Voice Activated Door Opener

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Abstract

The goal of this project is to make public buildings accessible to all persons with disabilities by accomplishing the following: create a wireless device that can easily be carried by the user; create a second versatile device that can be coupled with a door opener; minimize and eliminate constraints to handicap accessibility; and provide a safe environment for the users and nonusers.

1 This material is based in part upon work supported by the National Science Foundation (NSF) under Grant Number CBET-1401507. Any opinions, findings, and conclusions or recommendations expressed in this material are those of the author(s) and do not necessarily reflect the views of the NSF.
1. Introduction

Public places, such as the NDSU campus, are required to be handicap accessible. Usually, accommodations are made by providing a switch activated openers to entryways. However, it is very difficult for students with quadriplegia or similar disabilities to operate such doors. Therefore, we propose a cost effective voice activated door opener. This system will be broken down into two primary parts: one device carried by the user, and a second device that is installed near the door. The device carried by the user will have a microphone to accept the user’s voice command. The command will be carried wirelessly to the door unit and the correct voice command will signal the door to open.

2. Previous Work

Figure 1: NanoPac door opener

NanoPac created a similar product called “Open Sesame” for people with quadriplegia. The picture to the left is the setup for their system. Similar to our design, this system opens the door by voice command. This door is equipped with a safety feature to prevent people from getting caught in the door. If the door feels resistance while shutting, the failsafe will stop the door from closing. Our system will rely on a fixed time programmed to allow enough time to pass through the door. The NanoPac product is advertised in a domestic setting. The system we have designed will provide accessibility in either the commercial or domestic setting. The voice control component is called Cintex. Cintex was developed by Silvio Cianfrone while he was vice president of Telex. Cianfrone started NanoPac in 1987 to create solutions for a person with quadriplegia, and continued to develop solutions for other disabilities as well. In 1992 NanoPac worked together with IBM to create Cintex2.
3. Requirements

There are primary and secondary requirements for hardware, mechanical, and software sub requirements. The primary requirements are absolutely necessary for the functionality of the device. Then the secondary requirements are not required for function, but can provide convenient indicators for basic troubleshooting and safety. This is a two device system. The device carried by the user will be referred to as device 1. The device mounted near the door opener will by referred to as device 2.

Primary Hardware Requirements

1) Device 1
   a) Power supply will be a coin battery to supply a minimum of 5VDC.
   b) Includes a microphone module with an operational amplifier.
      i) Example: MAX4669 input: (2.4V-5.5V)@24uA
      ii) Electret input: (3V-10V)@0.5mA max
   c) Transceiver transmission: XBEE with 1mW chip antenna, input (35mA – 45mA)@3.3V

2) Device 2
   a) Power supply: 120VAC power cord
   b) Voltage will step down to 12VAC to 20VAC through either a transformer or power supply
   c) Full wave bridge rectifier to convert AC to DC, rated 2A maximum
   d) Two capacitors will filter the signal with a 5V regulator, first capacitor will filter the ripple, second capacitor to filter the noise
   e) Voltage regulator output: 5VDC@500mA
   f) Control relay will be used to isolate the door opener from the control circuit
      i) Input: 3.5VDC@84mA, relay contacts: 16A@400VAC max
      ii) The relay is connected to a NPN transistor switch
      iii) The microcontroller will output a high to the NPN to provide a path to ground closing the circuit to the control relay and push button output
   g) Device two receiver: XBEE with 1mW chip antenna, input 50mA@3.3V

Secondary Hardware Requirements

1) Device 1
   a) PCB mount red LED
      i) Inputs 5VDC from the MCU output
      ii) Indicates that the device is on
      iii) Installs directly to the PCB and placed in holder through the enclosure

2) Device 2
   a) Panel mount red LED
i) Inputs 5VDC from the MCU output
ii) Indicates that the device is on
iii) Installed to the panel and fasten with a lock washer and nut

b) Panel mount green LED
   i) Inputs 5VDC from the MCU output
   ii) Indicates that the door is opening
   iii) Installed to the panel and fasten with a lock washer and nut

c) Panel mount buzzer
   i) Input range: 5VDC to 23VDC
   ii) 5VDC input is used to regulate the noise level

Primary Software Requirements

1) Device 1
   a) Input voice command “open” through microphone to an analog input of the MCU
   b) Once the voice command is received, the MCU will send a high through a digital output of the MCU, this will signal will transmit to the main device through the XBee

2) Device 2
   a) Voice command signal is received through the XBee
   b) If voice command is accepted the MCU signals highs to outputs for:
      i) Control relay to close the push button peripheral and the door opens
   c) The door will remain open for 20 seconds then close automatically

Secondary Software Requirements

1) Device 1
   a) MCU outputs a high signal to the red LED when the device is turned on

2) Device 2
   a) The MCU sends a high signal for the following indicators:
      i) The green LED turns on for a 20 seconds
      ii) The buzzer sounds three brief chirps

Primary Mechanical Requirements

1) Device 1 enclosure
   a) Will be small enough to be worn by the user
   b) There will be room towards the bottom of the enclosure for a battery holder
   c) Microphone will be mounted through the top of the chassis to efficiently input the users voice command
2) Door opener
   a) The door opener will be mounted onto the frame at the top of the door
   b) The arm that pushes on the door will be installed to the door in a manner that the pushing arm does not damage the door
3) Device 2 enclosure
   a) Will be mounted approximately 4 feet from the ground
   b) The wire from the door opener power supply will run through cord grip at the bottom of the enclosure
   c) A transformer or secondary power supply will be installed onto the mounting plate for control circuit supply
   d) The PCB will be firmly mounted to the enclosure to ensure no movement

Secondary Mechanical Requirements

1) Device 1 Enclosure
   a) The top of the enclosure will have two small holes to allow a neck band for carrying the device
   b) The PCB will be placed firmly into the enclosure with mounting screws to prevent movement
2) Door opener
   a) Additional hole may be made on the door opener for routing wires from the secondary supply
   b) A door closer will be added as needed
3) Device 2 enclosure
   a) The front of the enclosure will have two LED’s mounted through the chassis
   b) The front of the enclosure will have a buzzer mounted through the chassis

4. Design Options

The design options include RF transmission, power options, microcontroller options, and enclosure fabrication options. These options sifted through by either research or experimentation.

RF transmission

There are three different wireless choices that were tested for this product. First, the 433 MHz transmitter and receiver module; second, the 2.4GHz transceiver module; and third, the 2.4 GHz XBee module. After working with all of them, it is recommended to use the XBee module. The reasoning will be further demonstrated by examining the advantages and disadvantages of each module.

1) 433 MHz module (transmitter on the left and receiver on the right)
Advantages

a) This module is the cheapest module of the three
b) It is easy to connect to an Arduino
c) It works well in a short range

Disadvantages

a) There is not very much literature to for learning how to use these modules
b) These are not very reliable in longer range applications
c) If a longer range application is desired, a larger antenna must be added

2) 2.4 GHz transceiver module

Advantages

a) This is the second cheapest module, but is not much more expensive than the previous option
b) It is compatible to connect with an Arduino
c) It works well with short range applications with or without line of sight
d) It is easier to add an antenna if need to increase the range
Disadvantages

a) There is not very much literature to for learning how to use these modules
b) If a longer range application is desired, a larger antenna must be added
c) They are much more difficult to implement

3) XBee 2.4GHz transceiver

Figure 4: XBee module

Advantages

a) The XBee have a wide variety of transceivers to choose from for individual applications
b) It is compatible to connect with an Arduino
c) There are shields available to connect the XBee to the Arduino more efficiently
d) There are also breadboard shields for XBee’s that make prototyping easier
e) There is plenty of literature available for learning how to use the XBee

Disadvantages

a) This module is significantly more expensive than the other modules
b) Requires a lot of configuration and can be time consuming to learn

4) The final option to consider is the non-wireless system with only one device

Advantages

a) It would eliminate the need of a second device and reduce cost and complexity
b) It would eliminate the need to use a RF module which would also reduce the cost
c) Without the wireless, there is a lot less to troubleshoot when the system malfunctions
d) The user would not have to be concerned about the life of the battery on a mobile device, because all components would be powered from the wall outlet
e) This would allow for a greater variety of options for the microphone because there would not be the constraint of making it small enough to fit a wearable enclosure

Disadvantages
a) The voice command accessibility could be abused by those not in need of hands free accessibility
b) The microphone will not be as close to the user's mouth

Power Options
There are few different power options that were considered between the two devices. The power options for device 1: 2 coin batteries, 9 volt battery, or a custom lithium battery. The power options for device 2: 120VAC wall outlet or remove the transformer for a 7VDC to 15VDC input directly to the control circuit.

1) Coin battery

![Coin batteries](image)

Figure 5: Coin batteries

Advantages
a) The coin battery is the smallest of the options listed and fits into the enclosure easily
b) There are coin battery holders that allow the batteries to be stack back to back without the need for additional space
c) Coin batteries are cheap

Disadvantages
a) Coin batteries do not have as much battery life as the other options
b) Coin batteries may be more difficult to change out than other options

2) 9 VDC battery
Advantages

a) Easy to implement into the design
b) These batteries are widely available in most convenient stores
c) The battery is easier to change out

Figure 6: 9 volt battery

Disadvantages

a) It is a more expensive option
b) This battery would require a larger enclosure to implement into the design

3) Custom made lithium battery

Advantages

a) Lithium batteries have a longer lifespan than a lot of the disposable and other rechargeable alternatives.
b) Comes in various sizes and as shapes. Therefore it can be designed to fit the enclosure better.

Disadvantages

a) These batteries can be relatively expensive.
b) Harder to design and implement.
c) They are not widely available for replacement the user would have to get a new one directly through the manufacturer.

Microcontroller Options

1) PIC18

Advantages

a) Low cost or free development tools
b) There is a lot of literature available for the PIC18
c) Large variety of options for different applications
Disadvantages

a) Instead of having fixed analog and digital pins it would require programming of analog to digital conversion
b) MPLab is a more difficult compiler to use
c) More difficult to learn than other options

2) Arduino (ATMEGA328P)

Advantages

a) There is a lot of literature for instruction of use
b) There is a large open software library to help get projects started
c) The power supply hardware is already present to protect microcontroller
d) Serial communication over USB makes it easier for programming
e) Provides a more efficient way of prototyping
f) Has free development software on the website

Disadvantages

a) Uses its own C language
b) Not commonly used at commercial level
c) May use up more space in the design since it has more hardware than just the microcontroller

3) Raspberry Pi Model B+ (ARM1176JZF-S)

a) Large and expandable storage
b) Variety of programming languages can be used
c) Large community support
d) Several open source voice recognition options
e) Free development tools

Disadvantages:

a) Demands knowledge of Linux
b) Not bare bones, complete with a circuit

Enclosure Fabrication Options

The following fabrication options compare the different options for wearing or mounting depending on the device. Device 1 has a couple of options as to how the user may choose to wear the device. Then device 2 has a couple of options of how to mount the device for the most efficient setup per situation.

1) Enclosure fabrication device 1
There are two main options to consider the neckband and a clip. The neckband has almost no possibility of falling off of the user. Alternatively, the clip on may lose its grip. Given that our user will most likely not be able to retrieve the fallen device, it is recommended to use the neckband.

2) Enclosure fabrication device 2

Device 2 has the option of either being mounted on the wall near the door or being mounted on the door itself. If the door opener is a large unit, it would be more advisable to place device 2 on the wall about 4 feet from the floor. If there is room on the door to place device 2 next to the door opener, this may eliminate the length of wire running from the door opener to device 2.

5. Software

![Flowchart of Device 1](image)

The microcontroller (MCU 1) in device 1 will have one input and one output. The input is an analog signal from the microphone when the user says the voice command. Then the output is a digital signal to the XBee. The following gives a description of each stage of the software:

1) Input1: voice command “open”
2) Output1: MCU 1 to XBee
3) Output1 = 0 (continues to listen)
4) Output1 = 1 (XBee transmits)
The microcontroller (MCU 2) in device 2 will have one input and four outputs. The input is a high signal from the receiving XBee. The first output sends a high signal anytime the device is on to light up the red LED. Then the other three outputs will send a high signal simultaneously to turn on the green light for 20 seconds, open the door, and sound the buzzer three times. After the 20 second delay the door will close and the buzzer will sound three more times.

1) Input1: MCU input
2) Output0: RLED (Red LED)
3) Output1: GLED (Green LED)
4) Output2: Buzzer
5) Output3: Door opener
6) Receive: XBee input
6. Wireless Voice Command

The software used for this project was written in C and C++. Speech recognition is very processor intensive. Many companies such as Google and Microsoft use cloud computing for accurate voice recognition. Our requirements were to have a small unit with low power consumption and internet connectivity wasn't a viable option. This is why an open source library named uSpeech by Arjo Chakravarty was chosen and modified to fit our speech recognition requirements. This library and software was chosen for the simplicity it provides, small memory footprint, and its ability to be run on a small low powered micro-controller unit. uSpeech was designed to work well with servo motor control with commands such as left, right, and stop. This was modified to work as best possible for the command “open”.

The XBee 802.15.4 module was chosen for the wireless communication capabilities because of its thorough documentation and ease of use. For set-up XBee modules needed to have matching PAN IDs and channels. Each unit needed the address of the opposite unit as the destination address. The XBee modules needed to be configured to have a coordinator device and an end device. In our case the coordinator device is on the worn device and the end device is on the door unit. The sample rates on the XBee modules needed to match and the I/O capabilities need to be enabled on each device. The I/O needed to be set as an input on the coordinator device and an output of the end device. The internal pull-up resistor also needed to be enabled on the end device because it had the output.

The worn devices micro controller was programmed with the modified uSpeech library to recognize “open” and then send a signal to the coordinator XBee module. uSpeech first needed to be set-up for our microphone. The volume of the microphone while no speech is happening was recorded and set as the minimum volume. The six phonemes that uSpeech recognizes were tested and the values were recorded so phonemes could be returned by the getPhoneme method. A loop was then made to call the getPhoneme method and if the phonemes in the word open were recognized through the microphone a digital high was sent to the coordinator XBee module.

The microcontroller on the door was connected to the end device XBee module. When the end device received a digital high from the coordinator, a high was also sent to micro controller. The microcontroller was programmed to loop while testing for a digital high from the XBee module. Once there was a high it ran through a script that causes four outputs and the microcontroller to send signals out. The four outputs were a solid high attached to a red LED that is always on for power, a solid high that is on for the duration of the door being opened attached to a green LED, an output that blinks high and low three times and then stays low to sound the buzzer, and an output that goes high for one second to send power to the door opener.
7. Hardware

Figures 9, 10, and 11 are the device 2 PCB schematic, top layer of the PCB layout, and the bottom layer of the PCB layout. The microcontroller design is simple, all of the outputs can be found on the bottom right corner. The only input is from the XBee on the left side. The power coming in is split between two voltage regulators. The 3.3 volt regulator supplies power to the XBee and the control relay. The 5 volt regulator supplies power to the microcontroller and the buzzer.

The device 2 PCB layout is design with all of the output peripherals along the bottom of the board. This will allow for easy implementation of the panel mount indicators and the push button peripheral output. The indicators will be wired to the terminal blocks installed at P2. Then the push button peripheral output is P6.

![Device 2 PCB Schematic](image)

<table>
<thead>
<tr>
<th>Label</th>
<th>Component Description</th>
<th>Label</th>
<th>Component Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>P1</td>
<td>Power Supply</td>
<td>IC2</td>
<td>XBee Module</td>
</tr>
<tr>
<td>P2</td>
<td>Indicator Terminals</td>
<td>Q3&amp;Q4</td>
<td>NPN Transistor</td>
</tr>
<tr>
<td>P4</td>
<td>5 Volt Regulator</td>
<td>C1</td>
<td>470uF Capacitor</td>
</tr>
<tr>
<td>P5</td>
<td>3.3 Volt Regulator</td>
<td>C2&amp;C3</td>
<td>0.1uF Capacitor</td>
</tr>
<tr>
<td>P6</td>
<td>Door opener</td>
<td>C4&amp;C5</td>
<td>22pF Capacitor</td>
</tr>
<tr>
<td>CRY</td>
<td>Crystal</td>
<td>D4</td>
<td>Diode</td>
</tr>
<tr>
<td>IC1</td>
<td>ATMEGA328P MCU</td>
<td>F1</td>
<td>Fuse</td>
</tr>
<tr>
<td>R1&amp;R2</td>
<td>150Ω</td>
<td>K3</td>
<td>Control Relay</td>
</tr>
<tr>
<td>R3</td>
<td>10kΩ</td>
<td>R4</td>
<td>3.3kΩ</td>
</tr>
</tbody>
</table>
Figures 12, 13, and 14 are the device 1 PCB schematic, top layer of the PCB layout, and the bottom layer of the PCB layout. The microcontroller design is simple, all of the outputs can be found on the bottom right corner. The only input is from the XBee on the left side. The power coming in is split between two voltage regulators. The 3.3 volt
regulator supplies power to the XBee and the control relay. The 5 volt regulator supplies power to the microcontroller and the buzzer.

Figure 12: Device 1 Schematic

<table>
<thead>
<tr>
<th>Label</th>
<th>Component Description</th>
<th>Label</th>
<th>Component Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>P1</td>
<td>Power Supply</td>
<td>R1</td>
<td>Crystal</td>
</tr>
<tr>
<td>P2</td>
<td>Microphone</td>
<td>C1</td>
<td>0.1uF Capacitor</td>
</tr>
<tr>
<td>P3</td>
<td>Reserved Pins</td>
<td>C2</td>
<td>470uF Capacitor</td>
</tr>
<tr>
<td>R5</td>
<td>150 Ω</td>
<td>C3&amp;C4</td>
<td>22pF Capacitor</td>
</tr>
<tr>
<td>VR1</td>
<td>3.3 Volt Regulator</td>
<td>D5</td>
<td>Red LED</td>
</tr>
<tr>
<td>IC</td>
<td>ATMEGA328P MCU</td>
<td>IC1</td>
<td>XBee Module</td>
</tr>
</tbody>
</table>
The device 1 PCB layout is designed with the microphone to the side of the board to make it easy to route the wires from the input power to the microphone. The LED is placed right next to the through hole of the panel where it will reside. The LED will not even need to route wires since it is propped close enough to bend down and into the LED panel holder.

![Figure 13: Top layer](image1)  ![Figure 14: Bottom layer](image2)

The two figures below are of device 1. There are four holes lower on the interior to mount the PCB to the enclosure. This would eliminate all possible movement of the PCB. The four holes higher up the enclosure are for mounting the cover on the PCB. The battery pack is plugged into the header just above the XBee.

![Figure 15: Device 1 interior](image3)  ![Figure 16: Device 1 side/top view](image4)
The figures below show the interior and the exterior of device 2. As shown in the PCB layout the indicator terminal blocks are on the bottom right corner. These are convenient because if an LED burns out it will not be necessary to remove the entire PCB for desoldering. Instead simply just unscrew the terminal to release the wire and remove the LED. The PCB is mounted to the aluminum back plate by using sticky foam. Another option for mounting would be to use standoffs. This would require drilling additional holes into the PCB. The aluminum back plate is firmly mounted to the enclosure to ensure no movement will occur within the enclosure.

![Device 2 interior](image1)
![Device 2 front view](image2)

8. Installing the System

First, place two coin batteries into the battery holder of device 1. Make sure that the red LED lights up to indicate that the power is on. Then the XBee will also have an orange, green, and blue lights that come on. Place a neckband through the two holes at the top of the device. After the neckband is securely fastened and the indicators appear to be on, device 1 is ready.

Device 2 should be installed either on the wall or on the door near the door opener. If installed on the wall, it is recommended that it is placed 4 feet from the floor to optimize the use of the indicators. Be sure to place a mounting screw in each of the four corners of the enclosure. The device needs to be plugged into the wall outlet. Make sure it is installed near an outlet that can supply 120VAC. Before applying power, hook up the control output to the push button peripheral of the door opener. Then plug the unit in and the red LED should come on. After the red LED lights up the system is ready for use.
## 9. Item List

<table>
<thead>
<tr>
<th>Component</th>
<th>Qty</th>
<th>Purpose</th>
</tr>
</thead>
<tbody>
<tr>
<td>Transformer</td>
<td>1</td>
<td>Step down 120 VAC wall voltage to 12 VAC</td>
</tr>
<tr>
<td>Fuse</td>
<td>2</td>
<td>Protects the control circuit on both sides of the transformer</td>
</tr>
<tr>
<td>Rectifier</td>
<td>1</td>
<td>Creates a forward bias signal to prepare for a DC conversion to the voltage regulator</td>
</tr>
<tr>
<td>3.3V Voltage Regulator</td>
<td>2</td>
<td>Power supply for the microcontroller in device one, control relay in device two, and the XBEE in both devices</td>
</tr>
<tr>
<td>5V Voltage Regulator</td>
<td>1</td>
<td>Power supply for the microcontroller and buzzer</td>
</tr>
<tr>
<td>XBEE adapter board</td>
<td>2</td>
<td>Makes installing, configuring, and replacing much easier</td>
</tr>
<tr>
<td>XBEE 2.4GHz, 1mW</td>
<td>2</td>
<td>Provides wireless communication between the two devices</td>
</tr>
<tr>
<td>0.1 µF Capacitor</td>
<td>3</td>
<td>Eliminates low frequency component from the power supply output (noise reduction)</td>
</tr>
<tr>
<td>470 µF Capacitor</td>
<td>1</td>
<td>Eliminates high frequency component from the power supply output (ripple reduction)</td>
</tr>
<tr>
<td>22 pF Capacitor</td>
<td>4</td>
<td>Two are used with a crystal to provide a resonator for the microcontroller</td>
</tr>
<tr>
<td>150 ohm Resistor</td>
<td>3</td>
<td>LED current limiting resistors</td>
</tr>
<tr>
<td>10k ohm Resistor</td>
<td>2</td>
<td>The base resistor to the NPN transistor switch</td>
</tr>
<tr>
<td>Transistors</td>
<td>2</td>
<td>Used as a switch to sink the voltage when the microcontroller goes high</td>
</tr>
<tr>
<td>Control Relay</td>
<td>1</td>
<td>Isolates the door opener circuit from the device two control circuit</td>
</tr>
<tr>
<td>Diode</td>
<td>1</td>
<td>Prevents the control relay coil from surging the transistor</td>
</tr>
<tr>
<td>Microcontroller</td>
<td>2</td>
<td>Provides the control circuit with I/O's for indicators and voice command</td>
</tr>
<tr>
<td>Red LED (panel mount)</td>
<td>1</td>
<td>Panel mount LED to indicate when the device two is on</td>
</tr>
<tr>
<td>Green LED (panel mount)</td>
<td>1</td>
<td>Panel mount LED to indicate when the door is opening</td>
</tr>
<tr>
<td>Red LED (small)</td>
<td>1</td>
<td>LED for device one that indicates power on</td>
</tr>
<tr>
<td>Buzzer</td>
<td>1</td>
<td>Sound indicator for the door opening</td>
</tr>
<tr>
<td>Enclosure (Device 2)</td>
<td>1</td>
<td>Housing for the control board and transformer</td>
</tr>
<tr>
<td>Panel Kit</td>
<td>1</td>
<td>Aluminum back plate for enclosure to secure circuit board and transformer</td>
</tr>
<tr>
<td>Enclosure (Device 1)</td>
<td>1</td>
<td>Housing for device one circuit</td>
</tr>
<tr>
<td>Microphone Module</td>
<td>1</td>
<td>Input for the voice command</td>
</tr>
<tr>
<td>Crystal</td>
<td>2</td>
<td>Used as a part of the resonator circuit for the microcontroller</td>
</tr>
<tr>
<td>PCB</td>
<td>2</td>
<td>There is one PCB per device</td>
</tr>
<tr>
<td>Cord grip</td>
<td>1</td>
<td>Used to contain wires exiting the enclosure</td>
</tr>
<tr>
<td>Door Opener</td>
<td>1</td>
<td>Opens the door when the microcontroller outputs a high to the control relay</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
10. How to Use the System

After the user has the device powered and have the microphone is secured near the mouth, the system is ready to be used. The user will approach the door and then voice the command: “open”. The green light will come on to indicate the transmission was successful. The buzzer will chirp three times to alert bystanders that the door is opening. Then the user will pass through the door. After 20 seconds has passed since the door has opened, the door will close. The buzzer will sound again as the door closes to alert bystanders that the door is in motion again.

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References


APPROVED BY

Adviser Name __________ Samee Khan, Ph.D. ___________________

Adviser Signature ________________________________ Date ________