Nigerian Journal of Engineering Science Research (NIJESR).
Vol. 5, Issue 3, pp.01-11, September, 2022
Copyright@ Department of Mechanical Engineering, Gen. Abdusalami Abubakar College of Engineering, Igbinedion University, Okada, Edo State, Nigeria.
ISSN: 2636-7114
Journal Homepage: https://www.iuokada.edu.ng/journals/nijesr/

The use of Dual Tone Multi-Frequency DTMF Signaling for Home Automation in Nigeria

[1]*Umeozor Sopuruchukwu Stanley, [2]Irorere Kelvin, and [3]Uche Orisakwe Ijeoma

[1]Department of Electrical and Computer Engineering, College of Engineering, Igbinedion University Okada, Nigeria
umeozor.stanley@iuokada.edu.ng

[2]Department of of Electrical and Computer Engineering, College of Engineering, Igbinedion University Okada, Nigeria

[3] Department of Electrical and Electronic Engineering, Federal Polytechnic Owere. Nigeria
Iroreregreg@gmail.com

**Corresponding Author: Umeozor Sopuruchukwu Stanley; umeozor.stanley@iuokada.edu.ng*

Manuscript History
Received: 27/05/2022
Revised: 24/07/2022
Accepted: 10/08/2022
Published: 19/09/2022

Abstract: *Home appliances in our homes, like air conditioners, refrigerators, lighting points and Televisions are more enjoyable when they are controlled from anywhere around the world. This can be achieved through home automation. Automation is a method or technique in which electronic systems and communication protocols are used in reducing human involvement in certain operations for more flexibility, accuracy and speed. The problem of electrical fire in homes due to forgetfulness and inability to switch off electrical appliances from far distance has causes loss of properties and energy in Nigeria. This study aimed at developing a dual tone multi-frequency signaling system combined with manual switches for use in automatic and manual control of home appliances in Nigeria. The objective was to design a DTMF Home automation system and test the built system on Testing board component by component with a view to ascertain its workability before placing on the permanent board for soldering. Design and implementation method was employed. The final result was that the connected appliances were controlled with a mobile phone from a distance approximately 400km away from the appliances. The appliances were also controlled with a Manual switch attached to the system. The system works like a two-way switch in which one end is manual switching while the other end is automation control via mobile phone (DTMF signaling). Voltage measurements were taken from important points of the system to determine the electrical behavior of the major components used in the system when in operation and when not in operation. The system was able to control three light bulbs which represented different appliances.*

Keywords: *Dual Tone Multi-Frequency (DTMF), Home Automation, Home Appliances, Remote Control*

INTRODUCTION

Home appliances like refrigerators, televisions, air conditioners, and electric heaters make homes comfortable and enjoyable. However, the problem of electrical fire in homes due to forgetfulness and inability to switch off these electrical appliances from far distance cause loss of properties, lives and energy (Shah *et al*., 2021). These losses, negatively affect the economy of the nation directly or indirectly. The more easily and flexible these appliances can be controlled the more comfortable and safer the home becomes (Tiwari and Gedan, 2016; Diaa and Ahmed, 2018). Home appliances can be controlled through manual switches, short distance wireless remote control from a few meters away, and home automation systems which include smart phones, internet, and voice (Kundu *et al.*, 2020; Priyanka et al., 2018). Among the above methods, home automation system with mobile phones control and any of the communication protocols are more flexible and has the ability to control these home appliances from a far distance (Tiwari and Gedan, 2016; Majeed *et al*., 2020).

Automation could be a method or a technique in which electronic systems and communication protocols are used to reduce human involvement in certain operations to a minimum level for more flexibility, accuracy, and speed (Bawankunle *et al*, 2019). Different communication protocols for home automations include, Zibee, Z-wave, Bluetooth, Wi-Fi, Insteon, microwaves, infrared rays and radio frequency (RF), all of which come under wireless communication protocols (Bawankunle *et al*., 2019). The above-mentioned wireless communication protocols type of automation suffers the problem of short distance of coverage, which reduces the flexibility of controlling home appliances (Imam, 2020). Home automation using Dual Tone Multi-Frequent signaling solves this problem of short distance coverage, because home appliances can be controlled from anywhere around the world where there is a mobile phone service provider (Akpu *et al.,* 2018). However, using a mobile phone when it is convenient to use a manual switch could be a waste of resources therefore this paper combined the DTMF automation and manual switching for the control of home appliances. It works like a two-way switch in which one end is manual switch while the other end is automation control via DTMF signaling.

DTMF was developed in 1963 in Bell Lab, when it was used in push button analog telephony (Oluwole *et al*., 2021). It is a dual tone multi frequency signal that travels via a telephone voice channel from a transmitting phone to the receiver where it is received and decoded. Nowadays, DTMF signaling is also useful in telephone dialing, data entry, voice mail system, and remote control of other consumers' products (Oluwole *et al.*, 2021). Akpu *et al* (2018) carried out a research work titled Design of Home Automation System Using Global System for Mobile (G.S.M.) Communication. They successfully used Pic microcontroller to process the output of the DTMF decoder and controlled home appliances. According to their claim, when keys 1, 2, 3, or 4 of the cell phones were pressed, output socket one, two, three, and four powered on. When Keys 5, 6, 7, or 8 was pressed, output sockets one, two, three, and four powers off, but when # was pressed all the output sockets powered off. Diaa and Ahmed (2018) conducted research titled SHAS-IoT: Smart Home Automation System (SHAS) using Internet of Things (IoT) to Improve Safety and Security. They used smart phone with android application to control home appliances like lighting, heating, air conditioning, fire control system and doors. Kendu *et al.,* (2020) proposed the design and implementation of home automation, monitoring, and home security through internet of things (IoT). They focused on making smart wireless home security system that sends an e-mail with a picture to homeowner if any trespasser enters the home and also gives and alarm in case of fire. The system could control and monitor the house temperature, humidity, flames condition and all home devices from anywhere in the world. Their proposed system could control appliances via smart phones, voice and electrical switches. This type of system will be expensive for an average Nigerian therefore the proposed method in this paper needs to be simplified for affordability.

Tiwari and Gedan, (2016) did a paper review on home automation system based on internet of things technology. Their work focused on using Wi-Fi for communication between server and home appliances. Low-cost Wi-Fi module ESP8266 was used to build the smart unit. They stated that the user could remotely control home appliances via mobile application as the server was connected with relay hardware circuit that controls the appliances running at home. Shah *et al.*, (2021) employed a Raspberry PI in home automation to serve as a micro-controller and internet of things. The Raspberry PI was connected to server for internet. Temperature sensor (DHT11), smoke detector (MQ6), and Sonar sensor for measuring the depth of water were connected to the Raspberry PI. The sensors were used to sense the environmental condition of the home and report back the condition to the Raspberry as a micro controller which then operates relays to turn on or off a given appliances.

MATERIALS AND METHODS

MATERIALS

This section describes the materials/components that were employed to achieve the home automation using DTMF signaling as shown in circuit diagram below. Fig. 1 is the block diagram that contains different blocks of the system while the circuit diagram Fig. 2 contains different components of the system and their connection to one another.

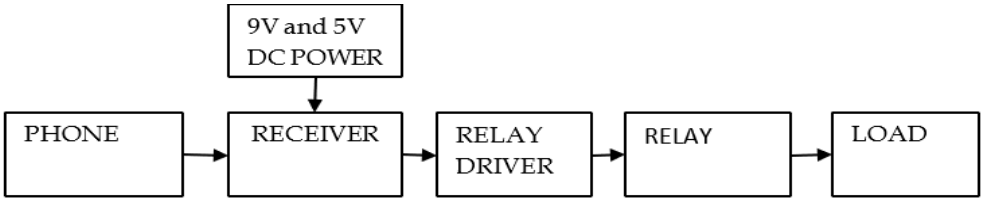

Fig.1 Block Diagram of the DTMF Home Automation System

Table-1 Components, Specifications and Quantity

S/N	Name of the component	Specification (Ratings)	Quantity
1	DTMF decoder	MT8870	1
2	Crystal oscillator	3.58MHZ	1
3	Darlington transistor	ULN2003A	1
4	Cell phones	Tecno	2
5	power adapter	5V	1
6	Aux cable		1
7	Capacitor C1	0.1uf	4
8	Capacitor	100uf	4
9	Resistor	100kΩ	1
10	Resistor	330kΩ	1
11	Resistor	1kΩ	4
12	Relay	4 in one relay module	1
13	Switch	Manual	4
14	Circuit board	Vero board	1
15	Testing board	2 in one	1
16	Connecting wires		3 roles
17	IC sockets		4

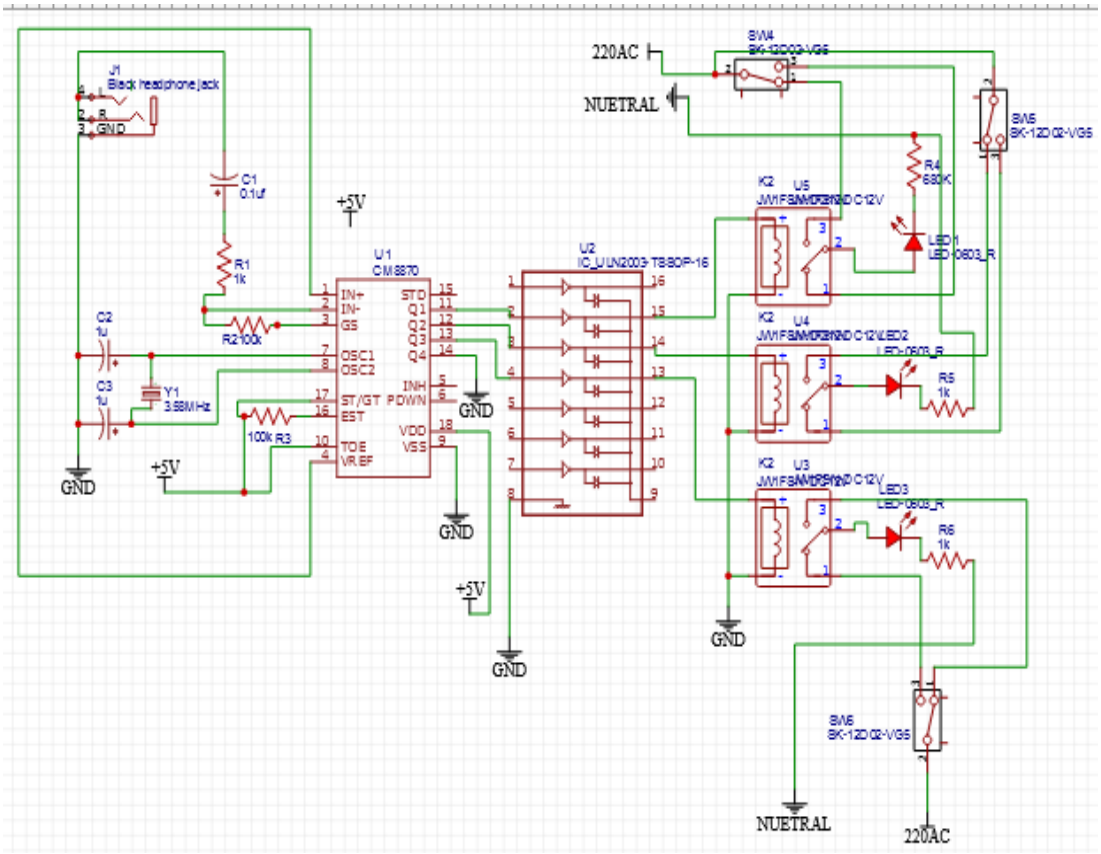

Fig. 2 Circuit diagram of DTMF Home Automation System

A. Mobile Cell Phone

Mobile cell phones were used as the transmitter and receiver in this study. The transmitting mobile phone generates different patterns of the Dual tone multi frequency signal (DTMF) when any of the keys is dialed. The receiving cell phone operates in automatic receives calls to automatically establish connection with the transmitting phone when it is called.

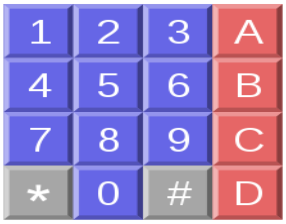

Fig. 3 DTMF Keypad Layout

B. DTMF Decoder (MT8870)

M T8870 decoder is a single 18 – pin Dip (Dual in line package) Integrated Circuit (IC) that receives any of the 16 DTMF tone pairs, separate the signal into its low and high frequency with the help of band split filter, decode the received signal and convert them to a 4-bit digital code (0s and 1s) which are distributed to the output pins of the IC accordingly. It is the digits (0 or 1) at any given output pin of the decoder that determines the state of the load connected to the pin. Fig. 5 shows the input and output pins of the MT8870 decoder while Fig 4 shows its internal structure.

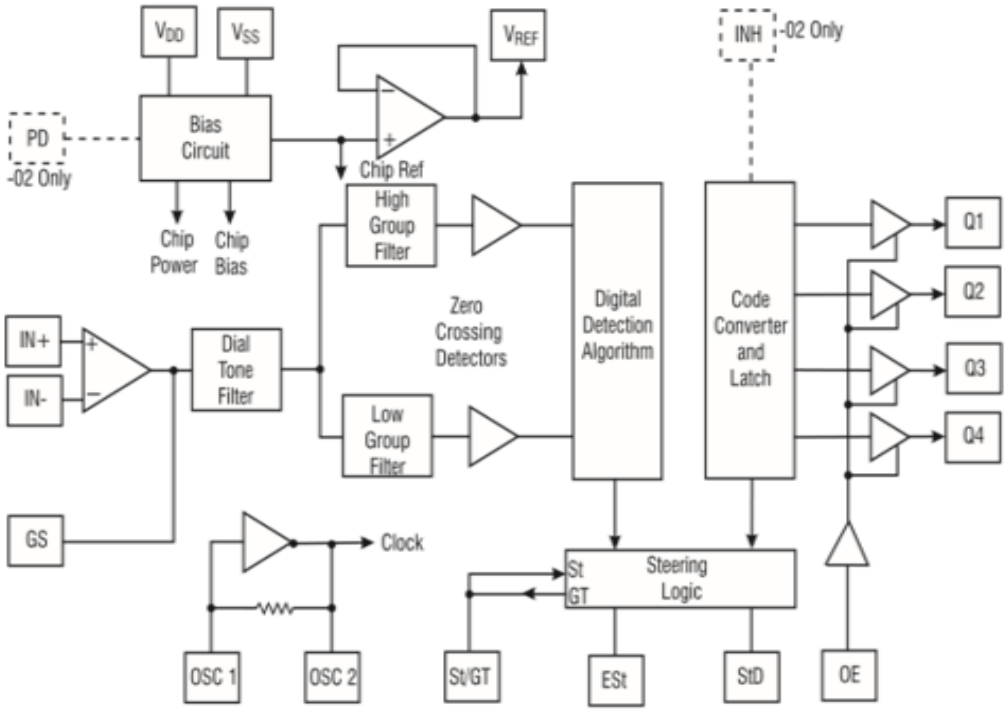

Fig. 4 Internal Structure of MT8870

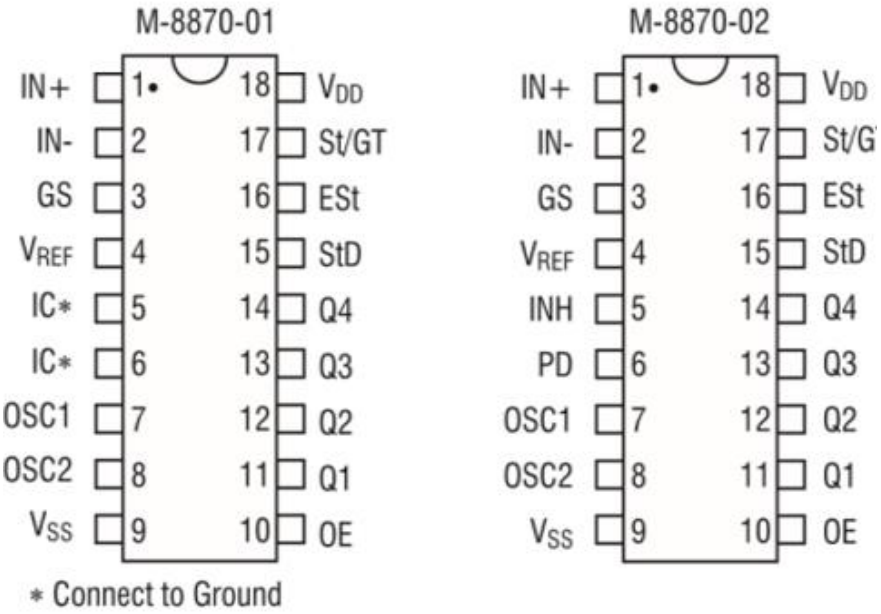

Fig. 5 Input and Output Pins of MT8870

C. ULN 2003

The ULN2003 is a unipolar Darlington pair IC that contains seven Darlington transistors pairs with each having its input pin on the left and its output pin on the right as shown in Fig. 6. It was employed in this work for current amplification so that the output current could drive loads with higher current rating like mottos in electric fans.

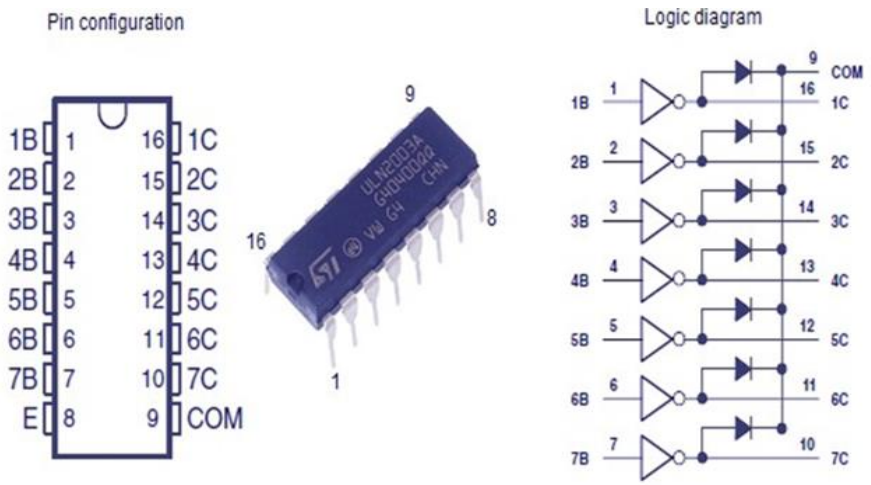

Fig. 6 ULN IC Input and Output Pins

D. Relay

Relay is an electronic automatic switch that uses the principle of electromagnetic induction to engage any load that is connected to its normally open terminal when the coil is energized with a DC current. The relay module used in this work contains four relays with some other components as shown in Fig. 7 below.

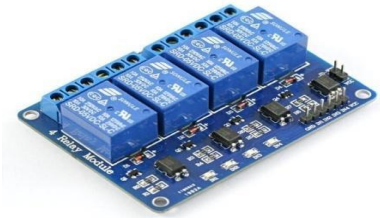

Fig. 7 Electronic Relay Module

METHOD

The method that was employed in this work was design and implementation method in which a prototype of the proposed system was designed, built and tested. In this method, the system was designed and connected to operate like a two-way switch in which one end is a normal toggle electrical switch and the other end the mobile phone (automation).

A. Design

The block diagram of the system was formulated according to the functions required from each section for proper function of the entire system. Firstly, DTMF tone signals have to be received by the proposed system and this gave rise to the first block termed phone or receiver. For the receiving function, mobile phone was chosen and the first block was called phone or receiver block as shown in Fig 1. Secondly, the received DTMF need to be processed and decoded into digital codes therefore the block that will handle the decoding function was termed decoder block. For the final output current from the decoder to drive inductive loads it must be amplified.

This led to the third block termed relay driver block. Moreover, the amplified current should be able to operate a switch by itself to make the system automatic; therefore, a section that will handle that was termed relay block. Lastly the load to be driven was termed the load block.

B. Components Selection

After the block diagram of the system, different components that will work together in order to meet the function of each block were chosen. The data sheets of all the chosen components were consulted for proper information on using each of the components.

C. External Components Calculation/Selection

Determining /Calculating the Value of the Timing Circuit Resistor R2

$$tGTP = RCLn\left[\frac{\text{Vdd}}{Vdd-VTst}\right] \quad (1)$$

$$tREC = tDP + tGTP \quad (2)$$

where,
$tGTP$= The validation periods
RC = Time constant
Vdd = Supply voltage
VTst = Threshold of the steering logic to register the tone pair
Ln = Natural Log
$tREC$= The minimum signal duration to be recognized by the receiver
Maximum V_{dd} for M 8870 IC = 5.25V
Minimum V_{dd} for M8870 IC = 5V
Minimum VTst for M 8870 IC = 2.2V
Maximum VTst for M8870 IC = 2.5V
Tdp for M8870 IC = minimum 5ms maximum 14ms
The maximum tREC = 40ms for M8870 IC
Chosen values;
Let tREC be 35ms for this project,
Let the 0. 1µ be chosen as capacitance of the timing circuit
From Eq. 1

$$tGTP = 0.1 \times 10^{-6} \times RLn\left[\frac{5.25}{5.25-2.5}\right] \quad (3)$$

$$tGTP = 0.1 \times 10^{-6} Rln[1 \cdot 90909091] \quad (4)$$

$$tGTP = 0.1 \times 10^{-6}\ R \times 6.46627165 \times 10^{-1} \quad (5)$$

$$tGTP = 6.46627165 \times 10^{-8} R \quad (6)$$

From Eq. 2

$$tGTP = tDP + tGTP$$

$$35 \times 10^{-3} = 14 \times 10^{-3} + tGT \quad (7)$$

$$35 \times 10^{-3} - 1410^{-3} \quad (8)$$

$$tGTP = 2.10000000 \times 10^{-2} \quad (9)$$

From Eq. 5

$$2.10000000X10^{-2} = 6.46627165X10^{-8}R$$

$$6.46627165X10^{-8}R = 2.10000000X10^{-2} \quad (10)$$

$$R_3 = \frac{2.10000000X10^{-2}}{6.46627165X10^{-8}} = 3.2476106X10^{5}\Omega \quad (11)$$

$$R_3 = 324.762106 \times 10^{3}$$

$$R_3 = 325\Omega$$

Resistor tolerance is 1%

Therefore; $\frac{1}{100} \times 325\Omega = 3.25 \times 10^{3}$ (12)

The above $3.25 \times 10^{3}\Omega$can be added or subtracted from the real value to give the value of the resistor

$$R_3 = 325X10^{3} + 3.25X10^{3}3 = 328\Omega \quad (13)$$

But since 328kΩ is not available the 330kΩ which is very close to the above value was used.

R_3=330kΩ

Umeozor *et al.*, (2022). ***The use of Dual Tone Multi-Frequency DTMF Signaling in Home Automation in Nigeria. Nigeria Journal of Engineering Science Research (NIJESR). 5(3), pp. 01-11***

D. Determination/Calculation of Values for R_4, R_5, R_6

R4, R5, R6 are used as current limiting resistors to limit the amount of current flowing into the led. However, a light emitting diode requires a maximum of 20mA for full extreme brightness or illumination. But in this project let 5mA be chosen to drive the LED. Using ohm's law, $R = \frac{V}{I}$ we can calculate the values. Voltage output of each pin of the IC is 5V.
Therefore,
V = 5V.
$R = \frac{220v}{20mA} 11K\Omega$.
Therefore R4= R5= R6 =$11K\Omega$

E. Selection of Feedback Resistor
Let the gain of the input differential amplifier be unity

$$A = \frac{R_2}{R_1} \quad (14)$$

$$R_2 = AR_1 \quad (15)$$

Let,
$R_1 = 100K\Omega \; and \; A = 1$
Therefore,
$R_2 = 1 \times 100 \times 10^3 = 100K\Omega$
But,
$R_2 = R_1$

E. Implementation

During the implementation of the proposed research the selected components were tested and the whole system placed on a testing board as shown in Fig. 8 below to confirm the workability before placing them to the permanent board for soldering. At this point LEDs were used to represent the loads. The placement of components was done according to the designed circuit diagram, in Fig. 2.

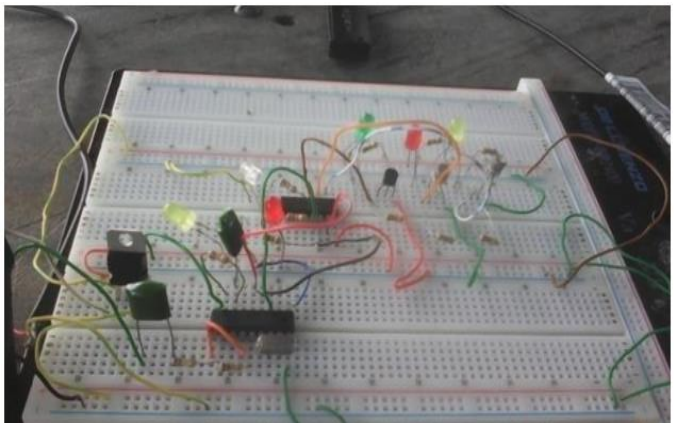

Fig. 8 DMTF Home Automation System built on Testing /Bread Board

RESULTS AND DISCUSSION

The results section presents and discussed the results obtained from the Home Automation System. The result of the design calculations is shown in Table-2. The result of the voltage measurement is shown in Table-3. The operation truth able that shows the result obtained by dialing different keys of the sending mobile phone is shown in Table-4.

Table-2 Results of the Design calculation

Resistors	Function	Resistance values(KΩ)
R_1	Input resistor	100
R_2	Feedback	100
R3	Timing resistor	330
R4	Current limiting	1
R5	Current limiting	1
R6	Current limiting	1

The result of the calculation as shown in Table-2 is the outcome of the calculation of the components values during the design phase. The validation period tGTP which is the period the DTMF signal will last to be validated depends on the RC circuit as shown in equation 1. The value of the capacitor C was chosen and the value of the resistor R was determined through series of calculations as shown in the design section (G and H) above. The time required to validate the DTMF signal can be varied by changing the value of the resistor R used in the RC circuit. In our case 330k was calculated and used. On the other hand, the feedback resistor R_2 was calculated using equation 14. The same value of R2 was chosen for R1. Current limiting resistors R4, R5 and R6 were determined using ohms law, and 20milliamps was chosen for good brightness of the light emitting diode.

Table-3 Powered, But Not in Operation Mode Voltage Readings on Decoders Pins

Pin No	Voltage (Volt)	Pin No	Voltage (volt)
Pin 1	2.44	Pin 10	5.03
Pin 2	2.44	Pin 11	0.00
Pin 3	2.49	Pin 12	0.00
Pin 4	2.44	Pin 13	0.00
Pin 5	0.00	Pin14	0.00
Pin 6	0.00	Pin 15	0.00
Pin 7	2.31	Pin 16	0.00
Pin8	2.49	Pin 17	0.00
Pin 9	0.00	Pin 18	4.96

The result in Table-3 shows the voltage measurements on the DTMF decoder pins, when the circuit was powered but not receiving a DTMF signal. This result shows that the circuit was turned on by showing voltage readings on input pins. However, the output pins; Pin 11, Pin 12, Pin 13 and Pin 14 were all zero indicating that no valid signal was latched to the output pins. This confirmed that there was no stray current flowing to the output pins to turn the appliances on when valid DTMF signal has not been received.

Table-4 the Operation Truth table of DTMTF Home Automation System

	DIGITAL OUTPUT PINS			
Mobile phones Keys	PIN 11	PIN 12	PIN 13	PIN 14
1	1	0	0	0
2	0	1	0	0
3	1	1	0	0
4	1	0	1	0
5	0	0	1	0
6	0	1	1	0
7	1	1	1	1
8	0	0	0	1
9	1	0	0	1
10	0	1	0	1

During the testing phase of the proposed system, it was first built on a testing board as shown in Figure 8 above and several tests were carried out before transferring them to a permanent board. However, the first test that was carried out on the system was an operation test. In the operation test the attached phone to the system at Okada was called from Akwa Ibom State, 400Km away, and the appliances connected to the system at Okada were operated, as shown in Fig. 9, Fig. 10, and Fig. 11. The system was also operated from the manual switch attached to the system, making it both manually and an automated controlled system. Table-4 is a truth table that shows the state of each connected appliances when the keys on the mobile phone were dialed in turns. In this work Pin 14 was grounded, because no appliance was connected to it. When key 1 on the phone keypad was pressed, Pin 11 was high which made only the first bulb to turn on. When key 2 was pressed, pin 12 was high and the rest low, only the second bulb turned on. When key 3 was pressed pin 11 and pin 12 were high and pin 13 low. This caused the first bulb and second bulb to turn on while only the third bulb was off. Pressing key 4 on the phone made pin 11 and pin 13 high and pin 12 low. Therefore, the first and third bulbs were turned on and the second bulb was off. Key 5 caused only pin 13 to go high and rest low, which made only the third bulb turned on with first and second bulb turned off. When key 6 was pressed it caused high on pin 12 and pin 13 but low on pin 11. This made the second and third bulbs to turn on while the first bulb was off. Key 7 turned all the three pins high and caused all the three bulbs turned on. Key 8 turned all the three bulbs off.

Fig.9 All bulbs off

Fig.10 First and third bulb on

Fig.11 First and second bulb on

CONCLUSION

The result obtained from the proposed system shows that the practical application of DTMF tones in home automation is very simple and cost effective. Despite the simplicity of this method of automation it can also be applied for great things in the area of farm automation and many far distance equipment controls. The proposed system was used to control home appliances both from far distance using mobile phone and from short distance using manual switch. The addition of manual switching to the system in this paper further reduced the system operation cost to the barest minimum.

CONFLICT OF INTEREST

I hereby declare that no conflict of interest is associated with this work.

REFERENCES

Aaditya G, S., Aashish G., Abhishek A., Ganesh K, S., (2021) Home Automation System. *International Research Journal of Modernization in Engineering Technology and Science* 3(4)1785 - 1789

Akpu, Maxwell O., 2 Akpu, Nwamaka I., and 1UMARU, I. (2018) Design of Home Automation System Using Global System for Mobile (G.S.M.) Communication International Journal of Innovative Scientific & Engineering Technologies Research, 6(1):32-38

Bawankunle et al. (2019). Home Automation System Using DTMF. *International Journal for scientific research and development, 7* (01), 56 - 58.

Diaa S.A., Ahmed, A, T., (2018) SHAS-IoT: Smart Home Automation System (SHAS) using Internet of Things (IoT) to Improve Safety and Security. *Research Journal of Applied Sciences*, 13: 209-215.

Imam S.A., (2020). Design and Implementation of a self-reliant home automation system. International Research Journal of Computer Science (IRJCS) ISSN: 2393-9842 Issue 10, Volume 07

Kendu, D., Abrahim, M.D.K., Tushar K.D., Abdullah A.M. (2020). Smart Home Automation System Using on IoT. *International Journal of Scientific and Engineering Research*, 11(6):697-701

Oluwole (2021). Application and Recent Development of DTMF Based Technology in Home Automation. *European Journal of Electrical Engineering and Computer Science, 5* (3), 60 - 65.

Priyanka et al. (2018). DTMF Home Without Using Microcontroller. *Int. J. Sc. Res. in Network Security and Communication, 6* (2).

Rizwan, M., Nurul A, A., Imran A, Y, B, Z., Muhammad, F, M., Muhammad, U., (2020) An Intelligent, Secure, and Smart Home Automation System. *Scientific Programming Towards a Smart World*

Tiwari, S., Gedan R., (2016). A Review Paper on Home Automation System Based on Internet of Things Technology. *International Research Journal of Engineering and Technology (IRJET)*, 3 (5) 1187 – 1190