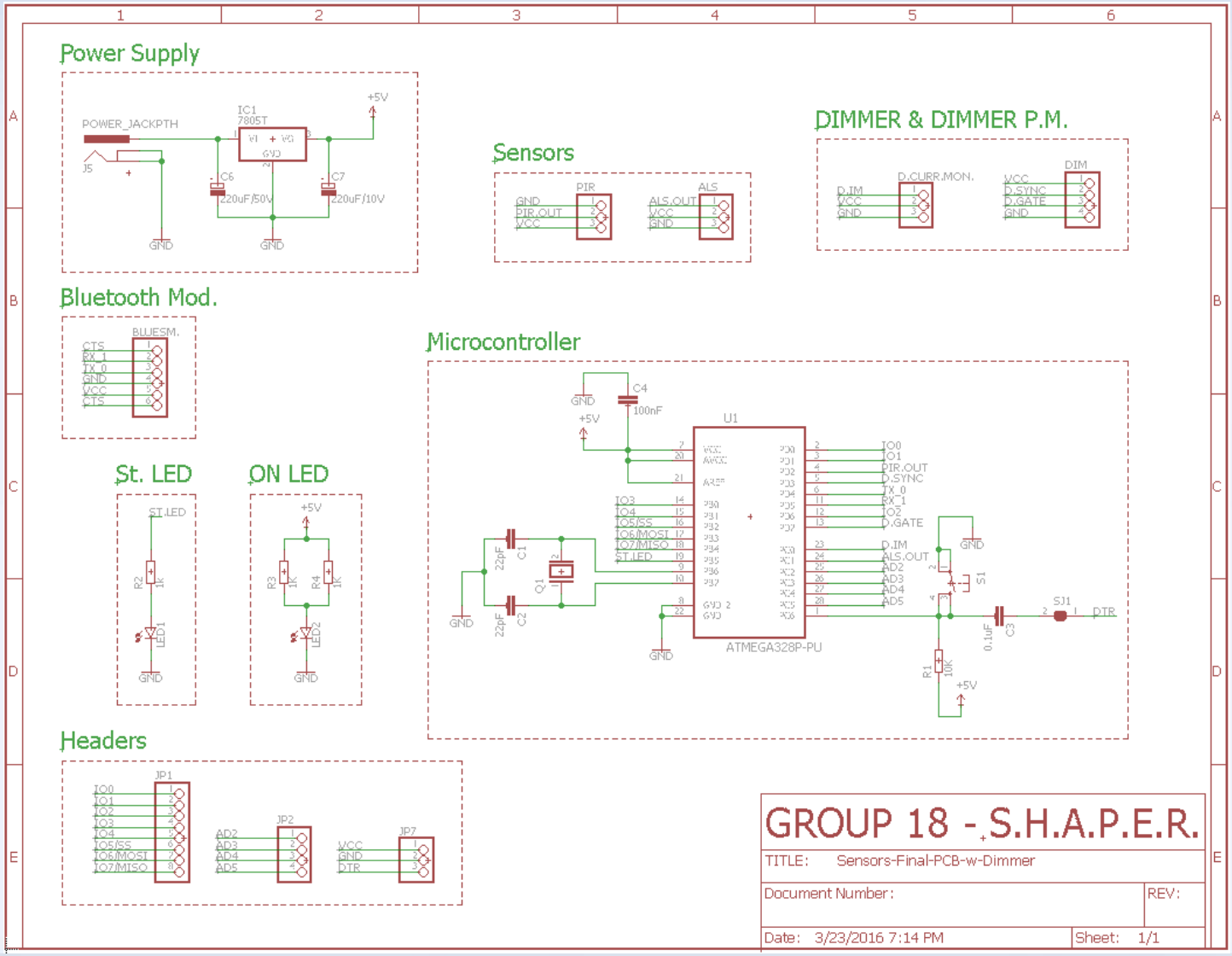
Features:

- Features the RN-42 module
- Built-in antenna ready for applications
- Physical Interface is UART
- Support speeds from 2400bps to 115200bps

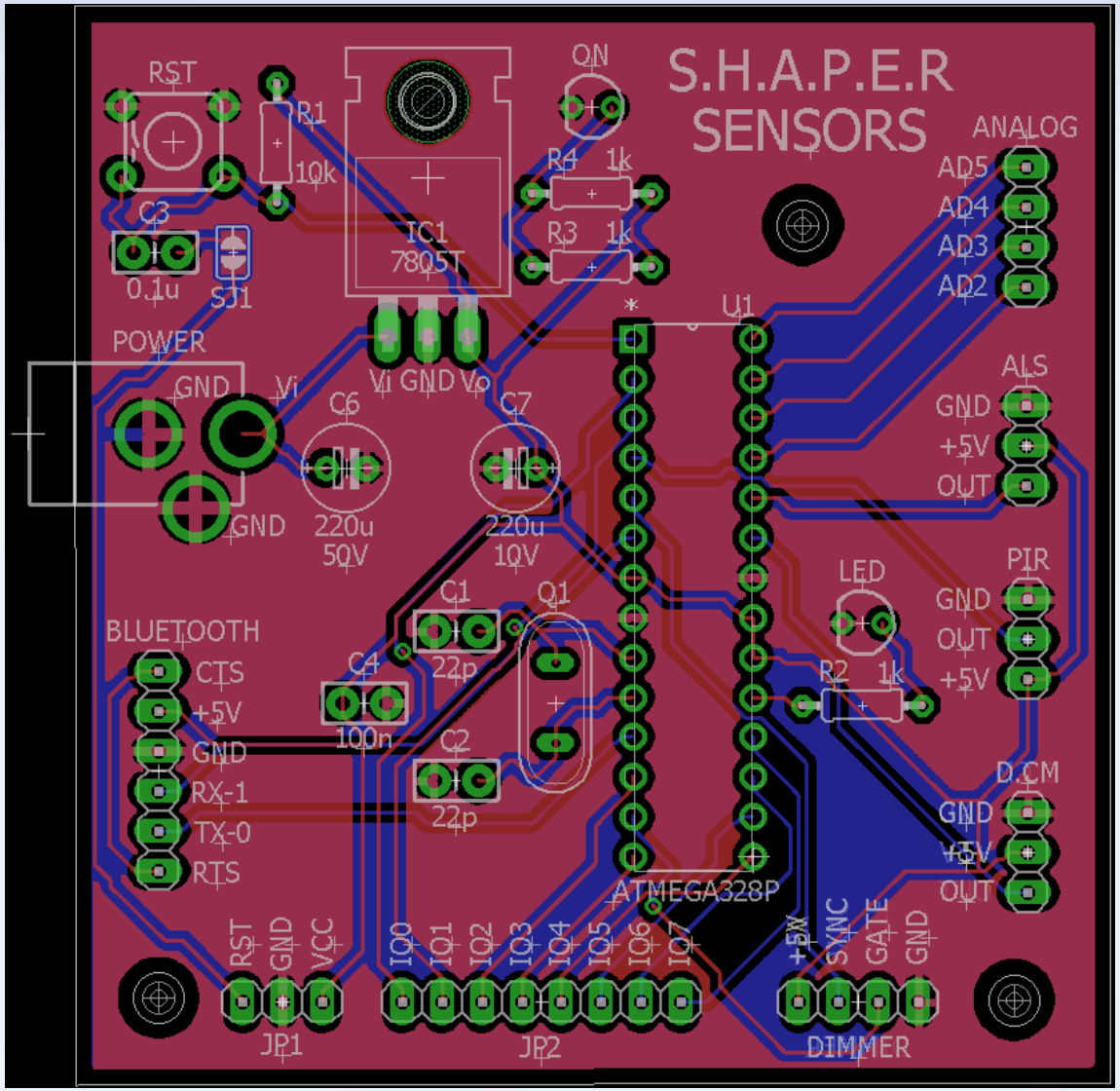
Parameter	Specification
Dimensions	16.6mm x 45mm x 3.9mm
Bluetooth Version	v2.0
Operating Voltage	3.3V to 6.0V
Frequency	2.4GHz
Price/ Vendor	$24.95/ Sparkfun

Printed Circuit Boards Design

Sensors Station Schematic

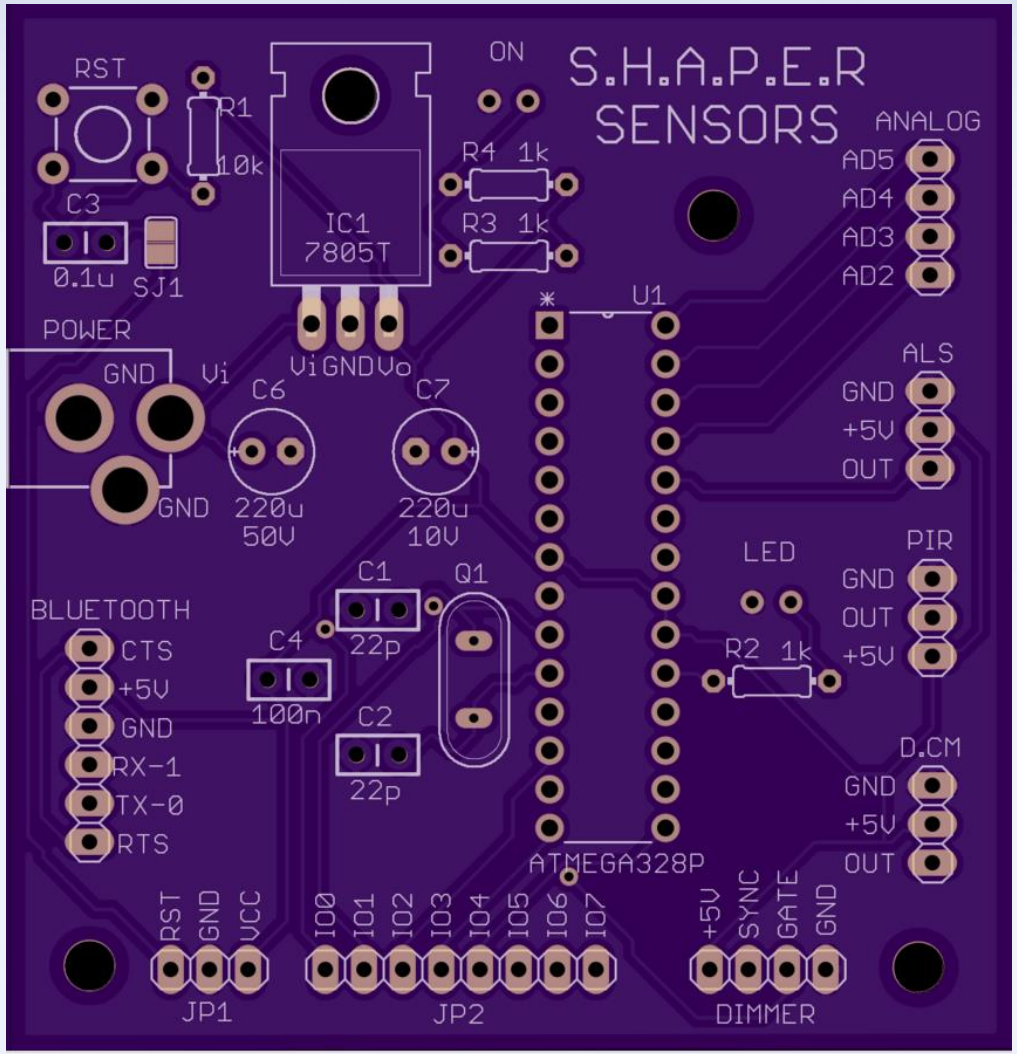


Sensors Station Board

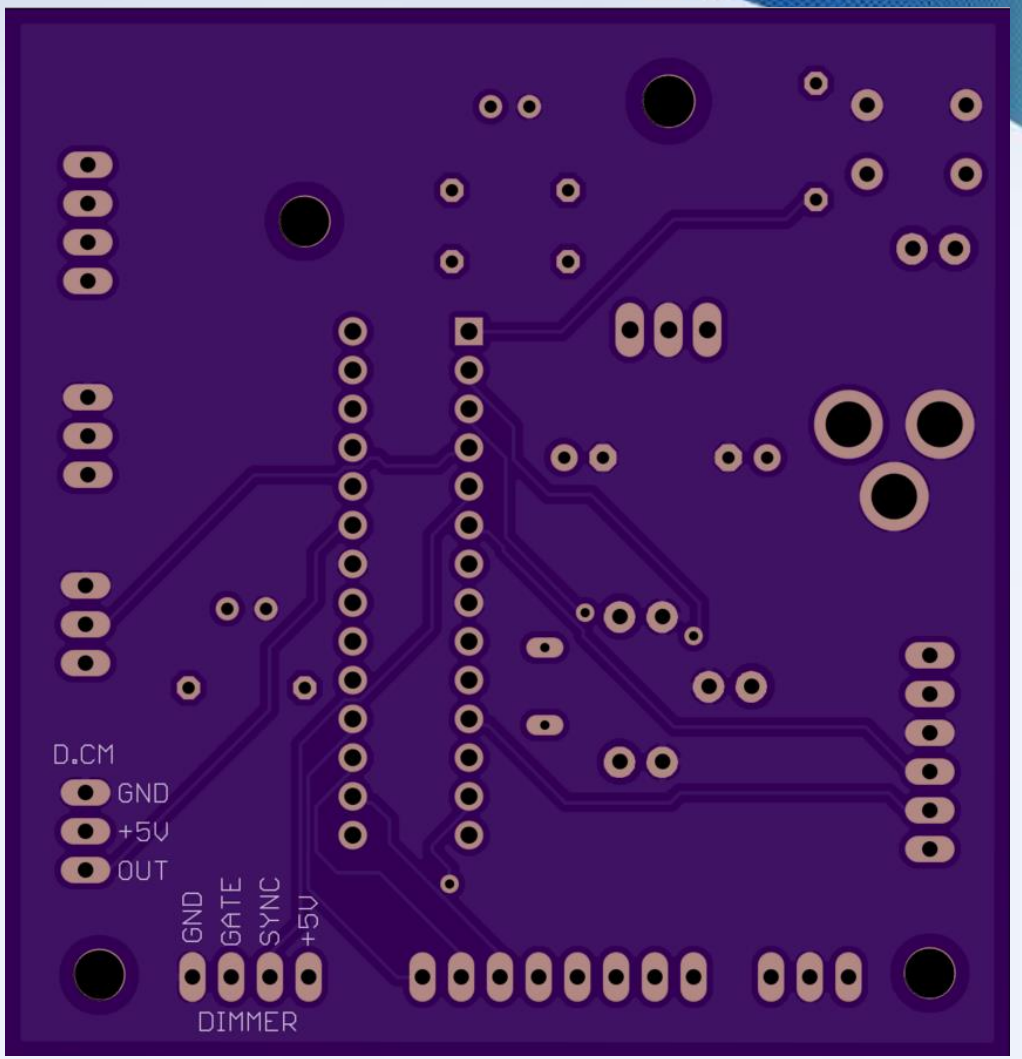


Sensors Station Final PCB

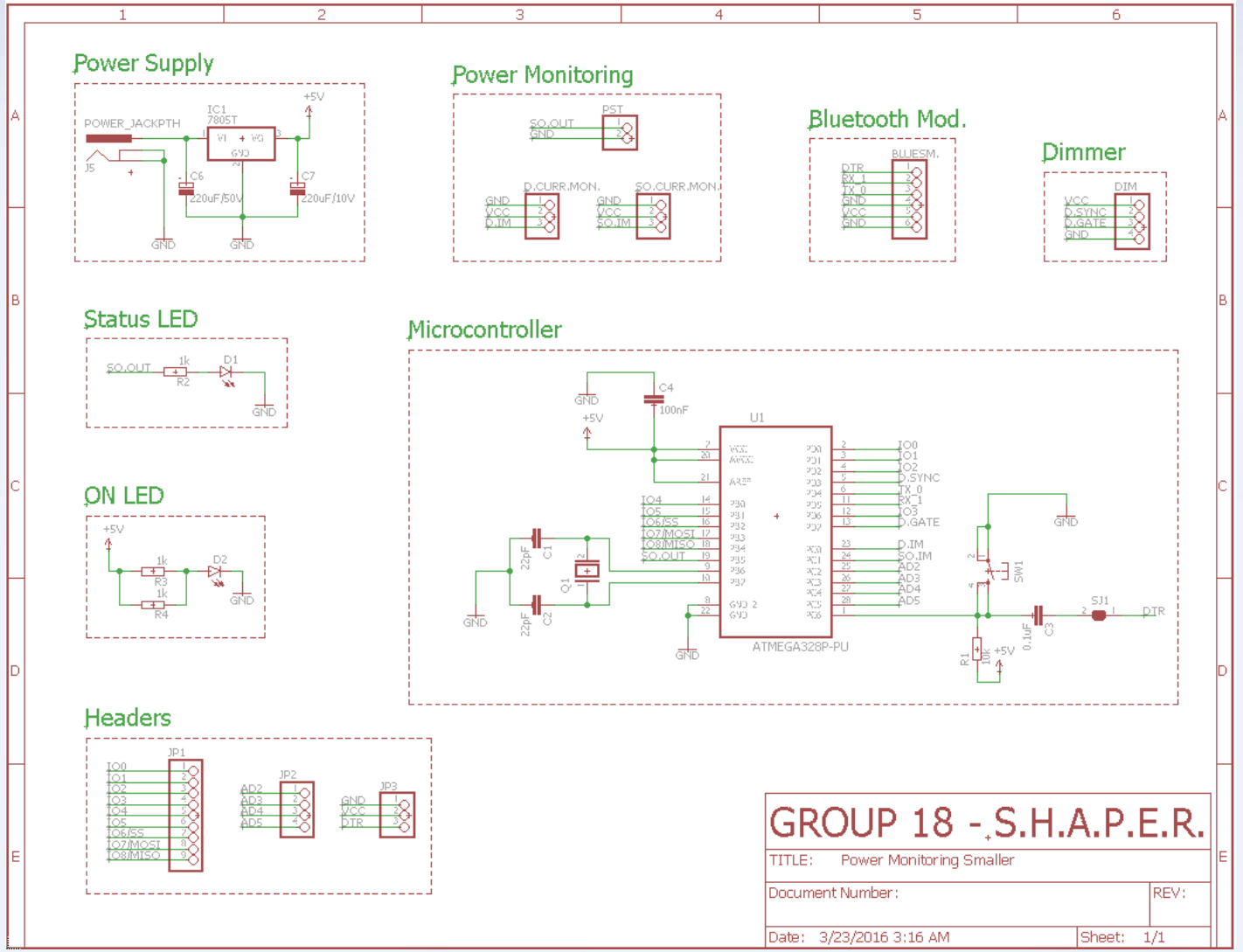
Top View



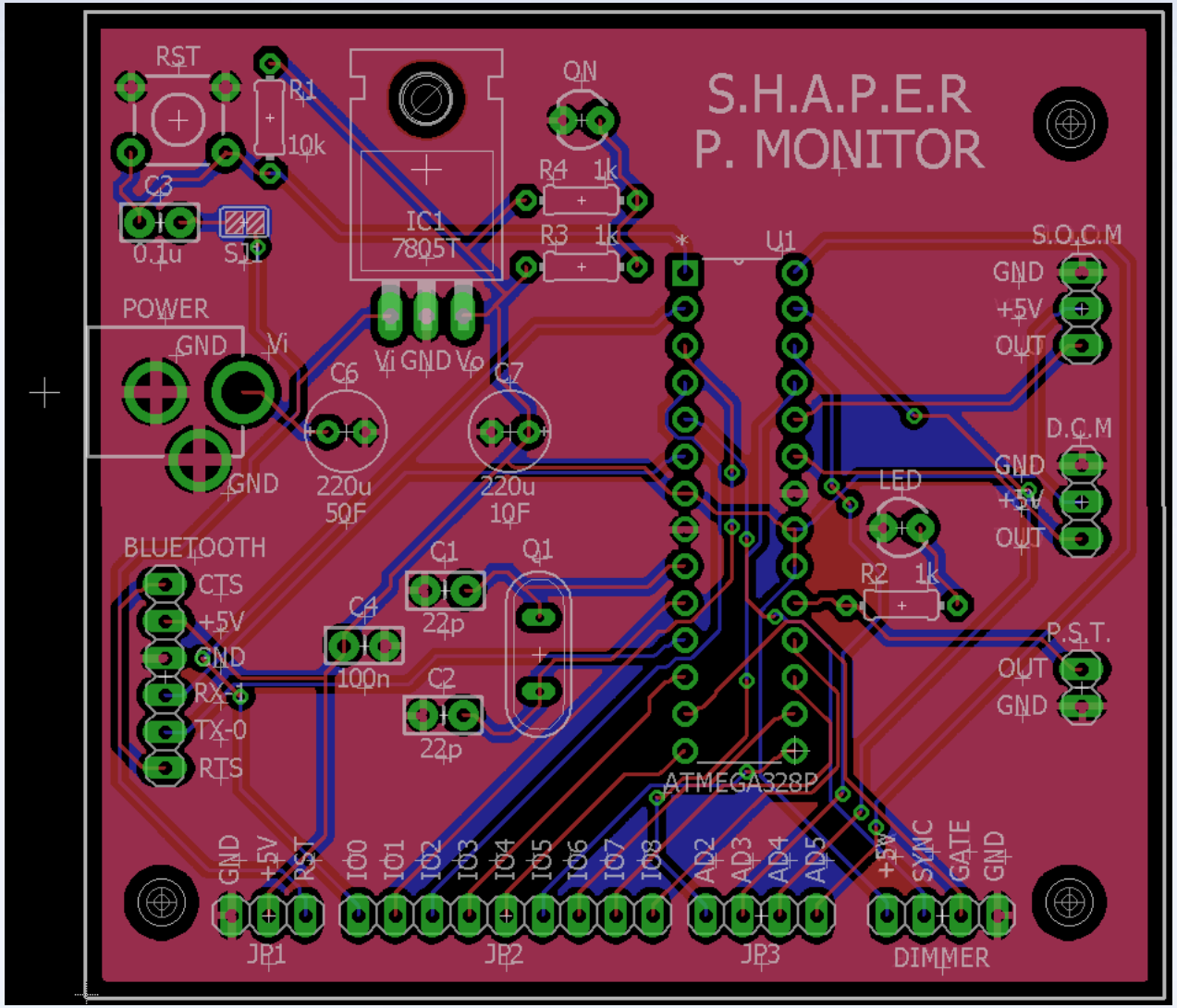
Bottom View



Power Monitoring Schematic

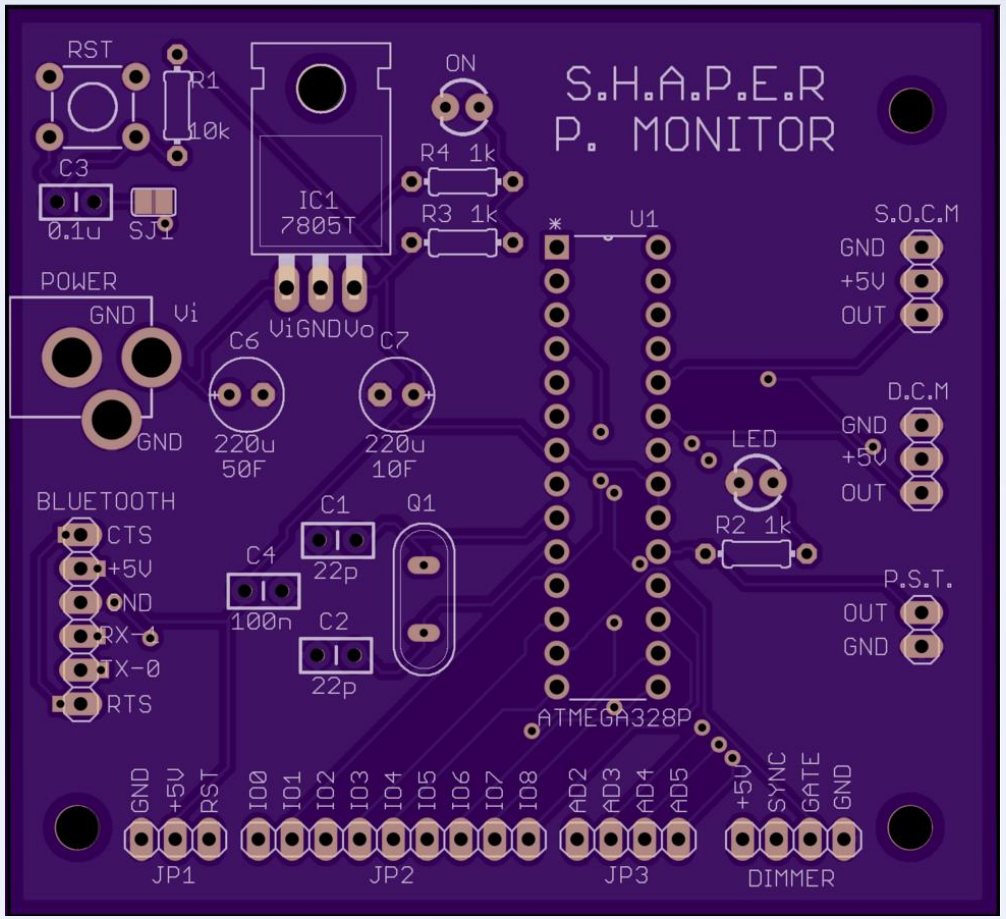


Power Monitoring Board

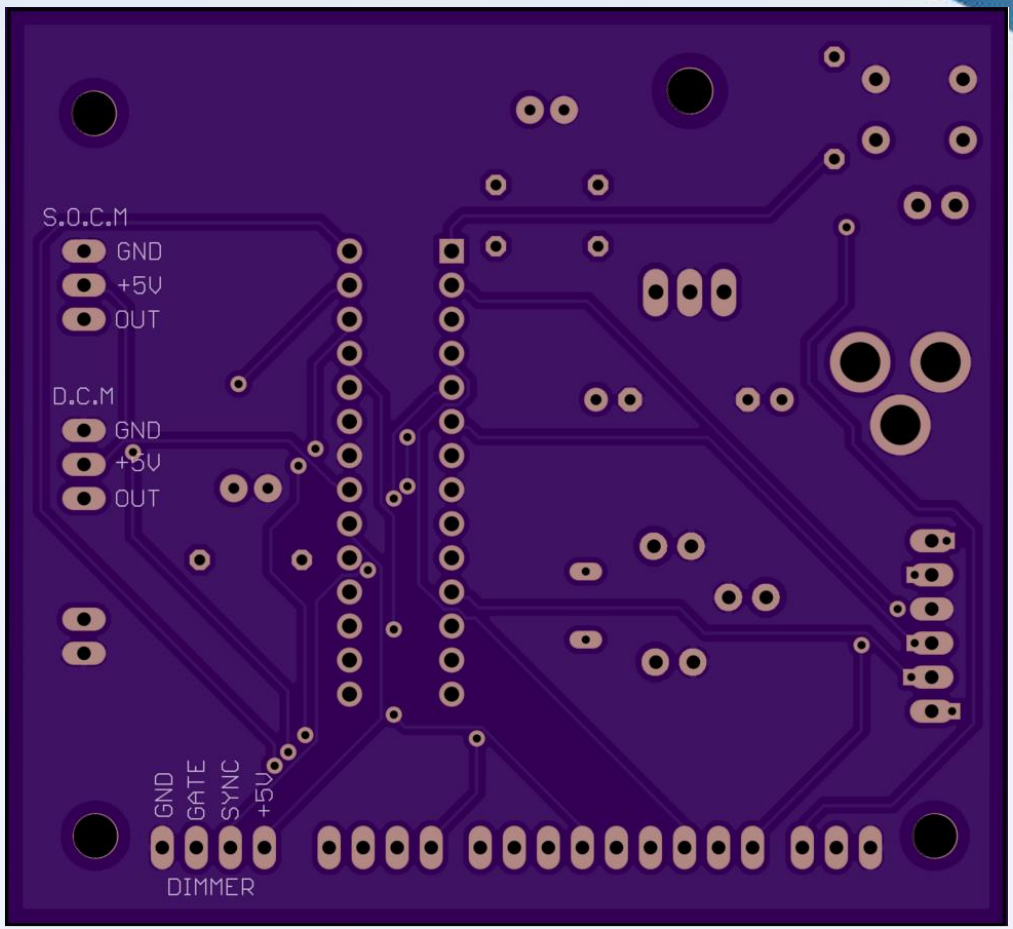


Power Monitoring Final PCB

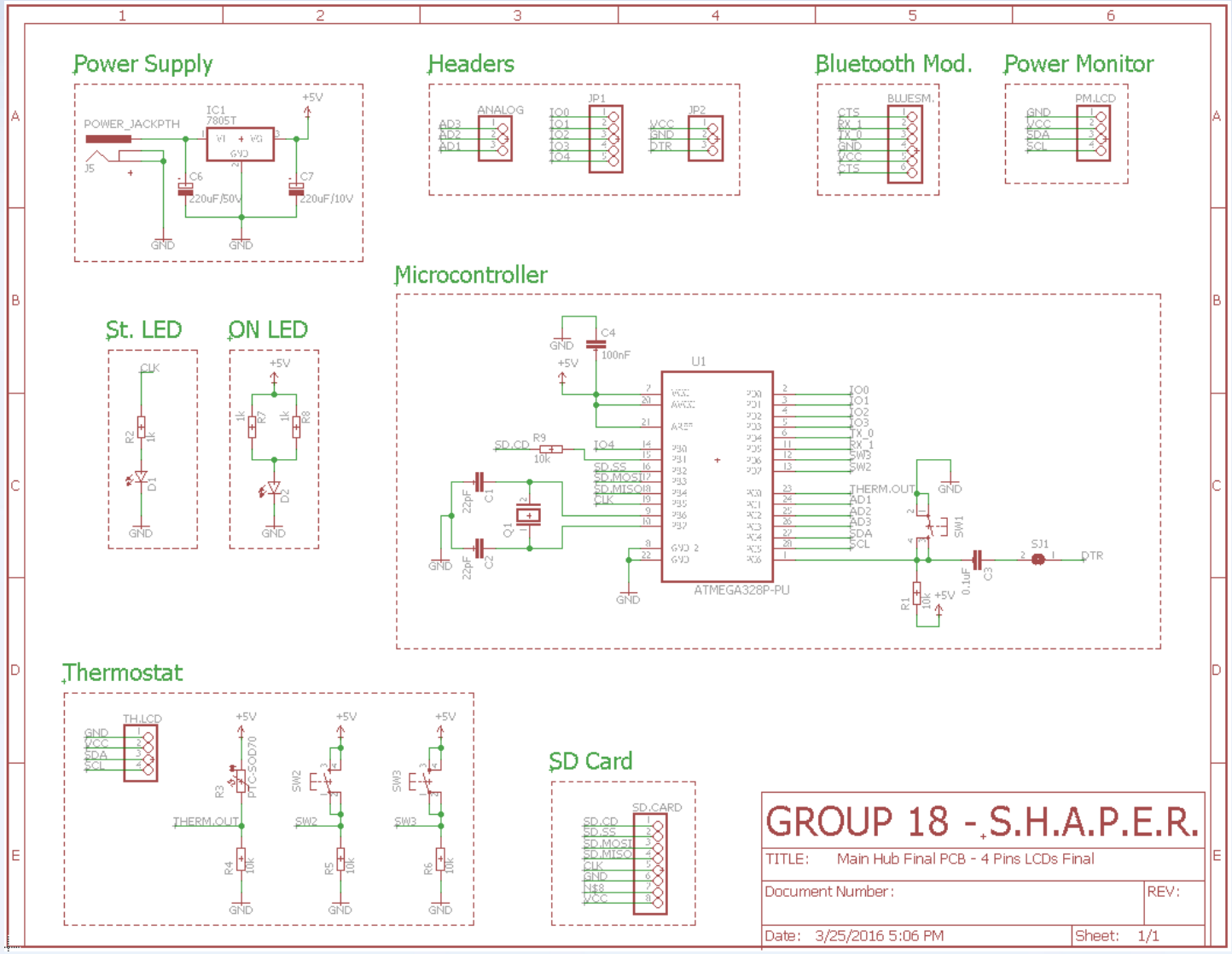
Top View



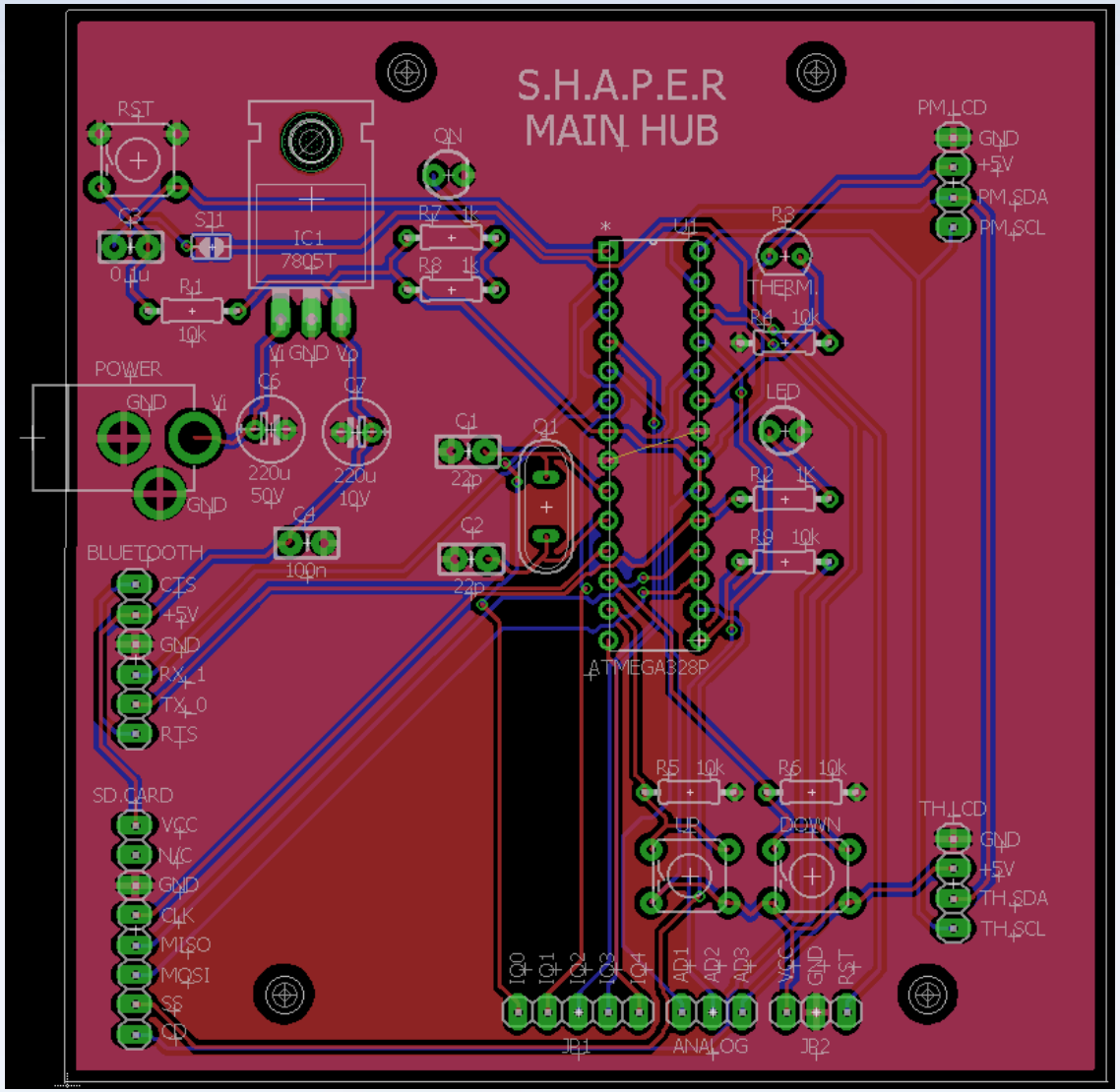
Bottom View



Main Hub Schematic

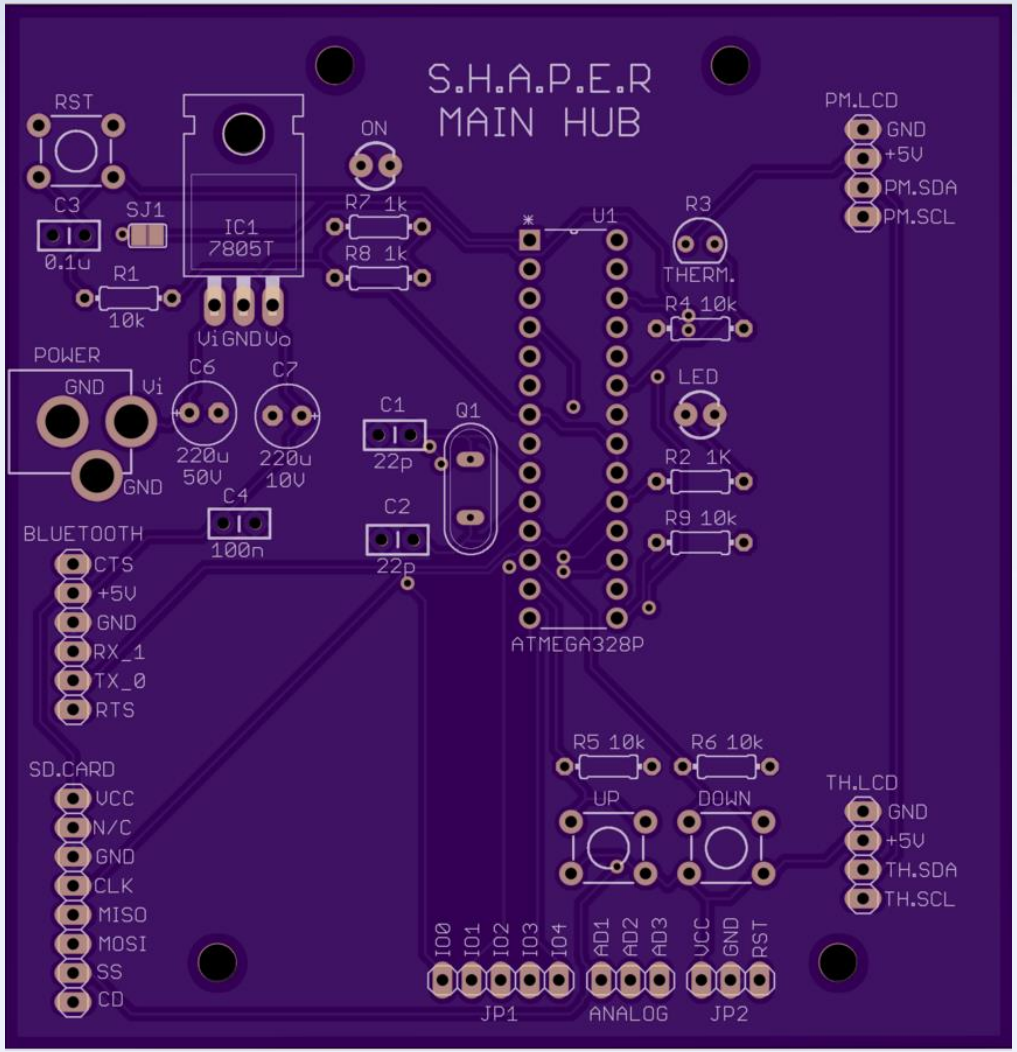


Main Hub Board

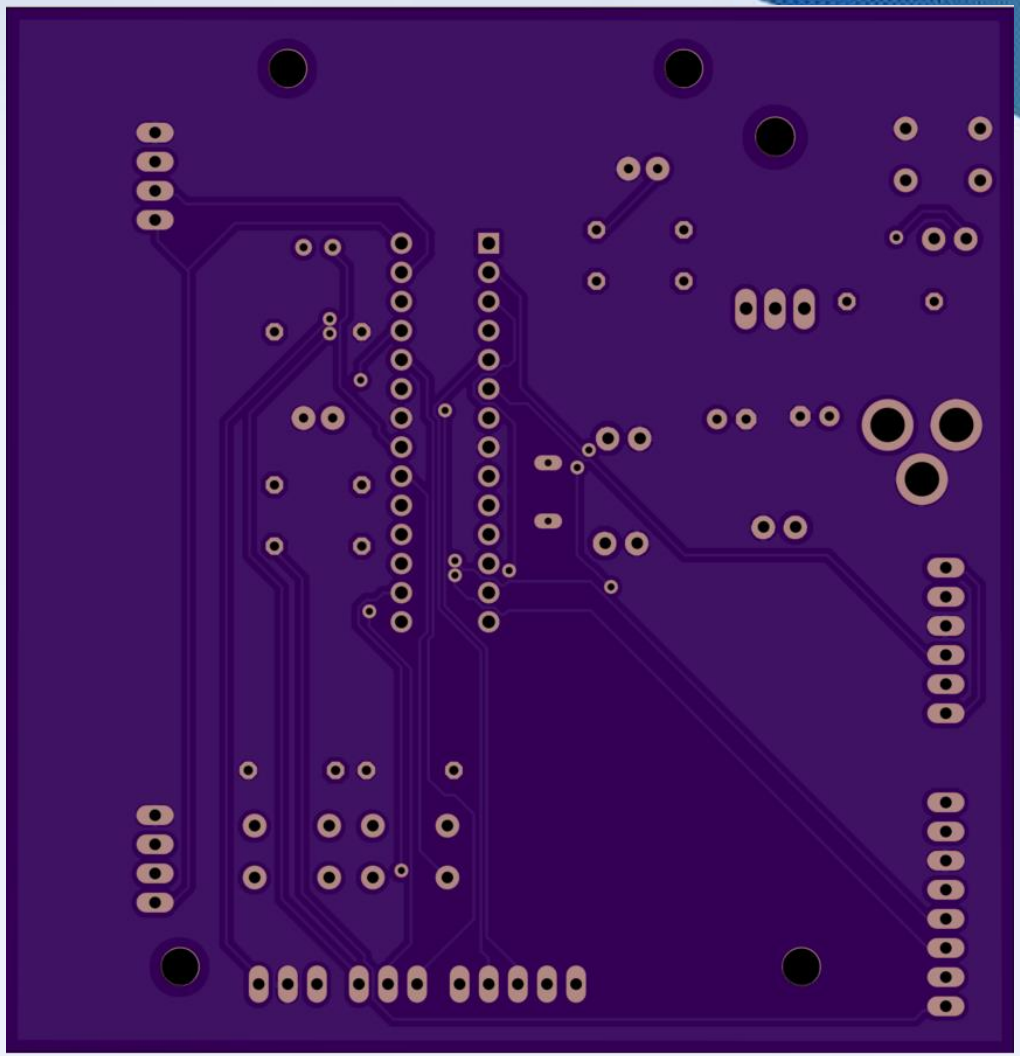


Main Hub Final PCB

Top View



Bottom View



Software Development

Software Design

- Arduino IDE
  - Great documentation and datasheets
  - Simplified user interface
  - Intelligent learning tools
  - System will execute operations based on priority of tasks

Software Design

- Arduino IDE 1.6.7
  - Uses LGPL

Programming Languages	C	C++	Java
Pros	• Widely used • Built-in functionality • Compile time fairly reasonable	• Low memory usage • Higher level than C • Nice exception handling	• Simple to use • Portable • Code is easily extended
Cons	• Uses more memory • Can be difficult to learn • Allows for more bugs	• Slower compilation time • Convoluted error messages	• Lack of garbage collection • Very large footprint

Software Design

- BlueSmirf Configuration
  - Initial Setup
    - > '$$$' – CMD mode to setup for Master/Slave configuration
    - > 'SM' – Master or Slave
    - > 'SN' – Change the name of the module
  - Setup code

```
#include <SoftwareSerial.h>
```

- Used for Serial Communication (Rx⟷Tx)

```
bluetooth.begin(115200);
```

- Set default baud rate in bps

```
bluetooth.println("U,9600,N")
```

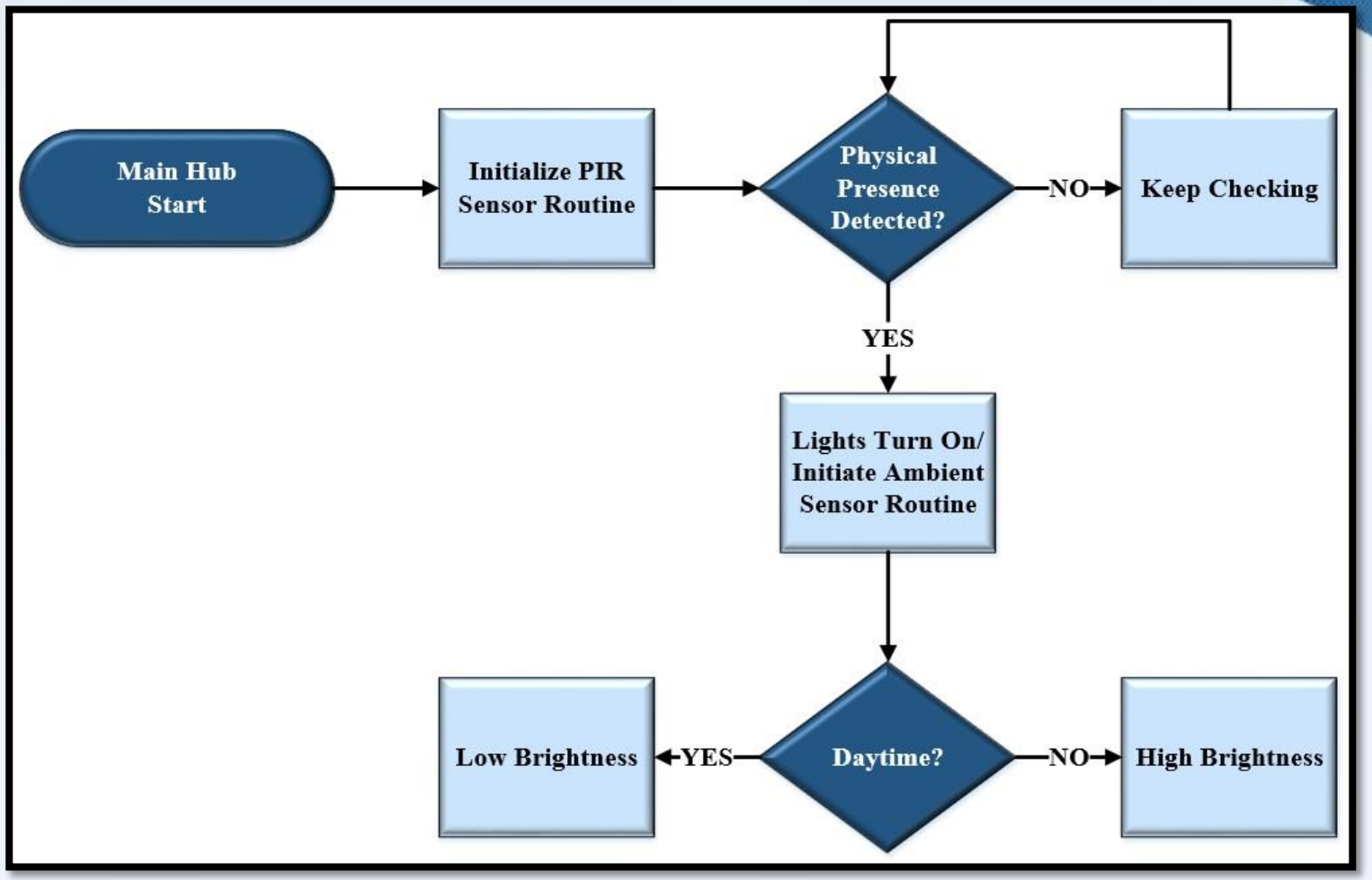
- Set parity and new baud rate

```
if(bluetooth.available())  // If the bluetooth sent any characters
{
  // Send any characters the bluetooth prints to the serial monitor
  Serial.print((char)bluetooth.read());
}
```

Lighting Control Routine

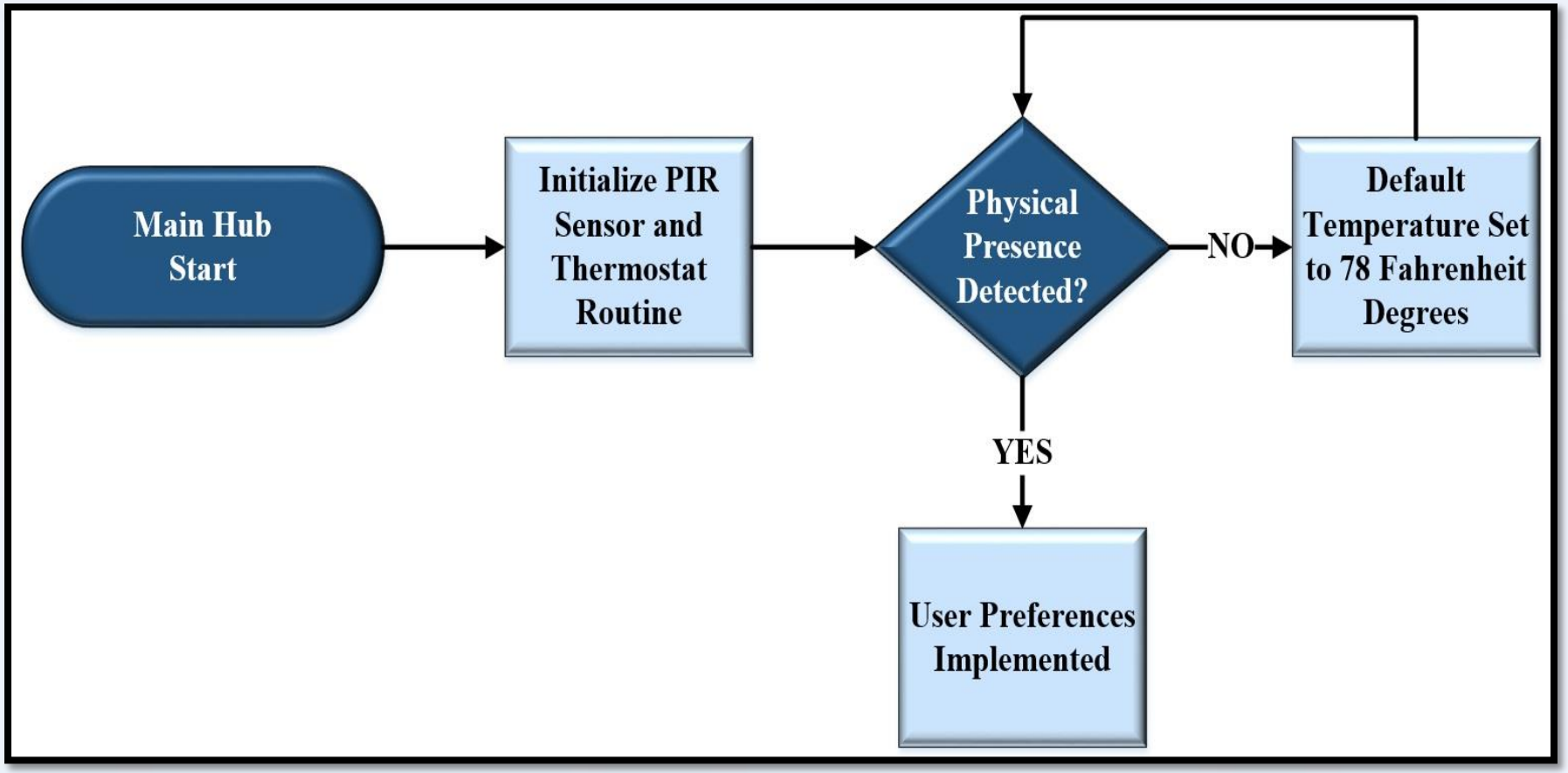
- Both PIR and Ambient sensor will be working in tandem
- Ambient sensor converts voltage change into data bits

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



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 Home Screen

Purpose: Gateway to other sections of the application.

Features:

- Colors and symbols to optimize the intuitiveness of the application
- Where the Bluetooth connection is initialized.
- Utilizes universal usability.

Lighting Control

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

Features:

- Able to set desired light output when room is occupied.
- Turns off lights when no longer needed.
- Exit to return control to sensors board.

Cooling Control

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

Features:

- View of current temperature in the environment.
- Ability to view and modify occupied temperature.
- Turn on and off thermostat.

Power Monitoring

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

Features:

- Observe the current power being utilized
- Turn on and off smartoutlets
- View real time power consumption in the form of a line graph
- See how the power is being divided per appliance

Administrative Content

Division Of Work

	Power Consumption and Main Hub Hardware & Software / Sensor Station Software	Sensors Station Hardware / PCBs / Bluetooth Interaction / Administrative	Mobile Application Development	SD Card / Bluetooth Troubleshooting
Juan Aleman	**Primary**	Secondary		
Maria Alfonso	Secondary	**Primary**		
Gregory Pierre	Secondary		**Primary**	Secondary
Francine Vassell			Secondary	**Primary**

Difficulties

- Designing and assembling the PCBs
- Implementing the thermostat
- Shipping time constraints
- Bluetooth connectivity

Budget Prior to Revised Design

Part	Projected Cost per unit (USD)	Projected Quantity	Projected Total Cost	Actual Cost per unit (USD)	Quantity	Total Cost (including Shipping)
Thermostat	65.73	1	65.73	18.98	1	28.98
LED Dimmable Light Bulb	17.49	3	52.47	3.49	4	13.99
Ambient Light Sensor	N/A	N/A	N/A	7.95	1	7.95
Bluetooth Module	29.99	1	29.99	Vary	5	44.64
Planned BT Module for PCB	N/A	N/A	N/A	16.96	3	57.88
Microcontroller	0.99	5	4.95	10.13/ 4.95/15.71/10.58	1/3/1/1	58.27
Development Board	29.99	1	29.99	19.99/17.99	1/1	37.98
Motion Sensor	10.99	4	43.96	18.32	1	22.12
LCD Screen for PM	N/A	N/A	N/A	30.00	1	30.00
LCD Screen for Therm.	N/A	N/A	N/A	10.00	1	16.05
BT for PCB Dev. Board	N/A	N/A	N/A	22.60	1	27.57
Planned PM Circuit	N/A	N/A	N/A	Vary	Vary	50.68
FPGA programmer	N/A	N/A	N/A	11.55	1	11.55
Dimmer	N/A	N/A	N/A	18.95	1	23.90
Relay (PST)	3.99	8	31.92	19.99	1	26.89
Misc. Electronics	Vary	60	7.50	Vary	Vary	92.30
TI Misc.	N/A	N/A	N/A	Vary	Vary	46.21
Ceramic Capacitors	0.10	30	3.00	6.75	1	6.75
DC – DC Voltage Regulator	1.99	5	9.95	4.50	1	4.50
Outlet	1.99	2	3.98	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
Wi-Fi Module	49.99	1	49.99	TBD	TBD	TBD
Hard Disk Drive	69.99	1	69.99	TBD	TBD	TBD
RF Tx/Rx	4.99	4	19.96	TBD	TBD	TBD
Temperature Sensor	2.99	1	2.99	TBD	TBD	TBD
Total			**1006.30**			**608.21**

Updated Budget

Part	Actual Cost per unit (USD)	Quantity	Total Cost (including Shipping)
Printed Circuit Board	Vary	3	170.05
PIR Motion Sensor	2.07	4	13.25
Arduino Dev. Board	Vary	8	93.85
Thermostat LCD 16x2	Vary	5	47.19
P. Monitoring LCD 20x4	10.75	3	32.25
BT Module BlueSmirf	Vary	7	226.98
BT BLE for Testing	Vary	3	39.97
Ambient Light Sensor	Vary	4	26.12
Thermostat Components	Vary	Vary	18.71
PCB Components	Vary	Vary	100.61
Extras	Vary	Vary	104.00
MicroSD Card Breakout Board	17.99	1	17.99
SD Card	29.99	1	29.99
9V Power Supply	Vary	4	31.31
Power Switch Tail	19.99	1	26.89
Dimmer	20.95	2	51.80
Current Sensor	8.95	6	71.70
Lamp	8.38	1	8.93
Showcase Building Misc. Purposes	Vary	N/A	217.95
Total			**1329.54**

Projected Budget Prior to SD2	**$1006.30**	**Projected Budget Prior to Revised Design**	**$608.21**	**Updated Budget**	**$1329.54**	**Final Total Budget**	**$1937.75**

Sponsors

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

Thank you!

Questions?