Development of Home Appliances Controller with DTMF Signal

N.A.A. Nawir, A.S.M. Isira , N.A.M. Yunus, A.A. Basari
Centre for Telecommunication Research & Innovation (CeTRI), Fakulti Kejuruteraan Elektronik dan Kejuruteraan Komputer (FKEKK), Universiti Teknikal Malaysia Melaka (UTeM), 76100, Durian Tunggal, Melaka, Malaysia
sadhiqin@utem.edu.my

***Abstract*— This paper presents the development of home appliances controller design that utilizes Dual-Tone Multi Frequency (DTMF) signal from the landline telephone. The device contains microcontroller that links with a decoder IC that converts DTMF signal into binary codes and vice versa. It is proven that the device enables residents to send and receive signal from outside the house; thus enabling them to control the appliances at home. Finally, the results from an experimental setup found that the device is proven to be working.**

***Index Terms*—Dual-Tone Multi Frequency (DTMF); Home Appliances; Controller;**

I. INTRODUCTION

Home automation is a modern technology that gives homeowner the ability to take action and control the device, and place security system; hence, providing convenience for the homeowners even when they are not being physically in the house. This device is becoming more popular nowadays and among the common examples of these applications are the infrared remote control, light-activated switch on the lighting system on the road and wireless remote control switches for the automated sliding gate.

This area of interest has been in existence since the World War 1 (1914), where the wireless remote control was first patented and unveiled by Nikola Tesla in 1898, when he controlled a miniature boat using radio waves [1]. Since then, after the Second World War, numerous types of home automation system have been evolving rapidly until today. The first Home Automation existed in 1995. Depending on telephone line, this device used a system based on DTMF signals that could be sent through a loop of wire to switch ON/OFF the home appliances using a personal computer. However, the system has limitation, in which the number of appliances were limited by the number of keys in the keypad [2].

Rozita et.al. implemented the home automation device through Short Message Service (SMS) text messages using Global System for Mobile Communication (GSM) modem to control home appliances that allows users to control for afar using the frequency bandwidths by using PIC16F88 [3]. In the same year, Onukwugha et.al presented a remote control of home appliances that uses a mobile phone in a ubiquitous environment. This device requires no other phone at the receiving end and it can communicate with a controller with multiple ports [4].

In the same year, another work had been presented by Marvin R. G. Garcia. This work introduced an electricity management for smart home through cloud computing [5]. This work utilises the ability of web technology in sending and transmitting signal from the user anywhere to any electrical devices that are connected to the Internet. The proposed system is composed of a web server as the controller, website, hardware interface and a software application to monitor the electrical switch control. Subsequently, a system using web-based interface has been implemented by T. Gabriele, L. Pantoli, and V. Stomelli. They focused on the development of a fully real-time monitor of household appliances and home environmental parameters by using smart sensing unit, wireless sensors and actuators, and a Web-based interface. It uses cloud-based data server which manages the information and provides services for users by transmitting data and receiving user's commands from mobile application [6]. This system has advantages on the reliability of the developed algorithms. It also has a good modularity, low power consumption and system cost efficiency.

A design based on a standalone Arduino board with a Bluetooth was developed in 2011, where this system has added security features. One of the features is Bluetooth, which is password protected to ensure that the system is secure from any intruders. But the drawback is that the Bluetooth working range is only within a small area, which is 10m to 100m only [7]. In 2015, Shirisha Tadoju and J. Mahesh designed a remote switching control system for home automation via android phone application using Bluetooth technology to help fulfil the needs of the elderly and disable persons at home. The Bluetooth enables the system to communicate on the laptop or smartphone with the Graphical User Interface (GUI) that acts as a server to transmit data from or to the smartphone and main control board after they had been connected [8]. R. Harinath and S. Santhi had focused on the design and implementation of Global System Messaging (SMS) based secured device control system using App-Inventor for Android mobile phones. The purpose of this system is to use the inbuilt SMS facility of a mobile phone and GSM Modem [9].

Nowadays, most home automation system is using Wi-Fi technology. Hayet Lamine and Hafedh Abid had developed an application based on the Android system. To ensure the communication between the remote user, server, raspberry Pi card and the home appliances, they developed an interface card (an application) that was installed on an Android Smartphone, a web server, and a Raspberry Pi card to control the shutter of windows. The smartphone with the Android application was used to issue command to a Raspberry Pi card. The interface card has been used to update signals between the actuator sensors and the raspberry Pi card [10].

In 2007, a safe and secure way of intelligent home automation that uses PIC controller and DTMF technology had been presented, where A pin-check algorithm had been introduced in order to broaden its security [11]. R.Ghosh [12] designed a system to control the operation of multiple relays and to improve the efficiency of PV cell by regulating the open circuit voltage of the cell using DTMF based controller. One of the limitations of the suggested method in [12] was the unwanted noise problem, while sending or receiving the DTMF signals [13].

For safety precautions, before leaving the house, all of the appliances need to be turned off to avoid short circuit, power overload and etc. However, there are times when the appliances were left switched on by the user when they are, for example 15km away from home. The user might not be able to return to their home if the distance is too far.

Recent technologies make it possible to solve this problem. In this project, DTMF control system is chosen where it can be used as a switch to control the appliances remotely by just picking and dialling up the phone. This technology can work from anywhere as long as there is a landline telephone. It can also be controlled from any mobile phone, and it is completely safe from radiation.

Therefore, the main objective of this project is to design and develop a device that allows the user to remotely control and monitor multiple home appliances using landline telephone. It can control home appliances by switching them ON/OFF from outside. The main advantage of this design is that the user is possible to control the home appliances even without any power at home as long as the appliances are with power. The main contributions of this paper are as follow:

1) The design and development of this system includes the setup and programming of a microcontroller connected to a DTMF decoder that converts DTMF signal. The microcontroller then will carry the information to the appliances to switch them ON/OFF.

2) User identification is implemented by combining caller identification with an authorized password as the security measure.

The rest of the paper is arranged as follows. Section II provides the fundamental knowledge and problem statement of the design. Next, Section III presents the design and development of the controller proposed in this paper. In Section IV the software aspects of this controller is explained. Section V provides the experimental outcome of the designed controller and Section VI concludes the paper.

II. DTMF FUNDAMENTALS

This project work focuses on the ability to switch ON/OFF any electrical appliance remotely and automatically. The electrical appliances are limited to the household appliances; 3 bulbs and 1 alternate current fan. It has the ability to be controlled from anywhere as long as the user has a working telephone network. The scopes of this project are concentrating on this following diagram as shown in Figure 1 below.

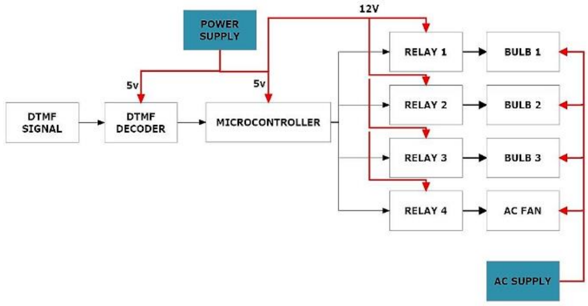

Figure 1: Scope of Work Diagram

As can be seen from the block diagram above, the power supply produces two main output voltage, which are the 12V for relays and 5V for DTMF decoder IC8880 and the microcontroller PIC16F873. The DTMF transceiver, IC8880 is used as the decoder to translate the DTMF signal that is transmitted by the user into binary numbers as the inputs to the microcontroller PIC16F873.

The telephone that is programmed by the microcontroller will be automatically answered on the twelve rings and the ONLINE LED will be turned on to indicate the Home Control System (HCS) is in the active state. Then, the user needs to enter 4-digit password in order to activate HCS and then send the command through the keypad number to be executed by the microcontroller, as shown in Table 1.

Table 1
User's Home Control System (HCS) Number Code

Code	Description	Operation
xxxx#	Enter default password. (2345#)	HCS become active
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

For safety purpose, this system comes with a default password: 2345. After receiving the correct combination number, the HCS will become active. However, if the user wants to change the combination number, they can change it by activating the PROGRAM mode.

The IC8880 can transmit and receive the signal to be used as an alarm trigger. Once the signal is received, the limit switch activates the alarm system and the microprocessor will send a signal to call the user phone. For this to happen, the user needs to set the phone number in the HCS program.

The last part of the HCS is the Client Appliances Unit (CAU), which consists of four relays: Each are connected together and powered by AC power supply. They act as the switching devices with normal open (NO) contact. Whenever the microcontroller sends high input commands to the relays, they will be activated, which is to turn on the home appliances until low inputs are received.

Dual-Tone Multi-Frequency or DTMF, in short, is a technique of signalling used for telecommunications between one telephone to another telephone or other communication devices like mobile devices. DTMF generation is a composite audio signal of two tones between the frequency of 679Hz and 1633Hz. The DTMF keypad is arranged such that each row will have its own unique tone frequency and each column will have its own unique tone [14].

A representation of the typical DTMF keypad with the associated row or column frequencies is shown in Figure 2. DTMF generations are based on this 4x4 keypad matrix that represents 16 DTMF signals, which include the numbers from 0 to 9, special keys of ∗ and # and the four-letter A to D normally used for the military purpose that needs to have their own special secured communication systems. DTMF signal is generally based on eight different frequencies, in which each of the four frequencies represent the low group frequencies (697Hz, 770Hz, 852Hz and 941Hz) and the high group frequencies (1209Hz, 1366Hz, 1477Hz and 1633Hz) [15].

Figure 2: 4x4 Matrix Keypad [15]

Each DTMF signal is a combination of two signals that are generated simultaneously when pressing the number according to the finding of Formula 1. By pressing a key, for example, number 2, it will generate a dual tone that consists of 697 Hz for the low group, and 1336 Hz for the high group. The tone frequencies are selected such that harmonics and intermodulation products will not cause an unreliable signal. Figure 3 shows the illustration of the frequency spectrum in which each tone must fall within the proper bandpass before a valid decode take place. If one, or both tones falls outside the spectrum bandpass, the decoder becomes unreliable or non-operational [16].

DTMF signal can be expressed by (1) [16]:

$$f(t) = A_0 \sin(2\pi f_a t) + B_0 \sin(2\pi f_b t) \quad (1)$$

where

f_a, f_b are two different voice frequencies.

A_0, B_0 are the peak amplitude of the two signals.

f is the resultant frequency for the DTMF signal.

f_a is for the low frequency group and f_b is for the high frequency group.

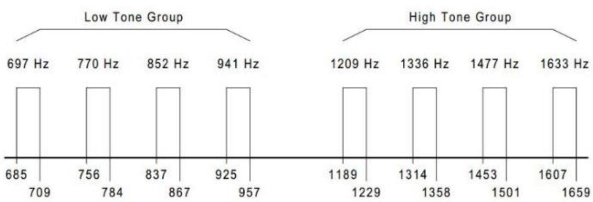

Figure 3: DTMF Frequency Spectrum [16]

The combination of the two frequencies can be seen in Figure 4.

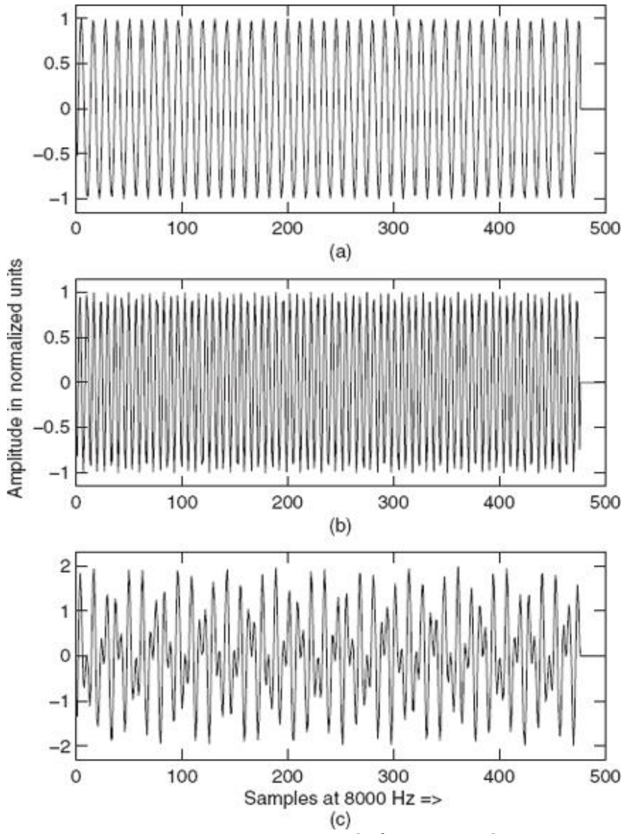

Figure 4: Digit-1 tone generation example for 320 samples, 40ms. (a) Row tone at 697Hz at unity amplitude. (b) Column tone at 1209 Hz at unity amplitude. (c) Combined tones for digit-1 [16].

The following explains the function of the DTMF Communication Unit (DCU). It is the first unit from the DTMF HCS used to decode and convert the DTMF signal produced when the keypad number is pressed. The signals are decoded to 4-bit nibble data by using IC8880 chip connected to Central Control Unit (CPU).

DCU is where the detection and decoding of the DTMF signal takes place. This unit will only consider the DTMF signal that is paired with the validated low and high tone frequencies.

DTMF needs to differentiate the correct silence between the tones. This specific requirement needs to be fulfilled to prevent false alarm by identifying noise as a signal instead of detecting the different levels of signals. This level of differences of signals is called the twist. The high-frequency tone may be received at a lower level than the low-frequency tone due to the magnitude response of the communication channel, which is known as a forward twist. The reverse twist is the other identified difference where the received low-frequency tone has a lower level than the high-frequency tone [15]. The DTMF decoder needs a receiver that is able to avoid mistakenly identified speech signal as valid DTMF to become a good decoder. The ability to distinguish between the speech and the DTMF signal is referred to the talk-off performance [15] [16].

The user can control the HCS by dialling the telephone's the number connected to the circuit. The telephone is programmed to be auto answer so that the caller can send the DTMF signal by pressing the keypad button.

The separated signals will be channelled to two digital filters to decode the exact tone. Since these digital filters operate with internal clock signals, it needs to have a clock oscillator that has the accurate and stable frequency to ensure consistent filtering and decoding [16]. As shown in Figure 5, the clock source for this decoders is an external colour burst crystal with the value of 3.5795 MHz, which is connected to the OSC1 and OSC2 integrated circuit pins.

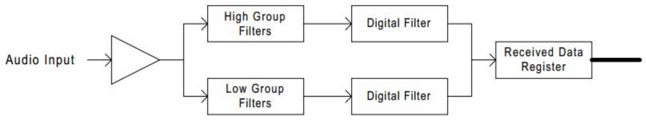

Figure 5: The DTMF Detection Filter Scheme [16]

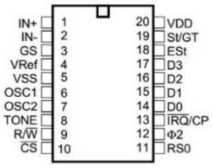

Figure 6: The IC8880 DTMF Decoder [17]

DTMF IC8880 is a microprocessor system that comes with a fully integrated DTMF transceiver on a chip. It can be configured to send or receive "touch" tones used in many phone and radio communication systems. Communication with the IC8880 takes place over a 4-bit bus, consisting D0 through D_3, with three additional bits used for the operation modes selection, which are the chip select (CS), read/write (RW) and register select (RS0) [17].

The DTMF decoder uses digital counting techniques to detect and decode all 16 DTMF tone pairs into a 4-bit binary coded decimal (BCD) numbers as shown in Table 2, and the schematic diagram provided by California Micro Devices in Figure 7 [17].

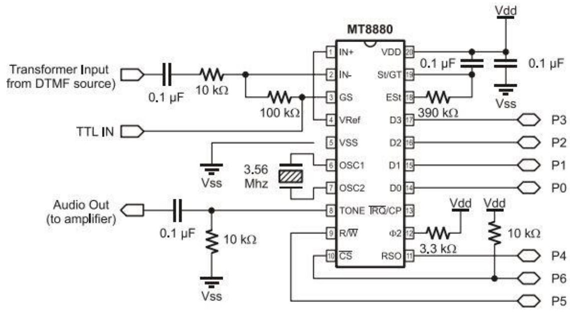

Figure 7: The IC8880 Single End Input Connection [17]

This circuit is a single-ended configuration system. As can be seen, the input arrangements at pin 1,2,3 and 4 of IC8880 provide a differential-input operational amplifier as well as a bias source V_{ref} that is used to bias the inputs at V_{DD} /2. With a voltage gain of $(A_v) = R_f / R_{IN}$, the gain can be adjusted by connecting the feedback resistor to the operational amplifier output (GS) [17].

Crystal oscillator used as the external clock pulse to the microprocessor is not as important as the steering circuit [17]. This circuit checks for a valid signal duration performed by an external RC time constant driven by ESt at pin 18,19 and 20. The output pins on the IC8880, which are at pin 14 to 17, will send the input to the microcontroller on the CPU.

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	#	1	1	0	0
697	1633	A	1	1	0	1
770	1633	B	1	1	1	0
852	1633	C	1	1	1	1
941	1633	D	0	0	0	0

III. CONTROLLER CIRCUIT DESIGN

Figure 8 represents the high-level block diagram of the DTMF remote switching system. The HCS are divided into three major units, which are the DCU, CPU and CAU. In order to remotely switch the household appliances using DTMF signal, it is necessary to have a remote controller, which is in the form of a telephone or a mobile phone. This will enable the user to control the system from a distant place using DTMF signalling.

A. *DTMF Communication Unit*

Home Appliances Controller receives DTMF signal from the landlines telephone. The DTMF Communication Circuit needs an interface to feed the DTMF signal from the telephone to the transceiver. The circuit in Figure 9 is the interface circuit that is connected to the DCU in Figure 10.

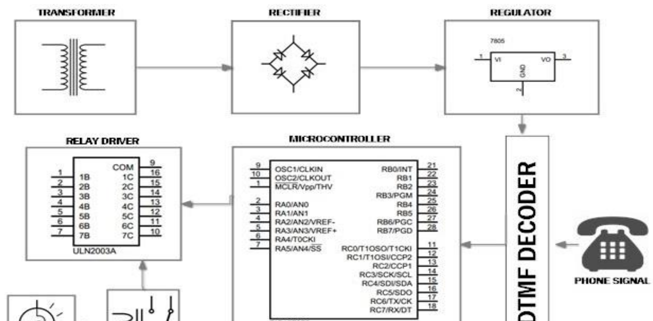

Figure 8: Block Diagram of Home Appliances Controller

The basic telephone wiring connection consists of two wires, which are red and green. The green wire is for tip wire and the red wire is for ring wire. As shown in Figure 9, there are two connector blocks, where each of them has two wires that represent the tip and ring wire. Both of these ports are connected parallel to the Home Appliances Controller so the telephone system will not interfere.

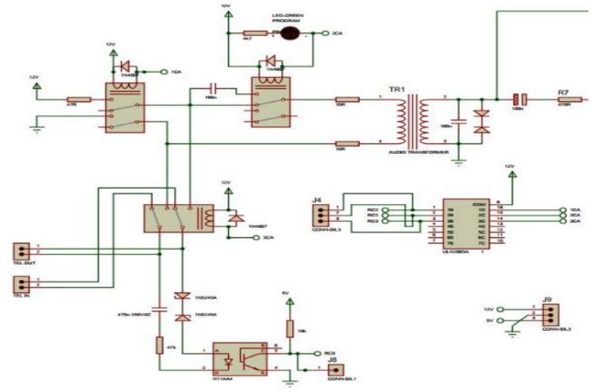

Figure 9: Telephone Interface Circuit

When a user calls the number of the telephone connected to the Home Appliances controller system, the telephone will start ringing. At this stage, H11AA4, the optocoupler will act as a counter to count the ring number until reaches 12 rings. When the number of rings has reached the specified number, the controller at pin RC_1 will give an output high to switch on the ONLINE LED that indicates the system are now in the online state.

The audio transformer used in this circuit functions as a magnetic isolator that isolates the electrical signal between DTMF decoder and the telephone line. It has a ratio of 600Ω/470Ω that isolates the system ground and the telephone ground. Therefore, DTMF decoder in Figure 10 will not be affected by the electrical noises.

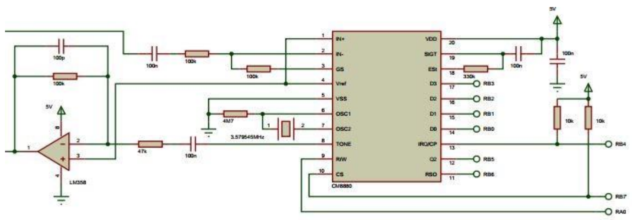

Figure 10: DTMF Communication Unit Circuit

For the DCU circuit, a controller of IC8880 had been used as the DTMF decoder. It decodes the DTMF signal transmitted via the telephone line and will produce 4-bit digital information at pin 14-17 (D_0, D_1, D_2, D_3) connected to the PIC input pins RB_0, RB_1, RB_2, and RB_3. The keypad codes entered by the caller will be decoded by the IC8880, determined by the program written and then loaded into the PIC16F873.

The connection of the DCU shown in Figure 10 can be compared to the schematic diagram in Figure 7. By using a signal conditioning circuit, which is an operational amplifier is connected to get a unity gain and biasing input at $1/2V_{DD}$. The internal clock circuit of the DTMF decoder is completed with the addition of a standard burst crystal oscillator that has the resonant frequency of 3.579545 MHz.

B. Central Control Unit

For this system, PIC16F873 is used as the heart of this system. The connection of the PIC controller to another element of the circuit is shown in Figure 11. There are 22 I/O pins within 3 ports available in this microcontroller. The status of the pin whether to be an input or an output is set up by the programming codes. There will be two input ports and one output port in this system using PIC16F873 [18].

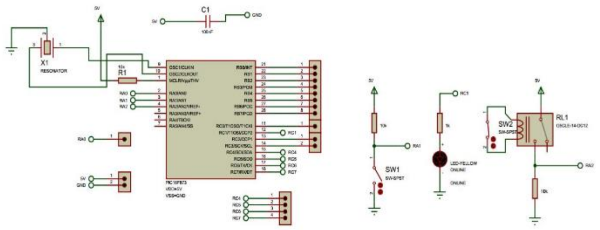

Figure 11: Central Control Unit Circuit

The microcontroller will wait until the optocoupler gives a feedback to indicate that the required number of ring is already reached or otherwise, when a call is made. It will answer automatically and wait for the four-digit password from the user before going back to the standby state if the caller did not enter any password or key in the wrong combination number within 15s. The system will only allow the right password to access the system.

With the right password is entered, the home appliances can be controlled by pressing the keypad button according to the dedicated number, as shown in Table 1. The microcontroller will then switch the specified pins between RC_4, RC_5, RC_6 and RC_7 to high signal for activating the relay driver in the CPU circuit.

Another add-on feature in this project is the anti-burglar alarm system that will notify the user phone number automatically. Beforehand, the user needs to set the system into PROGRAM mode by clicking the button SW1, which produces a high input signal to RA_1. The coded program in the microcontroller will produce a high output at pin RC_2 and simultaneously turn on the program LED to indicate that the user is now in the PROGRAM mode. In PROGRAM mode, the user can set a telephone number that they want to be notified. The microcontroller will store the inserted number in the EEPROM.

C. Client Appliances Unit

The CAU circuit is designed to control the load. The loads can either be the lamp, fan, air-conditioner, motor or other types. The load will be turned ON/ OFF through the relay in this unit. Since only 4 relays are used in this system, only four loads will be used, which are three light bulbs and one alternating current fan. The relay ON/OFF is controlled by the switching transistor in the ULN2003 controller. The connections of the relay system are shown in Figure 12.

There are four relays, where each of its function is to control one load. The load can be integrated into the system by connecting them to the terminal block. As the relays are normally connected to NO (normally open) pins, one wire from the load needs to be connected to the common of the relay and the other connects to the NC (normally closed) contact.

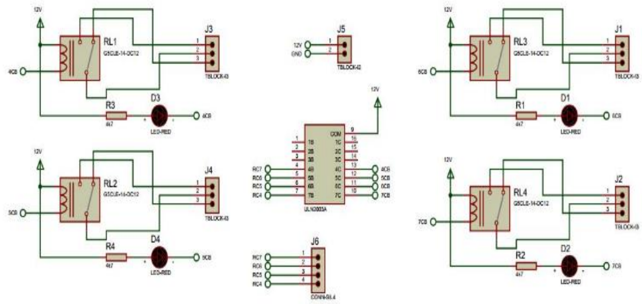

Figure 12: Client Appliances Unit Circuit

When the microcontroller receives the decoded signal from the caller keypad, it will determine which load to be turned ON/OFF. The microcontroller will send high inputs to ULN2003 to trigger the coil and actuate the armature, resulting in the load to be turned ON.

IV. SOFTWARE DESIGN

The flowchart of the PIC programing code is shown in Figure 17 (a) and Figure 17 (b) in the appendices. The program is written with MPLAB X IDE software using MPASM Assembler in assembly programming language. The software designing process started with having a function declaration and some basic subroutines such as delays. Some functions, which are used to decode password, decode output port, save the password, send bib tone and also activate the alarm had been written in the EEPROM.

The program is in a continuous looping, which means that it will set in the MAIN loop to remain actively scanning for inputs when the microcontroller is powered up. To activate the system, the user needs to call the telephone that is connected to the system. The system is on standby mode to actively scan for the input. Whenever it receives a ringing signal, H11AA4 will automatically scan it and activate the input port of controller after scanning for 8 ringing tones.

The system will automatically change into the ONLINE mode and then Online LED will be turned on simultaneously. In the ONLINE mode, the microcontroller will count the variable until 1500, which is 15 seconds, unless interruption from DTMF decoder is detected. When the microcontroller reaches 1500 without getting any DTMF signal from the caller, the system will end the call and go to standby mode waiting for the ringing again. The number pressed on the remote phone will be decoded by the DTMF decoder, and it will send the 4-bit signal to the microcontroller.

Once the user enters the correct DTMF signal combination, the EEPROM will decode the password and send the command to the microcontroller. The user needs to enter the right output port combination to get the system to decode, in which relay need to be processed. If key 1 is pressed, process relay 1 will be conducted. However, if there is no combination code entered or wrong codes were entered, the system will hang up and switch to the system offline automatically.

The PIC16F873 will jump to the DECODE cycles and perform recognition of 4-bit code related to the initial values. If the code is recognized, the program jumps to do the certain cycle and performs it. When the program manages to build up without producing any errors, it will automatically compile the code and produce an extension of a .hex file. This file is the outcome of the compiled program and needs to be burned into the PIC16F873.

V. EXPERIMENTAL RESULTS

To test the DTMF decoder, IC8880, the chip is placed on the breadboard and the output pins D0, D1, D2, and D3 are connected to four LEDs acting as four binary digits to represent the numbers pressed by the caller. The purpose of this test is to make sure the decoder is in the right condition to use. The telephone DTMF signal is fed to the circuit using auxiliary phone jack.

Since the controller maximum input power specification is 5V, any power greater than that can lead to damaging the controller. An IC regulator, LM7805 is used together with 9V battery to regulate the source to only +5V. The input of 9V battery is connected to the first leg of the regulator. The others are the second pin for the ground and the third pin for the regulated output. This 5V input will be connected to the V_{DD}. The rest of the connection is represented by the datasheet as shown in Figure 7.

Figure 13 shows that the LED output that indicates the pressed keypad code: 0101 has to be read from the leftmost LED. The signal from the DTMF will be decoded into four-bit BCD. The corresponding LED will turn ON according to the decoded output. For digit 0101, it is number 5 in the 3x4 matrix keypad. The resultant output is recorded in Table 3 below. This data is then compared with the theoretical result in Table 2. It shows that the result is similar. Therefore, this controller is reliable to be used in this project.

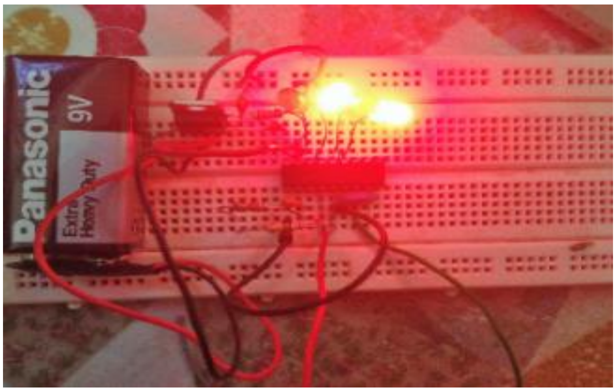

Figure 13: Testing IC8880 circuit connection

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
8	1	0	0	0
9	1	0	0	1
0	1	0	1	0

In order to make sure that the microcontroller is working properly, PICkit3 is used to burn the program into the PIC. A successful PIC program will show that the LEDs are blinking according to the time delay that has been set.

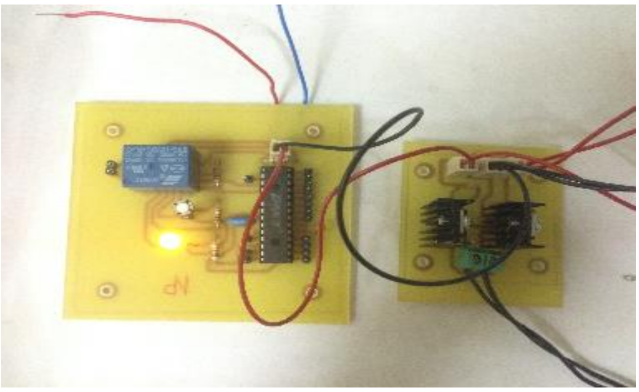

Figure 14: Testing programmed blinking LED

A simple test is done for the CAU to make sure it is in good condition. As this unit is connected to the high voltage load, a simulation experiment is done for safety. The simulation circuit includes a relay driver unit that is connected directly to the CAU.

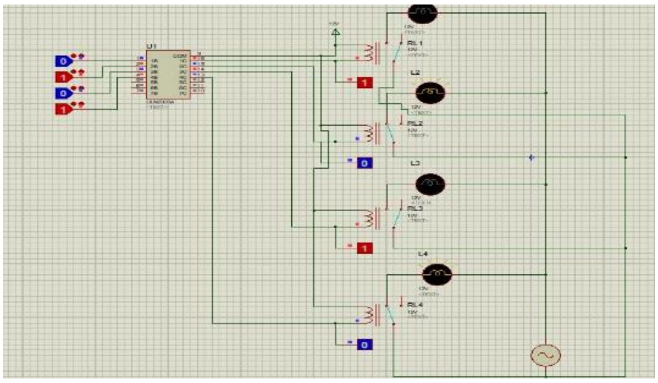

Figure 15: Simulating relay with AC load

The result of the simulation is shown in Figure 16. As the input of the ULN2003 is at the low state, it will produce a high output due to the NOT logic gate within its internal circuit connection. The 12V input relay voltage cannot flow to the high state level, thus the relay will remain idle. Whenever the input of ULN2003 is high, it will produce a low output 12V for the coil relay, which in turn energizing the coil. The armature will be attracted to the coil and thus short-circuiting the connection for the high voltage load.

Once the simulation is completed, the hardware components of the system are connected by connecting the relay to the high voltage load. The load used for this experiment is an AC fan with two wires. A wire of the fan is connected to the LIFE (L) wire of the power outlet and another wire connected to normally opened contact of the relay. This relay is only closed when the connection is activated by a 5V signal from the PIC that will eventually turn ON the AC fan.

VI. Overall Result

The finalized prototype setup is shown in Figure 16. The load for the house appliances consists of three light bulbs and one AC fan. In the beginning, the user needs to register their telephone number and password combination. The default password has been set to 1234#. This can be done by activating the PROGRAM mode. The user can hear a beeping tone if the registered number is correctly inserted.

When a caller wants to control the home appliances, a call can be made from any telco provider to the landline telephone number. The controller will be activated only in ONLINE mode program after eight times ringing tone. The telephone will be answered automatically by the program. In this case, the program allows only fifteen seconds for the user to enter the registered passcode. Note that the user can only control the home appliances successfully in ONLINE mode based on the combination number in Table 1. However, if user fails to do that in 15 seconds, the telephone will engage automatically and switch to IDLE mode.

This application is useful for cases where there is no power at home connected to the alarm system powered by battery. At all times, the user will be able to switch ON/OFF the alarm system by using their mobile phone or etc. The system is low cost and easy to be assembled. These advantages will definitely benefit the users in the long term.

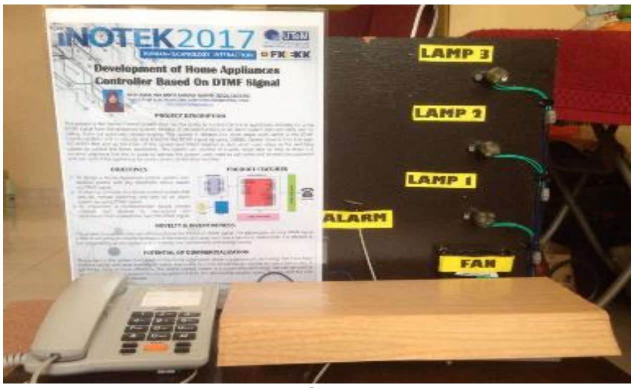

Figure 16: Final Prototype Setup

VII. Conclusion

In this paper, a home appliances controller has been designed and developed. It manages to control the devices remotely by using the DTMF signal from the telephone network and provides safety aspects in its operations. The control is also possible whenever there is no power at home provided the appliances such as alarm system and lights are battery powered. For future work, it will be useful to include Internet of Things (IoT) elements in the design for an enhanced monitoring process and control.

Acknowledgment

The authors would like to thank Universiti Teknikal Malaysia Melaka (UTeM) sponsored by 'UTeM Zamalah Scheme'.

References

[1] A. S. Marincic, "Nikola tesla and the wireless transmission of energy," IEEE Transactions on Power Apparatus and Systems, vol. PAS-101, no. 10, pp. 4064–4068, Oct 1982.

[2] B. Koyuncu, "Pc remote control of appliances by using telephone lines," IEEE Transactions on Consumer Electronics, vol. 41, no. 1, pp. 201–209, Feb 1995.

[3] R. Teymourzadeh, S. A. Ahmed, K. W. Chan, and M. V. Hoong, "Smart gsm based home automation system," in 2013 IEEE Conference on Systems, Process Control (ICSPC), Dec 2013, pp. 306–309.

[4] C. G. Onukwugha and P. O. A. (ph. D, “Remote control of home appliances using mobile phone: A polymorphous based system,” 09 2013.

[5] M. R. G. Garcia, H. R. B. Chan, B. E. V. Comendador, G. B. Cornell, C. D. Celestial, and A. E. P. Mercolesia, “Smart home electricity management system using cloud computing (shems),” pp. 44–48, 012013.

[6] T. Gabriele, L. Pantoli, V. Stornelli, D. Chiulli, and M. Muttillo, “Smart power management system for home appliances and wellness based on wireless sensors network and mobile technology,” in 2015 XVIII AISEM Annual Conference, Feb 2015, pp. 1–4.

[7] R. Piyare and M. Tazil, “Bluetooth based home automation system using cell phone,” in 2011 IEEE 15th International Symposium on Consumer Electronics (ISCE), June 2011, pp. 192–195.

[8] J. M. Shirisha Tadoju, “Bluetooth remote home automation system using android application,” pp. 1815–1818, 08 2015.

[9] S. S. R. Harinath, “Gsm-based home automation system using app-inventor for android mobile phone,” pp. 158–167, 04 2015.

[10] H. Lamine and H. Abid, “Remote control of a domestic equipment from an android application based on raspberry pi card,” in 2014 15th International Conference on Sciences and Techniques of Automatic Control and Computer Engineering (STA), Dec 2014, pp. 903–908.

[11] Y. Erol, H. H. Balik, S. Inal, and D. Karabulut, “Safe and secure pic based remote control application for intelligent home,” 05 2007.

[12] R. Ghosh, “Dtmf based controller for efficiency improvement of a pv cell and relay operation control,” pp. 2248–9622, 05 2012.

[13] R. Teymourzadeh, S. A. Ahmed, K. W. Chan, and M. V. Hoong, “Smart gsm based home automation system,” in 2013 IEEE Conference on Systems, Process Control (ICSPC), Dec 2013, pp. 306–309.

[14] B. N. Getu and H. A. Attia, “Identification of dialed telephone numbers in touch tone telephone system based on frequency analysis,” in 2014 World Symposium on Computer Applications Research (WSCAR), Jan 2014, pp. 1–5.

[15] S. M. Kuo, B. H. Lee, and W. Tian, Introduction to Real-Time Digital Signal Processing. John Wiley and Sons, Ltd, 2006, pp. 421–428.

[16] S. Nagireddi, VoIP Voice and Fax Signal Processing. John Wiley and Sons Inc., 2008, pp. 151–171.

[17] CM8880, CMOS Integrated DTMF Transceiver, California Micro Devices, 2000.

[18] PIC16F873, 28/40-Pin 8-Bit CMOS FLASH Microcontroller, Microchip Technology Inc., 2013.

APPENDICES

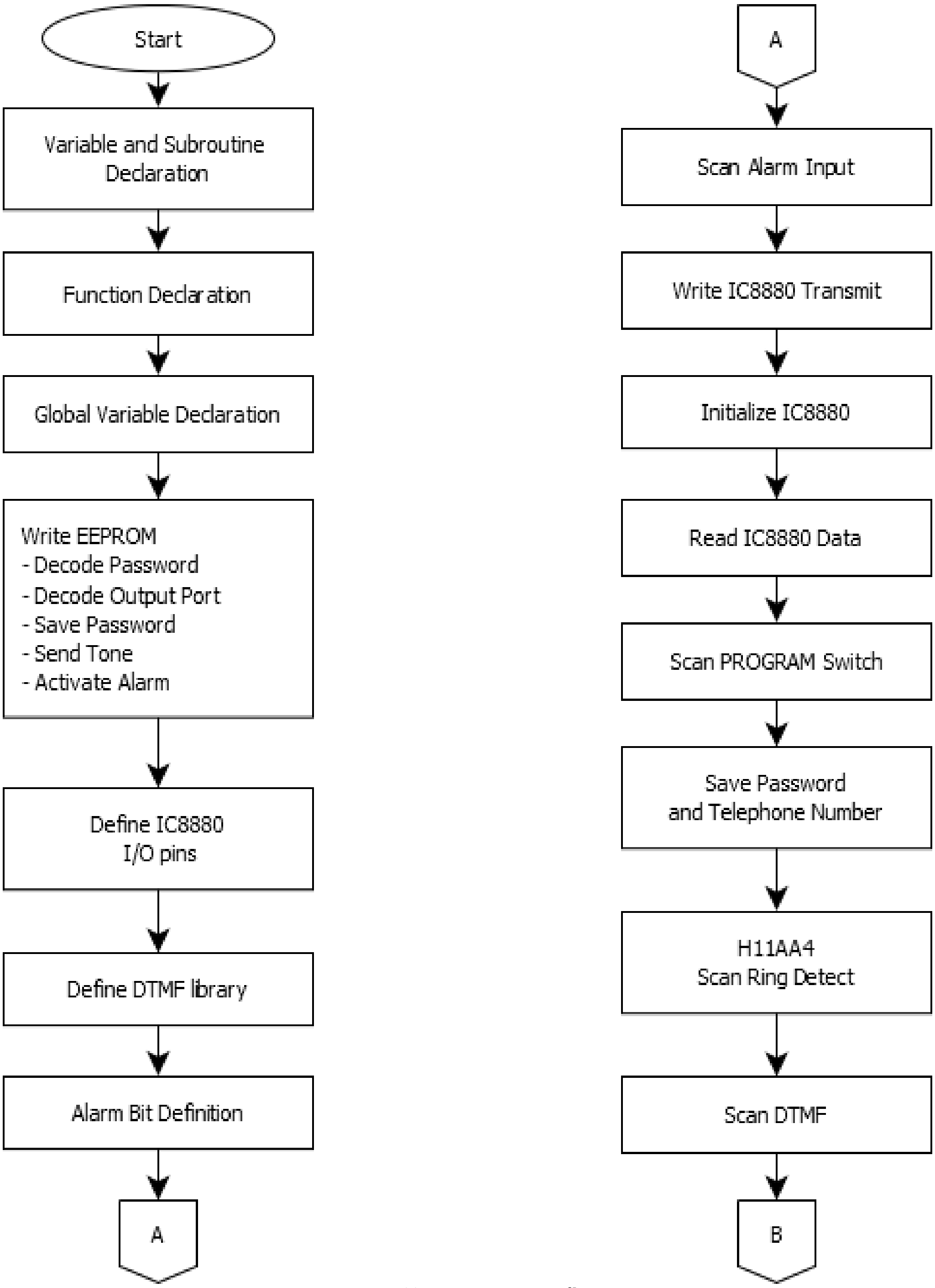

Figure 17: (a) Program Process flow

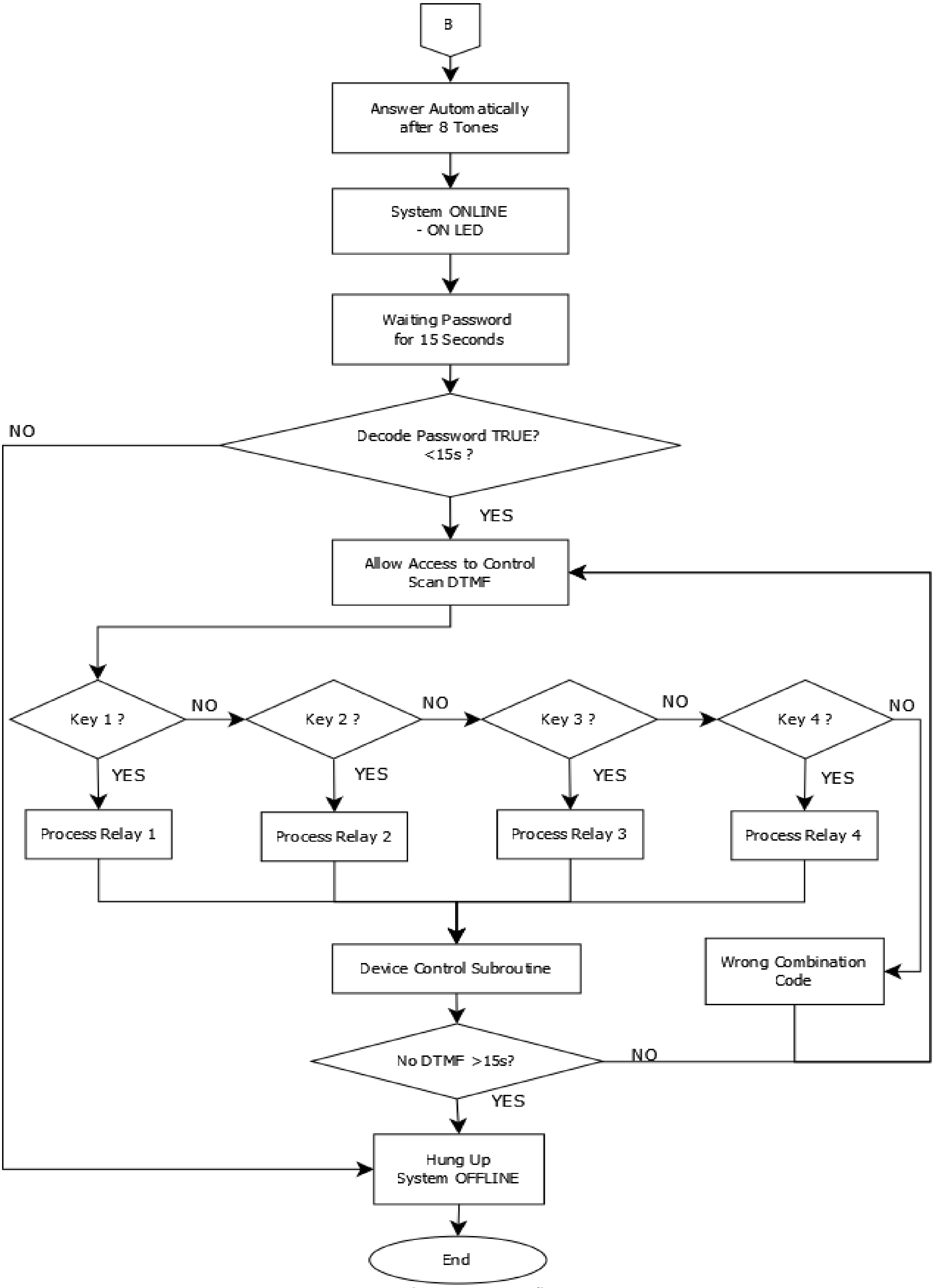

Figure 17: (b) Program Process flow