

SCREAM

Speech Controlled Responsive Electronics and Mechanics



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Group 21

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- 1.0 Executive Summary
- 2.0 Project Description
 - 2.1 Project Motivation and Goals
 - 2.2 Objectives
 - 2.3 Project Requirements and Specifications
 - 2.3.1 User Interface
 - 2.3.1.1 Wireless Microphone
 - 2.3.1.2 Push Buttons
 - 2.3.1.3 LCD Display
 - 2.3.1.4 LED Lights
 - 2.3.2 Power Supply Specifications
 - 2.3.2.1 AC/DC Converter Power Supply
 - 2.3.3 Single Supply Operational Amplifier (LM2904) Specifications
 - 2.3.4 Servo Motor Specifications
 - 2.3.5 Relay Control Unit specifications
 - 2.3.5 Microcontroller Specifications
 - 2.3.5.1 Microprocessor
 - 2.3.5.2 Microcontroller
 - 2.3.5.3 Digital Signal Processor (DSP)
 - 2.3.5.4 Family
 - 2.3.5.5 Splitting the Workload
 - 2.3.6 Wireless Transceiver Specifications
 - 2.3.7 Microphone Specifications
 - 2.3.7.1 Motorola Hint
 - 2.3.7.2 Motorola Whisper
 - 2.3.7.3 Motorola Silver II
 - 2.3.7.4 Motorola Boom
 - 2.3.7.5 Plantronics Voyager Legend
 - 2.3.7.6 Plantronics Marque2 M165
 - 2.3.7.7 Plantronics M55
 - 2.3.8 Speech Recognition Circuit Specifications
- 3.0 Research
 - 3.1 Existing Home Automation Systems (HAS)
 - 3.2 Technologies Applicable to a HAS
 - 3.2.1 ZigBee
 - 3.2.2 x10
 - 3.2.3 Z-Wave
 - 3.2.4 EnOcean
 - 3.2.5 INSTEON
 - 3.2.6 Bluetooth
 - 3.2.7 IPv6 over Low power Wireless Personal Area Networks (6LoWPAN)
 - 3.2.8 Wi-Fi, Wi-Fi Direct, Wi-Fi Peer-to-peer (P2P)
 - 3.3 Speech Recognition Overview
 - 3.4 Components Needed to Implement SCREAM
 - 3.4.1 Input Module
 - 3.4.2 Access Point or Master Module

- 3.4.3 Light Control Module
- 3.4.4 Door Control Module
- 3.5 Possible Architectures and Related Diagrams
 - 3.5.1 Microcontroller
 - 3.5.1.1 MSP430 + Zigbee
 - 3.5.2 CC3200
 - 3.5.3 MSP430 + Sub 1GHz
 - 3.5.2 Speech Recognition
 - 3.5.2.1 Android
 - 3.5.2.2 HM2007
 - 3.5.2.3 Windows
- 4.0 Hardware and Software Design Details
 - 4.1 Power Supplies
 - 4.2 Servo System
 - 4.3 Relay Control Unit
 - 4.4 Microcontroller
 - 4.5 Wireless Transceiver
 - 4.5.1 Using CC3100\CC3200 SimpleLink™ Wi-Fi® Network Processor Subsystem
 - 4.5.1.1 Universal Asynchronous Receiver/Transmitter (UART)
 - 4.5.1.2 Serial Peripheral Interface (SPI)
 - 4.5.1.3 Power Modes
 - 4.5.1.4 Networking
 - 4.6 Microphone
 - 4.7 Speech Recognition
- 5.0 Design Summary of Hardware and Software
- 6.0 Prototype Construction and Coding
 - 6.1 Parts Acquisition
 - 6.2 Bill of Materials
 - 6.2.1 Headset
 - 6.2.2 Main Unit
 - 6.2.3 Door Unit
 - 6.2.4 Power Control Unit
 - 6.3 PCB Vendor and Assembly
 - 6.3.1 Design
 - 6.3.2 Fabrication
 - 6.4 Final Coding Plan
- 7.0 Prototype Testing
 - 7.1 Hardware Test Environment
 - 7.2 Unit Testing
 - 7.2.1 Servo Operational Unit
 - 7.2.2 Speech Recognition Unit
 - 7.2.3 Relay Control Unit
 - 7.2.4 Wireless Transceiver Unit
 - 7.2.5 Overall Hardware System Test
 - 7.3 Software Test Environment

- 7.3.1 Code Composer Studio (CCS)
- 7.3.2 Energia
- 7.3.3 Additional Software
- 7.4 Software Testing
- 7.5 Integrated System Testing
- 7.6 Presentation Environment
- 8.0 Administrative Content
 - 8.1 Project Milestones
 - 8.2 Project Budget and Finance Discussions
 - 8.2.1 Budget
 - 8.2.2 Financial Discussions
- 9.0 Project Summary and Conclusions
- 10.0 Extending the Design
 - 10.1 User Interface and App Development
 - 10.2 Multiple Users
 - 10.3 Vocal Confirmation
 - 10.4 Email and Text Alerts
 - 10.5 Microphone Repeaters
- A Copyright Permissions
- B Datasheets
- C References
- D Figures and Tables Index

1.0 Executive Summary

A speech recognition system simplifies a user's interaction with a home automation system (HAS). Speech recognition applications can be classified into three broad groups of isolated word recognition systems which each word is spoken with pauses before and afterwards, small vocabulary command and control applications, and large vocabulary continuous speech systems. A smart home system uses the mixture of the second and third cases. The main feature of a smart home is the ability to remotely command the functions of the home via its appliances. For example, controlling the amount of light in a room by a light switch. This is the command and control function. Most command and control applications have a small vocabulary size that reflects the operations required to control the equipment. For example, "television off" would turn the television off. However, more complex commands can be managed through a known set of alternatives, such as days of the week, percentages, or times of the day. As the number of alternative wordings increases, the task of listing all possible combinations and associating them with a given set of actions become unmanageable and so a grammar syntax is required that specifies, in a more abstract way, the words and phrases along with their permissible combinations. Minimizing the vocabulary used to control devices also allows the SCREAM system to minimize its size and cost.

Unlike many HAS technologies, the SCREAM system would run on a secure network, be able to control door locks, and provide a signal which will manipulate power to electronic devices without using a core visual interface like a tablet. Vocal control from a wireless Bluetooth earpiece would allow the user the freedom to have their hands free while controlling their home. While wearing the wireless headset and speaking, the SCREAM system will be able to recognize speech commands, interpret them, and control the appropriate device. SCREAM will be much less expensive than other systems because there is no GUI, which removes the need for an expensive LCD display, and the number of electronic control units will be scalable. The system will run on low power to ensure that although the system provides these features, it will not add significantly to a utility bill. Due to the popularity of home automation technologies it will also be necessary to keep security in mind to prevent unwanted entities from gaining access to the premises. Lastly, the system will be easy enough to set up and use for the average person with minimal computer knowledge.

The concept of using speech recognition in smart homes can be related to the voice recognition system used in the Joint Strike Fighter (JSF) cockpit developed by Boeing. The system incorporates speech recognition technology specifically designed and optimized for ultra high accuracy in a noisy cockpit environment. The device and related software allow pilots to avoid some manual tasks so that they can remain better focused on their flight environment. Speech recognition technology enhances the pilot's aircraft management capabilities. Speech recognition systems can be used for multiple purposes. This concept can be expanded to homeowners. A HAS can improve the lifestyle and performance of its users while they are executing multiple tasks at home.

2.0 Project Description

2.1 Project Motivation and Goals

The formal idea of a home automation system (HAS) originated during the World's Fairs of the 1930s and has been a topic for many science fiction writers. For example, H.G. Wells wrote about automatic doors in *The Sleeper Awakes* published in 1899. Utopia, as theorized by science fiction writers and political ideologists alike, was associated with the idea of mitigated work through the use of machines and many automation methods aim to reduce the amount of work required to perform normal, often considered menial, tasks around the home. As case in point, wireless remotes could be used for vessels and vehicles to keep a person from having to physically be present to manipulate the device, an idea that Nikola Tesla patented in 1898.

Automation is already a common facet in a first-world home as seen in washing machines to clean clothes, dishwashers to wash dishes, water heaters to remove the need to manually heat water for bathing, and thermostats to automate the temperature but these technologies are only a fraction of the devices that can be automated. One of the most famous homes, the home of Bill Gates, expounds on the possibilities that lie in home automation. Each person is pinned with an electronic tracking chip and as a person traverses the home lights turn on ahead of the chip and turn off behind it. The chip maintains data on everything a person does and makes adjustments as it learns that person's preferences, including musical tastes and television channels. When two people pinned with such chips enter a room the system attempts to compromise between the preferences of both.

A "smart house," or a home that is equipped with lighting, heating, and electronic devices that can be controlled remotely as coined by the American Association of Housebuilders in 1984, began as a wired electrical system intended to provide power to multiple outlets, intended for a television and lighting, and a doorbell. 'Remotely' used to refer to another room located in the same domicile, but now the term 'remotely' has extended to include any location where an Internet-connected tablet or cell phone can reach. The boom of home automation is closely linked to the ability to control it from a tablet or touch screen device. Smart homes now contain any of the following automations: kitchen appliance and lighting, lawn watering and care, pet feeding, security systems, camera systems, audio and entertainment systems, window coverings, and utility usage to include both water and electric.

Utility conservation is becoming more essential to saving both money and the environment. The average U.S. home uses 1,000 kilowatt-hours (kwh) of electricity per month - the equivalent of 79 gallons of gas. Vampire power, like clock displays and LEDs, can add an additional 10 percent to a power bill and 75 percent of the electricity used to power home electronics is generally consumed when the device is turned off or in an idle state. Saving even an infinitesimal amount of energy per home can be monumental in conserving energy when every home implements that knowledge. For example, if every U.S. home replaced a single light bulb with an energy efficient light

bulb the amount of energy that would be saved could light an additional 3 million homes for a year. Home automation, when faced with the rising costs of energy and the dwindling reserves of freshwater, could save families hundreds in utility costs per year and help preserve the environment. A HAS should save the homeowner on their electric bill. Often times if a user is going to leave a room for a few minutes, they will not want to walk to the light switch to turn it off. This problem can be further compounded when multiple light switches are on and are not located next to each other. Home automation can be used to motivate an individual to turn off lights that are not in use because they do not have to be physically present at the switch, but preferably a light should turn off automatically.

Many first world nations, the United States included, have an aging population. Home automation technologies can solve a unique problem presented by the elderly and otherwise disabled. Health care costs, including nursing home costs, could be reduced as a person reaches end of life by extending the time a person can remain in their place of residence without, or with minimal, outside assistance. For a monthly subscription, companies, like ADT, Front Point Security, and AT&T are willing to provide 24/7 home monitoring for smoke, carbon monoxide, or glass breakage using sensors installed in key locations. There are also medical alert devices that a person can use when they have an accident, which will call an emergency number for them. For persons with limited mobility voice activated light control is used to help turn lights on and off and chair lifts can be installed to aid in traversing between floors. For the hard of hearing or hearing impaired, overhead lights or onboard LEDs can flash to indicate when a phone is ringing. Interactive voice response (IVR), like Siri, can be used to wake a person daily with the date, when medication needs to be taken, when medical appointments are, and even general house tasks that need to be done like taking out the garbage or recycling on the appropriate day. A smart refrigerator can be used to indicate when a particular food is low in supply and a smart oven can turn itself off if it reaches a certain temperature or is left on for too long. These technologies can help maintain independent living for longer, reducing the cost of nursing home or hospice care. A HAS should be easy to configure, run, and use regardless of visual capabilities.

The cost of installing and using a home automation system has often hindered otherwise interested parties from using one. The aforementioned monthly subscription involves little to no effort to install or maintain on behalf of the user. For AT&T a basic energy package requires 200 dollars upfront for installation and a five-dollar monthly fee. Automation for the garage door is \$50, a push button door lock is \$100, and a touchscreen door lock is \$150 with a \$50 upfront installation fee and a five-dollar monthly fee. ADT's Pulse program provides a basic home security service for a monthly service subscription of \$47.99 with a 36-month contract and does not include video or home management. Video and home management are included with a more expensive subscription that entirely relies on a broadband connection; in the event that Internet or power is lost, those features are lost as well. Front Point Security also offers a subscription service for a minimum of \$35 per month that includes intrusion protection, life safety, and fire and water protection. 'Crash and Smash Protection', or reimbursement in the event of a successful burglary, remote access and control, text

alerts, and light control can be added for an additional seven dollars. The highest tier of plans includes live video streaming, motion activated video recording, night vision capabilities, automated door locks, and energy management control for a total of \$50 per month. Monthly subscriptions often come with high installation costs and a long minimum required contract. In order to motivate a user to install and use a HAS, the long term cost should be minimized. To achieve this, both the installation cost and the cost to maintain the system should be kept low.

Home automation is still possible regardless of these obstacles. A personal home automation network can be controlled by a homeowner's voice. The system would run on a secure network, be able to control door locks, and provide power to electronic devices. Replacing the tablet with a wireless Bluetooth earpiece would allow the user the freedom to have their hands free while still maintaining control of their home. While wearing the wireless headset and speaking, the SCREAM system will be able to recognize speech commands, interpret them, and control the appropriate device. SCREAM will be much less expensive than other systems because there is no GUI and the number of electronic control units will be scalable. Lastly, the system will be easy enough to set up and use for the average person.

2.2 Objectives

One of the objectives of SCREAM is to allow users to vocally control their HAS. There are not as many HAS systems that use vocal control available on the market which means that SCREAM would have more value due to scarcity. Vocal control allows the user to have their hands free which benefits those who do not want to control their systems on a touch-based interface and those who are unable to use a touch-based interface. Vocal controls will be handled by the HM2007 chip, which can perform speech recognition independently or as a slave to a host processor. The chip can recognize several words lasting a second each, which will reduce the vocabulary the user can control the system with and will keep the cost of the embedded system low.

An embedded system is easier to manufacture and troubleshoot as most of the requirements the system needs will be handled on hardware. With a single microcontroller as the center node the overall size of SCREAM is going to be small. Each device that is SCREAM enabled will also be small due to its embedded nature. The embedded system will be more robust with no software to install, as everything the circuit needs will always be present on board. The size makes the system more attractive because it will take up less space and the onboard software will make the system easier to use.

SCREAM needs to use little power in order to operate. If the system can go into idle or sleep modes when not in use the system will need less power to operate. It needs, at a minimum, to be able to control access to a door with the use of a transmitter/receiver unit to a servos and it needs to be able to switch lights on and off at a user's vocal or local command. This means that both functions need to have appropriate vocal controls available on the chip and these commands need to activate each system accordingly.

2.3 Project Requirements and Specifications

SCREAM needs to be easy to make space for and move around. Therefore, all SCREAM components must be light enough to lift even if a user has issues with mobility and it needs to be small enough that it is unnoticeable when it is implemented in a home. A user needs to be able to operate the SCREAM system with some leeway and freedom without having to stand next to the unit in order to vocally control the modules. There must be a minimum amount of words that the system identifies in order to control the modules in the house. There must be enough words, for example, to control the television, the lights, and the door in this implementation. The system needs to be able to accurately identify the words used to reduce user frustration. In order to reduce the amount of maintenance that SCREAM would need to operate, the system must efficiently use power to help conserve battery life. This would reduce the amount of time the user needs to change and charge batteries. Finally, for the module that operates the door, the servos must be able to produce enough torque to operate a deadbolt locking mechanism. A summation of these requirements are detailed in Table 1.

1	Remote stations can communicate to the base station up to 10 meters away
2	Microphone can communicate to the base station up to 10 meters away
3	Speech recognition chip identifies up to 20 words
4	Speech recognition chip operates with 95% word accuracy
5	Mechanical door opener operates for 24 hours before batteries need replacement
6	Wireless microphone operates for 5 hours before batteries need recharging
7	Home stations dimensions is below 20 cm by 20 cm by 10 cm
8	Remote electrical stations dimensions is below 10 cm by 10 cm by 10 cm
9	Remote mechanical stations dimensions is below 20 cm by 20 cm by 20 cm
10	Home stations weight is below 1 kg
11	Remote electrical stations weight is below 500g
12	Remote mechanical stations weight is below 2 kg
13	Remote mechanical station will be able to output torque greater than 69.56 oz.in

Table 1 - Project Specifications

2.3.1 User Interface

A user will interface with the device through the following methods. SCREAM receives inputs in the form of voice commands through the wireless microphone. Additional inputs will be provided through the use of push buttons on board the embedded controller, which will provide a means for the user to train the speech recognition circuit during first time use. The device will provide the user with feedback in the form of a single LCD display and multiple LED lights.

2.3.1.1 Wireless Microphone

A wireless microphone will act as the primary means of entering information to the system and after the initial user setup the microphone can act as the only input source. A wireless Bluetooth headset will be provided for demonstration purposes but the system maintains the ability to sync any Bluetooth headset following the same wireless communication protocols should the user require a new one. Replacement would require that the new microphone have the same dongle type as the microphone that comes with the system or at least an adapter to ensure the new dongle fits in the same port. During the first time setup the user will use the microphone to train the system to remember certain voice commands. These recordings will be held in the systems memory and can be re-recorded at any time. For the user to be able to maintain full control of the system they are required to be wearing or within range of the microphone in order for it to receive voice commands. Due to the wireless nature of the device, it will be required for the user to regularly recharge the microphones battery. Any time the user is not home or is not using the system, the microphone can be placed in its charging station in order to maintain a high system runtime.

2.3.1.2 Push Buttons

The main station's housing will contain a number of momentary push button switches that will correspond directly to the number acceptable voice commands. The user will only be required to use the switches during the system's initial setup but maintains the ability to use them at any time should they choose. The push buttons are used to train each of the commands individually. To train a command the user will hold down one of the buttons that corresponds to a single household appliance. They will then speak the command they want to use later to activate the device into the microphone. The message will be stored within the device and will be used for identify voice commands later.

2.3.1.3 LCD Display

A Liquid Crystal Display will be embedded into the main stations housing. It will be used as the primary source of feedback to the user and will also assist in debugging. The screen will be sufficiently large that it will be able to display a message stating the machines current state and also error messages that will be useful to the user. In order to properly display all numbers and letters SCREAM needs a minimum of a 14-segment display but should not exceed 16 segments. Additionally, it needs a display that is at least 16 digit characters in length in order to properly output messages. The display will also contain the ability for the user to adjust its contrast. This will allow the display to be easily legible in a wide range of ambient lighting conditions.

2.3.1.4 LED Lights

Light Emitting Diodes will be used in both the main stations and the client stations. The main station will contain lights that will indicate the various states the system can be in. When the unit is powered on, the LED designated for power will be lit. There will also be a LED that will flash when an audio sample is being recorded. Lastly, next to the push button that corresponds to each of the client station's names will be an LED that will

indicate whether each device is turned on or off. This will allow the user to visually see which stations are in use without having to check them all individually. LEDs will also be used on the client stations. A single light will be used to indicate whether the device is functioning and an additional light will indicate if the device is providing power or not.

2.3.2 Power Supply Specifications

There is a high importance on the specifications of the power supply that will be implemented in the system. Depending on the accuracy of these specifications, the system will perform efficiently and without any operating complications or defaults. Ideally in design, it is common to meet the desired performance specifications and then try to minimize the power consumption. The minimal power required to obtain these specifications are then considered and integrated into good designs.

The power supply for SCREAM will consist on using an AC/DC converter and multiple batteries. The AC/DC converter will be implemented in order to power up the speech recognition IC (HM2007). The AC/DC converter will help to avoid the unnecessary use of batteries. This means that the speech recognition IC will never be at risk to lose power and lose communication with the transceivers implemented to control the home appliances. Batteries will be also implemented as a secondary type of power supply to power up the wireless transceiver MCU chips (CC3200), and the op amps (LM2904) that are going to be used to amplify the DC signal coming from the output of the MCUs. The relay units and the Servo motor will get their required voltage coming from the MCUs' amplified DC signals. In addition, power from a wall outlet will be connected to the contact of the relays. The relays in active mode (switch closed) will allow current to flow through and power up the selected home appliances. The power source coming from a wall outlet normally supplies around 110 to 120 AC volts (Equivalent AC current 15 to 20 amps) at 60 Hz. Table 2 shows the power supply specifications for each element that is going to be implemented in the project.

Device	Required Supply Voltage
Speech Recognition Circuit (HM2007 IC)	5 V
Wireless MCU (CC3200)	3.6 V
OP AMP (LM2904)	6 V
Servo Motor	6 V
Relay	6 V (Coil voltage)

Table 2 - Power Supply Specifications

In respect to the specification values shown above in table 2, the AC/DC converter must be able to convert 110/120 ACV to 5 DCV, which is the minimum required voltage supply to power up the speech recognition IC. The transceivers MCUs will require a power supply of 3.6 volts. The necessary number of batteries to supply 3.6 DCV to the transceivers will depend on the number of home appliances that the user would like to control by its voice commands. The op amps are going to help to attain the necessary

amplification of the output voltage coming from the MCUs. The op amps require the voltage supply of 6 DCV in order to be functional and amplify the input signal. The op amps must be able to amplified the signal and supply 6 DCV to the servo motor and the relays. The 6 DCV will power up the servo unit and will set the relay to be in active mode.

2.3.2.1 AC/DC Converter Power Supply

In recent years, AC/DC converters have been increasingly used in the industrial, commercial, and military environment. This increment is due to the advantages that these devices can offer, which are high efficiency, compact sizes, and moderate weight. Based on these facts the AC to DC converter is the best choice to implement the integral part for the power supply unit of SCREAM. The AC/DC converter is in charge of taking the regular AC voltage supply of 110/120 ACV coming from the wall outlet, and give a constant DC output voltage of 5 DCV approximated. The output voltage remains constant, which means it is regulated whether the load current changes or there are fluctuations in the input AC voltage.

AC/DC converters are composed of a transformer, a full wave rectifier, a filter, and regulator. The transformer contains two huge copper coils, one between the two terminals of the input power supply and other between the two terminals of the output. For this specific conversion case, a step down transformer is used, which it will convert high voltage to low voltage. The rectifier converts the AC voltage output of the transformer to a DC voltage. It reverses the polarity of one half of the period of the AC signal making both parts to have the same polarity. The output from the rectification process is DC. however is not constant. To fix this issue a capacitive filtering is needed to smoothen the output. Using a simple low pass filter at the output of the rectifier will help to give a much more smoother output. The final stage is using a voltage regulator to eliminate any minimal fluctuations. A simple zener diode based regulator is perfect to take care of this issue because zener diodes have a tendency to have a fixed voltage between its two terminals when reversed biased. When the input voltage changes, the existing current through the zener diode also changes inversely keeping the output constant.

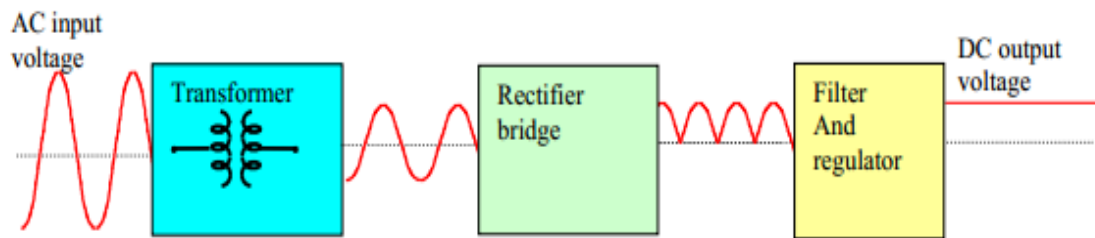


Figure 1 - AC/DC Converter Block Diagram

Allan R. Hambley, *Electrical Engineering Principles and Applications*, Chapter 15.
Permission Pending

For the simplicity to implement the AC/DC converter, a mobile phone device charger will be used to perform the AC to DC conversion task. Since the phone charger has a USB connector at the output, a modification needs to be made at the output. The output

connector needs to be removed by cutting it off from the plug and using the single wires as an input. The input coming from the wire of the charger will be used as a power supply for the speech recognition for SCREAM. The table shown below gives the spec values for the AC/DC power adapter charger for SCREAM.

Item	Specification
Input Voltage	100 to 240 ACV
Input Frequency	50 to 60 Hz
Output Voltage	5 DCV
Output Current	2000 mA

Table 3 - AC/DC Power Adapter Specifications

2.3.3 Single Supply Operational Amplifier (LM2904) Specifications

Single Supply applications have increased as a result of the popularity of portable equipment. Most portable systems operate with a single battery. Small size batteries that will work perfectly with small electronic designs sometimes do not provide the enough voltage supply to power up this specific device. For this type of circumstance a single supply op amp comes to play the role to amplify the small DC voltage signal, and provide the amplified signal to the device.

SCREAM uses a single supply op amps to amplify the small DC signals coming from the output of the transceiver MCU chips. The transceiver MCUs can only provide an output of 2.4 VDC, which does not meet the spec of 6 VDC require to set the relay or the servo in active mode. Since the relay units and servo require having a positive voltage supply, a non-inverting amplifier circuit will be implemented to amplify and supply this necessary voltage. This non-inverting amplifier is based on having an input voltage (MCU output voltage) connected to the non inverting terminal and have to two resistors connected to the inverting terminal (One resistor across the inverting terminal and ground and the other resistor across the inverting terminal and the output). The resistors will play a big role on this amplification process because in order to attain the required voltage gain of 2.5 to amplify a 2.4 VDC to 6 VDC will depend on these resistors values.

Picking the right op amp to implement a desired function is not an easy task. There is a wide variety of op amps with different specs and functions that might not work to respect to the design of the power supply for the servo motor and relays. In addition, there are some other factors that need to be considered like the availability of the device, the size, and the price. Table 4 shows the comparison of the op amps that could be used for the design of the power supply.

Item	TLC27L7	LM358	LM158	LM2904
Single supply voltage range	3V/16V	3 V/32 V	3 V/32 V	3 V/26 V
Dual supplies	±1.5V/±8V	±1.5V/±16V	±1.5V/±16V	±1.5 V/±13 V
Input offset voltage	1.5 mV	2 mV	1mV	3 mV
Input offset current	300 pA	5 nA	2 nA	2 nA
High Level Output Voltage	4.2 V	28 V	28 V	24 V
Low Level Output Voltage	50 mV	5 V	5 V	5 V
CMRR(Common-mode rejection ratio)	95 dB	85 dB	85 dB	80 dB
Output current	30 mA	20 mA	20 mA	20 mA
Supply current	0.015 mA	1.2 mA	0.5 mA	0.1 mA
Large Signal Voltage Gain	150 V/mV	100 V/mV	100 V/mV	100 V/mV
Output Current	60 mA	40 mA	40 mA	40 mA
Cost	\$0.88	\$0.95	\$2.13	\$0.89

Table 4 - Comparison of Single Supply Op Amplifiers

Item	MC33174	MCP602	LM3900	OP291
Single supply voltage range	3V/44V	2.7 V/6 V	4.5 V/32 V	2.7 V/12 V
Dual supplies	±1.5V/±22V	-----	±2.2V/±16V	-----
Input offset voltage	2 mV	2 mV	1mV	1 mV
Input offset current	5 nA	1 pA	-----	11 nA
High Level Output Voltage	-----	-----	29.5 V	3 V
Low Level Output Voltage	-----	-----	0.2 V	10 mV
CMRR(Common-mode rejection ratio)	90 dB	90 dB	85 dB	90 dB
Output current	-----	-----	20 mA	20 mA
Supply current	-----	-----	6.2 mA	-----
Large Signal Voltage Gain	500 V/mV	-----	2.8 V/mV	-----
Output Current	-----	-----	-----	-----
Cost	\$3.95	\$1.00	\$4.49	\$4.00

Table 4 - Comparison of Single Supply Op Amplifiers (Continued)

Making this comparison between all of these selected op amps helped to pick the most efficient and suitable device that will help to accomplish the desired performance and functionality for the power supply amplification. After comparing all of these devices, LM2904 is the best choice in respect to the desired specifications and reasonable cost.

2.3.4 Servo Motor Specifications

Servo motors are used in many applications, they are small in size and are very energy efficient. These features are great to operate remote-controlled or radio-controlled systems. SCREAM uses a generic high torque servo motor to implement a simple rotation open/close function for an automated door of a house. The servo circuitry is built right inside the motor unit and has a positionable shaft, which usually is fitted with a gear (as shown Figure 2). The motor is controlled with an electric signal, which determines the amount of movement of the shaft.

When the shaft of the motor is at the desired position, power supplied to the motor is stopped. If not, the motor is turned in the appropriate direction. The desired position is sent via electrical pulses from the wireless MCU chip through the signal wire. The motor's speed is proportional to the difference between its actual position and desired position. So if the motor is near the desired position, it will turn slowly, otherwise it will turn fast.

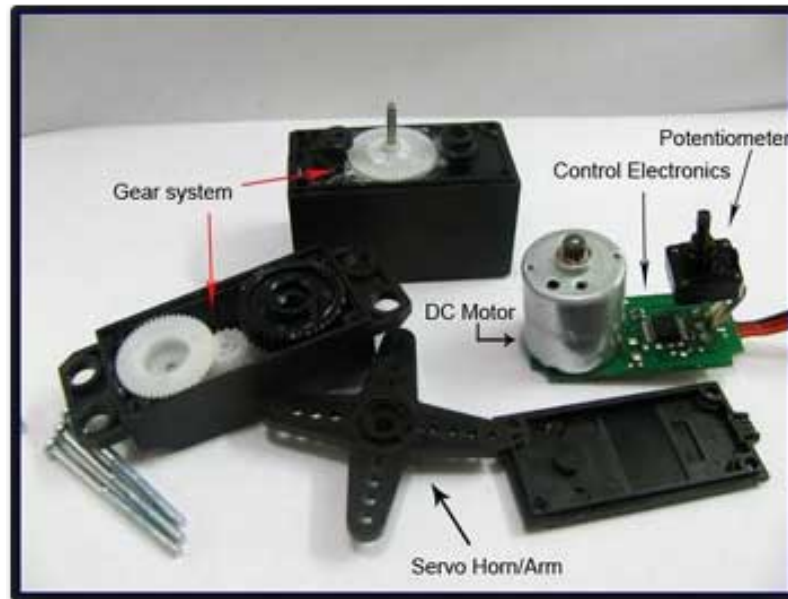


Figure 2 - Servo Motor Unit Parts

<http://electrical4u.com/servo-motor-servo-mechanism-theory-and-working-principle/>

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In addition, the implemented servo motor for this project is composed by a connector that has three colored wires, which are black for ground, red for power and white for the signal line (shown in Figure 2). The servo motor is controlled by pulses on the signal line that are referenced to the ground line, which is the return path both for servo power and the control signal. The pulse width corresponds to the position of the servo. For this specific servo the pulse width is in the range from 0.7 to 2.3 ms corresponding to the servo's "neutral" point. This neutral point is not necessarily the midpoint of the servo's maximum available range. Making the pulse shorter makes the servo go one way; making the pulse longer makes the servo go the other way.

The following tables show the specifications that are required in order to perform the desired task, which in this case is locking/unlocking the door when the user interfaces with the speech recognition circuit. The mechanical specifications will help to assemble to the servo motor with the door's deadbolt lock. The servo is going to be attached to the door using a metal frame according to its dimensions given in the table. In addition, the electrical and control specifications will describe the voltage require to power on the servo motor, the amount of torque force that is going to be distribute it in order to unlock/lock the door, and the speed of the motor gear to respect to the voltage supply.

Item	Specification
Size	A:40.8mm B:20.1mm C:38mm D:49.5mm
Weight	40g ±0.2(1.41oz)
Gear type	Plastic Gear
Limit angle	200°±5°
Motor	Metal brush motor
Connector wire	300mm ±5 mm
Horn type	Plastic

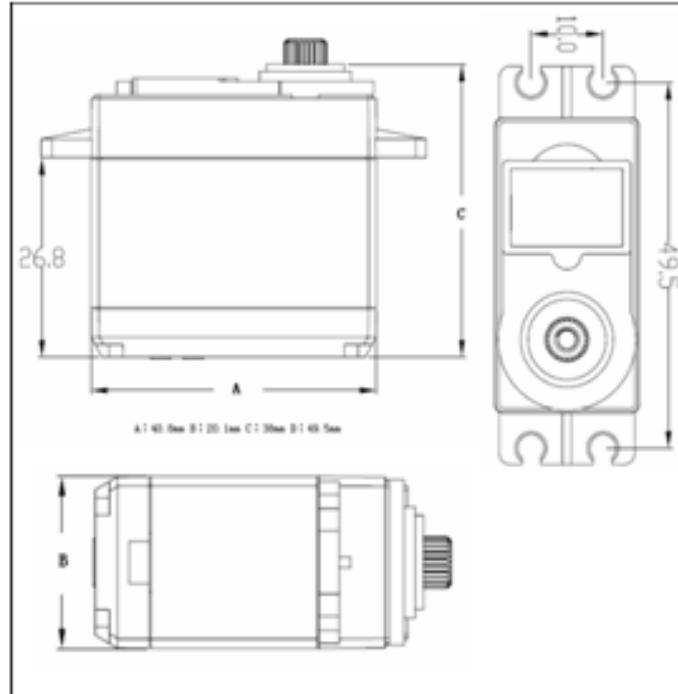
Table 4 - Mechanical Specifications for the Servos

Operating voltage range	4.8 V	6 V
Idle current (at stopped)	5 mA	7 mA
No load speed	0.18 sec/60°	0.16 sec/60°
Rating current (at no load)	160 mA	190 mA
Peak stall torque	69.56 oz.in	83.47 oz.in
Stall current	980 mA	1100 mA

Table 5 - Electrical Specifications for the Servos

Item	Specification
Command Signal	Pulse width modification
Amplifier type	Analog comparator
Pulse width range	0.7 – 2.3 ms
Neutral position	1.5 ms
Running degree	180 degrees
Rotating direction	Counterclockwise

Table 6 - Control Specifications for the Servos



*Figure 3 - Servo Motor Physical Dimensions
Feetech RC Model CO. LTD
Permission Pending*

2.3.5 Relay Control Unit specifications

Relays are going to be implemented to perform another important task, which is controlling the power supply coming from the wall outlet to the specific home appliance. Each relay unit will get a signal from the wireless receiver MCU chip according to the user's commands. Depending on this signal the relay will make the pole (or switch) to close or open, which will allow or block the power supply from the outlet to the device.

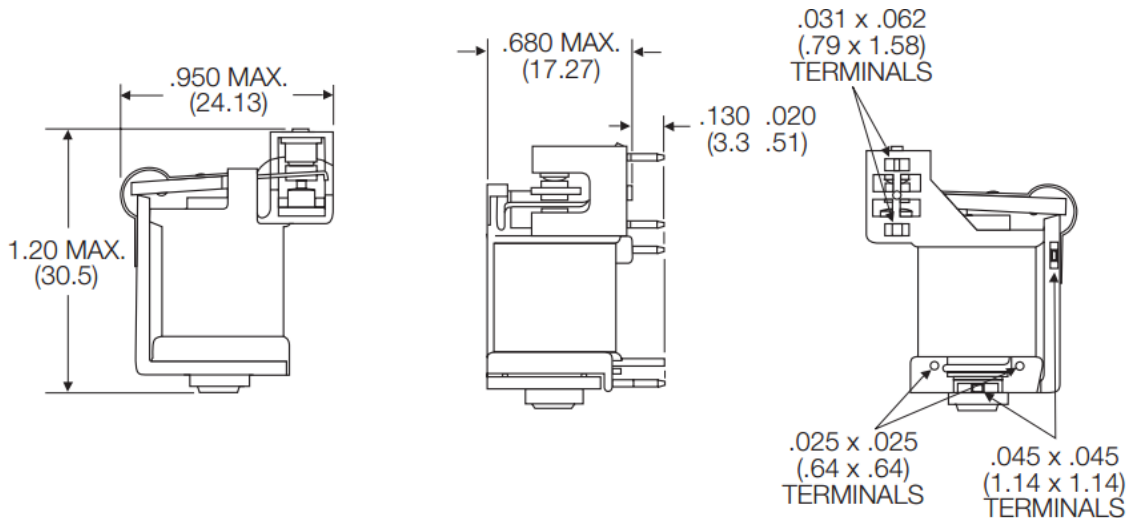
There is a broad selection of relay units to be considered in order to implement this type of wireless control for home appliances. One important factor that needs to be considered before choosing the right relay is if the unit would be capable of holding up the voltage supply from the outlet (110 to 120 AC volts) and amount of current (15 to 20 amps). Another couple factors to be considered are the size (Relay dimension need to be as small as possible) and the price of the relay. Table 7 shows a comparison of the relay units that could be implemented to the design of the power supply control unit used in SCREAM to control the on/off function of the home appliances.

Item	T90 Series	G5NB	G6B	G2R-1ZA
Type	Power Relay	Power Relay	Power Relay	Power Relay
DC Coil Voltage	6 V	5 V	5 V	5V
Maximum AC voltage	277 VAC	250 VAC	380 VAC	380 VAC
Rated Voltage	277 VAC	250 VAC	250 VAC	250 VAC
Relay Construction	Non-Latching	N/A	Single winding latching	Double winding latching
Maximum DC Voltage Relay	N/A	24 VDC	24 VDC	48 VDC
AC Coil Voltage	N/A	N/A	N/A	12 VAC
Coil Current	150 mA	40 mA	40 mA	167 mA
Coil Resistance	40 ohm	125 ohm	125 ohm	30 ohm
Contact Arrangement	SPDT	SPST	SPST	SPDT
Maximum Current Rating	30 A	5 A	8 A	16 A
Pin count	6	4	6	5
Maximum Pick Up Voltage	4.5 VDC	N/A	N/A	N/A
Weight	20 g	4 g	4.6 g	17 g
Minimum Dropout Voltage	0.6 VDC	N/A	N/A	N/A
Contact Form	1 Form C	SPST	SPST	SPDT
Operating Temperature	-55 to 85°C	-40 to 70°C	-25 to 70°C	-40 to 70°C
Operating Time	15 ms	10 ms	10 ms	15 ms
Dimension	30.5 x 24.13 x 17.27 mm	20.5 x 15.3 x 7.2 mm	20 x 10 x 10mm	29 x 25.5 x 13.5 mm
Cost	\$2.62	\$1.92	\$5.14	\$3.58

Table 7 - Comparison for Relay Units

According to these requirements and specifications, the best choice was to use an electromagnetic power relay (T90 series). This specific relay is a 1 Form C relay, which it can be characterized as SPDT (Single Pole Double Throw). SPDT Single Pole Double Throw Relays have three connections. These three connections are Common, Normally Open, and Normally Closed.

When the relay is off, the common is connected to the normally closed connection of the relay. When the relay coil is energized (6 VDC is applied), the Common swings over to the normally open connection of the relay. Single Pole Double Throw relays offer the advantage to have a normally open and a normally closed contact set in one relay. The moveable contact transfers continuity from one stationary contact to the other when the coil is energized or de-energized. Voltage isolation is then between opposing stationary contact and the moveable contact.



*Figure 4 - Electromagnetic Power Relay SPDT (T90N) Physical Dimensions
TE Connectivity
Permission Pending*

According to the specifications, this relay will work perfectly for the purpose of this project. This relay will be able to hold up the desired power source coming from the wall outlet and make the proper switch on time, allowing the required amount of power flow to the device. The small package design will help the assembly process and to save space that is going to be used on the PCB. In addition, the price of this relay is moderate and affordable, which helps to economize and to decrease the budget expenses.

2.3.5 Microcontroller Specifications

In order to choose the processor best suited for the task at hand, the class of processor to use had to be decided. The three dominant classes are microprocessors, microcontrollers, and digital signal processors. Each of the three have varying levels of capabilities, costs, and performance which are outlined below.

2.3.5.1 Microprocessor

A microprocessor is an integrated circuit that only contains a central processing unit. It contains no on chip memory, ROM or RAM, and no peripheral ports or drivers. For a microprocessor to be used in SCREAM, additional circuits for external memory, drivers, and wireless communication would be required, which would increase the size and cost of the circuit. Additionally, off chip memory would be slower and increase computational latency. For these reasons, a microprocessor would not be best suited for SCREAM.

2.3.5.2 Microcontroller

A microcontroller is a microprocessor but contains additional on-chip peripherals. Common components include ROM, RAM, UARTS, digital and analog signal conversion and drivers. Although a microcontroller costs more than its corresponding microprocessor, the cost of buying the additional external peripherals outweighs the

benefit. SCREAM will require considerable amounts of computation and communication which can be handled easily by a microcontroller but it also requires signal conversion which a MCU may not be capable of. The analog-to-digital converter on a typical MCU would not be fast enough to convert voice commands in real time and therefore a microcontroller cannot be used as the sole processing unit.

2.3.5.3 Digital Signal Processor (DSP)

A digital signal processor shares many of the capabilities that a microcontroller has but it has the added benefit of being able to easily implement many signal processing algorithms. Additional hardware allows for common processing operations to be completed in a relatively low number of clock cycles. Due to the speech processing required by SCREAM a digital signal processor would be an ideal candidate for the main processing unit. The additional processors required to control the power relays will not require the ability to process large quantities of signals so a DSP would not be required and a microcontroller may be used instead.

2.3.5.4 Family

There are three prevailing companies in the field of processor development and manufacturing. Intel, AMD, and ARM each have an array of strengths and weakness, but they ultimately differ on three fields: performance, power, and cost. Intel's processors are considered by most people to have the highest level of performance for all around usage. However, this is at the expense of cost and power consumption, both of which are a major concern for an embedded system. AMD, considered to be Intel's main competitor in the field of personal computing, offers a cost efficient alternative at only a small decrease in performance. The last manufacturer, ARM has recently become a major player in the field of mobile and embedded processing. They offer a low cost and power efficient solution that is ideal for SCREAM. ARM processors have lower performance, in metrics of clock speeds and throughput, but will be sufficient for the project's needs.

2.3.5.5 Splitting the Workload

There are three main jobs the main processor in the system is responsible for. Voice recognition, signal processing, and wireless communication. These three tasks are very different in nature and therefore it is not likely to find a single processor that is ideal for each task. For this reason the team has decided to split the job between two separate circuits. There will be a DSP to handle voice recognition and a microcontroller to handle the signal processing and communication. The integrated circuit responsible for voice recognition will work with its own external memory and when necessary this circuit will send data to the microcontroller. The microcontroller will be responsible for interoperating this data and wirelessly communicating with remote microcontrollers that will control the power relays.

2.3.6 Wireless Transceiver Specifications

The SCREAM system's main unit needs to be able to relay data to and from devices at the user's request. The user needs to know if the command did not work and needs to be

reissued. SCREAM creates this necessary user feedback via LEDs on the main unit. In order to turn this LED on the main unit needs to both transmit and receive data from SCREAM enabled devices on the network that also need to be able to send and receive data from the main unit. This is possible through a transceiver. The main unit is expected to control the slave units that allow the user to control devices. The slave units should then respond with a signal, regardless of whether or not the action was completed. This back and forth relaying of signals wirelessly describes a half-duplex requirement where the receiver is silenced while transmitting and the transmitter is silenced when receiving. This prevents damage to the other side of the transceiver. Half duplex will be cheaper (as full duplex units are more expensive to manufacture) to implement and adds a trivial limitation to the system. It will be impossible for the main unit to receive data while transmitting and vice versa.

Transceivers, regardless of top level protocol, are generally made using radio frequency (RF) communications. For embedded applications it is possible to use optical communication or infrared communication to transmit wirelessly, but both require line-of-sight which would not allow SCREAM to work as intended. Effective RF design is notoriously complex due to the sensitivity of radio circuitry and the necessity of proper antenna layout. In addition, it can be very difficult to achieve operation at the appropriate FCC designated frequency. Therefore, using a premade RF module is optimal due to the time constraints associated with the development of SCREAM. It is common for IC manufacturers to place RF modules on the same chip as a processor dedicated to a specific communications protocol resulting in a complete system on a chip (SoC). Thus, the transceiver can be grouped with the processor in its own unit. Texas Instruments makes SoC implementations for both ZigBee and Wi-Fi that are already IEEE 802.15.4 compliant. The host microcontroller, however, will need additional units to process the vocal commands.

2.3.7 Microphone Specifications

Microphones are acoustic-to-electric transducers that convert air pressure variation into electrical signals. For SCREAM, there needs to be an input mechanism that relays a user's commands into an electrical signal for use by the main device.

A dynamic microphone works on the principle of electromagnetic induction. Sound is converted to electrical energy via a permanent magnet attached to a diaphragm. The diaphragm moves with the changes of air pressure variation. The magnet vibrates through a conductive coil that lies within the magnet's magnetic field. A varying current proportional to the air pressure variation is produced in the coil. A common problem with this type of microphone is that the diaphragm does not respond linearly to all audio frequencies. Higher quality dynamic microphones often have different diaphragms, each responsible for responding to a certain frequency, that produce separate currents and are combined into one signal later. Dynamic microphones are relatively inexpensive to manufacture and are resistant to moisture and feedback.

A condenser microphone uses the idea of capacitance to convert acoustical energy to electrical energy. The diaphragm is made of a light material that vibrates and acts as one

plate of a capacitor. The two plates have a voltage across them which is applied by an external power source such as a battery or phantom power. Vibration causes the distance to change between the two plates which changes the capacitance. When the plates are closer together the capacitance increases and a charge current is formed. When the plates move apart the capacitance decreases and a discharge current occurs. This type of microphone generates a stronger signal than that from a dynamic microphone. Condenser microphones produce a flatter frequency response than dynamic microphones but are also prone to distortion at high sound levels which could be a problem if used for SCREAM.

A similar type of condenser microphone, the electret condenser microphone, replaces the phantom power needed by the capacitor with a polarized ferroelectric material which requires no polarizing voltage and is thus easier to manufacture. However, they often have a preamplifier integrated into the circuit which still requires external power. Monophonic versions of this microphone use a 3.5 mm plug that carries power to the preamplifier instead of providing a stereo signal. This specialized type of condenser microphone is often used for cellphones, computers, PDAs, headsets, and lavaliers due to decent signal response and low cost. This type of microphone is ideal for SCREAM.

Frequency responses of a microphone are often mapped on the polar plane and called polar patterns. For the purposes of SCREAM, an omnidirectional polar pattern, or a pattern that is equally responsive for all 360 degrees, could be used as it is equally responsive no matter where the microphone is placed, however it could also pick up room noise. Likewise, bidirectional, hypercardioid, supercardioid, and shotgun microphones should be avoided because of the risk of external noise pickup. Subcardioid or cardioid polar patterns are optimal for SCREAM as they respond the most to the direction they are pointed and shield sound from other directions.

A pop filter or a windscreen could be helpful in eliminating peaks in vocal transmissions. When speaking, the 's', 't', and 'p' sounds can be over pronounced and can cause distortion in the 4000 to 10000 hertz range. This may have an impact on vocal interpretation by the HM2007 chip. Pop filters are nylon coverings that are held by a wireframe on the outside of the microphone. If distortion is present during testing when using vocal commands like 'TV' or 'light' a makeshift pop filter or windscreen can be improvised by sewing a small nylon or foam covering over the end of the microphone if the microphone purchased does not already come with one.

In order for the microphone to reach most of the areas across modern American households the microphone must be wireless and must be able to transmit clearly across the domicile. Thirty feet is enough to encompass nine hundred square feet; this is large enough for most apartments and small households but is not enough to encompass larger manses. This puts a limitation on the SCREAM system, but could be expanded upon in later versions using a repeater. Two common microphone manufacturers, Motorola and Plantronics, offer wireless microphones using the Bluetooth 2.1 and later protocols and offer headsets that transmit 33 feet or more which is ideal for the requirements of the system. The microphone needs to either come paired with a USB dongle that the main unit can read the electrical data from or needs to be able to pair with a separate dongle

that the main unit can understand. There are many makers of Bluetooth enabled headsets but two of the primary developers are Motorola and Plantronics.

2.3.7.1 Motorola Hint

This headset is unique in that it comes with an infrared proximity detector which turns the unit on once it is within a certain distance of a heat source, in this adaptation the unit turns on once seated inside the human ear. Once in the charging case the unit automatically turns off. It allows 3.3 hours of talk time, which is a bit low for headsets of this class, but has a standby time of 33 hours, which makes this unit a bit more attractive. It supports up to Bluetooth 3.0, which is above the preference of Bluetooth 2.1 for security purposes. This unit does not come with a dongle, so the dongle would have to be purchased separately. It supports noise reduction and echo cancellation which would be helpful to clean up the audio signal for the HM 2007 and perhaps increase its vocal recognition. This unit excels at talk range with 150 feet of range between the unit and the receiving station which would increase the range of SCREAM considerably. The disadvantage of this unit, however, is the extreme cost of \$150 retail which is more than double the original budget of the headset component.

2.3.7.2 Motorola Whisper

This wireless microphone also uses Bluetooth 3.0 and provides noise reduction and echo cancellation. This headset, however, provides volume adjustment for the user and an increased talk time of six hours. Improved from the Motorola Hint, the Whisper allows the user 300 feet of roaming instead of 150 feet. It also has an increased standby time of six days. Unfortunately, this headset is also \$150 retail, which makes it undesirable for SCREAM. This headset sits in front of ear like a boom microphone. This unit does not come with a dongle, so the dongle would have to be purchased separately.

2.3.7.3 Motorola Silver II

This headset is also Bluetooth 3.0 compliant and offers noise reduction and echo cancellation. Both the talk time and the standby time are increased from previous units. Talk time is increased to 14 hours with a charging case and standby time is increased to 12 days. It sits behind the ear, similar to many earbud headphone models. This headset is a bit more affordable at \$130 retail, but again, is too pricey for the desired outcomes of SCREAM. This unit does not come with a dongle, so the dongle would have to be purchased separately.

2.3.7.4 Motorola Boom

This unit pairs using NFC which would require the user to physically tap the unit to the Bluetooth dongle. This also infers that the dongle chosen would require NFC abilities. Noise reduction, volume adjustment, and echo cancellation are standard features. Audio prompts are available that notify the user of battery levels. The Boom headset has a rapid charge feature that allows the user to talk for 2.5 hours for only 15 minutes of charging. On a full charge the unit allows six hours of talk time and eight days in standby mode. It

sits in the ear and hooks over the ear. At \$60 retail and 300 feet of roaming, this microphone could be used for SCREAM. This unit does not come with a dongle, so the dongle would have to be purchased separately.

2.3.7.5 Plantronics Voyager Legend

The Voyager Legend headset allows a user to pair with two devices instead of just one which would allow the user to speak with the master module and answer calls from another paired device like a mobile phone. Like many Motorola product lines, it offers noise cancellation using active digital signal processing. Plantronics does not list the roaming distance on this model, so it is difficult to rank this device in comparison to Motorola devices. This unit offers moisture protection and voice control to answer or ignore calls and does not come with a dongle, so the dongle would have to be purchased separately. The battery power on this unit allows for 7 hours of talk time and 11 days in standby mode which is comparable to Motorola. At \$100 it is a little over the budgeted amount for SCREAM

2.3.7.6 Plantronics Marque2 M165

The Marque2 M165 is priced within SCREAM's budget at \$60 and also allows for voice commands to answer and ignore calls. It also provides for noise cancelling and power saving features but does not come with a dongle, so the dongle would have to be purchased separately. In addition, it offers a "DeepSleep" mode extends the battery life up to 180 days, which is well beyond any headset examined thus far. Talk time on this device is about standard, however, at 7 hours. Plantronics does not list the roaming distance on this model, so it is difficult to rank this device in comparison to Motorola devices.

2.3.7.7 Plantronics M55

The M55 is the most desirable model among the Plantronics devices. It responds to voice commands and offers a power saving mode. The roaming distance is a standard 33 feet. The battery lasts 11 hours for active talk time, on standby the battery life is increased to 16 days, and on the "DeepSleep" mode the time is increased to 150 days. It is shaped like a standard boom mic that fits in front of the ear. The cost of the M55 is \$50 retail, which makes it desirable in terms of SCREAM's budgetary concerns but it does not come with a dongle, so the dongle would also have to be considered.

2.3.8 Speech Recognition Circuit Specifications

The speech recognition circuit is the most significant part of the project. This device must be able to take voice commands from a user and then send that signal wireless to the selected MCU chips. The speech recognition circuit will be composed of the speech recognition IC (HM2007), an external 64 KB SRAM (HM6264B IC) needed to store data, a 3 volt battery that will back up the memory of the external SRAM when the system is off because SRAM is volatile, octal latch IC (74HC573), which in charge to transfer the 8 bit output from the speech recognition IC to the 8 KB external SRAM, and

4x3 keypad that is going to be implemented to help training the board or to store each command that needs to be performed when the user interfaces with the circuit.

2.3.8.1 Speech Recognition IC (HM2007 IC)

The HM2007 IC is the main component of the speech recognition circuit. The HM2007 is a single chip CMOS voice recognition LSI circuit with the on chip analog front end, voice analysis, recognition process, and system control functions. The chip can recognize 40 words with the max length time of 0.9 sec per word or 20 words with the max length time of 1.92 sec per word. Also, the HM2007 is a low consumption power IC, it only requires a single 5 volt power supply in order to operate. A voice recognition system using the HM2007 IC can be composed of an external microphone, a keyboard, 64K SRAM and some other components.

Table 8 gives a more detailed description about the electrical characteristics of the HM2007 IC. The specifications shown in the table will help to have a more accurate and clear idea about the necessary amount of power needed to activate the HM2007 and the response time on which the system will be functioning. These factors are important at the time to implement the final design of the power supply for SCREAM.

Item	Specification
Supply Voltage	5 VDC
Response Time	300 ms
Operating Current	6 mA
Output Drive Current	1.5 mA
Output Sink Current	1.5 mA
Input Leakage Current	0.1 μ A
Input Current (Pull down)	200 μ A
Output Data Enable Width	280 ns
Output Data Holding Time	480 ns
Memory Enable Width	560 ns
Address Setup Time (to Memory Enable)	280 ns
Memory Enable to Data (Reading Starting)	280 ns
Memory Write (Write signal)	560 ns

Table 8 - Speech Recognition IC (HM2007)

2.3.8.2 64KB External SRAM (HM6264B)

The HM6264B IC will be used as the 64 KB external SRAM for the HM2007 IC. The HM6264B will support the HM2007 to store the trained words that are used at the recognition phase. The HM6264B is a 64k-bit static RAM organized by 8-kword \times 8-bit.

This device realizes higher performance and low power consumption by 1.5 μm CMOS process technology. Some beneficial features of using the HM6264B are the high speed process, low power consumption, completely static memory, so no clock or timing strobe required, and capability to achieve a battery backup operation.

Table 9 gives a more detailed description about the electrical characteristics of the SRAM HM6264B. The specifications shown in the table will help to have a more accurate and clear idea about the necessary amount of power needed to activate the external SRAM. HM6264B will be soldered to the PBC and connected to the speech recognition IC to contribute with an extended storage data space. These characteristics have great significance on the final design for the power supply for the speech recognition unit.

Item	Specification
Supply Voltage	5 V
Access Time	85/100 ns (max)
Operating Power Supply Current	7 mA
Input Pulse Levels	0.8 to 2.4 V
Average Operating Power Supply Current	30 mA
Standby Power Supply Current	3 mA
Power Dissipation	1 W
Output Low Voltage	0.4 V
Output High Voltage	2.4 V
Input High Voltage	2.2 V
Input Low Voltage	0.8 V
Read Cycle Time	100 ns

Table 9 - 64 KB External SRAM (HM6264B IC)

2.3.8.3 Octal Latch IC (74HC573)

The Octal Latch IC (74HC573) is high-speed octal D-type latch that is based on advanced silicon-gate P-well CMOS technology. This device possess the high noise immunity and low power consumption of standard CMOS integrated circuits, as well as the ability to drive 15 LS-TTL loads. Due to the large output drive capability and the 3-STATE feature, these devices are ideally suited for interfacing with bus lines in a bus organized system. When the LATCH ENABLE (LE) input is HIGH, the Q outputs will follow the D inputs. When the LATCH ENABLE goes LOW, data at the D inputs will be retained at the outputs until LATCH ENABLE returns HIGH again. When a HIGH logic level is applied to the OUTPUT CONTROL OC input, all outputs go to a HIGH impedance state, regardless of what signals are present at the other inputs and the state of the storage elements.

The Octal Latch IC must be able to hold onto the data at its inputs before transmitting the data to its outputs. This ability is useful for devices that share a single data bus, which can be related to the case of the HM2007. The Octal Latch IC will allow the processor to store data, go onto other operations that require the bus, and return to the stored data later if the need arises.

Table 10 shows the electrical characteristics of the Octal Latch IC 74HC573. The specifications shown in the table will give an accurate and a better idea about the necessary amount of power needed to power up the Octal Latch IC.

Item	Specification
Supply Voltage	2 V
Propagation Delay Time	18 ns
Input Current	1 μ A
Quiescent Current	80 μ A
Maximum Enable Time	15 ns
Power Dissipation	600 mW
Output Voltage	0 V
Ambient Temperature	+25 C
High Level Input Voltage	1.2 V
Low Level Output Voltage	0.8 V
Supply Current	0.008 mA
Pulse Width	14 ns
Set-Up Time	11 ns

Table 10 - Octal Latch IC (74HC573) Specifications

3.0 Research

3.1 Existing Home Automation Systems (HAS)

Similar to the concept of SCREAM, a voice-controlled HAS called VoicePod integrates both a mobile and a desktop device with voice controlled technology. It uses a proprietary service called BeSpoke, which uses machine learning to create a user-customized voice control menu. The special part of this HAS is that it does not require voice training in order to create the commands for the system to work. The security of this system is confined to a simple spoken PIN before issuing commands like ‘unlock door’ or ‘disarm security’. No internet connection is required to access the services, only a wake-up phrase like “Hello Voicepod” which is very similar to Google’s “Okay Google.” Like Siri, it uses text-to-speech and is thus able to say anything it needs to. For

example, it is able to read headlines from the news or stock quotes upon a market update. Installation of this HAS needs a professional touch – one of the ways the SCREAM system is different. VoicePod has two different system setups, one using ZigBee and one using Wi-Fi. The ZigBee version offers fewer features due to the limited bandwidth of the ZigBee protocol but is able to re-adjust the signal to adapt to changing home conditions and because it works between frequency bands it is resilient to interference and it is thus not prone to dead spots like Wi-Fi.

Another voice-controlled HAS technology, CastleOS, debuted on the market in 2012. It established its niche by offering a wide range of interoperability with integrated support of x10, INSTEON, Z-Wave, UPB, WeMo, LightwaveRF, Nest, Sonos, Ecobee, and others without any additional setup. It also implements voice control by using a Microsoft Kinect microphone. Its key features center around a mobile user interface, available on any phone operating system, that is easily changeable and focuses on reducing energy consumption through monitoring and event scheduling. The interface also allows for an adjustment of irrigation by the amount of rainfall expected by an independent weather service.

The Jasper Project is another voice-controlled HAS that is modeled after J.A.R.V.I.S made popular in the Ironman movies. Jasper uses also uses speech-to-text and text-to-speech using Pocketsphinx and eSpeak in order to understand voice commands and speak to the user, respectively. It uses a Raspberry Pi as a controller and a wireless modules to allow both ethernet and wireless communications. Jasper integrates Spotify to enable home theater automation and Facebook so that users can check Facebook updates. The software portion of Jasper is modular in nature, allowing developers to create their own voice commands using an open source developer API, Phonetisaurus, and CMUCLMTK. The Jasper Project uses cheap parts that, when used together, form a powerful voice controlled HAS.

HAL, or Home Automated Living, uses a PC or home server to control a home. Unlike other voice control technologies, however, HAL requires a user to use a phone, press the # key, and then issue a voice command. Unlike CastleOS, HAL provides a response when the command has been completed or was unable to be completed. The user interface is confined to a web application with an instant messaging option. HAL allows for ‘room scenes’ or a set of room configurations that saved and accessed with user key phrases. It also provides morning wake up calls, music suggestions, stock market notifications, and caller ID. The company is more open about user projects than the previous technologies as it welcomes users to provide their personal project details to share with its other users. Recent wireless technologies have caused smart houses, green buildings, and other associated home automation systems to fully realize their potential.

3.2 Technologies Applicable to a HAS

3.2.1 ZigBee

ZigBee, based on an 802.15 standard, uses AES 128 symmetric encryption keys which are important for maintaining physical access security. ZigBee defines a security toolbox

for key generation and distribution that can support multiple modes for residential, commercial, and even industrial applications. Conceived in 1998 but standardized in 2003 by IEEE, ZigBee is a freely (for non-commercial purposes) available standard typically used in low power, low latency, and low data rate (less than 250 kbit/sec) applications that require secure networking. It is designed to be simpler and less expensive than Bluetooth or Wi-Fi. Lastly, the ZigBee standard uses a mesh network to route traffic, which would be beneficial if a household has several ZigBee enabled devices. The mesh network is also a way to minimize the 10 meter line-of-sight limitation. If there are multiple devices in multiple rooms, a device in one room would use the mesh network to transmit a signal through other ZigBee devices until the signal reaches the destination. ZigBee operates in the 2.4 Ghz band for most countries worldwide, but for Australia and the United States, Zigbee operates at 915 Mhz. Unfortunately, it shares this band with Bluetooth, Wi-Fi, and other radios. It operates mostly in the physical and media access control layer, but includes a network layer, application layer, ZigBee device objects (ZDOs), and application objects. The network layer is responsible for routing, broadcasting requests, and processing received messages. The application later is the layer responsible for key establishment and propagating changes to a device across a network. ZDOs are responsible for keeping track of device roles, device security, and managing network requests. Application objects allow for customization.

There are three types of ZigBee devices. The ZigBee Coordinator (ZC) is the root of the network tree. It can bridge to other networks. It acts as the Trust Center for security keys and is generally the first device on the network. The ZigBee Router (ZR) is both a host for a running application as well as an intermediate router for other devices on the mesh network. The ZigBee End Device (ZED) is similar to a network node but it cannot relay data from other devices. ZEDs also have the longest battery life due to an increased amount of time in an idle state and can communicate with either a ZC or a ZR.

ZigBee devices, as they work in a mesh network, are subject to similar security concerns as ad hoc networks. Trust is assumed in the initial installation and processing of the keys and applications that use the same ZigBee transceiver are assumed to be trustworthy. Any layer within the ZigBee stack is responsible to maintaining its own security and access control within the layer. If used for the purposes of SCREAM, preinstalled keys would be preferred to establishing keys on the fly. This imposes a limitation of an inability to add new trusted devices to the preexisting network, but increases security by mitigating the chance of attack that could happen when adding a new device to the network and establishing trust. Simulating a ZigBee implementation is possible on network simulators like NS2, OPNET, and NetSim.

3.2.2 x10

X10 is a more mature standard developed in 1975. The benefit to using this standard is how inexpensive the components are due to how long the standard has been available. The protocol uses household electrical wiring to transmit data between x10 enabled devices. Data is encoded onto a 120 kHz carrier and a single bit is represented by a one ms burst of 120 kHz transmitted during the zero crossing of the 60 Hz AC waveform. To

meet the spirit of SCREAM, however, the radio transmission delineation of the x10 protocol would be more ideal to allow the use of wireless switches. The x10 radio protocol operates at a frequency of 310 Mhz in the United States. A radio receiver then provides a bridge to translate the radio packets into the normal electrical wiring based packets. But even normal packets are transmitted at an agonizingly slow data rate of 20 bits/sec or about 0.75 seconds to transmit a device address and a device command. This is a serious data rate transmission constraint and would limit the features that SCREAM is trying to implement and in order to use x10 the protocol those features would have to be limited to merely turning on or off a device. The dimming of lights can be performed, but due to the speed of the protocol the lights would dim in stages which would be both noticeable and annoying. In addition, x10 is susceptible to external noise from devices requiring an additional noise-filtering component to prevent spurious on or off signals. As far as security is concerned, not only does the protocol lack support for encryption but also interference is likely if an RF to power line device is used near the system.

3.2.3 Z-Wave

A newer technology that is reflected in its wider range of capabilities, Z-Wave is a proprietary wireless standard that was purchased by Sigma Designs in 2008. As such, it is not an open standard which has resulted in a relative scarcity of Z-Wave IC manufacturers when compared to ZigBee. Z-Wave transmits small packets up to 100 kbit/sec and operates at 908.42 MHz in the United States. This allows it to avoid the crowded 2.4 GHz ISM band and as such it avoids interference with Bluetooth and Wi-Fi but it can still compete with some types of cordless phones. Despite its proprietary nature, Z-Wave does have a community for hobbyists interested in HASs, like Open-zwave, which could be beneficial to implementing SCREAM.

Z-wave networks are limited to 232 nodes – which is more than enough for most residential HASs. A Z-Wave network consists of two types of nodes, a controller node and a slave node, and similar to ZigBee, it also allows data packets to travel up to 4 hops between nodes on the network (also mitigating the line-of-sight limitation) and can interface with GPIO, SPI, UART, and PWM on the Sigma Designs ZM3102 module. As an improvement on the ZigBee standard, Z-wave has an increased transmission range of 30 meters, up from 10 meters on ZigBee, between nodes. Key pairing needs to occur when each node is in its final intended location.

The Z-wave protocol also includes some security features. For example, it includes a way to use standard 128-AES encryption for pairing. But like most wireless technologies using packets (like ZigBee) it is possible to sniff encryption keys when initializing the devices and it is possible to inject packets. Both ZigBee and Z-wave are searchable through Shodan, an Internet of Things search engine, and have security exploits that have been presented to the public.

3.2.4 EnOcean

EnOcean is primarily intended for professional building automation systems, vice HASs, but it is flexible enough to be applied to residential purposes as well. It is also a relatively

new protocol developed in 2012. EnOcean modules are intended to perform without batteries as they are designed for energy-scavenging systems. It also uses small packets to transmit data at 125 kbits/sec by transmitting RF energy to symbolize a 1 and transmitting nothing for a 0. The protocol transmits at a distance of 30 meters like Z-Wave, but it does not have the open source communities that Z-Wave and ZigBee have. Security is not addressed by this protocol, so any security contributions would have to be implemented separately.

3.2.5 INSTEON

INSTEON is a unique blend of some of the features of x10 and newer mesh networking technologies like ZigBee and Z-Wave. It is like x10 in that data is transmitted over a physical layer that utilizes a home's existing electrical wiring but can also be transmitted wirelessly via RF technology. Every INSTEON device is a peer on a peer-to-peer network and autonomously transmits, receives, and repeats messages and thus does not require a controlling device. The protocol also has some error detection and correction similar to the Transmission Control Protocol (TCP). Adding a device to an INSTEON network requires "Tap-and-Tap" linking where a user locally manipulates the device to form a device-to-device control link where each device has its own unique ID. Like EnOcean, security is more of an afterthought than a core feature.

3.2.6 Bluetooth

Bluetooth is a twenty-year-old communication standard operating in the popular 2.4 to 2.486 GHz Industrial, Scientific, and Medical (ISM) band. It was standardized as IEEE 802.15.1 but the standard is now considered outdated. The protocol divides packets across a set number of channels. For Bluetooth there are 79 channels. For Bluetooth 4.0 there are 40 channels. It uses Frequency-hopping spread spectrum (FHSS) to transmit radio signals by switching across the 79 (original Bluetooth) or 40 channels (newer versions of Bluetooth) using a pseudorandom sequence known by the transmitter and receiver. A Bluetooth network consists of a master device and up to seven slave devices, but roles between devices can be switched. Switching communication to slave devices is done in a round robin fashion. The original version of Bluetooth allows for data transmission rates of up to 80 kbits/sec, but newer versions improve on this speed. It offers modest error correction using forward error correction.

Security is implemented in the pairing, or bonding, process between two devices. The two devices share a link key that is stored by both devices. Communication only occurs between bonded devices when the link key can be cryptographically authenticated. Legacy pairing is available for Bluetooth 2.0 and prior devices. Legacy pairing is where each device must share a PIN code and communication can only occur when two devices have the same PIN code. Bluetooth headsets are limited input devices that have a hardcoded 4-digit PIN. Encryption is not required and can be turned off for these devices. Secure Simple Pairing (SSP) is available for Bluetooth 2.1 and later devices. SSP is similar to public key cryptography and can prevent man in the middle attacks. To maximize security protection, Bluetooth 2.1 and later should be used.

It is very similar to Wi-Fi but Bluetooth was intended to connect portable devices. Due to the popularity of Bluetooth devices, particularly Bluetooth headsets, SCREAM would likely benefit from using a Bluetooth headset with a USB dongle due to the decreased cost. The microcontroller would need to have a method of receiving voice commands via the Bluetooth dongle and would need to route them to the voice control chip. Due to the hard-coded nature of the PIN, the headset would be easier to pair but also easier to exploit.

3.2.7 IPv6 Low power Wireless Personal Area Networks (6LoWPAN)

A relatively new protocol created in 2011, 6LoWPAN is intended to apply the Internet Protocol (IP) to the smallest, lowest-power, and most limited processing power Internet of Things (IoT) devices. It was formalized under RFC 6282 and defines an adaptation between the 802.15.4 link layer and a TCP/IP stack using IPv6. It operates using mesh network topologies, similar to ZigBee and Zwave, but there is no standard organization or alliance of organizations that certifies 6LoWPAN compliant devices, therefore different 6LoWPAN devices may or may not be interoperable on a local network. There are two security modes defined in the standard: Access Control List and Secure mode. This protocol is likely too recent to have a large open source community or maker community, which would likely be troublesome during prototyping.

3.2.8 Wi-Fi, Wi-Fi Direct, Wi-Fi Peer-to-peer (P2P)

Wi-Fi is a wireless technology developed in 1997 with the release of the first version of the 802.11 protocol. It operates in the crowded 2.4 Ghz ISM band and is the standard protocol for a large spectrum of devices such as PCs, video game consoles, smartphones, and tablets which could present a problem in terms of possible sources of interference. Wi-Fi offers a range of 66 feet indoors at speeds of at least 1 Mbit/sec but offers a higher power consumption which could present a problem to maintaining battery life. This protocol requires the use of an access point (AP) that has an Internet connection. Typically, APs default to open mode which does not provide any encryption. Wi-Fi has a few provisions for security, including some archaic methods that should not be used because they are no longer considered secure (Wired Equivalent Privacy or WEP and Wi-Fi Protected Setup). Wi-Fi Protected Access II (WPA2) uses Counter Mode Cipher Block Chaining Message Authentication Code Protocol (CCMP), an enhanced data cryptographic encapsulation using Advanced Encryption Standard (AES), and is considered secure as long as a strong password is used.

Wi-Fi Direct does not require a wireless access point in order to operate but does not sacrifice the speeds that normal Wi-Fi is capable of. A Wi-Fi Direct device has a software access point, or Soft AP, embedded into it. That is, no router is required because Wi-Fi Direct establishes an ad-hoc network where devices can communicate via a one-on-one connection or a group of devices can connect simultaneously. This part of the Wi-Fi standard, certified by the Wi-Fi Alliance, ensures that no Internet connection is required to connect devices utilizing Wi-Fi Direct. It also allows WPA2 connections, so there is no sacrifice of security to use it. Pairing can be done by pressing buttons, using a PIN code, using a QR code, or using a near field connection (NFC) to sync connections between

devices. It can also be done via a Bluetooth signal, which may make it possible to pair the hands-free microphone to the SCREAM MCU without having to add an additional Bluetooth receiver. It is also possible to know what kind of devices are available on the network without adding any additional components. Wi-Fi Direct is compatible with Android devices (since Android 4.0 Ice Cream Sandwich), iPhone5s (via iOS7), and BlackBerry (via OS BB 10.2.1) which could more easily allow a mobile component to be added to the system in later designs. Lastly, more than 6000 devices are Wi-Fi Direct certified and the protocol is forecast to ship in 80 percent of all Wi-Fi enabled devices in 2019. Using this standard will make SCREAM very interconnectable with other Wi-Fi enabled devices.

3.3 Speech Recognition Overview

Speech recognition is a normal part of many American lives whether it be interfacing with an automated help desk, dictating to a computer or smartphone, or controlling the actions of a computer or smartphone vocally. Speech recognition systems fall into two categories, small vocabulary intended for many different users or a large vocabulary intended for few users. Small vocabulary systems are limited to a small number of inputs and commands that are predetermined, like a basic menu option or choosing a number from that menu. Small vocabulary systems can understand a larger number of users regardless of accents, due to the smaller amount of the words used. Larger vocabulary systems, however, are intended for use by a smaller group of people due to the lower accuracy rate. The lower accuracy rate comes from the decreased amount of recognition that comes with using larger phrases. There are discrete voice recognition systems that processes words with a small pause between each word, but most prefer a continuous speech system that recognizes speech that occurs continuously or flowingly because it sounds conversational in nature.

Acoustical vibrations in the air caused by speech is sent to an analog-to-digital converter which translates the analog signal to a digital signal. This is done by sampling the acoustic wave at precise and frequent intervals, known as the Nyquist frequency. Unwanted noise is removed by the use of filters. Unwanted noise could be background noise, which would come through as a low rumble, and can be filtered through the use of a low pass filter around 50 Hz or a high pass filter around 15000 Hz. These filters remove frequencies that are not often found within the normal speaking range. The wave could also be normalized for volume. If perhaps the speaker was yelling or the user bumped into an object which caused a peak in the audio waveform, the speech processor would have difficulty recognizing the word intended. Normalizing the level of sound would increase the accuracy of the processor. It is imperative that the user, during voice training the SCREAM system, be aware of their surroundings. They must speak in a quiet environment and speak in a normal tone of voice. Otherwise, the voice recognition system will be have significantly reduced accuracy when recognizing words. The wave would then be sped up or slowed down in order to match the template of commands saved in the processor. A user could speak faster or slower than what was saved in memory, so changing the speed of the wave could rectify this. The wave is then separated into very small segments in order to match known phonemes in the appropriate language. A phoneme is a representation of the sounds made to conjugate expressions in the

language of choice. Phonemes are examined with regards to the phonemes around them. The processor examines a contextual phoneme plot and runs it through a complex statistical model, comparing the phonemes to a library of known words, phrases, and sentences. Once a hit is found, software using this processor could then interpret what command the user was trying to use and act accordingly.

Recent speech recognition systems use statistical modeling systems, like the Hidden Markov Model and neural networks, in order to predict what words the acoustical waves represented. These systems are intended to find the word represented regardless of accent, homonym, or enunciation. For SCREAM, however, a vocal network of 60,000 words requires too much computational power to be acceptable for the embedded world.

Speech recognition is classified into two categories, speaker dependent and speaker independent. Speaker dependent systems are trained by the individual who will be using the system. These systems are capable of achieving a high command count and better than 95% accuracy for word recognition. The drawback to this approach is that the system only responds accurately only to the individual who trained the system. This is the most common approach employed in software for personal computers. Speaker independent is a system trained to respond to a word regardless of who speaks. Therefore the system must respond to a large variety of speech patterns, inflections and enunciations of the target word. The command word count is usually lower than the speaker dependent however high accuracy can still be maintain within processing limits. Industrial requirements more often need speaker independent voice systems, such as the AT&T system used in the telephone systems.

Speech recognition systems have another constraint concerning the style of speech they can recognize. They are three styles of speech: isolated, connected and continuous. Isolated speech recognition systems can just handle words that are spoken separately. This is the most common speech recognition systems available today. The user must pause between each word or command spoken. The speech recognition circuit is set up to identify isolated words of 0.96 second lengths. Connected is a halfway point between isolated word and continuous speech recognition. Allows users to speak multiple words. Continuous is the natural conversational speech we are use to in everyday life. It is extremely difficult for a recognizer to sift through the text as the word tend to merge together. Continuous speech recognition systems are on the market and are under continual development.

3.4 Components Needed to Implement SCREAM

3.4.1 Input Module

In order for SCREAM to control devices, the commands to the system must be received. A user will control the system vocally using a wireless headset. The headset will be Bluetooth enabled and will communicate via the Bluetooth protocol to a dongle located on the master module. Of the devices researched for the SCREAM system, the Plantronics M55 was the most appealing. It provides the needed amount of roaming, talk time, standby time, and is below the budgeted amount for the headset.

3.4.2 Access Point or Master Module

The access point is made up of a designed circuit board that will integrate with the CC3200 microcontroller. The CC3200 will provide SCREAM with a wireless transceiver to communicate with the other SCREAM modules. A printed circuit board is intended to interface a USB port holding the Bluetooth dongle with the HM2007 speech recognition system and TI's CC3200 allowing the speech recognition chip to process vocal commands.

3.4.3 Light Control Module

A CC3200 will be used to receive commands from the access point. A power relay will be used to implement the function on/off for the light, which is going to perform this task depending on the transceiver CC3200. The contacts of the power relay are going to be connected to CC3200, the wall outlet power source, and the light. When a user says command the access point will transmit this command wireless to the transceiver CC3200. Once the command is received, the CC3200 will send a high and low electrical signal to the power relay. The high electrical signal will activate the relay and make the switch of the poles. After the switch is made, the relay will allow the power from the outlet wall go through it. The power coming from the outlet wall going through the relay contact will turn on the light until the user says the command to turn off the light. The off command will make the transceiver to send a low electrical signal, which will make the relay poles to switch back to its original position blocking the power source for the outlet.

3.4.4 Door Control Module

A CC3200 will be used to receive commands from the access point. A servo motor unit is required for the design of the door control module, which it will be in charged of performing the close/open function for the door. The CC3200 will send high or low electrical pulse signals to the servo depending on the commands of the user. If the user wants the door to be opened, then the CC3200 will send a high electrical signal to the servo. The high pulse signal will make the shaft of the servo to rotate to the desired direction to unlock the door. If the user wants the door to be closed, then the CC3200 will send a low electrical signal to the servo. The low pulse signal will make the shaft of the servo to rotate to its original position moving the deadbolt to its locking position.

3.5 Possible Architectures and Related Diagrams

3.5.1 Microcontroller

3.5.1.1 MSP430 + Zigbee

The initial design of SCREAM used a MSP430 to process data in conjunction with a Zigbee module that would handle the wireless communication. The processor would communicate to the Zigbee module through the Universal Asynchronous Receiver Transmitter (UART). The limitations of the design included a low range on the wireless

communication subsystem. Additionally having a processor and an external communication circuit would take up more hardware space than having a single chip that could handle both processing and communication.

3.5.2 CC3200

The CC3200 is a product made by Texas Instruments that combines a microcontroller and a Wi-Fi communication system into a single chip. It has an ARM Cortex-M4 MCU with on-chip wireless internet and security protocols. Running at 80MHz and also having on-chip RAM and ROM make the CC3200 an ideal candidate for the project. Using Wi-Fi will allow communication to remote chips in a wider area throughout the household and having all of these capabilities on a single chip will reduce the space requirements.

3.5.3 MSP430 + Sub 1GHz

Another communication option available while using the same MSP430 microcontroller is to use a communication booster pack. Texas instruments makes a CC110L RF Booster Pack which can be easily added on to a development board. The boosterpack operates in the 902 - 928 MHz ISM bands and can be controlled using their software application, the AIR BoosterStack. Each of the extension kits are transceivers so they can both send and receive data. Using frequency attenuation can enable a single transmitter to operate with multiple receivers. Booster packs do require the use of some GPIO pins, but there would still be adequate pins available.

3.5.2 Speech Recognition

3.5.2.1 Android

The Android Software Developers Kit has built in libraries and an API designed for speech recognition. The use of this kit in an embedded environment would involve the use of an open source operating system which would likely be a Linux platform. The addition of an operating system introduces a new set of challenges. They are slower than a system running without one and require overhead during power up and data transfers. Additionally, the speech recognition would still not happen on chip. Android SDK uses servers owned by Google to process the data and therefore would require access to Wi-Fi. Third party servers can have unpredictable congestion and this latency is undesirable for real time speech recognition. An alternative approach would be to use the speech recognition that is built into Android smartphones. This has similar drawbacks as the aforementioned design but would allow SCREAM to run without an OS. A problem with this option would be the additional hardware that would be required as the user would have to own or buy and an Android phone to use this product. Application development on the Android platform would also result in additional costs for licensing.

3.5.2.2 HM2007

The HM2007 is a single chip CMOS voice recognition LSI circuit with on chip analog voice analysis and recognition. Using the standard 64K SRAM a maximum of 40 words each up to 0.96 seconds in length can be trained. Alternatively 20 words up to 1.92

seconds in length can be configured. Using an external microphone and keyboard, the microprocessor can store the voice data of these commands which can later be recognized as matching words. The circuit has a response time less than 300 ms and can operate with a single 5 V power supply. It supports two control modes, manual and CPU. SCREAM would use CPU mode in conjunction with a microprocessor which would handle processing and relaying the communication to the remote stations.

3.5.2.3 Windows

All Windows operating systems after Vista have preinstalled voice recognition software. It supports over a dozen languages which would increase the potential market for SCREAM. The software allows the user to train the software to their style of speaking which helps solve the problem of words not being recognized due to accents. It is also equipped with means to compensate for different microphone configurations and room acoustics. The drawback of using Windows OS is that it would not allow the product to be a self-contained embedded system and would rely on the use of an additional computer to operate. This would increase the cost due to the additional processing and memory requirements to run and maintain a Windows platform and the size of SCREAM would increase to enclose all the additional system components.

3.6 Servo Control System

Servo control systems are the most important and widely used forms of control systems. Any piece of equipment that has rotating parts will contain one or more servo control systems. A servo system mainly consists of three basic components, which are a controlled device, an output sensor, and feedback system. This servo system is an automatic closed loop control system. Instead of controlling a device by applying a variable input signal, the device is controlled by a feedback signal generated by comparing output signal and reference input signal.

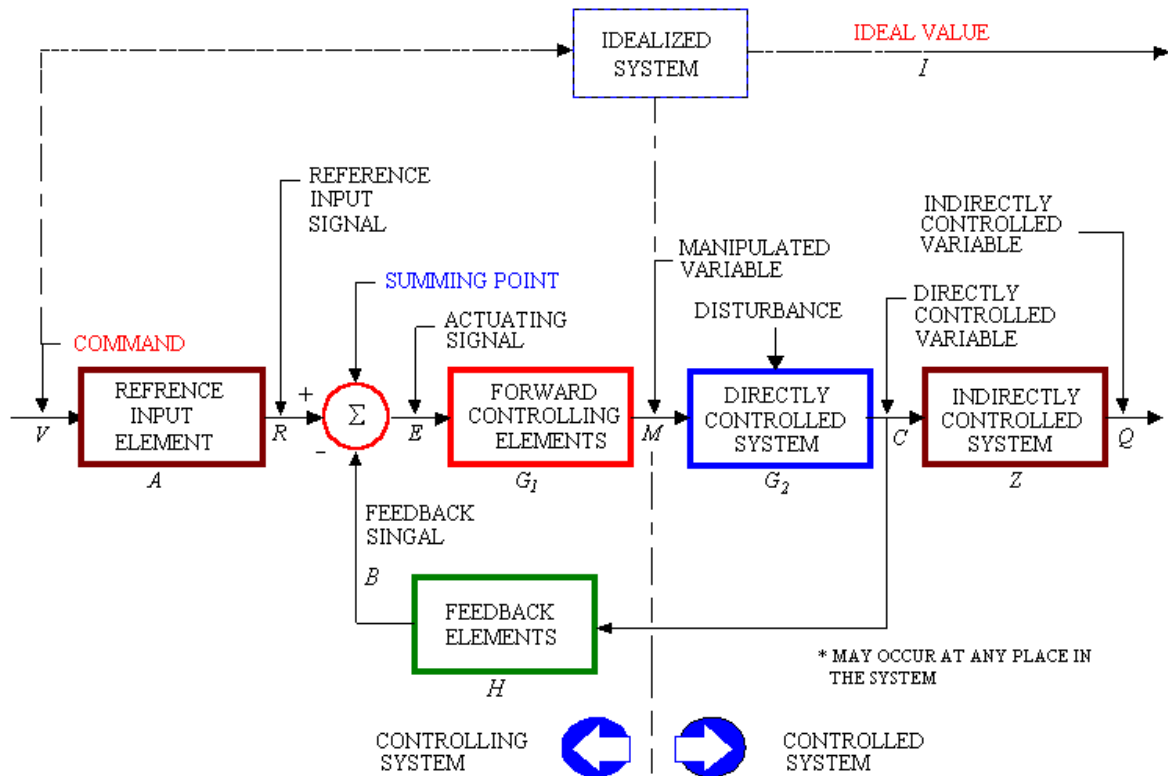


Figure 5 - Block Diagram of a Closed-Loop Control System

<http://pemclab.cn.nctu.edu.tw/peclub/W3cnotes/cn04/>

Permission Pending

The servo system takes a command signal, which is issued from the user's interface panel and comes into the servo's positioning controller. The positioning controller is the device, which stores information about various jobs or tasks. It has been programmed to activate the motor/load (change speed/position). The signal then passes into the servo control or amplifier section. The servo control takes this low power level signal and increases, or amplifies, the power up to the appropriate levels to actually result in movement of the servo motor/load.

These low power level signals must be amplified. Higher voltage levels are needed to rotate the servo motor at appropriate higher speeds and higher current levels are required to provide torque to move heavier loads. This power is supplied to the servo control (amplifier) from the power supply, which simply converts AC power into the required DC level. It also supplies any low level voltage required for operation of integrated circuits. As power is applied onto the servo motor, the load begins to move. speed and position changes. As the load moves, so does some other device move. This other device is either a tachometer, a resolver or an encoder (providing a signal which is sent back to the controller). This feedback signal is performing the positioning controller whether the motor is doing the proper job.

The positioning controller looks at this feedback signal and determines if the load is being moved properly by the servo motor; and, if not, then the controller makes

appropriate corrections. For example, assume the command signal was to drive the load at 1000 rpm. For some reason it is actually rotating at 900 rpm. The feedback signal will inform the controller that the speed is 900 rpm. The controller then compares the command signal (desired speed) of 1000 rpm and the feedback signal (actual speed) of 900 rpm and notes an error. The controller then outputs a signal to apply more voltage onto the servo motor to increase speed until the feedback signal equals the command signal, i.e. there is no error.

Therefore, a servo involves several devices. It is a system of devices for controlling some load. The load, which is regulated, can be controlled in any manner, position, direction, and speed. The speed or position is controlled in relation to a reference (command signal), as long as the proper feedback device (error detection device) is used. The feedback and command signals are compared, and the corrections made. Thus, the definition of a servo system is that it consists of several devices, which control or regulate speed/position of a load.

3.6.1 Servo Motor Control

A servo motor is basically a DC motor along with some other special purpose components that make a DC motor a servo. In a servo unit, you will find a small DC motor, a potentiometer, gear arrangement and an intelligent circuitry. The intelligent circuitry along with the potentiometer makes the servo to rotate according to the user commands.

A small DC motor will rotate with high speed, but the torque generated by its rotation will not be enough to move even a light load. This is where the gear system inside a servomechanism comes into picture. The gear mechanism will take high input speed of the motor and at the output; there will be an output speed, which is slower than original input speed, but more practical and widely applicable.

At the initial position of the servo motor shaft, the position of the potentiometer knob is such that there is no electrical signal generated at the output port of the potentiometer. This output port of the potentiometer is connected with one of the input terminals of the error detector amplifier. Now an electrical signal is given to another input terminal of the error detector amplifier. Now difference between these two signals, one comes from potentiometer and another comes from external source, will be amplified in the error detector amplifier and feeds the DC motor. This amplified error signal acts as the input power of the DC motor and the motor starts rotating in desired direction. As the motor shaft progresses the potentiometer knob also rotates as it is coupled with motor shaft with help of gear arrangement. As the position of the potentiometer knob changes there will be an electrical signal produced at the potentiometer port. As the angular position of the potentiometer knob progresses the output or feedback signal increases.

After the desired angular position of motor shaft the potentiometer knob reaches at such position the electrical signal generated in the potentiometer becomes same as the external electrical signal given from the amplifier. At this condition, there will be no output signal from the amplifier to the motor input as there is no difference between the external

applied signal and the signal generated at the potentiometer. As the input signal to the motor is nil at that position, the motor stops rotating.

4.0 Hardware and Software Design Details

4.1 Power Supplies

The design of the power supply for SCREAM will consist of using an AC/DC converter, batteries and operational amplifiers. The main power supply of SCREAM is the AC/DC converter, which is in charge to supply the required 5 DC volts to the speech recognition unit. For the AC/DC converter, an AC/DC wall power charger adapter for an Android tablet is going to be used as the main power supply for the HM2007. For the purpose of simplicity of the power supply design, the wall charger adapter device is the best choice due to its cost, availability and electrical characteristics. The wall charger adapter requires a modification at the output connection because the output is connected to a USB connector, which is not essential for the purpose of the design. The USB connector will be removed and the single wires from the plug of the adapter will be used as the input power supply for the speech recognition system. Figure 6 shows a block diagram of how a power supply converts electrical power from a wall socket to a device.

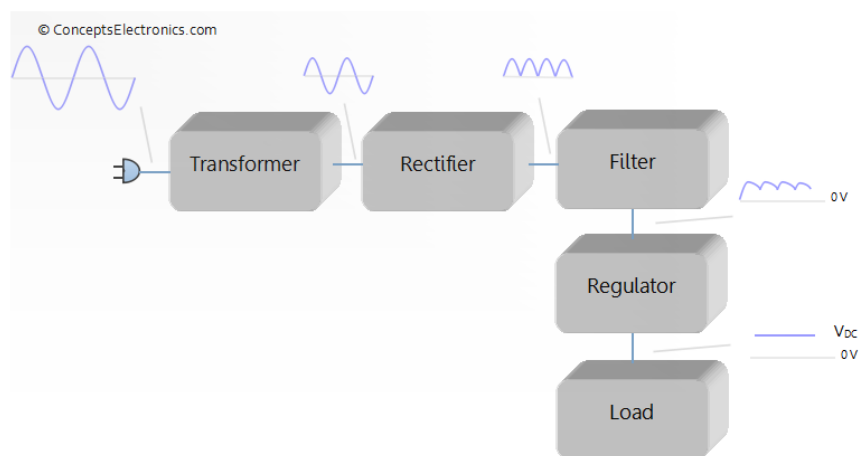


Figure 6 - Block Diagram of Power Supply
ConceptsElectronics.com
Permission Pending

Using the wall charger adapter will always give the required constant DC voltage, which means that the user will never have to worry about having the system shut off for a lack of voltage, discarding the idea of constantly changing batteries. Another beneficial factor is the space that will be saved on the design because the adapter wires will be only connected to the speech recognition unit instead of having a battery pack attached to the PCB.

In addition, batteries are going to be implemented as a secondary power supply to power up the wireless transceivers and the operational amplifier. The number of batteries required will depend on the number of home appliances that are going to be controlled by user's voice commands. A 3.6-volt battery will be needed to supply the necessary voltage

to the MCU chips. One negative factor about these MCU chips is the fact that they have a specific max output supply voltage of 2.4 VDC, which is not the sufficient amount that is needed in order to activate the relay units and the servo. Hence, op amps are going to be required to amplify this low DC signal from the MCUs. Since the MCU chips provide positive unipolar DC voltage signals, a single supply op amp will be needed to accomplish the necessary voltage amplification, which will help to set the relays and the servo in active mode.

The single supply operation of this specific type of op amps has become an increasingly important requirement, as systems get smaller, cheaper, and more portable. Portable systems, such as the speech recognition project being developed, rely on batteries, and total circuit power consumption is an important and often design issue, and in some instances, more important the cost. This makes low-voltage/low supply current operation critical.

The implementation of a single supply will help to limit the polarity of the output voltage. When the supply voltage is equal to 6 volts, the output voltage is going to be limited to the desired range from 0 to 6 volts max. This limitation precludes the negative output voltage when the circuit has a positive supply voltage, but it does not preclude negative input voltages when the circuit has a positive supply voltage. As long as the voltage on the op amp input leads does not become negative, the circuit can handles negative input voltages, which is not the case to respect to the input that will be applied to the op amp in order to meet the required specs.

For the purpose of positive amplification, a non-inverting amplifier design to accomplish this task. For this type of amplifier, the negative feedback increases the input impedance and decreases the output impedance. This type of circuit will depend of having a input voltage source connected to the non inverting input, which is the positive terminal and. This input voltage is going to be amplified to respect to the resistance values of the two resistors that are going to be connected to the inverting terminal, which is the negative terminal. The first resistor (R1) is going to be connected across ground and the inverting terminal and the second resistor (R2) is going to be connected across the inverting terminal and the output of the op amp.

The voltage across R1 is the feedback voltage applied to the inverted input. The feedback voltage is almost equal to the input voltage. Now to analyze the circuit more in depth a virtual short is applied. The virtual short will help visualize the input terminals of the op amp. Using the virtual short in the between the two terminal will mean that the input voltage appears across R1. Since no current can flow through a virtual short, the same current must flow to R2, which means the output voltage will be represented as the following equation.

$$V_{out} = I(R1 + R2)$$

Divide V_{out} by V_{in} in order to get voltage gain:

$$A_v = \frac{R2+R1}{R1} , \text{ or } A_v = 1 + \frac{R2}{R1}$$

Applying the above equation will help to calculate the values of the two resistors that will be implemented in the design to respect to the necessary gain that will be needed to amplify 2.4 volts to 6 volts. After the amplification process is completed, the amplified DC signal (6 VDC) will be sent to the selected relay or servo motor depending on the command given by the user. Table 11 shows the estimated values for the voltage gain, input voltage, output voltage and the two resistors. The values are really crucial for amplification process and the implementation of the secondary power supply for SCREAM.

Input Voltage	2.4 VDC
Output Voltage	6 VDC
Voltage Gain	2.5
R1	2.4 KΩ
R2	3.6 KΩ

Table 11 - Op Amp Estimated Values

4.2 Servo System

The servo system is one of main elements to design the automated door part of the project. The servo system will be in charge of applying the necessary force to unlock and lock the door when user says a command. A typical servo motor system is not complex. The servo motor has control circuits and a potentiometer that is connected to a output shaft. The shaft, which is the output device, links to a potentiometer and control circuits that are located inside the servo.

The potentiometer, coupled with signals from the control circuits, control the angle of the shaft anywhere from 0 to 180 degrees, sometimes further. The potentiometer allows the control circuitry to monitor the current angle of the servo motor. If the shaft is at the correct angle, the servo motor idles until next positioning signal is received. The servo motor will rotate the correct direction until the angle is correct. Each servo motor works off of modulation known as Pulse Coded Modulation, or PCM. The motor has a control wire that is given a pulse application for a certain length of time. The angular degree of the shaft is determined by the length of the pulses, which the servo motor anticipates every couple seconds.

A normal servo is mechanically not capable of rotating further due to a mechanical stop built into the main output gear. The amount of power applied to the motor is proportional to the distance it needs to travel. So if the shaft of the servo motor needs to turn a large distance, the servo motor will run at full speed. If the servo motor needs to rotate only a small amount, the motor will run at a slower speed. This is referred to as Proportional Control. The servo motor expects to see a pulse every 20 milliseconds, (0.02 seconds)

and the length of each pulse will determine how far the servo motor will rotate.

Servo motors operate on negative feedback, meaning that the control input is closely compared to the actual position via a transducer. If there is any variance between physical and wanted values, an error signal is amplified, converted, and used to drive the system in the direction necessary to reduce or eliminate error. Servo motors are controlled by a pulse of variable width that is sent from a micro-controller output pin to the servo motor's control wire. The shaft angle is determined by the duration of the pulse, also known as pulse width modulation (PWM). This pulse has to have specific parameters such as: minimum pulse, a maximum pulse, and a repetition rate. Given these constraints, neutral is defined to be the position where the servo has exactly the same amount of potential rotation in the clockwise direction as it does in the counterclockwise direction. It is important to note that different servo motors will have different constraints on their rotation, but they all have a neutral position, and that position is always around 1.5 milliseconds (ms).

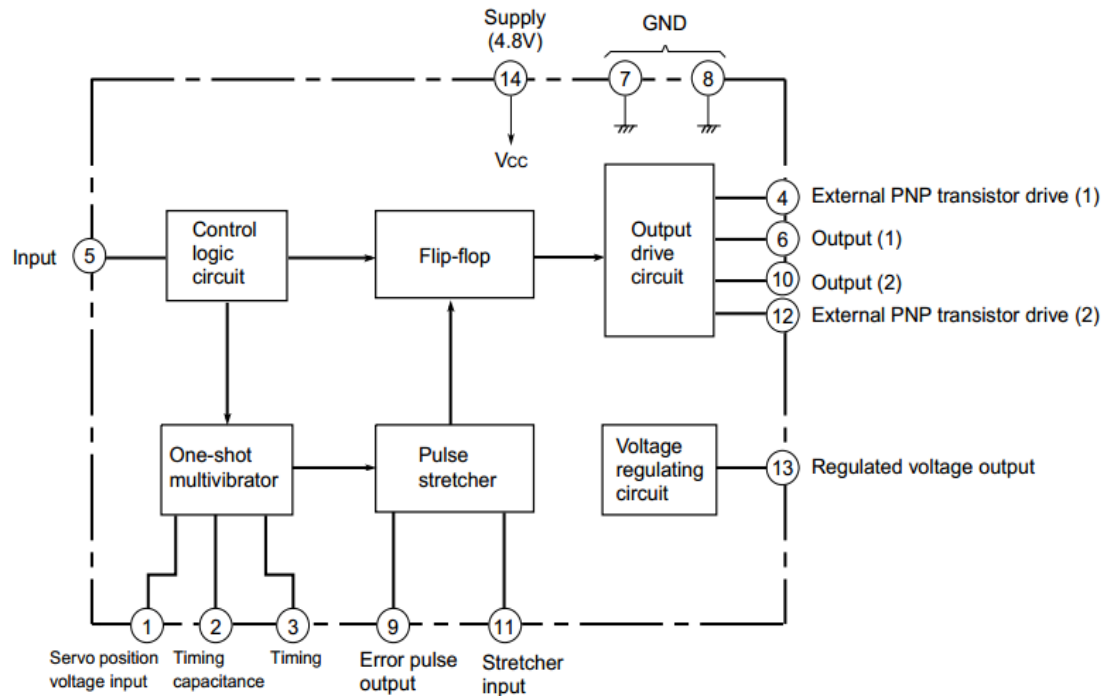


Figure 7 - Servo Motor Block Diagram

<https://www.princeton.edu/~mae412/TEXT/NTRAK2002/292-302.pdf>

Now, in order to select an appropriate servo motor for an application some people may be naive in thinking that they can just check size the motor based on the horsepower rating of the presently installed motor, or exclusively based on the application's torque requirements. The following factors must all be taken into account when selecting the appropriate motor: inertia ratio, speed, and max torque at desired speed. Any rotating object has a moment of inertia, which is a measurement of how difficult it is to change the rotating velocity of that object. Moment of inertia in a servo system can be divided into two parts; load inertia and motor inertia. The motor inertia is part of the servo design and is typically listed in the manufacturers' specification sheet. Load inertia is more

complicated because it involves every component that is moved by the motor, and is calculated using proper equations for each component. A typical inertia ratio for most applications is 5:1, but the lower the ratio is, the higher performance will be, and vice versa.

There may be a variety of servo motors that meet the required inertia ratio specifications, the next step is to find the smallest, most cost-effective servo motor that will meet the speed and torque specifications for an specific design. Servo motor manufacturers normally provide speed-torque curves for each series of motors, which illustrate several interesting points of the servo motor's characteristics. The speed-torque curve contains two regions, which are continuous and intermittent, which can translate to correct match or incorrect match (respectively) for the application. If the speed-torque required for a specific application falls into the continuous region of the speed-torque curve, then that motor can produce that torque and speed without overheating. If the speed-torque required for the application falls into the intermittent region of the speed-torque curve, then that motor can only produce that speed and torque for a limited amount of time before overheating.

In addition, the cost of the Servo Motor is based on the case, bearings, connectors, and feedback devices. The case is usually industrial grade, often sealed to achieve an IP65 rating or better. The bearings are high quality to ensure that the Servo Motor can run the speeds desired and can handle the appropriate axial and radial loads. The connectors are typically mil-style connectors that can be detached at the Servo Motor, but are very reliable and industrial grade. The feedback devices are typically differential encoders and or resolvers. These devices are very expensive and add cost to the Servo Motor. For the purpose to design automated doors for homes, the price for the selected servo motors that will help to supply the necessary rotational force to lock and unlock doors is not too expensive because to perform this task a great amount of force or high specs that are required for other industrial tasks are not needed.

4.3 Relay Control Unit

The relay control unit is in charge of controlling the AC power supply from the wall outlet to the home appliances depending on the selected command given by the user. The relay control unit is based of using a wireless MCU that will send a pulse signal that will set the relays in active mode, allowing the flow of the AC power to the home electrical devices. This section will concentrate on the design of this unit using a wireless receiver MCUs and relays. Relays come in a variety of factors, styles, and technologies. Selecting the right relay to implement the design for the control unit is critical and it will mainly depend on the application, which for this project is to control the on/off function of a home appliance.

A SPDT power relay is a switch, which uses an electromagnetic coil in order to close or open a circuit. Power relays also contain an armature, a spring and one or several contacts. If the power relay is designed to normally be open, when power is applied, the electromagnet attracts the armature, which is then pulled in the coil's direction until it reaches a contact, therefore closing the circuit. If the relay is designed to be normally

closed, the electromagnetic coil pulls the armature away from the contact, therefore opening the circuit. The SPDT power relay consists of a coil, 1 common terminal, 1 normally closed terminal, and one normally open terminal. When the coil of the relay is at rest (not energized), the common terminal and the normally closed terminal have continuity. When the coil is energized, the common terminal and the normally open terminal have continuity.

For this specific task an electromagnetic power relay SPDT (Single Pole Double Throw) T90 series 1 form C was chosen. This type of relay is widely used in remote control, automatic control and communication systems. T90 series relay will allow the circuit to switch a second circuit, which can be completely separate from the first. For SCREAM the wireless receiver MCU will supply the low voltage to relay to switch to a large AC signal for other circuit.

4.4 Microcontroller - CC3200

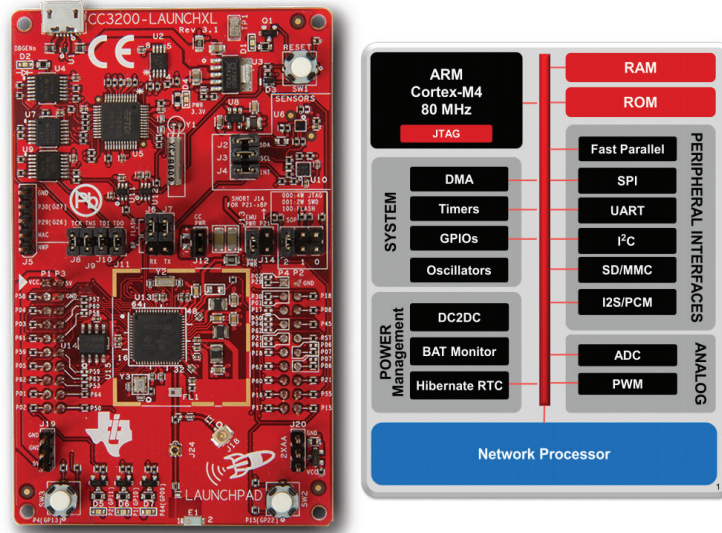


Figure 8 - Texas Instruments CC3200 and Functional Block Diagram
Block Diagram from CC3200 SimpleLink™ Wi-Fi® and Internet-of-Things Solution, a Single-Chip Wireless MCU Page 3

4.4.1 Power Modes

Only two power modes of operation are explicitly enabled for host devices: hibernate and enabled. `sl_PolicySet` is the API used to configure power management. The policies that are available are:

Normal/Active: The most efficient policy between traffic delivery time and performance. The MCU executes code at an 80-MHz state rate.

Sleep Mode: The MCU clocks are gated off in sleep mode and the entire state of the device is retained. Sleep mode offers instant wake up.

Long Sleep Interval: State information is lost and only certain MCU-specific register

configurations are retained. A maximum sleep time parameter can be specified by the user to tell the system how long to sleep between two consecutive wakeups with an upper limit of two seconds, but this only works for the client. The MCU can wake up from external events or by using an internal timer. The wake up time is less than 3 ms. This is the lowest power state available and the subsystem's volatile memory is not maintained. This cannot be used for TCP/UDP servers as this interval can lead to unpredictable system behavior.

Hibernate Mode: The lowest power mode in which all digital logic is power-gated. Only a small section of the logic directly powered by the input supply is retained. The RTC clock keeps running and the MCU supports wakeup from an external event or if the RTC timer expires. Wake-up time is about 15 ms plus the time to load the application from serial flash.

4.4.2 Power Requirements

An external power source will be required for each CC3200 in order to power the device in accordance with the operating conditions summarized in the table below. However, for the door module two AA batteries will be used since a door is unable to be plugged into a wall unit.

Parameters	Pins	Min	Max
V _{BAT} and V _{IO}	37, 39, 44	-0.5 V	3.8 V
V _{IO} - V _{BAT} (differential)	10, 54	-	0.0 V
Digital Inputs	-	-0.5 V	V _{IO} + 0.5 V
RF Pins	-	-0.5 V	2.1 V
Analog Pins (XTAL)	-	-0.5 V	2.1 V
Operating Temperature	-	-40 C	85 C

Table 12 - CC3200 Operating Conditions

4.4.3 Clocks

The CC3200 has two separate clocks. The slow clock runs at 32.768 kHz which is the real time clock (RTC). The fast clock runs at 40 MHz and is used for the internal processor and the WLAN subsystem. Internal oscillators enable the use of other crystals instead of the dedicated ones. In addition, the RTC can also reuse an existing clock on the system.

4.4.4 Peripherals

4.4.4.1 Universal Asynchronous Receiver/Transmitter (UART)

Two UARTs are available on the CC3200. Each UART has a programmable baud-rate generator which allows speeds up to 3 Mbps. There are separate transmit and receive

FIFOs (of a programmable length) to reduce the strain on the CPU interrupt. The UART has standard line break generation and detection, and standard asynchronous communication bits for start, stop, and parity. The serial interface is fully programmable, allowing for 5 to 8 data bits, an even, odd, or no parity bit generation and detection, and 1 or 2 stop bits. Regardless if there is an OS behind the driver, it supports a simple OS wrapper, sync objects, locked objects, and logic within the driver in the case that the system is not running an OS (like SCREAM).

4.4.4.2 Serial Peripheral Interface (SPI)

The CC3200 includes one SPI module that can be configured as a master or slave device. It only supports the use of 4-wire SPI. It can use 8-, 16-, or 32-bit word length in Default mode 0 (CPOL=0, CPHA=0). The SPI clock can be configured up to 20 Mbps. An additional IRQ line is required for asynchronous operations, but should not be required for the purposes of the project.

4.4.5 Memory

The CC3200 device stores a proprietary file system on the SFLASH that contains the service pack file, system files, configuration files, certificate files, web page files, and user files. A format command is available through the API that will allow users to access the total size allocated for the file system. The starting address is always located at the beginning of the SFLASH and cannot be changed. The file system API works in plain text but the encryption and decryption subsystems are invisible to users. Encrypted files can be accessed through the file system. Regular files are stored in blocks of 4 KB and use a minimum of 4 KB flash space. Encrypted files take up double the space at a minimum of 8 KB. The maximum file size is 16 MB, which should be plenty of space for SCREAM provided that the code is programmed efficiently.

Application programs are downloaded and executed from on-chip SRAM. The SRAM must be used for both code and data. The ROM is available at address 0x0000_0000 and programmed with the bootloader and the peripheral device library. The bootloader is used as an initial program loader when the serial flash memory is empty and the library performs peripheral initialization and control functions. These can be controlled using the DriverLib software provided by TI.

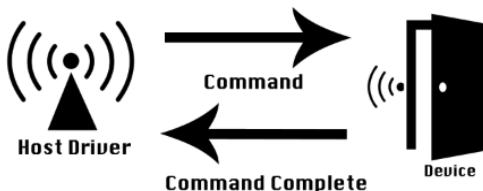
4.4.6 Cortex Processor Boot Sequence

1. After power-on-reset the processor starts execution.
2. The processor jumps to the first few lines of code in the ROM to determine if the current boot is the initialization boot or the second MCU boot. That determination is based on the status of the device-init flag in a secure register. The registers in the secure region are accessible only in the device-init mode.
3. If the current boot is the first boot, the processor executes the device-init code from ROM.
4. At the end of the boot, the processor clears the Device-Init flag and changes the master ID of the processor and the DMA. These registers are part of the secure region.

5. The processor resets itself, initiating a second boot.
6. During the second boot, the processor rereads the Device-Init flag, the bit is cleared, and the processor obtains a different master ID.
7. After executing FFL and the unsecure boot code, the processor jumps to the developer code (application).
8. For the rest of the operation (until the next power cycle), the Cortex mode is designated the MCU. During this phase, access to the secure region is restricted.

4.4.6 Using the CC3200's Transceiver

The SimpleLink Host driver to run the MCU as an Access Point (AP) requires less than 7KB of flash memory and 700B of RAM for a TCP client application. The driver can run 8, 16, or 32-bit, at any clock speed because there is no time dependency, and can use either big or little endian. To enable the bus interface in the CC3200 SPI is used, for the CC3100, SPI or UART can be used. To enable the Wi-Fi subsystem in the CC3200 the microcontroller must be used, for the CC3100, the external host processor. Unfortunately, the software and programming additional interfaces that use this software have to be ANSI C89 compliant to ensure compatibility. Sockets are formed using the Berkeley socket API. The host driver supports asynchronous event handling because networking commands, like WLAN connection establishment, may take time to process. If this happens, the host will get an Command Complete response followed by an asynchronous event. Asynchronous events signal that the command that took an extended amount of time has finished and signals a process return. Commands between the host driver and the device work as depicted in the following Figure 9:



*Figure 9 - Communication Procedure for CC3200 Network Processor Subsystem
Icons made by Freepik from www.flaticon.com is licensed under CC 3.0*

Security options for the subsystem are open security, WEP with a 5 to 13 character ASCII password, and WPA with a 8 to 63 character password. For SCREAM, WPA will be used and not WEP due to the increased security associated with WPA.

4.4.6.1 Networking

In order to create an application that utilizes the network via the SimpleLink MCU, the application must have a series of basic components. First the system must be woken from the hibernation state. Then, the device must check its configuration. If the configuration must be changed, for example if the MAC address must be changed or the device is changed from an AP to a peer-to-peer (P2P) device, the system has to reboot in order for the change to take effect. Afterwards, an IP address must be received before working with TCP/UDP sockets via a WLAN connection. Sockets must then be used to set up the

TCP/IP stack. The type of socket must be determined at this time (TCP or UDP) and whether the device will act as a client or a host device. If the device is to be a client, the DNS protocol must be used to determine the server's IP address by using the server's name. Once this information about the socket is determined, the socket is bound to the device. Data is then transmitted between the client and the server. Once the data transaction is complete, the socket is closed and the system is moved back into the hibernation state. Below is a diagram that details the finite state machine that must be adhered to in order to create a networking component via the SimpleLink MCU.

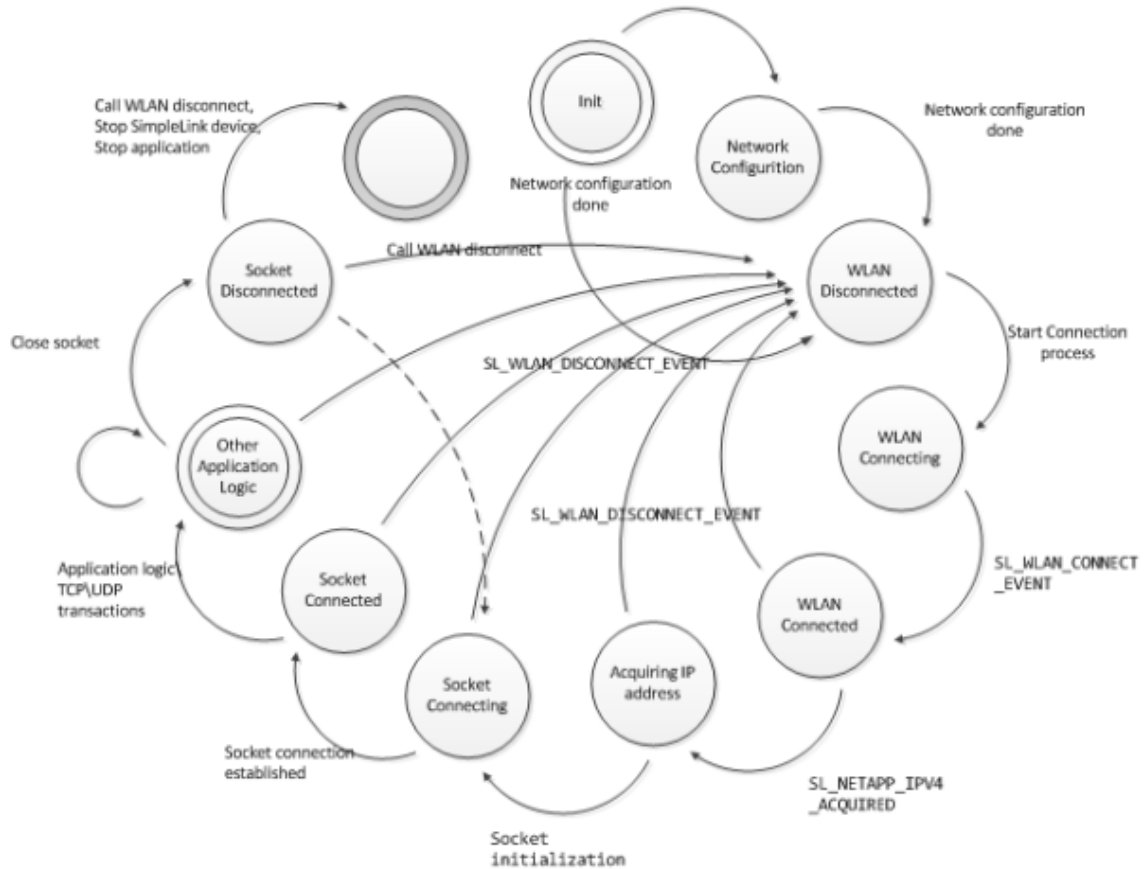


Figure 10 - Basic Networking Application State Machine
Basic Networking Application State Machine made by Texas Instruments from CC3100\CC3200
SimpleLink™ Wi-Fi® Network Processor Subsystem Programmer's Guide Page 14

4.5 Microphone

The M55 will be unit that SCREAM will utilize as a headset. It has a roaming distance of 33 feet and a battery life that lasts 11 hours for active talk time, on standby the battery life is increased to 16 days, and on the "DeepSleep" mode the time is increased to 150 days which is above the minimum required specification for battery life. The headset provides for noise reduction and echo cancellation which will allow acoustic data to be more easily processed by the speech recognition unit. The cost of the M55 is \$50 retail which allow another \$20 to purchase a generic Bluetooth 2.1 or above dongle.

The first time the headset is turned on it will automatically go into discoverable, or pairing, mode. The indicator light on the headset should flash red-white on the device while in this mode. While charging the light is solid red until it is fully charged. Two hours is required for a full charge. While at very low battery life the indicator light will give three red flashes while powering on. If the headset is out of range from the paired device, DeepSleep mode is available after 90 minutes. To exit this mode, the Call button should be tapped. This unit gives voice alerts to various statuses, but the 'Lost Connection', 'Pairing', 'Pairing Successful', and 'Pairing Incomplete' alerts should be the most useful while troubleshooting the device.

4.6 Speech Recognition

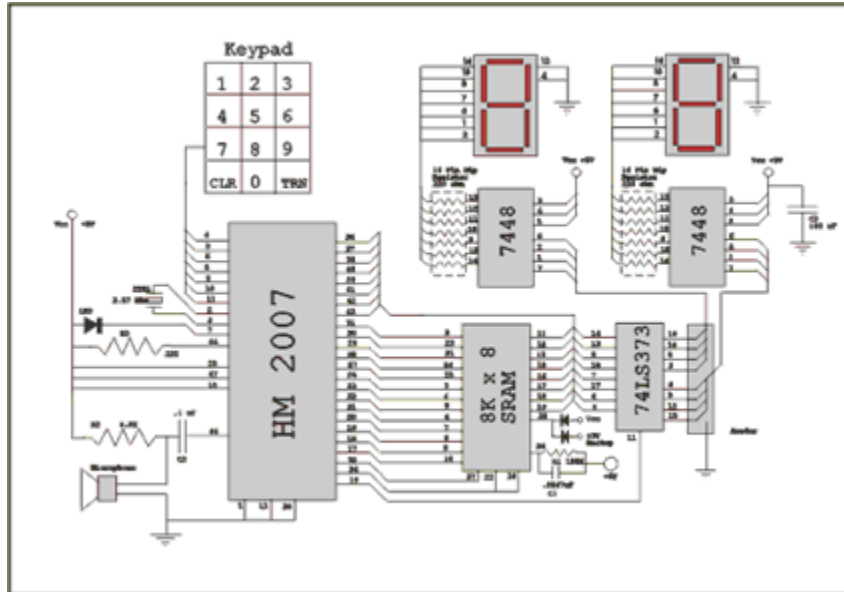
The embedded speech recognition sub system will use the HM 2007 single chip LSI circuit. It features front-end voice analysis, a recognition process and a series of control functions. It uses an external microphone 35mm port as its analog input and uses push button switches and external SRAM to store and recall voice patterns. The chip can be configured to run in manual mode which functions independently of additional control logic or in CPU mode where a microprocessor maintains control. Additionally the memory allows the use of variable length recordings for situational optimization.

The integrated circuits diagram and pin descriptions are available in Datasheet: Speech Recognition IC(HM2007) for reference. However the pins needed for operation are described in Table 12 below.

Symbol	Function
S1	Output buffer/Status register selection pin
S2	Internal register content placed on K bus
S3	K bus content placed in input buffer
RDY	Low signal when HM2007 is ready for voice input
K1-K4	Bidirectional data bus between HM2007 and microcontroller (K bus)
WLEN	Word length selection pin
CPUM	CPU mode selection pin
WAIT	Voice processing skip
DEN	Data enable signal
SA0-SA12	External memory address bus (SA bus)
ME	Memory enable pin
MR/MW	Memory read/write select pin
D0-D7	External memory data bus (D bus)

Table 13 - Description of HM 2007 Pinout

The board will first be configured and tested in manual mode to insure the proper function of the integrated circuit and peripheral components. To set the board to manual mode the pin CPUM will be connected to GND. A diagram outlining the IC, external memory, LCD display and corresponding drivers, and they keyboard are shown below.



*Figure 11 - HM 2007 IC
Reprinted from Speech Recognition Tutorial
with permission of Imagesco Scientific Instruments*

The HM2007 is able to communicate to the 64K SRAM through two unidirectional busses. A 13 bit address bus (SA bus) is used to access blocks of data and an 8 bit data bus (D bus) is used to send the data back to the IC. Also connected to the D bus are the LCD displays and their drivers. By latching on to returning data, the drivers can decode the signals and display two digit codes to provide feedback to the user.

In this configuration the keyboard is connected to pins S1-S3 and K1-K4 which are used to communicate to the microcontroller in CPU mode. They keyboard consists of 10 numbered pushbutton switches in addition to a CLR and a TRN button which will be used to program the circuit. The circuit is designed to be able to detect the use of the 12 buttons with the use of only 7 pins by using a matrix circuit configuration shown in the diagram below.

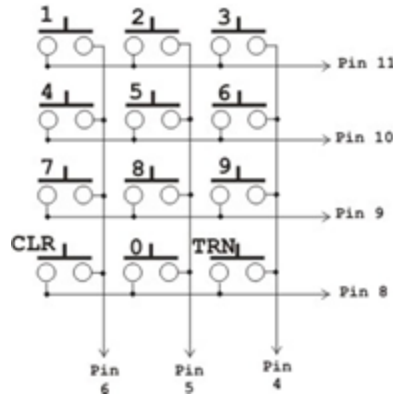


Figure 12 - HM 2007 Keypad
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A keyboard matrix is composed of rows and columns each made up of conductive wires and each key acts as a switch. When a key is pressed the column and row wire make contact and complete a circuit. The HM2007 has an integrated keyboard controller that can detect this closed circuit and register the corresponding key press. Due to this setup only a single key press can be detected at a time which doesn't present a problem for the functionality of the system but is a hazard the user should be aware of.

Manual mode supports the following operations:

- 1) Power on. Begins the initialization process. If the WAIT pin is low, the IC will perform a memory check to ensure the SRAM is available and configured correctly. If the WAIT pin is high the IC will skip the memory check. Following the completion of power on, the IC will enter recognition mode.
- 2) Recognition mode. If the WAIT pin is low the IC will not take any voice inputs. If the WAIT pin is high the IC will record the following preset word length's duration of audio. After that the processor will begin its recognition process on the word pattern and attempt to match it to a stored recording. When the processing is finished its results will be placed on the D bus and the DEN pin will be set to high indicating a result is available. The result will be in the following format.

D7	D6	D5	D4	D3	D2	D1	D0	Description
0	0	0	0	0	0	0	0	Power ON
A				B				Word AB
0	1	0	1	0	1	0	1	Voice too long
0	1	1	0	0	1	1	0	Voice too short
0	1	1	1	0	1	1	1	No Match

Table 14 - Recognition Mode Format

- 3) Training mode. To train a pattern the user first has to select which voice pattern number they want to train. To do this they will select a two digit number using the push buttons. Acceptable inputs are number 1-20 if using 0.98 second long recordings or 1-40

if using 1.96 second recordings. Following the two digit input, the user will press the TRN button. If the WAIT pin is set to low no recording will be taken, only when the WAIT pin is set to high will the recording begin.

4) Clear pattern mode. The user will enter a two digit number in the same manner as in training mode. Following the number input, the user will press the CLR button. At this point if the pattern number is valid, the recording will be cleared from memory.

5) Clear all patterns. If the number “99” is entered into the keyboard and the CLR is subsequently pressed, the HM2007 will clear all voice patterns from memory.

This concludes the functions available during manual operation mode. The same operations are available for use during CPU mode with slight modifications and there are additional functions available. To set the IC to CPU mode the CPUM pin must be connected to V_{cc} .

The HM 2007 has three four bit internal registers. A read only status buffer which is used to reflect the IC’s operating state, a read only output buffer register which is used to send results to a microcontroller and a write only input buffer register which is used to receive commands from the microcontroller.

The status register uses only its lower two bits to reflect its operating state. The four possible states are outlined in the table below. An external device can poll the K bus to see its state by setting the S2 pin high and the S1 and S3 pins low.

ST3	ST2	ST1	ST0	Operating State
X	X	0	1	Ready for voice input
X	X	1	0	Ready for command
X	X	1	1	First nibble of data is ready
X	X	0	0	Second nibble of data is ready

Table 15 - Possible States

While the HM2007 is in its “Ready for command” state the microprocessor can control its actions. To send the unit a command, the S3 pin must be set high and the S1 and S2 pins must be set low while the command code is on the K bus. The following table outlines the available commands.

Command	Code	Low Word	High Word
Recognition	001		
Training	010	B3 B2 B1 B0	0 0 B5 B4
Result	100		
Upload	101	B3 B2 B1 B0	0 0 B5 B4
Download	110	B3 B2 B1 B0	0 0 B5 B4
Reset	111		

Table 16 - Commands Available

The functions that were available during manual mode are still available but the user input that previously came through the use of the keyboard now has the option to be controlled by the microcontroller's code.

The additional commands that are not available in CPU mode are the following:

1) Resulting mode. Following the recognition mode, the IC will have the option to enter recognition mode. During this time the result from recognition mode is available to the external device. Following the RESULT command the external device must take a series of read operations to retrieve the line number and matching score. The first two reads will contain a 6 bit line number which will correspond to the matching word. The next two reads will contain an 8 bit matching score which will reflect how close the voice command matched the stored information. The scores range from 0 to 256. Using this information the external device can set a threshold to determine if the voice command was "close enough" to the recording to be a match. The application being developed for the project will allow a reasonable low threshold but a higher threshold can be set for instances where the original speaker is the only intended operator. The following table shows the encoding of the four read operations

1st read	2nd read	3rd read	4th read	Result
B3 B2 B1 B0	0 0 B5 B4	V3 V2 V1 V0	V7 V6 V5 V4	Word # and Score

Table 17 - Read Operations

2) Upload pattern. The HM 2007 stores voice recording in 64K of nonvolatile SRAM which is powered by a 3V external battery. However, if power was ever to be removed from the device all recordings will be lost. CPU mode allows for the user to upload a recording to a different external memory device. When a UPLOAD command is received, the HM2007 will wait for two additional write to occur to send the intended pattern number. The first write will send the lower 4 bits of the word and the second will send the high 2 bits of the word. Then the HM2007 will place the pattern length, in the same format, on the K bus. Following the pattern length will be the data itself which will be written to the K bus four bits at a time. After the data is received on the external device it must be stored for later access.

3) Download pattern. The download process allows for an uploaded pattern to be returned to the HM2007. The process is the same as uploading but in reverse. Now the external device sends the Download command followed by the pattern number, length, and data on the K bus.

5.0 Design Summary of Hardware and Software

SCREAM will comprise of four units, the headset, the main module, the door module, and the light module. Additional features that SCREAM could integrate are discussed in section 10. The headset will be Bluetooth 2.1 or later enabled and communicate using the Bluetooth protocol to a Bluetooth 2.1 or later dongle. The dongle will be housed in a fabricated PCB board that holds the USB port, the speech recognition system, and ports

the interface with the CC3200. The CC3200 will handle the RF transceiving that will be needed to communicate between the main module and the door module or the light module and it will provide power to the main module. Similarly, on the door module a separate CC3200 will receive commands from the main module and control a servos that will actuate a deadbolt door lock open and closed. For the light module a CC3200 will receive commands from the main module and relay power to turn a light on and off. Below is a diagram of the speech recognition system that will receive vocal commands from the headset via the Bluetooth dongle in the USB port.

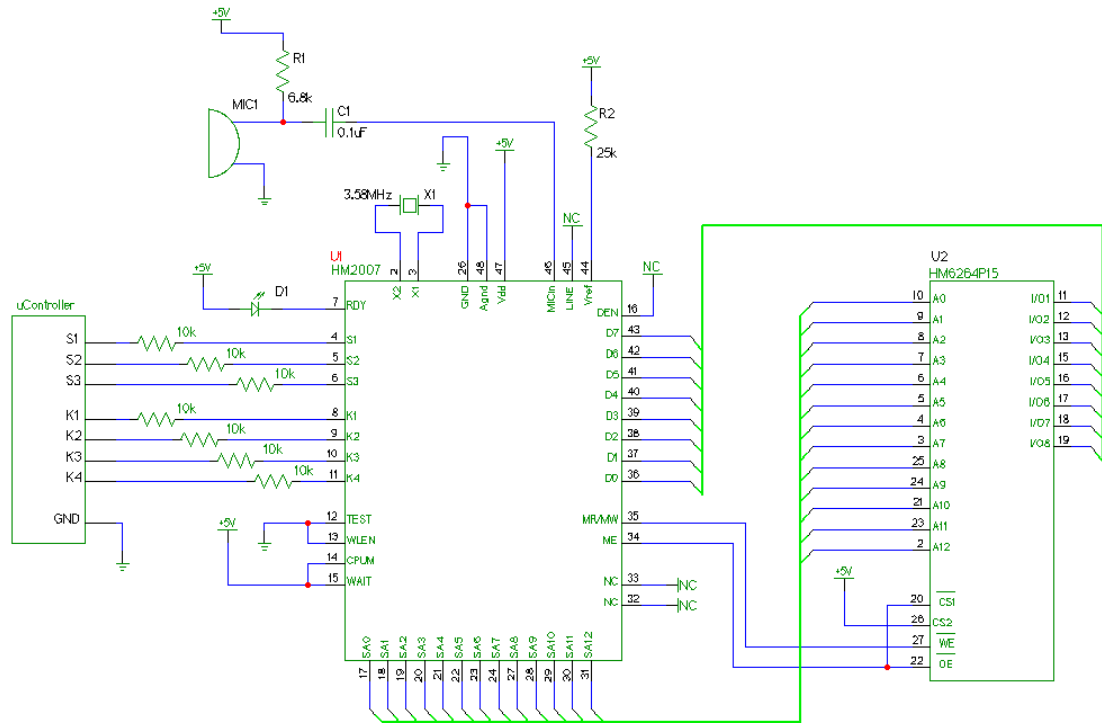
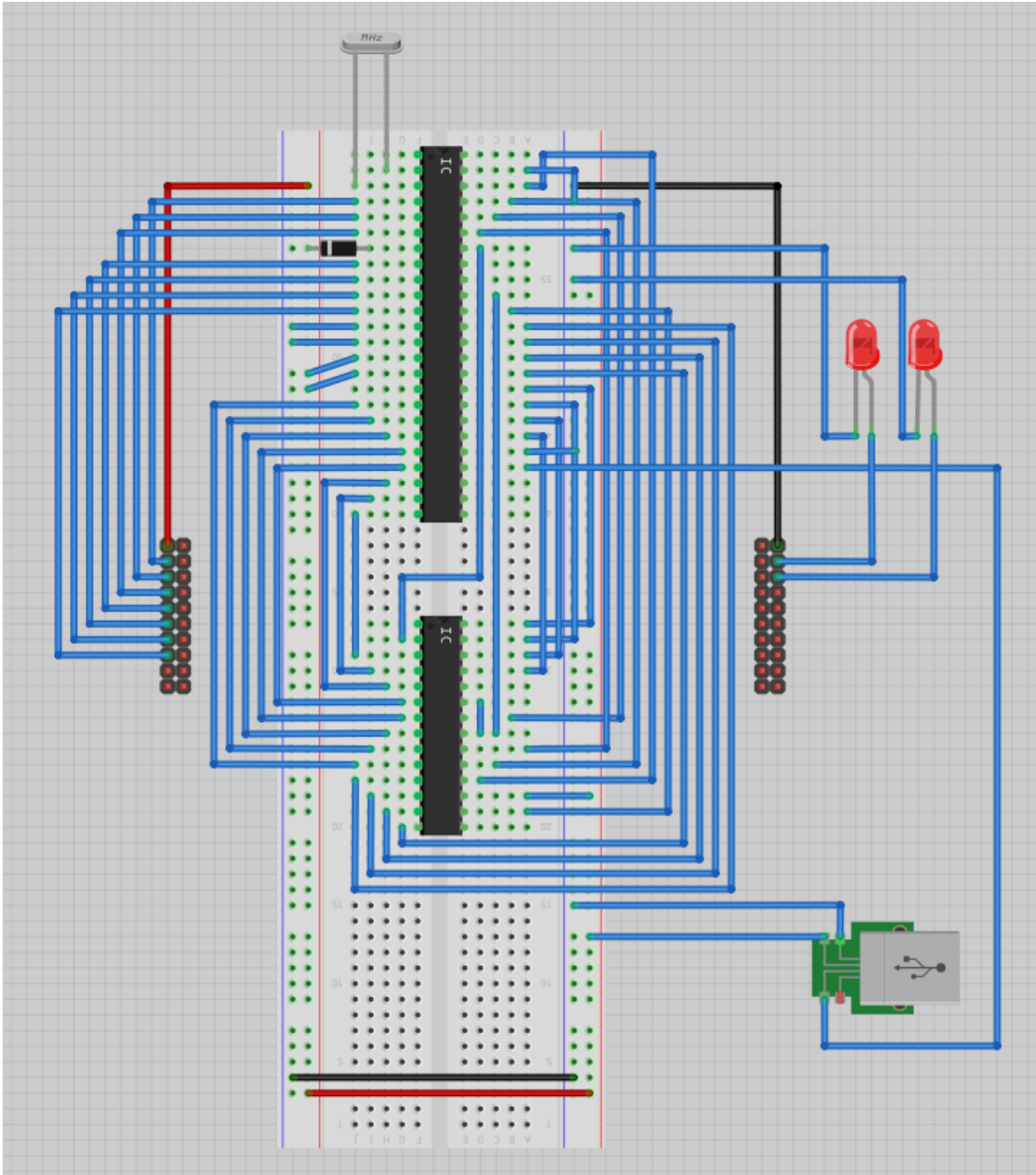


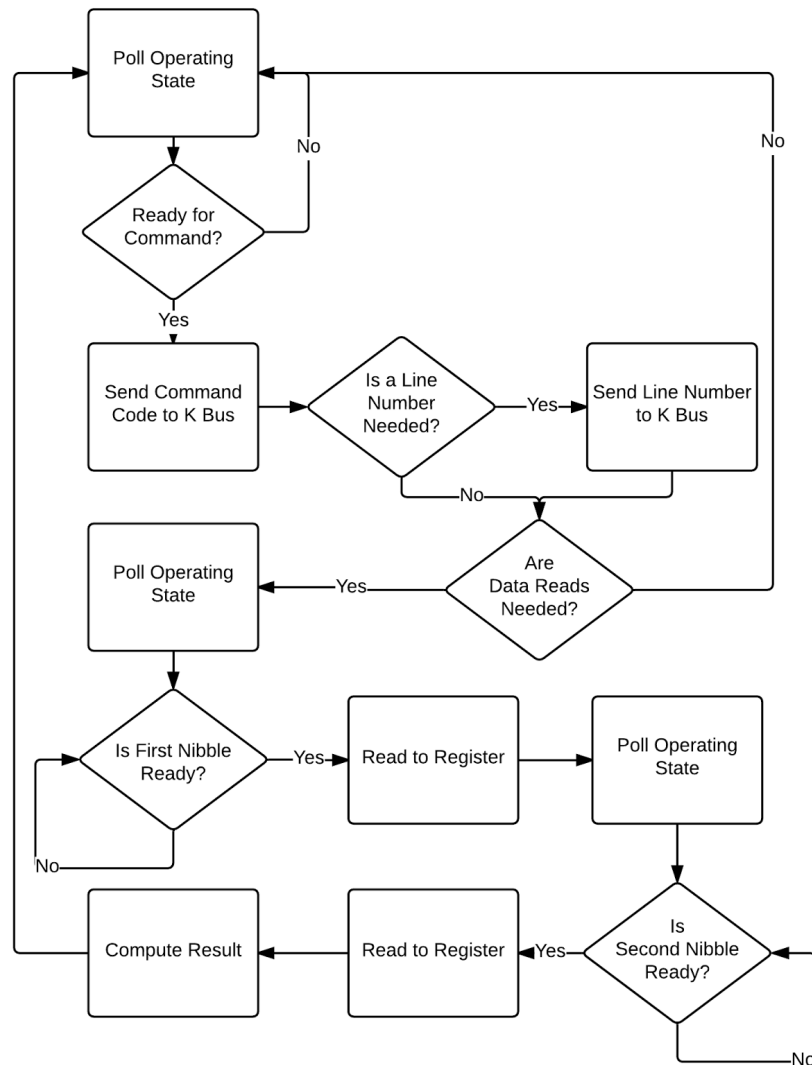
Figure 13 - Speech Recognition Subsystem

In order to begin prototyping SCREAM, a breadboard will be used to establish how connections will be formed and to ensure proper voltages are sent and received where appropriate. Below is a diagram of how the breadboard will look with the speech recognition system and the USB port.



*Figure 14 - Main Unit Breadboarding
Designed Using Fritzing*

Below is a flowchart outlining the general sequence of instructions required to send and receive information between the microprocessor and the speech recognition IC and accompanying peripherals. The operating state is obtained by reading data off of the designated S bus while commands are send on the K bus. The operating state allows the processor to know when it the SR chip is ready to receive commands as well as when it has its own data it is read to output. The unconditional loop at the end of the flow chart indicates that the program is going to run indefinitely.



*Figure 15 - Polling Block Diagram
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The following three flowcharts outline the specific list of steps to complete a successful recognition, training, and resulting sequence. Due to the difference in clock speeds between the Speech Recognition IC and the TI processor the sequence of steps can not occur synchronously. To solve this problem, the SR IC uses a status register to reflect its current operating state. So, if the processor reads the register at a high clock rate it can react to the change in state quickly enough to take the appropriate actions. The K bus which is used for data similarly has to compensate for the difference in clock rates. Since the data will be read within a given period following the change in state, the data has to be held on the bus for the specified duration.

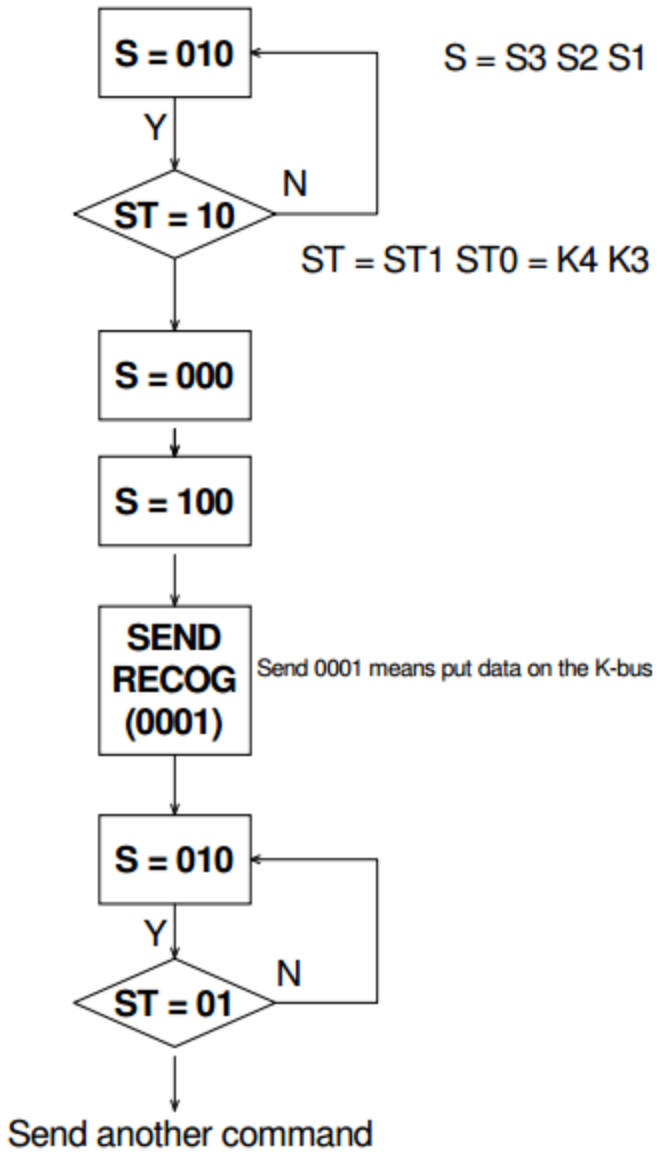


Figure 16 - HM2007 Recognizing a Command Flowpath
 Reprinted from Speech Recognition Tutorial
 with permission of Imagesco Scientific Instruments

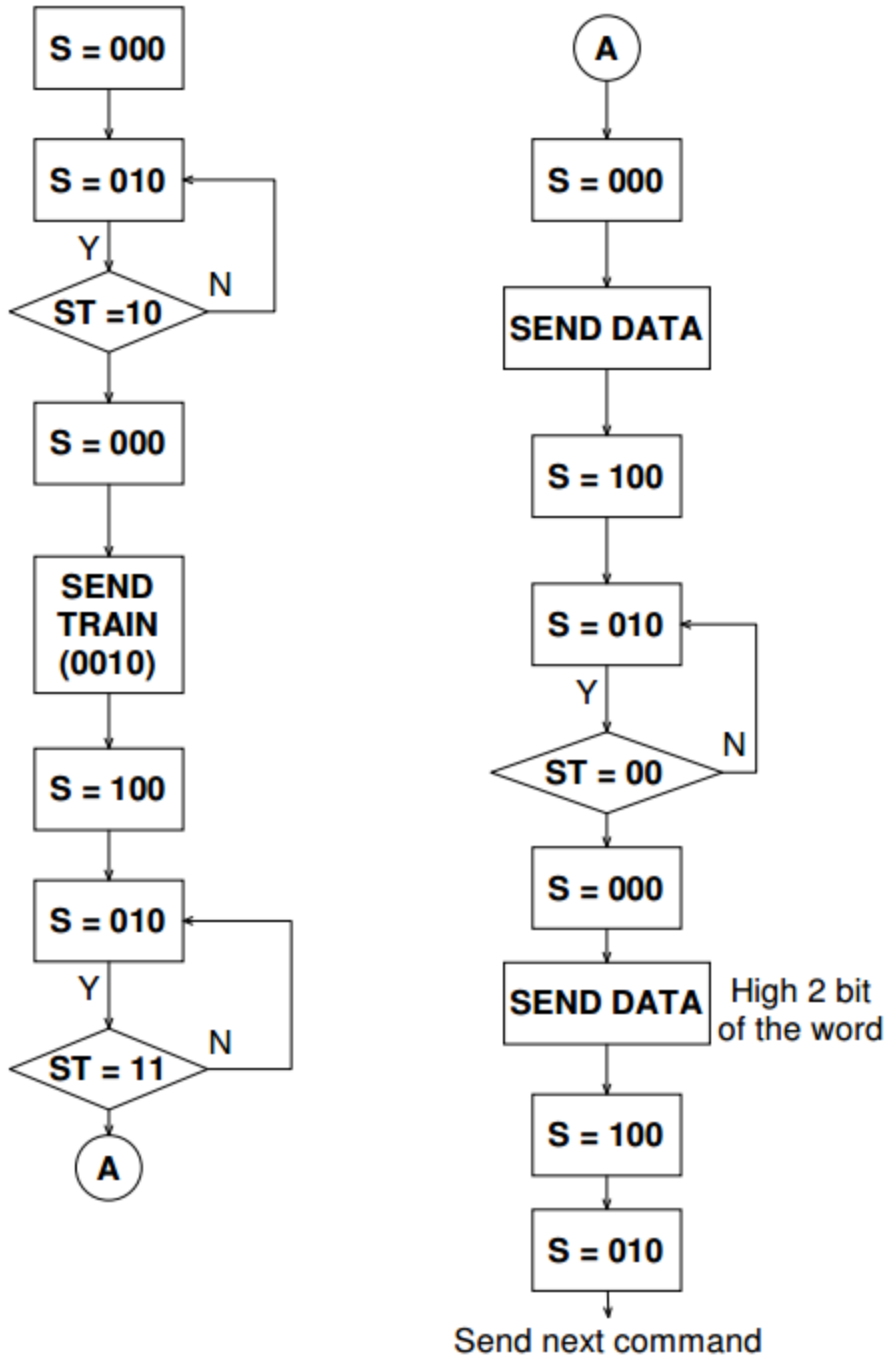


Figure 17 - HM2007 Training a Command Flowpath
 Reprinted from Speech Recognition Tutorial
 with permission of Imagesco Scientific Instruments

Updated flow chart

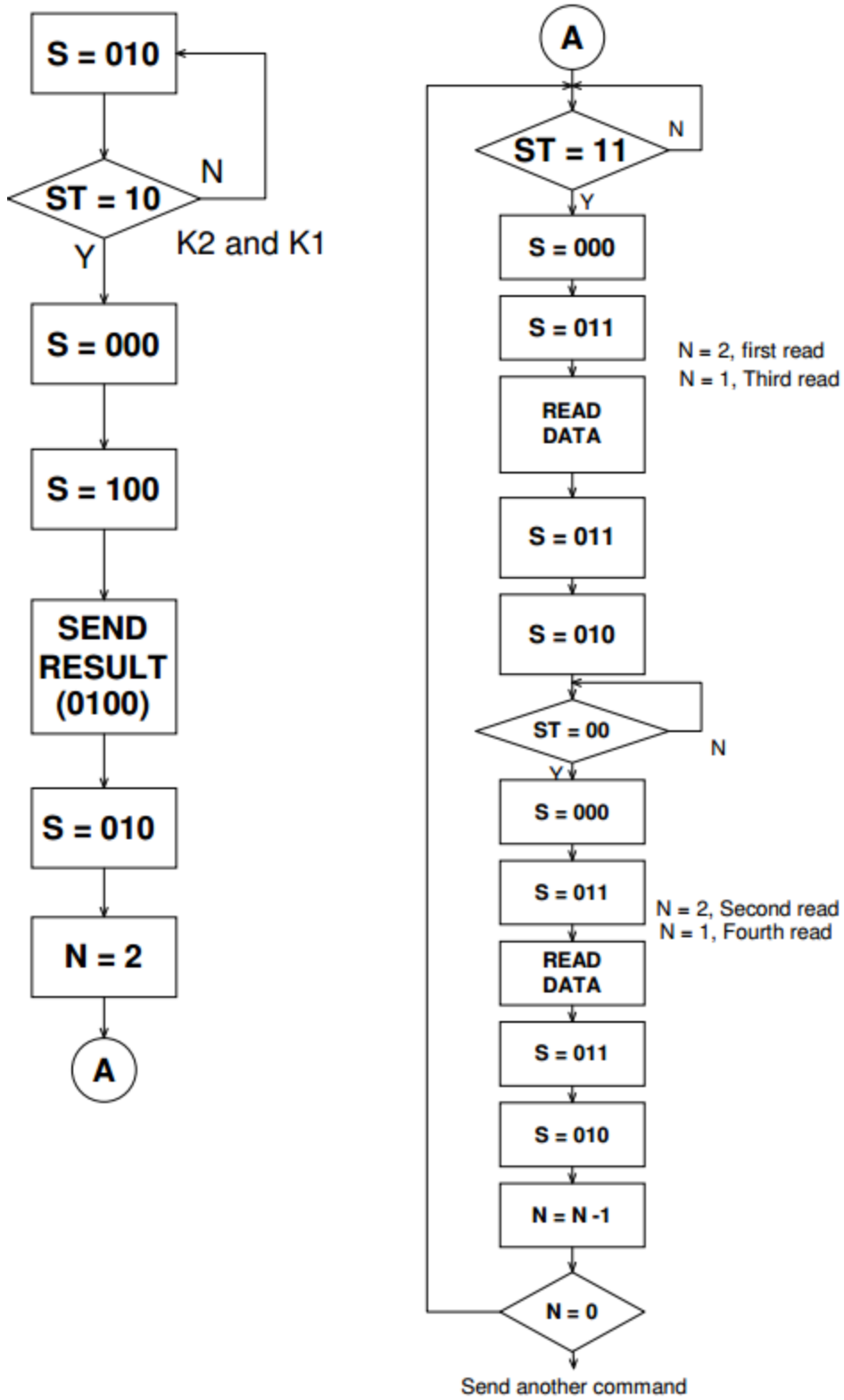


Figure 18 - HM2007 Result Command Flowpath

6.0 Prototype Construction and Coding

6.1 Parts Acquisition

The required parts for SCREAM will be acquired depending on the requirements and specification values that are needed to construct a prototype for the speech recognition system. Table 18 shows a list of the components needed to build the prototype for SCREAM. The components listed in the table are available in stock from the selected suppliers, so there will be no problem to have these components delivered in a short amount of time.

Quantity	Description	Supplier	Part Number
1	Mobile Bluetooth Headset	Plantronics	M55
1	USB Micro Bluetooth Adapter	Azio	BTD-V201
4	Single Chip Wireless MCU	Texas Instruments	CC3200
1	Speech Recognition Circuit	Imagesco	HM2007
1	USB Female Single Connector PCB mount	Velleman	CC088
3	Electromagnetic Relay SPDT	TE Connectivity	T90 (9-1393208-5)
1	Generic High Torque Servo Motor	Karlsson Robotics	ROB-11965
4	Single Supply Op Amps	Texas instruments	LM2904
4	Lithium 3.6 V batteries	Saft	LS14250
4	6 Volt Batteries	Duracell	28A
1	AC/DC Wall Power Charger Adapter	Hewlett Packard	728002801
1	Door Deadbolt Lock	The Home Depot	B60N609
1	Experiment Breadboard w/ Jumper Wires	Amazon	IB751750
1	150 W Light Bulb Lamp	Walmart	N/A

Table 18 - Parts Acquisition Table

6.2 Bill of Materials

The bill of materials for SCREAM is going to be split in subsections for each part of the whole system. Every subsection will have different components, which are going to be listed using multiple tables. Each table will show the price for the components implemented in a specific subsystem. The tables will give a subtotal for every section, which at the end all the subtotals are going to added to get a final total. The final total is shown in the Budget section (section 8.2.1).

6.2.1 Headset

Qty	Description	Supplier	Part Number	Unit Price	Total Price
1	Mobile Bluetooth Headset	Plantronics	M55	\$38.03	\$38.03
1	USB Micro Bluetooth Adapter	Azio	BTD-V201	\$12.99	\$12.99
				Total	\$51.02

Table 19 - BOM for the Headset

6.2.2 Main Unit

Qty	Description	Supplier	Part Number	Unit Price	Total Price
1	Speech Recognition Circuit	Imagesco	HM2007	\$179.95	\$175.95
1	USB Female Single Connector PCB mount	Velleman	CC088	\$0.96	\$0.96
1	AC/DC Wall Power Charger Adapter	Hewlett Packard	728002801	\$5.98	\$5.98
1	Experiment Breadboard w/ Jumper Wires	Amazon	IB751750	\$14.49	\$14.49
				Total	\$197.38

Table 20 - BOM for the Main Unit

6.2.3 Door Unit

Qty	Description	Supplier	Part Number	Unit Price	Total Price
1	Single Chip Wireless MCU	Texas Instruments	CC3200	\$18.08	\$18.08
1	Generic High Torque Servo Motor	Karlsson Robotics	ROB-11965	\$12.95	\$12.95
1	Lithium 3.6 V battery	Saft	LS14250	\$4.00	\$4.00
1	Single Supply Op Amp	Texas instruments	LM2904	\$0.67	\$0.67
1	6 Volt Battery	Duracell	28A	\$4.79	\$4.79
1	Door Deadbolt Lock	The Home Depot	B60N609	\$29.98	\$29.98
				Total	\$70.47

Table 21 - BOM for the Door Unit

6.2.4 Power Control Unit

Qty	Description	Supplier	Part Number	Unit Price	Total Price
3	Single Chip Wireless MCU	Texas Instruments	CC3200	\$18.08	\$54.04
3	Electromagnetic Relay SPDT	TE Connectivity	T90 (9-1393208-5)	\$2.62	\$7.86
3	Lithium 3.6 V battery	Saft	LS14250	\$4.00	\$12.00
3	Single Supply Op Amp	Texas instruments	LM2904	\$0.67	\$2.01
3	6 Volt Battery	Duracell	28A	\$4.79	\$14.37
1	150 W Light Bulb Lamp	Walmart	N/A	\$6.17	\$6.17
				Total	\$96.45

Table 22 - BOM for the Power Control Unit

6.3 PCB Vendor and Assembly

6.3.1 Design

Following the successful software and hardware tests of the SCREAM modules using the development board, the design will transition to a printed circuit board. The components necessary for the speech recognition circuit, the microcontroller, and all peripherals will be embedded on a single circuit board. A board layout capable of housing SCREAM will be created using software available from PCB manufacturers' websites. PCB Artist Layout Software is a free tool used by the company 4PCB that allows for the customization of all parts of the PCB design. Used in conjunction with FreeDFM software, the design should have no issues which would affect manufacturability.

6.3.2 Fabrication

SCREAM will be fabricated by 4PCB, a company with multiple manufacturing locations throughout the United States. They offer a discount for engineering students in the form of 2 layer full spec prototypes for thirty-three dollars each. They have reliable quality and low lead times which are desirable for SCREAM.

An additional option that will be explored is the creating of a Printed Circuit Board designed specifically to be used a Booster Pack compatible with Texas Instruments line of development boards. There are a collection of tools available through TI's Build Your Own Booster Pack program that provide software and manufacturing guidelines for creating a PCB.

6.4 Final Coding Plan

All coding will be done to test unit functionality of each component needed in the final design before a final code is created. There are a series of tests outlined in section 7.4 Software Testing that will be performed. The code for each of these tasks will be written in Code Composer Studio and tested using the CC3200 development board. Following the successful completion of each unit test, additional software will be used to facilitate real time code testing and debugging. Using the terminal program Putty, the programmer will be able to issue individual commands to the processor to confirm the functionality of each software test working in conjunction with each other.

Software will need to be written that establishes the main module as a server and establishing both the light module and door module as clients using the Wi-Fi protocol. Both clients will continuously poll for commands from the main module and will go into sleep mode following 30 minutes of idle time. A diagram of the polling program dataflow is available in section 5. The main module will be coded with wake up commands when it has commands that need to be relayed. After the completion of all traffic coding, encryption mechanisms will be put into place that uses WPA as the means to encrypt packet traffic on the network for security. This will be accomplished using the CC3200's embedded TCP/IP stack and TI's software which already has the means to utilize WPA encryption. Testing the network 802.11 traffic will be performed using Wireshark as

discussed in section 7.2.4.1.

7.0 Prototype Testing

7.1 Hardware Test Environment

Hardware testing will be performed in the Senior Design Laboratory. At a minimum for the hardware testing a multimeter and oscilloscope must be available to ensure that components are receiving the required voltage and current and that logic devices are receiving the correct signals at the appropriate intervals.

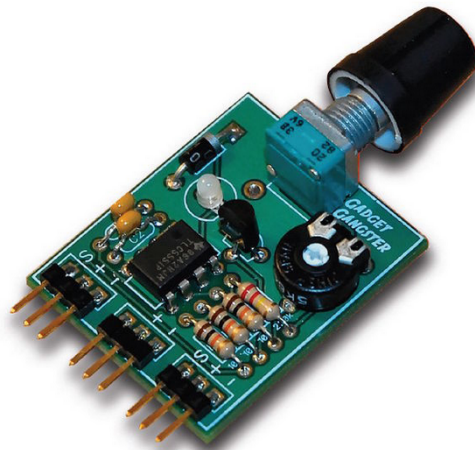
7.2 Unit Testing

7.2.1 Servo Operational Unit

The Servo Operational Unit is mainly based of using a RC servo motor to control the locking/unlocking function for a deadbolt lock of a door. Since the servo motor is one of the most important parts for this unit, it is required to be tested before is implemented to the prototype. The servo motor can be tested in two different ways depending on the circumstances.

The first way to test the servo motor is to connect it to a DC power supply and a function generator. The voltage from the DC power supply will be set depending on the operating voltage range of the servo, which in this case is about 6 DCV. The servo motor has three different connector lines, which are ground, positive and signal. To power up the servo, the ground and positive lines need to be connected to the DC power supply. Once the power supply is connected to the servo, the signal line needs to be connected to the function generator. The function generator needs to be set on the pulse signal wave mode with the corresponding frequency and peak-to-peak voltage for the servo. After all the line connectors are connected to their corresponding devices, the electrical and mechanical functionality of servo can be tested. The shaft of the servo will react to respect of the duty cycle from function generator and DC voltage supply applied to the motor. The shaft will rotate clockwise and counterclockwise on different degree positions depending of the change of the duty cycle in the function generator. If the shaft moves at the right speed and the right directions to respect to the duty cycles, then this means that the servo is functional and it can be implemented to the prototype.

The second way to test the servo motor is only going to be applied if the user does not have the necessary equipment. The user will have to build or purchase a servo tester. The servo tester is easy to build and the price to purchase one is really reasonable. The servo tester will consist of using a LM555 timer, which is configured as a low frequency astable multivibrator, which can provide good control over pulse width. The servo tester will perform the same function as the function generator, which is in charge of the control signal. The servo tester requires 5 volts to be functional. Using a 5-volt battery and the tester will let the user to run a test to check if the servo is electrically and mechanically functional for the purpose of the prototype design for SCREAM.



*Figure 19 - Servo Tester
Instructables
Pending Permission*

7.2.2 Speech Recognition Unit

The speech recognition unit has to be tested in a quiet environment where it can assimilate the voice of the user. The speech recognition circuit is continually listening when it is turned on. An easy way to test the speech recognition unit is to repeat a trained word into the wireless headset and check if the number of the word display on the digital display is right output for that specific word. For instance, if the word “test” was trained as word number 25, then the number 25 should be displayed on the digital display when the user says the word “test” into the wireless headset.

In addition, the speech recognition unit can give error codes that will be display on the screen to let the user know if there was a failure in the input word. The speech recognition unit will show the following error code if there was an error in the voice input:

- 55 = word too long
- 66 = word too short
- 77 = word no match

7.2.3 Relay Control Unit

The relay control unit is in charged to accomplish the on/off function for the home appliances. One of the main devices included in this unit is the power relay. The power relay is the one that will allow the power from the outlet wall go through to lamp or to any other home appliance. Before running a test of the whole unit is recommended to test the relay to make sure is functional. The following steps need to be performed to test the power relay using a multimeter:

- a. Keep the multimeter in the continuity check mode.
- b. Check for continuity between the N/C contacts and pole.
- c. Check for discontinuity between N/O contacts and the pole.
- d. Now energise the relay using the operating rated voltage.
- e. Again check for continuity between N/O contacts and pole.
- f. Again check for discontinuity between N/C contacts and pole.
- g. Finally measure the resistance of the relay coil using a multimeter and check whether it is matching the value stated by manufacturer.

Now if the power relay is functional after testing it, then it can be implemented to the prototype and run a full test of the control unit. The control unit can be tested by saying commands to the speech recognition unit and then see the response of the relay. For instance, when the user says the command “light on”, it means the speech recognition will recognize this command and it will send a wireless signal to the transceiver. Part of this test is going to be related to the response of the relay once the transceiver send an electrical pulse to make the relay switch to be closed or opened. Now, since the command of the user was “light on”, then the transceiver will send a high electrical pulse to the relay. The relay control unit will pass the test if the light turns on ;otherwise it will fail.

7.2.4 Wireless Transceiver Unit

The transceiver unit is already part of the CC3200’s SoC. Therefore, testing for this unit will not be hardware related (as the RF parameters are already designed and manufactured to meet FCC guidelines and regulations) but more software related to ensure that each CC3200 MCU can successfully communicate with each other. Testing will occur with a wireless packet sniffer and network analyzers that can grab and decode packets transmitted wirelessly.

7.2.4.1 Wireshark

Wireshark will be used to grab 802.11 compliant packets from the air by selecting the frequency from the preferences pane. WPA can also be decrypted using Wireshark by selecting the appropriate checkboxes and including the WPA key in the preferences pane (shown below). While the modules attempt to communicate with each other, a new live packet capture will start which will save the packet data transmitted at the predetermined frequency. These packets can then be examined to troubleshoot communications between modules.

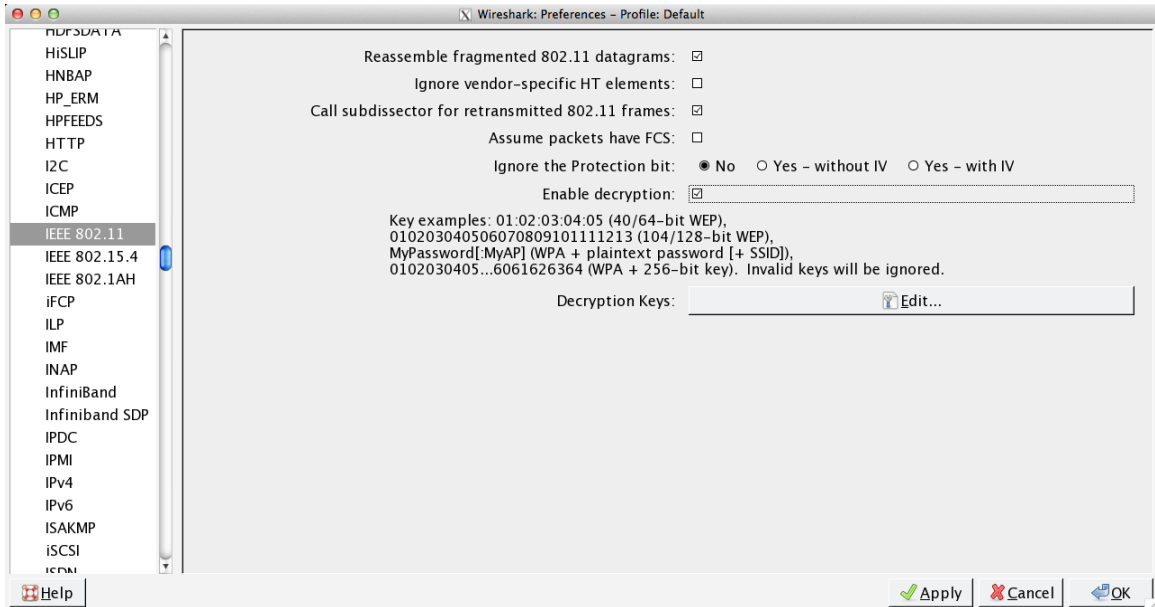


Figure 20 - Wireshark 802.11 Preferences

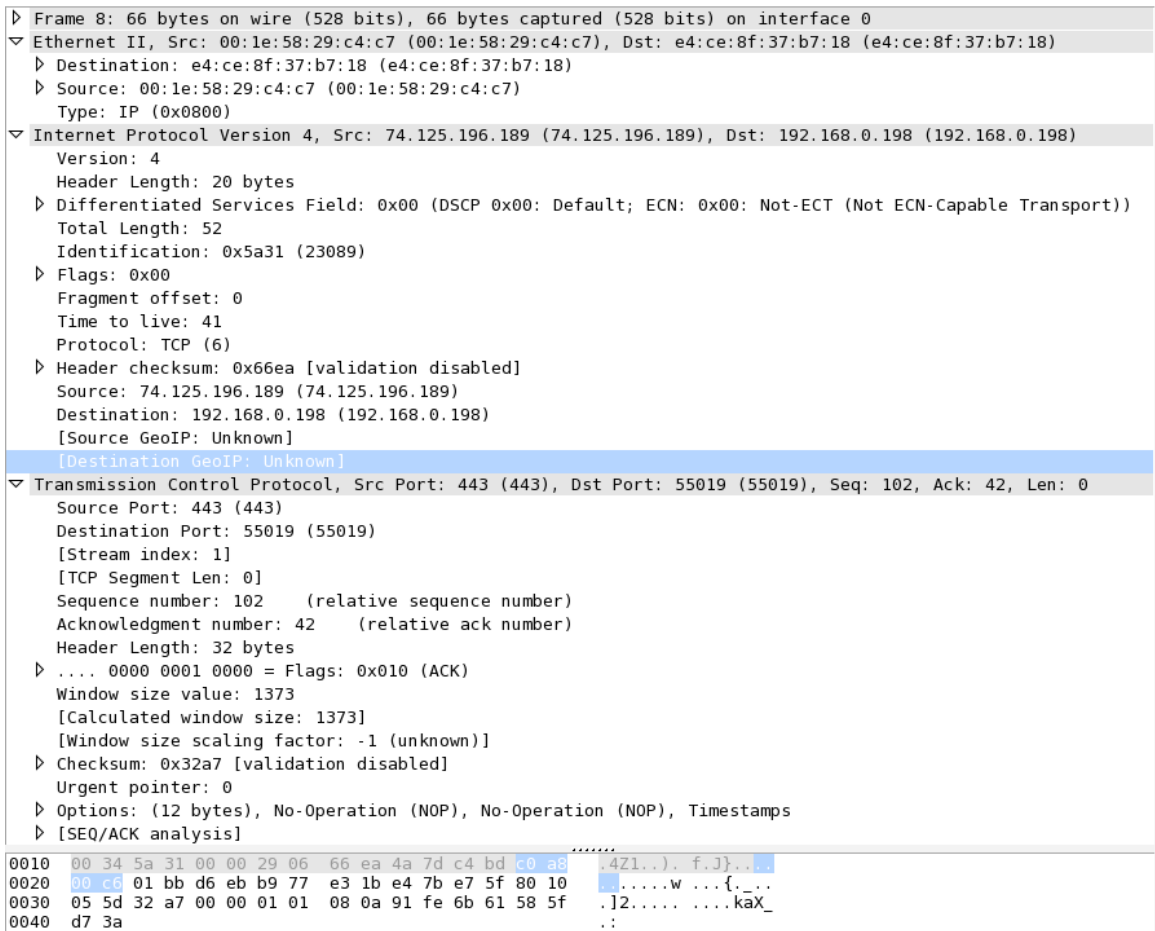


Figure 21 - Example TCP Packet Dissection in Wireshark

7.2.4.2 Ubiqua with SmartRF Packet Sniffer

Testing the functionality of multiple TI platforms is possible with a protocol analyzer developed by both Texas Instruments and Ubilogix provided that the capture device is set up with the same data rate and modulation. Ubiqua supports the IEEE 802.15.4, ZigBee 2007, ZigBee 2007 PRO, ZigBee RF4CE and 6LoWPAN protocols. In addition, this packet analyzer is capable of importing TI's SmartRF Packet Sniffer capture files. TI's packet sniffer is available on a USB drive that can be directly plugged into a PC that comes with the sniffer preinstalled with no configuration file required or can be loaded onto a flash drive. The dataflow for the packet sniffer is shown below in Figure 21. Unfortunately the software is Windows only. The packet sniffer code is also available so additional software can be created that uses the capture files. CC Debugger or SmartRF Studio can be used to debug the USB firmware.

When using SmartRF Studio, Texas Instruments advises programmers to use breakpoints with caution as they may stop the execution of code on the flash drive which may lead to Windows disconnecting the flash drive and turning off its power supply. This could be a problem during the testing and debugging phase of the project. In addition, undefined behavior may cause Windows to crash. If this happens the flash drive may have to be reprogrammed without it being powered by Windows.

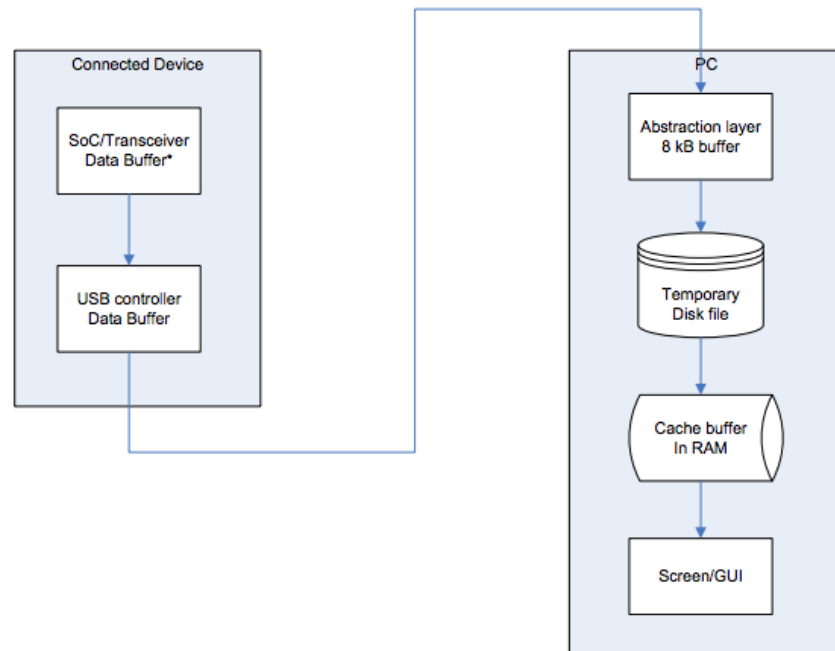


Figure 22 - Data flow for the packet sniffer (SoC)
TI's SmartRF™ Packet Sniffer User's Manual Section 1.3

7.3 Software Test Environment

7.3.1 Code Composer Studio (CCS)

CCS is Texas Instruments' integrated development environment that supports the use of all TI microprocessors and embedded processors. It contains an optimizing C compiler in addition to a source code editor and a project build environment. This suite of tools assists in the development and debugging of embedded applications. CCS is built on the Eclipse software framework but has the addition of advanced debugging capabilities. Additionally, this software development tool is used in UCF's Embedded Systems course so it is a familiar platform and requires no additional learning to begin programming.

7.3.2 Energia

Energia is an open source electronics prototyping platform that also supports the use of many TI microprocessors. This suite includes a source code editor, build environment, and similar debugging tools to CCS and Arduino. The difference between the two mainly lies in the framework. Energia is designed to bring the wiring framework used by Arduino to be used on TI launch pads. It comes equipped with a SETUP, LOOP structure and an easy to use API which makes it easy to learn.

7.3.3 Additional Software

In addition to the IDE chosen to prototype, additional software will be used to configure and test the wireless communication system. SimpleLink and AIR BoosterStack can be used to configure Wi-Fi and Sub1GHz communications respectively. Also, a terminal emulation program such as Hyperterminal or Putty can be used to test data transfers over the network. Wireshark or Ubiqua and TI's SmartRF Packet Sniffer can also be used to sniff wireless packet traffic and may help troubleshoot problems that may arise with the packaging of data according to the protocol used.

7.4 Software Testing

There will be a series of software tests that will be performed throughout all stages of system integration. The first tests will be using only the CC3200 development board and subsequent tests will be done using each additional peripheral. The list of required test stages are outlined in table 23.

Num	Summary	Hardware Needed	Software Needed
1	Blinking LED	CC3200	CCS
2	GPIO Pin Mux	CC3200, Multimeter	CCS
3	Hardware Interrupt	CC3200, Power Supply	CCS
4	Power Modes	CC3200	CCS
5	UART	CC3200	CCS, Putty
6	Serial Wifi	CC3200 x2	CCS, Putty
7	LED Control	CC3200, LED	CCS
8	LCD Control	CC3200, LCD	CCS
9	Servo Control	CC3200, Servo	CCS
10	Relay Toggle	CC3200, Relay	CCS
11	SR Reading	CC3200, HM2007	CCS, Putty
12	SR Writing	CC3200, HM2007	CCS, Putty
13	SR Training	CC3200, HM2007	CCS, Putty
14	SR Recognition	CC3200, HM2007	CCS, Putty
15	SR Resulting	CC3200, HM2007	CCS, Putty
16	SR Upload/Download	CC3200, HM2007	CCS, Putty
17	SR Reset	CC3200, HM2007	CCS, Putty
18	SR Overall	CC3200, HM2007	CCS, Putty
19	SR + Wireless Communication	CC3200 x2, HM2007	CCS, Putty
20	System Test	All	CCS, Putty

Table 23 - Software Tests

Test number 1, Blinking LED, will load the preconfigured C program provided by Code Composer Studio. By loading this simple program it will be confirmed that the unit is receiving power from the supply unit and that it is communicating properly with the IDE and compiler.

Test number 2, GPIO Pin Mux, is both a hardware and a software test. Using CCS, each pin on every port designated by the manufacturer as a general purpose I/O pin will be testing to ensure functionality. A multimeter will be connected between the ground pin and the GPIO pin being testing. Its voltage will be monitored before being toggled on to confirm their is no voltage inadvertently being applied. Next the pin will be toggled on and a voltage reading will be taken again. If the reading is the desired 3.3 V or within an acceptable range of tolerance, the pin will be confirmed as functional. If there was any unexpected noise on the pin, it can be assumed it is not configured as a GPIO pin and is being used by a peripheral such as the UART. Some of this pins may be reconfigured if

additional pins are needed.

Test number 3, Hardware Interrupt, will test the usage of external interrupts. The manufacturer diagrams designate a number of pins as having the capability of interrupts. To test these pins a simple program will be written to confirm their use. The program will place the process into the lowest level sleep mode that still has interrupt capability. Next, there will be an interrupt function that when triggered will exit the processor from sleep mode and toggle one of the embedded LEDs. To test the interrupt an external power supply set to 3.3V will be applied to the pin. If the LED is toggled, the interrupt is functional.

Test number 4, Power Modes, will test the use of the four MCU power modes and the three Network Subsystem power modes. The following table describes the device power modes:

MCU Power Mode	Network Sub-system		
	Disabled	LPDS	Active
Hibernate	Hibernate	N/A	N/A
LPDS	LPDS	LPDS	Active
Sleep	Active	Active	Active
Active	Active	Active	Active

Table 24 - Device Power Modes

Each of the power modes active subsystems will be tested. To ensure minimum power consumption during operation, the lowest possible power mode that provides the necessary functionality will be used.

Test number 5, UART, will test the use of the using real time keyboard input. Although the end user will not have access to the UART, it will enable additional real time software tests to be performed. There is a sample UART program available in the CC3200 Software Developers Kit that will be modified based on the project's requirements.

Test number 6, Serial Wi-Fi, will be the first test performed that uses the wireless communication ability of the CC3200. Two development boards will be loaded with the same program code that will allow them to communicate using a virtual text messaging service. This program will later be modified to reflect the host and client nature of the processors. The central module will have the ability to communicate with all remote modules, while the remote modules will only be able to send acknowledgements back.

Test number 7, LED Control, will test the use of external LEDs. Individual LEDs will be connected to GPIO pins and toggled on and off. This test is to ensure the proper power is being supplied to the LEDs reach the proper light level.

Test number 8, LCD Control, will test the use of the two 7 segment LCD displays and their controllers. A program will be written that tests the processors ability to write data to the LCD displays using the controllers.

Test number 9, Servo Control, will test the microcontroller ability to drive the servo motor. While applying a range of voltages to the servo, the desired operating voltage will be determined. Factors to be considered include, speed to turn deadbolt, noise, and power consumption.

Test number 10, Relay Toggle, will connect the relay circuit to the GPIO pins on the development board. The pins will be toggled on and off and the relay will be monitored to ensure it is reacting appropriately.

Test number 11, SR Reading, will attach the HM2007's S bus to the GPIO pins. Their status will be polled by the CC3200's software to detect the SR circuit's operating state. Each of the four operating states will be entered to ensure the processor can detect them all.

Test number 12, SR Writing, will attach the HM2007's K bus to the GPIO pins. This test will ensure the HM2007 is able to receive input from the processor. Both of the Reading and Writing functions described above will be used to test the other Speech Recognition functions.

Test number 13, SR Training, will test the processors ability to communicate to the HM2007 that it wants to train a command. It will also provide the SR circuit with the line number to be trained.

Test number 14, SR Recognition, will test the processors ability to communicate to the HM2007 that it wants to listen for a user command. At this point the SR circuit will enter recognition mode for 1.92 seconds while it listens to input from the microphone. After the recognition period ends. The circuit will enter resulting mode to process it.

Test number 15, SR Resulting, will return information to the processor on the K bus. It will return the line number of the word if it is recognized or an error code if it was either not recognized or invalid.

Test number 16, SR Upload/Download, will test the ability to upload and download stored recordings from the HM2007's memory to the processor's memory. The sequence of commands sent between the two units include command code, line number, and data. This process is further explained in Section 4.7 Hardware Design Details - Speech Recognition.

Test number 17, SR Reset, will give the user the ability to reset the SR circuit. When the reset command is received, the HM2007 will erase all stored data in memory and power cycle.

Test number 18, SR Overall, will test the performance of all of the speech recognition features. The programmer will be able to issue text commands to the processor using the UART interface. All of the functions will be thoroughly tested to confirm compatibility.

Test number 19, SR + Wireless Communication, will extend the speech recognition program to allow for wireless communication capabilities. One CC3200 will act as the central processor and the second will act as a remote processor. After an ON or OFF command is received the central processor will send a wireless signal to the remote processor which will use an embedded LED to indicate its state.

Test number 20, System Test, will extend the speech recognition and wireless communication program to incorporate the relays and servo controller. It will have the same functionality as test 19 but will control the other subsystems instead of the embedded LEDs.

7.5 Integrated System Testing

Integrated testing will occur in order to test the system prior to presenting it. The main module is the most important facet of SCREAM as it relays commands to and from the individual modules. Therefore, integrated testing will occur with the access point and an outlying module one at a time to ensure that each facet of SCREAM works as intended prior to testing the entire system as a whole.

7.5.1 Main Module and Headset

The first integrated test will occur between the main module and the wireless headset. An external power source will be required for the main module, and the headset should be fully charged for this test. The test will begin from a shutdown state and power will be applied to the main module and the headset will be turned on. At this point a user will attempt to pair the headset to the module through the Bluetooth USB dongle and vocally train the main unit. Once successful, the user will move to 10 feet away from the main module with the headset on to relay commands.

After the headset and dongle are paired, the user will begin to train the module. Each of the remote modules will be assigned two training channels, one will be for the module on command and the second will be to turn it off. The two channels will be consecutive lines and will be ordered according to the module number. For example channels 1 and 2 will be used to turn on and off module 1, similarly channels 3 and 4 will control module 2. The user will begin training the module by using the arrow keys until the desired channel number is displayed on the LCD display. Next they will press the button labeled TRAIN which will allow the system to record the next 1.92 seconds of audio. After the recording is stored the system will blink an LED to the user to indicate it was successful.

Commands will be given to the module to test if the module successfully receives and processes commands. Mock commands for SCREAM can be given, such as to turn off the lights, with no expectation of the commands to be successful as this is only part of the

full SCREAM system. If the test is successful at 10 feet, the user will then move to 20 feet, still line of sight, and the test will be run again. Following the completion of the test at 20 feet, the test will be run a third time at 30 feet.

The test will be considered successful if the following conditions are met: the main unit is successfully trained, the headset can relay commands up to 30 feet away, the main unit processes commands and attempts to relay them with the appropriate module.

7.5.2 Main Module and Door Module

Only once the integrated testing between the main module and the headset is complete can the test between the main module and the door module begin. An external power source will be required for the main module, the batteries for the door module should be fully charged, and the headset should be fully charged for this test. The test will start again from a cold system. The headset will be paired with the main module and the main module will be trained. The headset will still be used to relay commands from a set distance of 5 feet away from the main module.

Each of the remote modules will be assigned two training channels, one will be for the module on command and the second will be to turn it off. The two channels will be consecutive lines and will be ordered according to the module number. For example channels 1 and 2 will be used to turn on and off module 1, similarly channels 3 and 4 will control module 2. The user will begin training the module by using the arrow keys until the desired channel number is displayed on the LCD display. Next they will press the button labeled TRAIN which will allow the system to record the next 1.92 seconds of audio. After the recording is stored the system will blink an LED to the user to indicate it was successful.

The commands ‘LOCK DOOR’ and ‘UNLOCK DOOR’ will be spoken into the headset and received by the main module. The main module will then process and relay these commands to the door module. The door module will receive and process these commands and provide power to the servos which will then lock or unlock the door as appropriate. The test will be considered successful if the following conditions are met: the main unit is successfully trained, the main unit processes commands and attempts to relay them with the appropriate module, the door module receives and processes commands and appropriately manipulates the servos, the servos successfully locks and unlocks the door on command.

7.5.3 Main Module and Light Module

Only once sections 7.5.1 and 7.5.2 are complete can the test between the main module and the light module begin. An external power source will be required for both the main module and light module, and the headset should be fully charged for this test. The test will start again from a cold system. The headset will be paired with the main module and the main module will be trained. The headset will still be used to relay commands from a set distance of 5 feet away from the main module.

Each of the remote modules will be assigned two training channels, one will be for the module on command and the second will be to turn it off. The two channels will be consecutive lines and will be ordered according to the module number. For example channels 1 and 2 will be used to turn on and off module 1, similarly channels 3 and 4 will control module 2. The user will begin training the module by using the arrow keys until the desired channel number is displayed on the LCD display. Next they will press the button labeled TRAIN which will allow the system to record the next 1.92 seconds of audio. After the recording is stored the system will blink an LED to the user to indicate it was successful.

The commands 'LIGHT ON' and 'LIGHT OFF' will be spoken into the headset and received by the main module. The main module will then process and relay these commands to the light module. The light module will receive and process these commands and provide power to the light as appropriate. The test will be considered successful if the following conditions are met: the main unit is successfully trained, the main unit processes commands and attempts to relay them with the appropriate module, the light module receives and processes commands and appropriately provides power to the light.

7.5.4 Overall System Test

All test sections indicated before this point must be complete prior to the beginning of the overall integrated system test. An external power source will be required for the main module and light module, the batteries for the door module should be fully charged, and the headset should be fully charged for this test. The test will begin from a shutdown state and power will be applied to the main module and the headset will be turned on. At this point a user will attempt to pair the headset to the module through the Bluetooth USB dongle and train the main module vocally. Once successful, the user will move to 10 feet away from the main module with the headset on to begin issuing commands.

After the headset and dongle are paired, the user will begin to train the module. Each of the remote modules will be assigned two training channels, one will be for the module on command and the second will be to turn it off. The two channels will be consecutive lines and will be ordered according to the module number. For example channels 1 and 2 will be used to turn on and off module 1, similarly channels 3 and 4 will control module 2. The user will begin training the module by using the arrow keys until the desired channel number is displayed on the LCD display. Next they will press the button labeled TRAIN which will allow the system to record the next 1.92 seconds of audio. After the recording is stored the system will blink an LED to the user to indicate it was successful.

Commands will be given to the module to test if the module successfully receives and processes commands. The aforementioned commands will be used, in no particular order, to ensure that the main module receives commands, processes them, and relays them to the appropriate module correctly. If the test is successful at 10 feet, the user will then move to 20 feet, still line of sight, and the test will be run again. Following the completion of the test at 20 feet, the test will be run a third time at 30 feet.

The test will be considered successful if the following conditions are met: the main unit is successfully trained, the headset can relay commands up to 30 feet away, the main unit processes commands and relays them to the appropriate module, the corresponding module receives the commands, processes them, and the appropriate action is taken by that module.

7.6 Presentation Environment

The presentation environment is expected to be the final environment used to show SCREAM's functionality in its entirety. A table will support all modules and a user will wear the headset like portrayed in figure 23. Prior to presenting, the system will already be vocally trained and a list of words that have been trained will be recorded. The modules will lie on the farthest possible ends of the table and will have to be setup in those locations. Setup includes pairing the headset to the access point in its stationary position, and ensuring line of sight is available between the modules and the access point. The light module and access point will need an external power source. The door module will need fresh batteries.

Testing will involve a user speaking a command into the headset. The access point will receive the command, process the command, and relay it to the appropriate module. That module will then perform the action assigned. At least four commands must be issued, locking and unlocking the door and turning the light on and off. The test will be a success if the door module successfully locks and unlocks the door and the light module successfully turns the light on and off.

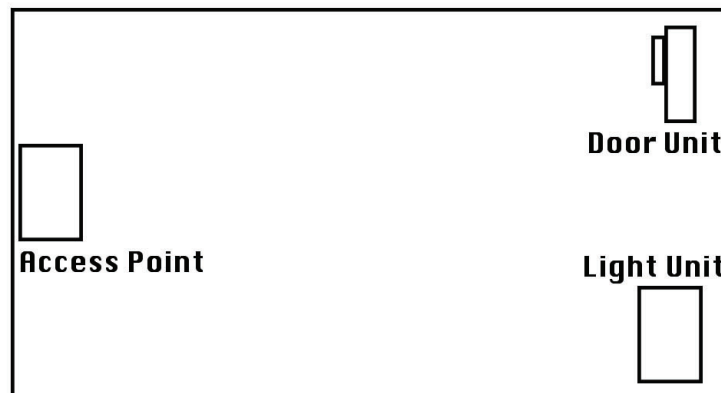


Figure 23 - Presentation Environment Layout

8.0 Administrative Content

8.1 Project Milestones

A list of major milestones was compiled to keep the project from suffering from schedule creep. The milestones should be used as guidelines to completing both the research paper and the prototype on time. It is extremely important to finish as much of the research as possible by the middle of October in order to begin designing the prototype. Much of the paper can be completed in tandem to reduce the workload towards the end of the first semester. The design stage of the project must be finished by the end of October to allow time to finish the final proposal paper and begin parts acquisition. Prototyping is intended to be completed by the first week in February and must be finished to allow time for testing, scheduled to be finished before the second week in March. Please see Appendix D for a detailed timeline.

8.2 Project Budget and Finance Discussions

8.2.1 Budget

SCREAM is intended to service a niche in the HAS market where customers may be intimidated by the cost needed to implement or maintain a HAS. Therefore, the budget for SCREAM is modest and intended to reduce cost wherever possible. Table 17 below delineates the budget for each component with a contingency built in to safeguard against unforeseen costs. Five hundred is the target budget amount in order to keep SCREAM affordable but in the initial budget outline \$528 was funded by Boeing Company. Many HASs already available on the market cost more than SCREAM, either via subscription where the cost is broken up over time or upfront in sheer cost of components and installation. Additional units of SCREAM would be cheaper due to the increased costs associated with prototyping.

The first table, the original budget, shows the original cost breakdown that was assumed to be needed to acquisition the parts needed for SCREAM. Notice that most values are rounded up to the nearest whole dollar and tax and shipping are not included. Rounding up to the nearest whole dollar and adding the contingency field were ways to ensure that getting parts for SCREAM would not go over budget. The second table, the complete projected budget, is a more complete price estimation of what exact parts are needed and the prices are not rounded.

Item	Price	QTY	Total
Bluetooth Headset	\$70.00	1	\$70
Bluetooth Dongle	\$10.00	1	\$10
Speech Recognition Chip	\$114.95	1	\$115
Microcontroller	\$40.00	4	\$160
Power Supply	\$5.00	4	\$20
Wireless Transceiver	\$5.00	5	\$25
Servo	\$20.00	1	\$20
Relay Control Unit	\$5.00	4	\$20
Contingency	\$87.99	1	\$88
Subtotal			\$440
Total			\$528

Table 17 - Original Budget

Qty	Description	Supplier	Part Number	Unit Price	Total Price
1	Mobile Bluetooth Headset	Plantronics	M55	\$38.03	\$38.03
1	USB Micro Bluetooth Adapter	Azio	BTD-V201	\$12.99	\$12.99
1	Speech Recognition Circuit	Imagesco	HM2007	\$179.95	\$179.95
1	USB Female Single Connector PCB mount	Velleman	CC088	\$0.96	\$0.96
1	AC/DC Wall Power Charger Adapter	Hewlett Packard	728002801	\$5.98	\$5.98
1	Experiment Breadboard w/ Jumper Wires	Amazon	IB751750	\$14.49	\$14.49
1	Single Chip Wireless MCU	Texas Instruments	CC3200	\$18.08	\$18.08
1	Generic High Torque Servo Motor	Karlsson Robotics	ROB-11965	\$12.95	\$12.95
1	Lithium 3.6 V battery	Saft	LS14250	\$4.00	\$4.00
1	Single Supply Op Amp	Texas Instruments	LM2904	\$0.67	\$0.67
1	6 Volt Battery	Duracell	28A	\$4.79	\$4.79
1	Door Deadbolt Lock	The Home Depot	B60N609	\$29.98	\$29.98
3	Single Chip Wireless MCU	Texas Instruments	CC3200	\$18.08	\$54.04
3	Electromagnetic Relay SPDT	TE Connectivity	T90 9-1393208-5	\$2.62	\$7.86
3	Lithium 3.6 V battery	Saft	LS14250	\$4.00	\$12.00
3	Single Supply Op Amp	Texas Instruments	LM2904	\$0.67	\$2.01
3	6 Volt Battery	Duracell	28A	\$4.79	\$14.37
1	150 W Light Bulb Lamp	Walmart	N/A	\$6.17	\$6.17
				Total	\$419.32

Table 26 - Complete Projected Budget

8.2.2 Financial Discussions

After reviewing the revised total cost of SCREAM, the budget is now approximately twenty dollars under the projected amount. There is still a contingency amount of \$80 dollars from the desired cost of SCREAM of \$500 and a contingency amount of \$108 from the original allocated budget. Some of the parts listed have not been optimized to

reduce cost, so it is still possible to reduce the projected cost to purchase SCREAM components. It should be noted, however, that shipping and taxes are not included in the projected budget and will have to be deducted from the contingency amount. Also not included is the cost required to PCB the board that will interface with the CC3200 in the main unit and house both the Bluetooth dongle for the headset and the HM2007 speech recognition unit. Additionally, when calculating the cost of SCREAM for additional units the costs of a lamp and a deadbolt should not be included as they are for demonstration purposes and should not be considered part of the system.

9.0 Project Summary and Conclusions

SCREAM is a HAS intended to fill an unfulfilled market space in current market offerings. By providing a way to wirelessly and vocally control enabled devices, SCREAM is empowering its users to be both energy conscious and more independent despite physical or mental limitations. SCREAM is a robust HAS that can enable many to use a HAS when they might have previously been intimidated by the cost or the technical knowledge required to install and use one.

SCREAM uses an embedded architecture and SoC technologies allow the system to be cheaper, smaller, and easier to use. It is cheaper because the system is cheaper to manufacture. That is, the system requires a commonly used headset with few limitations in order to send commands. It does not use a proprietary protocol to package data so there are plenty of IC manufacturers that make the parts required for SCREAM to function and no scarcity of parts. A premade RF module is used which reduces the cost and time of development. Many of the parts for the servos and relays come from eastern manufacturers where the labor cost is lower and so the cost of SCREAM is lower. There is no recurring subscription to renew each year or pay each month.

SCREAM is easier to use as it is smaller because many of the systems SCREAM needs to run are coupled together resulting in the system using less space. For example, the transmitter and receiver are coupled together in a transceiver and the transceiver is only half duplex and not full duplex (which is more expensive) because the system does not need it. The transceiver and the processor that handles protocol manipulation are present on the same chip. SCREAM uses an embedded platform requiring no PC or server to use. The system is easier to use because it is intended to be used vocally with little system manipulation required to voice train the speech recognition chip. There is no GUI to be confused by, no overarching operating system to configure or troubleshoot or update, no additional wiring, and maintenance the system requires is minimal. Maintenance is confined to changing the vocal commands as required and charging batteries. There are few moving parts with the exception of the servos to operate the door lock.

SCREAM uses a Bluetooth headset to allow a user to vocally control devices with minimal physical interaction. The headset is easy to procure because of the popularity of smart phone devices and the necessity of hands free driving techniques. The headset is easy to pair with the Bluetooth dongle. The dongle is also easy to procure due to the rise in popularity of enabling PCs to use Bluetooth devices with programs like Skype. The

headset is Bluetooth 2.1 or later compliant which allows some increased security when using the system and acts as a preventative measure for unwanted intruders.

The user will speak into the headset and the dongle will relay vocal commands to a fabricated board that will house a speech recognition system. The speech recognition system is easy to train, and will store trained vocal commands. Once it receives a command the system will process the audio to try to compare it with the files it stored during training. Once it identifies a command with one already stored it will communicate with the CC3200. The CC3200 will communicate via Wi-Fi to a corresponding module, either to manipulate the door or to manipulate a lamp. Hibernation modes are used to conserve battery life. WPA will be used to encrypt the data traffic flowing between modules and also acts as a preventative measure for unwanted intruders. The door module and the light module will receive commands from the main module and either a relay or a servos will act accordingly. Although there are many ways that SCREAM could be improved upon, SCREAM acts as a HAS that is easy to install, cheap to manufacture, and easy to use and maintain.

10.0 Extending the Design

10.1 User Interface and App Development

Currently the user interface is limited to only accepting voice commands. Most modern home automation systems rely on the use of a touch screen display, typically in the form of a tablet or smartphone. A feature that could be added to SCREAM would be the added tactile use through a cellphone. Android, a popular open source mobile operating system is a common platform for app development due to its Android Open Source Project (AOSP) source code being available for modification.

10.2 Multiple Users

Currently SCREAM is limited to control via a single wireless microphone. While sufficient for some situations, others living in multiple person households may desire additional microphones so each person in the house could operate the system. The addition of having multiple analog inputs would require additional hardware responsible for multiplexing the signals through a single medium.

10.3 Vocal Confirmation

SCREAM only reports feedback to the user in the form of the LCD display and LED lights. By converting the wireless audio receiver into a transceiver, it could extend the design capabilities to allow for tones to be played back to the user to confirm their commands were recognized and completed or if there was an error and they need to repeat the command. Additionally the use of Text-to-Speech hardware could be implemented to allow for more accurate feedback.

10.4 Email, Text Alerts, and Remote Manipulation

SCREAM has the ability to monitor which appliances are turned on and also if doors are left unlocked. A current trend in home automation is the use of text and email alerts to remind the homeowner when the door is left unlocked to help prevent unauthorized entry and also when appliances are left on when no one is home. Since the product is already connected using Wi-Fi the ability to send an email to the user would be within its capabilities. Some HASSs allow the user to manipulate modules in the home remotely but this is not currently supported in SCREAM. For example, while the homeowner is away from the domicile they can watch live camera feeds of their home and turn lights on and off from a phone application. This could be implemented through the use of a home server or other computer which could provide the additional computational power required to implement this feature.

10.5 Microphone Repeaters

As designed, SCREAM uses a microphone that uses a Bluetooth enabled headset that pairs with a unit on the main device. This limits the overall range of the system to the range specified by the headset and due to the Bluetooth protocol, the user must be within line of sight of the main unit. Unfortunately, every home is not less than nine hundred square feet. In order to increase the range either the system can integrate Bluetooth repeaters around the domicile to increase the signal strength or a special mesh network protocol, like ZigBee, enabled microphone could be created. A mesh network protocol enabled microphone can become part of the mesh network and thus signals that the device needs routed could hop through other mesh network protocol enabled devices (for a maximum of 4 hops) in order to reach the main unit.

10.6 Television Integration

As currently designed, SCREAM can be used to turn a television on and off much like a light can be turned on and off through the removal of electrical power. Televisions today, however, are far more complex than this. Many other features can be changed including channels, brightness, volume, inputs, etcetera. SCREAM does not currently include this functionality but could be changed to include it. Several other HASSs, like VoicePod and Jasper include this functionality, indicating that this can be added. To include this it would require more words available to use when vocally training the unit which would require more resources like memory and processing power. Additional code would have to be added to a new television unit that would be able to control functions like changing the channels or inputs.

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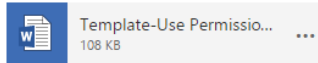


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Thank you for your time and understanding

B Datasheets

Generic High Torque Servo Motor

<http://dlnmh9ip6v2uc.cloudfront.net/datasheets/Robotics/FS5106B%20specs.pdf>

Speech Recognition IC(HM2007)

<http://www.imagesco.com/speech/HM2007.pdf>

Wireless chip MCU(CC32000)

<http://www.ti.com/lit/ds/symlink/cc3200.pdf>

General Purpose Power Relay(T90 series)

<http://www.onlinecomponents.com/datasheet/913932085.aspx?p=10517136>

LM2904 Dual Operational Amplifier

<http://www.ti.com/lit/ds/symlink/lm2904.pdf>

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D Project Milestones

		Project Milestones											
		AUG	SEP	OCT	NOV	DEC	JAN	FEB	MAR	APR			
Description	Start	End											
1 Form Groups	8/18/2014	8/28/2014											
2 Research Projects	8/18/2014	9/2/2014											
3 Initial Project Proposal	9/2/2014	9/9/2014											
4 Conduct Further Research			Research										
Microcontroller and Power Supply	8/30/2014	9/25/2014											
IP/Website	9/16/2014	10/3/2014											
Wireless Transmitter / Receiver	9/25/2014	10/9/2014											
Door Cam System	9/25/2014	10/9/2014											
Speech Recognition Implementation	9/25/2014	10/13/2014											
5 Design				Design									
Transmitter/Receiver (Hardware)	9/25/2014	10/24/2014											
PCB (Hardware)	9/25/2014	20/24/2014											
Implement the SR /API (Software)	10/6/2014	11/3/2014											
6 Final Proposal Paper	9/9/2014	12/4/2014											
7 Parts Acquisition													
8 Prototyping							Prototyping						
Wireless Transmitter / Receiver													
PCB													
SR API (Software)													
9 Unit Testing													
Test Speech Recognition													
Test Mechanical Subsystem													
Test Electrical Subsystem													
Test Wireless Communications													
Test Speech Recognition with Microcontroller													
Test Microcoller with Wireless Communications													
10 Testing (Whole System)													
11 Final Documentation													
12 Final Presentation													

E Figures and Tables Index

Table 1 - Project Specifications	pg 5
Table 2 - Power Supply Specifications	pg 7
Figure 1 - AC/DC Converter Block Diagram	pg 8
Table 3 - AC/DC Power Adapter Specifications	pg 9
Table 4 - Comparison of Single Supply Op Amplifiers	pg 10
Figure 2 - Servo Motor Unit Parts	pg 11
Table 4 - Mechanical Specifications for the Servos	pg 12
Table 5 - Electrical Specifications for the Servos	pg 12
Table 6 - Control Specifications for the Servos	pg 12
Figure 3 - Servo Motor Physical Dimensions	pg 13
Table 7 - Comparison for Relay Units	pg 14
Figure 4 - Electromagnetic Power Relay SPDT (T90N) Physical Dimensions	pg 15
Table 8 - Speech Recognition IC (HM2007)	pg 21
Table 9 - 64 KB External SRAM (HM6264B IC)	pg 22
Table 10 - Octal Latch IC (74HC573) Specifications	pg 23
Figure 5 - Block Diagram of a Closed-Loop Control System	pg 34
Figure 6 - Block Diagram of Power Supply	pg 36
Table 11 - Op Amp Estimated Values	pg 38
Figure 7 - Servo Motor Block Diagram	pg 39
Figure 8 - Texas Instruments CC3200 and Functional Block Diagram	pg 41
Table 12 - CC3200 Operating Conditions	pg 42
Figure 9 - Communication Procedure for CC3200 Network Processor Subsystem	pg 44
Figure 10 - Basic Networking Application State Machine	pg 45
Table 13 - Description of HM 2007 Pinout	pg 46
Figure 11 - HM 2007 IC	pg 47
Figure 12 - HM 2007 Keypad	pg 48
Table 14 - Recognition Mode Format	pg 48
Table 15 - Possible States	pg 49
Table 16 - Commands Available	pg 49
Table 17 - Read Operations	pg 50
Figure 13 - Speech Recognition Subsystem	pg 51
Figure 14 - Main Unit Breadboarding	pg 52
Figure 15 - Polling Block Diagram	pg 53
Figure 16 - HM2007 Recognizing a Command Flowpath	pg 54
Figure 17 - HM2007 Training a Command Flowpath	pg 55
Figure 18 - HM2007 Result Command Flowpath	pg 56
Table 18 - Parts Acquisition Table	pg 57
Table 19 - BOM for the Headset	pg 58
Table 20 - BOM for the Main Unit	pg 58
Table 21 - BOM for the Door Unit	pg 59
Table 22 - BOM for the Power Control Unit	pg 59
Figure 19 - Servo Tester	pg 62
Figure 20 - Wireshark 802.11 Preferences	pg 64
Figure 21- Example TCP Packet Dissection in Wireshark	pg 64

Figure 22 - Dataflow for the packet sniffer (SoC) pg 65

Table 23 - Software Tests pg 67

Table 24 - Device Power Modes pg 68

Figure 23 - Presentation Environment Layout pg 73

Table 25 - Original Budget pg 75

Table 26 - Complete Projected Budget pg 76