Web-Controlled Distributed Wireless Power Control

ECE 445 Design Review
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We selected this project because it involves a great deal of concepts we have studied throughout our ECE careers. We formed our group before enrolling in the class and decided to take on the challenge of senior design because we had the idea of implementing this system. We are very excited in creating this design because the concept will not only build on our knowledge about RF, Power, and Web/App development, but the idea can prove to fill a niche market as a consumer product.

Objectives

The main goal of our project is to implement a modular wirelessly controlled power strip system that provides a user the ability to control power strips that are connected to a central hub that will be accessible through a network broadcasted UI. To define modularity, we are hoping to achieve the connection of two separate power strips up to a single hub that will control both of the individual power strips but we are including support for more power strips through our method of encoding our wireless data transmission.

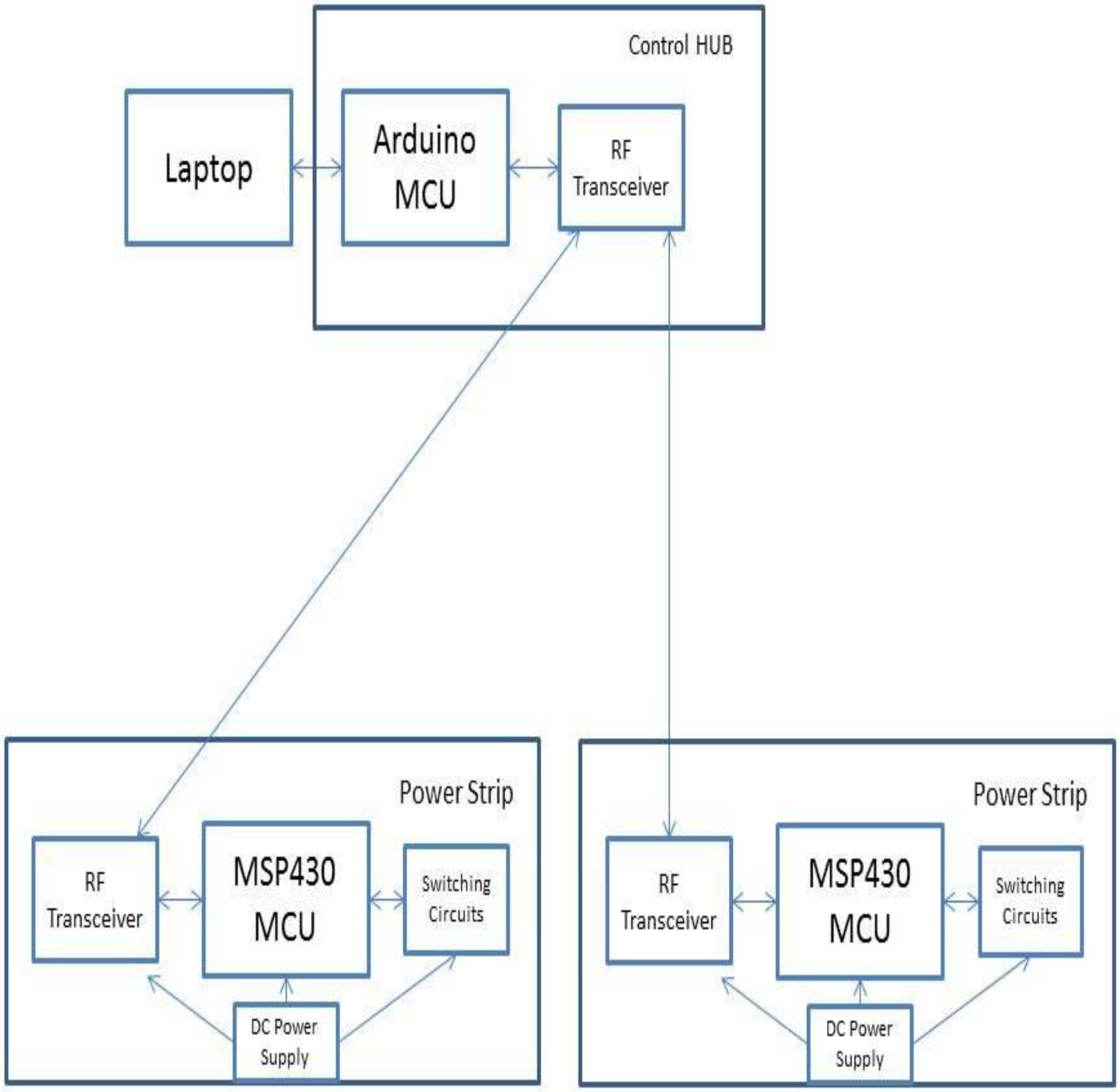
Benefits

i. Control multiple power strips from central hub
ii. Allow more freedom in power strip location as they can be controlled wirelessly

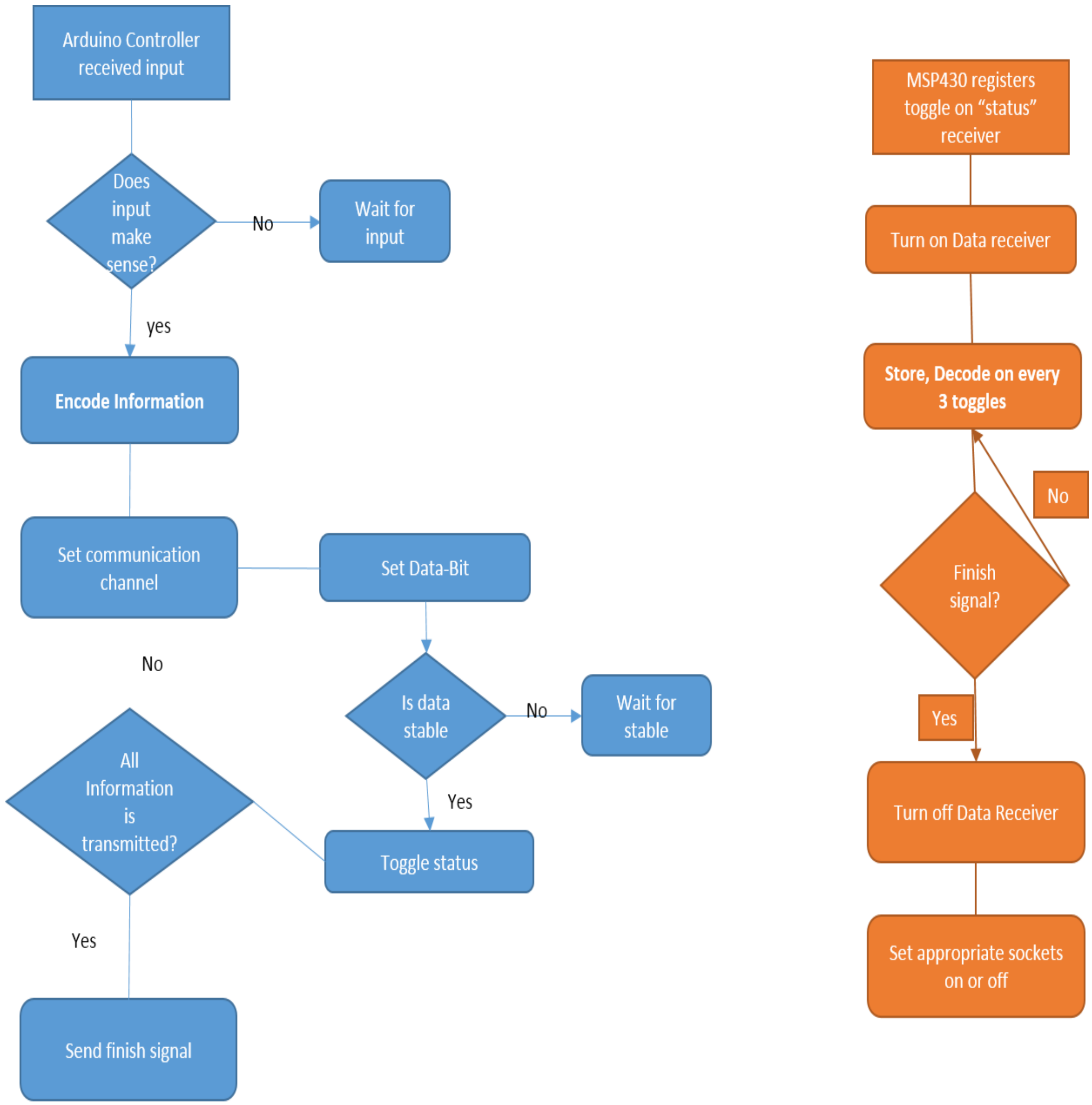
Features

i. Individual socket control on each power strip will be given to the user through the app interface
ii. Modular support power strips that will be controlled from the central hub
iii. User portal interface accessible from any network connected device

Block Diagrams



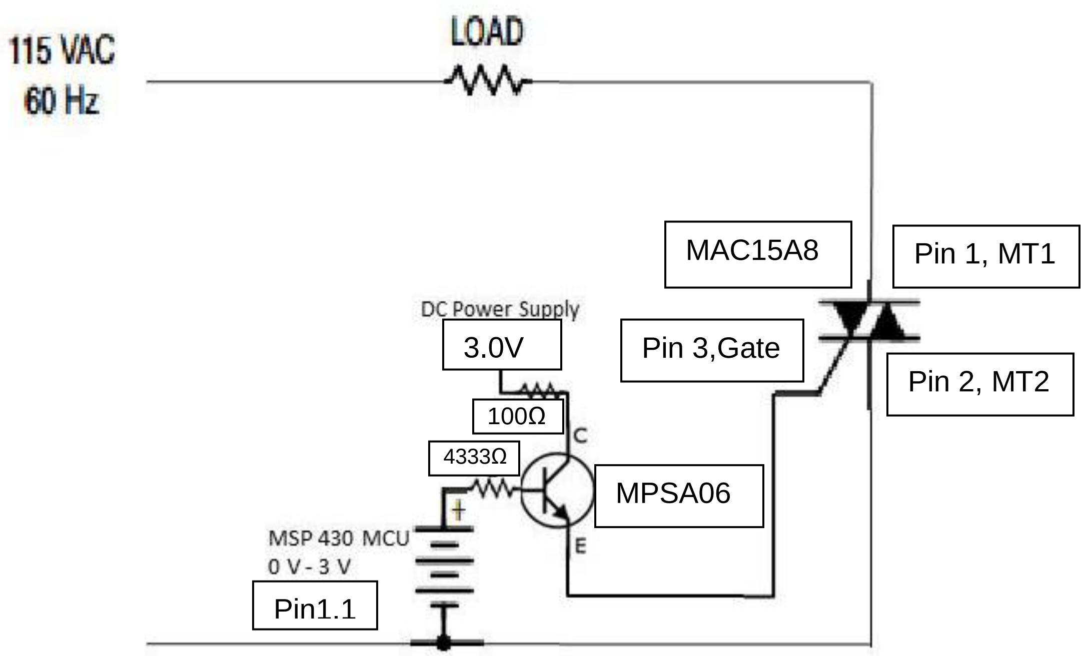
System Operation Block Diagram



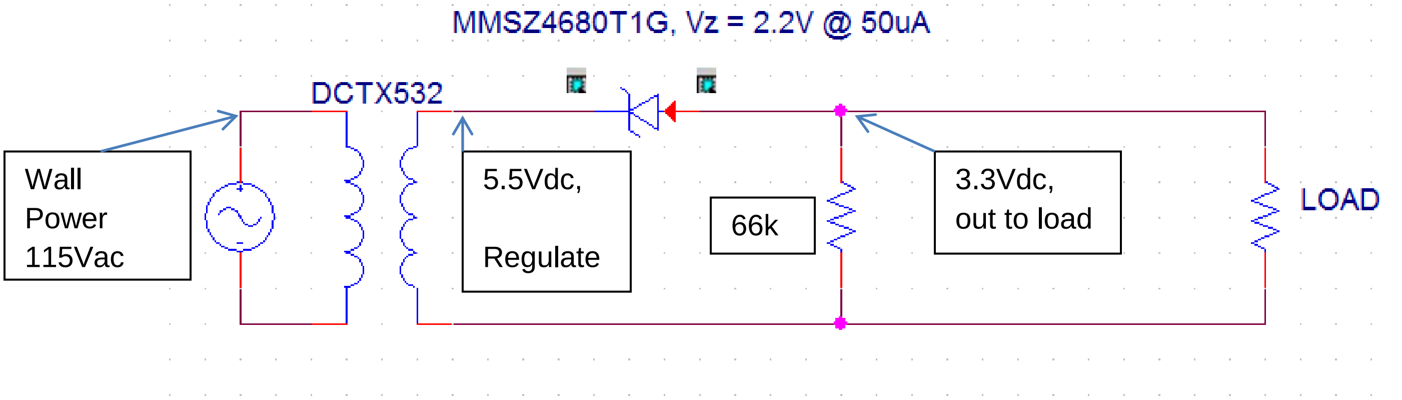
Software Operation Block Diagram

Schematics

Each power socket in every power strip will be controlled by a triac. The triac is a bi-directional AC switch, and it can be switched from high-impedance to low impedance by the presence of a gate current. The triac we will use is the MAC15A8, and it requires 20mA of gate current in order to switch into a low impedance state. It also requires the presence of this current during every zero-crossing in the AC power signal in order to maintain its low-impedance. The gate current will be controlled by MSP430, but this controller cannot supply enough current, so the controller will excite the base of a BJT which will then supply enough current to the triac for conduction. The BJT we have chosen is an MPSA06 because it is the cheapest transistor that we have readily available, and it can easily supply the necessary currents. The transistor will be run in saturation mode so as to minimize the effect of any voltage deviance in the circuit. According to their respective data sheets, the triac requires a .95V difference across it's gate and MT2 terminal. The transistor will need a .75V difference across its base and emitter pins. This forces the base pin to a 1.7V difference with respect to ground, and since the MSP430 can drive an output to at least 3V, then a 4.333K Ohm biasing resistor is necessary between the controller and the transistor. The same technique is used to choose the resistor value on the collector side of the transistor in order to endure the current into the triac is 20mA. The power-supply circuit will be the source that provides the collector current and the circuit that powers the microcontroller and the RF radio.



Switching Circuit



Power supply

There will be one power supply circuit per power strip to provide power to the radio reciever, microcontroller, and 6 triac gates. These elements draw a maximum of 24mA, .23mA, and 120mA respectively. This adds up to a maximum drawn current of 145mA. The transformer we are using, the DCTX-532 is rated to transform AC power from a wall jack to 5.5V DC at 300mA, but it is regulated to not increase in voltage if the current drawn is less. 5.5V is a voltage that will damage our equipment, so we drop 2.2 Volts using a Zener diode in reverse bias. We place a large resistor in parallel with the load to ensure that there will always be at least 50uA flowing through the diode at all times to bias it in reverse breakdown mode even if we switch our circuitry into a very low-power state.

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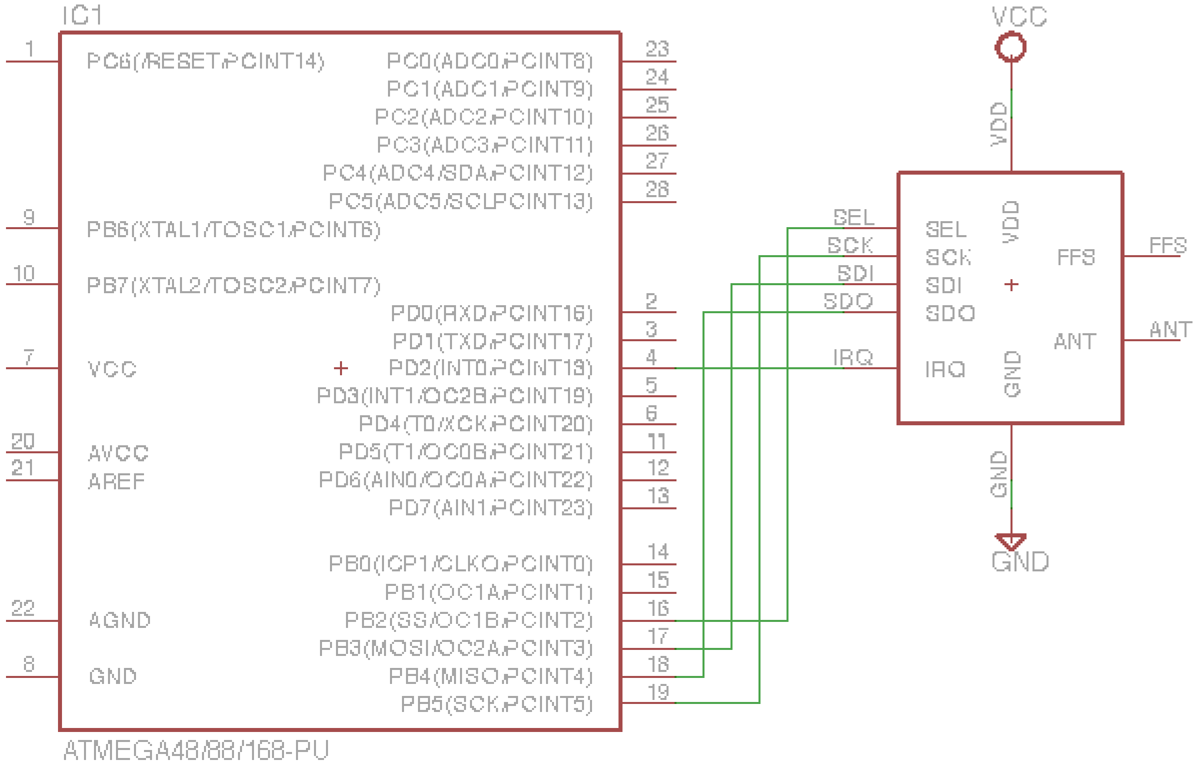
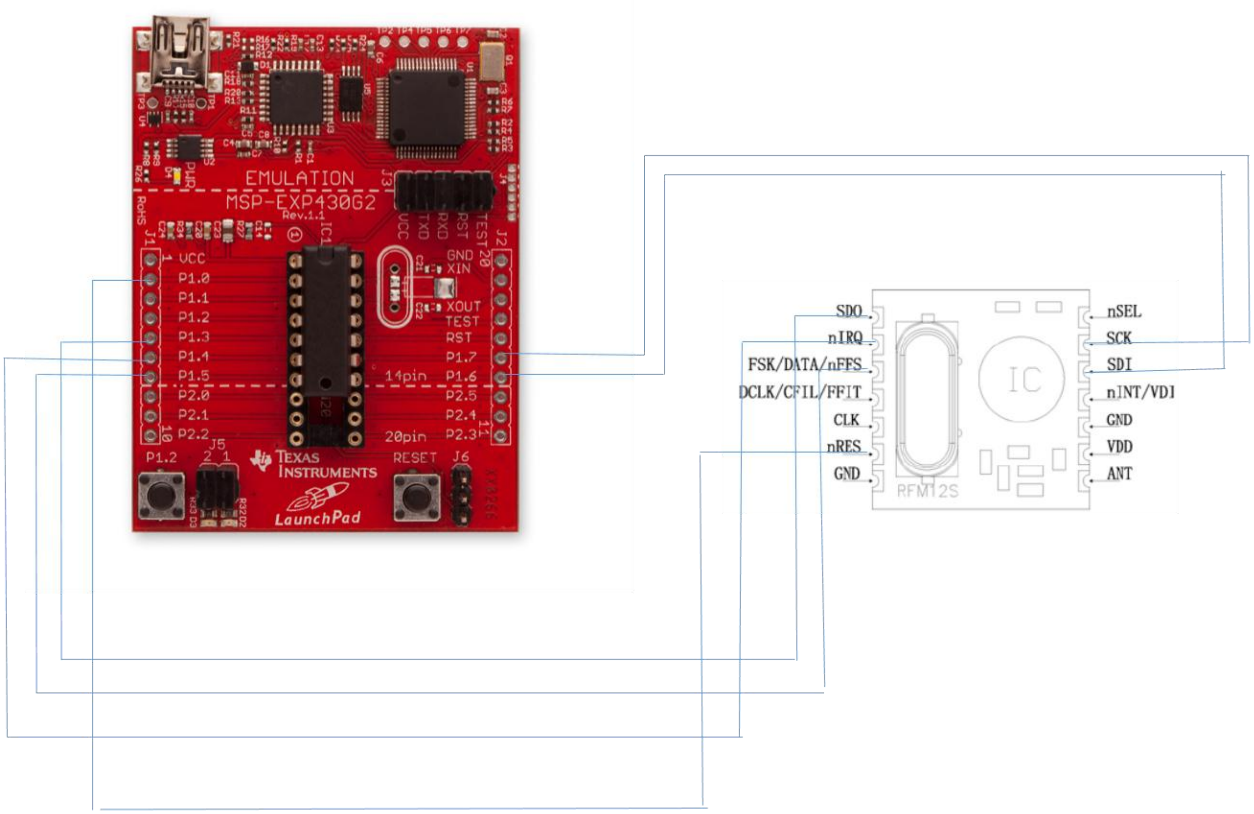


Arduino Pin out (Provided by JeeLabs)



MSP430 Pin Connections to RFM12 Transceiver

Simulation:

Because of the stable nature of our circuits, a simulation would deliver no more information than what can be read off data sheets and arrived at through well-established equations. The triac in our switching circuit conducts current through its conducting terminals as long as a minimum value of current has passed through it's gate terminal. This minimum value of gate trigger current is shown in **Figure 4** of the MAC15 series datasheet from http://onsemi.com. Two assumptions are made before the minimum gate current is determined. The first is that we are only operating the device in quadrants 1 and 3. The second is that we will not operate the device below 0 degrees Celsius. Given those two constraints it is clear that the minimum value for the gate trigger current will be no more than 20 mA. The performance of the device will not be affected by the value of the gate current as long as it is between 20mA and 10A.

The voltage across the conducting terminals of the device can be seen as a function of conducting current in **Figure 5** of the datasheet. Our circuit is designed to conduct between .1A and 15A, as is outputted from the wall. From this figure it can be seen that this range of current corresponds to a voltage range from .8V to 1.5V across the conducting terminals. This voltage however can be assumed constant relative to the magnitude of the wall power signal which is at least 100V.

The transistor supplying the gate current will be driven in saturation mode so as to be more reliable and impervious to small deviations in supply voltage.

The transformer in our power supply circuit is rated and regulated to deliver a DC voltage as long as it is plugged into the wall, and the Zener diode across it is biased to maintain the 2.2V voltage difference across its terminals, so the circuit as a whole should deliver a DC output voltage of 3.3V.

Tolerance Analysis:

Power Circuit

There's no doubt that the transformer will be able to draw its rated 1.65 Watts from the wall. This voltage is regulated however by an internal Zener diode across the output of the transformer. The specifications of this Zener diode are unknown but it is uncommon for commercial Zener diodes to have tolerances above 5%. This expands the range of the output of the transformer to between 5.225V and 5.775. The external Zener diode which is designed to drop 2.2V has its own 5% tolerance. According to its datasheet it may in reality drop between 2.09V and 2.31V at the designed bias point. After this voltage drop the voltage at the output that is incident on the load could fall in between 2.915V and 3.685V. The extremes of this range do not meet our requirements, but the external Zener Diodes are cheap and any diodes that we find that have been made at the extreme of their tolerance will be discarded and replaced in order that the final power supply circuit falls within our requirements.

Switching Circuit

The MSP430 is expected to deliver a HIGH level logic signal at a voltage very close to the voltage delivered to it by the power supply. The resistors were assumed ideal and designed for a 3.0V power supply. As the voltage from the power supply can only be higher than 3.0V, the currents drawn by these resistors will only be higher than what we've designed for. This works to our advantage, because more base current would serve to drive our transistor further into saturation mode, and more gate current into our triac will not affect its performance. Both values are designed at minimum acceptable values. The resistors in practice will have 5% tolerance on their resistance values, but if this turns out to be a 5% decrease in resistance then the resulting increased current will not affect our design. Resistors are cheap and can be measured and chosen to have at least the resistance that we have designed for.

Testing:

Requirement	Validation
Power Supply 1. Maintain a supply voltage of 3.3 Volts to within .3V while supplying current from between 0 to 200mA 1.1 Open circuit Voltage must be between 3.0 and 3.6 Volts 1.2 Supply Voltage must be between 3.0 and 3.6 Volts when supplying 100mA of current to a load 1.3 Supply Voltage must be between 3.0 and 3.6 Volts when supplying 200mA of current to a load	1. Verification of 1.1-3 1.1 Supply Power supply with wall power, verify that output voltage is within range for 20 seconds using a voltmeter 1.2 Supply Power supply with wall power, load the power supply with resistors connected in series, one of these resistors will be a 1Ω sensing resistor, verify using a voltmeter that the sensing resistor carries a .1V difference across it, and that the entire resistive load network carries a voltage difference of between 3.0 and 3.6 Volts across it, verify that voltages each stay within range for 20 seconds 1.3 Supply Power supply with wall power, load the power supply with resistors connected in series, one of these resistors will be a 1Ω sensing resistor, verify using a voltmeter that the sensing resistor carries a .2V difference across it, and that the entire resistive load network carries a voltage difference of between 3.0 and 3.6 Volts across it, verify that voltages each stay within range for 20 seconds
Switching Circuit 2. Switch must not conduct any power	2. The switch circuit will be supplied with a 3.3V voltage supply and a 0V input

from the wall socket when it is inputted with 0V 2.1 Switch must conduct power from the wall socket to a load when it is inputted with 3V 2.2 Assuming requirement 2 is met, while the circuit is conducting power to the load, the circuit must absorb less than 2% of the power that it delivers	voltage through voltage sources in the lab. A 1MΩ resistor will be used as the load of the circuit, and wall power will be introduced across the circuit and the load. An oscilloscope will be used to measure the voltage across the load, and verify that it is below .1Volts for at least 20 seconds. 2.1 The switch circuit will be supplied with a 3.3V voltage supply and a 3.3V input voltage through voltage sources in the lab. A 1MΩ resistor will be used as the load of the circuit, and wall power will be introduced across the circuit and the load. The voltage across the load will measured by an oscilloscope and will be verified to be an AC signal with a frequency between 59 and 61 Hz 2.2 The switch circuit will be supplied with a 3.3V voltage supply and a 3.3V input voltage through voltage sources in the lab. A 1MΩ resistor will be used as the load of the circuit, and wall power will be introduced across the circuit and the load. The voltage across the load and the triac in the circuit will measured by an oscilloscope and the respective powers dissipated in each will be calculated and the power dissipated in the triac will be verified to be less than 2% of the power dissipated in the load.
Laptop Computer Requirements 1) Must connect with Arduino MCU and be able to send data to the MCU 2) Must connect with Arduino MCU and be able to receive data from the MCU 3) Must connect with home network and broadcast access to UI on network	1) Connect Arduino to laptop computer and load hardcoded program to Arudino memory. The hardcoded program will set the values of the digital output pins on the Arudino to a high value of 5V. This will be verified using a voltmeter on each of the digital out pins set to this high value 2) Connect Arduino to laptop computer and load hardcoded program to

	Arduino memory. The hardcoded program will perform reads from the digital inputs on the Arduino and send them back to the computer. The digital inputs will be driven by the power supply in our lab kit to drive the inputs to have a 5V reading which will be registered by the arduino as a 'high' value and should be communicated back to the computer as such. 3) Connect laptop to home network using standard 802.11 protocols, and run web server code to broadcast UI page. Verify access using another computer on the network connected using same protocol and other network connected devices by trying to access the web UI using a given address.

Processor Portion (Requirement)	Testing Process:
Arduino/RFM interface 1) Arduino is able to interface with transceiver and: a)Is able to send a 434MHZ signal via RFM transmitter b)Is able to send two signals with two transmitters simultaneously, one at 434MHZ and a second at 444MHZ	1a1) Fit spectrum analyzer with antenna. Set spectrum analyzer to read around the 434MHZ frequency. Pulse control signal through arduino to RFM. 1a2) Verify through spectrum analyzer that 434 MHz signal is propagating in space 1b1) Second test will be to try to send two signals, one at 434MHZ and I at 444 MHz at the same time to see if both send and receive. Arduino will send control signals to two RFMs to transmit at the two mentioned frequencies 1b2) The RFM recievers will be set up with lab-controlled signals, and their outputs will be measured using volt meters to verify the respective reconstruction of the two signals sent out by the arduino
MSP430 2) MSP430 is able to interface with receiver and does: a)able to receive a 434MHZ signal via RFM receiver b) Receive and interpret two receiver signals	2a) Test using serial out stream from MSP430 to see the data that it is receiving utilizing the tools provided by Code Composer, or any Linux platform. b) Use similar test pattern to check for multiple signal traces simultaneously from two receivers connected to one single

	microprocessor
3) MSP430 Is able to decode information sent by Arduino	See if proper switch gets activated, or connect LEDs to corresponding pins and see if they get active
4) Arduino is properly able to send right number of bits to MSP430	Give it a test sequence of bits and scan with oscilloscope for those values at desired frequency
5) Once MSP430 signal is interpreted proper output signals are loaded high.	See if the right output signals are being driven by using an ohmmeter to see if the transistors that correspond to the switches are getting excited and activated.

Software Process:

For the sake of simplicity I will just define the terminology with which I will be referring to the individual units within the design. The first is going to be our Hub. The hub is going to consist of a fairly strong microcontroller with access to the net so it may be able to channel information over a webserver or through a smart phone on the same wireless network. There is meant to be one hub per household taking control of a series of switches. The hub is also going to be called the transmitter because it will be the means of relay for any and all information that is going to the Switches. The switches, which are basically modified surge protectors, are the receivers of the data being transmitted. Each surge protector will be modified with an MSP430 of which we will be connecting to two RFM12B transceivers.

One of the first problems that we ran into while trying to implement this RF power control system is a means of managing the clock in two separate controllers and having them both respond in a synchronous fashion. Our proposed solution is to use two transceivers per switch block. One of the RFM's will be receiving a "status" signal, while the other receiver will be receiving the "data" signal. The purpose of this is so the controller knows when to start listening to the data. Once the "data" stream becomes stable we will pulse the status signal, upon the pulse the data receiver can be turned on and read, and the value stored.

In order to maintain modularity of the switches (meaning we can add multiple surge protectors to the system) we are going to allot a switch ID to each switch. Upon data receive, bits will get stored into onboard memory of MSP430. Once the ID of the receiver is matched the actions to turn on the right power sockets will then take place. We have made the assumption that each surge protector will have at least six and up to eight sockets. For that reason, we decided that we will only need to read three bits of data to control the sockets. The power sockets will be numbered 0-8. Socket zero will correspond to bit encoding "000" while socket seven to "111." This encoding will make it easy for the MSP430 to decode and turn on those connections.

Testing(Software):

We will be testing software in a very systematic format. First, we will program the Arduino to start interfacing with the RF chip. Once it is properly wired up, we will start transmitting a series of signals on a set frequency band. Once we have a certain degree of certainty that it is working, we will start programming the MSP430 to receive signal. Initially the MSP430 will just have a wired up receiver doing nothing but receiving a signal. Once we can say that the transmitter and the receiver seem to be working to some degree, we will then pair the second transmitter and receiver to simulate the status and data bits. At this point we will start to receive signal on the toggle instead of waiting for any random signal. Finally once the transmitters and receivers work in the way they are supposed to work, we will start to implement the decoding process and encoding process to ensure that only certain signals in a given circuit go high. After all of this is finalized the software end will have been adequately tested and processed. After all of this, its just a matter of connecting the test circuit from the analog signal end to the MSP430.

Ethics

The ethical concerns brought about in our project focus on ensuring the safety of others by avoiding injury to any one that uses our design. The risk involved with our design comes from the interaction from high voltage sources that can cause harm to the user. We will work to prevent any harm to the user by thorough testing methods described above and solid design work to ensure the user will not be injured during the operation of our design.

Parts List

Product	MFR/Part #	Quantity	Unit Cost	Cost
Surge Protector BE106000-2.5	Belkin	2	$6	$12
RFM12B Radio Transceiver	Modern Devices	6	$1	$6
Raspberry PI	Raspberry PI	1	$35	$35
Arduino Microcontroller	Arduino	1	$30	$30
BJT MPSA06	ON Semiconductor	1	$0.15	$0.15
15 amp Triac MAC15A8	ON Semiconductor	1	$2.58	$2.58
Resistors(125,250,13,8, 8 K OHMs)	RSB-125RCT 23J8K0E W81S249	4	$1.50	$4
MSP 430 Microcontroller	Texas Instruments	2	$6	$12
Regulated DC Supply DCTX-532	All Electronics Corp.	1	$4	$4
Total Cost				$106

Schedule

Week	Task	Member
9/24	Order all the parts necessary Research Web UI services Research switch control	Chaitanya Patchava John Ehsan
10/1	Find a proper system to synchronize clocks Procure all elements for the switching circuit Setup web development environment	Chaitanya Ehsan John
10/8	Start to connect Arduino with RF transmitters Develop switching prototype Create web UI layout	Chaitan Ehsan John

10/15	Connect receivers to MSP430 Procure all elements for the power supply Test web ui controls	Chaitan Ehsan John
10/22	Test micro controllers with Ehs's design Develop power supply prototype Setup ui broadcast to network	Chaitan Ehsan John
10/29	Setup encoding/decoding for two switches/sockets Provide integration support Test send/receive from ui to arduino	Chaitan Ehsan John
11/5	Practical test of encoding and decoding block. Provide integration support Implement control of BJT input from ui control	Chaitan Ehsan John
11/12	Run tests with laptop and phone chargers Provide integration support Test control of different socket control based on MCU control	Chaitan Ehsan John
11/26	connect arduino to input/output buffer Provide integration support Perform final testing of ui control	Chaitan Ehsan John
12/3	Project Demos	Chaitan
12/10	Final Paper	John
12/10	Final Project Presentations	Ehsan

Triac MAC15A Datasheet Attached (Under PACE Appendix)