Wireless Remote Switching System for Controlling Devices with an Algorithm based DTMF Detection

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***Abstract*—This paper deals with the design and implementation of a system kit which allow the easy use of a mobile phone to control the devices with security. A user can send DTMF tone to the control unit using any GSM mobile phone from anywhere in the world. To access the control unit, the user should send an authentication code (DTMF) along with the desired command to perform on the devices. A mobile phone attached to the microcontroller which can answer automatically works as the DTMF receiver. PIC16F628A microcontroller is programmed and it can control (ON/OFF) eight devices. In addition, we have implemented the DTMF decoder within the microcontroller using an algorithm (Goertzel algorithm). Upon being properly authenticated, the ON/OFF of different devices can be carried out by the microcontroller according to users own accord. The proposed work has been done and verified in real time.**

Keywords—DTMF, GSM, Goertzel algorithm, Devices.

I. INTRODUCTION

Today electricity is the dying need of human civilization. Man uses a lot of home appliances in their home. Sometimes he needs these appliances and sometimes not according to circumstances. For the sake of comfort life it is required to control these appliances remotely. Besides we need the remote operation of the machines in industry.

The idea of home automation using telephone lines and a PC was shown in [1]. The system was based on the dual tone multi frequency (DTMF) signals that could be sent through a loop of wire to switch on/off various appliances via a personal computer (PC). We got the idea of the user identification number for preventing non-authorized use of the control unit from the work [2], which was also designed based on the telephone network. An attempt was made to address automation based on dual-tone multi frequency remote control system for industrial and household applications in the reference [3] which was also implemented on existing telephone lines. More and more smart systems have been used in modern household. We see smart household control system realization procedure based on DTMF remote transmission in the article [4-6]. Later, DTMF (Dual Tone Multiple Frequency) signaling was suggested to control water flow for irrigation [7]. Lisa showed a general process of device control by using GSM network [8]. Web based remote exploration and control system using android mobile phone has also been developed in [9]. In their work a DTMF detection circuit, interfaced with mobile phone, can automatically detect the DTMF tone signal and generates 4 bit digital code output. This digital output code can be utilized to control any electrical device. Tele-operation of a mobile robot through the DTMF signal is also developed in [10-13].

The system kit, developed in this paper aims to make the control process easy, flexible and secure. Our aim was to control the devices remotely using mobile phone. We choose it because mobile phone has become an indispensable part of our daily life. Here we have constructed a control kit to on or off the devices. We have used a programmed microcontroller which is connected to a mobile. This one acts as the receiver of the users command. The command syntax is defined within the program. The user connects to the receiver with his mobile. He can communicate with the receiver using GSM network. The user sends the authentication code along with control command using DTMF tone generated with his mobile. Most of the papers cited previously used MT8870 decoder IC for DTMF detection. But we have implemented the decoder within the microcontroller using an algorithm which is known as the Goertzel algorithm [14].

II. LITERATURE REVIEW

A. GSM

GSM stands for Global System for Communication and is an open, digital cellular technology used for transmitting voice and data. It is the most widely used accepted standard and is implemented globally. It makes use of narrowband Time Division Multiple Access (TDMA) technique for transmitting signal [15]. It has an ability to carry 64 kbps to 120Mbps of data rates.

B. DTMF

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. Ten buttons for numerals zero through nine and the remaining six (*, #, A, B, C, D) being reserved for special signaling. 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 [16-17]. The use of DTMF signaling is increasing widespread due to innovative technological advances. The frequencies generated on pressing different phone keys are shown in the Fig. 1.

Fig. 1. Touch tone keypad

III. SYSTEM DEVELOPMENT

A simplified block diagram of "Wireless Remote Switching System for Controlling Devices with an Algorithm based DTMF Detection" is shown in Fig. 2.

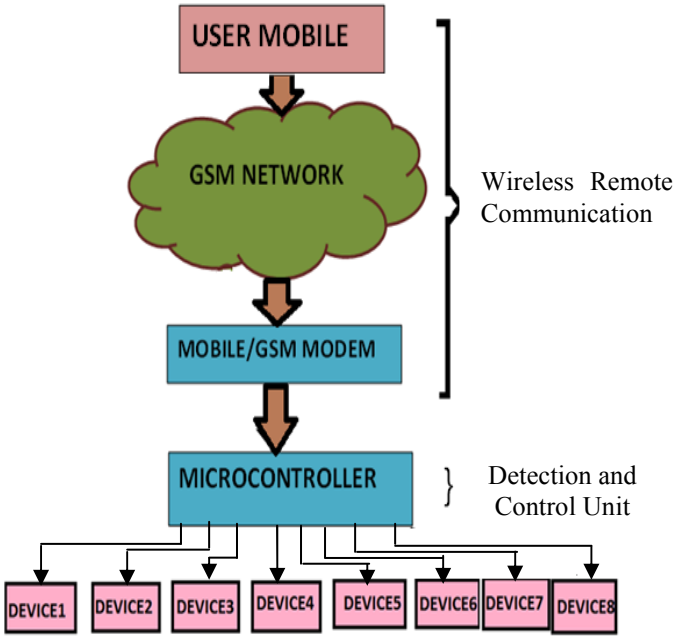

Fig. 2. Wireless Remote Switching System for Controlling Devices with an Algorithm based DTMF Detection

A. Wireless Remote Communication

A wireless communication system is required to control the devices remotely. We will use the existing infrastructure of cell phone networks for communication. So we do not require the construction of transmitter and receiver units. For the wireless communication the user will use a cell phone as transmitter to send the DTMF tone. A Subscriber Identity Module (SIM) would be assigned to the user mobile which will make a call to receiver. This is the transmitter of the DTMF tone. On the other hand the receiver will be a GSM modem (for example with CMS-GMS-MOD) or a cell phone. For our convenience we will use a cell phone as the receiver. To establish a communication the user call the Subscriber Identity Module (SIM) assigned to the receiver. The receiver will receive the call automatically and receive the DTMF tone one by one when key is pressed by the user.

B. DTMF Tone Detection and Control Unit

It is only a microcontroller circuit where DTMF detection and the control (ON/OFF) command of the devices are integrated. A microcontroller is a small computer containing a processor core memory and programmable input/output peripherals. Microcontrollers are used in automatically controlled products and devices. Here PIC16F628A is used. The DTMF detection and the control process require some programming. In most of the work of DTMF based remote control system, DTMF detection is done by the DTMF decoder MT8870. But we will use an algorithm to integrate the DTMF detection within the microcontroller. Thus our system kit will be cost effective than the other systems cited previously. In this unit DTMF tone is detected using the Goertzel algorithm (Goertzel filter). In this case only a selected number of values of the DFT are desired. The Goertzel filter is a two pole IIR type filter that uses the feedback to perform a filtering operation on the input data sequence. The Goertzel algorithm [14] leads to the system function in the form

$$H_k(z) = \frac{1 - e^{-j\frac{2\pi}{N}kz^{-1}}}{\left(1 - 2\cos\left(\frac{2\pi k}{N}\right)z^{-1} + z^{-2}\right)} \quad (1)$$

The direct form II realization of the system is shown in Fig. 3.

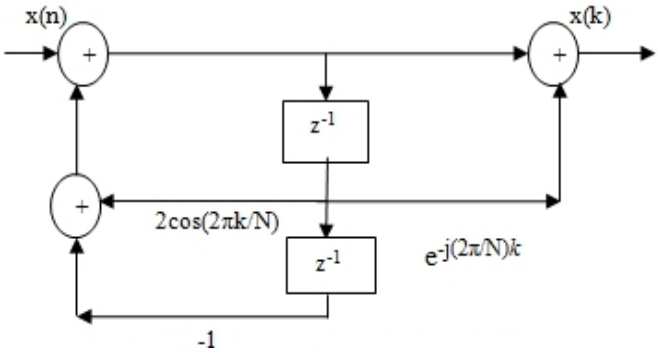

Fig. 3. Direct form II realization of Goertzel filter

Data are processed sequentially and efficiently as they arrive. When the end of the sequence is reached, the result is ready for issue. To filter a frequency we need to calculate the value of k. The value of this constant determines the tone we are trying to detect and is given by

$$k = N \times \frac{f_{tone}}{f_s} \quad (2)$$

We know that it is common to use a sampling rate of 8000Hz and block size N=205 in telecom application. Then the value of k would be 18, 20, 22, 24, 31, 34 and 38 for the frequencies 697 Hz, 770 Hz, 852 Hz, 941 Hz, 1209 Hz, 1336 Hz and 1477 Hz respectively. Since there are only seven frequencies, we will take the form of seven parallel banks of filters where each filter selects one of the frequencies. A DFT produces the same numerical result for a single frequency of interest making it a better choice for tone detection. The main purpose of using the Goertzel filters is to calculate the spectral value at the specified frequency index using the filtering method. The output from each Goertzel filter is fed to its detector to compute its spectral value, which is given by

$$m = A_k = \frac{2}{205}\sqrt{|X(k)|^2} \quad (3)$$

Each calculated spectral value m is compared to a specified threshold value. If the detected value m is larger than the threshold value, the logic operation outputs the logic 1 otherwise it outputs the logic 0. This simple threshold test of the energy will tell if the tone was present or not. Then the logic operation at the last stage is to decode the key information based on the 7-bit binary pattern as shown below.

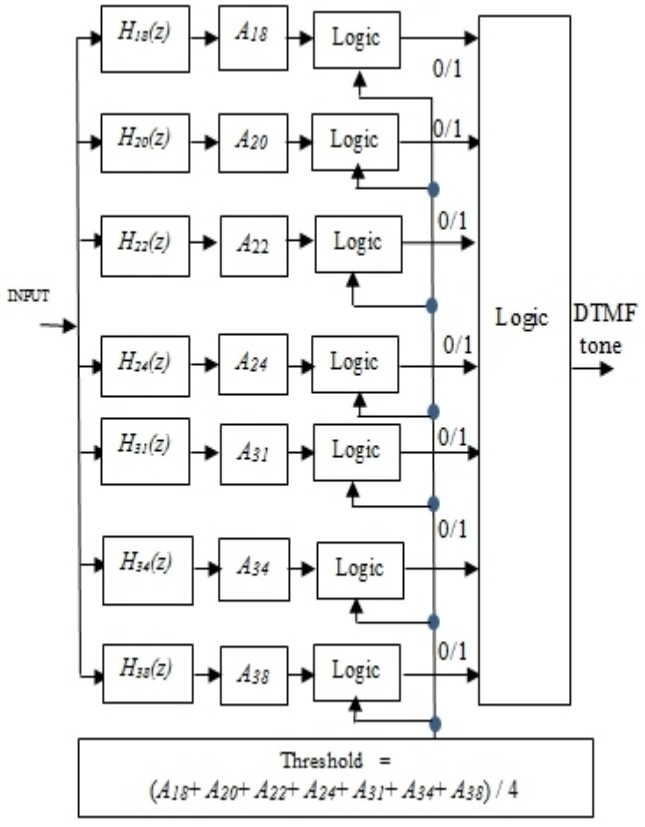

Fig. 4. DTMF tone detection process

Now we will approach to the main control function. The eight output ports are connected to the eight devices. Microcontroller is programmed such that eight different devices in the output could be done on or off by pressing the button of the cell phone. The command syntax which is defined within the program would be as #ABCD#XY*

- #ABCD# stands for a 4 digit authentication code surrounded by #
- X indicates the output port (1,2,3……8)
- Y indicates the control function ON (1) or OFF(0)

IV. WORKING PRINCIPLE

To operate a device the user will call the Subscriber identity module assigned to the receiver. It will receive the call automatically. After the call is received the receiver is ready to receive the DTMF tone. The system works according to the following flow chart.

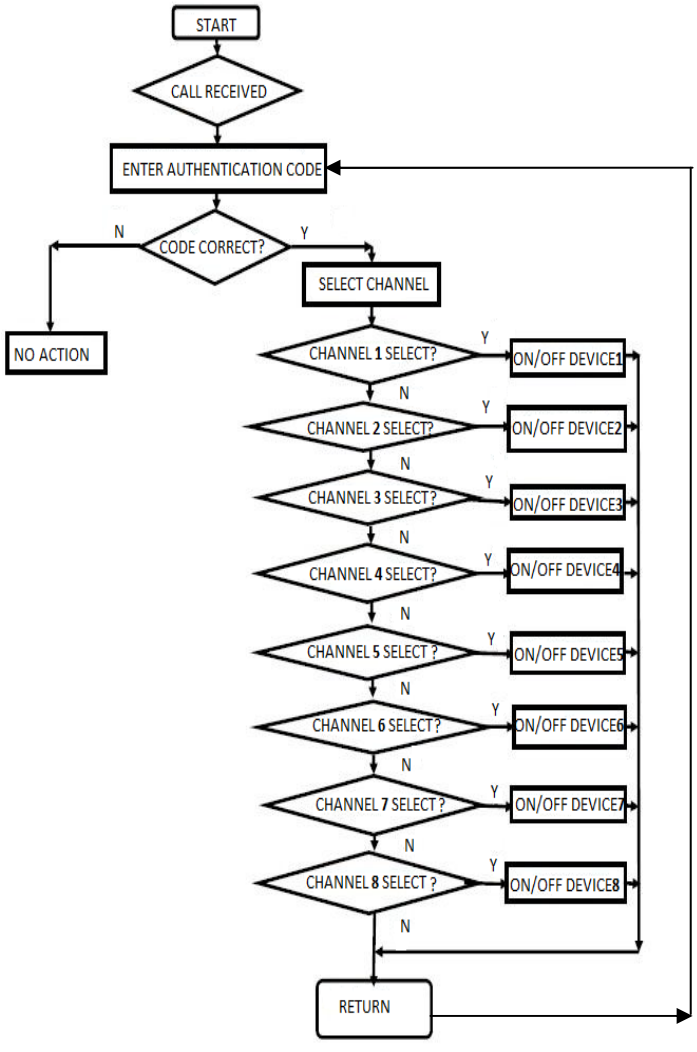

Fig. 5. Flow chart of the system

In the control unit DTMF tone is detected using the Goertzel algorithm. The authentication code is defined according to the programmer. In this program it is a 4 digit code surrounded by #. Here we will consider the eight output ports as channel. Eight devices can be controlled with eight channels (output ports). After the code is properly authenticated the channel is selected by pressing the button (1 to 8), since we have only eight channels. After the selection of channel we press the control digit (1 for ON and 0 for OFF). At last we press * to execute the command. Here we have to be careful about that, each digit is properly decoded. If any digit is missed then the command will not execute.

V. MICROCONTROLLER PROGRAMMING AND CIRCUIT DESIGN

The implementation requires programming of the microcontroller PIC16F628A [18]. While programming the microcontroller we have assigned various names to various registers which can be used later by using those names to make the program more readable. Then the input and output ports are defined and the comparator module is configured. The constant "k" for each of the DTMF (Low group frequency and high group frequency) frequency is defined. The comparator compares the energy of the incoming frequency with the threshold value and thus detects the tone. The authentication code is defined according to the programmer. In our program it is a 4 digit code surrounded by #. The code is defined as #2468#.

After programming we will compile it with a compiler named mikroC and we will burn the hex file into the microcontroller. Then the microcontroller is ready to use in the circuit of the system kit. The number of required components is given in the following table I.

TABLE I. COMPOINENTS

Component name	Quantity (Pcs)
Resistor	14
PIC16F628A	1
Audio capacitor	1
Led	1
Capacitor	2
Transistor (c828)	8
1N4148 Diode	2
20 MHz crystal oscillator	1
IC 7805	1
Relay(6v)	8

For our convenience we will show the operation of device 1 (electrcal light) with relay and use only LEDs for other 7 devices. By using relay we can be able to control the electrical appliances or machines instead of LED. The overall circuit diagram of detection and control unit is given in Fig. 6.

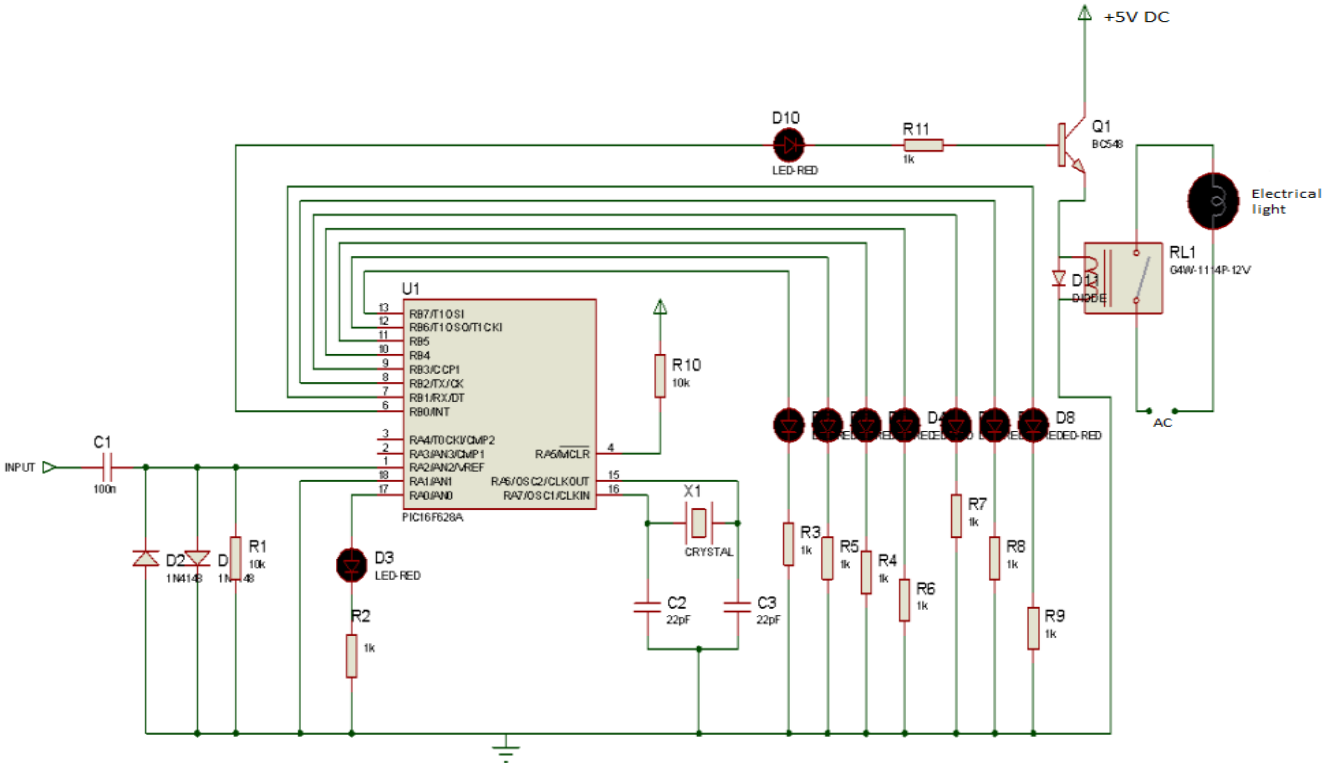

Fig. 6. Circuit diagram of Detection and Control Unit

VI. PERFORMANCE TEST

This work uses a microcontroller which decodes the DTMF tone and control eight different devices. A remote user sends a command to control the devices. After proper arrangement of the system kit with programmed microcontroller, we see that the devices are properly operated according to the command. In our program we have set the code as "#2468#". We have verified the various operations in real time according to command syntax as shown in the following table II.

TABLE II. OPERATION ACCORDING TO COMMAND SYNTAX

Command syntax	Operation	Performance
#2468#11*	DEVICE 1 ON	√
#2468#10*	DEVICE 1 OFF	√
#2468#21*	DEVICE 2 ON	√
#2468#20*	DEVICE 2 OFF	√
#2468#31*	DEVICE 3 ON	√
#2468#30*	DEVICE 3 OFF	√
#2468#41*	DEVICE 4 ON	√
#2468#40*	DEVICE 4 OFF	√
#2468#51*	DEVICE 5 ON	√
#2468#50*	DEVICE 5 OFF	√
#2468#61*	DEVICE 6 ON	√
#2468#60*	DEVICE 6 OFF	√
#2468#71*	DEVICE 7 ON	√
#2468#70*	DEVICE 7 OFF	√
#2468#81*	DEVICE 8 ON	√
#2468#80*	DEVICE 8 OFF	√
#3457#11*	NO ACTION	×
#2456#11*	NO ACTION	×

From the above table we observe that when the code is correct then the user can control the devices. The user who doesn't know the proper code can't access the control unit and no action is performed. The authentication code can be varied while programming the microcontroller. Thus the system provides the security on the remote control of appliances.

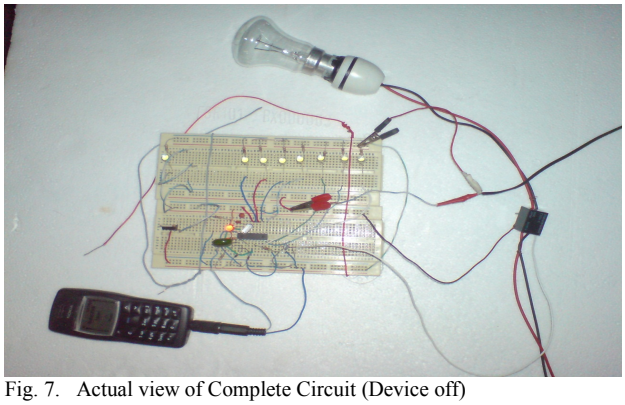

Fig. 7. Actual view of Complete Circuit (Device off)

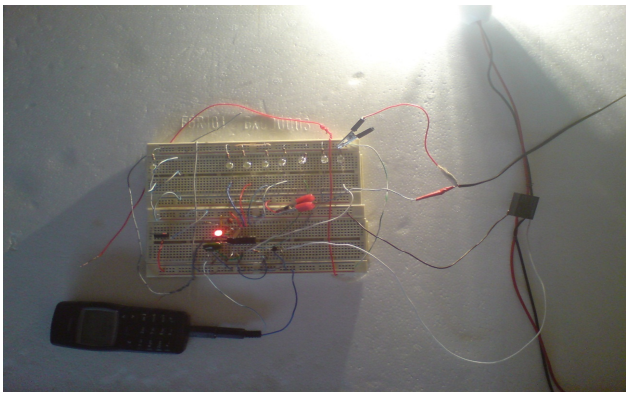

Fig. 8. Actual view of Complete Circuit (Device 1 on)

VII. CONCLUSION

Our motto was to control the devices remotely using cell phone and we are successful to reach the goal. The system kit can be used to control the ON/Off mode of the devices in our home and industry remotely. An interesting feature of this system kit is the use of authentication code, which implements the safe and secure access. As a result the system kit developed can be used not only to control the home appliances or machines in industries but also in some important cases where security is the part and parcel (such as robotics). Another feature is that the DTMF decoder is implemented within the microcontroller. Although dedicated ICs exist for the application of DTMF decoding, implementing the function in software costs less. So it is more economical and reliable than the other DTMF based remote control system.

REFERENCES

[1] B. Koyunch, "PC remote control of appliances by using telephone lines", IEEE Trans. Consumer Electron., Vol. 41, pp. 201-209, 1995.

[2] I. Coskun, H. Ardam, "A remote Controller for Home and Office Appliances by Telephone", IEEE Trans. Consumer Electron., Vol. 44, pp. 1291-1297, November 1998.

[3] R. Shama, K. Kumar and S. Viq, "DTMF based Remote Control System", IEEE International Conference ICIT, pp. 2380-2383, 2006.

[4] C. K. Das, M. Sanaullah, H. M. G. Sarower and M. M. Hasan, "Development of a cell phone based remote control system: an effective switching system for controlling home and office appliances", International Journal of Electrical & Computer Sciences(IJECS), Vol. 9, No. 10, pp. 37-43.

[5] A. R. Delgado, R. Picking, V. Grout, "Remote-controlled home automation systems with different network technologies." Proceedings of the 6th International Network Conference (INC 2006), pp. 357-366, 11-14 July 2006.

[6] Liu Wei, Gao Yonghui, Jiang Wenlong, Ren Tao, "Remote control of smart household based on DTMF", 2nd International Conference on Advanced Computer Control (ICACC), Vol. 3, pp. 391 – 394, 2010.

[7] V. Dubey, N. Dubey, S.S. Chouhan, "Wireless Sensor Network Based Remote Irrigation System and Automation using DTMF Code", International Conference on Communication System and Network Technologies, pp. 34-37, 2011.

[8] Lisa Muhury, A.H.M. Ashfaq Habib, "Device control by using GSM network", 15th International Conference on Computer and Information Technology, Chittagong, pp. 271-274, 22-24 December 2012.

[9] M. A. A. Milton, A. A. S Khan, “Web based remote exploration and control system using android mobile phone”, International Conference on Informatics, Electronics and Vision (ICIEV), pp. 985-990, 2012.

[10] G. K. Dey, R. Hossen, M. S. Noor, K. T. Ahmmed, “Distance controlled rescue and security mobile robot”, International Conference on Informatics, Electronics and Vision (ICIEV), pp. 1-6, 2013.

[11] D. Manojkumar, P. Mathankumar, E. Saranyaand S. Pavitradevi, “Mobile Controlled Robot using DTMF Technology for Industrial Application”, International Journal of Electronics Engineering Research, pp. 349-355, 2010.

[12] Yun Chan Cho and Jae Wook Jeon, “Remote Robot control System based on DTMF of Mobile Phone” IEEE International Conference on Industrial Informatics (INDIN), pp. 1441-1416, July 2008.

[13] K. M. Al-Aubidy, M. M. Ali, A. M. Derbas, A. W. Al-Mutairi, “GPRS-based remote sensing and teleoperation of a mobile robot”, 10th International Multi-Conference on Systems, Signals & Devices, pp. 1-7, 2013.

[14] Dr. Naimdahnoun, Goeretzel Algorithm, chapter 17, Bristol University (c) Texas instruments 2004.

[15] http://www.tutorialspoint.com/gsm/gsm-architecture.htm, [accessed December 07, 2012]

[16] Taljappa, M Ladwa, Sanjay M Ladwa, R Sudharshan Kaarthik, Alok Ranjan Dhara, NayanDalei., “Control of remote domestic system using DTMF,” Proceedings of ICICI-BME, Indonesia, pp. 69-74, 2009.

[17] http://www.engineergarage.com/sites/default/files/imagecache/original/wysiwyg-imageupload/1/DTMF, [accessed December 07, 2012]

[18] http:/www.microcontroller.com/. [accessed December 07, 2012]