Speech Controlled Responsive Electronics and Mechanics (SCREAM)

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***Abstract*—Speech Controlled Responsive Electronics and Mechanics (SCREAM) will focus on technologies and services that can be used to simplify interaction with smart homes using a speech recognition system. Utilizing speaker dependant voice analysis and easily reconfigurable hardware, a user can setup their own inexpensive and reliable system. By creating its own wireless network, an array of remote electrical devices can be turned on and off using relays. Additionally, door access can be monitored and controlled using electric deadbolts.**

***Index Terms*—Automatic Speech Recognition, Wireless Networks, Home Automation, Electronic Switching Systems, Relays, Microcontrollers.**

I. Introduction

Conceived as a way to fill a niche in the home automation market, SCREAM was designed to combine speech recognition technology and wireless communications to provide a homeowner with a low cost and easy to maintain home automation system (HAS). SCREAM is an embedded solution using both custom PCBs and development boards. The system takes audio input from the user via a 35mm port which is provided to the speech recognition circuit. The SRC then interprets the audio against user-programmed audio files. Commands are relayed via Wi-Fi to a Texas Instruments CC3200. Two modules are provided with this version of SCREAM with the ability to add more. A door control module consists of a CC3200 and an electric deadbolt while the electrical control module consists of a CC3200 and a relay.

II. System Components

SCREAM is modular in nature and is thus best described in terms of its individual modules that work together to create the system as a whole. This modularization is intended to create a HAS that is both customizable to the home owner's needs and maintains a low cost by removing unneeded components.

A. Speech Recognition Circuit

Speech recognition systems are categorized using two main parameters: intended speaker and style of speech. If the system is designed to only work for a specific user, a speaker-dependent system is the best choice. Speaker-dependent systems require training by the user but can operate regardless of user language or accent. Traditionally used for systems with smaller lexicons, a speaker-dependent system's initial training time is often an acceptable trade-off for higher recognition accuracy. On the other hand, speaker-independent systems require no training but can suffer from poor performance. If a users language is not supported by the system or if their vocal patterns are not approximately what is expected, the system is rendered inoperable. Style of speech is also an important factor when classifying speech recognition systems. Isolated speech recognition has the best accuracy but requires the user to pause between words. Continuous speech recognition is more difficult to implement but allows the user to talk in a conversational style. Connected speech recognition is a combination of the two and can recognize small phrases with acceptable accuracy. The speech recognition circuit (SRC) implemented in this project is a speaker-dependent connected speech system.

The heart of the speech recognition system is the HM2007. It is a single chip CMOS voice recognition LSI circuit with on-chip analog-to-digital conversion (ADC) which is used for voice analysis and recognition. Using 64K of SRAM, a maximum of 40 words, each up to 0.96 seconds in length, can be trained. Alternatively, the device can be configured to accept 20 words up to 1.92 seconds in length. Using an external microphone and keyboard the circuit can store voice recordings which can later be recognized as matching words. The circuit has a response time of less than 300 ms and can operate with a single 5V power supply. The SRAM has a 3V battery back up used for memory retention should power ever be removed from the main circuit.

The HM2007 IC is conceptually designed to be able to run in two different modes: Manual and CPU. In manual mode, a 4x3 button keypad is used to input command numbers during the training sequence. The keypad uses a keyboard scanner which allows the required number of I/O pins to be reduced from 12 to 7. CPU mode interfaces those same I/O pins with a micro controller and allows commands to be sent and statuses to be read using on chip input and output registers. The advantage of CPU mode is that software can handle inputting command numbers and free the user from having to use the keypad. However, there is a well documented flaw with the IC which prevents use of CPU mode. For this reason, manual mode was used and keypad entries are still handled by the user. To alleviate the burden of having to look up command codes, they have been provided to the user in the systems interactive training menu.

B. Microcontrollers

Originally, the CC3200 by Texas Instruments was intended to drive all of the modules in SCREAM, including the main module with the SRC. However, it was determined that the CC3200 could not accept more than one connection once established as an access point (AP). This was unacceptable for the purposes of SCREAM as the main module must accept and communicate with multiple modules. Upgrading the microcontroller in the main module was necessary both to handle an unexpected increase in the required number of I/O pins and to ensure an AP could be created to handle the network traffic to the outlying modules.

The ODROID-C1 is a Raspberry Pi derivative created by HardKernel. Unlike the Raspberry Pi, however, the ODROID-C1 provides more computational power and faster RAM for the same price. The standard USB ports available allowed the ODROID-C1 to be equipped for wireless communications via a Wi-Fi dongle and the ethernet connection allowed for easier setup and troubleshooting via Wireshark. The 19 available general purpose I/O (GPIO) pins were enough to drive the SRC, the LCD, and the rotary encoder. A 16 GB flash secure digital (SD) card provides space to save both the operating system and any additional content for the ODROID. SCREAM does not require a graphical user interface so instead of using Ubuntu 14.04 as the Linux platform, an ARM distribution of Arch Linux was used instead. Arch Linux is a minimal installation distribution meaning that only the services required for the system to be operational needed to be installed. This conserved space on the SD card that was later used as available space for scripts and configuration files.

As the CC3200 could still establish itself as Wi-Fi station using WPA encryption and operate as a HTTP server, it remained the driving microcontroller for the outlying modules. The CC3200 is a Wi-Fi certified single chip microcontroller unit (MCU) with built-in 802.11 b/g/n Wi-Fi. With an ARM Cortex-M4 core it provides up to WPA2 encryption and embedded proprietary TCP/IP and TLS/SSL stacks. Sockets are established using the Berkeley socket API. Software written for the CC3200 can be compiled and debugged in Code Composer Studio or Energia and can be flashed to the available 16 MB of space using TIs proprietary software, Uniflash.

C. Electrical Control Unit

High power capacity switching relays are implemented in the electrical control unit of the home automation system. The relay selected is a single pole double throw (SPDT) type, capable of switching with a capacity of 20 A. The relay operation response time is 20 ms and requires only 800 mW of power to operate. The relay is powered by a 9 V battery which is used to toggle the relay when switching is necessary. When the CC3200 receives a command to turn on or off a device, it controls the switching of the relay with the assistance of a P2N2222A bipolar NPN switching transistor. Depending on the output signal supplied from the CC3200, the transistor is either set to a saturation state or a cut-off state. When the CC3200 manipulates these states the transistor acts as a current control switch for the relay. During the switching process, the coil of the relay acts as an inductor and stores a significant amount of current. This can create a high voltage spike which would damage the electronic parts in the unit. A IN4005 rectifier diode is used to handle the coil current and protects the unit from the voltage peaks coming from the relay when the system turns off.

D. Door Control Unit

A normally-open (NO) mode fail-secure electric deadbolt is the fundamental part of the door control module. The electric deadbolt consist of an electromagnet and an armature plate. The locking device is fail-secure, which means the device remains locked if power is lost. The armature plate is attached to the door and the electromagnet portion of the lock is attached to the door frame. The unit operates at 12 W of power (12 V_{DC}, 1 A) and is powered by a lithium-ion rechargeable battery. The rechargeable battery supplies a nominal voltage of 12 V_{DC} with a capacity of 3800 mAh. The CC3200 launchpad permits the wireless communication between the speech recognition circuit and the door module. The CC3200 behaves as a transceiver receiving an input signal when the user interfaces with the system and provides a corresponding output of 3V. To control the locking/unlocking functionality of the electric deadbolt, the TIP120 darlington transistor is incorporated with the CC3200. Depending if a high or low output signal is supplied from the CC3200, the transistor is either set to saturation state or cut-off state, respectively. The CC3200 manipulates these states which makes the transistor act as a current control switch, and thus sets the electric deadbolt to be locked or unlocked. The electric deadbolt works by magnetic induction. When the system is suddenly turned off it might create a high voltage spike signal that can cause damage to the circuitry of the system. The IN4005 rectifier diode is used to handle the current and protect the unit from a high output voltage peak coming from the solenoid of the bolt when system turns off.

III. System Concept

Before examining the system at a more technical level, it needs to be clear how the system modules connect with each other. A user speaks into a microphone which is received by the HM2007. The HM2007 processes the audio signal and compares the signal to a list of user preprogrammed commands. The subsequent command is relayed to the ODROID-C1 which uses Wi-Fi via a wireless dongle to communicate to the corresponding control unit. The control unit then operates the device or door as requested. A diagram of this system is shown in Figure 1.

IV. Hardware Details

A. Audio Input

The SCREAM system was designed to allow the user to choose their desired wired or wireless microphone. The back panel of the enclosure has a 35 mm (1/8th in) audio port which can be used to directly plug in a wired microphone. In this setup the users mobility is limited by the length of the

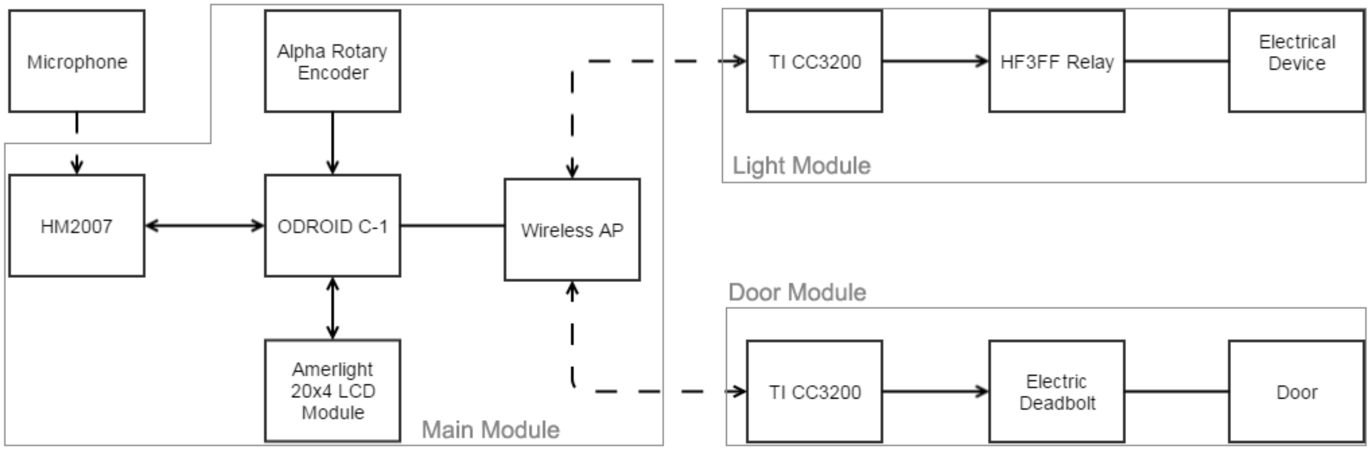

Fig. 1. Hardware flowchart for SCREAM

microphone cable but the system can operate on modules as far as 30 meters away from the home station. Alternatively, the user can use the system while a greater distance from the home station through the use of a wireless audio adapter. Using the Bluetooth protocol, class 1 adapters can increase the range of a paired wireless microphone to a distance of 100 m. The adapter must have an 35 mm lineout to interface with the system and can be powered externally or by an available USB port also available on the back panel of the enclosure.

B. Audio Processing

After an analog audio signal is received from the 35 mm audio port it must be processed into usable data. First it passes through a high pass filter to attenuate any signal below a determined frequency. Using a 6.8 kΩ resistor and a 0.1 μF capacitor, a cutoff frequency of 234 Hz was obtained. This frequency was chosen because it eliminated nearly all background channel noise without compromising the integrity of the voice signal. The filtered audio output then enters the HM2007 IC where an internal ADC further processes the signal. Using pulse code modulation with a bit depth of 8, the analog signal is sampled at a rate of 3.57 MHz. If the circuit is in training mode the memory address is calculated and the data is stored into memory. If the IC is in recognition mode, the data is compared with the samples recorded in memory. If a comparison is made whose hamming distance is below a set threshold, a valid match has been found and its memory address is temporarily placed on the data bus. When a match is found, the data enable pin of the HM2007 is set to high. Using a 74LS373 which is a positive edge triggered octal latch, this address can be stored for use by an external device.

C. ODROID Connections

The ODROID has a 5 V, 2 A power input and uses discrete DC-DC converters and an NCP372 for power protection. It provides 5, 3.3, and 1.8 volt outputs, has 19 available GPIO pins as well as several specialized ones, which are all available on a 20x2 pin header. The ODROID interfaces with the speech recognition circuit and other peripheral hardware through the use of these 40 IO pins. Using a 40 pin ribbon cable, the processor provides power to the printed circuit board (PCB), which houses the hardware, and handles all digital signal communications. The HM2007, its memory and the latch all use 5 V provided from the ODROID while the IO pins each use 3.3 V. Seven I/O pins are used to receive data output from the speech recognition circuit. These are attached to the output lines of the lower seven bits of the octal latch. An eighth pin is also connected the HM2007s data enable line which will be used for detecting new outputs. Additionally, the ODROID powers and communicates with a 20x4 liquid crystal display. The displays backlight is powered by 5 V routed through a 10 kΩ linear potentiometer to allow for adjustable contrast. It also uses seven I/O pins for the processor to send it information to display. The last three I/O pins used are connected to the output lines of a twelve step rotary encoder which is powered by 3.3 V and is used for user input.

D. Sending Wireless Communications

Meanwhile, in the outlying modules, once power is applied to the CC3200 the ARM A4 Cortex processor begins its 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 direct memory access. These registers are part of a 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 the first few lines of code and the unsecure boot code, the processor jumps to the application.
8) Until the next power cycle, the Cortex mode is designated the MCU and access to the secure region is restricted.

Once the processor runs the application, the CC3200 initializes the board to run as an HTTP server and network communications are handled through software over the 2.4 GHz industrial ISM band.

E. Electrical Control Unit

The CC3200 in the relay control unit processes received signals and when necessary applies or removes voltage from GPIO pin 29. This I/O pin is also connected to an onboard LED so a change in status can be noticed even if no electrical device is connected. The CC3200 launchpad operates with two AA batteries, which allows the CC3200 to send a high level signal of 3V and 10.75 mA through pin 29. Voltage is applied/removed across pins 29 and 20 (GND pin) to send a high/low level voltage signal to the relay control unit's (RCU) printed circuit board (PCB). The board size is 3.94x2.03 inch and the PCB is a 2 layer design. The board houses a high power switching TMP relay SPDT type, a P2N2222A bipolar NPN switching transistor, a rectifier diode 1N4005, a 270 Ω resistor, a three pin female header power connector, and rechargeable 9 Volt Lithium Polymer Battery. A rudimentary diagram of the custom circuit is shown in Figure 2.

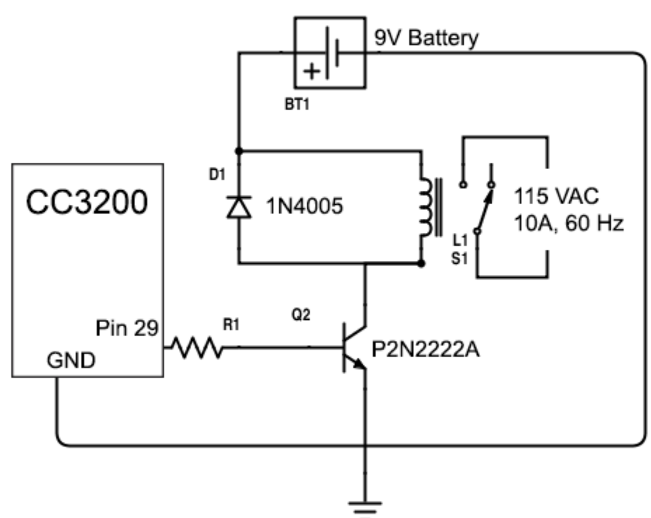

Fig. 2. Light Control Unit Schematic

The CC3200 GPIO (pin 29) and GND (pin 20) pins connect to the female header power connector on the RCU board. The female header power connector supplies the high level voltage signal through the 270 Ω resistor that is connected to the base of the P2N2222A. A rechargeable 9 V battery connects to the collector of the P2N2222A with the task to supply 9 V_{DC} to the relay. The 270 Ω resistor is connected to the base to limit the amount of current flowing to the base by 1/10 of the collector current. The base resistance value is found by using the following DC parameters:

$$\frac{I_C}{I_B} = h_{FE} = 10 \tag{1}$$

$$R_B = \frac{V_{CC3200} - V_{BE}}{I_C} \tag{2}$$

The P2N2222A transistor operates in two states, the cutoff state and the saturation state. Using the two states, the transistor may be used as a current control switch. The collector and emitter are the switch terminals and the base is the switch handle. In other words, the small base current can be made to control a much larger current between the collector and emitter. The saturation state happens when the base-emitter and base-collector junctions are forward bias. In addition, the effective resistance between collector and emitter in saturation state is small, making the transistor act as a closed-circuit. The parameters for a NPN transistor during saturation mode are shown below:

$$V_{CE} \leq 0.1V \tag{3}$$

This is known as the saturation voltage, or $V_{ce(sat)}$

$$I_B > 0, I_C > 0 \tag{4}$$

$$V_{be} \geq 0.85V \tag{5}$$

During saturation mode, the 2N2222A operates with a base-emitter junction voltage of 0.85 V_{DC} ($V_{be(sat)}$), a collector-emitter voltage ($V_{ce(sat)}$) of 0.1 V_{DC} and the minimum current gain of 10. The following figures show the correlation of the collector current to respect to the turn-on voltage (V_{be}) and the collector-emitter voltage (V_{ce}):

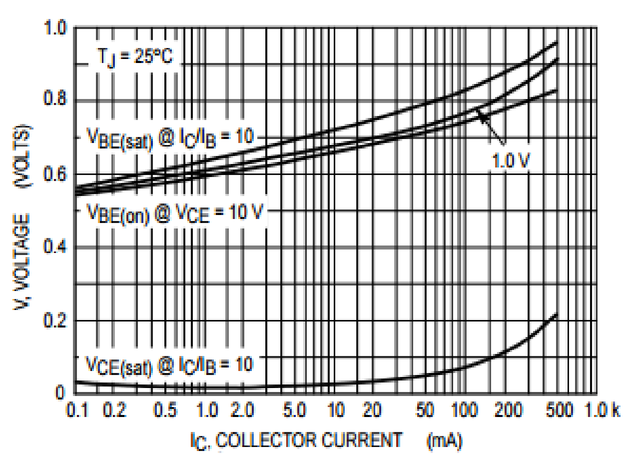

Fig. 3. P2N222A Base-Emitter Saturation Voltage and Collector-Emitter Saturation Voltage

The CC3200 GPIO supplies a sufficient amount of voltage to the transistor to set the two junctions to be forward bias. When the CC3200 sends a high level signal, the transistor is in saturation state. During this state the transistor acts as a closed-circuit allowing the current to flow to the coil of the relay. When system is not used by the user or the CC3200 sends a low signal, the transistor is in cut-off state. During this state the transistor acts as open-circuit interrupting the current flow to the coil of the relay.

The high power switching TMP relay is implemented in the system to control the on/off function of the home appliances. The relay is capable to control a maximum switching capacity of 5540 W (20 A, 277 V_{AC}) using the normally open (NO) terminal. The relay requires 800 mW (9 V_{DC}, 89.1 mA) of power in order to be functional. The TMP relay is equipped with a drive terminal (coil terminal) on one side, and a load terminal (tab terminal) on the reverse side. The coil terminal uses two bottom pins of the relay and they are directly attached to the RCU board. One pin is connected to the positive terminal of the 9 V battery and the other is connected to the collector connection of the P2N2222A transistor. During the switching process the coil of the relay acts as an inductor storing a significant amount of current that might create a high voltage spike that can damage the electronic parts in the unit. The IN4005 rectifier diode is connected across the coil terminal pins. The IN4005 handles the coil current and protects the unit from a high output voltage peak coming from the relay when the system turns off. In addition, there are three tab terminals, which are common (COM), normally closed (NC) and normally open (NO). These tab terminals are located on the top side of the relay. The COM tab terminal is connected to one of the AC wire connections from a power adapter cable. The power adapter cable is used to connect the unit to the AC power coming from a wall outlet. The COM tab transfer the AC power to the NO tab when the relay is on operation mode. The NO tab is wired to a terminal tab connection that is located on the back of power entry connector. The power entry connector is used to connect the relay control unit to any home appliance.

F. Door Control Unit

The door module also uses the CC3200 launchpad to communicate with the home system. Like the light module, the CC3200 receives the transmitted wireless signal at a frequency of 2.4 GHz. The CC3200 processes the received signal and sets the red LED on the board to be high or low depending on the command. The red LED notifies the user if the wireless connection is achieved in the system. The red LED shares the same connection with the general purpose input/output (GPIO) pin 29. The CC3200 launchpad operates with two AA batteries, which allows the CC3200 to send a high level signal of 3 V and 10.75 mA through pin 29. The GPIO pin 29 and pin 20 (GND pin) are applied to send a high/low level voltage signal to the door control unit (DCU) board. The DCU board is responsible to control the unlock/lock function for the door module. The board size is 2.43 x 1.49 inch and the PCB is a 2-layer design. The board consists of using a TIP120 NPN Darlington transistor, a 1N4005 rectifier diode, a 390 Ω resistor, a 2.1 mm inside diameter (ID)/5.5 mm outside diameter (OD) power jack connector, a two position 3.5 mm pitch terminal block, and a three pin female header power connector. An elementary diagram of the custom circuit is shown in Figure 4.

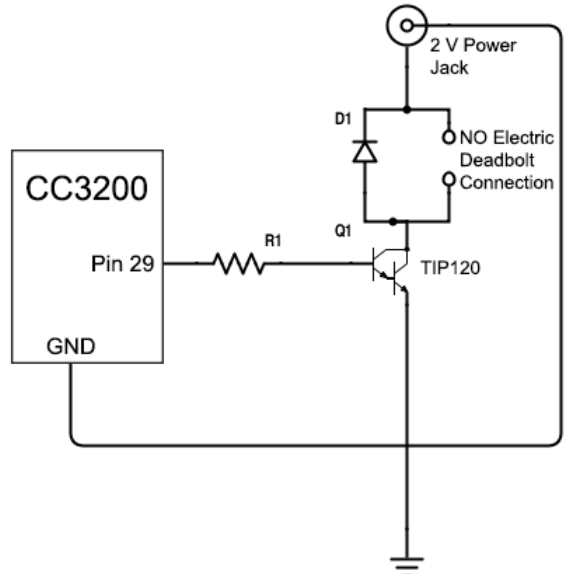

Fig. 4. Door Control Unit Schematic

The CC3200 GPIO (pin 29) and GND (pin 20) pins connect to the female header power connector on the DCU board. The female header power connector supplies the high level voltage signal through the 390 Ω resistor that is connected to the base of the TIP120. A rechargeable 12 V battery connects to the collector of the TIP120 with the task to supply 12 V_{DC} to a normally-open (NO) mode fail-secure electric deadbolt. Originally, the design intended for a servo to drive a deadbolt installed in a door, but an electric deadbolt proved to be easier to install and more secure.

The 390 Ω resistor is connected to the base to limit the amount of current flowing to the base by 1/250 of the collector current. The base resistance value is found by using the following DC parameters:

$$\frac{I_C}{I_B} = h_{FE} = 250 \tag{6}$$

$$R_B = \frac{V_{CC3200} - V_{BE}}{I_C} \tag{7}$$

Similarly to the 2N2222A transistor, the TIP120 darlington transistor operates in two states, which are cutoff and saturation. Using these two states, the transistor may be used as a current control switch. The parameters for a TIP120 darlington transistor during saturation mode are shown below:

$$V_{CE} \leq 0.6V \tag{8}$$

$$\tag{9}$$

This is known as the saturation voltage, or $V_{ce(sat)}$

$$I_B > 0, I_C > 0 \tag{10}$$

$$V_{be} \geq 1.5V \tag{11}$$

During saturation mode, the TIP120 operates with a base-emitter junction voltage of 1.5 V_{DC} ($V_{be(sat)}$), a collector-emitter voltage ($V_{ce(sat)}$) of 0.6 V_{DC} and the minimum current gain of 250. The following figure shows the correlation of the collector current to respect to the turn on voltage (V_{be}) and the collector-emitter voltage (V_{ce}):

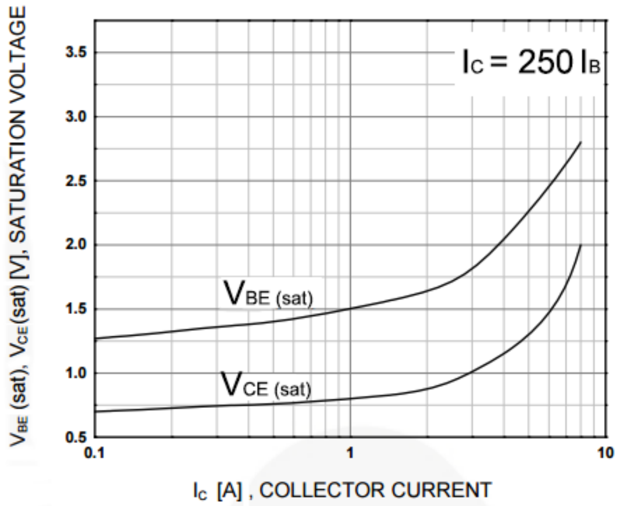

Fig. 5. TIP120 Base-Emitter Saturation Voltage and Collector-Emitter Saturation Voltage

The CC3200 GPIO supplies a sufficient amount of voltage to the transistor to set into saturation mode. When the CC3200 sends a high level signal, the transistor is in saturation state. During this state the transistor acts as a closed-circuit allowing the current to flow through the solenoid of the electric bolt assembly. When system is not used by the user or the CC3200 sends a low signal, the transistor is in cut-off state. During this state the transistor acts as open-circuit interrupting the current flow through the solenoid of the electric bolt assembly.

The normally-open (NO) mode fail-secure electric deadbolt is used to perform the lock/unlock function in the door module. The electric deadbolt operates at 12 W ($12V_{DC}$ 1 A). The electric deadbolt consists of the main body that is attached to the door and the magnetic base that is attached to the door frame. The main body dimension is 28 x 200 x39 mm and the magnetic base is 25 x 90 x 25 mm. The two components are in contact when the door is closed. When the solenoid of the main base is energized, a current passing through the solenoid creates a magnetic flux that causes the magnetic base to interface with the main base, creating an unlocking/locking action. The electric deadbolt uses a timer to control the unlocked position while the door is opened, and the main base and magnetic base are separated. The timer can be set to 0, 3 or 6 seconds. The solenoid of the electric deadbolt has two wires that are connected to the terminal block of the DCU board. One connection of the terminal block is connected to the 2.1 mm (ID)/5.5 mm (OD) power jack connector. The power jack connector is used in the DCU board as an input connector for the rechargeable 12 V battery and the other connection is connected to the collector connection of the TIP120. The rechargeable battery can supply a high capacity of 3800 mAh, which is enough power to unlock the deadbolt for a few seconds for multiple times. During the on/off process, the solenoid of the electric deadbolt can store a significant amount of current that might create a high voltage spike that can damage the electronic parts in the unit. The IN4005 rectifier diode is connected across the two connections of the terminal block. The IN4005 handles the solenoid current and protects the unit from a high output voltage peak coming from the relay when the system turns off.

V. Software Details

A. Main Unit Drivers

The main processing unit in the home station is the ODROID-C1. It is responsible for interfacing with the speech recognition circuit, the liquid crystal display and the rotary encoder as well as wirelessly communicating with the remote stations (the CC3200s). Using a ported version of WiringPi, a GPIO interface library developed for the Raspberry Pi, the 19 available GPIO pins can be utilized. The software is hierarchically structured such that individual drivers control the hardware elements are at the lowest level. Above them are menu management and wireless communication systems and at the highest level is the main function that initializes and calls upon the substructures.

The liquid crystal display driver is based on the Hitachi HD44780 alphanumeric dot matrix controller. The display has a command and a data register which can be selected using the Register Select (RS) bit. The data register can be read from or written to using the Read/Write (R/W) bit. Both data and commands are sent to the device using eight or four parallel data bits. Four bit mode operation was chosen to conserve readily available GPIO pins. Lastly all transfers are made using the falling edge of a Clock Enable (CE) signal. To relay data to the device, bytes of data are sent four bits at a time, the upper nibble followed by the lower nibble. After the data bits, RS bit, and R/W bit are set the CE pin is strobed and the data is transferred. When the device is initialized a series of commands are sent to configure the display. Four bit mode operation with each character having its own 7x5 dot matrix is set by writing bytes to the command register. A full list of available commands are listed in the Hitachi HD44780 datasheet. After the device is initialized, strings can be displayed by sending ASCII codes one byte at a time to the correct memory address. The base addresses of the four display lines are as follows: 0x00, 0x40, 0x14, 0x54. To minimize delays between data transfers and ensure each nibble is accurately written, a busy flag is polled from the device between each transfer. The rotary encoder has three pins which interface with the ODROID. There are two channels used to detect rotation and one used to detect a button press. The rotation channels output gray code and are used to determine direction. By polling the two channels and ensuring both pins are set to high and then low again in the correct sequence we can eliminate the chance of debouncing.

The ODROID interfaces with the speech recognition circuit through seven data pins and one data enable pin. The HM2007 was originally designed to display output data on two seven segment displays. Therefore the lower four data bits are the binary representation of the decimal ones digit and the upper three data bits are the binary representation of the tens digit.

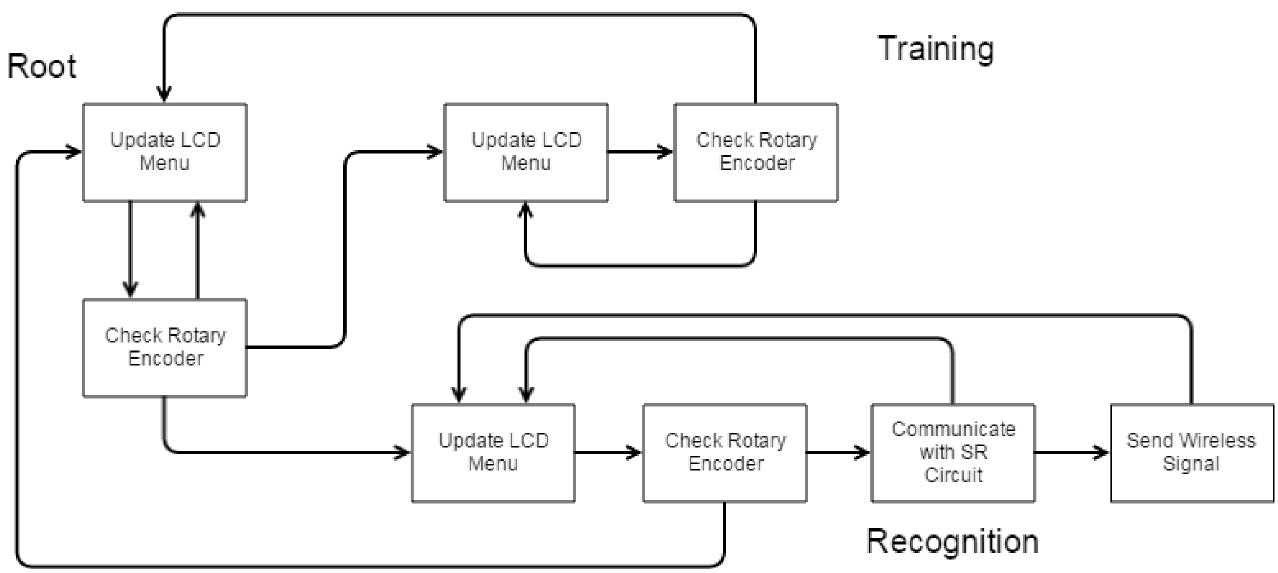

Fig. 6. Software flowchart for SRC

Only three data bits are needed for the upper digit because the highest possible output from the device is 77 which is an error code used to display that a match has not been found. Using the three aforementioned device drivers, a menu system is developed to interface the user with the system. The root menu gives the user access to the three submenus: Recognition, Training, and Settings. In the recognition menu, the system will poll the speech recognitions output to look for matching keywords. In the training menu, the user can scroll through the list of remote stations and record their on and off commands for each. Finally, in the settings menu the user can set the number of electrical and door control units the system will recognize. A diagram of menu system is available in Figure 6.

B. Wireless Communication

Upon startup, the ODROID-C1 establishes itself as a wireless AP using hostapd, dnsmasq, and iptables on the Arch Linux platform. Hostapd configures the wireless access point, iptables performs traffic routing, and dnsmasq deals with DNS routing and provides DHCP leases. The IP address for the ODROID-C1 uses the reserved address space of 192.168.1.0/24, allowing for up to 100 devices to connect to the AP. Bourne Again Shell (BASH) scripting has been used to automate the setup of these services on startup.

Each CC3200 has had its serial flash programmed with code to establish it as a HTTP server. Once power is applied to the device, the board is initialized and configured as a station. The unit then pings the APs gateway to check the connection and connects to the AP with security parameters (the SSID name, encryption method, and the password) specified in connect.h. WPA2 is used to encrypt the communications between modules. Of the available encryption schemes, like WEP, WPA2 is the current acceptable standard supported by all devices that provides a secure communications channel. It allows for a password of up to 63 characters. Once the connection is established the client attempts to open a socket connection with the server. This is accomplished with the following series of function calls:

- `BoardInit()` sets up TI-RTOS and initializes processor
- `PinMuxConfig()` configures the pin configuration
- `MAP_PRCMPeripheralReset()` initializes UART
- `MAP_UARTConfigSetExpClk()` initializes UART
- `DisplayBanner()` displays a banner that can be seen on a COM port
- `ConfigureSimpleLinkToDefaultState()` wipes any profiles or persistent settings
- `ConnectToNetwork()` connects to the Network in AP or STA Mode
- `WlanConnect()` attempts to connect to the AP given the SSID, the encryption method, and the password
- `CheckLanConnection()` pings the AP gateway
- `sl_Socket()` establishes a socket connection
- `SimpleLinkHttpServerCallback()` establishes the method through which POST requests change the LED status

Wireless socket communication occurs between the ODROID-C1 and the CC3200 when the SRC sends a signal to the outlying modules. Bash and Python scripting is used to identify which module to send the signal to based on a unique MAC address. Specifically, a curl command sends a POST request to the HTTP server:

```
curl --data "SL_P_ULD=LED1_ON"
http://$1/led_demo.html
```

The server accepts the request and manipulates the status of pin 29 which is connected to the red LED as well as the device controller.

VI. Conclusion

SCREAM is a HAS intended to fill an unfulfilled 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 any physical limitations. SCREAM is a robust system that can enable many homeowners to use a HAS when they might have previously been intimidated by the cost or the technical knowledge required to purchase and operate one.

SCREAM uses an embedded architecture and SoC technologies which allow the system to be cheaper, smaller, and easier to use. It is cheaper because the components are less expensive to manufacture and are simple to assemble. Also, it uses Wi-Fi which is far more prevalent than a proprietary protocol like Zigbee or Zwave to package data. As a result, there are plenty of IC manufacturers that make the parts required for SCREAM and the premade RF modules which are used reduce the cost and time of development. Finally, there is no recurring subscription or third party monitoring service to pay fees.

SCREAM is easier to use because it is intended to be used vocally with little system manipulation required to voice train the speech recognition chip. It uses an embedded platform requiring no PC or server to use which allows for maximum operation time. There is no GUI to be confused by, no overarching operating system to configure or troubleshoot or update, 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 which could break, with the exception of the electric deadbolt required to lock the door.

The advantages of only being able to easily communicate with the system using vocal commands can also be viewed as a drawback. Most modern home automation systems rely on the use of a touch screen display, typically in the form of a tablet or smartphone. Moving forward with the projects advancement, a feature that could be added is the development of a mobile application. 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. An additional extension of the project could be the use of email or text alerts to remind the homeowner when a door is left unlocked or an appliance left on while no one is home. Since the product is already connected using Wi-Fi, the ability to send an email or text message to the user would be within the current hardwares capabilities.

VII. Engineers

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