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DESIGN AND DEVELOPMENT OF A DTMF BASED REMOTE HOME APPLIANCE CONTROLLER USING PIC16F873

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Abstract: *This paper discusses the design and implementation of the home appliances controller that uses a 'Dual-Tone Multi Frequency (DTMF)' signal from a home telephone. The system incorporates a microcontroller which interfaces with the DTMF decoder IC which transforms the 'DTMF signal' to binary and vice versa. This project aims to control the ON and OFF functions of household appliances using Dual-Tone Multi-Frequency (DTMF) signals. This device allows users to control electrical appliances at home simply through a telephone from anywhere. In addition, users can also turn on specific appliances in advance before returning home as a security measure. This device is also equipped with an alarm system that will be activated and automatically notify the owner via a phone call. To activate this device, users only need to make a call to their home and enter a password after twelve ringtones. If the entered password combination is correct, the user will be authorized to control the connected household appliances. The findings of the study indicate the device is capable of controlling the appliances in the house as it can transmit and receive signals from outside the house. This approach offers a user-friendly interface and utilizes existing telecommunication infrastructure, making it a viable alternative for smart home applications. Finally, through an experimental setup, the device was determined to be functioning optimally.*

Keywords: *DTMF, Home Appliances Controller, Microcontroller, IC8880, Home Automation*

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Introduction

Through home automation, a homeowner can proactively manage a device such as a homestead security system. Currently, these systems can be accessed and managed remotely, allowing users to physically step away from home without worrying about their security. Singh et al. Singh et al. (2014) and Abhadiomhen et al. (2021) have extensively discussed how remote-control capabilities enable homeowners to monitor and control security functions, such as surveillance systems and sensor-based detectors, thereby reducing the worry of leaving properties unattended. These studies emphasize that remote monitoring, which is often facilitated by technologies such as GSM, Wi-Fi, and IoT integration, is paramount in ensuring that users feel secure regardless of their physical location. Rahman et al. (2015) further support this perspective by describing how GSM technology can be utilized to remotely operate home security devices, ensuring real-time responsiveness to security breaches or environmental changes. Home automation is a new trend. Examples include devices like sliding gates controlled by infrared remote control, light sensors that turn lights on during the day, and wireless remote-controlled switches. The remarkable innovation of the time, Nikola Tesla patented a wireless remote control in the year 1898. He was able to send radio signals to a small boat which acted as the forerunner for modern remote boating (Correa, 2025). Various forms of home automation have been evolving since the Second World War until the present day. The advancement of DTMF home automation systems began in 1995 as the first telephone-based system used to control household appliances employed DTMF signaling. Through a computer, electric loops controlled the appliance on-off functions, but there were limits on the number of appliances that could be controlled, which depended on keypad inputs (Ameen, 2023).

Abubakar et al. (2020) developed a Home Automation System which enables SMS-based control of household appliances sent by a phone on a GSM Modem through a 'PIC16F88 Microcontroller'. Based on the study conducted by Nur-A-Alam et al. (2021), it was the purpose of this research to design an intelligent system which not only automates appliances but also allows for remote monitoring and controls them using 'LoRa' technology via a low powered battery and an Android application with a range of 3 to 12 km.

Problem statement

In today's lifestyle, many households face the recurring issue of ensuring that all electrical appliances are switched off when the premises are vacated. Forgetting to turn off appliances such as lights, fans, or other electrical devices can lead to significant consequences including fire hazards, electrical overloads, increased utility bills, and overall energy wastage. This is particularly concerning when individuals are far from home and unable to return promptly to rectify the situation. The need for a reliable solution to manage household appliances remotely has therefore become more critical than ever. Current smart home automation systems offer various methods for remote control and monitoring, often leveraging internet connectivity and modern IoT (Internet of Things) technologies. However, these systems tend to require complex configurations, high-speed internet access, and advanced hardware, which can be costly and difficult to maintain for the average user. In many regions, particularly rural or developing areas, access to reliable internet and modern infrastructure remains limited, making these solutions less feasible.

Moreover, many existing automation systems lack built-in security and alert mechanisms, such as notifying users of unauthorized access or abnormal conditions within the home. This highlights the importance of integrating a security component that can provide real-time alerts to homeowners during emergencies. To address these limitations, there is a need to develop a cost-effective, reliable, and user-friendly system that does not rely on internet access. Utilizing

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Dual-Tone Multi-Frequency (DTMF) signals through conventional telephone lines presents a practical solution. DTMF technology is widely available, simple to implement, and does not require additional infrastructure. A system based on DTMF, integrated with a microcontroller and alarm module, can enable users to remotely control appliances and receive notifications, offering both convenience and enhanced security for household management.

Based on this, the primary aim of this investigation is to create a device which enables a user in the household to manage different household devices through a landline telephone. The user can control the appliances by remotely activating the handset. Such designs have numerous advantages. For instance, controlling appliances remotely is an advantage since it can be done even in the absence of power in the house as long as power to the appliances is there. This paper contributes to the issue by presenting a new idea of design and technology for home appliances that can be controlled using telephones.

1) This system encompasses the installation and configuration of a microcontroller system that interfaces with a DTMF decoder (which converts DTMF signals), as well as its design and development. The microcontroller will subsequently transmit the information to the appliances so that they can be switched ON/OFF.
2) The security feature uses a password to implement user identification along with the caller identification to verify the user.

Many households face challenges in managing electrical appliances remotely, especially in areas with limited access to internet infrastructure or advanced IoT technologies. Existing smart home systems often require high-speed internet, complex configurations, and expensive hardware, making them inaccessible to users in rural or underdeveloped regions. Additionally, these systems frequently lack robust security features, such as user authentication or real-time alerts for unauthorized access. To address these limitations, there is a need for a cost-effective and reliable solution that does not rely on internet connectivity. Dual-Tone Multi-Frequency (DTMF) technology, which operates through conventional telephone lines, offers a practical alternative due to its simplicity, wide availability, and ease of implementation. By integrating DTMF signals with a microcontroller-based system, users can remotely control household appliances while benefiting from enhanced security features like password-based authentication and caller identification. Therefore, this paper discusses the design and implementation of the home appliances controller that uses a ‘Dual-Tone Multi Frequency (DTMF)’ signal from a home telephone**.**

Literature review

In the same year, Nasab et al. (2021) provided a new approach to managing home electricity consumption using cloud computing technology. Modern developments in web technology have made it possible to transmit signals from users' sites to any internet-connected devices. A web server composed of a controller, a webpage, an interface with hardware, and a programme managing the switch control of relays serves as the switching unit for the electrical circuits. A bit later, Stolojescu-Crisan et al. (2021) implemented a system using a web-based interface. The smart sensing units, wireless sensors, and even graphical user interfaces enabled the development of an automatic monitoring system that tracks household devices, as well as the real-time environmental parameters of the house. Furthermore, there is the mobile application which allows user command controls to manage information through the cloud data server. This system is reliable due to the ‘rational algorithms developed, good modularity, low power consumption, and cost-effective performance.

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The 'design of a standalone Arduino board with Bluetooth capabilities' served as the basis for the additional security layer added in 2011. One of the improvements made was to make certain that the system could not be accessed by anyone through the Bluetooth connection by enforcing a password. Nonetheless, one of the drawbacks to this feature is that Bluetooth has a maximum operational distance of between 10m and 100m (Mohammadi, 2021). When the connection between the system and a laptop or smartphone containing a GUI acting as a server for the messages exchanged between the 'smartphone' and the 'main control board' is established, bidirectional communication can take place (Bushnag, 2022). Zeyad (2022) investigated design and development issues of a 'Global Systems Mobile Messaging (SMS) Based Secured Device Control System' using 'AppInventor' for 'Android.' The aim of the system is to control a device via SMS through the GSM modem interfaced with the mobile phone.

Commands to smartphone applications are piped through the Raspberry Pi that handles shutter movement. The interface card's purpose was signal passing, designed to facilitate communication on the hierarchy that is the 'actuator's, sensors', and the Raspberry Pi card (Gupta, 2018). Shashank and Vincent describe an intelligent and secure office/home automation system for IoT devices that is controlled by a microcontroller. It incorporates multiple parts interfacing with a single microcontroller. It also controls the sensors that sense motion, light, and obstruction in pipes. Additional functionality includes assisting physically challenged individuals while managing power saving as well as controlling devices like gardening sockets. (Shashank, 2020) designed a DTMF controller to operate multiple relays for better 'efficiency of PV cells by regulating their open-circuit voltage' (Abdullah, 2020). There was the issue of unwanted noise interference when sending or receiving DTMF signals (Ahmad, 2020). In order to mitigate risks like short circuit, power overload or other potential hazards, all appliances have to be powered off before the house is vacated. This does not consider the situations where an appliance is automated or an appliance is left on by the user. Take a scenario where an individual is 15 kilometres away from their house, and suddenly remembers that one or several appliances are left powered on. If this person is too far away, he or she may not be able to travel back in a reasonable time. Modern day technologies can solve this issue. The method used in this project is a 'DTMF control system' activated by a phone call. This system can be accessed through any landline or mobile phone. Moreover, the user is not exposed to any form of radiation from the system at any time.

Methodology

Controller design

In Figure 1, the high-level block diagram of the DTMF remote switching system is displayed.' To switch the household appliances on and off with DTMF signals, a remote control in the form of a landline or mobile phone is mandatory. DTMF signal commands will be enabled through remote access.

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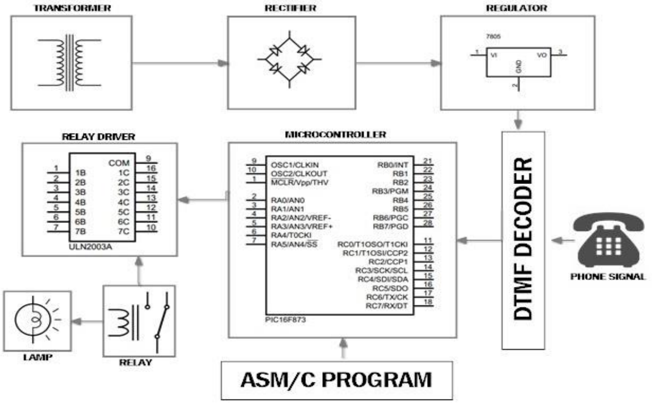

Figure 1: Block Diagram of Home Appliances Controller

The Home Control System can be partitioned into three constituent parts which are the DTMF Communication Unit, Central Control Unit, and Client Appliances Unit.

A. 'DTMF Communication Unit'

The Home Appliances Controller receives DTMF signals from a conventional telephone. There is a basic communication circuit that interfaces the 'DTMF' signals from the telephone to the transceiver. The 'DTMF Communication Circuit,' is seen in the 'schematic of Figure 2, while in Figure 3 it is shown connecting to the DTMF Communication Unit.

A standard telephone has a wiring configuration consisting of 'two wires: red and green.' The former is the ring wire, and the latter is the tip wire. As shown in Figure 2, there exist two connectors, each with a pair of wires representing the tip and ring of port 1 and port 2. The Home Appliances Controller connects all these ports in parallel, which ensures they do not interfere with the telephone system.

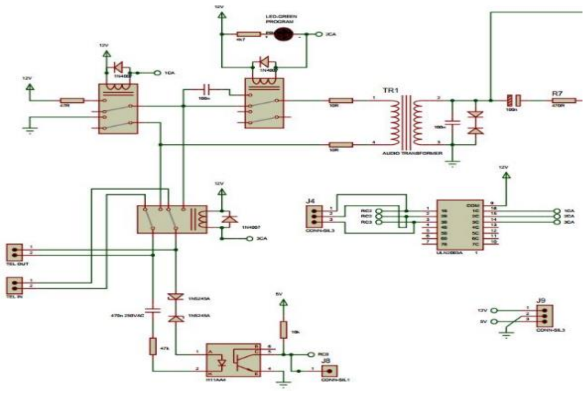

Figure 2: Telephone Interface Circuit

When one dials the number linked with the telephone integrated with the controller of the Home Appliances Supervision System, their mobile phone is set to ring. At this time, an optocoupler known as H11AA4 will act as a counter to keep track of the ringing count and it will count it up to twelve. Upon achieving the set value, the 'ring controller at pin RC1 will generate a logic high pulse to 'switch ON the ONLINE LED' which indicates which confirms that the system is in online mode.'

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Within this diagram, the function of the audio transformer located within the circuit is that of a magnetic barrier which electrically isolates the 'DTMF' decoder from the telephone line. Its impedances are 600Ω/470Ω thus shutting off the system ground and telephone ground. Therefore, the 'DTMF decoder shown in Figure 3 does not receive any undesired signal distortion from any other sources.

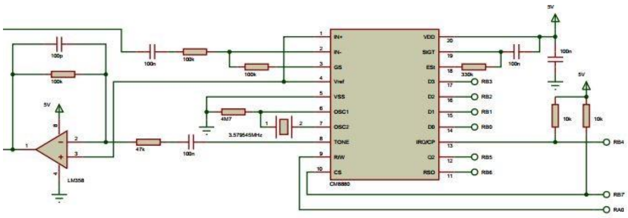

Figure 3: DTMF Communication Unit Circuit

The DTMF Communication Unit circuit employed an 'IC 8880 DTMF decoder' which decodes the 'DTMF' signals received over the telephone line and generates corresponding 4-bit binary outputs at pins '14-17 (D0, D1, D2, D3)' which were interfaced to the 'PIC' at ports 'RB0, RB1, RB2, and RB3.' The 'IC8880' will decode the entered keypad by the caller and determined by the pre-programmed logic on 'PIC16F873.'With the use of 'a signal conditioning circuit' which comprises an 'operational amplifier' configured for unity gain feedback with the input biased at '1/2VDD,' the requirement of the 'DTMF' decoder's clock circuit is satisfied by adding a 'burst CMOS crystal oscillator with a nominal frequency of 3.579545 MHz.

B. 'Central Control Unit'

In this system, the crucial component is the PIC16F873. The wiring of the 'PIC' controller to other parts of the circuit is given in Figure 4. This specific microcontroller has three ports comprising '22 I/O pins' altogether. Each port may be programmed as an input or an output depending on the instructions given in the program. Given the case of using 'PIC16F873,' there are 'two input ports and one output port' [18].

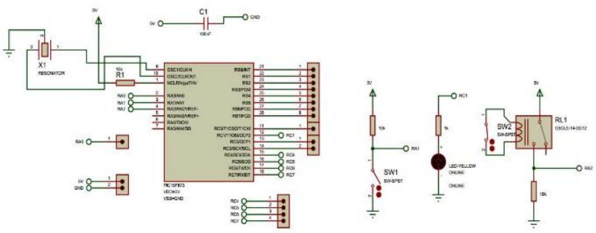

Figure 4: Central Control Unit Circuit

The 'microcontroller' remains idle until it receives appropriate feedback from the optocoupler on whether the specified number of rings has been reached with respect to the incoming call. In case the required password is not entered after 15 seconds, the user is restricted from accessing the system blindly or by entering a wrong combination. The system in question requires that access is granted only upon entering the correct password. The home appliances can be operated using the correct alphanumeric password, with control granted through appropriate buttons on the keypad corresponding to the numbers presented in Table 1. The specified 'RC' connections will be elevated to a high status enabling the microphone controller to energise the relay driver incorporated in the 'Client Appliances Unit' circuit.

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Table 1: User's Home Control System Number Code

'Code'	'Description'	'Operation'
'xxxx#'	'Enter default'	'Home'
'11#'	'LED 1 or Bulb 1'	'Status ON'
'21#'	'LED 2 or Bulb 2'	'Status ON'
'31#'	'LED 3 or Bulb 3'	'Status ON'
'41#'	'LED 4 or AC Fan'	'Status ON'
'10#'	'LED 1 or Bulb 1'	'Status OFF'
'20#'	'LED 2 or Bulb 2'	'Status OFF'
'30#'	'LED 3 or Bulb 3'	'Status OFF'
'40#'	'LED 4 or AC Fan'	'Status OFF'

This project includes an extra function of an anti-burglar alarm system which will automatically call the designated phone number of the user. The system will enter the programme mode when the user pushes the button 'SW1' which will generate 'a high input signal to RA1.' According to the triangle programme logic flow chart, the microcontroller will activate pin 'RC2' and light the programme 'LED' indicating the user is in programme mode. In programme mode, the user may set custom reminder telephone numbers. The user's input is stored in the EEPROM of the microcontroller.

C. 'Client Appliances Unit'

The Command Appliance control subsystem is managed by the Client Appliances Unit control circuit. It can be any appliance such as lights, fans, air-conditioners, motors, etc. The appliance control unit will 'ENABLE' or 'DISABLE' a specific unit on the relay. As previously mentioned, only 4 relays are able to be used in this system. Hence, it will control four loads, three bulbs and a fan. The relay is OFF/ON in this configuration, i.e. will be turned ON/OFF by the ULN2003 Controller through the switching Transistor. Figure 5 shows the connections for the relay system.

The system is equipped with four relays, each designated to command one load. The appliances can be plugged into the system's terminal block. The relays are linked to 'NO (Normally Open)' pins which means one wire from the corresponding wire needs to be wired to the relay common while the other wire hooks up into connected with 'NC (Normally Closed)' contact.

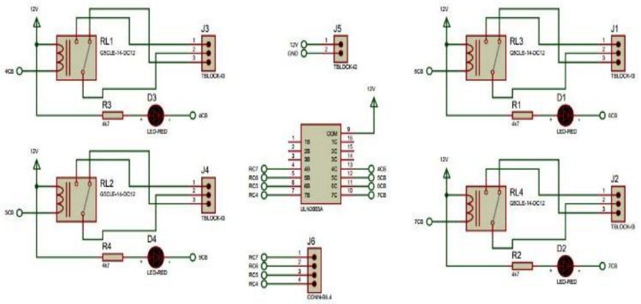

Figure 5: Client Appliances Unit Circuit

Upon reception of the 'decoded signal from the caller keypad,' the 'microcontroller' will make a decision on 'which load to turn ON/OFF.' The input from the 'microcontroller' would be set to high on the ULN2003 which will switch on the coil and energise the armature, consequently enabling the load since the connection will now be a short circuit.

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Software design

The design phase of the software begins here. This is the phase which involves designing the algorithm for the main programme. The entire system development can be aided using a flowchart of the system's process flow.

The programme is crafted through the MPASM Assembler via the MPLAB X IDE using assembly language. The process of software design starts with a function prototype and some essential subroutines such as the delay subroutine. The EEPROM had already been programmed with several functions that included password decoding, output port decoding, password storage, tone generation, and alarm activation.

To activate the system, the user simply dials the telephone linked to the system. The system scans for input while in standby mode. When the system receives a ringing signal, the signal will be scanned by 'H11AA4.' However, the input port of the controller will only be enabled after eight ring tones have been detected. The system will enter 'Online mode' and the 'Online LED' will be activated simultaneously. The system will automatically hang up after 15 seconds if no DTMF signals are detected from the caller. This is to ensure that the line is free to receive other incoming calls.

Once the DTMF signal combination is properly entered, the 'EEPROM will decode the password' and send a command to the 'microcontroller.' The user must enter the correct output port combination for the system to identify which relay it is supposed to process. If 'key 1is pressed, then relay 1 will be attended to.' In case there is no combination code or an invalid combination is entered, the system will, in any case, disconnect and switch the system offline.

Experimental results

In order to verify the operation of the 'DTMF decoder, the chip is mounted onto the breadboard enabling D0, D1, D2, and D3 outputs to power 4 LEDs' which visually indicate the binary number corresponding to the pressed button. The primary goal of these experiments is to determine whether the decoder is properly configured. An external phone jack was used to input the DTMF signal into the telephone circuit.

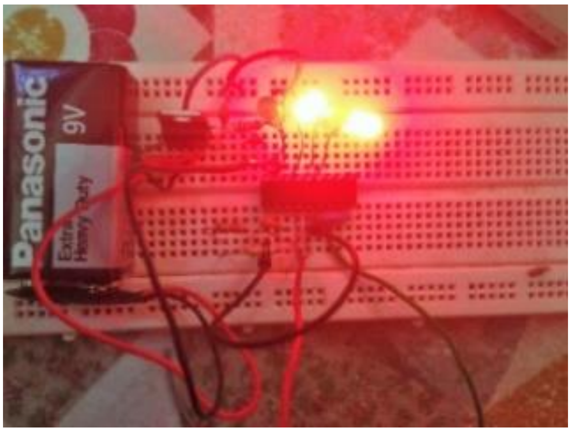

Figure 6: Testing IC8880 circuit connection

The controller in question is limited to a maximum input voltage of 5V; exceeding this threshold may result in adverse effects. In order to avoid this, we connected an LM7805 IC regulator to a 9V battery. The LM7805 automatically sets the output voltage to +5V, which is the value needed by the controller. The first pin of the 9V battery goes to the input pin of the regulator

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and the second pin acts as the system ground. The last pin is the output, which is used to supply the VDD.

Table 2: The DTMF data into BCD digits [17]

‘Flow’	‘Fhigh’	‘Key’	‘Q4’	‘Q3’	‘Q2’	‘Q1’
‘697’	‘1209’	‘1’	‘0’	‘0’	‘0’	‘1’
‘697’	‘1336’	‘2’	‘0’	‘0’	‘1’	‘0’
‘697’	‘1477’	‘3’	‘0’	‘0’	‘1’	‘1’
‘770’	‘1209’	‘4’	‘0’	‘1’	‘0’	‘0’
‘770’	‘1336’	‘5’	‘0’	‘1’	‘0’	‘1’
‘770’	‘1477’	‘6’	‘0’	‘1’	‘1’	‘0’
‘852’	‘1209’	‘7’	‘0’	‘1’	‘1’	‘1’
‘852’	‘1336’	‘8’	‘1’	‘0’	‘0’	‘0’
‘852’	‘1477’	‘9’	‘1’	‘0’	‘0’	‘1’
941	1209	0’	1	0	1	0
941	1336	*	1	0	1	1
941	1477	# A B C D	1	1	0	0
697	1633		1	1	0	1
770	1633		1	1	1	0
852	1633		1	1	1	1
941	1633		0	0	0	0

In Figure 6 indicates how the ‘LED output indicated that the keypad was pressed as 0101,’ starting from the ‘leftmost LED.’ The ‘DTMF signal will be processed into a 4-bit BCD format.’ An LED will be turned on for every output increment, one per step sequentially. For value ‘0101,’ it is the output ‘5’ on the ‘3x4 matrix keypad.’ The output is captured in ‘Table 3 below.’ Compared to the expected results shown in Table 2, this is still an acceptable outcome however. Hence, this controller can confidently, without risk, integrate into the design of this project in any aspect.

Table 3: The result of the DTMF digits

‘Key’	‘D3’	‘D2’	‘D1’	‘D0’
‘1’	‘0’	‘0’	‘0’	‘1’
‘2’	‘0’	‘0’	‘1’	‘0’
‘3’	‘0’	‘0’	‘1’	‘1’
‘4’	‘0’	‘1’	‘0’	‘0’
5	0	1	0	1
6	0	1	1	0
7	0	1	1	1

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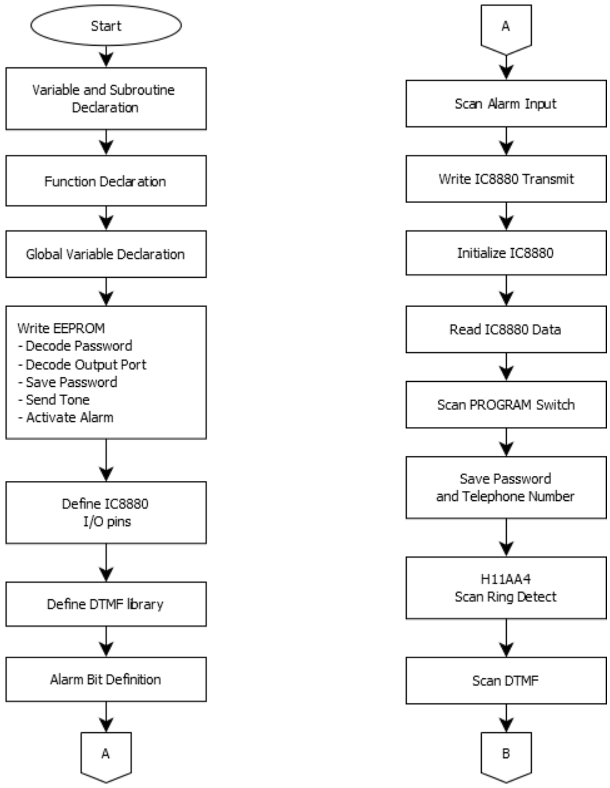

Figure 7: Program Process Flow

The 'microcontroller' is tested using 'PICkit3 as the programmer hardware.' It is vital to check if the PIC performs its functions or is broken beforehand. Currently, the credibility of the PIC is being verified with a simple test of blinking an LED. Successful execution of the 'LED blinking' programme is demonstrated in the next figure. The successful execution of the LED programme indicates that the PIC is in good condition and is ready for programmed data to be uploaded into its memory.

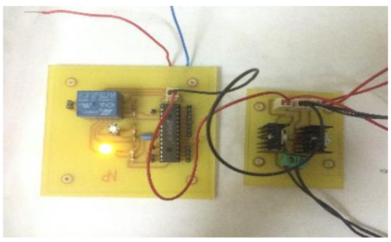

Figure 8: Testing programmed blinking LED

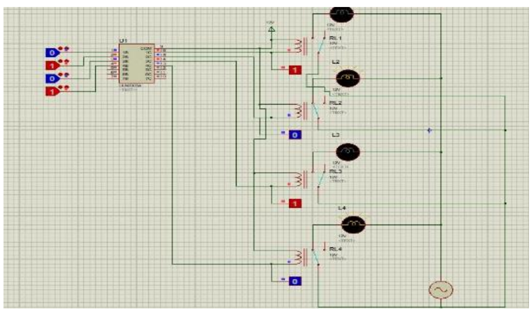

Figure 9: 'Simulating relay with AC load'

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The 'output of the simulation is displayed in Figure 9.' It is noted that the output ULN2003 receives should be high, meaning there is no 12V relay voltage at the moment. In this case, the ULN2003 logic gate will have a high output. Moreover, since the relay voltage does not reach the high state level, it will do nothing for now. The NOT gate performs its function. For logic three state ULN2003 when the input is high, it is necessary to force low output to active state level and then the 12V coil relay will close to flow to lower state level which will turn on the coil. Thus, one end of the high voltage load is short circuit connected and also cut connected to the armature will rotate to turn off the supply to the high load at the high position.

Now, an experiment on the relay by using the high voltage load are done carefully. The load used for this experiment is an AC fan that having two wires with it. One of the wires is connected to the LIFE wire and the other one is connected to the normally opened contact. The NEUTRAL wire leads to the Common pin of the relay. Connecting the AC fan will complete the circuits when the relay coil is powered on.

Home Appliances Controller program has a complex structure of various functions including the subroutines function such as cycles, condition relations and delays. The programme operates in an infinite loop which means that it gets stuck in the 'MAIN loop' where it continuously looks actively for inputs when the microcontroller is powered up.

In 'ONLINE mode, the microcontroller will increment the variable up to 1500, which equates to 15 seconds unless interrupts from the DTMF decoder are detected.' When the microcontroller hits '1500' without having received any 'DTMF' tone from a caller, the system ends the call and switches to standby mode, awaiting the next ring. Remote number pressing on the phone will be translated by the 'DTMF decoder' which will output the corresponding '4-bit code' to the microcontroller.

The 'PIC16F873 will now skip straight to the DECODE'cycles and recognition of 4-bit code relative to the given head values.' If the code is recognised, the programme will jump to do certain tasks and perform them. Each time the programme manages to execute its tasks without running into any errors, it will repeatedly compile the tasks and create a file with the 'suffix .hex.' This 'file is the result of the execution of the programme and needs to be burned into the PIC16F873.'

Conclusion

The study developed and designed a home appliances controller which can remotely operate the devices through DTMF signals from the telephone network while observing safety precautions. Operational precautions were also added to the systems to further improve safety. In addition, the controller can be used without power at home, as long as the devices are powered. This project successfully demonstrated the design and development of a home appliance controller system based on Dual-Tone Multi-Frequency (DTMF) technology. The system enables remote control of household electrical devices using a traditional landline or mobile phone, offering a simple yet effective method without requiring internet connectivity. The integration of the PIC16F873 microcontroller and DTMF decoder IC8880 allows the decoding of input signals and execution of ON/OFF functions for various appliances.One of the notable features of the system is its security mechanism, which requires users to enter a password after a predefined number of ring tones, ensuring only authorized individuals can access the control system. Additionally, the inclusion of an alarm system that notifies the user via a phone call enhances the safety aspect of the design.The experimental results confirmed

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the system's effectiveness, with successful signal decoding, command execution, and reliable switching operations.

Moreover, the system provides a cost-effective, user-friendly alternative to more complex IoT-based smart home systems, especially in areas with limited internet infrastructure. Moving forward, the project can be expanded by integrating IoT-based technologies and cloud platforms to enhance scalability, monitoring, and data logging capabilities. This DTM based approach has laid a solid foundation for secure, accessible, and smart home automation.

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