FAWG TECH PHON-E-MAIL

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November 5th, 2001

Dr. Andrew Rawicz
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**Re: ENSC 340 Design Specifications for the Phon-E-Mail System**

Dear Dr. Rawicz:

The attached document, *Design Specifications for the Phon-E-Mail System*, outlines the design specifications for our Phon-E-Mail System. Our intended project is to create a stand-alone device that allows visually impaired and blind individuals, as well as those who do not own a computer system, to utilize the power of electronic mail (E-mail) through the use of a standard Public Switch Telephone Network (PSTN) telephone system.

Our design specifications includes information for the detailed hardware and software development needed to build and test the Phon-E-Mail System. It includes a detailed explantion of all hardware circuits and descriptions of program flow that will run on both a Rabbit 16-bit micro-controller and a web server. Finally, the design specifications will include a detailed test plan and a user interface description from the developers point of view.

Fawg Technologies is comprised of five highly dedicated, ambitious, and intelligent engineering students. Each student brings a unique skill set to the project team that will allow us to work in a fast and efficient manner. Group members include **Marvin Tom**, President and CEO; **David Ciampi**, CFO; **Raymond Ngun**, COO; **Calvin Ling**, VP Marketing; and **John-Paul Costales**, VP Operations. Should you have any questions, concerns, or comments about our specification, please feel free to contact me at (604) 431-6508 or via the Internet at my-aplio@sfu.ca. Thank you for your time.

Sincerely,

Marvin Tom,
President and CEO
Fawg Technologies

**Enclosure : Design Specifications for the Phon-E-Mail System**

FAWG TECH

PHON-E-MAIL

# Design Specifications for the Phon-E-Mail System

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## ABSTRACT


The Phon-E-Mail system is a sophisticated piece of equipment that allows an individual to send and receive e-mails without the need of a computer. The Phon-E-Mail system features voice recognition and text-to-voice software. The Phon-E-Mail system is not actually a phone in itself, but rather a phone attachment that can be connected to existing phones to make them E-mail ready and enabled. With the Phon-E-Mail system, even individuals with no computer skills can easily receive and compose E-mail messages freely. The main vision of the Phon-E-Mail system, however, is to allow visually-impaired and/or blind individuals to yield the full advantages of the technological age, and utilize electronic mail without the need of a complex computer system.

The Phon-E-Mail system uses the Rabbit 16-bit micro-controller as the "brain of the system". The Rabbit micro-controller core is responsible for menu navigation and the overall control of the system. The Phon-E-Mail system has a large hardware core reducing the overall complexity of the software. There are Analog-to-Digital conversion and Digital-to-Analog conversion circuits that are used to record voice and to playback email messages. The system also uses DTMF detection techniques for menu navigation. Because of the large amount of communications between the hardware and software components of the system, the communications protocol between the two systems are clearly defined and adhered to.

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# 1 INTRODUCTION

Electronic mail has become a worldwide standard in communications. An individual can e-mail large corporations and receive e-mail and online help and instructions for everything from C++ software programming to French Cuisine culinary dessert recipes to specifications for a Boeing 747 Commercial Airplane. However, due to their fear of technology or lack of technical skill, some people still cannot and have not used a computer system, let alone utilize the power of electronic mail. These individuals have been seriously hampered by not being able to actively participate in the electronic mail phenomenon.

For other groups of people, such as the visually impaired and blind communities, complex computer systems that are largely graphically based and have components such as monitors, mouse, and video-related hardware and software, are simply a waste of money and desk space. Existing audio software, such as JAWS and WebSpeak, have allowed visually impaired and blind individuals to use computers systems, but are very expensive and require extensive technical knowledge in order to install and to use. As such, the learning curve on these software systems is long and can be frustrating for average users, and scare off individuals who are not technologically inclined.

The Phon-E-Mail system, developed by Fawg Technologies, is a sophisticated piece of equipment that allows an individual to send and receive e-mails without the need of a computer. The Phon-E-Mail system is not actually a phone in itself, but rather a phone attachment that can be connected to existing phones to make them E-mail ready and enabled. With this system, even individuals with no computer skills can easily receive and compose E-mail messages freely, and the learning curve is very short since they will be interfacing directly with the telephone and a user menu system, similar to existing voice mail systems. The main vision of the Phon-E-Mail system, however, is to allow visually-impaired and/or blind individuals to yield the full advantages of the technological age, and utilize electronic mail without the need of a complex computer system.

This document will outline the detailed design specifications needed to develop and test the Phon-E-Mail System. It will include all necessary hardware circuits and descriptions on all software program flows. It will then conclude with a detailed test plan and user interface description.

## 2 SYSTEM OVERVIEW

The Phon-E-Mail system can be broken down into three distinct areas that will need to be designed and implemented individually. Once the three components have been developed, the system will essentially be stitched together and the system as a whole will be tested. Figure 1 shows each of the individual components of the system.

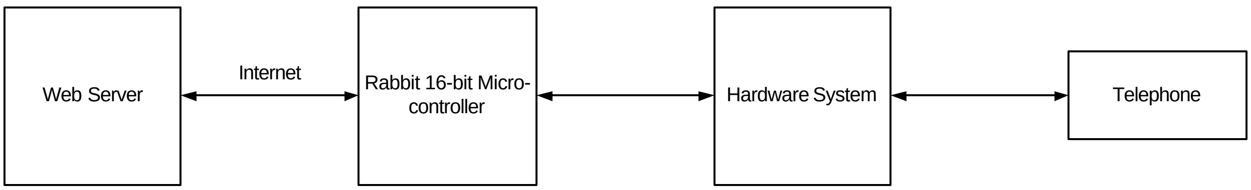


**Figure 1: System Overview**

There are two data paths in the system. The first data path is from the Web Server to the Telephone. This data path occurs when the user is attempting to retrieve an email message from the system. In this process, the text message is retrieved from the mail server and a text-to-voice conversion is performed. The voice is then played back to the user. The second data path is from the Telephone to the Web Server. This data path occurs when the user composes an email message. The voice is saved in wave format and included as an attachment to the outgoing email message. The email is then sent through the Internet via a mail server.

Each of the three individual systems will be discussed in subsequent sections along with a detailed specification on component communications and protocols.

# 3 RABBIT MICRO-CONTROLLER

The Phon-E-Mail system uses the Rabbit 16-bit micro-controller to be the "brain" of the system. This processor was specifically chosen because it already includes the TCP/IP stack necessary to retrieve and send emails via the Internet. It was also available to us from a previous project and helped to minimize development costs.

Specific to this project, the Rabbit is used to retrieve emails and send emails via the Ethernet controller using TCP/IP protocols. This Rabbit to Ethernet to Internet connection is shown in Figure 2.

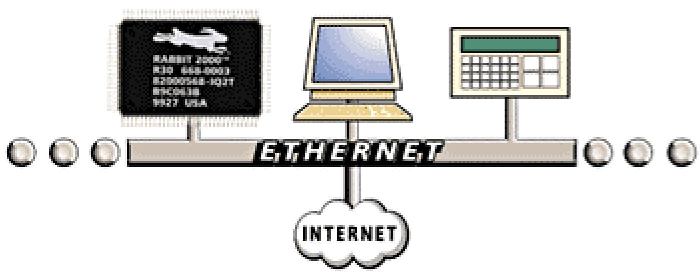


**Figure 2: Rabbit Ethernet Connection**

The Rabbit itself will not be used as an email server and thus an external server is used. To access the remote server, a couple of standardized protocols are used. To retrieve email, Post Office Protocol version 3 (POP3) is used. The POP3 protocol is a fairly simple text-based chat across a TCP socket, normally using TCP port 110. To send email, SMTP (Simple Mail Transfer Protocol) is used. Like POP3, SMTP is a simple text conversation across a TCP/IP connection. The SMTP server usually resides on TCP port 25 waiting for clients to connect. The software on the Rabbit will have to periodically check the POP3 email server for new messages. An architectural view of the Rabbit micro-controller and evaluation board is shown in Figure 3.

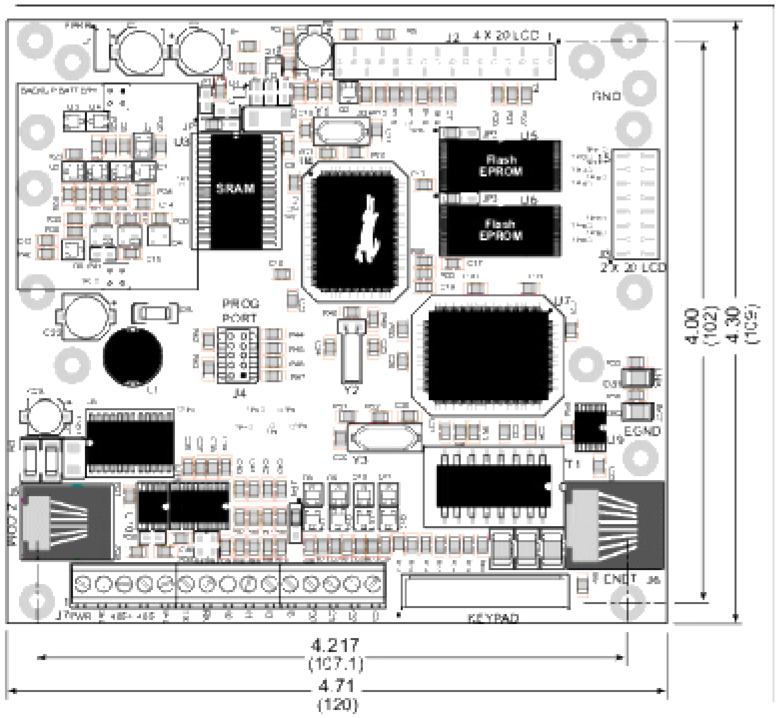


**Figure 3: Rabbit Evaluation Board Architecture**

## 3.1 DATA PROCESSING

When a new message arrives and is retrieved by the Rabbit, the text from the body of the message is sent to a second server that converts the text to speech using text-to-speech software. On receipt of the speech version of the email, the Rabbit stores this information in memory. The Rabbit is to then signal to the user a new message has arrived by ringing the phone.

When the user is ready to listen to the new message, the message is retrieved from memory and sent to a DAC at the rate of (8 kHz)125us per 8 bit sample. If and when the user wants to reply or send a new email, the Rabbit enables the ADC to digitize the user's analog voice signal from the phone. At a rate of 125us per sample, the data is read by the Rabbit and stored into memory. Upon the completion of the email (triggered by the pound key on the phone), the data is packaged into an email and sent using the SMTP protocol. To play the WAV file through the DAC, an internal timer is used to generate interrupts at 125us to output the WAV files. To record a WAV file, a clock is generated at 8KHz with a duty cycle of 75%. This clock is fed to a ADC that generates a sample during the 75% portion of the clock. During the falling edge of the clock, the Rabbit reads the sample. This sequence of data acquisition and processing for receiving and displaying in e-mail message can be summarized in Figure 4.

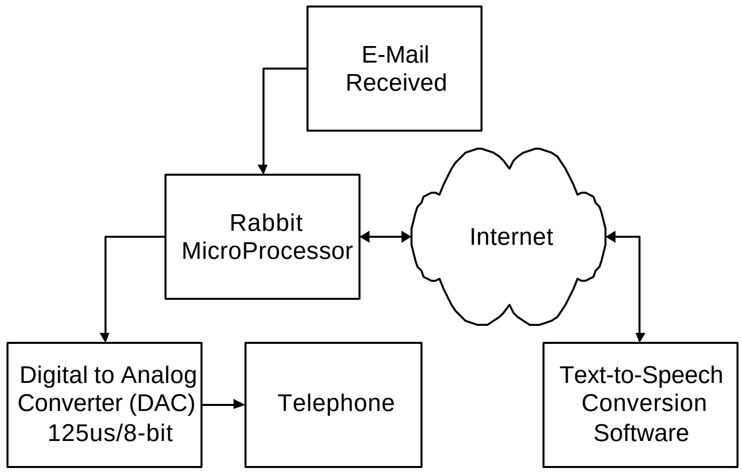


**Figure 4: Data Acquisition and Processing**

Note that because of limited code space on the Rabbit, the text-to-speech conversion will be performed externally to the Rabbit. During the conversion process, the Rabbit will send the email message to be converted to an external server. This external server will convert the text message to voice and send back

### 3.2 SERIAL FLASH MEMORY

The Rabbit TCP/IP development board has 256Kbytes of built-in flash as program space and 128Kbytes of SRAM as data space. Unfortunately, the Rabbit is a 16-bit micro-controller, so it can only address 65Kbytes in total of both flash and SRAM combined. There are built-in instructions on the Rabbit that allows the programmer to address outside of the 65Kbytes.

All of our voice will be stored in the form of wave files. A typical email message would be on the order of approximately 20 seconds. Since, we are recording and playing back email messages at a rate of 8 kHz, a 20 second message would requite approximately 160 Kbytes of SRAM data space. Since there is only 128 Kbytes of physical memory, some portions of messages will be need to stored off chip. An 8 MB serial flash is used to help alleviate these problems. The serial flash contains 8192 blocks of 1024 Kbytes. The data from the flash must be read and written to in blocks. Thus reading and writing to serial flash must be interleaved with the recording and playback of messages.

### 3.3 PROGRAM FLOW

The program flow of the Rabbit is kept simple because of the minimal amount of code space. The program flow flowchart is given below in Figure 5.

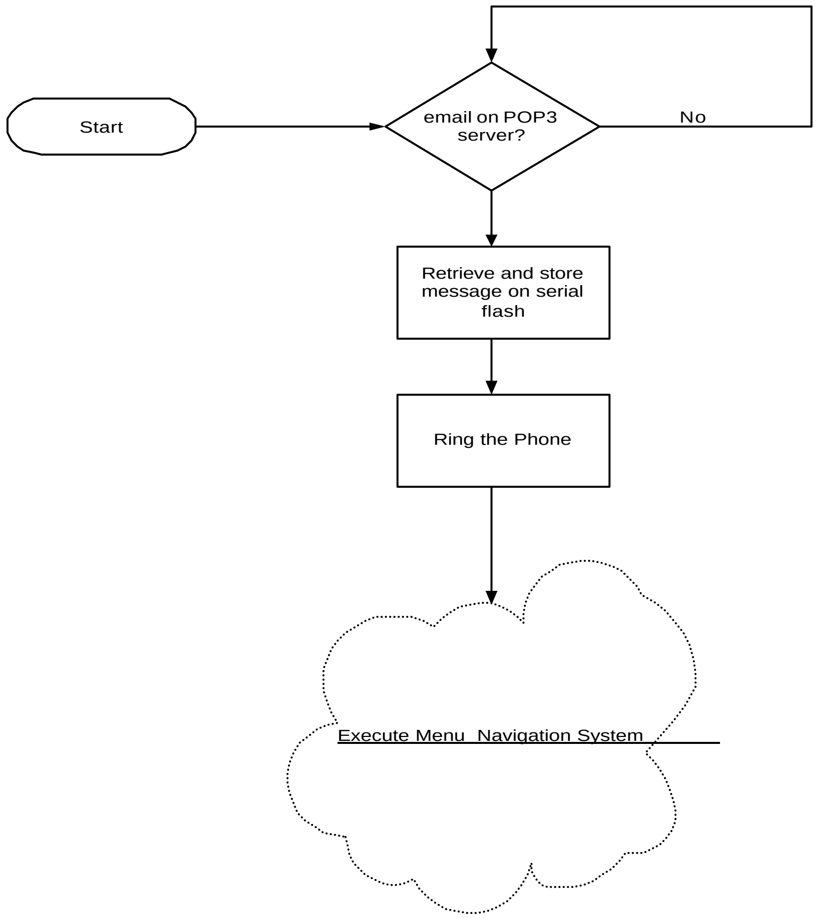


**Figure 5: Rabbit Program Flow Flowchart**

The menu navigation system is intentionally omitted in this section as it is explained in greater detail in the User Interface portion of the document.

# 4 HARDWARE SPECIFICATIONS

The hardware system of the Phon-E-Mail System is given in Figure 6.

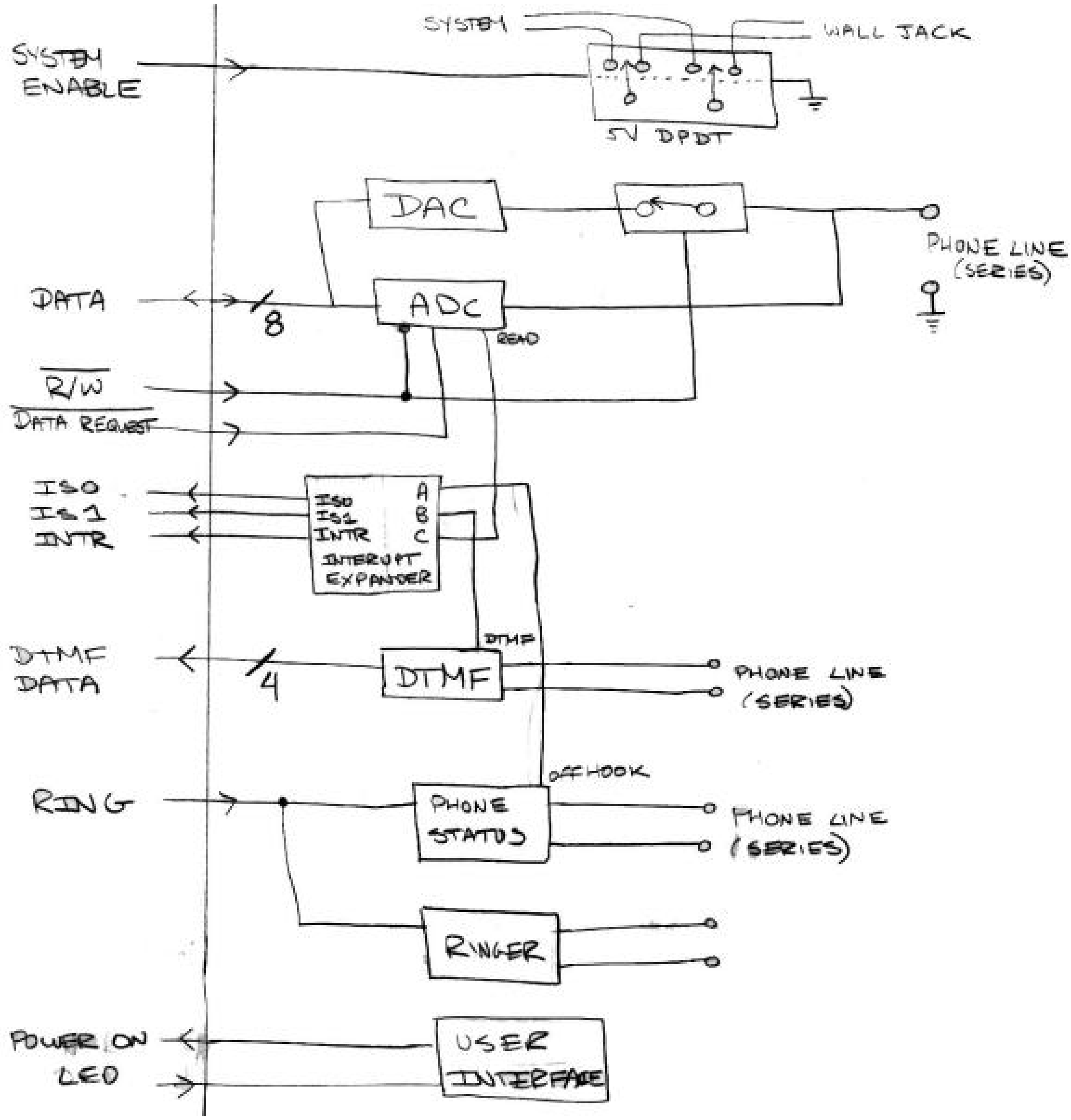


**Figure 6: Hardware System Overview**

The hardware portion of the system performs a series of functions including system power-up and enable, digital-to-analog conversion of voice, analog-to-digital conversion of voice, interrupt generation, DTMF (Dual Tone Multi-Frequency) detection, ring enable, and user interface functions. Each of the sub-components can be further broken down in the following sections.

### 4.1 ANALOG TO DIGITAL CONVERSION

Analog to Digital conversion occurs when the user of the system is composing an email message. A typical voice signal can have frequency components up to approximately 4 kHz. Therefore, according to Nyquist's theorem, we should sample the data at 8 kHz. The ADC circuit uses the ADC0803. This IC performs a 8-bit parallel analog-to-digital conversion. The ADC circuit is given in Figure 3.

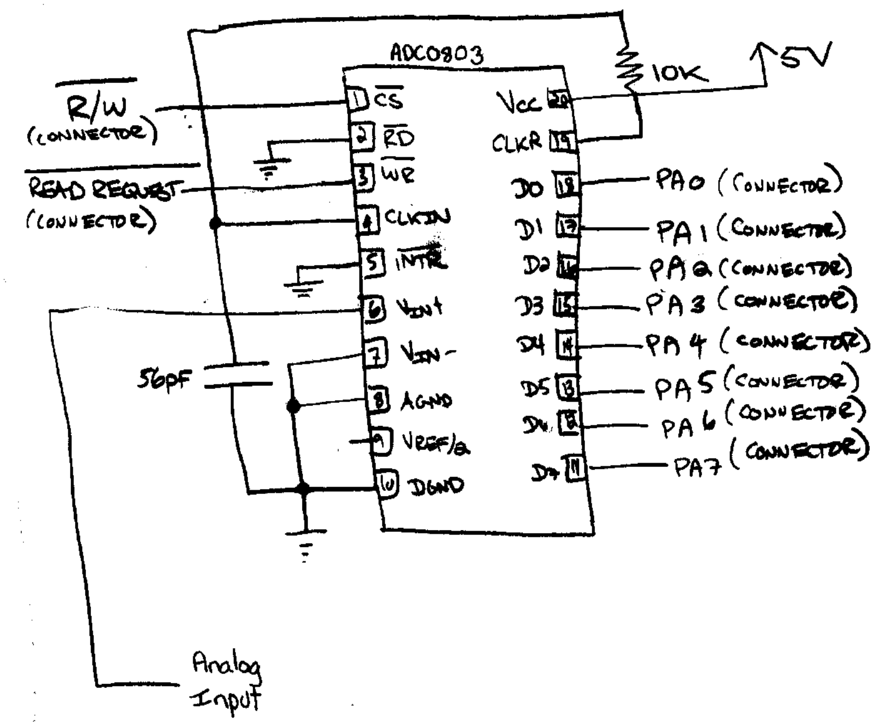


**Figure 7: Analog to Digital Circuit**

### 4.2 DIGITAL TO ANALOG CONVERSION

Digital to Analog conversion occurs when play back of email messages occurs. The play back of messages is done from wave files encoded at a rate of 8 kHz. These wave files are retrieved after a text-to-voice conversion is performed by software. This software implementation of this conversion is discussed in more detail in the Web Server portion of the document. The DAC0800 IC is used to perform an 8-bit parallel conversion. The DAC circuit is given in Figure 8.

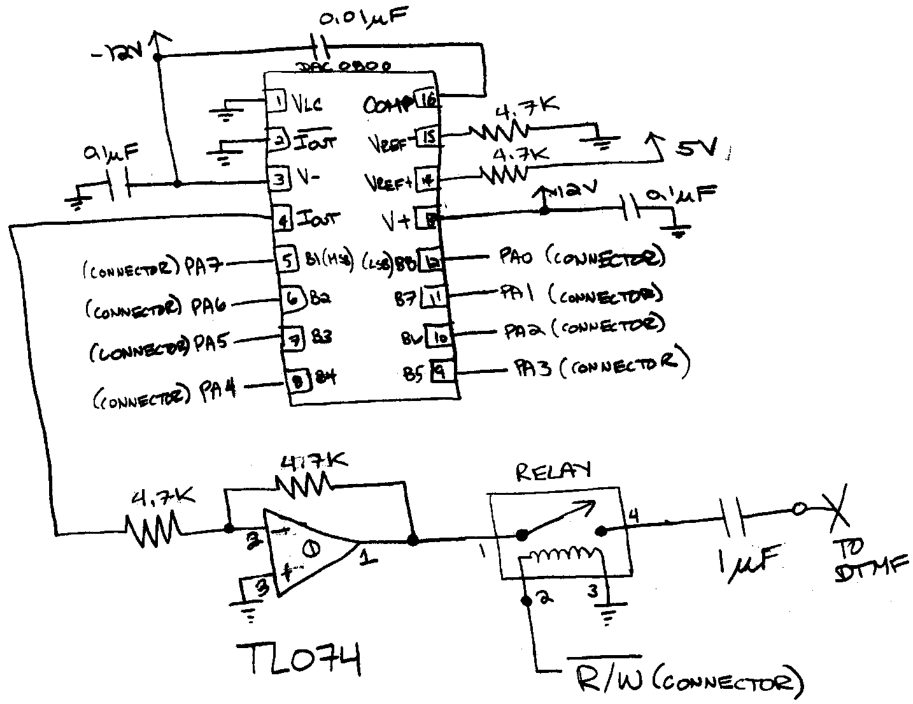


**Figure 8: Digital to Analog Circuit**

Note that both the DAC and ADC circuits share the same digital bus wires, namely Port A (PA) on the Rabbit micro-controller. It is the responsibility of the software to ensure that the bus wires are not simultaneously driven.

## 4.3 DTMF (DUAL TONE MULTI-FREQUENCY) DETECTION

DTMF detection is used when the user is navigating through the system menu. DTMF tones are generated by the keypad on the telephone. The tones are detected by the circuit in Figure 9. Once the tones are detected, the data is sent to the Rabbit micro-controller through a 4 bit encoded data bus.

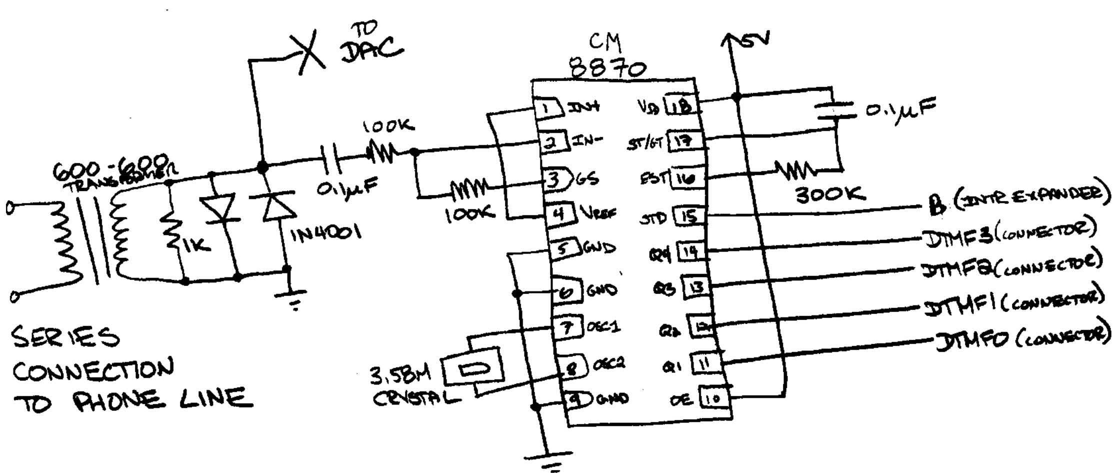

**Figure 9: DTMF Circuit**

## 4.4 TELEPHONE INTERFACE CIRCUIT

The telephone interface circuit shows the configuration needed to properly retrieve analog signals off the telephone line and drive analog signals onto the telephone line. The telephone line needs a DC bias of 24 volts supplied by a power supply. A 600-600 ohm telephone transformer is used to retrieve and drive signals onto the line. A protection circuit using back-to-back diodes is also included to prevent voltage spikes from damaging the system. The telephone interface circuit is given in Figure 10.

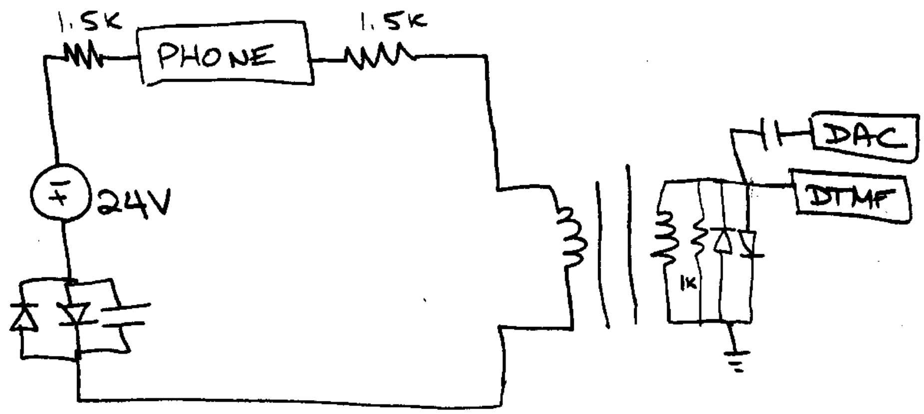


**Figure 10: Telephone Interface Circuit**

## 4.5 INTERRUPT EXPANDER CIRCUIT

The Rabbit micro-controller only supports 1 external interrupt. Since our system requires 4 external interrupts, a interrupt expander circuit is used to encode external interrupts. The external interrupts use a priority based system. The types of external interrupts are shown below in Table 1.

**Table 1: Interrupt Expander Description**

| Interrupt Priority | Interrupt Description | Encoded Value ( IS1, IS0 ) |
|---|---|---|
| 1 | Telephone Off Hook (Input A) | 11 |
| 2 | Telephone On Hook (Input B) | 10 |
| 3 | DTMF Detected (Input C) | 01 |
| 4 | ADC Read Complete (Input D) | 00 |

The interrupts can be easily encoded using K-maps and simple boolean algebra.

The interrupt expander circuit was implemented using a Quad 2-Input NOR gate IC and a Tri 3-Input NOR gate IC. The expander circuit is given in Figure 11.

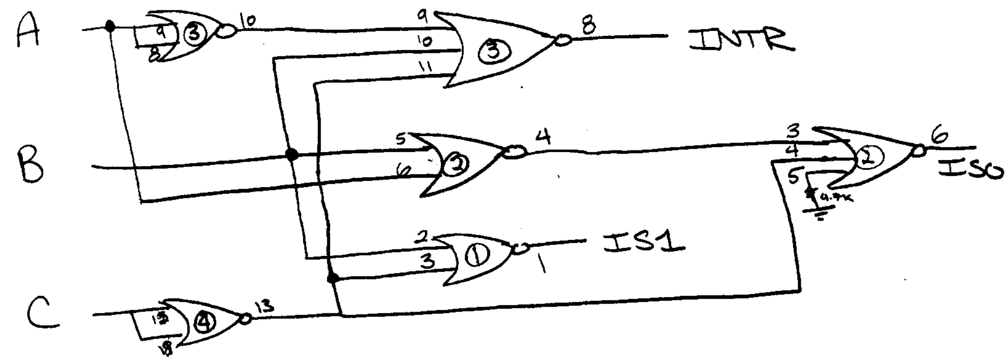


**Figure 11: Interrupt Expander Circuit**

## 4.6 RINGER CIRCUIT

The ringer circuit uses a 555 timer to ring the telephone when incoming email messages have been received. The user has the ability to vary the ring length via a 1MΩ potentiometer. The ringer circuit is given in Figure 12.

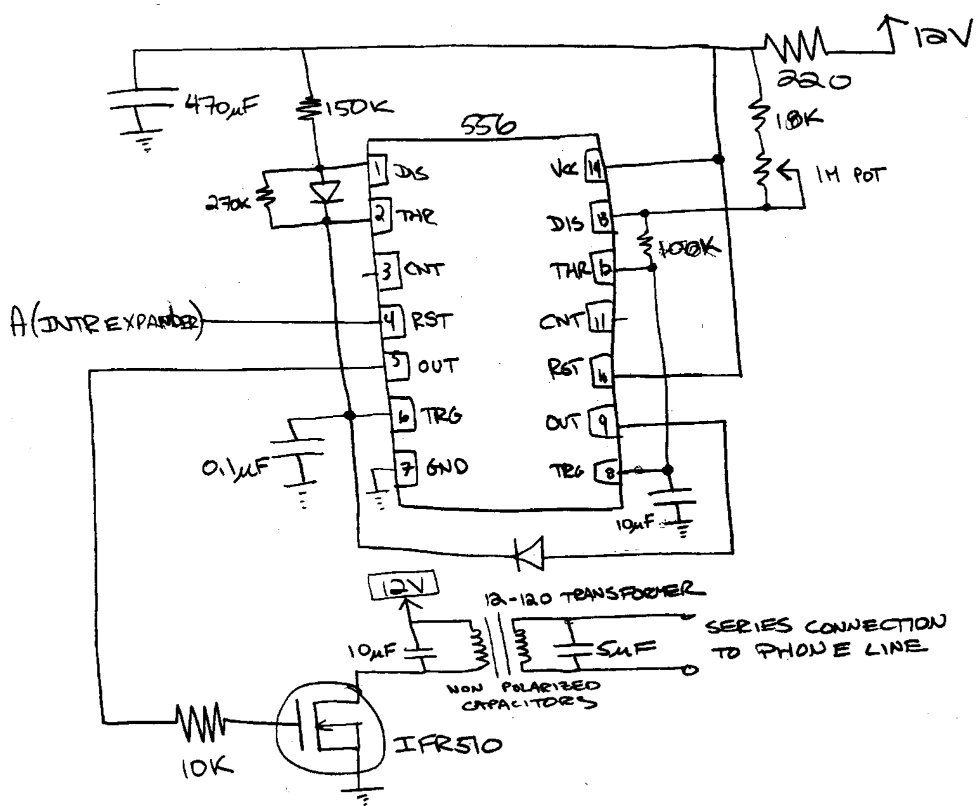


**Figure 12: Ringer Circuit**

## 4.7 PHONE STATUS CIRCUIT

The phone status circuit is used to indicate to the Rabbit whether the phone is on hook or off hook. The circuit is given below in Figure 13.

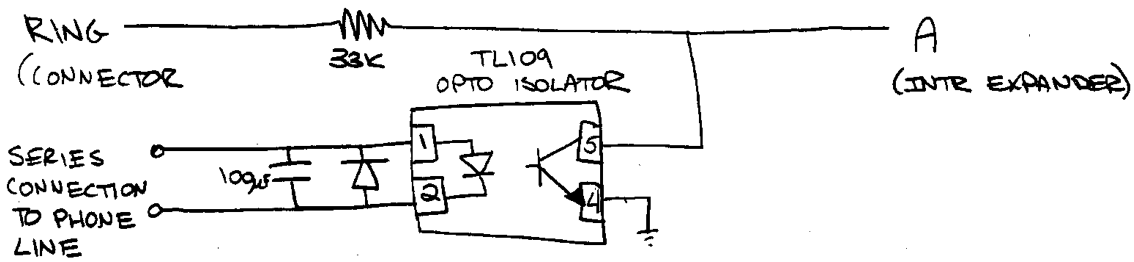


**Figure 13: Phone Status Circuit**

# 5 HARDWARE / SOFTWARE COMMUNICATIONS PROTOCOL

The hardware and software components need to constantly communicate with each other. There are 2 major interfaces that will be discussed. The first is the Rabbit/Hardware communication system and the Rabbit/Web Server system.

## 5.1 RABBIT / HARDWARE COMMUNICATION SYSTEM

The rabbit contains 8 bi-directional pins, 8 input pins and 4 output pins for communication to the hardware system. Table 2 outlines the purpose of each of these pins.

**Table 2: Rabbit Bi-Directional Pin Allocation**

| Pin Number | Pin Description |
|---|---|
| Bi-Pin0 | DAC/ADC Data 0 |
| Bi-Pin1 | DAC/ADC Data 1 |
| Bi-Pin2 | DAC/ADC Data 2 |
| Bi-Pin3 | DAC/ADC Data 3 |
| Bi-Pin4 | DAC/ADC Data 4 |
| Bi-Pin5 | DAC/ADC Data 5 |
| Bi-Pin6 | DAC/ADC Data 6 |
| Bi-Pin7 | DAC/ADC Data 7 |

**Table 3: Rabbit Input Pin Allocation**

| Pin Number | Pin Description |
|---|---|
| In-Pin0 | DTMF Encode 1 |
| In-Pin1 | DTMF Encode 2 |
| In-Pin2 | DTMF Encode 3 |
| In-Pin3 | DTMF Encode 4 |
| In-Pin4 | Interrupt Select 1 |
| In-Pin5 | Interrupt Select 2 |
| In-Pin6 | Unused |
| In-Pin7 | Unused |

**Table 4: Rabbit Output Pin Allocation**

| Pin Number | Pin Description |
|---|---|

| | |
|---|---|
| Out-Pin0 | ADC/DAC Chip Select |
| Out-Pin1 | ADC Read Request |
| Out-Pin2 | Ring Enable |
| Out-Pin3 | LED Status |

## 5.2 RABBIT / WEB SERVER COMMUNICATION SYSTEM

Because of memory constraints of the Rabbit micro-controller, the text-to-voice conversion must be performed by an external server. When the Rabbit has retrieved a text message to be converted to voice, the text message is send via TCP/IP. The external web server then receives the text file and performs a text-to-voice conversion. This conversion processes is performed using Festvox source code. Festvox is a readily available system that performs text-to-voice conversion. Its source code can be downloaded from the Internet at http://festvox.org/download.

Once the external web server has performed the text-to-voice conversion, it parses the resulting wave file into 1 kB chunks. Since the Rabbit may not have the memory capacity to store the entire wave file in to physical memory, the wave file must be received and written to flash memory. The web server will then send the 1 kB chunks at 0.1 second intervals to ensure that the Rabbit has ample time to receive the data chunks and write the data chunks to flash.

# 6 USER INTERFACE DESIGN

The Rabbit micro-controller is responsible for menu navigation of the user. The tree given in Figure 14 and Table 5 shows the entire flow of the navigation system.

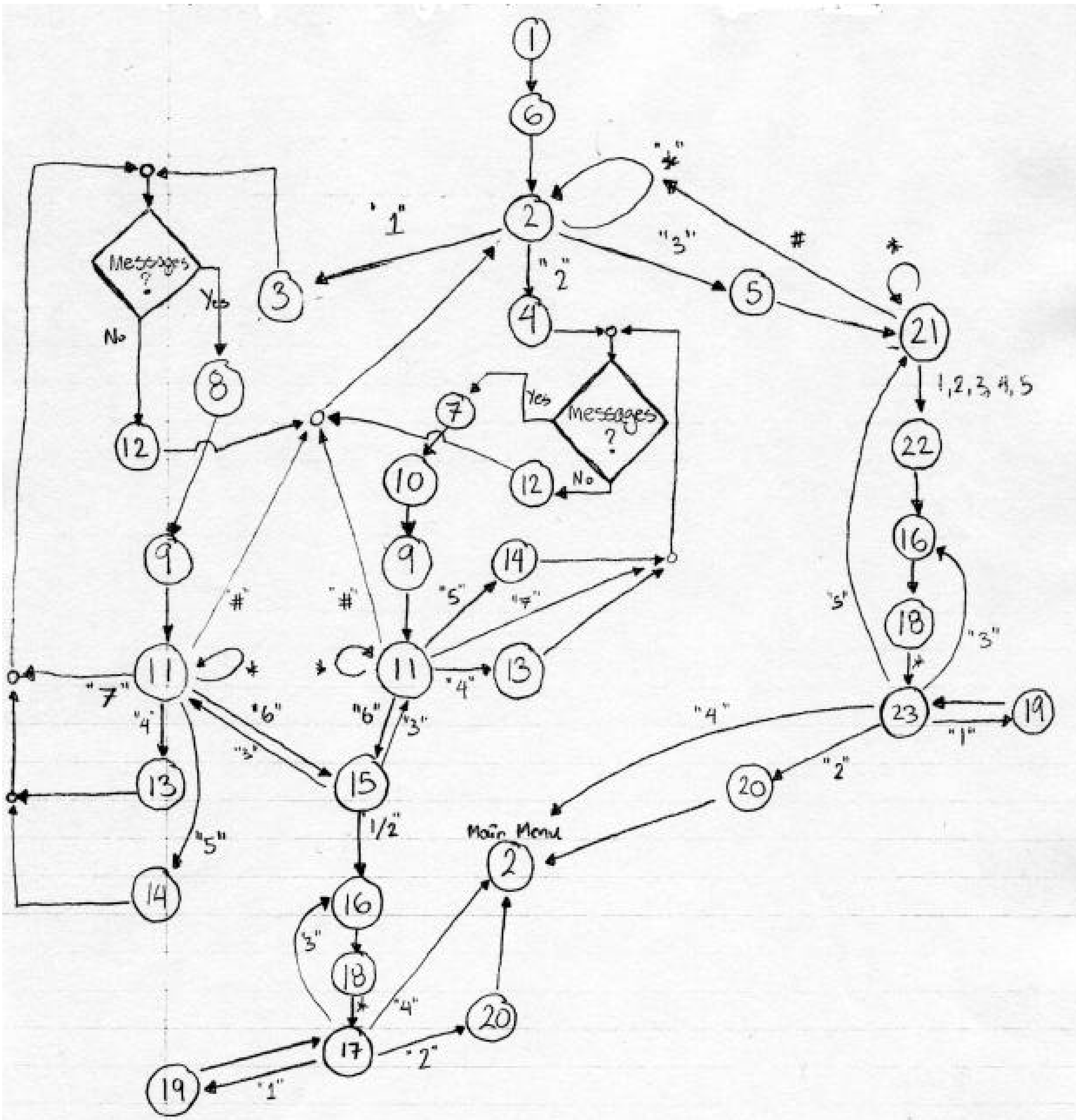


**Figure 14: Menu Navigation Tree**

**Table 5: Menu Navigation Prompts**

| **Message Number** | **Message** |
|---|---|
| 1 | Welcome to the Fawg Technologies phone-E-mail System |
| 2 | To listen to new messages, Press 1<br>To listen to saved messages, Press 2<br>To compose a new e-mail message, Press 3<br>To listen to this menu again, Press * |
| 3 | You have chosen to listen to new messages |
| 4 | You have chosen to listen to saved messages |
| 5 | You have chosen to compose a new e-mail message |
| 6 | You have (3) new email messages |
| 7 | You have (3) saved email messages |
| 8 | (First) new email message from (mtom@sfu.ca),<br>Sent (Monday, 29th October 2001 05:12:45)<br>Entitled (Meeting Update) |
| 9 | => Recite Email Message <= |
| 10 | (First) saved email message from (rkngun@sfu.ca),<br>Sent (Sunday, 17 October 2001 14:44:56)<br>Entited (Re: Func Spec) |
| 11 | End of email message.<br>To save this message, Press 4,<br>To reply to this message, Press 6,<br>To continue to the next email message, Press 7,<br>To repeat this menu, Press *,<br>To return to the Main Menu, Press #. |

# 7 TEST PLAN

The test plan for the system will include a functional test for various components of the system. Once the system has been completed, the system as a whole will be tested. Note that the test plan given below is an outline to test core functionality of the system.

## 7.1 FUNCTIONAL TESTING

### 7.1.1 RINGER CIRCUIT TESTING

1. Ensure that when the ring enable signal is applied that the phone will ring. When the ring enable signal is removed, ringing should cease.
2. Verify that turning the potentiometer changes the ringing length.

### 7.1.2 ADC / DAC TEST

1. Input a 1 kHz sine wave into the ADC circuit
2. Verify that the sample was properly stored in the Rabbit memory space.
3. Output the same data to the DAC circuit and ensure that the outputted tone is at the same frequency.

### 7.1.3 DTMF TONE DETECTION

1. Enter a series of DTMF tones
2. Verify that the tones were properly detected by the rabbit using software verification techniques.

### 7.1.4 WEB SERVER (TEXT-TO-VOICE CONVERSION)

1. Send a text file to the web server program via TCP/IP.
2. Perform a blocking wait and verify that the resulting wave file is sent back in 1 kB blocks.

## 7.2 SYSTEM TESTING

### 7.2.1 USER INTERFACE TESTING

1. Ensure that every branch found in Figure 14 is propagated through. This test must be performed using the telephone and verification is performed by comparing the user prompts to Table 5.

### 7.2.2 SEND EMAIL TEST

1. Using the send email function, a series of emails should be sent to at least 5 different emails.
2. Verify that the emails were sent with no corruption and that the resulting wave file attachments are audible.

### 7.2.3 Receive Email Test

1. Send a series of emails to the Phon-E-Mail system. Verify that proper text-to-voice conversion was performed and that the audio is audible.

## 8 CONCLUSION

There are many visually impaired individuals in society that may not own a computer due to their disability. These people still may want to be a part of the greatly expanding Internet, but have no gateway to it. There may be people only interested in using email and do not want to purchase an entire computer system. These groups may include people who have a fear of technology and do not want to spend thousands of dollars or the blind and visually impaired communities who do not need some of the standard computer equipment such as the monitor, mouse, and video card. These people would like to purchase the minimum amount of equipment to access the world of the Internet and electronic mail.

This document has outlined a detailed plan of how the Phon-E-Mail system will be designed, implemented and tested. This plan is a current up to date plan of how the development of this product will proceed. However, we reserve the right to change any portions of the plan as we see fit during the development cycle to satisfy the needs of potential customers or to meet the demands of the Functional Specifications. The attached test plan will also be strictly adhered to ensure that the quality of our product will be protected.

Our Phon-E-Mail system can provide an affordable means of accessing email via a regular telephone. It will provide a small compact design and provide a seamless link between a phone connected to the telephone company and the Internet. Our product is easy to use, yet has extremely powerful capabilities. The Phon-E-Mail System is truly a complete e-mail accessing system solution that introduces electronic mail to consumers without the complexity and requirements of a classic computer system.

# 9 REFERENCES

## 9.1 COMPANIES

Rabbit Semiconductor Inc. Davis, California. http://www.rabbitsemiconductor.com/

National Semiconductor Inc. Santa Clara, California. http://www.nsc.com/

Motorola Semiconductor Products Inc. Calgary, Alberta. http://e-www.motorola.com/

Festvox Text-To-Voice Conversion : http://fextfox.org/

## 9.2 SFU PROFESSORS

Dr. Andrew Rawicz. *Reliability physics and engineering, VLSI reliability, physical transducers, integrated sensors, film technology, nonlinear optics, materials processing in microelectronics.*

Patrick Leung. *Engineering Lab Instructor.*

George Austin. *Engineering Lab Instructor.*