Design document for

PCL: Personal Calls by Location

ECE 396: Senior Design I
Department of Electrical and Computer Engineering
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Making today’s calls a thing of the past

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1. Statement of Work

1.1 Background

With the invention of the telephone, came the possibility to communicate over long distances with family and friends. With the advancement of technology, humans were capable of developing phones from the wired to wireless. Today, people have phones that are capable of connecting to the internet, sending e-mail, and taking pictures. The telephone is probably one of the most essential utility found in a home. Although a telephone opens the door to the world of communication, it opens up the household to disturbing, soliciting, and unwanted calls. It also allows the disclosure of private information. These types of calls are problematic and can become very frustrating.

With the development of every new product, there is a necessity to advertise and mass-market it to the consumer. One of the most widely used methods in advertising is telemarketing. According to the Electronic Privacy Communication Center, “Millions of telemarketing calls are made to individuals every year.” Telemarketing is highly unpopular among consumers. Public opinion shows that they object to unsolicited sales calls.1

In addition, phone calls can become inconvenient. Often, a person picks up a phone that is not intended for them. This becomes very irritating when there are numerous calls. A person should not have to worry about picking up a phone call that is not intended for them.

Finally, the Health Insurance Portability and Accountability Act (HIPAA) requires that a physician not release patient information to anyone besides the patient.2 If a doctor calls a patient’s home, he is not allowed to release any information concerning the patient to anyone else in the household. Therefore, phone conversations regarding private matters should not be heard by anyone else but the intended person.

1.2 Team Project Goals

As a team, our goal is to design a device that will personalize the household phone system. By personalizing the household phone system, our goal is to eliminate some of the problems mentioned above. We are designing a system that will be able to filter incoming calls and transfer them only to the phone nearest to the desired individual. The Personal Calls by Location (PCL) is a system for making a phone call more private through the use of existing technology including microcontrollers, RFID, phones, and a personal computer.

1.3 Team Design Aspects

- The design should be completed by April 2004.
- The device will be primarily installed in a home and will not be portable.
- The device is to consist of a main control unit, several reader units, and a few RFID tags.

1 http://www.epic.org/privacy/telemarketing/complaints.html
2 http://www.cms.hhs.gov/hipaa/
• The reading range for the readers will cover the length of a medium-sized room.
• The user-interface will be simple and user-friendly, yet include options for complete user control.
• The user-interface will allow each user to set up the system based on their personal settings.
• A manual consisting of a detailed description for each feature will be provided.
• The device will correctly determine the location of the user relative to the phones in the household.
• The device should have low maintenance and operate on existing phone line power.
• The size of the tag will be small and easily attachable to the user.
• Additional equipment should be available for separate purchase.
• The failure rate should be significantly less than that of current similar products.
• The product must be safe and should not interfere with other household or personal electronic devices.
• The delay time for locating the user should be no longer than a few seconds.
• The device should operate over the range of temperatures and other climatic conditions of a home.
• The final cost of the prototype should be within the $350 - $450 range.

1.4 Deliverables of the Design Project

Our team will provide system design and detailed design documentation necessary to manufacture the device. A prototype will be provided to demonstrate the design. Our team will conduct formal tests to verify the correctness of the device’s operation.

Author(s): Daniel Dobrin, Rehan Shariff, Kunal Shah
2. Assessing Customer Needs and Wants

2.1 Determining the Customer

Defining the customer is probably the most important step before designing a product. The prospective customer for our PCL system is the middle to upper class family who reside in a home.

2.2 Determining Needs and Wants - Surveying the Customer

After determining the prospective customer of a product, the customer’s needs and wants for the product must then be determined. The customer’s needs and wants for our product were determined by surveying the customer. The main participants in our survey were parents, relatives, and friends.

Through a series of survey questions, we found the customer needs and wants for different criteria of our system. First, we wanted to determine whether customers were familiar with similar existing products. By determining how familiar the customers were with similar products, our team was able to decide whether we are competing against an existing product or creating something new. Second, we wanted to determine what the customers considered a user-friendly product. By determining this information, we were able to determine what we should include in our system design. Third, we wanted to determine the customer’s tastes in terms of size and appearance, so we could determine our packaging. Lastly, we wanted to determine the importance of reliability and maintainability of our system based on the customer’s responses.

2.3 Customer Survey Results

Following are the results of our customer survey in terms of the main product aspects of our system (familiarity, functional features, appearance/packaging, user interface, cost, reliability, maintainability, and delivery time):

**FAMILIARITY**  Need X Want

Have you ever picked up a phone at home and the call was not for you? If so, was it frustrating?

Do you often get telemarketing calls? If so, would you like to reduce or eliminate them?

Do you often run around the house trying to pick up the phone?

Do you think a system that will let you personalize your calls, based on your location in the house, will help you in reducing these problems?

Are you familiar with such devices currently on the market? If yes, do you think these types of products really work?
**FUNCTIONAL FEATURES**

Are complex features more important than ease of use?

Would the internet be an acceptable form of entering and editing your personal phonebook?

Must the device be completely automatic?

**APPEARANCE/PACKAGING**

If the package came with several units that must be placed in each room, would that be a problem?

Would carrying a small unnoticeable object be an inconvenience? If not, would you like a number of different sizes and shape designs for the object that you will be carrying?

Is sensor size an important factor in such a device? Will a keychain sized device be a problem or are small adhesives preferable?

Would you purchase optional add-on accessories such as additional sensors and power adaptors?

**USER INTERFACE**

Is portability a must?

Do you prefer a simple yet crippled user-interface or a user-friendly interface that will allow you to precisely customize a profile?

Would options such as time of day for personalizing and receiving a phone call be beneficial?

**COST**

If there was a new device that solved all the problems of currently available products, must it be less expensive than currently available devices?

**RELIABILITY**

Is reliability of such a device much more important to you than cost and size?

Is the reliability of the device in several different operating conditions important? Are false alarms unacceptable?

**MAINTAINABILITY**

Will changing batteries every so often be a problem?
Would light maintenance of such a product be a problem? Is durability a major factor in such a device?

Is a warranty for such a product a must? If so, what type of warranty (parts, labor, or both)?

**DELIVERY TIME**

Would you purchase one if it was available within the next year?

### 2.4 Survey Analysis - *Determining Conflicting Needs*

To analyze the survey, our team created a correlation matrix of all the survey categories.

<table>
<thead>
<tr>
<th>Functional Features</th>
<th>Appearance Packaging</th>
<th>User Interface</th>
<th>Cost</th>
<th>Reliability</th>
<th>Maintain</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Functional Features</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>+</td>
<td>++</td>
<td>++</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td><strong>Appearance Packaging</strong></td>
<td>+</td>
<td>+</td>
<td>+</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td><strong>User Interface</strong></td>
<td>++</td>
<td>+</td>
<td>+</td>
<td>+</td>
<td>-</td>
</tr>
<tr>
<td><strong>Cost</strong></td>
<td>++</td>
<td>+</td>
<td>+</td>
<td>+</td>
<td>-</td>
</tr>
<tr>
<td><strong>Reliability</strong></td>
<td>- -</td>
<td>-</td>
<td>+</td>
<td>+</td>
<td>++</td>
</tr>
<tr>
<td><strong>Maintain</strong></td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>++</td>
<td></td>
</tr>
</tbody>
</table>

++ Highly correlated positive  
+ Moderately correlated positive  
- Moderately correlated negative  
-- Highly correlated negative
Based on our survey results and our correlation matrix, we can see that there are possible conflicting needs between functional features, cost, user interface, and reliability. The user wants a product that is fully featured with a completely customizable user interface at a low price. Also, the user wants a feature rich product with very high reliability.

Other results indicate that increasing functional features of our PCL system enhances the user interface. This gives the user more control in setting their personal preferences. Also, increasing functional features affects the system packaging/appearance. Lastly, the more features the user is given, the more the final cost and maintainability of the product will be. If the system requires a significant amount of maintenance, the reliability of the system decreases significantly.

Author(s): Daniel Dobrin, Rehan Shariff, Kunal Shah
3. Technical Specifications

3.1 ECE 396/397 Deliverables

Our team will provide system design and detailed design documentation necessary to manufacture the device. A prototype will be provided to demonstrate the design. Our team will conduct formal tests to verify the correctness of the device’s operation. There are three main deliverables that are listed below:

- System Specifications
  - design concept
  - design alternatives
  - block diagrams
  - functional descriptions

- Design Documentation
  - parts list
  - completed analysis
  - circuit schematics and descriptions
  - user manual for setting up the PCL system
  - manufacturing test plan
  - cost analysis

- Prototype
  - physical representation of PCL
  - packaging
  - working demonstration

3.2 Testing Procedures

The PCL system is composed of two main parts: software and hardware. To guarantee that the system is operational, both parts must be fully and carefully tested. Therefore, the performance testing, which must be passed in order for the design to be successful, will be conducted at two different levels:

1. **Software.** In order for us to test the software, we will use a variety of equipment including a computer, C++, JAVA, and Assembly compilers, MPLAB, and others.

2. **Hardware.** In order to test the hardware, we will use equipment such as an oscilloscope, digital multimeter, function generator, power source, touch-tone phone, computer, and software such as PSpice, Pro-E.

Final testing to verify the correctness of the overall system design will be done by simulating hardware circuits on PSpice and software on MPLAB. The product cost test will be based on parts cost as explained in the section on product cost.
Acceptance Tests for Software:

The software program is the life of our PCL system. Without proper software program functionality, the PCL hardware will have no way of communicating with one another. The software program will let the PCL system know how the user and the system interface with each other. Therefore, software program testing procedures will be divided into two parts: microcontroller and user interface.

The first function of the software program is to correctly store all user preferences and send them to the microcontroller. To test this, the team will use a computer and the following testing procedures:

- Create a trial profile that will consist of a user name, address, and block call preferences.
- Create a trial phonebook. Next, add, update, and delete phone book entries. Verify that the software program properly accepts all changes.

The second function of the software program is to correctly store user phonebook entries into memory and correctly identify the touch-tone phone. To test this, the team will use a microcontroller and the following testing procedure:

- Using the trial phonebook, store phone numbers into the system memory.
- Make 3 separate calls: one call from a number listed in the user phonebook, one call from a number unlisted in the user phonebook, and one from a blocked number. Verify the following required system operations: if a phone number is listed in the user’s phonebook the phone will ring, if a phone number is blocked the phone will not ring at all, and if a phone number is not listed in a profile the phone will only ring if the option was chose in the trial profile.

Overall, this level tests the software program functionality to guarantee that the system accurately matches a source number with a number in the users’ phonebooks. Furthermore, this test will also determine if the system correctly transfers the incoming phone call to the correct phone base.

Acceptance Tests for Hardware:

The next thing to be tested is individual system hardware components. It is the hardware that will let the PCL system make use of the software program in order to interface with the user. Therefore, the hardware testing procedures will be divided into two main parts: transmitter/receiver, and phone line.

Transmitter/receiver: The function of a transmitter is to send out a unique signal for the receiver to pick up. To test this, the team will use the required equipment, mentioned above, and the following testing procedures:

- Turn on the transmitter. Verify its functionality by turning on the receiver and checking that they communicate with each other.
- Slowly move the transmitter away from the receiver until they are approximately 5cm apart. Allow approximately 2 seconds for every 1cm of movement. Verify transmitter functionality based on proximity range, response time, and accuracy of locating receiver.
- Block the transmitter signal by placing a metal or plastic plate. Record receiver response time until the signal is picked up, to verify that it will operate through different materials.
- Turn on other common household electronic devices that have the potential to create Electromagnetic Interference (EMI) and interfere with the transmitter signal. The devices include: cell phone, TV, radio, and cordless phone. This is required in order to test and avoid disturbance and signal interferences.
- Use 2 different transmitters in the same room to verify that the receiver can distinguish between the different incoming unique signals.
- Repeat the above procedure using 2 different receivers to verify that one transmitter will send the same unique signal to both receivers.

**Phone Line:** The function of the phone line is to correctly send the incoming call phone number to the system, and send phone ring signal to the correct phone base. To test this, the team will use the following testing procedures:

- Using the trial profile and phonebook created in the “Acceptance Tests for Software,” perform the 3 calls to the system to verify that it correctly picks up the line reversal signal and identifies the source number, and correctly uses the number to forward the call.
- Make 3 separate calls: one call from a number listed in the user phonebook, one call from a number unlisted in the user phonebook, and one from a blocked number. Verify the required system operations mentioned previously, and verify that the phone line correctly identifies the correct phone base for required system operation.

Overall, this level tests hardware functionality to guarantee the accuracy of the signal sent out by the transmitter, receiver communication with the system, phone line interface with the system, range, and effectiveness.

### 3.3 Numerical Technical Specifications

The successful outcome of our PCL system requires more than just following some testing procedures. It requires recording test results. If the test results are in conflict with the desired results, changes must be made and testing procedures performed again. If the new results turn out to be the desired results, then we have a successful outcome. In the following sections we are listing the numerical data we are required to obtain for successful and desired operation of our system. All results that we need to obtain from the testing procedures are listed under the corresponding testing procedure(s).

**Acceptance Results for Software:**

- saving user information and preferences, saving a new entry or an update to a phonebook, and transfer the phone numbers into the system memory, must be completed within 10 seconds or less of clicking save
- system user interface must logout after fifteen minutes of inactivity to protect user privacy

<table>
<thead>
<tr>
<th>Call</th>
<th>Transfer Call</th>
<th>Phone State</th>
<th>Response time from incoming to ring (seconds)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>yes</td>
<td>ring</td>
<td>1</td>
</tr>
<tr>
<td>2</td>
<td>no</td>
<td>off</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td>yes</td>
<td>ring all phones</td>
<td>1</td>
</tr>
<tr>
<td>3</td>
<td>no</td>
<td>off</td>
<td>0</td>
</tr>
</tbody>
</table>

**Acceptance Results for Hardware:**

<table>
<thead>
<tr>
<th>Components</th>
<th>Current</th>
<th>Voltage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Phone line</td>
<td></td>
<td></td>
</tr>
<tr>
<td>on-hook</td>
<td>50µA</td>
<td>on-hook</td>
</tr>
<tr>
<td>off-hook</td>
<td>20mA</td>
<td>off-hook</td>
</tr>
<tr>
<td>Transmitter/Receiver</td>
<td></td>
<td>TBD</td>
</tr>
<tr>
<td>receiver</td>
<td>active 100mA</td>
<td>receiver 9V</td>
</tr>
<tr>
<td>idle</td>
<td>5mA</td>
<td>supply 0V</td>
</tr>
<tr>
<td>transmitter</td>
<td>0</td>
<td>transmitter supply 0V</td>
</tr>
<tr>
<td>System</td>
<td>hook-switch</td>
<td>closed ~5mA</td>
</tr>
<tr>
<td></td>
<td>open 0</td>
<td>5V</td>
</tr>
</tbody>
</table>

**Transmitter/Receiver:**

- reading time must be ~70ms
- programming time can range from 200ms to 350ms
- reading range 0 to 60cm
- must be able to operate in household temperature ranges of 68°F to 80°F (70°C to 76°C)
- weight can range from 0.6g to 4.5g
- size can be in the range of ~2cm (penny) to ~5cm (key-chain)

Author(s): Daniel Dobrin
3.4 Draft User’s Manual

The system’s user interface will allow the user to enter their personal information and preferences, create phonebooks, setup default options, and configure options for blocked calls. For optimal and safe usage of the device, the user will refer to the manual provided with the package and follow the basic steps below.

- The user can click on the New User tab to set up accounts for other household members by entering the names and personal information of all the users in the home.

- The user can click on the Settings tab to configure options such as setting a default phone, setting options when the user is not home, settings for blocked incoming calls, and describe general rules of operation during different times of the day.

- The user can click on the Phonebook tab to create personal phonebooks. Additionally, they will be able to update their book by adding, changing, or deleting phonebook entries at anytime.

Following is a draft of the user manual.
Welcome to your very own Personal Calls by Locations system. In order to get started please make sure that you have the following items:

- Administrator registration card
- 4 readers
- 4 transmitters

Please connect each of the readers to the telephone wall jacks in all desired rooms. Secondly, connect the telephone wire from the phone bases to the reader units. Next, disperse each color-coded transmitter to the members of the household and have them place it onto their clothing whenever they are present in the home. They may press the off button to turn off the transmitters when they are not home or do not want to be disturbed. Lastly, follow the steps in the user interface manual to complete web setup.
Welcome to Personal Calls by Location.
In order to begin setup please have the following items ready:

1) Internet Access
2) Administrator Registration Card

Next, visit www.ece.uic.edu/~rshariff/ECE396/home.htm and click on the “PCL Login” tab on the left side of the screen.

Getting Started (Login)…
After clicking on the login tab, a login pop up box appears asking for two things:

1) User Name
2) Password

Fill in the fields and press “Ok” to continue. The information can be found on the provided Administrator Registration Card.

After entering the provided account information, you will be directed to the “Administrator Setup Page.”

Getting Started (New User Setup)…
Once on the “Administrator Setup Page,” you are given three options:

• Create New User
• Settings
• Logout

Please click on the “Create New User” tab.

You will be directed to the “New User Page”.

To exit the “Administrator Setup Page” at any time, click the “Logout” button.
**Getting Started (New User Setup cont’d)…**

This is the setup page for a new user. Please create an account for each member that will be using the phones in the household including the administrator.

Fill in the information for the New User into the following fields:

- First Name, Last Name
- User Login Name
- Password
- Tag ID- (specified transmitter)
- E-mail Address

All fields marked with a “*” are required

After entering the required information you can:

- Save
  - Directs you back to the Administrator Setup Page
- Cancel
  - Directs you back to the Administrator Setup Page

Repeat above steps for entering information of other household members.

---

**Getting Started (Settings)…**

Now that you have entered in all the information for the household members, please click on the “Settings” tab, and you will be directed to the “Administrator Settings Page”

**Getting Started (Settings cont’d)…**

This is the settings page for the administrator. As the administrator you are able to click on one of two options:

- On
  - All phones in the house will ring when the call is not listed on a specific household phonebook
- Off
  - No phones in the house will ring when the call is not listed on a specific household phonebook

After choosing your preference please click the “Save” button and you will be directed back to the “Administrator Setup Page”.

---

**New User Page**

Welcome to the PCL New User Setup Page

Please fill in the information of the new user below.

*Required Fields

*First Name: [ ]  *Last Name: [ ]

*User login Name: [ ]  E-mail: [ ]

*Password: [ ]  *Tag ID: [ ]

*Retype Password: [ ]

Save  Cancel

---

**Administrator Setup Page**

Welcome to the PCL Admin Setup Page

Please click on one of the buttons to continue

Create New User  Settings  Logout

---

**Administrator Settings Page**

Welcome to the PCL Settings Page

Please choose the option you would like when the call is not listed on a specific household phonebook.

On: All Phones in the house will ring
Off: No Phones in the house will ring

Default: On

Save  Cancel
Congratulations!!! You have just completed the initial setup of your Personal Calls by Location system. This is the logout page. You have one of two options:

- **Yes**
  - Directs you back to the Homepage
- **Cancel**
  - Directs you back to the Administrator Setup Page

Now that you have successfully completed the initial setup, please click “Yes” to logout. You will be directed to the PCL Homepage.

To continue finishing User Setup, please click on the “PCL Login” tab and login with your newly created personal username and password.

---

**Household Members Setup**

**Household Members Setup (Login)...**

After clicking on the login tab a login pop up box appears asking for two things:

1) **User Name**
2) **Password**

Fill in the fields above and press “Ok” to continue. This information will be provided to you by the Administrator of your Personal Calls by Location system.

After entering the provided account information, the User will be directed to his “Personal Setup Page”

**Household Members Setup (Phonebook)...**

Once on the “Personal Setup Page,” you are able to click on one of following three buttons:

- **Phonebook**
- **Settings**
- **Logout**

Please click on the **“Phonebook”** tab, and you will be directed to the **“Personal Phonebook Page”**.
Household Members Setup (Phonebook Add)...
This is the phonebook setup page. You will be able to click on one of following three buttons:
- Add
  Adds New Phonebook Entry
- Change
  Change New Phonebook Entry
- Main/Delete
  Return to Main Page (Personal Setup Page) or Delete New Phonebook Entry

Please click on the “Add” tab to continue. You will be directed to “Add Entry Page” Setup Page.

Household Members Setup (Add cont’d)...
This is the setup page for a new phonebook entry. Please add all your phonebook entries.

Fill in the information for the NewEntry into the following fields:
- First Name, Last Name
- Phone Number
- Address, City, State, Zip
- E-mail Address

All fields marked with a “*” are required.

After entering the required information you can:
- Save
  Directs you back to the Personal Phonebook Page
- Cancel
  Directs you back to the Personal Phonebook Page

Repeat above steps for entering other phonebook entries.

Household Members Setup (Phonebook Change)...
This is the page to change the information of a specific phonebook entry.

Information for the existing entry can be updated through the following fields:
- First Name, Last Name
- Phone Number
- Address, City, State, Zip
- E-mail Address

All fields marked with a “*” are required.

After changing the required information you can:
- Save
  Directs you back to the Personal Phonebook Page
- Cancel
  Directs you back to the Personal Phonebook Page

Repeat above steps for changing other phonebook entries.
**Household Members Setup (Phonebook Delete)…**

This is the page to delete an entry from your phonebook. You are able to click on one of two options:

- **Yes**
  - Directs you back to the Personal Phonebook Page
- **Cancel**
  - Directs you back to the Personal Phonebook Page
- **Main**
  - Directs you back to the Personal Setup Page.

Repeat above steps for changing other phonebook entries.

---

**Delete Entry Page**

**Welcome to the PCL Delete Entry Page**

Are you sure you want to delete the this entry?

- **Yes**
- **Cancel**
- **Main**

---

**Household Members Setup (Settings)…**

Now that you have entered in all the entries for your phonebook, please click on the “Main/Delete” tab, and click on the “Main,” button. You will be directed to the “Personal Setup Page.”

Next, click on the “Settings” tab.

---

**Personal Setup Page**

**Hello “________”**

Welcome to the PCL Personal Setup Page

Please click on one of the buttons to continue

- **Phonebook**
- **Settings**
- **Logout**

---

**Household Members Setup (Settings cont’d)…**

This is your settings page. You are able to click on one of two options:

- **On**
  - All phones in the house will ring when you are not present
- **Off**
  - No phones in the house will ring when you are not present

After choosing your preference please click the “Save” button and you will be directed back to the “Personal Setup Page”.

---

**Administrator Settings Page**

**Welcome to the PCL Settings Page**

Please choose the option you would like when you are not present in your home.

- **On**: All Phones in the house will ring
- **Off**: No Phones in the house will ring

- **Save**
- **Cancel**
Finishing Household Members Setup (Logout)...

Congratulations!!! You have just completed the setup of your Personal Calls by Location system. This is the logout page. You have one of two options:

- Yes
  Directs you back to the Homepage
- Cancel
  Directs you back to the Personal Setup Page

Now that you have successfully completed the setup, please click “Yes” to logout. You will be directed to the PCL Homepage.

Author(s): Kunal Shah
4. Design Alternatives

To guarantee the completion of our system, our group came up with three design alternatives. We believe that each of the design alternatives fulfills the required system operation. In the following design alternatives, the diagrams consist of several subsystems, which are described by large blocks. Communication between the subsystems is illustrated through large arrows. The smaller blocks indicate functions of the subsystems while the communication between them is shown by thin arrows.

4.1 Doorway Readers

A block diagram for a design that implements transponder technology is shown in Figure 4.1. In this design, the intent is for the users to input personal settings and phone numbers on a computer. The computer stores the information unto a removable memory card. The computer writes to the memory card through a cradle that is linked using the USB interface. The data on the memory card can then be transferred to the main control unit by plugging the card into it. The data is stored onto a memory that is located in the main control unit. The users will carry a transponder, which will transmit a signal to the readers/transmitters that are installed in the user’s home doorframes. The readers/transmitters will transmit a signal to the main control unit every time the user steps through the doorway. The microcontroller in the main control unit will determine the new location of the user. The users’ home phone line will be attached to the main control unit. When the users receive a phone call, the microcontroller will determine the person that the call is intended for based on the phone numbers stored in memory. Based on the location of the intended user, the microcontroller will transfer the call to the phone in the room that the user is in through the corresponding phone jack.

4.2 Reader Units

A block diagram for a design that implements reader/transmitter technology is shown in Figure 4.2. In this design, the intent is for the users to input personal settings and phone numbers on a private web server through the use of a computer. The users’ home phone line will be attached to the main control unit. The main control unit can download the user settings and phone numbers from the internet through the use of the home phone line. The information will be stored in memory for future use. The users must install readers on each phone in their house. The users will carry a transmitter, which will respond to the reader units when it receives an input frequency from them. When the users receive a phone call, the microcontroller will determine the person that the call is intended for based on the numbers stored in memory. The main control unit will communicate with the readers through two of the unused wires on the phone line and request the location of the user. The microcontroller will determine the location of the user based on the input from the readers and will transfer the call to the phone closest to the user.

4.3 Cordless Phones

A block diagram for a design that implements cordless phone technology is shown in Figure 4.3. In this design, the intent is for the users to input personal settings and phone numbers directly
Figure 4.1 - Doorway Readers

User Input through keyboard

User Interface

Data Base List

I/O Controller

USB

Read

Translate

Write

Memory Card

Phone Line

Phone Company

Telephones

Main Control Unit

Microcontroller

Calculations, Processes

Storing

MEMORY

Sending location change

Sending signal when nearby

I/O

Transponders

Transmitter

Reader

Readers/Transmitter

Computer

Memory Cradle

I/O Controller

Computer

User Interface

Data Base List
Figure 4.2 - Reader Units

User Input through keyboard

User Interface → Data Base List → Modem → Internet → Private Web Server

Main Control Unit

Microcontroller

Calculations, Processes → Storing

MEMORY

Phone line

Phone Jacks

Transmitters

Transmitter

Antenna

Reader Units

Receiver

Antenna

Microcontroller

Telephones

Telephone Company

Internet

Private Web Server

Phone Line
Figure 4.3 - Cordless Phones

Storing
Memory

User Interface

Main Control Unit

Microcontroller

Calculations, Processes

Phone line

Phone Line

Telephone Company

Telephone bases In the house

Phone Jacks in Different Rooms

In the house
onto the main control unit’s user interface. The data is stored onto a memory that is located in the main control unit, which can be accessed by the microcontroller. Each user in the household will carry their own small cordless phone. The users’ home phone line will be attached to the main control unit. When the users receive a phone call, the microcontroller will determine the person that the call is intended for based on the numbers stored in memory. The microcontroller will transfer the call to the cordless phone base that corresponds to the user.

4.4 Design Alternatives Risk Analysis

Lowest-Risk: The lowest-risk approach from our design alternatives is the Cordless Phones. The reason this is the lowest-risk is because it eliminates the need for internet and external hardware. By eliminating internet use, it reduces the amount of programming required, which in turn increases the chances that the project will work properly. Unlike the other two alternatives, the determination of who the call is for and transferring the call is done within the main control unit alone. This eliminates the use of external transmitters and readers. Furthermore, since user personal preferences are directly uploaded onto the main control unit, a personal computer is not required. Eliminating external hardware reduces the probability of hardware failure, increases system reliability, and decreases system maintenance.

Highest-Risk: The highest-risk approach from our design alternatives is the Doorway Readers. Unlike the Cordless Phone alternative, this alternative requires external inputs to the main control unit before being able to transfer the call to the appropriate location in the house. Therefore, this alternative increases the amount of new hardware required. This alternative also requires system software for the user interface on top of the new hardware. Furthermore, readers are required in all door frames. Also, this alternative requires the system to keep track of the user’s location relative to the rooms in the house. This requires complex algorithms for precise calculation of the user’s location. Since this alternative increases external hardware, it also increases the probability of system failure. Increase in the probability of system failure decreases system reliability and increases system maintenance.

4.5 Design Alternatives Technical Analysis

The Doorway Readers alternative is technically the most difficult. The main reason for it being the most difficult is because of the complicated algorithms mentioned above. In order to keep track which room the user is in, we must develop algorithms that will determine if the user is exiting or entering. Furthermore, we may run into circumstances where the user might be equal distance from two doorways and both doorways pick up the user location. Having two doorways picking up the user location will cause the phones in the corresponding rooms to ring. Having two phones ring eliminates purpose of our system.

4.6 Design Alternatives Cost Analysis

The design alternative that will potentially yield the least expensive product is the Cordless Phones alternative. The reason this alternative may yield the least expensive product is because it eliminates the need for external hardware. Unlike the other two alternatives, the determination of who the call is for and transferring the call is done within the main control unit alone. This
eliminates the use of external transmitters and readers; therefore, the final cost will be less. Furthermore, there is no need for purchasing any cordless phones because it will be provided by a team member for testing purposes. This alternative also eliminates the need for internet. By eliminating internet use, it reduces our costs of maintaining a private web server.

4.7 Fall-back Alternative

Our “fall-back” alternative for our system is the Cordless Phones alternative. We made this choice by realizing that this is the lowest-risk alternative, and it is the easiest to implement. If one of our ordered parts does not arrive on time, we would still have enough time to implement this alternative unlike the Doorway Reader and Reader Units alternatives. The latter two alternatives would take too much time and error checking to make our system reach its desired potential if a sudden delivery problem occurred. However, the Cordless Phone alternative decreases the problem of undelivered parts because not as many components are required to build this alternate system.

4.8 Expo Demonstration

During the Exposition we will be implementing our Reader Units design alternative. This alternative is most suitable for the demonstration because it most accurately portrays the desired operation of our system. The Reader Units alternative will allow us to actually incorporate a friendly user interface and allow users to set up certain preferences. Furthermore, this alternative precisely displays the system we would want released to the public because it is the most efficient.

Author(s): Daniel Dobrin, Rehan Shariff, Kunal Shah
5. Evaluation Criteria and Selection of Best Design Approach

Our group used the following six evaluation criteria when determining our selected design approach:

1. risk analysis
2. technical analysis
3. cost analysis
4. suitability for Exposition demonstration
5. customer survey results
6. installation requirement

5.1 Doorway Readers

<table>
<thead>
<tr>
<th>Evaluation Criteria</th>
<th>Advantages</th>
<th>Disadvantages</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td></td>
<td>highest risk</td>
</tr>
<tr>
<td></td>
<td></td>
<td>difficulty of design</td>
</tr>
<tr>
<td>2</td>
<td>automatic updating of user location</td>
<td>complicated algorithms</td>
</tr>
<tr>
<td></td>
<td>keeps track of what room the user is in</td>
<td>very sensitive</td>
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<tr>
<td></td>
<td>tracking ID is a passive circuit</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td></td>
<td>highest cost</td>
</tr>
<tr>
<td>4</td>
<td></td>
<td>least suitable for Exposition</td>
</tr>
<tr>
<td>5</td>
<td>user carries small tracking ID</td>
<td>unfriendly user interface</td>
</tr>
<tr>
<td>6</td>
<td></td>
<td>heavy professional installation required</td>
</tr>
</tbody>
</table>

5.2 Reader Units

<table>
<thead>
<tr>
<th>Evaluation Criteria</th>
<th>Advantages</th>
<th>Disadvantages</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>ease of design</td>
<td>must have a 4-wire phone line routed through house</td>
</tr>
<tr>
<td></td>
<td></td>
<td>internet access required for updates</td>
</tr>
<tr>
<td>2</td>
<td>uses phone line as power source</td>
<td>limited range</td>
</tr>
<tr>
<td></td>
<td>minimal coding for user location tracking</td>
<td>need receivers for each phone jack</td>
</tr>
<tr>
<td></td>
<td>tracking ID is a passive circuit</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>cost effective</td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>most suitable for Exposition</td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>user friendly interface</td>
<td></td>
</tr>
<tr>
<td>6</td>
<td>user carries small tracking ID</td>
<td></td>
</tr>
<tr>
<td>6</td>
<td>minimal professional installation required</td>
<td></td>
</tr>
</tbody>
</table>
5.3 Cordless Phones

<table>
<thead>
<tr>
<th>Evaluation Criteria</th>
<th>Advantages</th>
<th>Disadvantages</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>ease of design</td>
<td></td>
</tr>
<tr>
<td></td>
<td>lowest risk</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>no need for user location tracking</td>
<td>must include cordless phones</td>
</tr>
<tr>
<td>3</td>
<td>least cost</td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>user has a personal phone using home phone line</td>
<td>tedious user interface</td>
</tr>
<tr>
<td></td>
<td></td>
<td>user must carry phone handset (size)</td>
</tr>
<tr>
<td>6</td>
<td>minimal professional installation required</td>
<td></td>
</tr>
</tbody>
</table>

5.4 Analysis of Design Alternative Evaluations

After coming up with three design alternatives for our system, we decided to go with the second design alternative – Reader Units. Our decision was based on the above tables of advantages and disadvantages that we created for each of the design alternatives.

Not only does the Reader Unit alternative have the most advantages, it is the only alternative that has advantages in all of our selected criteria. In addition, the difference between the number of advantages and the number of disadvantages is much greater in the Reader Unit alternative than in either of the other alternatives. Furthermore, the disadvantages are not very significant for correct operation of our design. For example, in selection criteria 1, risk analysis, we have listed that the user must have 4-wire phone lines installed in their home. However, the majority of homes today already have 4 or more wire phone lines installed. We have also listed that the users must have internet access. Most of our target customers, the middle to upper class family, have internet access. Furthermore, this alternative is of moderate difficulty in relation to the other two alternatives. The alternative’s complexity is moderate, cost effective, has the most user friendly interface, and is the most suitable alternative for demonstration during Exposition.

Author(s): Daniel Dobrin, Rehan Shariff, Kunal Shah
6. Detailed System Design

The PCL system has two main components, which include hardware and software. Each of the components has to be defined and agreed on before the product can be implemented. Each describes the design decisions made about its component of the PCL product and the reasons for those decisions. An explanation of how the decisions will be implemented is also given.

6.1 Hardware

Our system’s hardware contains three subsystems: the main control unit, reader units, and transmitters. The system’s main control unit will be placed between the users’ home network interface and the phone jacks in the house. A reader unit will be placed between each phone in the house and its corresponding phone jack. The users will customize their system settings and set-up a personal phonebook on the system’s private web server, where it can later be downloaded by the main control unit. Each user will carry a transmitter, which transmits a unique signal. When the users receive a call on their home phone line, the main control unit will cross reference the source number with the users’ phonebooks. The system will then determine which user the call is intended for and request the reader units for his location. The reader unit that receives the strongest unique signal corresponding to the intended user will report to the main control unit. The main control unit will transfer the incoming call only to the phone which the intended user is nearest to. Figure 6.1 illustrates the three hardware subsystems.

![Figure 6.1 – Three of the PCL hardware subsystems](image-url)
6.1.1 Main Control Unit (MCU)

**Description**

The MCU is the processing center for all the information needed for the system. It controls switching of the phone line and communicates with the reader units. The communication, which is accomplished through the use of modular phone wire, is bidirectional. When the users receive a phone call, the MCU will request the reader units for the location of the user that the call is intended for and transfer the call only to that phone. The MCU consists of a microcontroller, memory, and a modem.

6.1.1.1 MCU Components

**Microcontroller**

A microcontroller is needed to process all the control data that is needed for the PCL system and perform actions based on the control data. There are several different microcontrollers that could be used to accomplish the task. The microcontroller that our system will utilize is the PIC 16F877A by Microchip. The device is a CMOS FLASH based 8-bit microcontroller and is available in a 40-pin DIP package. See Figure 6.2 for a pin-out of the DIP package. It features 256 bytes of EEPROM data memory, 32 I/O lines, 8 channels of 10-bit Analog-to-Digital (A/D) converter, parallel port, synchronous serial port that can be configured as a 2-wire Inter-Integrated Circuit (I²C™) bus, and many other features.

All of these features make it ideal for the PCL system. The microcontroller’s parallel port allows us to generate two high impurity tones simultaneously. The I²C™ interface allows easy connection of an external serial EEPROM memory. The built in EEPROM makes use of

---

3 http://www.microchip.com
FLASH technology and thus allows fast erasing and reprogramming. The program memory is 256 bytes, large enough to hold any data the PCL might need to use during operation. In addition, it has many I/O lines which are essential to the design. In short, we chose to use the PIC16F877A because it is an easy to use, easy to program, fast, low power, low cost microcontroller that has all the capabilities that our system needs.

An oscillator circuit is used for providing the microcontroller with a clock. The PIC16F877A can work with four different configurations of an oscillator. We will be using a dual crystal oscillator setup. The microcontroller includes a feature that allows the system clock source to be switched from a main oscillator to an alternate low frequency clock source. This alternate clock source is the Timer1 oscillator. Our high speed crystal operates at a frequency of 4 MHz and low speed crystal will operate at a frequency of 32.768 KHz. The low frequency crystal is a watch crystal and allows a real time clock to be implemented using Timer1. The main crystal is connected to the OSC1 and OSC2 pins on the microcontroller. See figure 6.3 for a schematic of the oscillator configuration.

Figure 6.3 – Crystal Configuration
Memory

Data used by the microcontroller is stored in RAM memory as long as there is power being supplied to the microcontroller. When there is no longer any power, the contents of the RAM memory are wiped out. For the PCL system, it is necessary to retain the user’s personal settings and phonebook entries for use much after the power is turned off. Therefore, the user’s information must be stored in permanent memory. Our system implements the 24AA256 Serial EEPROM from Microchip, which uses the I²C™ 2-wire interface bus protocol for communication with the microcontroller, to permanently store the user’s pertinent information. The 24AA256 is 32K x 8 (256K), features a page-write capability of up to 64 bytes of data, and is large enough to hold multiple users’ data. The EEPROM is interfaced to the microcontroller via the SCL and SDA lines. The SCL line is the clock for synchronizing the data sent via SDA line. See figure 6.4 for a schematic layout of the microcontroller-memory interface.

![Microcontroller - Memory Interface](image)

Modem

A single chip modem is needed to allow the MCU to download the user’s settings and phonebook entries from the PCL private web server to the microcontroller so it can be stored in permanent memory. Although there are a variety of such modems, our system implements the 73K222AL by TDK, a single-chip modem IC capable of 1200 bit/s full-duplex operation over home phone lines. The device operates on a single 5V power supply and is available in a 28-pin DIP package. Refer to Figure 6.5 for DIP package pin-out. It modem also supports V.22, allowing both synchronous and asynchronous communication.

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4 [http://www.microchip.com](http://www.microchip.com)
5 [http://www.tdksemiconductor.com](http://www.tdksemiconductor.com)
Therefore, the 73K222AL is model for use in the PCL, a system where data communication over a 2-wire telephone network is required for small amounts of data. It is a microprocessor peripheral and should thus easily interface with the PIC16F877A microcontroller for control of modem functions through its 8-bit multiplexed address/data bus. We chose it because it has high functionality, low power consumption, and only requires the addition of an RS-232 level converter for a complete modem.

![73K222AL Modem pin-out](image)

**Figure 6.5 – 73K222AL Modem pin-out**

### 6.1.1.2 MCU Input/Output

**Input:**

There are two main inputs to the MCU. The first input is the phone line coming from the network interface of a home. The unit will use the phone line so it can identify the number of the incoming call, transfer calls to the home phones, and download user settings from the internet. The second input is the output from the reader units. It will use the output from the reader units to determine the location of the user that the call is intended for, relative to the phones.

**Output:**

The main output of the MCU is to the reader units. After determining the intended user of the call, the unit will request the readers for the location of the user. After the readers report the requested information, it will allow the corresponding reader unit to transfer the phone call.

Following are implementations of some of the input/output methods that are implemented in our design:

**Telephone Line Interface**

Most residential homes have a network interface, a plastic box usually mounted outside the house, where the wiring running from the local telephone company enters the house. From the network interface (NI), a group of copper wires is routed throughout the home and is connected to each phone jack in the house as shown in Figure 6.6. In residential wiring, the most common kind of phone line has four wires, which are colored green, red, black, and yellow. A single
phone line only requires the use of the green and red wires, which are commonly referred to as tip and ring. In the vast majority of cases, the black and yellow lines are left unused.  

![Network Interface and Phone Line Wiring](http://www.ling.upenn.edu/~kurisuto/phone_wiring.html)

**Figure 6.6 – Network Interface and Phone Line Wiring**

The MCU will accept all four of the copper wires that coming from the NI as an input. We will use an RJ-11 modular phone jack with four contacts for the connection. The MCU will be placed between the NI and phone jacks. The incoming wires, tip and ring (green and red) connect to a bridge rectifier. Refer to Figure 6.7 for a schematic diagram. The bridge rectifier guarantees that only the correct voltage polarity is applied across any circuits that follow and provides an appropriate method of transporting audio signal to and from the telephone line. The bridge rectifier should be capable of withstanding all voltage and current conditions that may be present on the line. A MOV is used to absorb any voltage transients on the line and provide spike protection. The negative terminal of the bridge becomes the ground supply. The positive terminal consists of a DC voltage with an underlying AC signal and is used to connect to all the power supply and tone detection circuits. Line sensing circuits will be used to monitor the positive terminal for changes in voltage levels and for transforming audio signals into a form that the microcontroller is familiar with.

**MCU/Reader Unit Interface**

When the users of the PCL system receive a phone call, the MCU will request the reader units for the location of the user that the call is intended for. The communication can easily be accomplished by digital means by using the household’s existing phone wire. The two unused wires in the telephone line mentioned above (yellow and black) will be used for the communication. The yellow wire will be used for communication from the MCU to the reader units and the black wire will be used for communication from the reader units to the MCU. The MCU will use the output from the reader units so that it may allow the reader unit nearest to the user to transfer the phone call.

**Telephone Line Switching**

As mentioned earlier, the telephone line coming from the NI is routed throughout the home and is connected to each phone jack in the house. Since the MCU is placed between the NI and the
phone jacks, it must control the switching of the phone line. After determining the location of the user relative to the phones in the household, the MCU must then allow the reader unit connected to the corresponding phone to transfer the call. This will be accomplished by placing switches between an I/O port of the PIC16F877A and each of the lines being routed to the phone jacks. When the MCU must transfer an incoming phone call to a particular phone, it will turn off all the switches that control the jacks that are not connected to the corresponding phone by sending a signal to the port pins that they are connected to. Only the switch that controls the jack corresponding to the desired phone will remain on.

Figure 6.7 – Bridge Rectifier and Leakage Supply

6.1.1.3 MCU Features

Telephone Line Power

The telephone line carries both AC and DC signals simultaneously. The DC signal is used to power the telephone’s circuitry and comes from a battery with a nominal voltage of 48V located at the telephone company’s office. The telephone line has two main conditions: on-hook and
off-hook\textsuperscript{7}. The current in the on-hook condition is termed leakage current and is approximately 50uA. The current in the off-hook condition is called the loop current and is typically 20mA.

For our system to function without any requirement of batteries or adaptors, it must use the phone line as a DC power source. The main control unit needs approximately 5 volts to power the PIC16F877 microcontroller. Although there will be many other voltage drops in the power supply circuit, the microcontroller only needs a maximum of 5mA to operate correctly. When in the on-hook state, our system may draw a few tens of micro-Amps of leakage current. We can completely power the microcontroller from the telephone line if it uses an average of less that 50uA for its operation.

Figure 6.8 – Hook-Switch

Telephones use a large resistor to charge up a leakage capacitor from the line voltage. They use a gyrator device and a regulator circuit contained within the line interface IC to provide a stable dc power supply for the telephone\textsuperscript{8}. A zener diode may also be connected in parallel to prevent the voltage from rising above 5V.

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\textsuperscript{7} http://www.affordablephones.net/speechnetwork.htm
\textsuperscript{8} http://www.hut.fi/Misc/Electronics/circuits/teleinterface.html
The leakage supply, which allows a few micro-Amps of current to be drawn from the telephone line in the on-hook condition, allows the microcontroller to remain powered in sleep mode when it is not in use. It also provides power for the line event detection circuit, which is used to wake up the microcontroller from sleep mode. This happens when a phone is either ringing or lifted. The ringing signal is an AC signal anywhere from 40v to 150V with frequency in the range of 20Hz to 40Hz. The AC signal is superimposed onto the DC line voltage.

Our system implements a hook-switch, which separates the rest of circuit from the telephone line and prevents the flow of DC signals into the power supply section. When the hook-switch is open, no line current will flow and the device presents a very large DC resistance to the line. Refer to Figure 6.8 for a schematic diagram of the hook-switch.

![Gyrator Circuit Diagram](image)

**Figure 6.9 – Gyrator**

The purpose of the gyrator circuit shown in Figure 6.9 is to power the system by obtain DC power from the telephone line and prevents AC signals from being dissipated in the DC power supply section. Figure 6.10 illustrates all of the power supply components interfaced together.
Figure 6.10 – Power Supply

**Line Event Detection**

The circuit is able to wake up the microcontroller from sleep mode on a variety of different events that occur on the phone line including unplugging the system from the line, plugging in a phone, or lifting a phone. Since it uses a very small amount of current, it will operate when the system is in the on-hook condition. The circuit produces a logic high pulse to wake up the microcontroller when it detects a disturbance. See Figure 6.11 for a schematic diagram.

**Determining the Correct User**

Once the user’s household receives an incoming phone call, the MCU must determine which user the call is intended for before requesting the reader units for his location. To accomplish this task, the MCU will cross reference the incoming number with the users’ phonebooks stored in external memory. If it finds a match between the incoming number and a number in the phonebooks, it will determine that the intended user is the one whose phonebook stores the incoming number. Otherwise, it will operate according to the users’ settings, which are stored in the microcontroller’s memory. Depending on these settings, it may allow the call to transfer to all or none of the phones in the household. Before cross referencing the phonebooks, the MCU must be able to decode the incoming number. When a telephone rings, a line reversal signal is
sent along with the ring signal to the phone from the telephone company’s office. The line reversal signal is used to indicate that a Caller Line Identification (Caller ID) message is coming.

Figure 6.11 – Line Event Detector

The Caller ID service makes it possible to identify the number of the incoming call. The data, which is transmitted serially at 1200 baud in FSK mode between the first and second rings, is comprised into a packet of 10 bits. Each 8 bit word is preceded by a start bit and followed by a stop bit. A logical high is represented by 1200 Hz and a logic low is represented by 2200 Hz. The actual format of the transmitted data depends on telephone company providing the service. The two basic formats that are in use are the Single Data Message Format (SDMF) and the Multiple Data Message Format (MDMF)\(^9\). See Figure 6.12 for a diagram of the MDMF, the more popular message format.

Telephony works by superimposing an audio signal onto the DC line voltage. Touch tone telephones use a pair of audio frequencies to encode the digits used in dialing. Each transmitted

\(^9\) http://www.ee.washington.edu/conselec/A95/projects/jjblome/callerid.htm. Figure 6.12 was also taken from the website.
digit consists of two separate audio tones that are mixed together. The format for transmitting data by touch tone phones to encode the digits used in dialing is Dual Tone Multi-Frequency (DTMF). In DTMF, each digit is represented by two tones, determined by the intersection of the row and column of where the digit is. A complete touch-tone phone pad has 16 digits as shown in Table 6.1\(^\text{10}\). The four vertical columns on the phone keypad are known as the high group and the four horizontal rows as the low group.

<p>| | | | | | |</p>
<table>
<thead>
<tr>
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<tbody>
<tr>
<td>1</td>
<td>2</td>
<td>3</td>
<td>A</td>
<td>697 Hz</td>
<td></td>
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<td>4</td>
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<td>D</td>
<td>941 Hz</td>
<td></td>
</tr>
<tr>
<td>1209 Hz</td>
<td>1336 Hz</td>
<td>1447 Hz</td>
<td>1633 Hz</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Table 6.1 – Dual Tone Multi-Frequency (DTMF) Format\(^\text{10}\)

DTMF decoder ICs are used to decode the audio tones back into digits so that a microcontroller may interpret them. Although the devices are relatively low cost, the PIC16F877A microcontroller can be made to decode the tones directly. The PCL system will be implementing the direct method.

6.1.2 Reader Units and Transmitters

The reader units and transmitters together compromise the backbone of the PCL system. They are the means of tracking the location of the users relative to the phones in the household through wireless communication. A reader unit will be placed between each phone in the house and its

\(^{10}\) http://www.boondog.com/. Table 6.1 was also taken from the website.
corresponding phone jack. Each user will carry a transmitter, which transmits a signal containing identification data and will respond when it receives an input frequency from the reader units. The system will then determine which user the call is intended for and request the reader units for his location. The reader unit that receives the strongest response from the transmitters will report to the MCU. To accomplish these tasks, the transmitter/reader subsystem is making use of Radio Frequency Identification (RFID) technology. The transmitters will be realized using RFID transponders/tags and the reader units will be implemented using RFID readers.

*Input:*

These units have three main inputs. The first input is the output from the MCU to the reader units. The MCU will request the location of the intended user from the reader units. The second input to the reader units is the signal broadcasted from the transmitter devices that the users will carry. The input to the transmitters is the input frequency from the reader units.

*Output:*

These units have four main outputs. The first output is from the reader units to the MCU. The readers will locate the user that the call is intended for and report the information. The second output is from the reader units to the phones. The reader unit closest to the intended user will pass the call through to the phone it is connected to. The third output is the data transferred from the transmitters to the reader units. The fourth output is the signal sent to the transmitters by the reader units to request a response.

6.1.2.1 RFID Theory of Operation

Radio Frequency Identification (RFID) is a method of identifying and tracking objects using a radio transmission frequency, typically 125 kHz, 13.56 MHz or 800 MHz. The purpose of a RFID system is to store identification data in tags where it can be later retrieved at a desired place.

**RFID System Components**

There are three main components of an RFID system includes a transponder/tag, reader, and antenna as demonstrated in Figure 6.13.

RFID transponders are composed of an antenna coil, which is attached to an IC that includes memory and modulation circuitry. The tag responds to a transmitted request for the data it stores from the reader by wireless communication. The memory, which is non-volatile, is used for storing identification data. Typical devices with storage capacities of up to 128 bits are adequate to hold a serial or identification number. The transponder antenna allows the device to sense the interrogating field and transmit a response to the interrogation. RFID tags come in a wide variety of shapes, sizes, and packaging.11

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11 [http://www.aimglobal.org/technologies/RFID/](http://www.aimglobal.org/technologies/RFID/) . Figure 6.13 and 6.14 were also taken from the website.
In addition to tags, an RFID system requires a method of polling and reading the information from the tags and communicating the data to a host computer. The RFID reader handles the communication between the host computer and the RFID tag. The tag is energized by an electromagnetic radio frequency wave, called the carrier signal, transmitted by the reader. When the RF field passes through the antenna coil, an AC voltage is generated across it. The voltage is rectified to supply power to the tag. The information stored in the tag is transmitted back to the reader.

Finally, an RFID antenna is required for the reader to communicate with the tags. The antenna is connected to the reader and can be of various sizes and structures, depending on the distance of the communication. The antenna activates the tag and transfers data by emitting wireless pulses.

**Communication**

Communication of data between tags and a reader is wireless. Two methods that categorize RFID systems include inductive coupling and propagation of electromagnetic waves. Coupling is accomplished through an antenna structure, forming an essential feature in both tags and readers.
To transfer data efficiently through the air separating the tag and reader requires the data to be overlaid on a sinusoidal field or carrier wave. The process of superimposition, known as modulation, is based on changing the sinusoid’s amplitude, frequency or phase in accordance with the data carrying bit stream. Three basic procedures of coupling include amplitude shift keying (ASK), frequency shift keying (FSK) and phase shift keying (PSK).³²

**Carrier frequencies**

Three frequency ranges are generally distinguished for RFID systems: low, medium and high, which are typically characterized by 125 kHz, 13.56 MHz and 800 MHz frequencies. RFID transponders are developed using a frequency according to the needs of the system including read range and the environment in which the tag will be read. The read range and data transfer rate is primarily influenced by the frequency of the carrier wave used to carry the data between the tag and its reader. Generally, the higher the frequency is, the higher the read range and data transfer rate that can be achieved.¹¹

**Power**

The transponders require power to operate correctly. They are designated as either passive or active based on the method they derive power. Active tags are powered by an internal battery, are typically read/write devices, and have a finite lifetime. Passive tags operate without a battery by deriving power from the field generated by the reader. Passive transponders are consequently much lighter and less expensive than active transponders, and have a virtually unlimited lifetime. However, active transponders allow greater communication range, higher data transmission rates, and better noise immunity than passive transponders.¹¹

**6.1.2.2 RFID Implementation**

The transmitter/reader component of the PCL system takes advantage of RFID technology. The transmitters will be realized using RFID transponders and the reader units will be implemented using RFID readers. The host computer that the readers communicate with will be the MCU. Our reader units will consist of a reader and an antenna. The PCL system will derive power for the RFID subsystem from the telephone line coming into the reader units. In realizing the technology, our options included building the individual components and purchasing an evaluation kit with pre-built components. We decided to buy an evaluation kit that would come with all the tools necessary to produce an RFID system. The kit we choose, the Low Frequency Midrange Reader Evaluation Kit by Texas Instruments, comes with a micro-reader, antenna, and several low frequency tags in various packaging. Specifically, the contents of the package include an S2000 Micro Reader mounted on an interface board with an RS232 IF port, power connector, antenna connector, 80mm disk antenna, set of R/O, R/W, M/P transponders in various packages, PC interface cable, 9V power supply, a CD with user documentation and software, and a user guide.¹³ All of these features make it ideal for use in the PCL system. See figure 6.15 for a picture of the package contents. The kit uses inductive coupling technology and a low carrier frequency.

¹² http://www.rfid-handbook.de
¹³ http://www.ti.com/tiris/default.htm. Figure 6.15 and 6.16 were also taken from the website.
frequency of 134.2 kHz, which is ideal for a simple demonstration of our system, where only a short read range is required. The transponders are passively powered, which will allow us to eliminate the use of external batteries or outlet power in our system. In short, we chose the kit because it is an easy to use and program kit that has all the capabilities that our system needs.

Figure 6.15 – LF Reader Evaluation Kit

However, we will need to purchase an additional reader and antenna so that our demonstration may include two reader units and phones. See Figure 6.16 for a larger depiction of a few components in the kit.

Figure 6.16 – Tag, Reader, and Antenna

The Micro-reader is a plug-in module that provides RF and control functions to read and program transponders. It supports serial data communications between a PC and transponders. It features a Serial Communications Interface (SCI), which allows it to be directly connected to the PIC16F877A microcontroller. The Micro-reader supports TTL data communications with the addition of an RS232 transceiver and can remotely controlled by either providing certain inputs or by sending commands to the SCI. The Micro-reader supports all low frequency transponders provided by Texas Instruments and has been designed for use with a 47 µH antenna with a Q of
10 to 20 to generate the frequency of 134.2 kHz. Because of the Q level, it does not need to be tuned.

6.2 Software

6.2.1 User Interface

*Description:*

The system’s user interface will allow the user to enter their personal information and preferences, create phonebooks, setup default options, configure options for blocked calls, and describe general rules of operation. It will upload any updated information such as user preferences onto the system’s private web server, where it can later be downloaded by the MCU for storage in memory. Refer to section 3.4 for a draft of the user’s manual. The user interface will be programmed in HTML using PHP, ASP, and Perl scripts to realize the functions of a private web server.

6.2.2 Microcontroller Software

The microcontroller is the processing center for all the information needed for the system. It processes all the control data that is needed for the PCL system and performs actions based on the control data, controls switching of the phone line, and allows the MCU to communicate with the reader units. The microcontroller will be programmed in PIC Assembly with the aid of MPLAB, a PIC programming utility provided by Microchip. Figure 6.17 shows a flow chart of the software that will be contained in the microcontroller.
Figure 6.17– Microcontroller Software Flow Chart

Author(s): Rehan Shariff
7. Project Management

7.1 Task Breakdown

<table>
<thead>
<tr>
<th>Daniel Dobrin</th>
<th>Rehan Shariff</th>
</tr>
</thead>
<tbody>
<tr>
<td>- Manage Project</td>
<td>- MCU Interface</td>
</tr>
<tr>
<td>- Transmitter/Reader Interface</td>
<td>- phone line to microcontroller</td>
</tr>
<tr>
<td>- user to phone</td>
<td>- microcontroller to memory</td>
</tr>
<tr>
<td>- phone to MCU</td>
<td>- internet to microcontroller</td>
</tr>
<tr>
<td>- User Interface Programming</td>
<td>- Microcontroller Programming</td>
</tr>
<tr>
<td></td>
<td>- Telephone Line Interface</td>
</tr>
</tbody>
</table>

Kunal Shah

- User Interface Design
- User Interface Implementation
  - web programming
  - internet to microcontroller interface
- Microcontroller Programming

The testing of each of the system’s components and then the overall system performance will be done as a group. I believe that by doing this, it will allow us to quickly determine what might be wrong with either a certain system component or the overall system.

Author(s): Daniel Dobrin
7.2 Projected Project Cost

<table>
<thead>
<tr>
<th>System Components</th>
<th>Description</th>
<th>Part</th>
<th>Provider</th>
<th>Max. Delivery Time (days)</th>
<th>Cost Per Part</th>
<th>Quantity</th>
<th>Cost</th>
</tr>
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<tbody>
<tr>
<td>Main Control Unit (MCU)</td>
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<td>memory (serial EEPROM)</td>
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<td>Microchip</td>
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<td>$1.28</td>
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<td>v.22 modem</td>
<td>73K222AL</td>
<td>TDK</td>
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<td>$3.95</td>
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<td>RFID kit</td>
<td>RI-K3A-001A</td>
<td>Texas Instruments</td>
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<td>Extra Reader</td>
<td>RI-STU-MRD1</td>
<td>Texas Instruments</td>
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<td>Extra Antenna</td>
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<td>Texas Instruments</td>
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<td></td>
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<td>Jameco</td>
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<td>N/A</td>
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<td>~$20.00</td>
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| Total             |                              |                 |                          |                           |               |          | $484.13|

Table 7.1 – Project Projected Cost
7.3 Timeline

<table>
<thead>
<tr>
<th>Phase</th>
<th>Start</th>
<th>End</th>
</tr>
</thead>
<tbody>
<tr>
<td>System Design – All members</td>
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<td></td>
</tr>
<tr>
<td>(main control unit, user interface, readers, and transmitters)</td>
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</tr>
<tr>
<td>Parts and Equipment - Kunal</td>
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<td></td>
</tr>
<tr>
<td>(order necessary system parts and equipment – PC, PIC programmer)</td>
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<td>2.0</td>
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<tr>
<td>Transmitter - Daniel</td>
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<tr>
<td>(schematics, building, reader interaction, and testing)</td>
<td>5.0</td>
<td>4.0</td>
</tr>
<tr>
<td>User Interface - Kunal</td>
<td></td>
<td></td>
</tr>
<tr>
<td>(programming, implementation, and testing)</td>
<td>3.0</td>
<td>4.0</td>
</tr>
<tr>
<td>Main Control Unit (MCU) - Rehan</td>
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<td></td>
</tr>
<tr>
<td>(microcontroller &amp; memory programming, internet, phone interface, test)</td>
<td>6.0</td>
<td>4.0</td>
</tr>
<tr>
<td>Reader - Daniel</td>
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</tr>
<tr>
<td>(schematics, building, transmitter interaction, and testing)</td>
<td>4.0</td>
<td>4.0</td>
</tr>
<tr>
<td>Phones (Jacks and Lines) - Rehan</td>
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<tr>
<td>(implementation and testing with transmitter, reader, and MCU)</td>
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<td>2.0</td>
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<tr>
<td>Project Management - Daniel</td>
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<tr>
<td>(oversee team tasks, ensure timely project progress and delivery)</td>
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<td>13.0</td>
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<tr>
<td>Finalize – All members</td>
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<td></td>
</tr>
<tr>
<td>(finalize tests, prototype, and report)</td>
<td>8.0</td>
<td>2.0</td>
</tr>
</tbody>
</table>

Figure 7.1 – Timeline
8. Appendix – Data Sheets

Following are datasheets for the ICs and electronic components that are implemented by the PCL system.