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Industrial Application Of DTMF Communication In Robotics

T.L.V.V.Hemanth
IV/IV B.Tech, Dept. of ECE, K L University, Vaddeswaram, A.P, India
P.Sasi kiran
IV/IV B.Tech, Dept. of ECE, K L University, Vaddeswaram, A.P, India
A.Suresh
Assoc. Professor, Dept. of ECE, K L University, Vaddeswaram, A.P, India

Abstract:

We here by present controlling of cranes, electrical appliances using Dual Tone Multi Frequency (DTMF) technology. The crane is controlled by a mobile phone that makes a call to another mobile phone attached to the crane's control panel. During the call, if any button is pressed, tone corresponding to that button is heard at the other end of the call. This tone is received through headset which is subsequently used to relay the commands to a Programmable Logic Controller (PLC) that would perform switching action of motors, connected to the moving parts of the crane or electrical devices. Similarly in the place of motor driver if we replace it with relay driver we can control different electrical appliances also. With advantages of simplicity, audibility, cost effectiveness & unlimited range the hypothesis is that DTMF could replace Radio Frequency (RF) in simple communications. This paper proposes other application areas, such as Industrial environments, where DTMF is feasible and would be advantageous over RF. In this fashion, direction of motion of the crane can be remotely controlled by a mobile phone by DTMF technology via Global System for Mobile communication (GSM). The major advantage of DTMF over RF is the wide range of network provided by DTMF where ever the network of mobile is available we can implement this technology where as in RF the drawback is it low coverage area.

1.Introduction

The aim of the proposed system is to develop a cost effective solution that will provide controlling of industrial equipment's remotely and enable Industrial security against intrusion in the absence of industrial owner. The system not only does the same work in twenty times less capital but also provides an unlimited range of control unlike contemporary remotes based on radio frequency (RF) control. These remotes (RF) have a range of around 200 meters. However devices connected also consume electrical power. As a result, it is crucial to control these devices by turning on/off whenever required. Since now it is a necessity to control devices more effectively and efficiently at anytime from anywhere. In this system,

- To operate electric appliances we are going to develop a cellular phone based industrial equipment controller via PLC. To activate the cellular phone unit on the system a call is to be made and as the call is answered, the caller press the specific key or number in the keypad of cell phone turning ON or OFF the specific device allotted to that number. The device Switching is achieved by Relays. Security is preserved because these dedicated passwords owned and known by selected persons only. For instance, our system contains an alarm unit giving the user a remote on/off mechanism, which is capable of informing up to five different numbers over telephony network about the nature of the event.
- Similarly, While operating the cranes also a specific direction is allotted to specific keys in the key pad in such a way we can perform 12 operations on crane like key 2 for move front, key 4 for move left, key 6 for move right, key 8 for move back, key 5 to stop the crane…etc.,

3.DTMF Generation & Decoding

Dual-tone multi-frequency (DTMF) signaling is used for telephone signaling over the line in the voice-frequency band to the call switching center. The version of DTMF used for telephone tone dialing is known by the trademarked term Touch-Tone, and is standardised by ITU-T Recommendation Q.23. Other multi-frequency systems are used for signaling internal to the telephone network

DTMF-Dual Tone Multi Frequency i.e., in the mobile each number is accustomed with a certain range of frequency if a number is pressed corresponding frequency can be

decoded and particular operation is assigned to that frequency. It is what the principle used in the customer care centre eg: type 1 for Hindi, type 2 for English etc.,

Dual-Tone Multi-Frequency is the signal that you generate when you press an ordinary telephone's touch keys. Over the years, DTMF has replaced Pulse dialing, the early type of telephone dialing in which short pulses were used to relay the dialed number. With DTMF, each key press on your phone generates tones made of two specific frequencies.

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

Table 1

The frequencies were chosen to avoid harmonics: no frequency is a multiple of another, the difference between any two frequencies does not equal any of the frequencies, and the sum of any two frequencies does not equal any of the frequencies. Although DTMF works in normal human voice range, the combination of inharmonic frequencies makes it hard for the human voice to impersonate. Although mobile phone networks use digital signals instead of DTMF for direct dialing, DTMF is still used over mobile phones to navigate automated systems such as phone menus, voice menus and other advanced calling services.

A DTMF signal is the algebraic sum of two different audio frequencies, and can be expressed as follows:

$$f(t) = A0\sin(2*\Pi*fa*t) + B0\sin(2*\Pi*fb*t) + \ldots\ldots\ldots \longrightarrow \quad (1)$$

Where fa and fb are two different audio frequencies with A and B as their peak amplitudes and f as the resultant DTMF signal. fa belongs to the low frequency group and fb belongs to the high frequency group.

Each of the low and high frequency groups comprise four frequencies from the various keys present on the telephone keypad; two different frequencies, one from the high frequency group and another from the low frequency group are used to produce a DTMF signal to represent the pressed key.

The amplitudes of the two sine waves should be such that,

$$(0.7 < (A/B) < 0.9)V \longrightarrow (2)$$

The frequencies are chosen such that they are not the harmonics of each other. The frequencies associated with various keys on the keypad are shown in figure:

When you press the digit 1 in the keypad it generates a resultant tone signal which is made up of frequencies 697Hz and 1209Hz. Pressing digit 7 will produce the tone taken from tones 852Hz and 1336Hz. In both the cases, the column frequency 1209 Hz is the same.

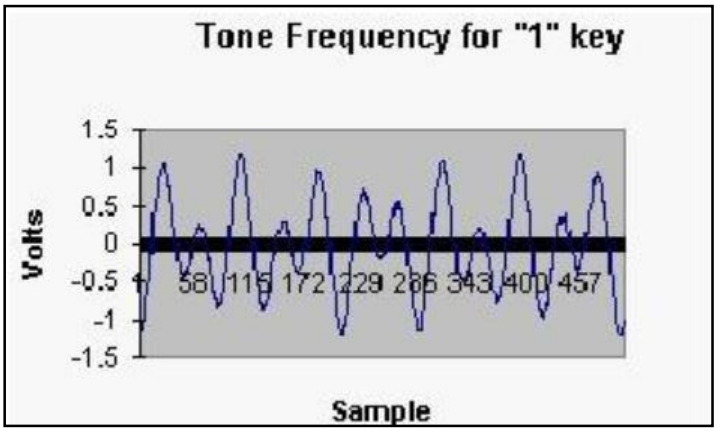

Figure 1

These signals are digital signals which are symmetrical with the sinusoidal wave.

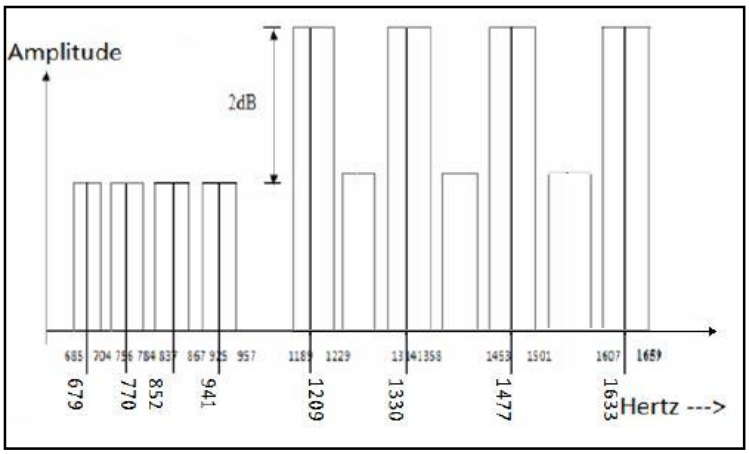

Figure 2:Dual Tone Multi Frequency (DTMF) spectrum

As the above frequency spectrum demonstrates, each & every tone must fall within the proper band pass before a valid decoding takes place. If one tone falls outside the band

pass spectrum, the decoder will not operate at all. The purpose of DTMF decoding is to detect sinusoidal signals in the presence of noise. The DTMF decoder IC interfaces with a controller. In addition, the signal processing associated with the decoding is usually beyond the scope of the microcontroller's capabilities. So the designer is forced to use the devoted IC or advance controller to perhaps a more costly digital signal processor. The theory is quite similar to the "classical" signal processing technique. To detect DTMF signals it is digitized w.r.t. the incoming signal and 8 DFT's (discrete Fourier transforms) are computed centered on the 8 DTMF composite frequencies. DFT's are preferred over FFT's because the frequencies are not equally spaced (in fact, they are logarithmically spaced). In its simplest form, the DFT can be written as:

$$DFT(x) = \Sigma\, x(k)\, W(k) \longrightarrow (1)$$

Where x (k) are the time samples and W (k) is the famous kernel function:

$$W(k) = e^{(j2\pi fk/N)} = \cos(2\pi fk/N) + j \sin(2\pi fk/N) \longrightarrow (2)$$

It means that multiplying the samples by sine waves and cosine waves and adding them together the W(k) can be found. This will give up eight complex numbers. The magnitudes of these numbers give an idea about how much energy is present for each frequency of the input signal. In other words, we have computed the frequency spectrum at the 8 DTMF composite frequencies. The reason why this works so well is because of the "orthogonality" of the sine waves. In other words, this happens if the DFT is performed on two sine waves as shown in the following equation:

$$DFT = \Sigma\, [\sin(f1t) \sin(f2t)] \longrightarrow (3)$$

From equation (3), it is clear that we will get the result as a "large" number if the two frequencies are the same and a "small" number or zero if they're different. "DFT" With Square waves

3.1.DTMF Decoder

The MT8870 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 MT8870 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. Minimal external components required include a low-cost

3.579545 MHz color burst crystal, a timing resistor, and a timing capacitor. The MT8870 provides a "power-down" option which, when enabled, drops consumption to less than 0.5 mw. The MT8870 can also inhibit the decoding of fourth column digits.

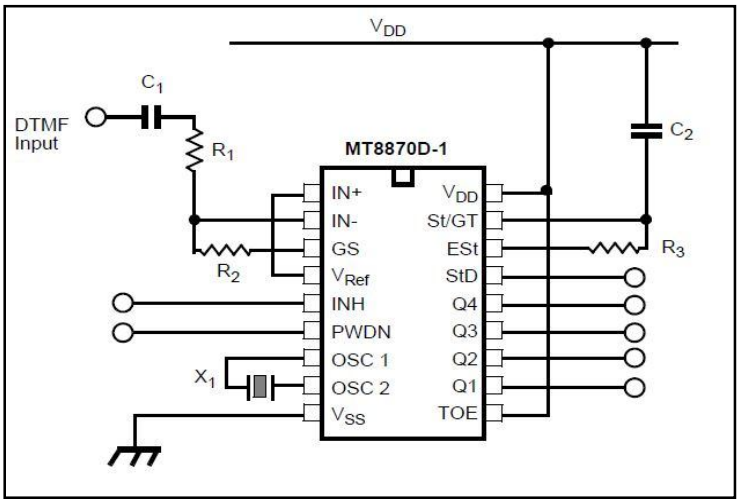

Figure 3: MT8870 IC circuit diagram

The input of the DTMF decoder is the DTMF audio tone; it is provided using an earphone jack cut and separated the tip and ring. DTMF decoder identifies the key pressed by the caller using the band width as discussed in the DTMF generation and is decoded. The decoded output is a binary output drawn at Q1, Q2, Q3, and Q4 as shown in the above circuit diagram. The corresponding outputs of different touch tones of keypad are listed below.

F_{LOW}	F_{HIGH}	Key (ref.)	OE	Q4	Q3	Q2	Q1
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	ANY	ANY	L	Z	Z	Z	Z
L = logic low, H = logic high, Z = high impedance							

Table 2

4.Block Diagram

Using PLC (programmable controller) for controlling of appliances:

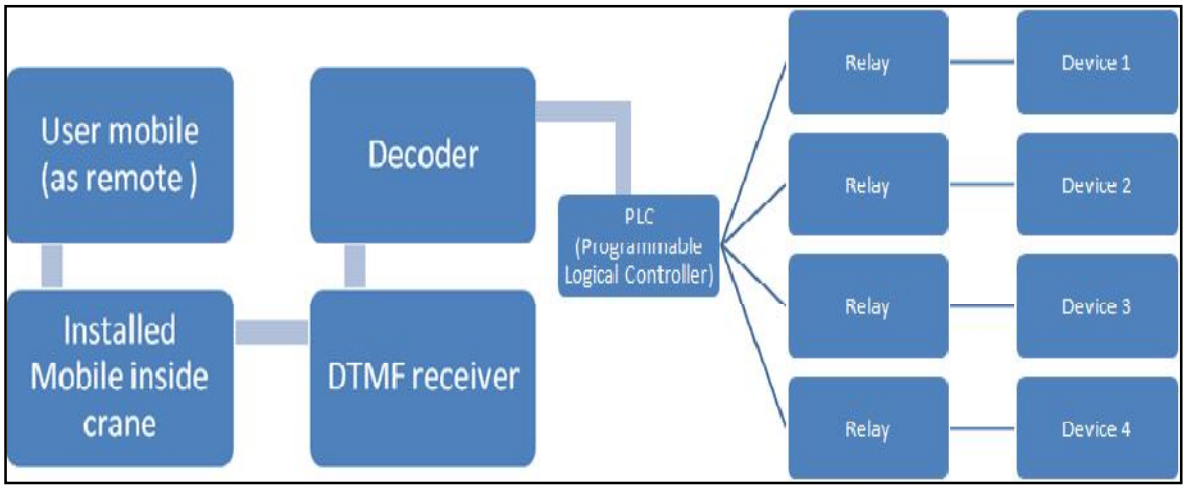

Figure 4

The devices may be motor, light, fan etc., all these appliances can be controlled on/off using the mobile phone by assigning each number to certain device. Relay driver plays a key role in this application to switch the devices or electrical appliances.

4.1.For Controlling Of A Robot

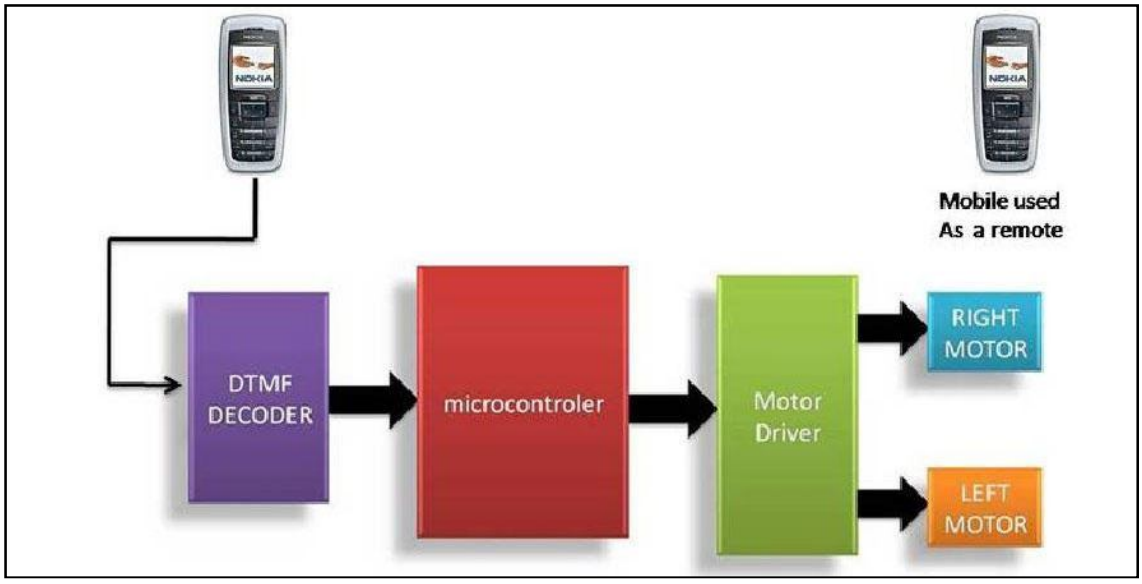

Figure 5

In general DTMF decoder is MT8870, micro controller is atmega16, motor driver is L293D

5.Complete Schematic Diagram Using Proteus Software

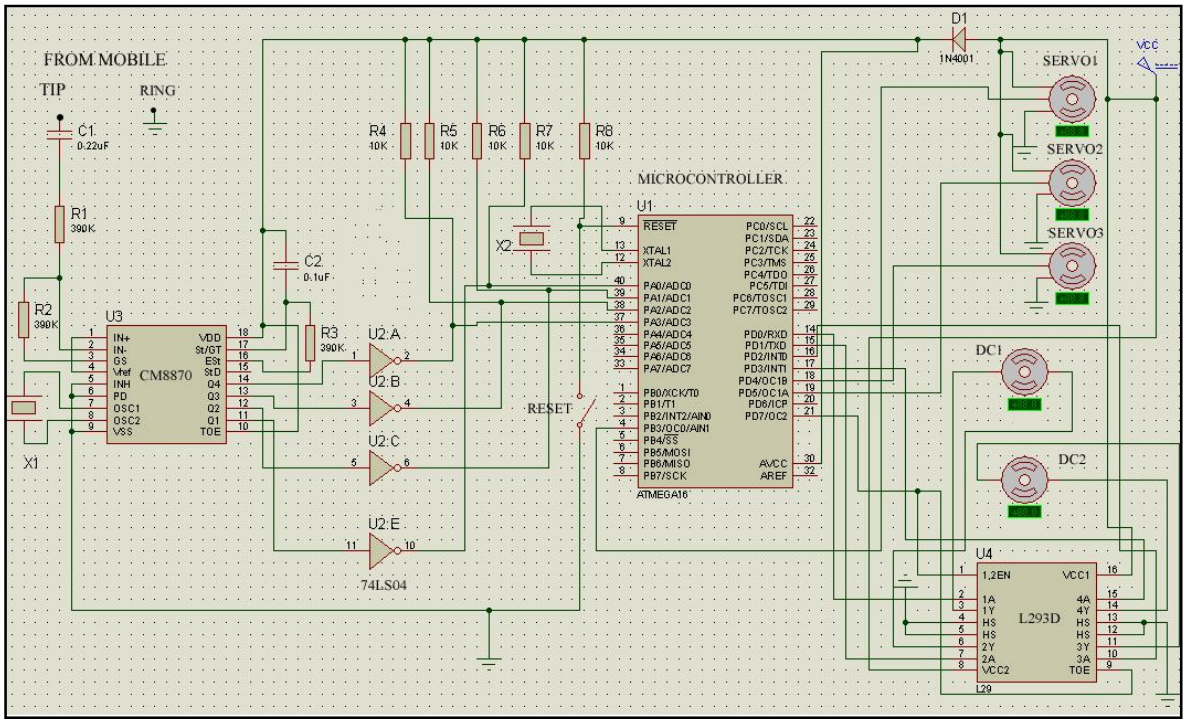

Figure 6

Proteus is a single application with many service modules offering different functionality (schematic capture, PCB layout, etc.).Supports large number of Microcontroller Units (MCUs) including ATmega 16.

6.Working Of The Hardware

Two mobile phones are used in the hardware 1 mobile is mounted in the crane and the other with the user the mobile in the crane is connected to the DTMF decoder using an ear phone set which has tip and ring wires. Make call to the mobile phone (as receiver) attached to the robot. Now after answering the call, and in the course of the call, if any button is pressed control corresponding to the button pressed is heard at the other end of the call. This tone is called dual tone multi frequency tome (DTMF) robot receives this DTMF tone with the help of phone stacked in the robot.

The received tone is processed by the AT89S52/atmega16 microcontroller with the help of DTMF decoder MT8870 the decoder decodes the DTMF tone in to its equivalent binary digit and this binary number is send to the microcontroller, the microcontroller is

preprogrammed to take a decision for any give input and outputs its decision to motor drivers in order to drive the motors for forward or backward motion or a turn.

The mobile that makes a call to the mobile phone stacked in the robot acts as a remote. So this simple robotic project does not require the construction of receiver and transmitter units. DTMF signaling is used for telephone signaling over the line in the voice frequency band to the call switching center. The version of DTMF used for telephone dialing is known as touch tone. DTMF assigns a specific frequency (consisting of two separate tones) to each key that it can easily be identified by the electronic circuit. The signal generated by the DTMF encoder is the direct algebraic submission, in real time of the amplitudes of two sine (cosine) waves of different frequencies, i.e pressing 5 will send a tone made by adding 1336 Hz and 770Hz to the other end of the mobile.

7.Output For Controlling A Crane

Number pressed by user	Output of HT9170 DTMF decoder	Input to the microcontroller	Output from microcontroller	Action performed
2	0×02 00000010	0×FD 11111101	0×89 10001001	Forward motion
4	0×04 00000100	0XFB 11111011	0×85 10000101	Left turn Right motor forwarded Left motor backwarded
6	0×06 00000110	0XF9 11111001	0×8A 10001010	Right turn Right motor backwarded Left motor forwarded
8	0×08 00001000	0XF7 11110111	0×86 10000110	Backward motion
5	0×05 00000101	0XFA 11111010	0×00 00000000	Stop

Table 3

Various operations we can perform on crane is shown above in such a way we can perform 12 operation on crane and can control nearly 12 elecrical appliances using a relay driver.

8.Software Used

The software is written in ‘C’ language and compiled using Code Vision AVR ‘C’ compiler. The source program is converted into hex code by the compiler. Burn this hex code into ATmega16 AVR microcontroller.

The source program is well commented and easy to understand. First include the register

name defined specifically for ATmega16 and also declare the variable. Set port A as the input and port D as the output. The program will run forever by using 'while' loop. Under 'while' loop, read port A and test the received input using 'switch' statement. The corresponding data will output at port D after testing of the received data.

9.Further Improvements & Future Scope

9.1.IR Sensors

IR sensors can be used to automatically detect &avoid obstacles if the robot goes beyond line of sight. This avoids damage to the vehicle if we are maneuvering it from a distant place.

9.2.Password Protection

Project can be modified in order to password protect the robot so that it can be operated only if correct password is entered. Either cell phone should be password protected or necessary modification should be made in the assembly language code. This introduces conditioned access &increases security to a great extent.

9.3.Alarm Phone Dialer

By replacing DTMF Decoder IC CM8870 by a 'DTMF Transceiver IC' CM8880, DTMF tones can be generated from the robot. So, a project called 'Alarm Phone Dialer' can be built which will generate necessary alarms for something that is desired to be monitored (usually by triggering a relay). For example, a high water alarm, low temperature alarm, opening of back window, garage door, etc. When the system is activated it will call a number of programmed numbers to let the user know the alarm has been activated. This would be great to get alerts of alarm conditions from home when user is at work.

9.4.Adding A Camera

If the current project is interfaced with a camera (e.g. a Webcam) robot can be driven beyond line-of-sight &range becomes practically unlimited as GSM networks have a very large range.

10.Reference

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