Control of Remote Domestic System Using DTMF

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***Abstract*— The human mind always needs information of interest to control systems of his/her choice. In the age of electronic systems it is important to be able to control and acquire information from everywhere. Although many methods to remotely control systems have been devised, the methods have the problems such as the need for special devices and software to control the system. This paper suggests a method for control using the DTMF tone generated when the user pushes mobile phone keypad buttons or when connected to a remote mobile system. The proposed work has been done experimentally and has been verified in real time.**

***Keywords*— DTMF, Data acquisition system, Band split filters, IC 8870, AT Commands.**

I. INTRODUCTION

The remote control technologies have been used in the fields like factory automation, space exploration, in places where human access is difficult. As this has been achieved in the domestic systems partially [1], many corporations and laboratories are researching the methods which enable human to control and monitor efficiently and easily in the house or outdoor. Controlling the domestic system regardless of time and space is an important challenge. As the mobile phone enables us to connect with the outside devices via mobile communication network regardless of time and space, the mobile phone is a suitable device to control domestic systems.

This paper proposes a method to control a domestic system using a mobile phone, irrespective of the phone model and mobile phone carrier. The system suggested consists of the mobile phone normally registered in communication service and a computer that can receive a call from another phone. Existing methods for control and monitoring, using mobile phones have usage problems because the cost and need for continuous control. One of the disadvantages, being the lack of feedback during the process. This paper proposes to solve the problems of existing methods of control that use simple voice call and SMS. Method proposed uses the DTMF (Dual Tone Multi Frequency) [2], [3], [4] generated when a keypad button of the mobile phone is pressed by the user. The mobile phone user controls the system by sending the DTMF tone to the access point. Mobile communication network coverage is larger than that of LANs, thus user can take advantage of mobile phones to control the system.

II. DTMF BASICS

DTMF is a generic communication term for touch tone (a Registered Trademark of AT&T). The tones produced when dialing on the keypad on the phone could be used to represent the digits, and a separate tone is used for each digit. However, there is always a chance that a random sound will be on the same frequency which will trip up the system. It was suggested that if two tones were used to represent a digit, the likelihood of a false signal occurring is ruled out. This is the basis of using dual tone in DTMF communication.

DTMF dialing uses a keypad with 12/16 buttons. Each key pressed on the phone generates two tones of specific frequencies, so a voice or a random signal cannot imitate the tones. One tone is generated from a high frequency group of tones and the other from low frequency group. The frequencies generated on pressing different phone keys are shown in the Table 1.

Table 1 – Frequencies generated on Key presses

Button	Low Frequency(Hz)	High Frequency(Hz)
1	697	1209
2	697	1336
3	697	1477
4	770	1209
5	770	1336
6	770	1477
7	852	1209
8	852	1336
9	852	1477
0	941	1209
*	941	1336
#	941	1477

Each row and column of the keypad corresponds to a certain tone and creates a specific frequency. Each button lies at the intersection of the two tones as shown in Table 2.

Table 2 – Row and Column Frequency Correspondence

1	2	3	697
4	5	6	770
7	8	9	852
*	0	#	941
1209	1336	1477	Frequency(Hz)

When a button is pressed, both the row and column tones are generated by the telephone instrument. These two tones will be unique and different from tones of other keys. So, whenever we say that there is a low and high frequency associated with a button, it is actually the sum of two waves is transmitted.

This fundamental principle can be extended to various applications. DTMF signals can be transmitted over a radio to switch on or switch off home appliances, flash lights, motors, cameras, warning systems, irrigation systems and so on. These encoded data can be stored in a microcontroller and can be transmitted serially to another system for processing. Block diagram for the proposed method is shown in Fig. 1.

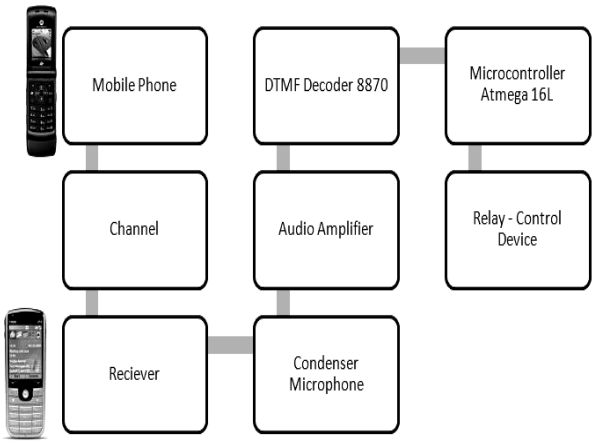

Figure 1 – Block diagram of the scheme

III. DECODER DESCRIPTION

The decoder used is M-8870. For operating functions see Fig. 3 – Structure of M-8870. M-8870 includes a band split filter that separates the high and low tones of the received pair, and a digital decoder that verifies both the frequency and duration of the received tones before parsing the resulting 4-bitcode to the output bus.

The M-8870 decoder uses a digital counting technique to determine the frequencies of the limited tones and to verify that they correspond to standard DTMF frequencies. A complex averaging algorithm is used to protect against tone simulation by extraneous signals (such as voice) while tolerating small frequency variations [6], [7]. The algorithm ensures an optimum combination of immunity to talk off and tolerance to interfering signals (third tones) and noise. When the detector recognizes the simultaneous presence of two valid tones (known as signal condition), it raises the Early Steering flag (ESt). Any subsequent loss of signal condition will cause ESt to fall.

IV. SIGNAL CONDITIONING

Before a decoded tone pair is registered, the receiver checks for valid signal duration (referred to as character-recognition-condition). This check is performed by an external RC time constant driven by ESt. A logic high on ESt causes VC (see block diagram Fig. 3) to rise as the capacitor discharges. Provided that signal condition is maintained (ESt remains high) for the validation period (tGTF), VC reaches the threshold (VTSt) of the steering logic to register the tone pair, thus latching its corresponding 4-bit code (see DC Characteristics in Data Sheet) into the output latch. At this point, the GT output is activated and drives VC to VDD. GT continues to drive high as long as ESt remains high. Finally, after a short delay to allow the output latch to settle, the delayed steering output flag (StD) goes high, signaling that a received tone pair has been registered. The contents of the output latch are made available on the 4-bit output bus by raising the three-state control input (OE) to logic high. The steering circuit works in reverse to validate the inter digit pause between signals. Thus, as well as rejecting signals too short to be considered valid, the receiver will tolerate signal interruptions (dropouts) too short to be considered a valid pause. This capability, together with the ability to select the steering time constants externally, allows the designer to tailor performance to meet a wide variety of system requirements.

The internal clock circuit of 8870 is completed with addition of external 3.579545 MHz crystal oscillator.

V. ATMEGA 16L MICROCONTROLLER

Atmega 16L microcontroller manufactured by ATMEL is used. It is a high performance 8 bit, low power microcontroller with two eight bit counters, two sixteen bit counters with pre scale feature, and compare mode, 16Kb of non volatile programmable memory and data memory, up to 64 Kb of extendable memory with many more features and modules. It is compatible with the industry-standard 80C51 instruction set and pin-outs.

VI. STRUCTURE OF PROPOSED WORK

A. *Operation of the Circuit*

The message is transmitted by calling the second mobile phone (which is connected to the computer as shown in the Fig.1) and typing in the desired number corresponding to the required control effort at the transmitter end.

When the handset of the phone at the receiver end is picked up or the phone is picked up automatically by the use of AT commands, the messages can be typed on the number pad of the transmitting phone. The receiver end

comprises of input device, decoder, microcontroller, computer and a mobile phone.

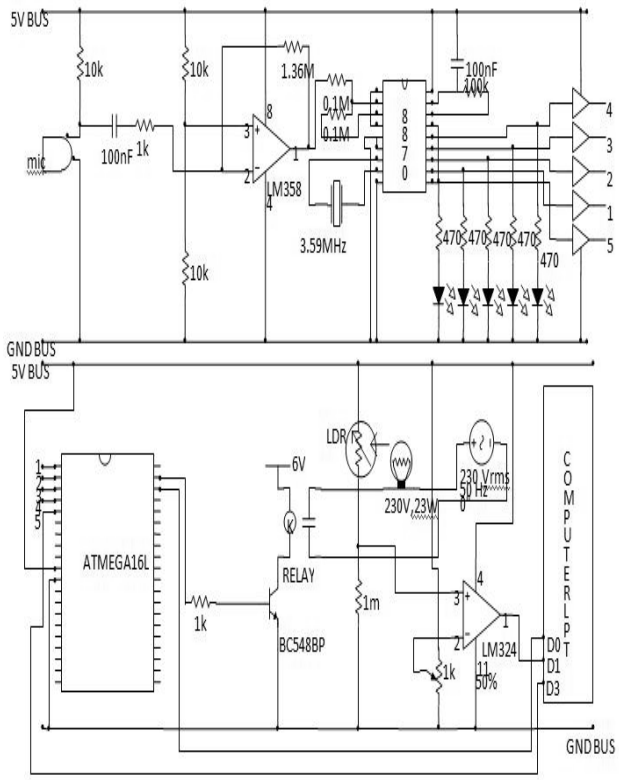

Figure 2- Circuit Diagram

The input section consists of a mobile/landline phone, condenser microphone and an audio amplifier. For the decoder section, the underlying concept is DTMF signal reception and the decoded signal is fed to the microcontroller through LPT [8]. The microcontroller is connected to the parallel port of a computer, and is connected to a relay which performs the required action. The computer also helps by responding to the input by playing a suitable audio file representing the status of the system, which can be heard at the transmitter end immediately as the key is pressed.

Once the connection is established between the two phones, whatever phone key is pressed at the transmitting end, the corresponding DTMF tone is heard in the ear piece of the receiver phone. The ear piece is connected to a condenser microphone which picks up the DTMF tone. Its output is amplified by the audio amplifier and this output is fed to the DTMF decoder. The DTMF decoder will give the corresponding BCD value of the tone. As shown in the circuit (Fig.2), LED 5 acts as a visual indicator when the valid signal is received by the system. This output, through a driver circuit is connected to PORT B of the Atmega 16L microcontroller. This microcontroller's output is fed to the relay and parallel port of the computer to affect the control effort and to trigger a voice feedback.

B. *Message Decoding Algorithm*

Table 3 – Values at Output Bus for various frequencies

Button	Low Frequency(Hz)	High Frequency(Hz)	Q1	Q2	Q3	Q4
1	697	1209	0	0	0	1
2	697	1336	0	0	1	0
3	697	1477	0	0	1	1
4	770	1209	0	1	0	0
5	770	1336	0	1	0	1
6	770	1477	0	1	1	0
7	852	1209	0	1	1	1
8	852	1336	1	0	0	0
9	852	1477	1	0	0	1
0	941	1209	1	0	1	0
*	941	1336	1	0	1	1
#	941	1477	1	1	0	0

Each key press at transmitter end reflects as a BCD value $Q_1Q_2Q_3Q_4$ at the outputs of 8870 DTMF decoder. The corresponding values are given in Table 3.

The outputs $Q_1Q_2Q_3Q_4$ are processed by microcontroller and sent to the relay. The device status which is being continuously monitored by the computer through parallel port triggers a voice response [9]. If the device is discovered to be faulty after the call has been disconnected, provision has been made to send an SMS to the transmitting end or any other mobile phone of the user's choice (Refer Appendix 3 for microcontroller program). The user can know the status of the message by pressing any key which is not assigned to any of the specific task.

The input to the computer is sensed by the software and the computer responds by playing a suitable tone already stored in the computer. The sound file can be a lossless encoding or any compression format supported by Windows Media Player. The computer programming is done in Microsoft Visual Studio 6 (Refer to Appendix 2 for the VB6 codes). The sound file is played and sensed by the mobile, whose effect can be heard at the other end by the user.

VII. RESULTS AND DISCUSSION

The DTMF signal waveform is shown in Fig 4. The two waves can have phase difference of an arbitrary value. The system is immune to external noise and the ring tone of the receiver mobile phone. There is a finite probability that the system turns on or turns off due to ambient noises like voice, sound arising from door latches etc.

The circuit was built and tested. Refer Fig.5 for the picture of tested circuit. The device controlled was a 230V / 23W Power Saving Bulb. The mobile phone at the receiver's end is controlled by the computer using hyperterminal and AT commands.

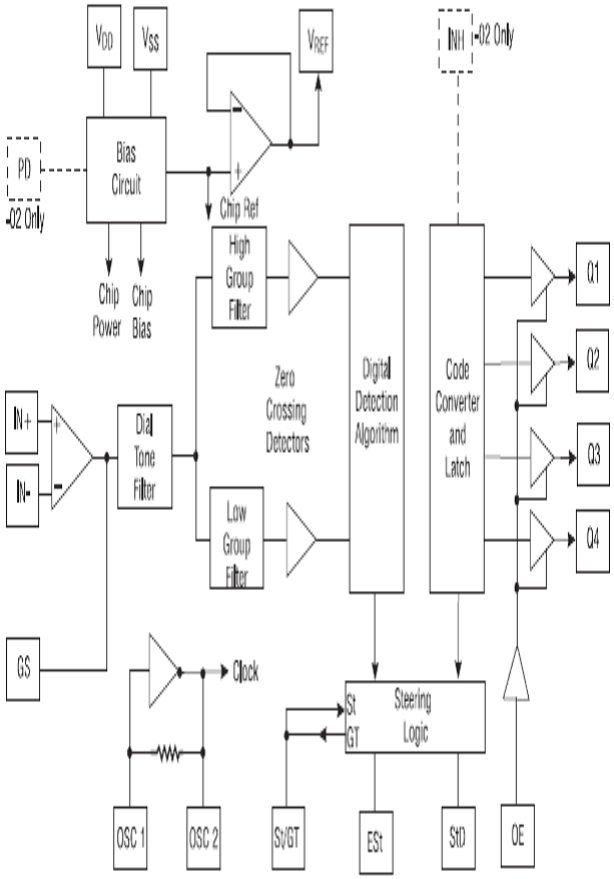

Figure 3 Structure of 8870 Decoder [6]

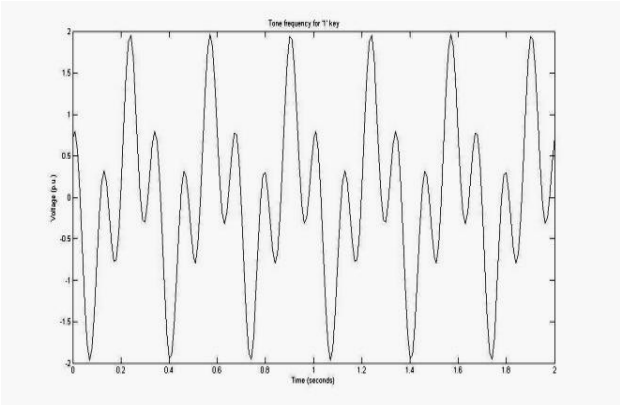

Figure 4 - Waveform for Key '1' press [6]

The additional feature included is the continuous monitoring of the device status by the software whose GUI is shown in Fig 6. The computer, through the receiver end mobile phone sends an SMS as soon as fault is detected in the system.

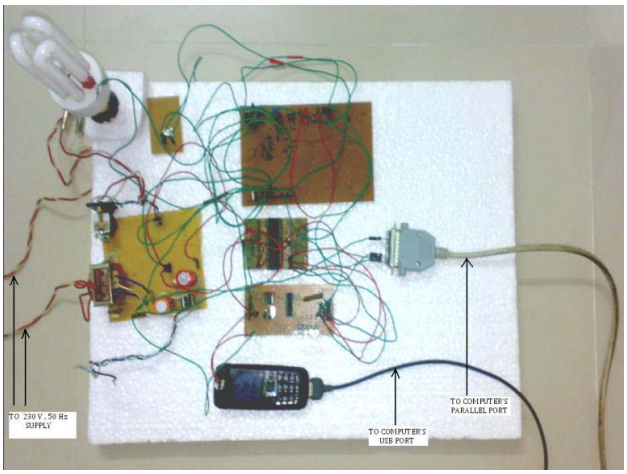

Figure 5 - Tested Circuit

Figure 6 - GUI of the Software

VIII. APPLICATIONS

This setup with a little modification can be adapted to the following applications.

1) Combination Lock
2) Home Security System
3) Mobile / Wireless Robot control
4) Wireless Radio Control
5) Continuous monitoring of system status
6) Remote Switches
7) Reporting during car accidents

IX. CONCLUSION

This paper presents a method to control a domestic system using the DTMF tone generated by transmitting telephone instrument when the user pushes the keypad buttons of the mobile phone connected to the remote domestic system. This control method uses commercial mobile communication networks as the path of data transmission. This enables the user to control the system continuously by sending the mobile phone DTMF tone. This system is implemented in the 2G mobile communication network, so video data cannot be obtained. Future work includes research on the robot

control system in the 3G mobile communication networks. This will facilitate controlling the remote robot, using the DTMF of mobile phone with video data from the remote mobile robot's camera.

XI. APPENDIX

A. *Appendix 1 -List of Components used and their description*

1) IC 7805
2) IC 7806
3) Power diodes 4001
4) 230/9-0-9 Transformer
5) Condenser Microphone
6) Audio Amplifier LM 358
7) 3.59 MHz Crystal Oscillator
8) 8870 DTMF Decoder
9) L 293D Driver Chip
10) Atmega 16L Microprocessor
11) Transistor BC 548
12) 6 Volts Relay
13) Comparator LM 324
14) A computer with Parallel Port DB 25

Refer circuit diagram (Fig. 7). IC 7805 and IC 7806 are positive voltage regulators whose input can be a DC of average value 7.5 to 16 Volts. They deliver an output of 5 or 6 volts at load at 1A or less. Power diodes 4001 are used for rectification in a full wave rectifier configuration. The input to the rectifier is through the 230/9-0-9 transformer. IC 7805 and IC 7806 are connected in parallel to get 5V and 6V supply separately.

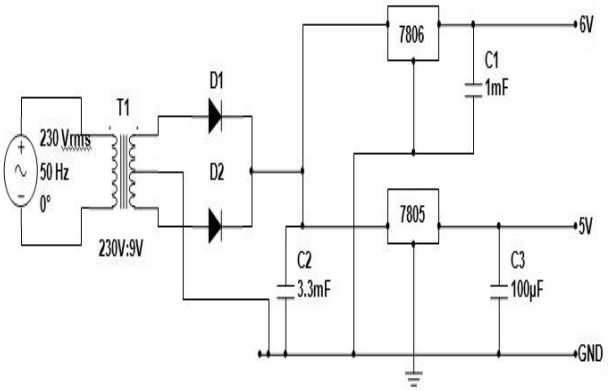

Figure 7 – Rectifier Circuit

The signal picked up by the condenser microphone is needs to be amplified as the signal power is insufficient for DTMF decoder 8870 to decode. So, audio amplifier LM 358 is used to strengthen the signal. The amplified signal is fed to DTMF decoder 8870 which has the following features.

The M-8870 is a full DTMF Receiver that integrates both band split filter and decoder functions into a single 18-pin DIP or SOIC package. Manufactured using CMOS process technology, the M-8870 offers low power consumption (35 mW max) and precise data handling. Its filter section uses switched capacitor technology for both the high and low group filters and for dial tone rejection. Its decoder uses digital counting techniques to detect and decode all 16 DTMF tone pairs into a 4-bit code. External component count is minimized by provision of an on-chip differential input amplifier, clock generator, and latched tri-state interface bus.

Atmega 16L receives decoded output from 8870 with the StD signal. Port B is used as input port and port A is used as output port. This output is fed to the relay through a buffer. DB 25 port of the computer is connected to the light detector (LDR) and the relay. The computer is connected to a speaker to enable instantaneous feedback to the transmitter mobile.

B. *Appendix 2 – VB Program*

```
Dim i As Integer
Dim a As Integer
Dim k As Integer
Dim tex As String
Dim l As Integer

Private Sub Command1_Click()
 Out Val("&H" + "37A"), 32
If (Val(Text1.Text) = 0) Then
MsgBox "PLEASE ENTER THE LPT ADDRESS",
vbInformation + vbOKOnly, "''Go Mobile''"
End If
If (Val(Text5.Text) = 0) Then
MsgBox "PLEASE ENTER THE COMM ADDRESS",
vbInformation + vbOKOnly, "''Go Mobile''"
End If
If(Val(Text7.Text)=0)Or
(Len(Trim(Text7.Text)) <> 13) Then
MsgBox "PLEASE ENTER THE VALID PHONE NUMBER
TO BE SEND ", vbInformation + vbOKOnly,
"''Go Mobile''"
End If
If (Val(Text5.Text) <> 0) Then
Comm1.CommPort = Val(Text5.Text)
If Comm1.PortOpen = False Then
'OPENING THE PORT
Comm1.PortOpen = True
Comm1.DTREnable = True 'control signal
Comm1.RTSEnable = True 'control signal
Comm1.RThreshold = 1 'control signal
Comm1.InputLen = 1 'to send one character
each time through serial port
Comm1.Output = "ATS0=3" & vbCrLf 'to set
the SMS in text mode and vbcrlf is like
"enter" we do in hyperterminal
Comm1.PortOpen = False
End If
End If
If (Val(Text1.Text) <> 0) And
(Val(Text5.Text) <> 0) And (Val(Text7.Text)
<> 0) And (Len(Trim(Text7.Text)) = 13) Then
Timer1.Enabled = True
End If
End Sub

Private Sub Command2_Click()
 Timer1.Enabled = False
```

```
MsgBox " READING FROM PARALLEL PORT STOPED ", vbInformation + vbOKOnly, "''Go Mobile''"
End Sub

Private Sub Command3_Click()
Load Form2
Unload Form2
End Sub

Private Sub Form_Load()
 MsgBox " PLEASE DO NOT RUN THIS PROGRAM IN LAPI ", vbInformation + vbOKOnly, "''Go Mobile''"
Out Val("&H" + "37A"), 32
Timer1.Enabled = False
Timer1.Interval = 1
i = 0
a = 0
k = 0
l = 0
tex = "The system has faced fatal error"
End Sub

Private Sub Timer1_Timer()
 i = Val(Str(Inp(Val("&H" + Text1.Text))))
a = i And 7
Text6.Text = a
If ((i And 4) = 4) Then
For l = 1 To 10000
Text6.Text = a
Next l
For l = 1 To 10000
Text6.Text = a
Next l
For l = 1 To 10000
Text6.Text = a
Next l
i = Val(Str(Inp(Val("&H" + Text1.Text))))
a = i And 3
Select Case a
Case 0
WindowsMediaPlayer1.URL = "C:\sound\2.WAV"
Case 1
WindowsMediaPlayer1.URL = "C:\sound\3.WAV"
Case 2
WindowsMediaPlayer1.URL = "C:\sound\3.WAV"
Case 3
WindowsMediaPlayer1.URL = "C:\sound\1.WAV"
End Select
End If
If (a = 1) Or (a = 2) Then
k = k + 1
If k = 1 Then
Comm1.CommPort = Val(Text5.Text)
If Comm1.PortOpen = False Then
Comm1.PortOpen = True
Comm1.DTREnable = True
Comm1.RTSEnable = True
Comm1.RThreshold = 1
Comm1.InputLen = 1
Comm1.Output = "AT+CMGF=1" & vbCrLf
End If
Comm1.Output = "AT+CMGS=" & Chr(34) & Trim(Text7.Text) & Chr(34) & vbCrLf
Comm1.Output = Trim(tex) & Chr(26) & vbCrLf
MsgBox "Message Sent to " & Text7.Text, vbInformation + vbOKOnly, "Sent"
End If
End If
End Sub
```

C. *Appendix 3 – Micro Controller Program*

```
#include<avr/io.h>
void main (void)
{
  unsigned char X,z;
  DDRA=0XFF;
  DDRB=0X00;
  while(1)
    {
       X=PINB;
       X=(0X10)&X;
       if(X==(0X10))
          {
             X=PINB;
             z=((0X10)&X);
             if(z==(0x10))
                {
                  X=(0X0F)&X;
                  switch(X)
                     {
                      case(1):PORTA=0X0F;
                              break;
                      case(2):PORTA=0X00;
                              break;
                     }
                }
          }
    }
 }
```

REFERENCES

[1] Yun Chan Cho and Jae Wook Jeon, *"Remote Robot control System based on DTMF of Mobile Phone" IEEE International Conference INDIN 2008, July 2008.*

[2] M J. Callahan, Jr., *"Integrated DTMF receiver," ZEEE J. Solzd-State Czrcuzts, vol. Sc-14, pp. 85-90, Feb. 1979.*

[3] M. Callahan Jr, *"Integrated DTMF Receiver," IEEE Transactions on communications, vol. 27, pp. 343-348, Febrary 1979.*

[4] R. Sharma, K. Kumar, and S. Viq, *"DTMF Based Remote Control System," IEEE International Conference ICIT 2006, pp. 2380-2383, December 2006.*

[5] Oppenheim, Alan V. and Schafer, Ronald W. *Digital Signal Processing. Prentice-Hall of India, 1989.*

[6] 8870 Datasheet, http://www.clare.com/datasheets/8870-01.pdf

[7] Suvad Selman, Raveendran Paramesran, *"Comparative Analysis of Methods Used in the Design of DTMF Tone Detectors" IEEE International Conference on Telecommunications and Malaysia International Conference on Communications, 14-17 May 2007, Penang, Malaysia*.

[8] R.C. Luo, T.M. Chen, and C.C. Yih, *"Intelligent autonomous mobile robot control through the Internet," IEEE International Symposium ISIE 2000, vol. 1, pp. 6-11, December 2000.*

[9] LPT, *http://en.wikipedia.org/wiki/parallelport*