Portable RF Light Socket Control

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Design Document for ECE 445, Senior Design, Fall 2017

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5 October 2017

Project No. 9

1 Introduction

1.1 Objective

For residents of temporary housing like apartments there is a need for a more practical solution to customizable lighting control. Landlords often discourage modifications to wall circuitry and current wireless based options are either difficult to set up or not customizable.

The wireless based system we are designing will enable apartment residents to control their lighting from a switch with a built in transmitter that can be mounted anywhere in their home. The other component of the design is a light socket insert that receives a control signal from the switch, so the installation of the system will be as involved as screwing in a light bulb. The resident will be able to control up to 4 sets of lights and be able to customize which lighting fixtures are contained in each set of lights by turning a selector dial on the socket insert.

1.2 Background

Many college apartments do not include built in ceiling lighting for large areas such as the living room. Once additional lamps are purchased, it becomes a chore to control the lighting since the resident must approach the lamp to turn the switch. The internet of things has tried to solve this problem with light bulbs that connect to the internet and are controlled by a smart phone. These bulbs have two issues. They are either too expensive with typical costs greater than $30 and often times they require the purchase of an additional communication hub [1]. College tenants have limited budgets for such luxuries.

A further issue with bulbs controlled via wifi communication is the communication range. The smartphone switching the light could be within close proximity, but regardless of this switch to light distance there could be connection issues because of the longer range intermediate communication between router and light bulb. Routers operating in the 2.4 GHz band have a range only up to 150 feet [2], so if a wifi controlled bulb is in a far corner of an apartment the resident may be out of luck.

Arguably the biggest drawback of wifi controlled lighting is the time delay between flipping the digital switch in an app and the light actually switching on. The time delay is on the order of a few seconds [3]. Flipping a light switch is an action that should be met with instant gratification. Our radio controlled solution will reduce this time delay substantially without the user ever having to open up their smartphone.

1.3 High-level Requirements

- The system will be capable of choosing among four sets of lights which set should receive its unique on/off signal based off of the button on the switch selected by the user.
- The switch and the socket insert will be able to communicate up to distances of 30 feet but no more than 100 feet in order to not interfere with other switch systems.
- The size of the socket insert will be less than 4 in in all dimensions as to fit into light fixtures and the size of the switch will be less than 6 in in length and width for easy portability by the user.

2 Design

Our solution consists of two components, a switch box and a light socket device. The switch box will be composed of a battery power supply, a TTL unit, and a radio transmission unit. The light socket device will be composed of a power supply, a TTL unit, and a radio receiver unit. The power supplies will both power the components but in their own way. The power supply of the switch box needs to be battery powered so it's portable and the power supply of the light socket device needs to power both the light bulb, TTL circuitry, and the radio receiver parts. The TTL units will act as the brain of their respective devices but they need to work together. The two separate TTL units will be able to communicate with each other through their radio units. The transmission unit will be responsible for sending information from the switch box to the device. The receiver unit will be responsible for receiving the information sent by the switch box.

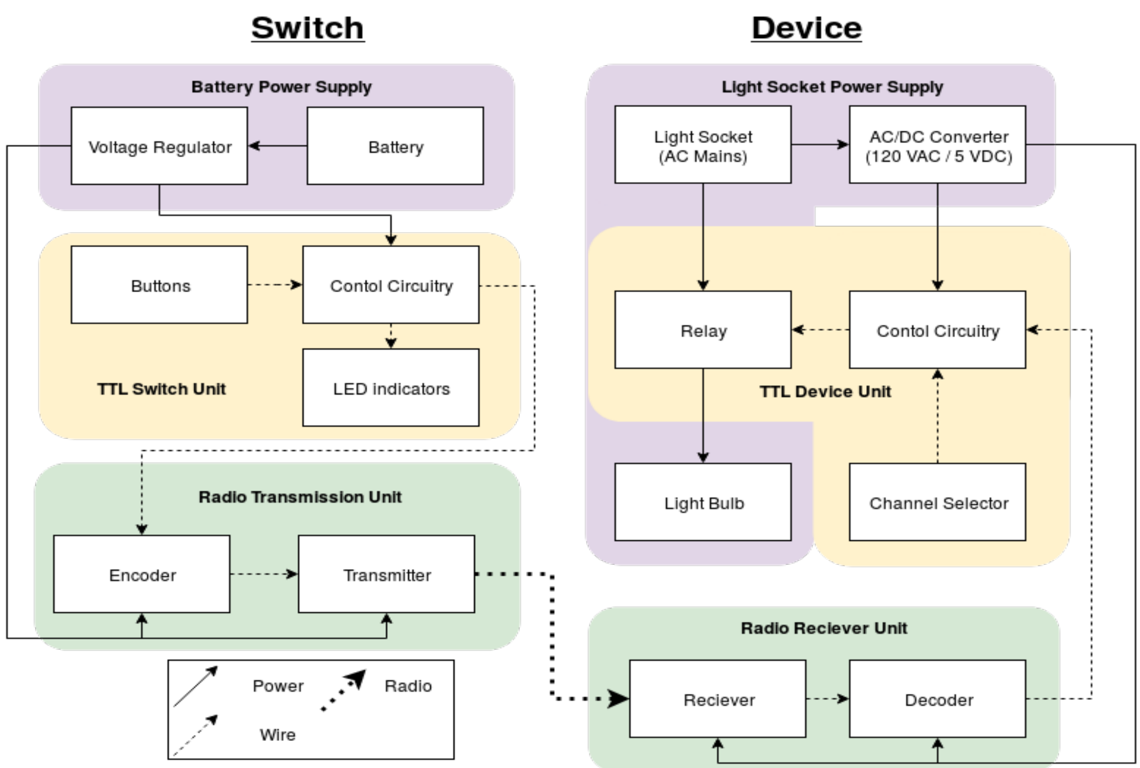

Figure 1: Block diagram of both the switch and device.

A rough idea of how these components will look like can be seen as Figure 2 for the switch box and Figure 3 for the light socket device. The switch box and device don't have physical dimensions yet because we're unsure of how large the PCBs of our design will be, but the switch box definitely needs to be small enough to be hand-held. The light socket device needs to be small enough to leave room for a light bulb in light fixtures because the device will screw into the socket of a light fixture and the light bulb will screw into the device itself.

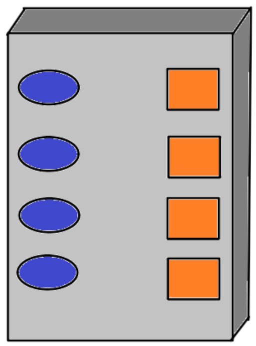

Figure 2: A rough sketch of the switch.

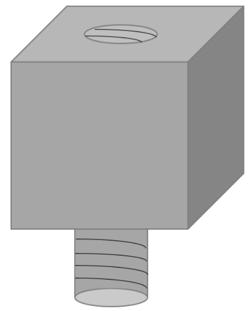

Figure 3: A rough sketch of the device.

2.1 Battery Power Supply

The portable switch box is powered by a battery pack. The battery pack contains alkaline batteries with a nominal voltage of at least 7 V. The battery pack will be comprised of Energizer E95 D batteries connected in series, each starting rated 1.5 V. Five connected in series will produce 7.5 V. 7.5 V works well for the design because the higher the battery voltage, the more power will be lost from the regulator. The E95 batteries are chosen because they have a large capacity for alkaline batteries, for our application upwards of 14,500 mAh.

The voltage regulator ensures the consistent delivery of nominal 5 V to the Control Circuitry in the switch box. The LM7805 is chosen to regulate the 7.5 V battery to a constant 5 V. This particular voltage regulator is rated for 1 A, which is well above our maximum switch control circuitry current of 80 mA.

The relay will act like a switch between the 120 VAC coming in from the light socket and the light bulb. The relay takes in digital input to turn the light on and off. We drive the relay with a circuit containing a NPN transistor and two resistors. This is due to the fact that the T77S1D10-05 relay requires 90 mA along the coils. The contact current rating is 10 A, which is far above what we need for light bulbs, which all require less than one amp. We place a reverse diode between ground and power to protect the 5 V supply when the relay is switching.

Requirement(s)	Verification
1. The battery must supply at least 7 V and have a capacity of at least 10 Ah. 2. The switch system battery life must be at least 150 operational hours. 3. The voltage regulator must output between 4.8 and 5.2 V	1. Using a multimeter across the battery pack terminals, verify that the the voltage is 7 V or greater. The capacity will be verified by extrapolating information from the data sheet for a discharge to .96 V per battery. 2. Power on the system and operate with all light sets set to on. Using a multimeter, measure the current out of the switch battery power supply. Divide the battery capacity [mAh] by the measured current [mA], and verify that the operation hours are at least 150. 3. Attach 5.0 ohm power resistor as the load. Attach oscilloscope across the load. Verify that the voltage is between 4.8 and 5.2 V.

2.2 Light Socket Power Supply

The light socket will power the entire device as well as a light bulb. The devices TTL and radio unit will need 5 VDC so the 120 VAC provided by the light socket needs to be converted into 5 VDC. The 120 VAC comes from the socket and is passed through the relay to power the light bulb. 120 VAC is also converted to 5 VDC to power the receiver and decoder. The 120 VAC power will be accessed through an edison screw socket adapter as pictured in Figure 3. Fuses are placed with the relay and the 120 VAC to 5 VDC power supply to protect the components from high voltage if something goes wrong.

The 120 VAC to 5 VDC converter takes the voltage from the light socket and converts it to 5 VDC which powers the control circuitry, the receiver, and the decoder. This component ensures the safe delivery of 5 VDC from the AC mains. The component will be an AC-DC Power Module, such as a deconstructed 110v/5v USB 700mA charger. Our AC/DC converter must be small enough to fit inside the housing that will screw into the light socket. With this constraint, safety, noise, and clearance between live and neutral become design issues. For these reasons, we will use an off the shelf converter to supply the 5 VDC power.

Requirement(s)	Verification
1. Voltage for our socket device circuitry must taken from the 120 VAC mains by a standard edison screw. 2. The AC/DC Converter must output between 4.8 and 5.2 V and be rated for at least 500 mA.	1. Insert Edison screw into socket. Read the output of the Edison screw adapter with a multimeter and verify 120 VAC. 2. Pug AC/DC converter into 120 VAC wall socket and attach 10 ohm resistor from the 5 VDC output. Using an oscilloscope, measure the 5 VDC output to verify it is between 4.8 and 5.2 V.

2.3 TTL Switch Unit

The TTL unit in the switch box will act as the brain of the switch box. It'll take in inputs from the buttons and will transmit an on/off signal to the device(s) on the channel linked to the button. The TTL unit in the switch box also has to display which channels have device(s) on and off. The control circuitry in the TTL unit will take in inputs received from the buttons and send them to the encoder to be encoded. The control circuitry will then transmit the encoded data when at least one channel is on and when the clock signal is high. The control circuity will also display which channels are on and off through LEDs.

Requirement(s)	**Verification**
1. Different buttons correspond with different channels of communication. 2. Output a digital signal to turn lights on/off that can be encoded. 3. The buttons stop bouncing within 10 ms after being pressed. 4. The LEDs must be visible when holding the switch box and each LED consumes less than 60mW.	1. Press each of buttons and see if the light(s) on the associated channel respond. 2. Send a known digital signal to the encoder and see if the same signal is the result after decoding. 3. Measure how long the bouncing of a button goes on by observing it's behavior on an oscilloscope. 4. Turn on the LED and see if it is visible from 3 feet away. To measure how much power the LED is consuming, we'll measure the voltage across the LED and current running through it. We then multiple the two to see the power consumption.

2.4 TTL Device Unit

The TTL unit in the light socket device will be responsible for taking in the digital signal handed from the decoder and determining whether to turn the light on or off. The control circuitry of the TTL unit will store the data bits received whenever there's a valid transmission. A valid transmission will be checked on every rising edge of the clock signal. The channel determined by the channel selector will determine which data bit is used to control the relay. The relay will act like a switch between the 120 VAC coming in from the light socket and the light bulb. The solid state relay takes in digital input to turn the light on and off. The channel selector will allow the user to select which light socket devices are on which channels. There's going to be four channels that the light socket devices can be tuned into.

Requirement(s)	Verification
1. Keep track of which channels are on and which are off. 2. The channel selector stops bouncing within 10 ms after being pressed.	1. Change the channel of the device and see if the status of the light changes according to the status of the new channel it's on. 2. Measure how long the bouncing of a button goes on by observing it's behavior on an oscilloscope.

2.5 Radio Transmission Unit

The switch's transmitter unit is comprised of not only a transmitter but also an encoder that converts the control data parallel output from the switch's control unit into a data packet that can be modulated onto a 433.92 MHz carrier channel. Once the switch's control unit sends the transmit enable signal, the switch's transmitter unit will shortly after begin radiating this data packet. The transmitter used is FS1000A XY-FST, a module that is commonly used as an add on for Arduino and the chosen encoder is the Holtek HT12E.

Two alternatives were considered for the internal components of the transmitter unit. One alternative was a Linx multi chip module that contained a transmitter and encoder all within a single package. The cost of this module was in the tens of dollars which contradicted the key motivation of our design for keeping the solution low cost. The other downfall for this module was lack of access for modifications to the transmitter chain which could be essential for fine tuning our design. The second alternative was utilizing the same transmitter as our chosen design but using an ATMega microcontroller for encoding parallel data into a serial package. Once we found a $0.50 encoder, we scrapped this solution. The operation of this module and the Light Socket Receiver Unit determine the range of communication of the system.

The data packet prepared by the Holtek HT12E encoder is a 12 bits. 4 of those bits are from the 4-bit control signal originating from the switchs control unit block which indicate which set(s) of lights need to be switched on/off. The other 8-bits are address bits that serve to only enable communication with corresponding socket decoders that have the same address. We have made the design decision to maintain the same address throughout every encoder and decoder in our system and instead use the data bits as the addressing mechanism for each set of lights. A data packet of 1-0-1-0-(Constant address) instructs sets 1 and 3 of lights to be on without affecting other neighboring systems with different addresses. The encoder operation follows the flowchart operation shown in Figure 4

The data packet from the encoder is modulated onto a 433.92 MHz carrier channel in an amplitude shift key scheme and radiated using a helical spring antenna. This transmitted signal is received by the socket's receiver unit. The FS1000A XY-FST transmitter operating voltage is between 3 and 12V. Flexibility for adjusting the systems communication range is provided by adjusting this operating voltage. A helical antenna is omnidirectional so the socket receives an equally strong signal whether it's 30 feet in front of, in back of or to the right or left of the transmitter. The helical shape allows the antenna to be shorter from end to end than a quarter or half wavelength.[4]

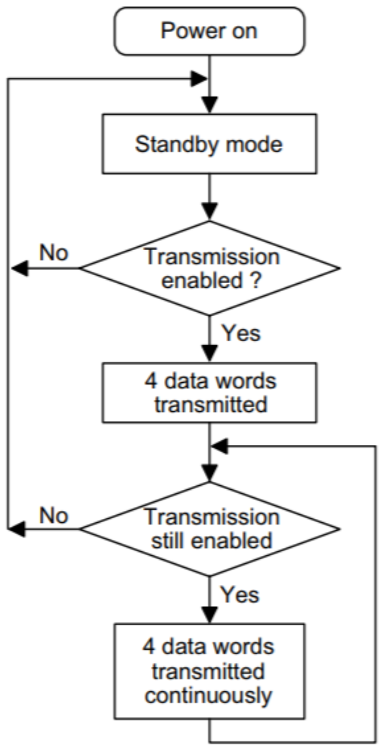

Figure 4: Flowchart of the encoder's operation.

Requirement(s)	Verification
1. Unmodulated encoder output must operate at a frequency that is less than one quarter of the receivers bandwidth in order for modulated transmission to remain within receiver bandwidth. 2. Main channel emissions must be between 3,750 to 12,500 micro volt/meter three meters away from the radiator to comply with FCC part 15.231b. Outside channel spurious emissions must be between 375 and 1,250 micro volt/meter three meters away from the radiator.	1. Determine receiver bandwidth by using signal generator to apply a high bandwidth 433 MHz signal to receiver antenna pin. Examine receiver output on spectrum analyzer and determine bandwidth. Use two variable resistors, one within a voltage divider to adjust the encoder's VDD pin, and the other across. the oscillator pins as shown in the encoder schematic. The encoder's oscillation frequency is dependent on these two resistors. Tune the variable resistors and observe results on spectrum analyzer. Record plots for oscillator frequency vs VDD and Rosc in lab notebook. 2. Assume the emissions from the transmitter are isotropic. Use the formula $E = ((30P)^{0.5})/d$ where P is transmit output power and d is distance from the radiator. Multiply by the antenna gain to obtain the worst case value. Measure transmit power using signal analyzer with a cable connected to the transmitter's antenna pin. Adjust VCC to obtain desirable value for microvolts per meter, record values in lab notebook.

2.6 Radio Receiver Unit

Much like the switchs transmitter unit, this block consists of a receiver to demodulate the transmitted signal back to baseband energy and a decoder to convert the data packet to parallel data on its output pins. As explained above, the addresses of all the decoders in all the light sets in the system are the same as that of the single encoder in the switch. The state of the i$^t h$ set of lights is determined by the value of the i$^t h$ data bit.

The receiver contains a helical spring antenna that listens for the signal sent by the transmitter and other radiated signals in the socket's environment. An all in one receiver module will be used so there will not be a need to individually choose components such as oscillators, amplifiers, mixers and filters. The receiver chosen has a sensitivity of -105 dBm which allows for less power to be required by the transmitter in the switch's communication unit. Once the signal has been converted back to baseband energy, the output is sent into the decoder.

The input to the decoder is the receiver output. If the address section of the data packet matches the decoder's address, then the decoders output pins contain the data section of the 12-bit serial data packet in parallelized form. The decoders data out pins maintain their value until a new data packet with the correct address arrives.

The decoder data out pins are the input to the sockets control unit. If the data received is 0010 and the socket's channel selector dial is set on channel 3, then the light will turn on since the third data bit is high. The operation cycle of the decoder is specified in the flowchart pictured in Figure (5).

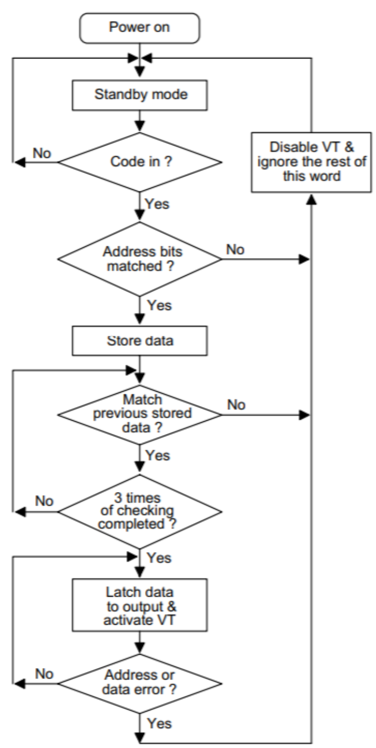

Figure 5: Flowchart of the decoder's operation.

Requirement(s)	Verification
1. Received signal must be at least -105 dBm 30 feet away from transmitter for an ideal antenna orientation. 2. Received signal must be at least -105 dBm 30 feet away from transmitter even when socket antenna is 5 degrees from perpendicular to transmitter antenna broadside direction (direction where radiation strength is much weaker). 3. Received signals must be decoded within 10 ms to prevent noticeable latency.	1. Use signal generator to Apply a 5V 433 MHz square wave to transmitter data-in pin. Connect receiver antenna pin to spectrum analyzer 30 feet away from transmitter. Place receiver antenna to be in same plane as transmitter antenna and orient in same direction. Record power spectrum vs frequency in lab notebook. 2. Use signal generator to Apply a 5V 433 MHz square wave to transmitter data-in pin. Place transmitter directly above receiver. Connect receiver antenna pin to spectrum analyzer. Apply attenuation on signal analyzer based off measured 30 ft power above to simulate distance. Orient receiver antenna in same direction as transmitter antenna. Record power spectrum vs frequency vs angle graph in lab notebook. 3. Simulate data packet of all ones by apply 5V 433 MHz signal to receiver antenna pin using signal generator. Set all address pins on decoder to high so decoder knows to decode simulated data packet. Probe decoder data out pins with multimeter. Record time delay between arrival of received packet to last data out pin being set in lab notebook.

2.7 Schematics

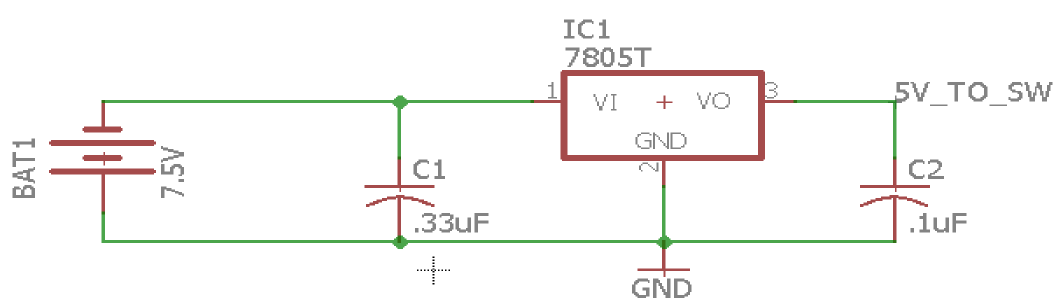

Figure 6: Schematic of battery power supply.

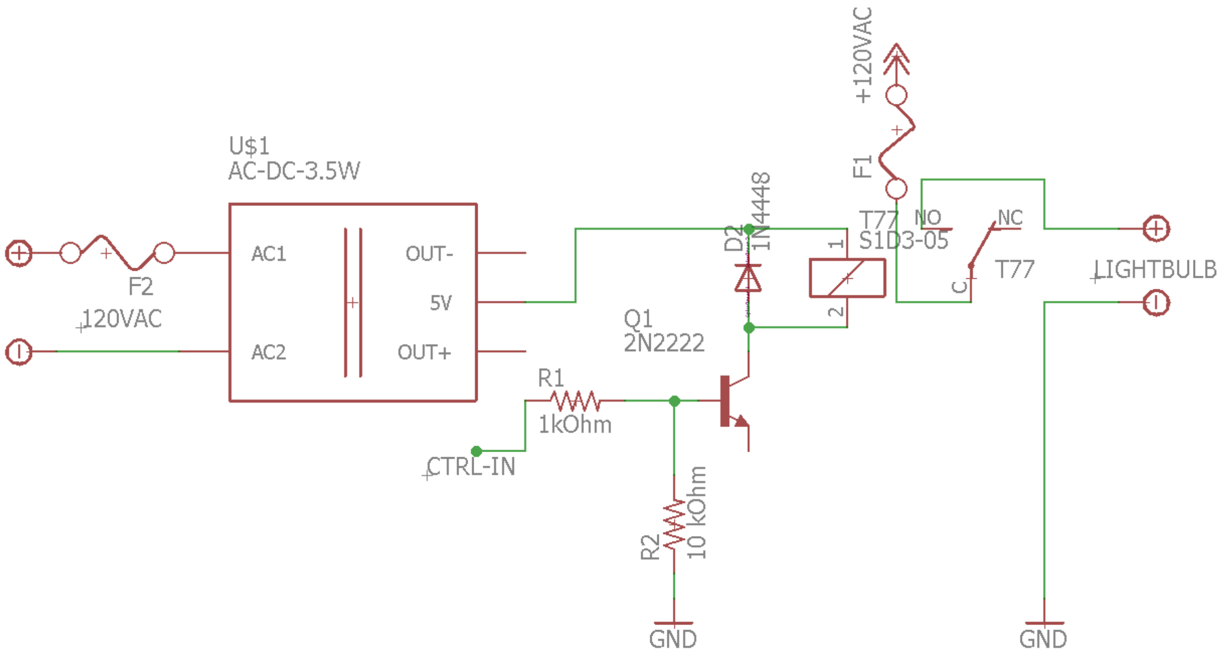

Figure 7: Schematic of light socket power supply.

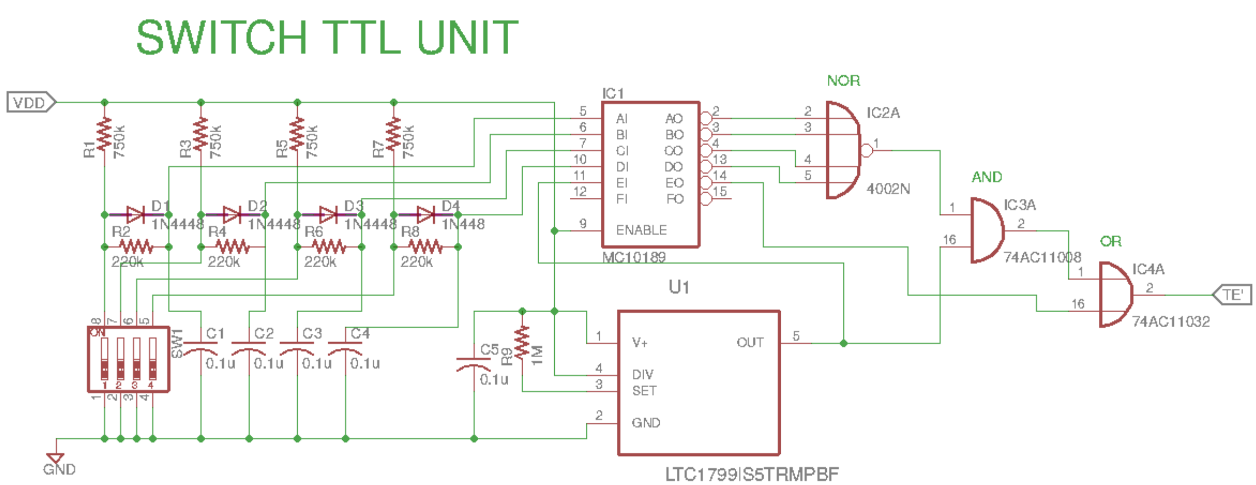

Figure 8: Schematic of switch's TTL circuit.

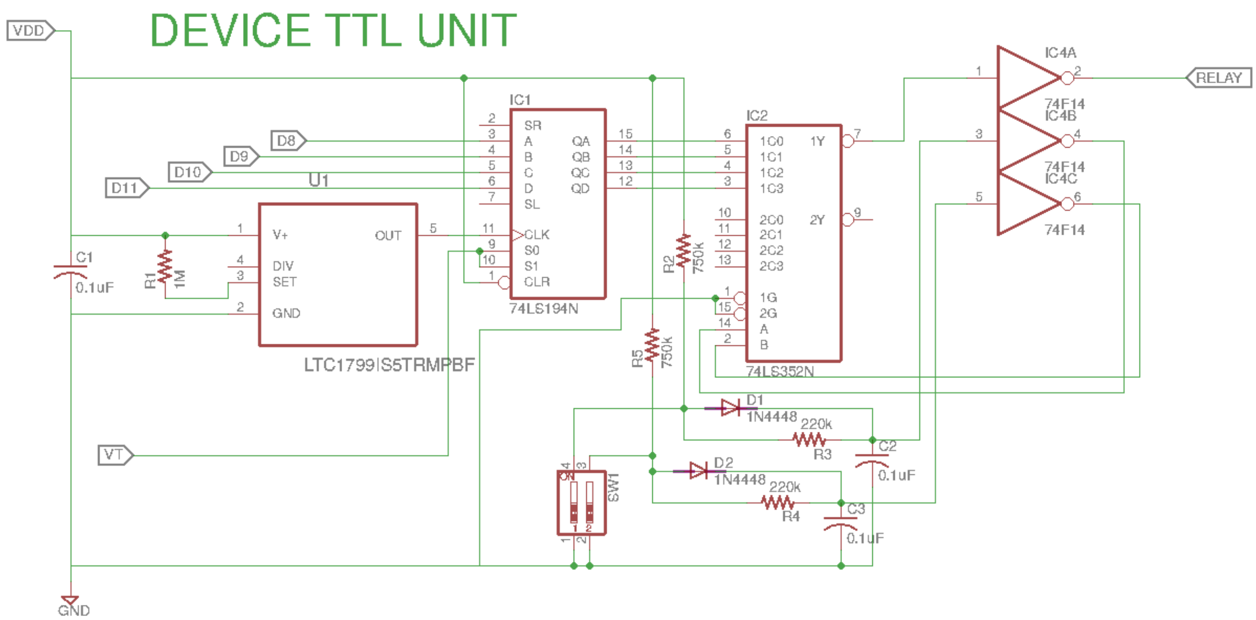

Figure 9: Schematic of device's TTL circuit.

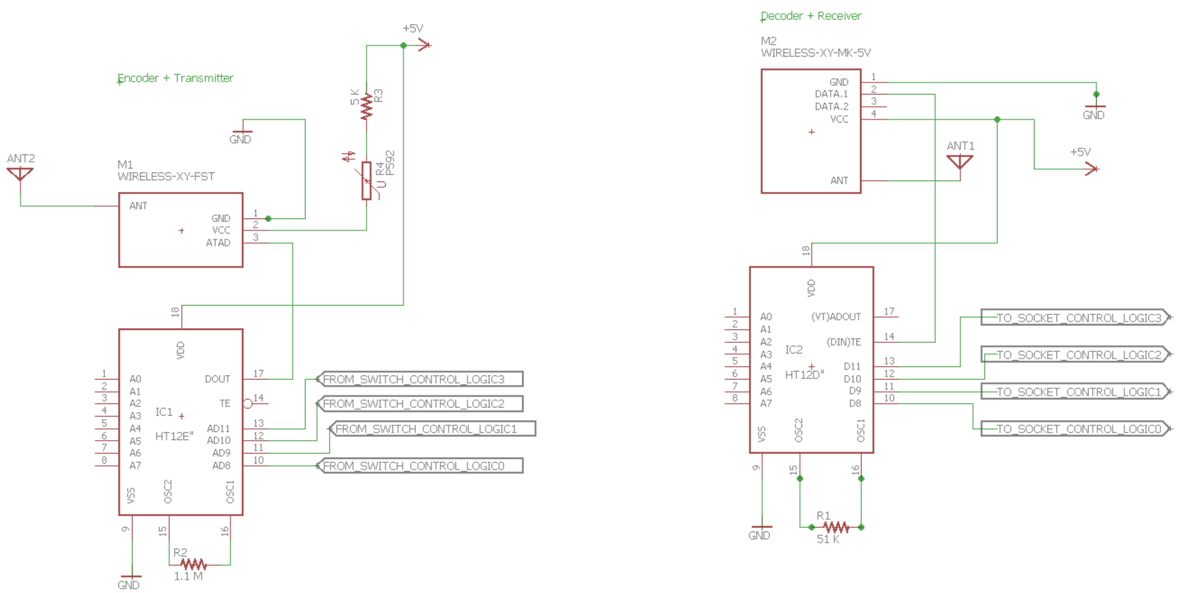

Figure 10: Schematic of both radio circuits.

2.8 Calculations

2.8.1 Battery Lifetime

The maximum switch current is 80 mA and the average switch current is 50 mA. According to manufacturer data for E95 batteries, discharging the battery at 100 mA down to .8 V yields a capacity of 17000 mAh. We will instead only be discharging to .96 V when considering our capacity, since 4.8 V is our minimum allowed voltage.

$$4.8/5 = .96V \tag{1}$$

Based on the E95 datasheet, our capacity will only be 84% of the typical capacity. Additionally, the 17000 mAh capacity is slightly too high due to the fact that data is taken from a 100 mA test. Accounting for this, 50 mAh is added to the maximum current capacity calculation and 125 mAh is added to the average current capacity calculation.[5]

$$Capacity\ for\ 100\ mA\ discharge : .84 \times 17000\ mAh = 14280\ mAh \tag{2}$$
$$Maximum\ Current\ Capacity : 14280 + 100\ mAh = 14380\ mAh \tag{3}$$
$$Average\ Current\ Capacity : 14280 + 250\ mAh = 14530\ mAh \tag{4}$$
$$Maximum\ Current\ BatteryLifetime : 14380/80 = 179.75\ hrs \tag{5}$$
$$Average\ Current\ Battery\ Lifetime : 14530/50 = 290.6\ hrs \tag{6}$$

We can power the portable switch system at maximum current for about 180 hours. This battery setup is expected to comply with our requirement of 150 maximum current operation hours. For typical operation, the portable switch power is predicted to last for almost 300 hours.

2.8.3 Voltage Regulator Power Dissipation

The maximum input voltage is 7.5 V and the output voltage is 5 V. The thermal resistance of the junction-case is $5\frac{^oC}{W}$ and the thermal resistance of the junction-air is $65\frac{^oC}{W}$. The power calculated in equation (7) is low enough that the voltage regulator will not need a heat sink, as the 7805 can handle a maximum temperature of 125^o C, and .2 W leads to only a 14^o C increase in temperature as calculated in equation (8).

$$Maximum\ Power\ Dissipation = (V_{in} - V_{out}) \times I_{max} = (7.5 - 5\ V) \times 80\ mA = .2\ W \tag{7}$$
$$Increase\ in\ Temperature = (65\frac{^oC}{W} \times 0.2\ W) + (5\frac{^oC}{W} \times 0.2\ W) = 14^oC \tag{8}$$

2.8.3 Debouncing Circuit

The debouncer circuits that interfaces between the buttons and the ICs is constructed as in Figure 11.

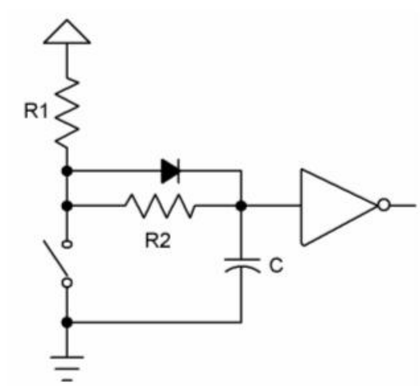

Figure 11: Circuit diagram of a RC debouncer.

The values of R_1, R_2, and C can be derived from the equations of a discharging and charging capacitor. The equation for a discharging capacitor and the rearranged form used to calculate R_2 with a chosen capacitance are equations (9) and (10) respectively where t is time in seconds, V_{cap} is the voltage across the capacitor at time t, V_{th} is the threshold voltage of the gate switches within an IC, $V_{initial}$ is the initial voltage of the capacitor, and R is resistance in Ohms, and C is capacitance in Farads.

$$V_{cap} = V_{initial}(e^{\frac{-t}{RC}}) \tag{9}$$

$$R_2 = \frac{-t}{C\ln(\frac{V_{th}}{V_{initial}})} \tag{10}$$

The equation for a charging capacitor and the rearranged form used to calculate R_1 with a chosen capacitance are equations (11) and (12) respectively where V_{final} is the final voltage across the capacitor [6].

$$V_{th} = V_{final}(1 - e^{\frac{-t}{RC}}) \tag{11}$$

$$R_1 + R_2 = \frac{-t}{C\ln(1 - \frac{V_{th}}{V_{final}})} \tag{12}$$

To fulfill the requirement that the buttons have to stop bouncing after 10 ms, t is set to 20 ms for good measure and the capacitance was chose to be 0.1 μF since they're inexpensive and easy to find. The values of R_2 and R_1 were calculated in equations (13-15) and the threshold voltage values of the 74F14 hex Schmitt inverter IC were taken from the data sheet [7].

$$R_2 = \frac{-t}{C\ln(\frac{V_{th}}{V_{initial}})} = \frac{-20\ ms}{0.1\ \mu F\ln(\frac{2}{5})} = 218\ k\Omega \tag{13}$$

$$R_1 + R_2 = \frac{-20\ ms}{0.1\ \mu F\ln(1 - \frac{0.8}{4.3})} = 972\ k\Omega \tag{14}$$

$$R_1 = 972\ k\Omega - 218\ k\Omega = 754\ k\Omega \tag{15}$$

Since a single resistor having either the values of 218 kΩ or 754 kΩ can't easily be bought, the closest values for R_1 and R_2 were selected to be 220 kΩ and 750 kΩ respectively.

3 Tolerance Analysis

One of the most critical parts of our design are the buttons because they're the only mode of input from the user and the physically positioning of the buttons store the knowledge of whether the lights on that channel are on/off. When the signal interpreted from the button bounces, it widely varies from high to low which could produce errors later on in the logic circuitry. To accurately read the user inputs from the buttons, a debouncer circuit interfaces between the button and the ICs it inputs to. The resistance values to be used for the debouncer circuit were 220 kΩ and 750 kΩ and the capacitance value was 0.1 μF. Both resistors and decapitators carry quite a bit of variance with them like ±5% for resistors and ±20% for capacitors. To ensure that the requirement of button bouncing stopping after 10 ms is fulfilled, this tolerance analysis will see how bad the discharging and charging times will get with the minimum and maximum values of both the resistors and capacitor. The discharging and charging times will be calculated with equations (16) and (17) respectively. The results are arranged into Table 1 where X_{max} is the upper bound of the variance, X_{exact} is the exact selected value, and X_{min} is the lower bound of the variance.

$$t_{discharging} = R_2 C \ln(\frac{V_{th}}{V_{initial}}) \tag{16}$$

$$t_{charging} = (R_1 + R_2) C \ln(1 - \frac{V_{th}}{V_{final}}) \tag{17}$$

Table 1: Resulting calculated times for a variety of resistance and capacitance values.

Capacitance	C_{max}		
Resistance	R_{min}	R_{exact}	R_{max}
Discharge Time	23.0 ms	24.2 ms	25.4 ms
Charge Time	18.6 ms	19.6 ms	20.6 ms
Capacitance	C_{exact}		
Resistance	R_{min}	R_{exact}	R_{max}
Discharge Time	19.2 ms	20.2 ms	21.2 ms
Charge Time	15.5 ms	16.3 ms	17.1 ms
Capacitance	C_{min}		
Resistance	R_{min}	R_{exact}	R_{max}
Discharge Time	15.3 ms	16.1 ms	16.9 ms
Charge Time	12.4 ms	13.1 ms	13.7 ms

As seen from the calculated time values, the absolute lowest time was 12.4 ms which is still above the 10 ms requirement needed to null the bounces produced by the buttons. It's surprising that calculating resistance and capacitance for double the requirement can actually be just good enough to pass the requirement as the absolute minimum (minimum resistance and capacitance) caused the charging time to only be greater by 2 ms from the requirement. Calculating values based off the worst case scenario seems like the best course of action to fulfilling any requirement.

4 Cost and Schedule

4.1 Cost

4.1.1 Labor

$$LABOR = 3\ people \times 38\frac{\$}{hour} \times 2.5 \times 12\frac{hours}{week} \times 12\ weeks = \$41,040 \tag{18}$$

Part	Cost (\$)	Quantity
FS1000A XY-FST Transmitter Module	0.83	1
XY-MK-5V Receiver Module	0.83	4
DAOKI 433MHz Helical Spiral Spring Antenna	0.55	5
HOLTEK HT12E Encoder	0.50	1
HOLTEK HT12D Decoder	0.50	4
Hex Inverter (MC10189)	0.65	1
Hex Inverter Schmitt (74F14)	0.17	4
Dual 4-input NOR (CD4002CN)	0.24	1
Diode (1N4448)	0.082	16

Quad 2-In OR (74HCT32)	0.50	1
Quad 2-In AND (74F08)	0.50	1
Dual 4:1 MUX (74LS352)	0.55	4
4-bit Shift Register (74LS195)	1.00	4
1kHz to 33MHz MHz Clock (LTC1799)	1.40	5
TE Relay (T77S1D10-05)	2.28	4
120VAC to 5VDC Supply	3.50	4
ON NPN Transistor (PN2222)	0.20	4
Littelfuse Fuse (38505000000)	0.60	8
7805 Voltage Regulator (7805)	0.48	1
Energizer Batteries (E95)	1.35	5
Switches w/ LED	0.20	4
Various RLC Components	0.10	55
Parts Total	68.71	

$$GRAND\ TOTAL = LABOR + PARTS = \$41,040 + \$68.71 = \$41108.71 \tag{19}$$

4.2 Schedule

Week	Andrew	Grant	Michael
10/2	Work on design document. Determine loading of encoder/decoder oscillator pins. Create communications schematic.	Work on design document, power schematics, battery considerations.	Work on design document. Create TTL schematics.
10/9	Wireless range testing on communications with transmitter/ receiver modules. Determine center frequency variation of transmitter resonator and receiver oscillator. Second team meeting with machine shop.	Order parts, wireless testing of transmitter/receiver modules.	Get parts from ECE service shop and order remaining parts. Test parts that are available.
10/16	Breadboard of entire system, determine optimal method for setting encoder/decoder addresses. Investigate if any additional amplifiers are needed on the antenna input/output based.	Testing battery power block and socket power through the relay, test verifications.	Test the parts that were ordered alongside the rest of the components and start PCB layout.
10/23	Board layout of communications section.	Debugging power systems, finalize PCB layout, housing considerations.	Finalize PCB layout

10/30	Construct through-hole prototype of communications szection for testing of signal strength in secluded light sockets.	Continue debugging if needed, integrate power module.	Debug any issues with integrating modules together.
11/6	Safety testing	Start assembling PCBs	Start assembling PCBs.
11/13	Assemble PCB and debug noise issues from AC mains radiation and other sources of interference. Determine is any extra shielding is needed.	Continue assembly of PCBs, final testing.	Finish assembly of PCBs and finalize product assembly.
11/20	Fall Break	Fall Break	Fall Break
11/27	Prepare for Mock demo, socket testing with entire system.	Prepare for Mock demo, socket testing with entire system.	Prepare for Mock demo, socket testing with entire system.
12/4	Demonstration	Demonstration	Demonstration
12/11	Finish final report.	Finish final report.	Finish final report.

5 Safety and Ethics

Our project has safety concerns which must be recognized and addressed. The most serious concern is the circuitry handling the 120 VAC mains. When working with 120 V, there exists the potential for both electric shock and fire hazards. Our design must present the safe delivery of 120 VAC to the bulb through a relay, as well as the conversion from 120 VAC to 5 VDC. With the proper design, handling, and safety precautions, safety concerns will be mitigated. Circuits will be arranged and soldered so that conductive contacts are safely separated and heat dissipation is managed. The one-hand method will be used when dealing with high voltages. Additionally, safe grounding will always be implemented to avoid electric shock. As a group, we will use the appropriate multimeters and measuring equipment, as well as carefully abide by rated parameters for each component used.

The frequency bands over which we intend to transmit the control signal will be within one of the several FCC assigned Industrial, Science and Medicine Bands. For this project, we intend to comply by FCC rule 15.23 for Home-built devices which states "Equipment authorization is not required for devices that are not marketed, are not constructed from a kit, and are built in quantities of five or less for personal use." Should we decide to develop this product beyond the duration of this course, the necessary steps will be taken to abide by the more strict regulations for commercialized products. Our device will only be transmitting for very limited durations of time when a flip of a switch occurs. Should situations occur where users are prolonging the very short transmission durations to unreasonable amounts by flipping the switch many times consecutively, we will ensure our system has some type of buffer to ensure transmissions qualify as periodic vs continuous as defined by the FCC. For the ISM band chosen, we will ensure our design follows the respective FCC limits on power transmission and does not increase communication range at the expense of polluting the spectrum.[8]

During this project and in preparation for our professional careers, we will follow the IEEE Code of Ethics. With every decision we make for this project, we will be consistent with Code # 1. Our actions must not only keep ourselves safe, but also pose no threat to the public or those who are exposed to our designed product. In accordance with Code # 7, we strive to learn through the process of working on our project, and will both accept and offer criticism to correct errors to the best of our ability. As we work together in a team, we will commit to Codes # 8 and # 10. Each member of our group will be treated fairly, and also all of the course staff. We seek to help each other meet individual and group goals, and support each other in following the ethical code.[9]

References

[1] "Best smart lights 2017 ultimate comparison." [Online]. Available: https://smarthomesolver.com/product/lights

[2] B. Mitchell, "How far will your WiFi reach?" [Online]. Available: https://www.lifewire.com/range-of-typical-wifi-network-816564

[3] S. Wolpin, "Heres why you never turn off a so-called smart bulb." [Online]. Available: https://www.gearbrain.com/smart-light-bulb-led-how-to-1801637028.html

[4] "Helical antenna," page Version ID: 791756076. [Online]. Available: https://en.wikipedia.org/w/index.php?title=Helical_antenna&oldid=791756076

[5] "Energizer e95 datasheet." [Online]. Available: http://data.energizer.com/pdfs/e95.pdf

[6] J. Ganssle, "A guide to debouncing." [Online]. Available: http://www.eng.utah.edu/~cs5780/debouncing.pdf

[7] "74f14 data sheet." [Online]. Available: https://media.digikey.com/pdf/Data%20Sheets/NXP%20PDFs/74F14.pdf

[8] "e-CFR: Title 47: Telecommunication , if the responsible party can demonstrate that because of price or performance the computer is not suitable for residential or hobbyist use, it may request that the computer be considered to fall outside of the scope of this definition for personal computers., in addition, devices operated under the provisions of this paragraph shall be provided with a means for automatically limiting operation so that the duration of each transmission shall not be greater than one second and the silent period between transmissions shall be at least 30 times the duration of the transmission but in no case less than 10 seconds., the double asterisks in condition three (**) shall be replaced by the responsible party with the angular pointing restriction necessary to meet the horizontal emission limit specified in paragraph (b)." authority: 47 U.S.C. 154, 302a, 303, 304, 307, 336, 544a, and 549. [Online]. Available: https://www.ecfr.gov/cgi-bin/text-idx?SID=2ca9d3fb1b02fce42a5c8f249f99e37d&mc=true&node=pt47.1.15&rgn=div5#se47.1.15_123

[9] "IEEE code of ethics." [Online]. Available: https://www.ieee.org/about/corporate/governance/p7-8.html