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REMOTE CONTROLLING OF AN AGRICULTURAL PUMP SYSTEM BASED ON THE DUAL TONE MULTI-FREQUENCY (DTMF) TECHNIQUE

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Abstract

In modern days, as a result of advances in technology, human beings are interested to remotely control different systems and applications. In this work, telephone signalling technique using Dual Tone Multi-Frequency (DTMF) signalling, is used to control switching of electrical loads such as agricultural pumps located in remote areas. A DTMF tone command sent from a transmitting fixed or mobile phone terminal will be used to SWITCH ON/OFF the motors used to pump water for agricultural fields. A processing electronic system at the receiving side is designed to interpret the tone commands and sends an appropriate signal to the motor driving circuit to complete the pump switching states. In the design methodology, it is possible to control several water pumps distributed in a certain agricultural site, however, in this work we considered four pumps and the paper presents the complete electronic design and simulation results at the different stages of the design. The electronic design is based on discrete passive and active electronic components and the system is tested and simulated using Multism program. The results of the simulation show that the design is capable of controlling the switching state of the motors. For a certain DTMF command, it is possible to switch ON/OFF a specific motor pump or all of the four motors.

Keywords: DTMF, Touch-tone, Remote control, Op-amps, Bandpass filters.

1. Introduction

Remote controlling is one of the greatest inventions of humankind. It is a method of controlling an electronic or electromechanical system remotely without the need to physically touch and operate the controlled device. While most of the earlier remote controllers were connected to the device being controlled by wires,

Nomenclatures

f_L	Low frequency, Hz
f_H	High frequency, Hz
T_s	Sampling time, sec
F_s	Sampling frequency, reciprocal of T_s, Hz
f_0	Resonance frequency, Hz
V_{cc}	Power Supply Voltage, volt
$V_f(t)$	Voltage of a sinusoidal signal of frequency f, volt
$V_o(t)$	Output voltage, volt
$V_{bp}(t)$	Output voltage of bandpass filter, volt
Q_j	Quality factor of the j-th stage,
f_{mj}	Resonant frequency of the j-th stage, Hz
A_{mj}	Maximum gain of the j-th stage
C_i	The i-th capacitance shown in figures, farad
B	Bandwidth, Hz
L_X	Outputs of buffer logic gates at the corresponding frequency
J_k	Logic functions SWITCHED ON the k-th motor
K_k	Logic functions SWITCHED OFF the k-th motor
X_i	The i-th lamp indicator

Greek Symbols

ω	Digital frequency
ω_0	Digital frequency of maximum normalized gain

Abbreviations

DTMF	Dual Tone Multi Frequency
LoS	Line of Sight
IC	Integrated Circuit
IIR	Infinite Impulse Response
IR	Infrared
DSP	Digital Signal Processor

the first wireless remote control for a consumer electronics device was invented in the 1950's [1]. Nowadays, remote controls are most commonly used in many applications and consumer electronic devices such as television sets, DVD players, air conditioners, automatic garage door opener systems with most of them operating wirelessly from a short Line-of-Sight (LoS) distance. The main technology used in home remote controls is infrared (IR) light. While IR transmission is limited to LoS operation, radio-wave transmission is used for controlling devices located in remote or distant locations. As a complementary method to infrared remote controls, the radio remote control is used with electric garage door or gate openers, automatic barrier systems, burglar alarms, industrial automation systems, military applications such as satellite linked remote controlling of unmanned airplanes (drones), space travels and other related applications. It is obvious that in the case of remote controlling using a radio, we need to have a transmitter that generates and transmits the control commands and a receiver at the remote site that receives the transmitted commands from the transmitter, interprets, and produces different states of operation depending on the transmitted commands. In the case of radio-communication, the control command can be transmitted using the wired or wireless network making it capable of controlling an application of interest at any time and any place.

Beyond the normal use of voice and multimedia communications, in recent years the use of wireless and mobile phone devices is becoming prevalent in remote controlling applications such as house and property security surveillance system, theft control and monitoring systems, remote motor speed control, remote real-time industrial process control & monitoring, remote door locking system, remote controlling of electrical apparatus control in offices and homes, remote operation of robotic systems, remote vehicular security systems, remote switching systems and other relevant applications, [2], [3]. Therefore, remote controlling of systems using telephone signals is not new however the implementation differs from application to application. Specifically the use of Dual Tone Multi-Frequency (DTMF) technique is becoming predominantly used in various remote controlling applications [4]-[9]. The DTMF is used for telecommunication signalling over analogue telephone lines in the voice-frequency band between telephone handsets and other communications devices and the switching centre [10]. In this work, DTMF based remote controlling technique is used to remotely control agricultural pumps used for irrigation.

A farmer controls the irrigation of an agriculture site by using AC motor (single phase or three-phase) which is responsible for mechanical rotation of the pump. The suitable motor size is selected depending on the area dimension of the site. More than one motor may be required for pumping different locations of a large agricultural site, which can be situated very far from the residential area of the farmer. In this case, the use of modern technology can facilitate the difficulty and demand of wide and remote-area irrigation system.

A remotely located farmer will have ability to press the keypad of the telephone handset and can switch on or off water pumps located at the different locations of the site. Depending on the requirement, one or several pumps that are available in the agricultural site can be switched on/off at the same time or at different times. A DTMF decoder and controlling logic circuit are designed to control high power pumps by issuing commands encoded as audio DTMF signals. The DTMF decoder and controlling circuit receives those remote commands and controls the switching states of the connected motor pump system. In contrast to the previous related designs that used commercially available DTMF decoder integrated circuit (IC) and microcontrollers [4]-[9], in this work the DTMF decoder and the subsequent logic controller are designed using easily available passive and active electrical and electronic components. The case of designing DTMF based controlling for the agricultural pump system has great impact in places where water and rain scarcity is highly predominant for example in desert areas. In this case, a farmer can make proper water management and controlling based on the weather, environmental and seasonal conditions. Remote controlling will make it flexible reducing the physical presence of the farmer to operate the pump systems. In general, the DTMF based remote controlling has great importance not only in this specific case of agricultural pump controlling but also in many versatile domestic home uses and industrial purposes as it reduces the risk of leaving an equipment or machines ON which is not meant to be running for a long period of time if the operator is not around. Switching ON and OFF will be possible from any location and any time as the need arises.

2. System Model

From the purpose of the proposed system, it is obvious that we need a transmitter phone (fixed or mobile), a receiver phone (fixed or mobile), DTMF decoder and Logic Controller which could be a microcontroller and a motor drive circuit used for switching the motor pumps. Fig. 1 shows the general block diagram of the receiving end showing the different parts of the system.

At the transmitter, the farmer or any other assigned user will send the DTMF control signal by first dialing the receiver mobile or fixed phone. After the answering mode is completed, the user will send an appropriate DTMF tone command to switch on/off one or several of the motor pumps. The received DTMF tone command will be decoded by an appropriate DTMF decoder circuit. In the previous other works, we have seen that people use a commercially available IC chips, however in this work we designed an analogue filter to decode the DTMF tones using easily available passive and active electronic components. After the decoding of the tones, a logic controller is designed to identify the exact transmitted phone digit corresponding to the DTMF tone as each digit of the telephone keypad is represented by two simultaneous tones selected from a set of frequencies. A motor driving circuit corresponding to the transmitted digit will be enabled and driving circuit will switch on/off one or several of the motor pumps according to the design specifications. In the previous works, we have seen that a microcontroller is used after the DTMF decoding circuit. In this work, we used our design instead of a microcontroller as we planned to make a new design (new approach) to implement the DTMF based controller.

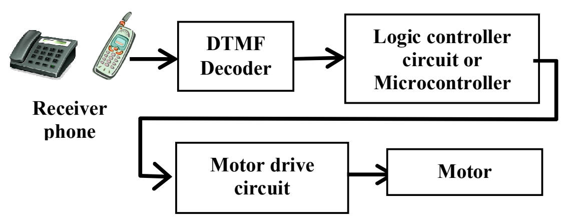

Fig. 1. System Block Diagram of DTMF Based Motor Pump Controller.

3. DTMF Signal and Decoder

Each digit of the telephone keypad is represented by two simultaneous tones selected from a set of frequencies. One set of frequencies consists the low frequencies (697 Hz, 770 Hz, 852 Hz, and 941 Hz) and the second set consists of the high frequencies (1209 Hz, 1336 Hz, 1477 Hz, and 1633 Hz) as shown in Fig. 2. Each time when we press a digit or symbol on the phone keypad, a sinusoid signal, which is a sum of the lower frequency (f_L) and the higher frequency (f_H) is generated. Therefore, the DTMF tone signal generated corresponding to a certain pressed digit on the keypad is given by:

$$x(t) = A\sin(2\pi f_L t) + B\sin(2\pi f_H t) \tag{1}$$

where A & B are the amplitude of the each frequency sinusoid. The discrete time version of the signal in Eq. (1) can be determined if we sample the signal and replace t with $t = nT_s$ where the sampling time T_s is the reciprocal of the sampling frequency F_s. F_s is often taken as 8000 Hz, which is the sampling frequency of voice signals.

Once the DTMF tones are received at the receiver, it is important to have an appropriate tone recognizing circuit so as to identify the individual digits. Since the signals for each digit have two unique frequencies, filtering could be one of the most suitable choices used to identify the individual digits corresponding to the tones. An analogue filter could be used for the analogue DTMF tone signal and a digital filter for the discrete time DTMF tone signal. In the case of digital implementation of the DTMF decoder, a DTMF tone can be decoded by using a Digital Signal Processor (DSP) or a personal computer by designing an appropriate software program or algorithm for detection.

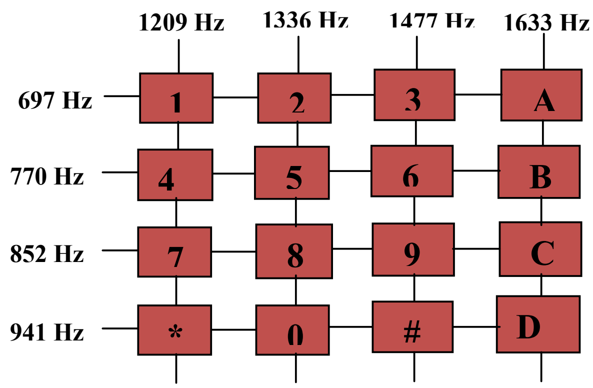

Fig. 2. The DTMF Tones Generated from a Phone Keypad.

Among others, infinite impulse response (IIR) filter techniques such as the Goertzel algorithm can be mentioned as an efficient way to implement a DTMF detector and decoder [11], [12]. For instance, a two–pole IIR filter can be designed by using the concept of poles and zeros. A pole is placed nearby the frequency to be detected so as to have a high gain and a zero nearby the frequency to be eliminated or not to pass through the filter. Suppose, we want the digital frequency ω to have a high output at ω_0, in the pole-zero plot, the poles of the digital filter or resonator are placed close to the unit circle with angle ω_0 and its zeros are placed at $z = \pm 1$. Therefore, the z-transform of the digital bandpass filter can be written as:

$$H(z) = \frac{G(1-z^{-1})(1+z^{-1})}{(1-re^{j\omega_0})(1-re^{-j\omega_0})} \tag{2}$$

where r is a real number representing the magnitude of the pole and having a magnitude close to unity and G can be chosen in such a way that the bandpass filter have normalized maximum gain of one at ω_0. The frequency ω_0 is the detected frequency of interest in radians and it is related to the resonance frequency f_0 of the filter as $\omega_0 = 2\pi f_0/F_s$ where f_0 is either f_L or f_H. Fig. 3 shows the magnitude of the frequency response of the eight digital bandpass filters used to detect the eight frequencies simulated in MATLAB. A similar result can be found by implementing the Goertzel algorithm as a second order two–pole recursive IIR filter. As you see in Fig. 3, the peaks of the eight filters are very close to the DTMF tone frequencies and hence confirming the capability of detecting the tones using this approach.

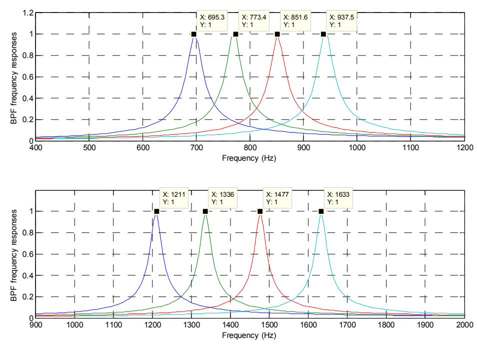

Fig. 3: Magnitude Frequency Response of the Eight Digital Filters for Decoding DTMF Tones.

In our approach, we focused on the implementation of the DTMF decoder using analog electronic circuits and hence we have followed an alternative approach of the decoder design by taking into consideration that we will build the circuit and test the functionality by making laboratory experiments. In the sequel, we give the designed circuit of each stages supported by MULTISIM simulations at the different stages of the overall proposed design.

3.1 DTMF Tone Generator

From Eq. (1), the DTMF tone signal is the sum of two sinusoid frequencies: one from the low frequency group of DTMF frequencies and the second one from the higher frequency group of the DTMF frequencies. In order to test the proposed DTMF decoder circuit using simulations, we need to have an input DTMF tone signal. For MULTSIM simulations, we designed an op-amp adder circuit that produces the sum of the two sinusoid signals at the output of the op-amp. Fig. 4 shows the circuit diagram of a non-inverting summer op-amp circuit [13].

The circuit generates the DTMF tone when the digit *"***0"** is pressed on the keypad of the telephone. The two generator sources produce sinusoidal voltages of 941 Hz and 1336 Hz. Let the sinusoidal voltage at 941 Hz and 1136 Hz as $V_{941}(t)$ and $V_{1336}(t)$ respectively, the output voltage of the summer op-amp (with $R_1 = R_2 = R_{14} = R_{23}$) will be $V_0(t) = V_{941}(t) + V_{1336}(t)$. Fig. 5 shows the resultant signal at the output of the non-inverting amplifier. As can be evident from the Figure, the resultant amplitude will be nearly twice of the individual amplitudes when the two signals are in-phase or summed constructively and the resultant magnitude will be very small near to zero when they are out of phase or summed destructively.

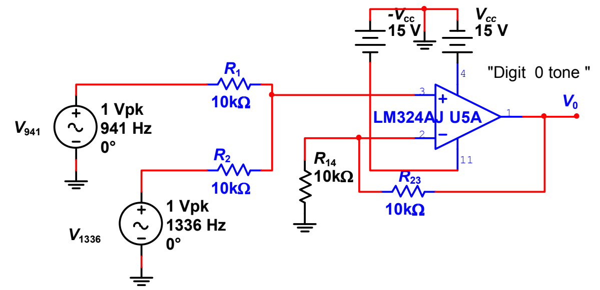

Fig. 4. DTMF Tone Generating Circuit.

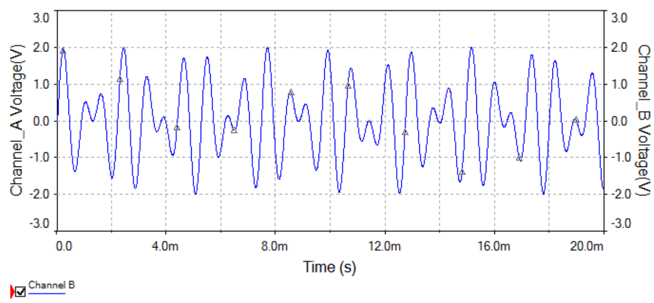

Fig. 5. The DTMF Tone Corresponding to the Digit "0" at the Output of the Non-inverting Summer Shown in Fig. 4.

3.2 Four-Pole Active Bandpass Filter

Once we achieved in generating the DTMF tone signal, the next step is to design a circuit that is able to identify the individual DTMF tone signals. After a literature survey and study in Multisim, we found that a four-pole active band pass filter based on the multiple feedback topologies is quite suiting for this job. The four-pole bandpass filter can be designed from a cascade or series connection of two identical two-pole multiple feedback topologies. The capacitor and resistance values can be determined using the design steps as mentioned in [14]. Fig. 6 shows a fourth order Butterworth active bandpass filter where the parameters are selected to have resonance or maximum gain at a frequency of 941 Hz, which is one of the eight DTMF frequencies. We will have eight fourth order bandpass filters corresponding to the eight DTMF frequencies. In this kind of topology, the quality factors and maximum gains of the two cascaded filters are identical. Let Q_1, f_{m1} and A_{m1} are the quality factor, the mid or resonant frequency and the maximum gain at the mid frequency respectively of the first stage and let Q_2, f_{m2} and A_{m2} are the quality factor, the mid or resonant frequency and the maximum gain at the mid frequency respectively of the second stage, as mentioned in detail in [14], these parameters are determined from the overall quality factor (Q) and the overall gain (A_m) of the fourth order bandpass filter. Afterwards, for a given capacitance value ($C_{11} = C_{12}$

$=C_{13}=C_{14}=C$), the rest of the resistance values of the overall filter are determined from the following relations:

$$R_{12}=\frac{Q_1}{\pi f_{m1}C},\quad R_{11}=-\frac{R_{12}}{2A_{m1}},\quad R_{10}=-\frac{A_{m2}R_{11}}{2Q_1^2+A_{m1}} \tag{3}$$

$$R_{30}=\frac{Q_2}{\pi f_{m2}C},\quad R_{13}=-\frac{R_{30}}{2A_{m2}},\quad R_{31}=-\frac{A_{m2}R_{13}}{2Q_2^2+A_{m2}} \tag{4}$$

The values of the components for Fig. 6 are determined for bandwidth, B = 100 Hz (Q =100/941), C =100 nF and overall gain of A_m =2. We used B = 100 Hz for the higher frequency DTMF frequencies (941 Hz, 1209 Hz, 1336, 1477 Hz) and a bandwidth of B = 60 Hz for the low frequencies (697 Hz, 770 Hz, 852 Hz). Several simulation trials have been done for different bandwidth specifications, selection of a higher bandwidth for the higher frequencies will provide a stable result compared with using the same bandwidth specifications for all DTMF frequencies. This is because the bandwidth has to be increased to get a comparable quality factor for the higher frequencies compared with the lower DTMF frequencies.

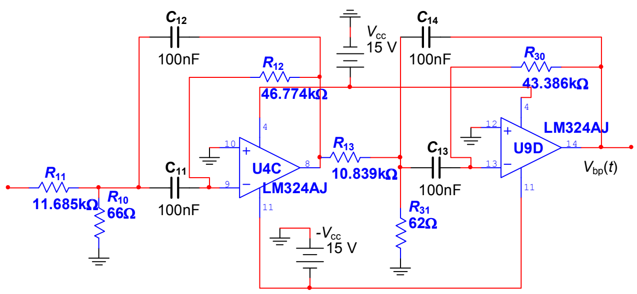

Fig. 6. Fourth Order Multiple Feedback Topology Active Bandpass Filter (Component Values are for f_m =941 Hz).

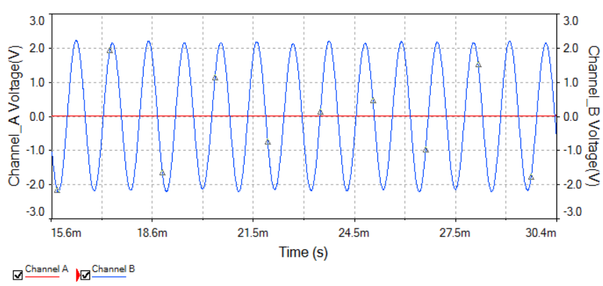

Fig. 7. Output of Active Bandpass Filter for Frequency f_m =941 Hz.

Figure 7 shows the output of the active bandpass filter shown in Fig. 6 when the DTMF signal for digit "**0**" is passed through the filter. It clearly shows that the circuit filters the input DTMF tone corresponding to the digit "**0**" and produces the sinusoid signal of frequency 941 Hz at its output.

3.3 The Comparator and Integrator Circuit

The active filter circuit designed as shown in Fig. 6 attenuates other DTMF frequencies that are different from the resonance frequency and therefore there will be very small amplitude signal at the output for the frequencies different from the resonant frequency. For instance, if the digit "**0**" is pressed, only the active bandpass filter with the parameters as shown in in Fig. 6 produces a high amplitude signal at its output compared with the output of the filters designed for the other DTMF frequencies. For this reason, we designed a comparator circuit following the bandpass filter and then an RC integrator circuit and buffer to produce HIGH voltage (+15 V) for the DTMF frequencies corresponding to the pressed digit and a LOW voltage (0 V) for the other filters. Fig. 8 shows the comparator circuit, followed by the integrator RC circuit, buffer logic gate (U24D) and at the end a 15 Volt indicator lamp (X_3) for indicating the detection of the DTMF frequency.

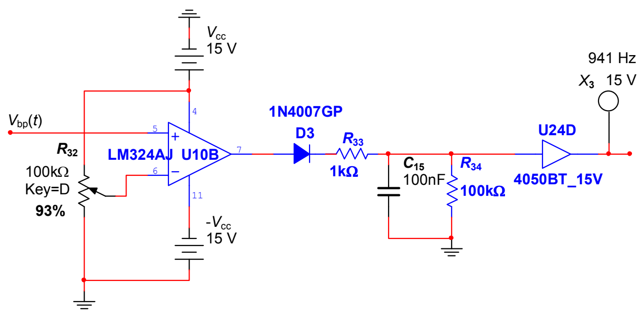

Fig. 8. A Comparator, Integrator and Buffer Circuit.

The potentiometer is set for a reference voltage of approximately 1V and the comparator gives an output voltage of 15 V (HIGH) when the output of the bandpass filer is above 1 V and an output voltage of -15V (LOW) when the bandpass output voltage is less than the 1 V. The output of the comparator will be a square wave as shown in Fig. 9 (Channel A output of the oscilloscope) and the output after the RC integrator circuit output is also shown in Fig. 9 (Channel B output of oscilloscope) giving nearly 15 V output voltage after the detection of the 941 Hz DTMF frequency.

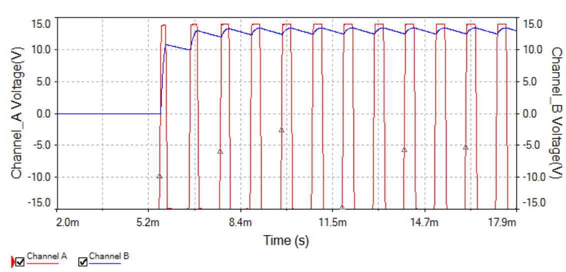

Fig. 9. A Comparator Output (Channel A) Integrator Output (Channel B).

The output of the buffer (U24D) will be HIGH (15 V) if a DTMF frequency is detected and LOW (0 V) if a DTMF frequency isn't detected. Fig. 10 shows the output for detection of the 941 Hz DTMF frequency as a result of pressing the digit "**0**'. Note that in this case where digit "**0**" is pressed or transmitted, the output of the comparators following the other filters (filters except for the 941 Hz and 1336 Hz) are LOW (-15 V) since the amplitude of the bandpass filter outputs are too weak to make the comparator output HIGH. In these cases, the outputs of the corresponding buffer logic gates are LOW (0 V) fulfilling our target. In other words, when digit "**0**" is pressed on the telephone keypad and transmitted from the DTMF transmitter, only the buffer logic gates corresponding to 941 Hz and 1336 Hz bandpass filters are HIGH (logic 1) and all other buffer outputs are LOW (logic zero).

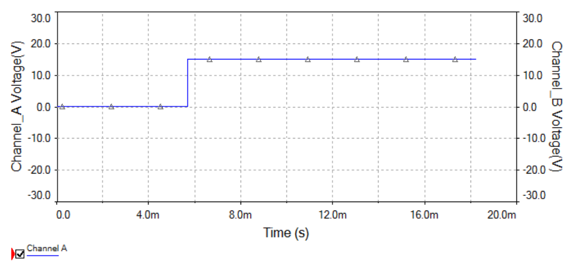

Fig. 10. A Buffer Logic Gate (U24D) Output.

4. Logic Controller Circuit

In the above analysis, we have shown that the possibility of complete detection and recognition of the DTMF frequencies using the DTMF decoder circuit. We get a "logic 1" if a DTMF frequency is recognized and a "logic 0" if a DTMF frequency isn't detected or recognized by the decoder. The logic controller controls four motor pumps assumed to be located in four different locations in a certain agricultural site. When "*digit* 1" is pressed or the DTMF tone corresponding to the digit is transmitted, *all four motors* will be functional (ALL SWITCHED ON). When "*digit* 0" is pressed, *all four motor pumps* will stop working (ALL SWITCHED OFF). When *digit* 2, *digit* 3, *digit* 4 and *digit* 5 are pressed, Motor-one, Motor-two, Motor-three and Motor-four respectively are separately activated (SWITCHED ON) and start working. When *digit* 6, *digit* 7, *digit* 8 and *digit* 9 are pressed, Motor-one, Motor- two, Motor- three and Motor-four respectively are separately de-activated (SWITCHED OFF) and stop working.

Let the outputs of the buffer logic gates for the frequencies 697 Hz, 770 Hz, 852 Hz, 941 Hz, 1209 Hz, 1336 Hz, and 1477 Hz are denoted by L_A, L_B, L_C, L_D, L_E, L_F and L_G respectively. Table 1 shows the outputs of the buffer logic gates, when the digits "**0"** to "**9"** are pressed or their DTMF tones are transmitted. Let the logic functions for "SWITCHED ON" conditions for motors one, two, three and four are J_1, J_2, J_3 and J_4 respectively, these switched on conditions are given by the following logic functions:

$$J_1 = (L_A \text{ and } L_E) \text{ or } (L_A \text{ and } L_F) = L_A L_E + L_A L_F \quad (5)$$

$$J_2 = (L_A \text{ and } L_E) \text{ or } (L_A \text{ and } L_G) = L_A L_E + L_A L_G \quad (6)$$

$$J_3 = (L_A \text{ and } L_E) \text{ or } (L_B \text{ and } L_E) = L_A L_E + L_B L_E \quad (7)$$

$$J_4 = (L_A \text{ and } L_E) \text{ or } (L_B \text{ and } L_F) = L_A L_E + L_B L_F \quad (8)$$

Let also the logic functions for "SWITCHED OFF" conditions for motors one, two, three and four are K_1, K_2, K_3 and K_4 respectively, these switched off conditions are given by the following logic functions:

$$K_1 = (L_D \text{ and } L_F) \text{ or } (L_B \text{ and } L_G) = L_D L_F + L_B L_G \quad (9)$$

$$K_2 = (L_D \text{ and } L_F) \text{ or } (L_C \text{ and } L_E) = L_D L_F + L_C L_E \quad (10)$$

$$K_3 = (L_D \text{ and } L_F) \text{ or } (L_C \text{ and } L_F) = L_D L_F + L_C L_F \quad (11)$$

$$K_4 = (L_D \text{ and } L_F) \text{ or } (L_C \text{ and } L_G) = L_D L_F + L_C L_G \quad (12)$$

Table 1. Outputs of Buffer Logic Gates Corresponding to Different Digital Transmission.

Frequency	Buffer Logic Gate Name	Digits Transmitted									
		0	1	2	3	4	5	6	7	8	9
697 Hz	L_A	0	1	1	1	0	0	0	0	0	0
770 Hz	L_B	0	0	0	0	1	1	1	0	0	0
852 Hz	L_C	0	0	0	0	0	0	0	1	1	1
941 Hz	L_D	1	0	0	0	0	0	0	0	0	0
1209 Hz	L_E	0	1	0	0	1	0	0	1	0	0
1336 Hz	L_F	1	0	1	0	0	1	0	0	1	0
1447 Hz	L_G	0	0	0	1	0	0	1	0	0	1

When a particular motor is switched on, it remains in switched on state unless it is switched off by the switched off command and vice versa. It means, there is a need for tracking the state of the motor and hence a requirement not only a combinational but also a sequential circuit. One can show that the sequential state change for each motor can be represented by a JK flip flop. As an example the switching state of motor one can be given by the truth table shown in Table 2 and the truth table for the other motors can be provided in a similar way. The next switching state of motor one is determined by the output logical state of $Q_1(t+1)$ of the JK flip flop corresponding to motor one. The conditions $J_1 = K_1 = 1$ will not occur since there is no a condition of "SWITCHING ON" and "SWITCHING OFF" the motor at the same time. Suppose the initial states $J_1 = K_1 = 0$ and we want to switch on motor one, then by pressing and transmitting the DTMF tone for "*digit* 2", we get the command $J_1 = 1$ and $K_1 = 0$, and thus $Q_1(t+1) = 1$ (motor one is "SWITCHED ON"). If we want to switch off motor one, we can transmit the DTMF tone corresponding to "digit 6" and hence $J_1 = 0$ and $K_1 = 1$, and thus $Q_1(t+1) = 0$ (motor one is "SWITCHED OFF"). In this way, a similar JK flip flop truth table can be constructed for all the four motors and can be controlled according to the user's need. Fig. 11 shows the logic controller circuit for motor one and similar circuits are designed for the other motors. The J_1 and K_1 inputs of the JK flip flop (4027BD) are according to the relations shown in Eqs. (5) and (9), where motor one is switched on (J_1 –input) if the digit "**1**" or "**2**" are pressed and transmitted from the transmitting phone of the user and motor one is switched off (K_1-input) if digit "**0**" or digit "**6**" are pressed and transmitted from the transmitter. The X_1, X_2 and X_3 lamps are placed for state indication purposes where the lamps are switched on with the condition of logic one and switched off with the conditions of logic zero.

Table 2. Switching State of Motor One.

JK FLIP FLOP		
J_1	K_1	$Q_1(t+1)$
0	0	No change
0	1	SWITCH OFF
1	0	SWITCH ON
1	1	Toggle

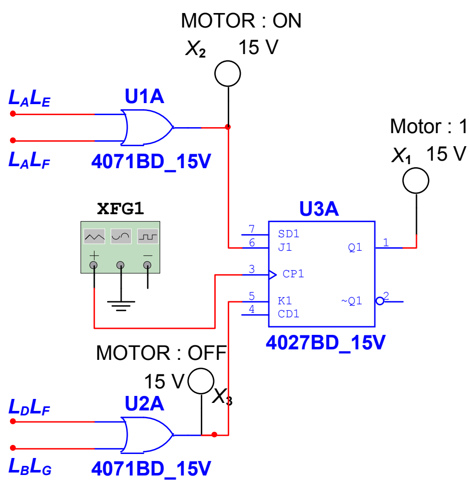

Fig. 11. Controller Circuit for Motor 1.

When switching on motor one, Q_1 will be in logic state HIGH (15 V), and afterwards this signal can be supplied to a relay switching circuit where the AC/DC power supply to motor one will be switched on and hence the motor will start working (pumping) and on the other hand, when switching off motor one, Q_1 will be in logic state LOW (0 V) and as a result the subsequent relay switching circuit will be de-energized and hence disconnect the pumping motor from any power supply circuit and stopping its pumping functions.

The overall circuit for controlling all the four motors is designed and constructed according to the descriptions in sections 3 and 4. There are seven

DTMF signal generators, seven DTMF decoders (bandpass filters, the comparator and integrator circuit), 16 AND gates, 8 OR gates and 4 JK flip flops. The designed circuit is simulated and tested using the MULTISIM software for various cases of motor switching ON and OFF conditions and the simulations showed perfect switching control for all cases.

5. Conclusions

This paper investigates and proposes an electronic circuit for controlling remotely located agricultural motor pumps based on the DTMF technique. The stages of the proposed system are designed based on discrete components, gates, flip flops and op-amps. Especially a new DTMF decoder is designed instead of using the commercially available and previously used decoder ICs. The functionality of the overall circuit is tested using MULTSIM simulation software and full motor switching state control is achieved using the designed circuit. This proposed electronic design can be used for remotely controlling motor pumps used for agricultural site without requiring the physical presence of the farmer or the user at the site. As a result, the use of the system achieves proper water management, saves time, human power, resources and related costs required for not using a remote control system. The system and the technique can be adopted and used for remotely controlling of any home or industrial applications. Future works will be on practical implementation and testing of the proposed electronic system in the Laboratory and to study on a closed loop control system where switching of the motors will be based on feedback information acquired from the agricultural site.

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