Design of a Circuit for Remote Control of Multiple Devices using DTMF Encoder and Decoder

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Abstract- With the advancement in technology, the number of electronic devices in our day-to-day lives has increased to make life simpler. So a necessity to construct a Universal Remote System that will easily control all these devices from a distance will not only reduce the complexity of handling the number of devices simultaneously, but also save power.

This paper presents a successfully developed hardware of a Universal Remote Control System using DTMF (Dual-Tone Multi-Frequency) tones as the control signals. The uniqueness of DTMF is that it is simple to generate and noise-immune. This system was also implemented using GSM links besides the wired channel, the main advantage of it being that it helps in controlling devices located at any part of the world or at any place like hazardous plants, where the presence of a human could prove dangerous. So there are a number of practical applications associated with this system. It is simple, economical, easy to use and could be further upgraded by adding a password-protection to it. Through this, only selected people can access control on the devices. A voice-controlled command could be embedded to make the system more flexible.

Index Terms- DTMF, IC 91215B, IC CM8870C, Remote Control Design.

I. Introduction

In this modern era, life without Electronics is unimaginable. With the progressive increase in the number of electronic gadgets, it has become essential to design a remote control system that can control a number of them at the same time. A remote control system now finds a large number of crucial applications like controlling of artificial satellites, manufacture of products by machines or in the control of chemical reactions in hazardous plants from a distance.

For the design of a remote control system that will control the switching of multiple electronic devices at the same time, DTMF (Dual-Tone Multi-Frequency) tones have been used. The main reason for the use of DTMF is that one can control a maximum of twelve (if 3x4 type DTMF keypad is used) to sixteen (if 4x4 keypad is used) devices simultaneously by means of a single remote system.

II. BASIC PRINCIPLES OF DTMF

DTMF as stated, is the short form of “Dual-Tone Multi-Frequency” and it is a method of designating digits with tone-frequencies that will be transmitted via an analog communication channel or network like a telephone line. It was developed by Western Electric and introduced by AT&T in 1963. During its development, unique individual frequency filters were chosen carefully so that the tones could easily travel via the telephone lines (the maximum guaranteed bandwidth for a standard telephone line extends from around 300 Hz to 3.5 kHz). DTMF was not intended for data transfer, rather for control signals only. With a standard DTMF encoder/decoder, it is possible to signal at a rate of around 10 tones/signals per second.

The DTMF keypad is laid out in a 4x4 matrix, with two frequencies (each row representing a low frequency and each column representing a high frequency) played simultaneously by a standard home phone/fax or mobile phone. Each key on the telephone’s keypad has a unique frequency assigned to it. Pressing a single key (such as ‘1’) will send a sinusoidal tone for each of the two frequencies (697 Hz and 1209 Hz). The multiple tones are the reason for calling the system as multiple-frequency. This prevents the misinterpretation of the harmonics and hence, it is immune to noise. These tone are then decoded by the switching center to determine which key was pressed. When any key is pressed on the DTMF keypad, the circuit plays the corresponding DTMF tone. A typical DTMF keypad is illustrated in the table below:

Table I: Row and Column Frequencies corresponding to the digits of the 4x4 DTMF Keypad

1	2	3	A	**697**
4	5	6	B	**770**
7	8	9	C	**852**
*	0	#	D	**941**
1209	**1336**	**1477**	**1633**	**Frequencies (in Hz)**

Table I shows us the two frequencies generated when a particular digit is pressed. The intersection point of any two groups of frequencies will give us that digit.

In the table that follows, the frequencies generated for all the digits have been listed.

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Table II: High-Group and Low-Group Frequencies corresponding to the digits

Digit	Low-Group Frequency	High-Group Frequency
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	1336
*	941	1209
#	941	1477
A	697	1633
B	770	1633
C	842	1633
D	941	1633

III. THE EXPERIMENT

A. Principle Experimental Components

DTMF Encoder (IC 91215B)/mobile phone and an earphone, DTMF Decoder (IC CM8870C), Demultiplexer (IC 74154), J-K Flip-flops (IC 7473) and the DTMF Keypad are the key blocks of the remote control's hardware.

B. Function of the Components and their Connections

[1] DTMF Encoder: The DTMF keypad along with the encoder is used to generate DTMF tones corresponding to each key. It encodes the keys pressed by the user into two sinusoids, one having a lower and the other higher group of frequencies. This DTMF tone is transmitted through a channel, which will be controlling the electronic devices.

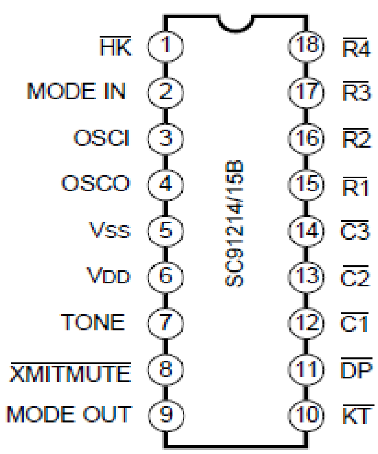

Figure 1: DTMF Encoder IC

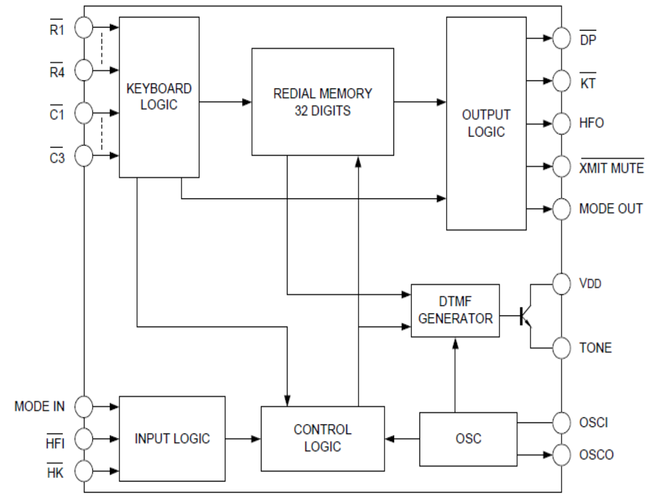

Figure 2: Internal Circuitry of the DTMF Encoder

[2] DTMF Decoder: The decoder receives the DTMF tones transmitted by the encoder. The received tone is decoded into a particular electrical signal and one can comprehend which key has been pressed. There are four output lines here and depending on the signal received by the decoder, these lines be high or low. The status of these lines will help us to know which key has been pressed at the encoder end.

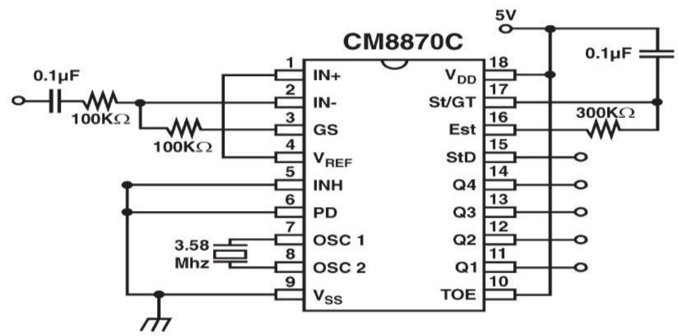

Figure 3: DTMF Decoder IC

F_{LOW}	F_{HIGH}	KEY	TOW	Q_4	Q_3	Q_2	Q_1
697	1209	1	H	0	0	0	1
697	1336	2	H	0	0	1	0
697	1477	3	H	0	0	1	1
770	1209	4	H	0	1	0	0
770	1336	5	H	0	1	0	1
770	1477	6	H	0	1	1	0
852	1209	7	H	0	1	1	1
852	1336	8	H	1	0	0	0
852	1477	9	H	1	0	0	1
941	1336	0	H	1	0	1	0
941	1209	*	H	1	0	1	1
941	1477	#	H	1	1	0	0
697	1633	A	H	1	1	0	1
770	1633	B	H	1	1	1	0
852	1633	C	H	1	1	1	1
941	1633	D	H	0	0	0	0
-	-	ANY	L	Z	Z	Z	Z
L Logic Low, H = Logic, Z = High Impedance							

Figure 4: Functional Decode Table

[3] Demultiplexer: The function of the demultiplexer is to convert the output of the DTMF decoder into sixteen distinct output signals, which in turn will control sixteen different devices. Here, a 4:16 DEMUX has been used and four output lines of the decoder is fed to four input lines of the demultiplexer.

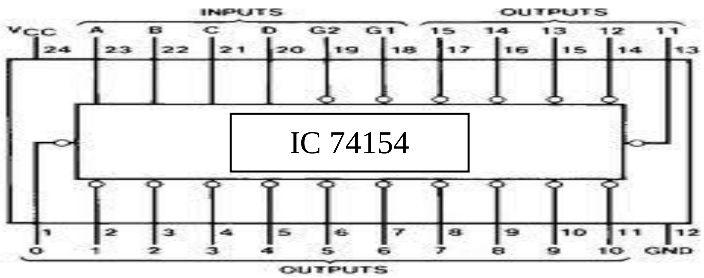

Figure 5: Demultiplexer IC

Inputs						Outputs															
G1	G2	D	C	B	A	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
L	L	L	L	L	L	L	H	H	H	H	H	H	H	H	H	H	H	H	H	H	H
L	L	L	L	L	H	H	L	H	H	H	H	H	H	H	H	H	H	H	H	H	H
L	L	L	L	H	L	H	H	L	H	H	H	H	H	H	H	H	H	H	H	H	H
L	L	L	L	H	H	H	H	H	L	H	H	H	H	H	H	H	H	H	H	H	H
L	L	L	H	L	L	H	H	H	H	L	H	H	H	H	H	H	H	H	H	H	H
L	L	L	H	L	H	H	H	H	H	H	L	H	H	H	H	H	H	H	H	H	H
L	L	L	H	H	L	H	H	H	H	H	H	L	H	H	H	H	H	H	H	H	H
L	L	L	H	H	H	H	H	H	H	H	H	H	L	H	H	H	H	H	H	H	H
L	L	H	L	L	L	H	H	H	H	H	H	H	H	L	H	H	H	H	H	H	H
L	L	H	L	L	H	H	H	H	H	H	H	H	H	H	L	H	H	H	H	H	H
L	L	H	L	H	L	H	H	H	H	H	H	H	H	H	H	L	H	H	H	H	H
L	L	H	L	H	H	H	H	H	H	H	H	H	H	H	H	H	L	H	H	H	H
L	L	H	H	L	L	H	H	H	H	H	H	H	H	H	H	H	H	L	H	H	H
L	L	H	H	L	H	H	H	H	H	H	H	H	H	H	H	H	H	H	L	H	H
L	L	H	H	H	L	H	H	H	H	H	H	H	H	H	H	H	H	H	H	L	H
L	L	H	H	H	H	H	H	H	H	H	H	H	H	H	H	H	H	H	H	H	L
L	H	X	X	X	X	H	H	H	H	H	H	H	H	H	H	H	H	H	H	H	H
H	L	X	X	X	X	H	H	H	H	H	H	H	H	H	H	H	H	H	H	H	H
H	H	X	X	X	X	H	H	H	H	H	H	H	H	H	H	H	H	H	H	H	H

H = High Level, L = Low Level, X = Don't Care

Figure 6: Functional Table of the Demultiplexer

[4] J-K Flip-flops: J-K flipflops (IC 7473) have been used for latching the demultiplexer. They were converted to T-flipflops by keeping J='1', K='1' (toggle condition). The output of the demultiplexer is fed to the clock of T-flipflops and the outputs of the flipflips are connected to the multiple devices via an amplifier/buffer or through relay drivers as per requirements.

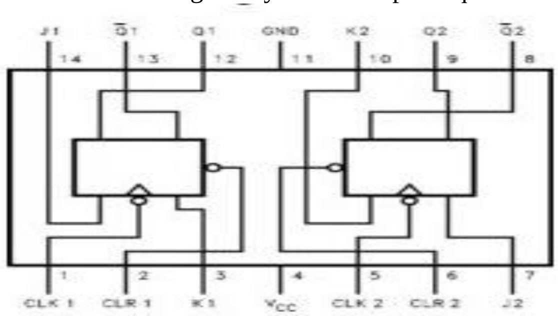

Figure 7: J-K Flip-flop

Inputs				Outputs	
CLR	CLK	J	K	Q	$\overline{Q}$
L	X	X	X	L	H
H	⎍	L	L	Q_0	$\overline{Q}_0$
H	⎍	H	L	H	L
H	⎍	L	H	L	H
H	⎍	H	H	Toggle	

Figure 8: Functional Table of the J-K Flip-flop.

H- High logic level, L- Low logic level, X- Either Low or High, Pulses represent positive pulse data, the J & K must be held constant while the clock is high. Data is transferred to the outputs on the falling edge of the clock pulse. Q_0 is the output logic level before the indicated input conditions were established. Toggle- Each output changes the component of its previous level on each HIGH level clock pulse.

C. The Working Model and its Explanation

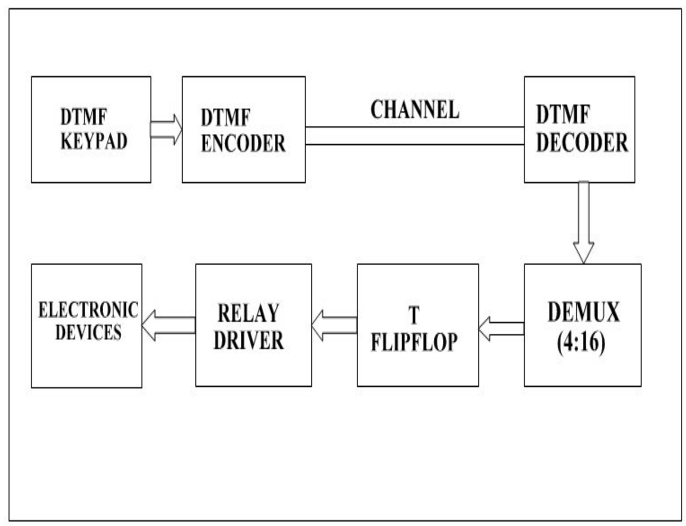

Figure 9: Block Diagram of the Remote Control System

The DTMF Keypad, encoder, decoder, demultiplexer, a series of T-flipflops and relay-drivers are the primary functional blocks of this project.

The DTMF Keypad along with the encoder is used to generate the DTMF tones. Alternatively, a mobile phone/telephone can also be used for the purpose of encoding. These encoded tones can be transmitted over a wired/wireless channel. If the design is to be wired, then telephone lines can be used and if it is to be wireless, GSM links are used.

After the transmission of these tones, they are received and decoded at the receiving end. In wireless implementation of this project, a mobile phone is used as a receiver. The received signal is fed to the decoder which converts these tones into code words of 4-bits that correspond to the key pressed in the DTMF keypad. This 4-bit code word is then demultiplexed using a 4:16 demultiplexer. The output of this demultiplexer is latched with the help of a series of T-flipflops (with J='1'& K='1', toggle condition).

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The aim of this experiment is to control multiple devices and these can either be DC or AC in nature. For DC devices, the latched signal is amplified using an amplifier and for AC devices, relays are used. In doing so, a proper remote control system for multiple devices is successfully implemented.

D. The Experimental Setup

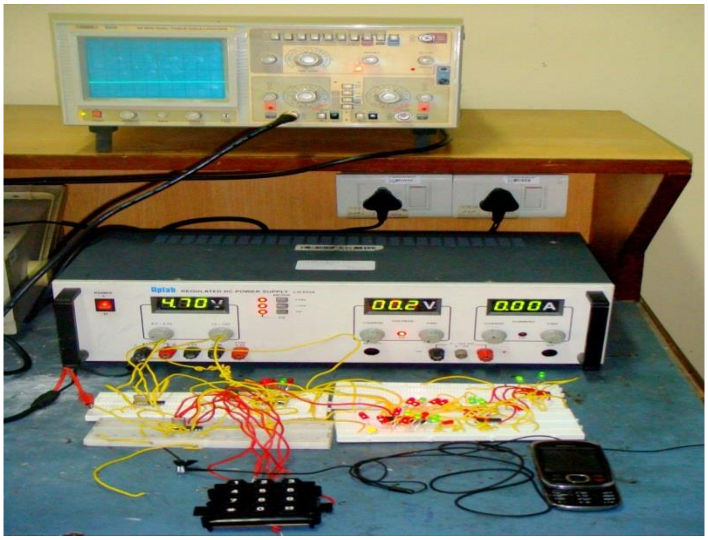

Figure 10: The Experimental Apparatus

IV. EXPERIMENTAL RESULTS

Encoding pulses: The figures below are the Time-Domain representations of tones '2' and '8' respectively. These were captured while performing the experiment.

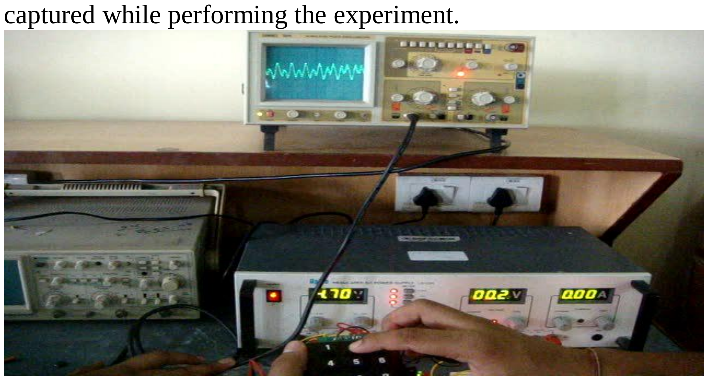
Figure 11: Pulse corresponding to key '2' being pressed

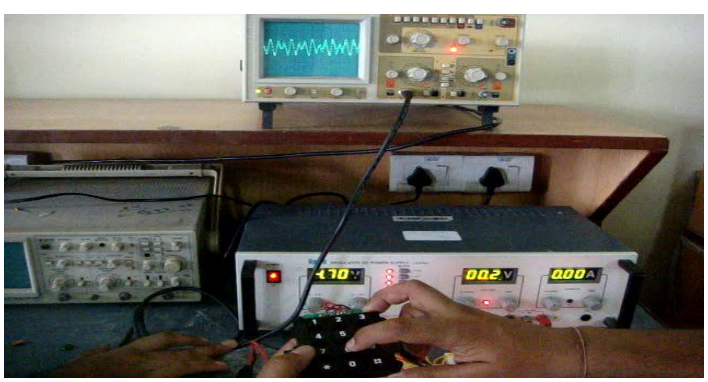
Figure 12: Pulse corresponding to key '8; being pressed

Table III: The Decoding Algorithm

Digit	Low Frequency (Hz)	High Frequency (Hz)	Q4	Q3	Q2	Q1
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

Table III represents the output at the decoding/receiving end when the keys of the DTMF keypad (3x4 type) are pressed. The outputs Q4,Q3,Q2,Q1 are 4-bit codewords whose logic levels were realized using four Light Emitting Diodes (LEDs). For example, if '1' is pressed, the codeword is 0001, if '2' is pressed, the codeword is 0010 and so on. Logic '0' represents the off-state, while logic '1' is the on-state of the LEDs.
Following are 12 real-time pictures of the generation of the codewords on pressing a particular key on the DTMF keypad.

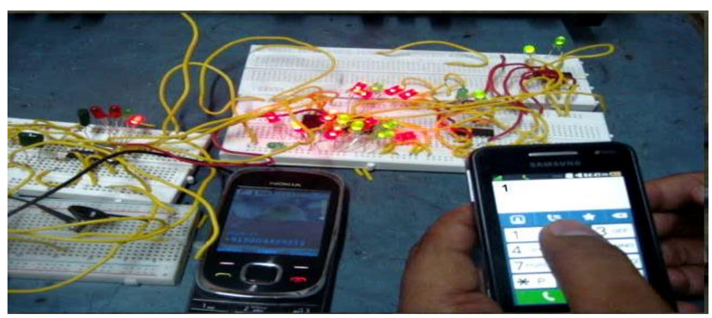
Figure 13: The first breadboard on the left side giving the codeword 0001 when 1 is pressed on the phone (as accordance with the Decoding Algorithm Table)

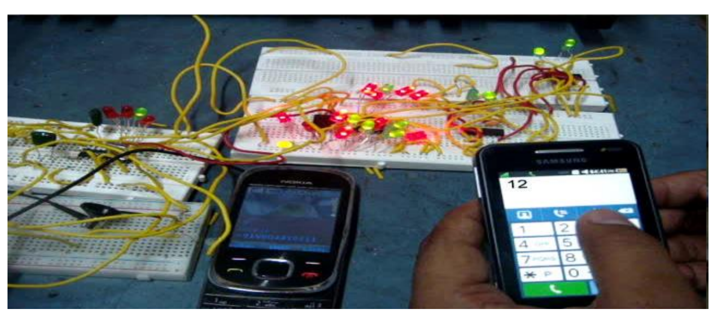
Figure 14: Codeword generated 0010 on pressing 2

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Figure 15: Codeword generated 0011 on pressing 3

Figure 16: Codeword generated 0100 on pressing 4

Figure 17: Codeword generated 0101 on pressing 5

Figure 18: Codeword generated 0110 on pressing 6

Figure 19: Codeword generated 0111 on pressing 7

Figure 20: Codeword generated 1000 on pressing 8

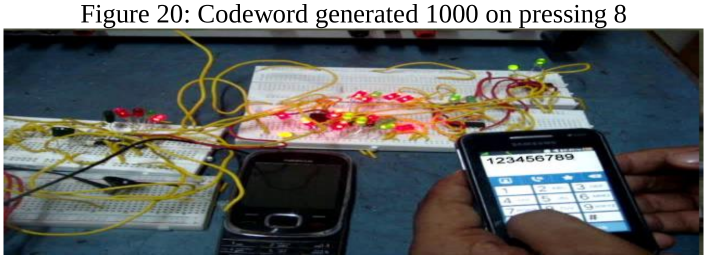

Figure 21: Codeword generated 1001 on pressing 9

Figure 22: Codeword generated 1011 on pressing *

Figure 23: Codeword generated 1010 on pressing 0

Figure 24: Codeword generated 1100 on pressing #

The results have been video recorded and uploaded on Youtube. The links for the results of encoding and decoding are provided in the 'References Section'.

V. APPLICATIONS & ADVANTAGES

[1] DTMF tones can be transmitted over GSM links and hence, we can control different devices over a large distance wirelessly.
[2] Effective control of home appliances using mobile phone.
[3] Increases power efficiency and the lifetime of the appliances..
[4] Power wastage is reduced.
[5] DTMF has enabled the long distance signaling of dialled numbers in the voice frequency range over telephone lines. This has eliminated the need of telecom operators between the caller and called party and evolved automated dialling in the telephone switching centers.
[6] Use of two frequencies make the system more noise immune. Hence, DTMF is popularly used.

VI. CONCLUSION & DISCUSSIONS

This experiment was designed keeping in mind the interest of the common people with the belief that the ultimate outcome of this project will be of much help to them, making their lives simpler.

It was done using the wireless system and it is extremely fast and efficient. The DTMF tone can be transmitted over the GSM links and hence, the basis for the control of multiple devices from a distance was successfully achieved. This will help people to regulate the switching of a device situated at a hazardous place like a chemical plant where the presence of a human is harmful.

VII. SCOPE FOR FUTURE WORK

The efforts in building the home automation concept did not utilize the need for microcontrollers. Using them would bring more control techniques and flexibility. This experiment can be further enhanced to high voltage AC applications by changing the relay ratings. Control and monitoring of high speed induction & synchronous motors can be done in an economical way with these principles. Additional security features could be included in the circuit. One such way is by password protection. By means of this, only selected people can access this control over home appliances and other devices. Use of voice-controlled commands will add more flexibility to the system. By making use of a camera, we can also check the status of any appliance at home from a distant location, like an office for example.

VIII. APPENDIX

Datasheet Links:
DTMF Encoder (IC 91215B)
http://www.datasheetarchive.com/ic%2091215-datasheet.html
DTMF Decoder (IC CM8870C)
http://www.datasheetarchive.com/CM8870C-datasheet.html
Demultiplexer (IC 74154)
http://web.mit.edu/6.115/www/datasheets/74hc154.pdf
J-K Flipflop (1C 7473)
http://www.datasheetcatalog.org/datasheets2/40/40432_1.pdf

ACKNOWLEDGMENT

I would like to express my sincere gratitude to my mentor, Prof. (Dr.) Prabir Banerjee for supporting and encouraging me to complete the task successfully.

COST ESTIMATION TABLE

Seri-al No.	Components	Specification	No. of Units	Cost per unit (Rs)	Total Cost (Rs)
1	Encoder	IC 91215B	1	35	35
2	Decoder	CM8870C	1	50	50
3	Demultiplexer	IC 74154	1	60	60
4	J-K Flip-flop	IC 7473	6	20	120
5	DTMF Keypad		1	80	80
6	Resistors	100K, 270K, 33K		0.50	2
7	Capacitors	0.1uF	2	2	4
8	Crystal Oscillator	3.58MHZ	2	10	20
9	LED		12	1	12
				Total	**382**

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