Dr. Andrew Rawicz
School of Engineering Science
Simon Fraser University
Burnaby, BC
V5A 1S6

Re: ENSC 440 Functional Specification for uControl Solutions

Dear Dr. Rawicz,

Attached is a document describing the design specification for the uControl. We at Universal Control Solution aim to create a product which extends far beyond improving the luxury and comfort of the user. We aim to create a device which could potentially be used to control your entire home all the touch of your fingers. Our device aims to take a firm hold of the rapidly expanding tablet market and allow the users to control their lights, heating/cooling systems, and various multimedia systems all at the touch of your fingers from ONE place, your personal computer!

Our team consists of 3 highly talented electronics engineering student Stoyan Petrov, John Kenyon and Sajib Saha, and me, Ivan Petrov, a senior biomedical engineering student who will be responsible for integrating the user interface in a simple and "sexy" way that allows users to quickly access all of our product features. One other major component of our product is that we will attempt to integrate it with an environmental control system and could potentially replace the currently existing X10 systems. This plays a huge factor for assisting those with physical disabilities who have some form of access to a PC.

The design specification that is described in the document applies to the proof-of-concept model only. Any design improvements that is discussed in this document will not be implemented in the initial developing prototype. If you have any questions or comments please contact me at ivp@sfu.ca , or by phone (604) 588-5429. I will convey your message to my fellow team members.

Thank you for attention.
Sincerely,

Ivan Petrov
Chief Executive Officer
Universal Control Solution
ivp@sfu.ca
604-588-5429

Enclosure: *uControl Solutions' design specification is attached below* uControl Solutions

uControl: Home Automation System

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Submitted To: Dr. Andrew Rawicz
Mike Sjoerdsma

Date Submitted: March 14, 2011

Executive Summary

“Your home at your command”! This is the goal of uControl Solutions. What we are offering is the best solution for affordable home automation. Our product “uControl” will not only bring ease to the user in their everyday life but also greatly assist physically disabled people. Simple, Elegant, and Effective is the best way to describe uControl. The uControl system will revolutionize the term ‘universal remote’. At uControl Solutions our aim is to develop a truly universal remote control. One that is not overloaded with features but does everything you ask it to do. People are no longer bounded to having to point at their TV to change a channel.

The design specification for our universal remote describes a set of design principles and steps we followed and are still following for our developing prototypes. Even though the first prototype will solely be a proof of concept model only, openings are left for further improvement in designing the system before mass production. This document also provides justification of our designing choices for our system. General software program process flow is also included. A description of test plans for the system and its subcomponents is provided near the end of the design specification to make sure our prototype is working the way we specified.

The duration of this project was estimated to take around 4 months to complete, starting from January 4, 2011 to April 4, 2011 which includes researching, designing and building prototypes, and debugging. And we are still hoping that we will be able to finish it within our predicted timeline.

This document is meant to be framework for the engineers to work on with regards to the required features projected for our unit. However, this is not a final document and it will be continuously revised and updated after vigorous researching and numerous testing to provide a highly satisfactory end product.

Contents

Table of Figures

1. Introduction

uControl is designed to be an all-in-one home automation solution aimed towards increasing the user's home experience by greatly focusing on integrating the user's entertainment systems. We view the user's experience as primary indicator to the success of this product. By allowing the user to control light/media systems and allowing room for expansion, we are creating an all in one solution for a home automation system at a very affordable price.

Everything will be at the user's fingertips and the ever growing tablet market will allow our system to be exposed to even more users. With our system, a tablet PC will communicate with a central unit which in turn communicates with as many modules as the user wishes to purchase. This system is visually represented in the Figure 1 below.

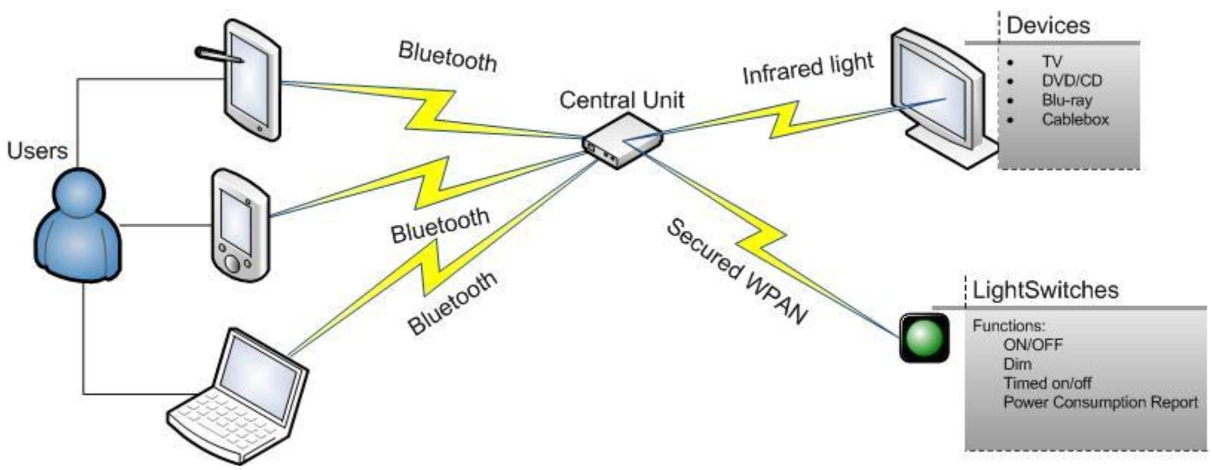


Figure 1 : System Overview

Because of our modular design, the user will have the freedom to purchase as many or as little modules as necessary thereby reducing the cost for the basic system which would only allow the control of the user's media center through programmable remote controls.

Each of our unit will have programmable remote controls which allow the user to store all their remotes on our system. This is a key component of our system that separates uControl from all other home automation systems.

This document is designed to describe components we have used to create our unique product. This design specification provides for the proof-of-concept model only which was described in the functional specification. That means the specifications that were denoted by ***i** and **ii*** are only implemented in the development stage. Further development and mass production plan will be integrated in the future development stage after the initial working prototype is built successfully. The design specification discusses the following topics in the overall paper.

- **Central Unit Design Specifications**
- **Light Module Design Specification**
- **Software Behavior (this is how the central unit communicates with modules)**

1.1 Scope

This document specifies the design of our uControl System including the central unit, the light modules, infra-red remote control, and a brief overview of the control software that allows the interaction between each component. Furthermore, this document explains how our design specifications meet the functional requirements as specified in the Functional Specification for uControl.

1.2 Intended Audience

This document is designed to be used as a guideline to the design engineers associated with uControl Solutions. The test engineers shall use this document as a way to verify the functionality of each specification and to confirm the correct behavior.

1.3 Glossary

AC	Alternating Current
CU	Central Unit
DC	Direct Current
E.D	Entertainment Devices
GPIO	General Purpose Input/Output
IC	Integrated Circuit
ISR	Interrupt Service Route
MRF	MRF24J40
RX	Receive
SMD	Surface Mount Device
SPI	Serial Peripheral Interface Bus
TRIAC	Triode for Alternating Current
TX	Transmit
ZVC	Zero Volt Crossing

2. Central Unit

2.1 Hardware Overview

2.1.1 Overview

The high level design of the central unit is shown in Figure 2. The micrcontroller in the Central Unit is in charge of communicating the user handheld device through bluetooth, communicate with the uControl Modules, and control entertainment systems with build in LED transmitters. The Central unit is also able to recode entertainment systems remote control codes through its build in infrared LED receiver.

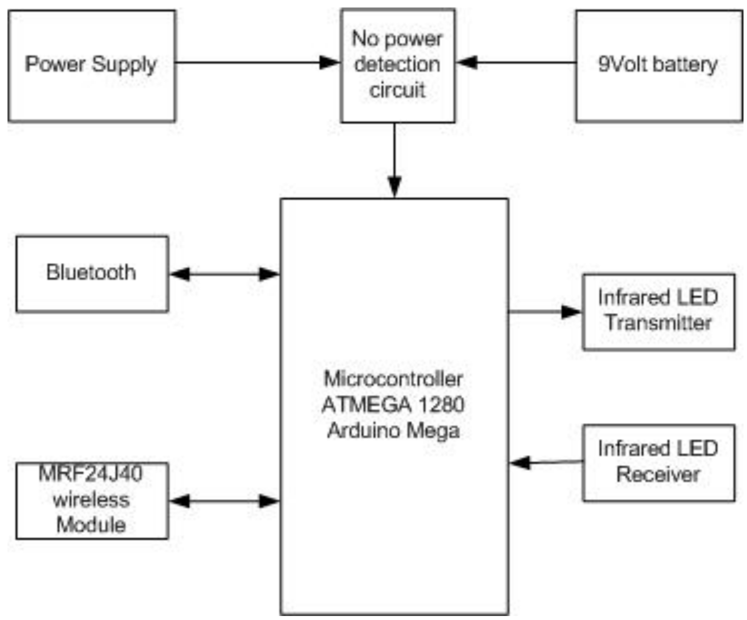


Figure 2 : Central Unit High Level Design

2.1.2 Power Supply

The CU main power supply is an 110VAC - 9V power adapter connected to the mains line. To prevent data loss, when the main power supply is disconnected the “No power detection circuit” supplies the Central Unit with a 9V battery. The CU will then load the data into internal EEPROM memory or external FLASH memory and restore based on the saved data when the main power supply is reconnected. This prevents any data loss and repairing with light switches if the CU is accidentally disconnected or a power outage occurs. With the 9V battery the CU will be able to operate for 24 hours. To extend this time the CU will enter sleep mode, in which it can last four months with the 9V battery.

2.2 Wireless Modules

2.2.1 Bluetooth

The Bluetooth module we are using is explained in detail in the wireless network section of the design specification.

2.2.2 MRF24J40MA

The RF modules we are using is explained in detail in the section 3.1.5 (wireless) of the design specification.

2.3 Software Architecture

2.3.1 Architecture Overview

The following chart shows how our central unit is going to act after receiving a bluetooth signal from the user interface. Normally it is at idle state always looking from an incoming signal from the paired main controlling unit. As soon as it receives it enters the bluetooth RX state.

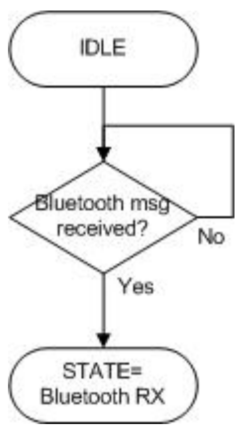


Figure 3: Idle State Algorithm

After it enters the bluetooth RX state it looks for the type of message. If it receives acknowledgement type message it transmits ACK and to do that it enters the Bluetooth TX state. If it receives a control type data, it loads the data and processes it. After processing the data, central unit enters into control state. If it receives configure type data it acts the same way as it does for control. It loads the data and enters config state.

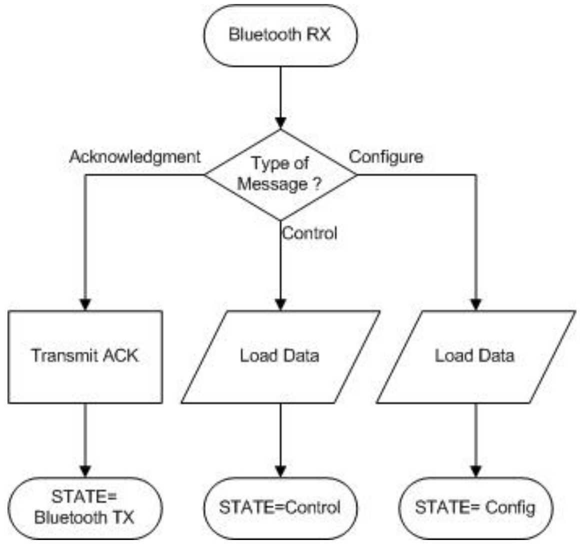


Figure 4: Bluetooth RX Algorithm

In the CONFGI State after processing the data it decides which module to configure. If it is a entertainment device (E.D.) it goes to the E.D. config state. In this state it learns the codes of the remote of the entertainment system and saves it. If it is a light switch, it loads data, address, PANID and other necessary thing to configure and set the address for the light switch. And after that it enters the light switch control state where it sets the light switch state, power level and the destination address of the light switch. After that it enters state MRF TX where it is going to transmit an acknowledgement data that it is ready to be controlled by our central unit.

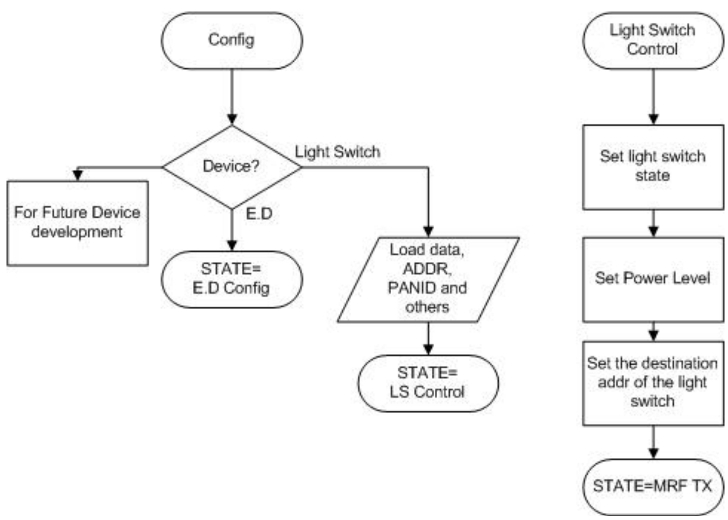


Figure 5: Config and Light Switch Control Algorithms

2.3.2 State Machine

The Central Unit will be load with the following state machine.

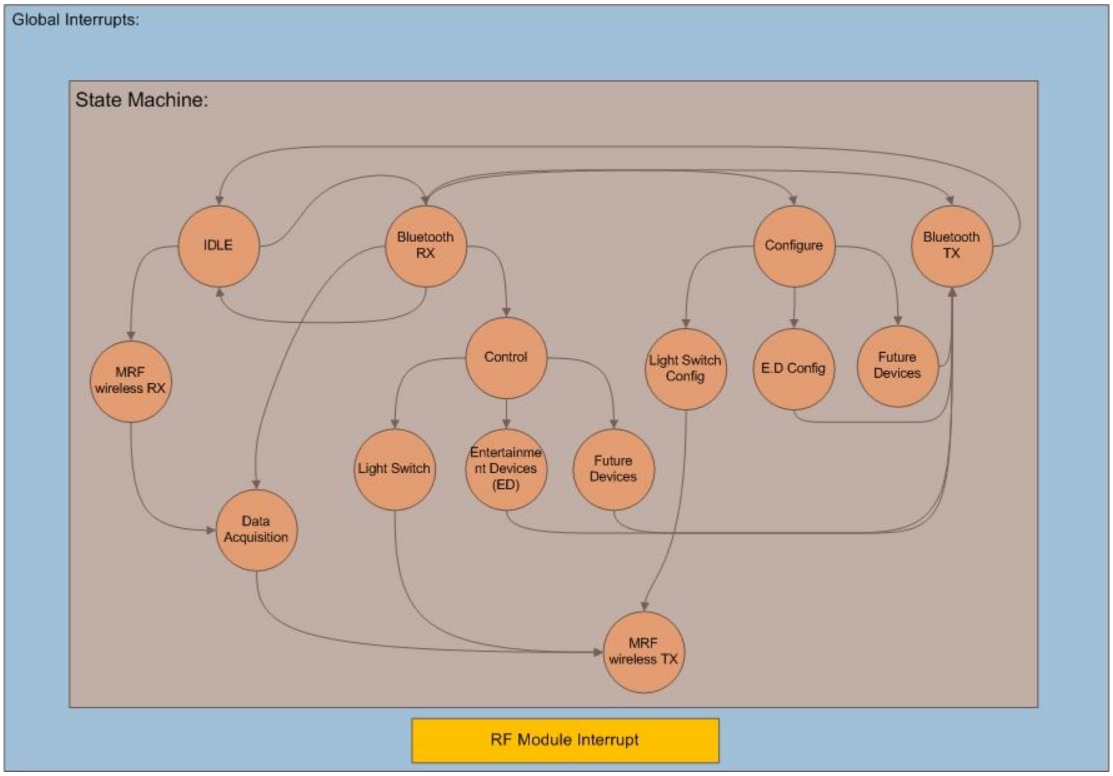


Figure 6: Central Unit State Machine

State translation can be triggered within each state or by the global interrupt.

2.3.3 Interrupt Service Routines

In the Central Unit the global interrupt is enabled for the MRF24J40 wireless module. The state machine is in idle if a Bluetooth message has been received or it an MRF interrupt has occured. The interrupt allows for real time detection of light switch state change and real time displaying on the user hand held device.

2.4 Enclosure

The central unit is the central hub for all of our modules. It's importance is far greater than any other component of the system and thus requires adequate protection from dust, temperature changes, and physical damage. The enclosure design is meant to be sleek, yet affordable, while providing full functionality. It should be small enough that it can be hidden out of site but large enough to fit all of the components inside. Furthermore, it must be recyclable, in tune with the cradle-to-cradle design. For now we have decided to use the following enclosure for our developing prototype which fits perfectly with our design.

Figure 7: Central Unit Enclosure. To be redesigned for production

3. Light Switch

3.1 Overall Design

The Mains line provides the light switch module with power. In North America the Mains ranges between 110-120Vac, thus the light switch needs to convert this voltage to a suitable 3.3DC voltage. Dimming of the lamps is achieved with a TRIAC, and the module needs to detect the zero crossing of the Mains line to control the TRIAC appropriately. Commands from the user can be applied by the Central Unit, wirelessly, and or by a pushbutton. A microcontroller is used as the main processor of the light switch module.

The following diagram shows how our light switch is going to look like.

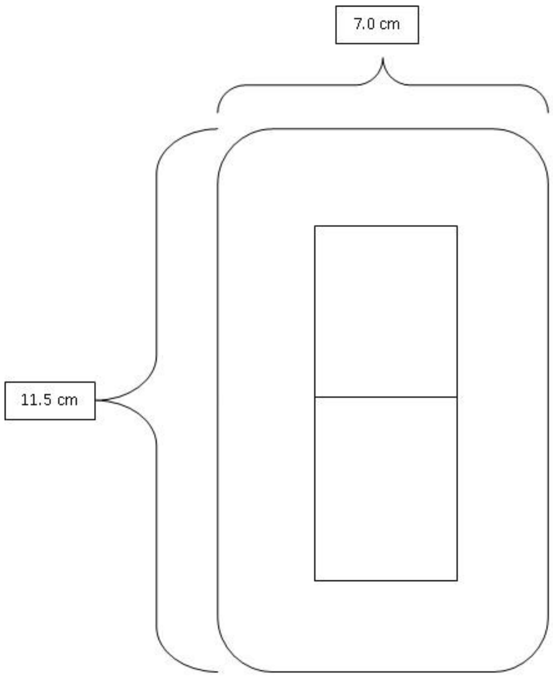


Figure 8: Light Switch Design

3.1.1 Power Supply

The power supply of the light switches must be able to supply at least 35mA and consume as little power as possible. Various power supplies were considered. The power supply chosen for the uControl light switches is a capacitive power supply with a rectifier bridge, sourcing 50mA at 3.3V. The supply is capacitive to dissipate as little power as possible. If power consumption is not a criterion, resistive power supplies can be used. The capacitive power supply is more appealing due to its low power consumption.

The power supply utilized in the uControl light switches is shown in Figure 9.

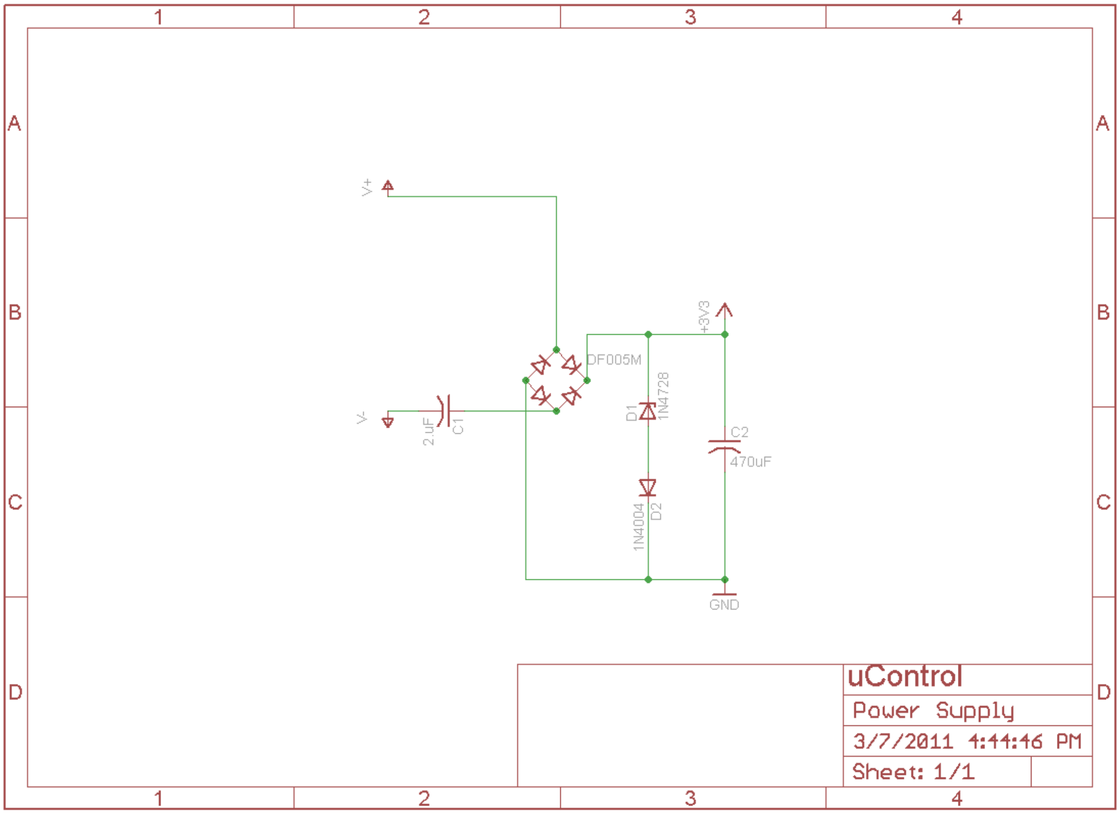


Figure 9: Light Switch Power Supply

The circuit takes advantage of an IC Rectifier Bridge to convert the AC into a DC voltage. The 2.2uF limits the current supplied to the circuit. A Zener diode connected back to back with a diode limits the voltage to 3.3V. The capacitor then filters the voltage to a straight 3.3V DC.

Advantages:

- Very low power dissipation
- Stable output voltage
- 140% more efficient that other power supply circuits.
- Can supply the required current
- Very low heat dissipation

Disadvantages:

- Slightly more expensive
- No common reference between the Mains and the output voltage making TRAIC control without any other components is impossible.

The output voltage has no common with the mains line, making TRIAC control without an opto-isolator or other components are impossible. Refer to TRIAC Control on pg.x.

C1 needs to be rated for greater than 150VAC for North America use, and greater than 300VAC for European use. Capacitors that meet these requirements are relatively expensive. Increasing the capacitor will increase the sourced current, making the power supply more expensive. Large current, is not required thus a 2.2uF capacitor will supply the required current keeping the cost low.

The Rectifier Bridge is rated for 440VAC making it usable for both 110-120VAC and 220VAC Mains lines.

The zener diode must be rated for higher than 150mA zener current. The zener voltage is 3.3V at 200mA. The Circuit will not be able to supply the zener with enough current to stabilize to 3.3V, thus a 0.7V diode is connected back to back with the zener diode.

C2 must be rated for greater than 6V if the required supply voltage is 3.3V. If the required supply voltage is 5V, C2 must be rated for greater for 10V. All the modules on the light switch will operate at 3.3V thus a 6V capacitor is sufficient.

3.1.2 Zero Volt Detection

An impulse applied to the gate of a TRIAC will open it until the zero volts crossing (ZVC) of the Mains line occurs. Another impulse is then required to open the TRIAC. The ZVC is detected using an opto-isolator, as shown in Figure 10.

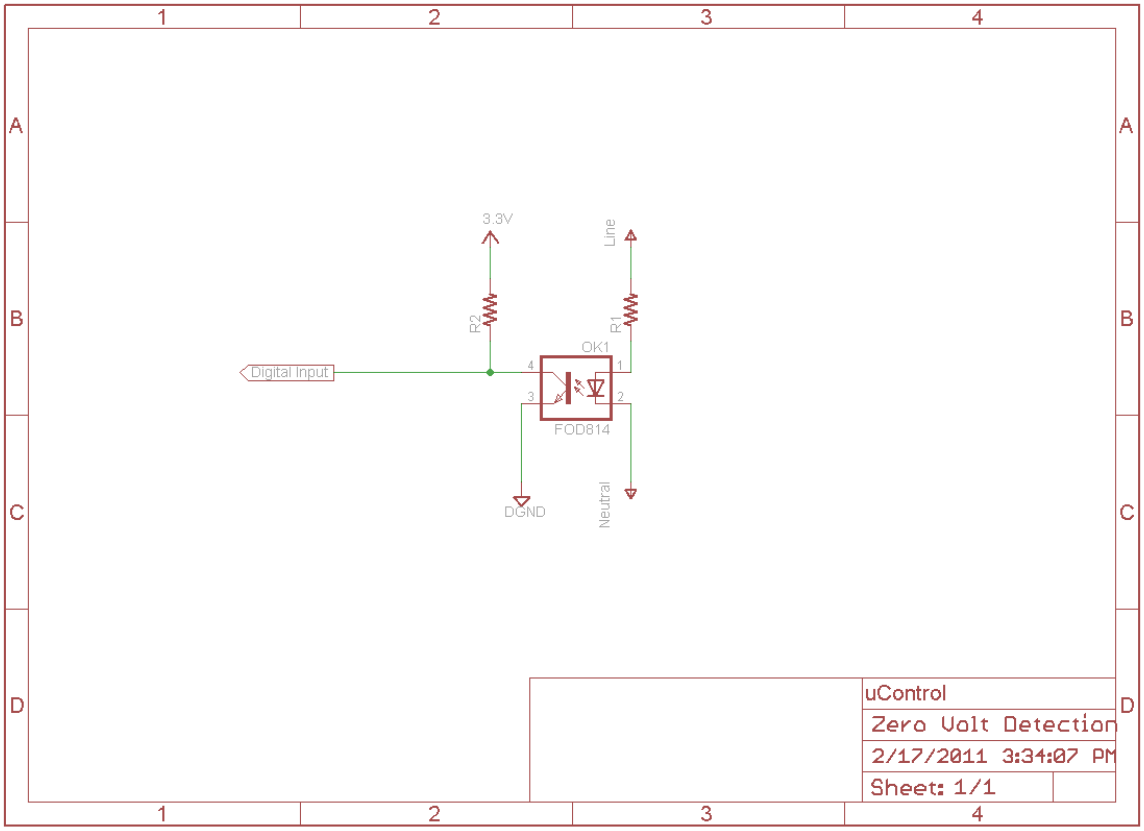


Figure 10: ZVC Detection Circuit

R1 limits the current through the diode, and R2 is a pull-up resistor. The Digital Input of the microcontroller will be capable of generating interrupts to ensure the ZVC is detected instantaneously.

When the AC line reaches near +-1V, the LED turns off, pulling the digital input to high, The digital input is pulled low when the voltage is greater than 1V or less than -1V. Thus the interrupt can either be set to detect a rising or a falling edge. A falling edge is preferred to ensure the TRIAC trigger is triggered ones in the half period.

Figure 11 shows the AC near zero crossing and the generated ZVC detection signal. Setting the interrupt for falling edge, it's observed that it will occur approximately

$$t = (\sin^{-1}\frac{1}{Va})/(2\pi f)$$

Where Va is the amplitude of the AC line and f is the frequency. For Canada Va=110V, and f=60Hz, thus the time is approximately 1.38 ms. The TRIAC can be triggered immediately at the falling edge, making the light bulb shine at max power or 5-6 ms after making it shine the lowest.

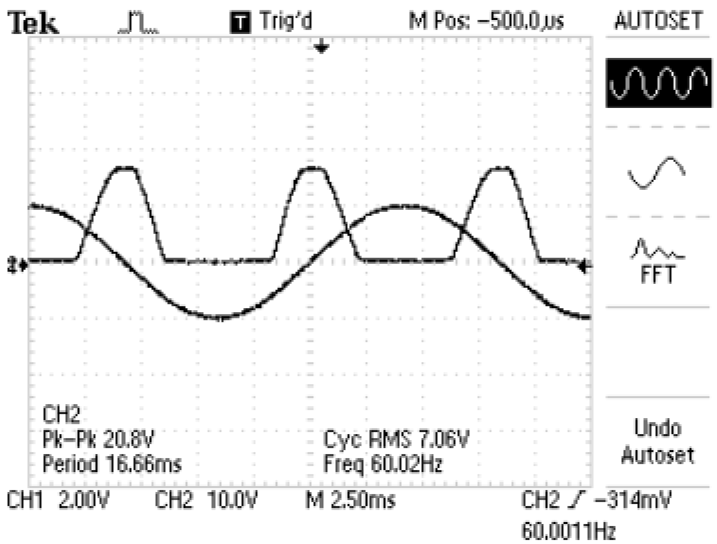


Figure 11: Zero Volt Crossing Detection Circuit test

Figure 12 displays the AC line and the control impulse for a light shining at full power.

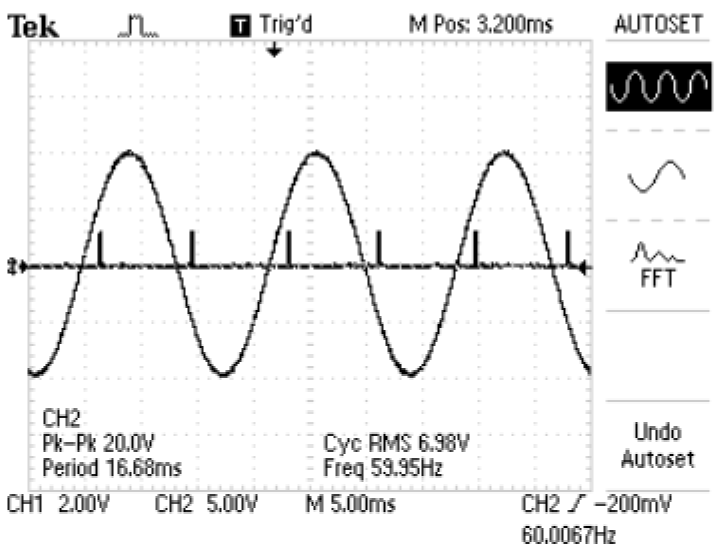


Figure 12: Light Switch Control Example

The opto- isolators used for the ZVC detection is FOD814 made by Fairchild Semiconductors. It's able to block 400VAC and it is inexpensive compared to other opto-isolators. Using an opto-isolator to detect the ZVC is a lot cheaper than other circuits used for ZVC detection, but it is just as effective. Two requirements are the operation/blocking voltage and the gain of the transistors in the IC. The data sheets states it can block 400VAC, but does not mention the gain of the transistors. Experiments were done on various opto-isolators samples and the FOD814 had the best price to performance ratio.

The current limiting resistor, R1 is 100kΩ, rated for 0.25W. It is very common and inexpensive at large quantities. R2 is 4.7kΩ pull-up rated for 0.25W. This is also very common and inexpensive.

3.1.3 TRIAC Trigger

The TRIAC requires a common reference with its gate. The microcontroller does not have a common reference with the AC line therefore a direct connection to the TRIAC gate is impossible. An opto-isolator designed for TRIAC control is used to by-pass this limitation of the TRIAC.

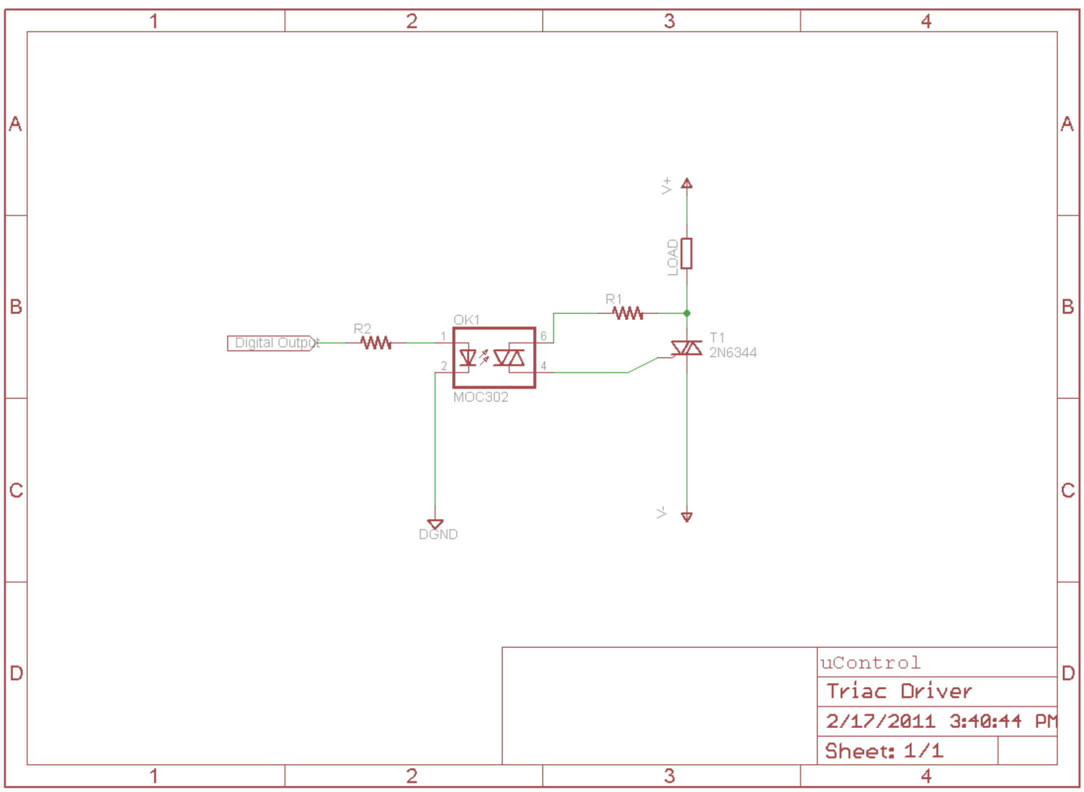


Figure 13: TRAIC Driver Circuit

Using the circuit in Figure 13, an impulse applied to R2 will trigger the TRIAC. The opto-isolator is relatively inexpensive and is vital for the TRIAC control. A control impulse with a width of 25us can be used to control the TRIAC. This is due to the TRIAC chosen. With a small impulse, power can be further preserved. The 2N6344 is able to control an 8A load, more than enough for house hold lights, and it has a low threshold current allowing for smoother control of the lights. R1 is connected to the mains, and it acts to limit the current entering the opto-isolator on pin 6. The opto-isolator selected for this is the MOC3020. The value of R1 is 180Ω, and power rating is 0.25W. Current will only flow through the resistor for only 25us thus, it's low power rating is not a problem.

3.1.4 Manual Control

Due to time limitations a regular push-button will be used to manually toggle the lights. For final production a touch panel can be used to allow for manual dimming as well. The circuit below shows how the button will be debounced and connected to the microcontroller. The Digital Input will be set up as an interrupt to allow real time toggling of the light switch.

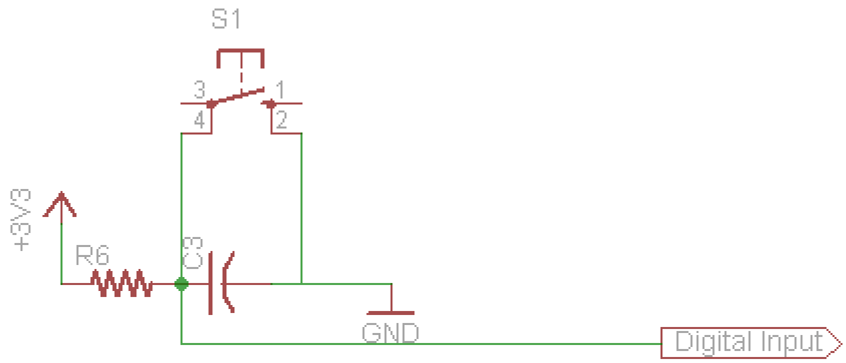


Figure 14: Manual Button Control Circuit

3.1.5 Wireless

The light switch needs to be equipped with a wireless transceiver to transmit and receive commands from the central unit. For the prototype a pre-made wireless module will be used. This is due to the lack of equipment required to solder the tiny IC transceivers and surface mount components. The module is the Microchip's MRF24J40MA.

MRF24J40MA is a certified 2.4GHz IEEE 802.15.4 radio transceiver module. [REF]It has a pre-built PCB antenna and a small footprint, 2.5cm by 1.7 cm, allowing for easy placement on the light switch's PCB.

Figure 15: MRF24J40 Picture Example

The IEEE 802.15.4 standard was developed for low power applications and supports various protocol stacks. The protocol stack utilized by uControl will be custom made and it is explained under Wireless Network section. The module features are listed below.

- 2.4 GHz IEEE 802.15.4 Transceiver Module
- FCC (USA), IC (Canada), ETSI (Europe) Certified
- Integrated PCB Antenna with
- Simple four-wire SPI interface to PIC® microcontroller
- Low current consumption
    - Tx 23mA
    - Rx 19mA
- Sleep 2uA
- Hardware CSMA-CA Mechanism
- Automatic ACK response
- Hardware security engine (AES-128)
- Automatic packet retransmit capable
- Surface Mountable

More explanation of the wireless module will follow in the Wireless Network section.

3.1.6 Microcontroller

The microcontroller utilized in the light switch modules is the ATMEGA168. It was chosen due to its relatively availability, easily usable chip size, and requires no expensive programmers or programming boards. For production other chips are available and they will be considered later on, near the final stage of the project.

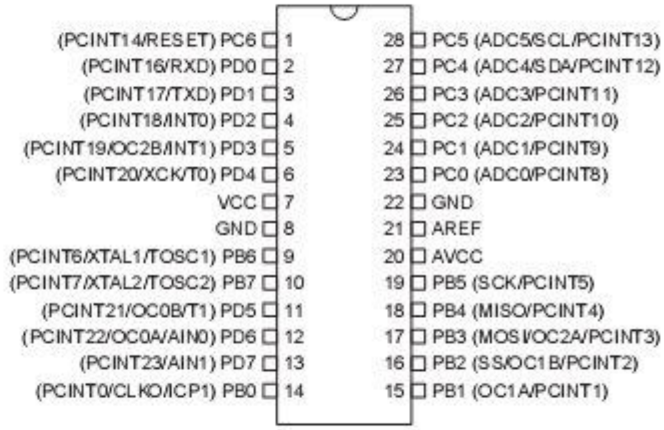


Figure 16: Light Switch Microcontroller

The ATMEGA168 is an AVR microcontroller with 24 pin General Purpose Input/output (GPIO) pins of which 16 can be used for interrupts. It can operate at 8MHz with no external hardware which is suitable for this project. The number of GPIO pins allows for easy expansion on new ideas. It supports hardware SPI which is required for the wireless module, and it can operate at 3.3V. The microcontroller is in charge of detecting the ZVC, fire the TRIAC control impulse while waiting for user commands: wireless or manual.

3.2 Software Architecture

3.2.1 Overview

The software architecture is displayed in Figure 17.

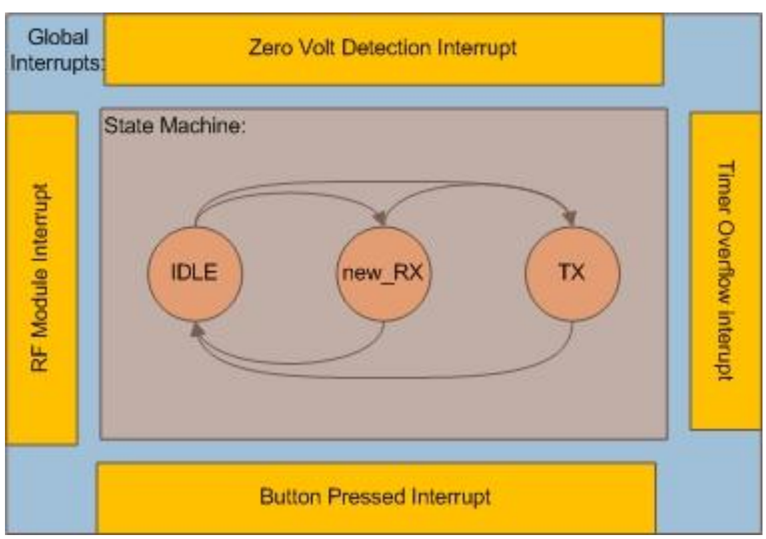


Figure 17: Light Switch Software Architecture

The state machine has three states, and four global interrupts. The global interrupts will force a change state after the current state has been executed. The Zero Volt Crossing Detection interrupt is used to detect the ZVC of the ac line, timer Overflow interrupt is used to enable the control of the TRAIC for different power levels, the RF Module Interrupt is triggered by the MRF24J40 Module and the Button interrupt is triggered by manually pressing the control button.

3.2.2 Interrupt Service Routes

TRAIC control is achieved by detecting the zero volt crossing of the ac line and firing an impulse. The time from the ZVC and the impulse determines the intensity of the light, and to accurately detect the ZVC a global interrupt is enable. When the Mains is at zero the interrupt triggers the Interrupt Service Route (ISR) for the ZVC, within this ISR a timer overflow interrupt is enabled with an initial value count from 100 to 255 as shown in Figure 18. The intensity of the light is mapped from 100 to 255 with 255 set as the max shining intensity.

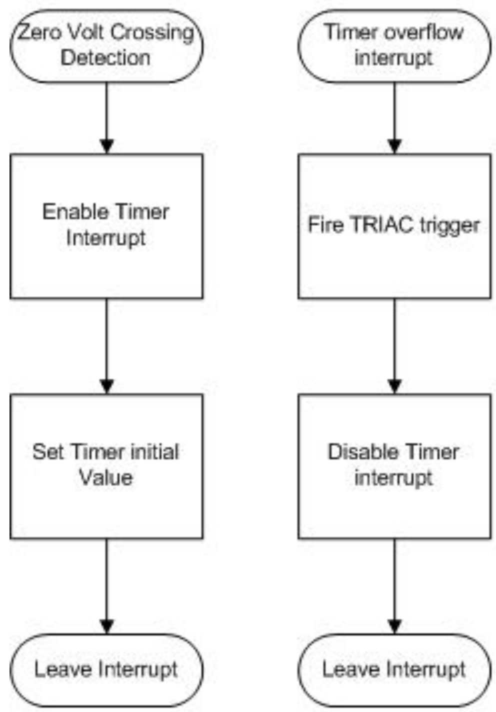


Figure 18: ZVC and Timer Over flow Algorithms

A Button interrupt is also enabled to allow for real time toggling of the lights. If the button is pressed it will either turn it on or off, depending on the light switch state. When the light is on, the ZVC is enabled and disabled if the light is off. At any light switch state translations , the light switch reports the translation to the Central Module by entering the TX state. The algorithm of the Button ISR is described in Figure 19.

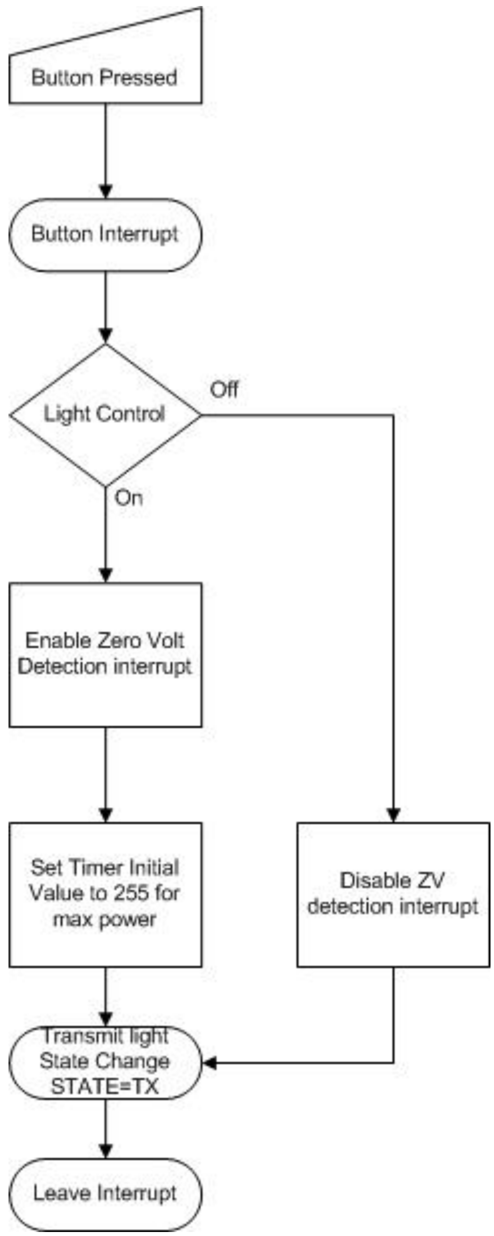


Figure 19: Button Pressed Algorithm

The MRF24J40 module is configured to produce an interrupt only when a new message is received. If other interrupts are triggered a fault has occurred therefor the ISR is left and the machine state is set to IDLE. Otherwise a new message is received and the machine state is set to new_RX.

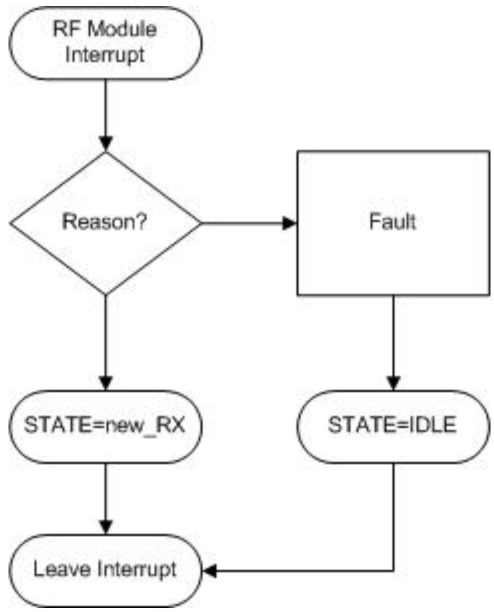


Figure 20: MRF24J40 ISR algorithm

3.2.3 Machine States

At power on, the module will configure itself as described in the Wireless Section, and immediately enter the idle state. State translations occur within the appropriate interrupt and can also occur within the individual states.

New_RX decodes the received message and executes the desired command. Commands include controlling the light or data reporting to the Central Unit. Figure 21 shows the fow chart of the New_RX State. This state is triggered within the RF Module Interrupt when a new message has been received.

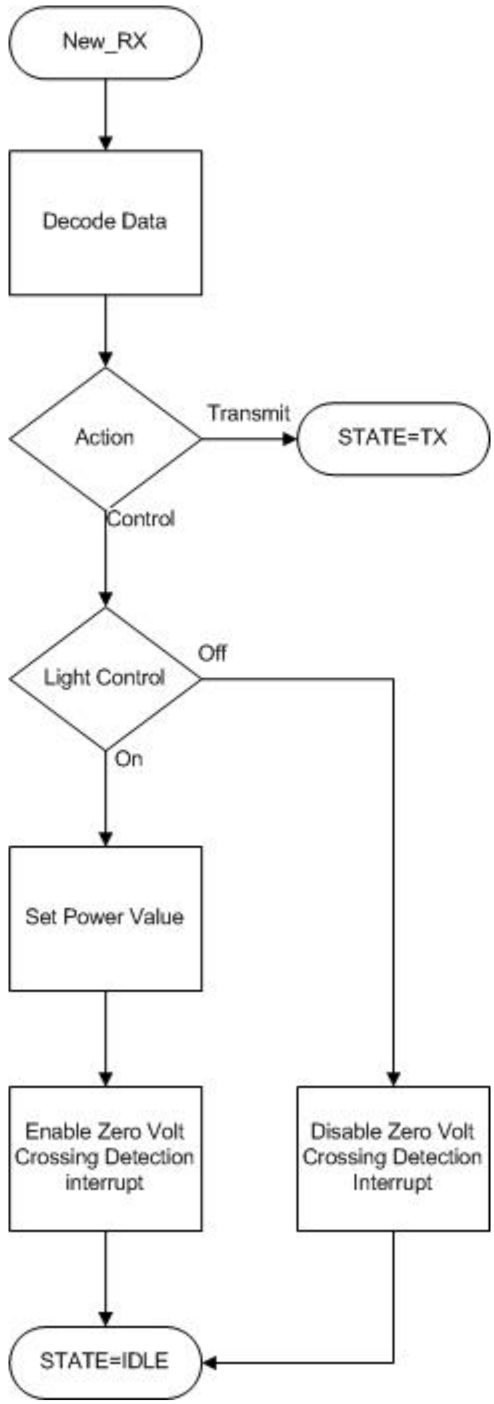


Figure 21: new_RX state algorithm

The TX state transmits any light switch transitions from on to off, and also transmits the data requested by the Central Unit. This data can include power consumption, fault detections and other useful information to the user.

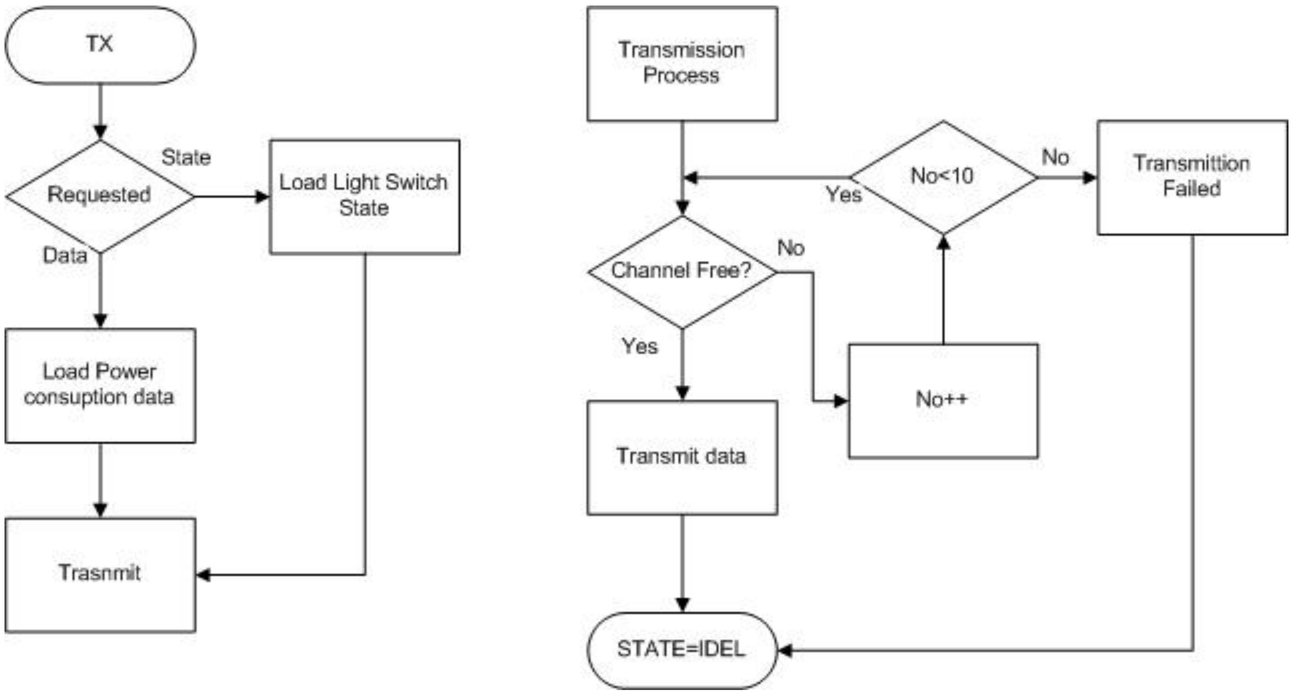


Figure 22: Additional State Algorithms

The transmission process is not a state but rather a function that handles the transmission of the message. When a transmission is requested, the wireless channel is verified to see if it is free or in use. If it is in use the module will attempted to transmit for a few clock cycles or terminate transmission if a decision is made to stop transmission. If the channel is free the module then transmits the requested data.

3.3 PCB Design

Tue to time limitation and lack of equipment required to solder small surface mounted devices (SMD) , all the components in the light switch come in through hole packages. In the final product most of the components can be selected in surface mountable packages. SMD production lines are usually cheaper than through hole, and thus for the final production a redesign of the PCB to use SMD components will be made. Most of the components chosen for the prototype can be purchased in SMD packages therefore a redesign of the circuit is not required. Using SMD packages will degrease the footprint of the module by at least a half, saving additional material costs. The PCB on the final product will be two sided to allow for less cluttering and reduce the size even further.

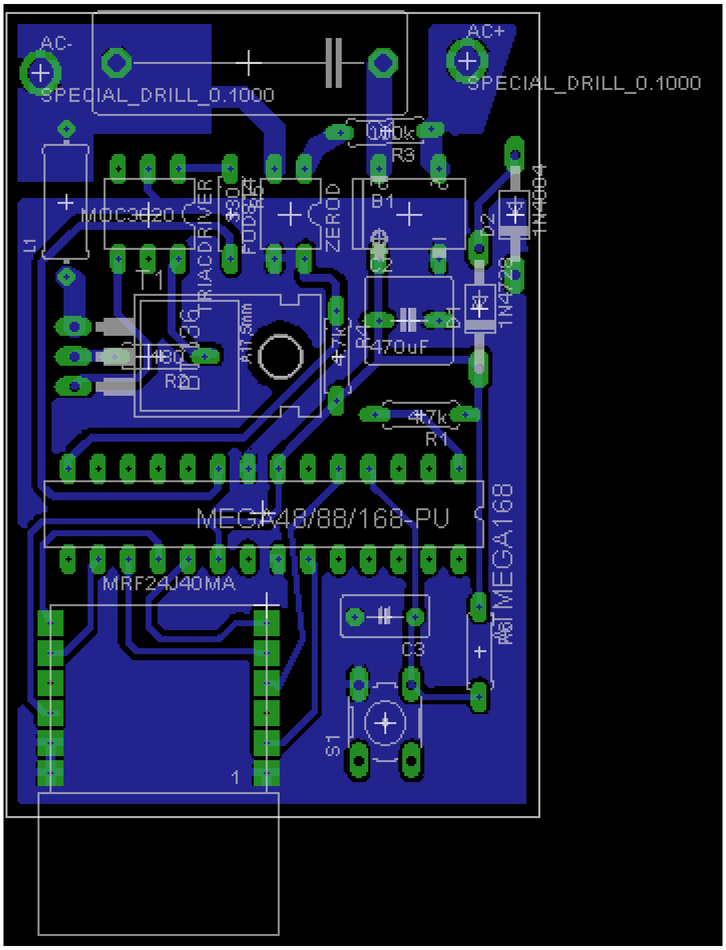


Figure 23: Light Switch PCB design. 7cm by 4 cm

4. User Interface

Our goal for the design of our user interface is that it must be simple, easy to use, and reliable. Our primary goal was to design this in such a way that it could be used with tablets and other touchscreen devices. What this means is that we need to limit embedded menus and have all our features presented in an easily accessible manner. To achieve this, we have decided to design the user interfaces in a tabbed manner where each component resides in its own tab.

The Figure 24 shows a sample overview of the user interface.

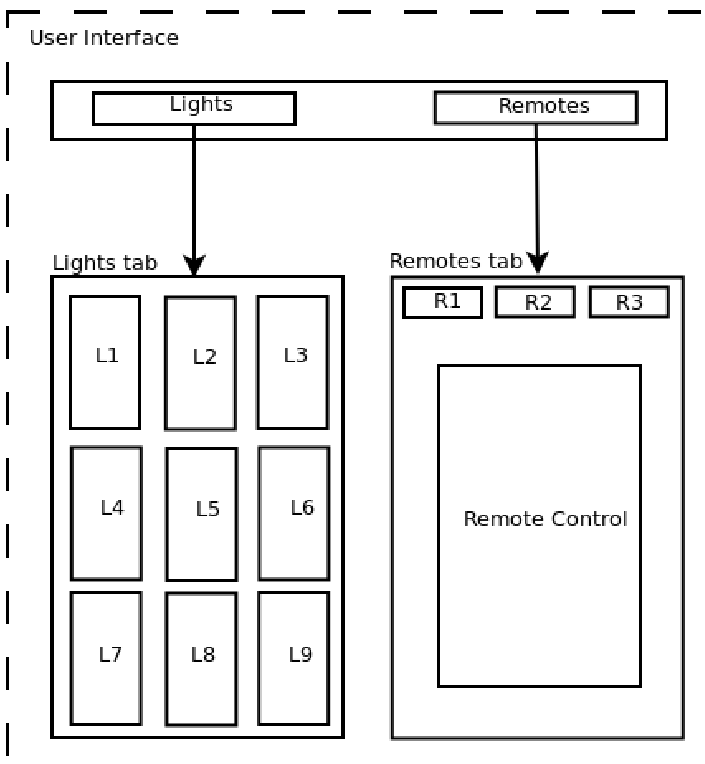


Figure 24: User Interface example

Each light module will be present within the Lights tab. Consequently, each remote control will reside within the Remotes tab. If additional components are later added to the system, it is the Central Unit's duty to alert the User Interface that a new component has been added. The user interface must then add the component within the appropriate tab. An example of a light component is shown in the Figure 25 below where Light Name represents the name of the component. This name will be user customizable.

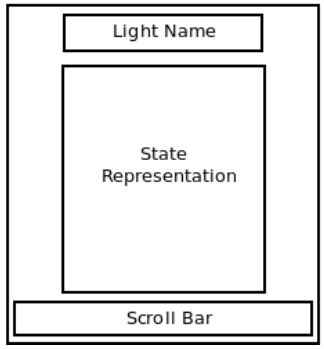


Figure 25: Additional UI example

We still intend to follow all the specification we mentioned in the functional specification that were marked either I or II. No future change in the design of the user interface is still made because this is the simplest way to represent our complex system that we could think of. There may be slight change in the design during the end of our prototype design when we would be implementing the whole system with the user interface. That is in the last developing stage of our prototype.

5. Wireless Network

5.1 Overview

5.1.1 Bluetooth

Communication between the user handheld devices to the Central Unit will be done through bluetooth. Any communication between the Central Unit and the Light Switch Modules will be done on a secured Wireless Personal-Area Network (WPAN). Any communication from the Central Unit to the home entertainment devices will be done through infrared light.

This is the bluetooth module we are using for our central unit. The features are listed below.

Figure 26: Bluetooth Module

- Class 1 Bluetooth® Radio Modem
- Fully qualified Bluetooth module
- Fully configurable UART
- Low power consumption : 25mA avg
- Hardy frequency hopping scheme - operates in harsh RF environments like WiFi, 802.11g, and IEEE 802.15.4
- Compatible with all Bluetooth® products that support SPP (almost all do)
- Includes support for BCSP, DUN, LAN, GAP SDP, RFCOMM, and L2CAP protocols
- Operating Voltage: 3.3V-6V
- Serial communications: 2400-115200bps
- Operating Temperature: -40 ~ +70C
- RP-SMA Connector for all 2.4GHz antennas (RP common on routers and 2.4GHz devices)

5.1.2 Secure WPAN

The wireless modules utilized in uControl supports the IEEE 802.15.4 standard that was designed for low power WPAN. The IEEE 802.15.4 packets are between 5 and 127 bytes. The packet has designated fields for destination address, source address, a length field, and data payload. Addition information is also stored in the packets that are automatically generated by the module. The Figure 27 displays a standard IEEE 802.15.4 Packet Format.

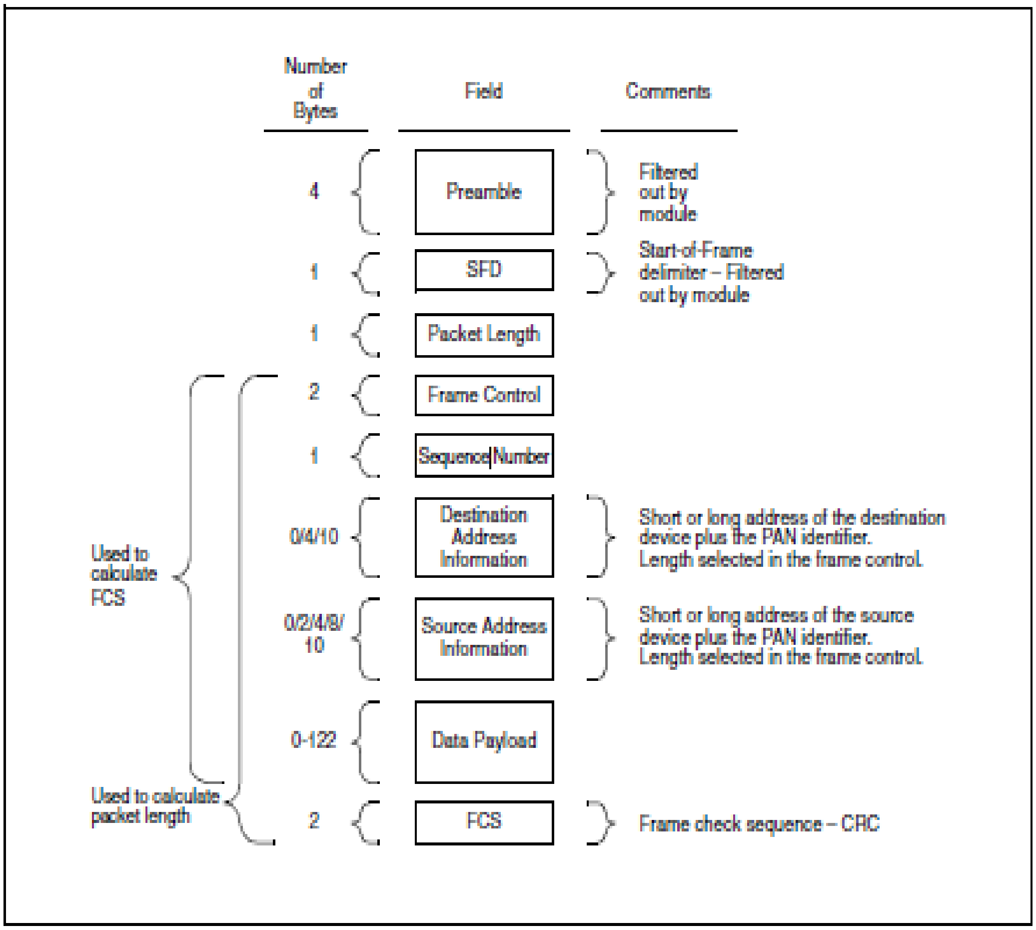
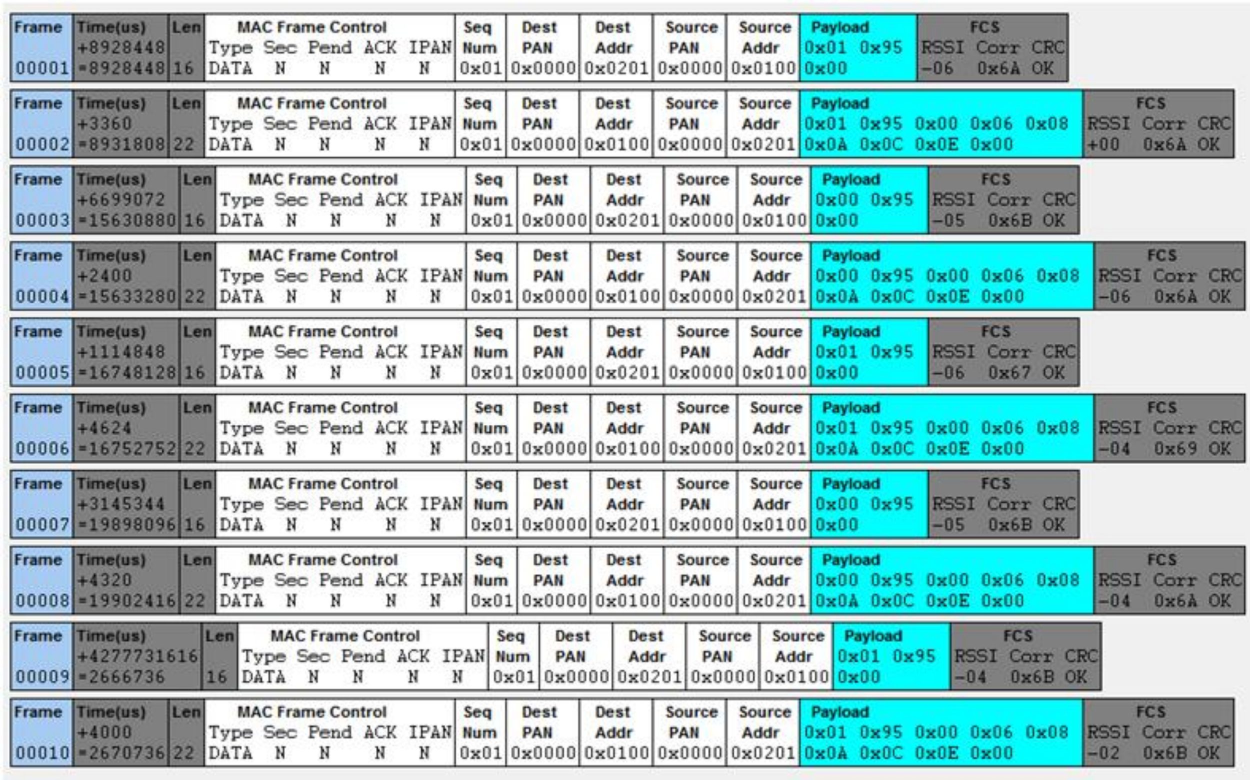


Figure 27: IEEE Standard Packet

The RF module samples the set channel frequency and listens for its address to appear in the Destination Address Information of the IEEE 802.15.4 packet format. Once the message is verified, it will trigger an interrupt to the microcontroller indicating a valid packet has been received. The microcontroller is then in charge of loading the information and acting out the commands.

The destination address information must match the address of the module. Unique addresses must be used for every module connected to one network. To achieve this upon installation the light switch will exchange information with the Central Unit to synchronize to the same PAN ID and exchange addresses. The central unit will then designate a unique address for the light switch and store in flash or EEPROM memories to ensure no pairing up is required if power is lost. The light switch's microcontroller has built in EEPROM memory to store the Central Unit address and the PAN ID of the network.

A sample of two modules communicating between each other is shown in Figure 28.



Frame	Time(us)	Len	MAC Frame Control (Type Sec Pend ACK IPAN)	Seq Num	Dest PAN	Dest Addr	Source PAN	Source Addr	Payload	FCS (RSSI Corr CRC)
00001	+8928448 =8928448	16	DATA N N N N	0x01	0x0000	0x0201	0x0000	0x0100	0x01 0x95 0x00	-06 0x6A OK
00002	+3360 =8931808	22	DATA N N N N	0x01	0x0000	0x0100	0x0000	0x0201	0x01 0x95 0x00 0x06 0x08 0x0A 0x0C 0x0E 0x00	+00 0x6A OK
00003	+6699072 =15630880	16	DATA N N N N	0x01	0x0000	0x0201	0x0000	0x0100	0x00 0x95 0x00	-05 0x6B OK
00004	+2400 =15633280	22	DATA N N N N	0x01	0x0000	0x0100	0x0000	0x0201	0x00 0x95 0x00 0x06 0x08 0x0A 0x0C 0x0E 0x00	-06 0x6A OK
00005	+1114848 =16748128	16	DATA N N N N	0x01	0x0000	0x0201	0x0000	0x0100	0x01 0x95 0x00	-06 0x67 OK
00006	+4624 =16752752	22	DATA N N N N	0x01	0x0000	0x0100	0x0000	0x0201	0x01 0x95 0x00 0x06 0x08 0x0A 0x0C 0x0E 0x00	-04 0x69 OK
00007	+3145344 =19898096	16	DATA N N N N	0x01	0x0000	0x0201	0x0000	0x0100	0x00 0x95 0x00	-05 0x6B OK
00008	+4320 =19902416	22	DATA N N N N	0x01	0x0000	0x0100	0x0000	0x0201	0x00 0x95 0x00 0x06 0x08 0x0A 0x0C 0x0E 0x00	-04 0x6A OK
00009	+4277731616 =2666736	16	DATA N N N N	0x01	0x0000	0x0201	0x0000	0x0100	0x01 0x95 0x00	-04 0x6B OK
00010	+4000 =2670736	22	DATA N N N N	0x01	0x0000	0x0100	0x0000	0x0201	0x01 0x95 0x00 0x06 0x08 0x0A 0x0C 0x0E 0x00	-02 0x6B OK

Figure 28: Example of two modules communicating

The modules were configured to communicate between each other every time a button on Module A, source address 0x01, was pressed. Then Module B, source address 0x0201, responses with a message of its own. From the source address field the microcontroller knows which module is communicating with and how to store data from it and how to transmit commands.

The following flowchart describes how our central is going to respond to a user input via Bluetooth.

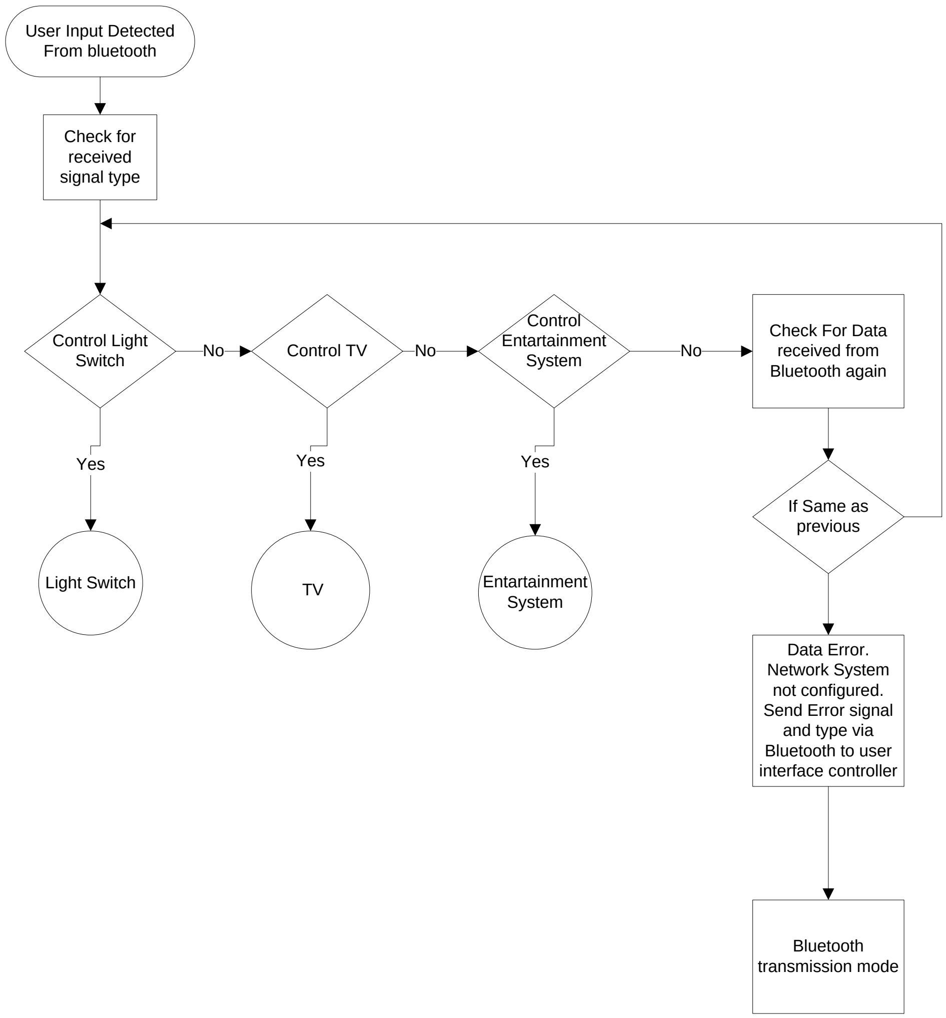


Figure 29: Overview of CU to light switch communication

In this WPAN, the Central Unit acts as a network coordinator. Its duties include sending and receiving data from the light switch modules, automatically pairing up with newly installed light switch modules, detecting any fault in the wireless channels, and for future updates, support Frequency Hopping Algorithms. The amount of modules that can be paired up is only limited to the amount of memory on the microcontroller. The Central Unit microcontroller has internal EEPROM with 4KB memory. One address is 8 bytes long; therefore up to 503 addresses can be stored. Each Central Unit is able to coordinate 503 devices without external memory. With external flash memories that range from 124KB to a few gigabytes, the number of modules connected to the network can be potentially endless.

The MRF24J40MA module uses hardware security engines allowing for secure networks. It also handles automatic checking of the received message and only receives messages with no error. If an error is detected it will automatically request a new message to be sent. All this is done by the hardware on the module, freeing microcontroller time and allows the use of cheaper and less power full microcontrollers.

The reason we are using the microchip wireless modules because of the cost and expandability. A Bluetooth module alone costs 26$.where else the microchip modules cost only $4.55. When we mass produce it the price will come down below 50%. Also a single Bluetooth module can only pair up to 8 modules at a time. But with the microchip wireless the possibility is limitless. As mentioned before we just have to store the different address assigned to the microchips modules which depends on the flash size of the microcontrollers which is easily expandable.

6. Test Plan

A test plan will be devised to ensure the safety, functionality, and reliability of the uControl proof of concept prototype will meet the standards of the end user. The modular nature of the system means that testing involves creating a specific test plan for each piece of the final system and then a general test plan that will encompass the system as a whole. First, the components of the modules and central unit will be tested to ensure their functionality. Then, tests to the integrated central unit and modules, built using the tested components, will be conducted. A separate test plan for the software used in the handheld device will be made using standard regression software testing. Finally, the entire system will be integrated and tested using both basic and extreme end user scenarios. The light switch module represents all subsequent modules.

6.1 Component Testing

Light Switch Module:

Power Supply

Condition: Ability to convert 110Vac to 3.3Vdc

Procedure: Plug the power supply circuit into a wall outlet and scope the 'load' power input to ensure 3.3Vdc is read

MCU

Condition: Ability to function using power from power supply unit

Procedure: Connect the power supply to the MCU for 24 hours and ensure no damage is procured to the unit at the end of the allotted time

RF Transceiver

Condition: Ability to function using power from power supply

Procedure: Connect the power supply to the RF Transceiver for 24 hours and ensure no damage is procured to the unit at the end of the allotted time

Central Unit:

MCU

Condition: Ability to function using power from power supply unit

Procedure: Connect the power supply to the MCU for 24 hours and ensure no damage is procured to the unit at the end of the allotted time

RF Transceiver

Condition: Ability to function using power from power supply
Procedure: Connect the power supply to the RF Transceiver for 24 hours and ensure no damage is procured to the unit at the end of the allotted time

Bluetooth Module

Condition: Ability to send and receive signals from the user's control device
Procedure: Connect the power supply to the Bluetooth module for 24 hours and ensure no damage is procured to the unit at the end of the allotted time

User Controlled Device:

Bluetooth Module

Condition: Ability to send and receive signals from the user's control device
Procedure: Create a program on the user's control device that sends simple predetermined commands to the central unit

6.2 Device Testing

Light Switch Module:

Functionality

Condition: Should turn on when light switch is manually turned on
Procedure: Connect a light switch in the off position to a light and power supply, connected to the respective terminals, and then press the light switch manually to on, the light will turn on

Radio Signaling

Condition: Should turn 'on' light when receiving a turn 'on' message wirelessly
Procedure: Connect a light switch in the off position to a light and power supply, connected to the respective terminals, and then send a 'light on' message to the transceiver from another transceiver

Central Unit:

Functionality

Condition: Ability to function while being powered
Procedure: Plug the Central Unit into the wall outlet and wait for 24 hours and ensure no damage is procured to the unit at the end of the allotted time

Bluetooth

Condition: Ability to send and receive signals from the user's control device
Procedure: Create a program on the user's control device that sends simple predetermined commands to the central unit

Infrared

Condition: Ability to send infrared signals
Procedure: Using a programmer, force the central unit to send an 'on' command to a television with known infrared protocol

Radio Signaling

Condition: Should turn 'on' a light module when sending a turn on message wirelessly
Procedure: Connect a light switch in the off position to a light and power supply, connected to the respective terminals, and then send a 'light on' message to the light switch module from the central unit

User Handheld Device:

Functionality

Condition: Ability to send commands to the central unit
Procedure: Set up a desktop computer with a bluetooth module, link with the central unit via Bluetooth, and send simple data from the computer to the central unit. Monitor using a simple LED circuit

6.3 Software Testing

UControl Solutions will use a laptop to perform software testing on. This is the fastest route since all the software testing tools are readily available and necessary changes can be implemented with ease. Simple regression testing will be performed on top of these.

User Controlled Device Software:

Light Controls

Condition: Clicking 'on' an 'off' light button should turn it to 'on', repeat but from on to off
Procedure: On the handheld device software, click on a light that is off and ensure it turns it to on. Repeat the procedure but turn an 'on' light 'off'

Television Controls

Condition: Clicking 'on' an 'off' television button should turn it 'on'

Procedure: On the handheld device software, click on a light that is off and ensure it turns it to on. Repeat the procedure but turn an 'on' light 'off'

6.4 System Testing

System testing involves testing the uControl System as a whole and the best way to test the whole system is by performing typical user scenario tests on it. The following scenario tests ensure that we conform to the functional specifications we detailed previously.

Typical User Scenarios:

Precursor: Assume user has installed several light switch modules in their home and has set up the central unit to act as a universal remote for their television and other entertainment modules. Furthermore, they have installed the uControl control software and a bluetooth module on their laptop.

1. User opens the uControl software on their laptop
    2. User wishes to turn on a specific light in the room and so presses 'light on' for the selected light in the uControl control software
    3. After the light has turned on, user wishes to watch television and presses 'television on' in the uControl control software
    4. User wishes to change channel and presses desired channel from the uControl control software

6.5 Failure Testing

One of the design points stressed by uControl Solutions is simplicity. Our goal is to make the end user's experience as enjoyable as possible. To achieve this we must ensure that any accidental or misplaced use of the product does not result in total failure or damage to the system. Furthermore, the uControl System should provide helpful information or make user friendly choices should any problems arise.

1. To avoid the end user having to do unnecessary work, the bluetooth modules will connect themselves to the central unit. Will require to set up a program that allows the

7. Conclusion

Simple, Elegant, and Effective is the best way to describe uControl. The ability and freedom it provides in controlling your environment ALL from one place at the touch of your fingertips is unprecedented. With our product, you can enjoy your favourite TV shows, set the mood by playing music and dimming your lights and most importantly is you who control all this and much more. Our device is expandable, portable and usable by anyone with access to a computer. Furthermore it can also be used for individuals with physical disabilities to interact with their environment. This is one of the major factors in developing this product. Every existing system falls short behind uControl. The features we offer all in ONE place are unprecedented. uControl is all that and more!

This document is meant to be framework for the engineers to work on with regards to the required features projected for our unit. However, this is not a final document and it will be continuously revised and updated after vigorous researching and numerous testing to provide a highly satisfactory end product. The development is divided into 3 stages and the first build is already in progress which will prove the concepts that of being able to create a working affordable universal home remote.

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