

DUAL TONE MULTI-FREQUENCY (DTMF) ENABLED AUTOMATIC ACCESS CONTROL SYSTEM

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ABSTRACT

Traditionally, most doors are controlled by manually unlocking, opening and closing them. With time, this method seems to be very strenuous, especially for garage doors as one has to alight from their vehicle to manually operate the door each time; for both opening and closing. As the world gets more technologically advanced, we find new technologies that help us carry out simple tasks more easily. This

report details a new method of opening and closing garage doors with the use of a DTMF cell phone remotely, which is more convenient than traditional methods. In this proposed system, operation of the garage door was done by using a mobile phone. The keypad of a mobile phone was used to signal a DTMF decoder interfaced to a micro-controller system which in turn is connected to the mechanism that opens or closes the garage door, provided the correct pass-code was entered. This is based on the concept of Dual Tone Multi-Frequency (DTMF). The buttons on the keypad of the mobile phone generate a unique frequency when pressed. These frequencies were decoded by the DTMF decoder at the receiving end which is fed to the ATMEGA328 micro-processor. When this decoded value matches with the values stored in the micro-controller, the micro-controller initiates a mechanism to open the door through a motor driver connected to the garage door. This method of operating garage doors has proven to be more convenient, making the task easier.

KEYWORDS: DTMF, Access control, automation, ATMEGA 328.

INTRODUCTION

A system that gives you total control over an equipment, appliance or object without having to move around is a revolutionary concept. It adds more comfort to everyday living by removing the inconvenience of having to move around to operate (switch on or switch off) the electrical, electronic or mechanical equipment. Most doors are controlled by manually unlocking, opening and closing them which is strenuous. Technology presents us more convenient ways of doing such things through various forms of wireless communications which include infrared based remote control, radiofrequency based remote control, Bluetooth control technology and GSM control. This research takes advantage of the general acceptance of cell phones and telephone networks in today's society to introduce automation and convenience.

The research adopts a GSM phone control method based on dual-tone multi-frequency system to control a garage door from anywhere around the world. Dual-tone multi-frequency (DTMF) is a technology that can be used to send information through phone lines.^[1] The keypad of a mobile phone is used to signal a DTMF decoder interfaced to a micro-controller system which in-turn is connected to the mechanism that opens or closes the garage door, provided the correct password (unique number) was entered. This method of operating garage doors has proven to be more convenient, making the task easier.

LITERATURE REVIEW

There are lots of control systems in the market nowadays. These systems are studied in order to get more ideas for the work that was built. Although most systems in the market have newer technology, it is still important that previous works on this technology and their limitations be reviewed.

Mechanical Door Lock uses a tangible object as its key. A physical key is inserted into an inlet part, turned or twisted to rotate a tumbler arrangement and then withdrawn from that same part. Mechanical wearing can set in after a long time of using the key.

Electronic Door Locks are locks whose key is a piece of information for activating mechanism to permit entry to a secured area, by inputting code within the memory unit.

Key-Card Door Control Systems are a type of electronic lock that have the control assembly mounted on the inside of the outer door of the enclosure. It controls the movement of a

solenoid for releasing or disengaging the door from its locked position. When an ID card is slotted onto the transceiver mounted in front of the door, it receives the code from the card and compares it with the present one. The door opens if they are same, if not it remains locked.

Biometric Door Control systems are a type of electronic door lock where personal identification data are used in the place of codes, such data are biological in nature which includes Human-Palpi, blood group (DNA) and eyelid. This serves as a source of code for entrance. The biological data are stored in a programmable microprocessor. Anytime there is supposed to be access, the person's biological data is impressed on the transceiver, this is compared with the already stored data. If it tallies entrance is granted. If not, access is automatically denied.

Remote Control Door Security is another electronic lock system. The door is controlled remotely with a wireless device. This is based on Bluetooth or Infrared technology. When the button on the remote is pressed, the signal it sends out is received by the receiver. The receiver has a relay on the inside which is switched from open to closed position to send a signal to a controller. The controller actuates a servo motor which pushes the dead-bolt forward into the door frame. Pressing the remote's close button will cause the servo motor to actuate in the opposite direction and retract the dead-bolt from the door frame.

Previous means of controlling and accessing garage doors have some limitations. These limitations make it difficult for these systems to be convenient and more efficient.

For the mechanical systems, operation of the door is done manually, which is strenuous. Rusts and wearing can set in after a long time of using the key. Someone else can formulate or get a master key to lock or unlock the door illegally.

For the electronic systems, most of the locks used are accessed with a key-card. If the key-card gets lost, someone else might pick it up and use it for unauthorized purposes.

Biometric door control systems give access to only the individual whose biometric data was used in configuring the system. This makes the system restricted as only a specific individual can access it.^[2]

The remote control door security systems are effective in unlocking doors but not controlling them. The Bluetooth and Infrared technology used in these systems require close proximity to the control sensor. They cannot be operated from afar. The working proximity is sometimes as short as just one meter distance.

The project we are working on overcomes all these limitations because it is safe, convenient and can be accessed from anywhere around the world.

METHODOLOGY

The circuit is divided into four sections; each section does a particular task. The block diagram in figure 1 shows the signal flow of the access system.

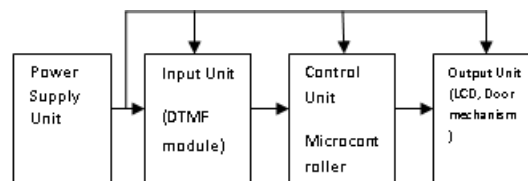


Figure 1: Block Diagram of a Garage Door Opening System Controlled by DTMF Cell Phone.

The power supply unit supplies power in terms of current and voltage to the other units. The power supply uses a rectified dc power source and a power pack. The rectified power source would be used to supply the input unit, control and the output unit (relays). The power pack would be used to power the motor.

The input unit consists of the DTMF module used in receiving signals from the cell phone.

The control unit consists of the ATMEGA328 controller. The controller has a memory space of 2 kilobyte RAM and 32 kilobyte ROM. The controller uses operating voltage of 5 volt DC.

The output unit is made up of the relays, the motor, gear system and the sliding door (DVD rail). The relay uses 5 volt DC to operate, the motor and gear system requires 5 volt DC to operate.

Power Supply Unit

The power supply unit consists of the step down transformer (TR1), which steps down the 220Vac utility power supply to 12Vac. A bridge rectifier (BR1) then converts the 12Vac to +12Vdc. A filter capacitor (C4) is used to filter the dc voltage obtained. The capacitor filters

off any ac ripples in the 12Vdc voltage. The voltage required by the circuit is 3.3Vdc and 5Vdc so 3 voltage regulators were used to regulate the voltage from the filter capacitor and supply a constant voltage. U1 and U2 supplies 5Vdc. A light emitting diode (d1) was used as the power indicator. Figure 2 shows the circuit diagram of the power unit.

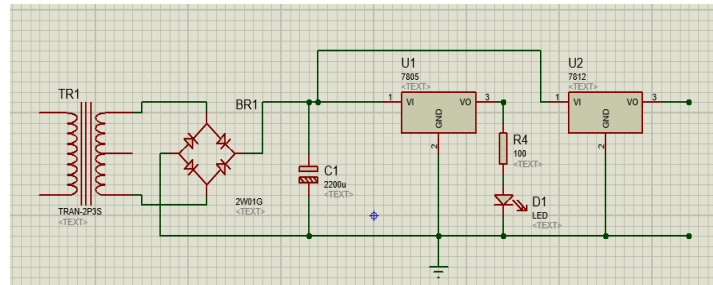


Figure 2: Circuit Diagram of the Power Supply Unit.

A 220Vac to 12Vac step-down transformer with a current capacitor of 500mA was used in the design of the circuit. A 220Vac from mains is supplied to the transformer which is then stepped down to 12Vac.

The maximum voltage of the secondary side of the transformer can be calculated using equation 1.

$$V_m = \sqrt{2}V_s \quad \dots (1) [3].$$

$V_m =$ The maximum voltage from the secondary of the transformer

$V_s =$ The voltage from the secondary of the transformer

$$V_m = \sqrt{2} \times 12 = 17 \text{ volts}$$

The maximum peak voltage is 17 volts.

The average dc voltage gotten is calculated from the formula given in equation (2)

$$V_{dc} = 0.636V_m \quad \dots (2)$$

$V_{dc} =$ Average dc voltage

$V_m =$ Maximum Voltage of the Transformer

From equation 3.1, the maximum voltage is 17 volts.

$$V_{dc} = 0.636 \times 17 = 10.81 \text{ volts}$$

From the calculation, the average dc voltage is 10.81 volt. The bridge rectifier rectifies the voltage. Equation 3.shows the voltage obtained after the bridge rectifier.

$$V_{dc} = V_m - 2(V_d) \quad \dots (3) [3].$$

$V_d =$ forward voltage drop across the silicon diodes = 0.7

$$V_{dc} = V_m - 2(0.7) = 17 - 1.4 = 15.6 \text{ volt}$$

The design used a capacitor of 1000uf, with PIV of 50v as the filter capacitor. This capacitor filters off the ac ripples in the dc voltage, reducing it to a minimal level. The capacitor also meets the requirement of PIV of capacitor greater than the peak voltage from the bridge rectifier output. The capacitance of 1000uf was chosen because it is estimated to be able to filter off the ac ripples from the output voltage.

Two 7805 voltage regulators giving 5V were used. From the datasheet, the 7805 output voltage is 5V.

A light emitting diode (LED) was connected to the circuit. This indicates when there is power in the circuit. A resistor is connected in series with the LED. The resistor reduces the current that flows through the LED to prevent burn out. The formula used to calculate the current through the diode is shown below.

From Kirchoff's voltage rule,

$$V = V_r + V_d$$

V_d = Voltage drop across light emitting diode

V_r = Voltage drop across the resistor

V = Total Voltage

$$V_r = I \times R$$

From the datasheet for the red LED, V_d is 2volts, and the permissible current is 1mA to 30mA. V is the voltage gotten from the voltage regulator (U2) ($V = 5$ volts).

Substituting this into the equation,

$$5 = I \times 1000 + 2$$

$$5 - 2 = I \times 1000$$

$$3 = I \times 1000$$

$$I = 3/1000 = 3 \text{ mA}$$

The current flowing through the light emitting diode is 3mA. This is within the permissible current. A 1000 ohms resistor was used.

Input Unit

The input unit is the Dual Tone Multi-Frequency (DTMF) signal circuit. This circuit detects the dial tone from a telecommunication line and decodes the keypad pressed on the remote phone. The dial tone sound that is heard when a phone keypad is pressed is called DTMF in short.

The input unit comprises of the DTMF decoder and an octal buffer. The signal from the cell phone is received here, decoded and output sent to the microcontroller unit.

The cell phone is set to auto-answer. The keypad tone was turned on and set to the highest volume. Each key on the keypad have a distinct tone which is converted to four digit binary codes by the DTMF decoder IC (mt8870). The table below shows the conversion. The outputs from the DTMF IC are fed directly into the micro-controller.

Table I: The Status of Outputs on Pressing Keys on the Gsm Keypad.

Key No.	Q3	Q2	Q1	Q0
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
*	1	0	1	1
#	1	1	0	0
A	1	1	1	1
B	1	1	1	0
C	1	1	1	1

Control Unit

The control unit is made up of the micro-controller. The micro-controller is connected to the input unit, the power supply unit and the output unit. The micro-controller used in this project is the ATMEGA328.

The ATMEGA328 micro-controller pin outs are connected to the DTMF module, the uln2004 IC, and the liquid crystal display. The RFID module is connected to pins 26 and 29 of the controller. It communicates with the DTMF module using parallel communication by

sending 4 bit of data (nibble) to the controller. The DTMF module is used to receive signal from the user's phone.

The micro-controller scans the unique number gotten from the DTMF module and check if its stored in the memory of the micro-controller, if it is the same with the numbers stored in the micro-controller, the door will slide open.

The user is able to communicate with the device via the use of a liquid crystal display which the micro-controller sends data to, for the user to visualize and communicate with the system. The liquid crystal display is connected to the digital pins of the micro-controller. The liquid crystal is used to display that the garage door opens and closes.

The door system is controlled by the micro-controller via the two relays used in the system. The relays are connected to the uln2004 (transistor array chip) IC (U3), which is used to switch on and off the relay. The uln2004 IC is used in the circuit because of the current gain of the array of transistors used in the internal architecture of the IC. The IC (U3) turns the relay when 5 volts is sent to it by the micro-controller and turns off when 0 volt is sent to it by the micro-controller.

The ATMEGA328 has an on-chip oscillator but it requires an external clock to run it. A quartz crystal oscillator (X1) is connected to pin 7 and pin 8 of the ATMEGA328 controller (U3). Also, two 20pf capacitors (C5 and C6) were also connected to the crystal while the other end is connected to the ground. They are used to remove noise from the oscillator. According to the datasheet of the ATMEGA328, a capacitor of 18pf to 30pf is used to remove noise at the crystal terminal of the micro-controller. Figure 3 shows the ATMEGA328 chip

The crystal is used to control the processing speed of the micro-controller. The speed of the micro-controller refers to the maximum oscillator frequency connected to XTAL pins.

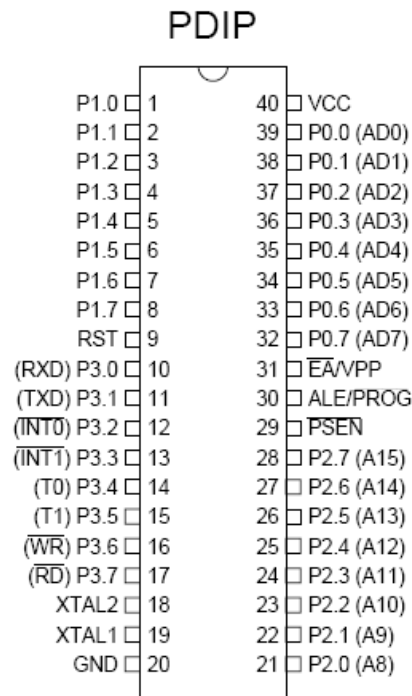


Figure 3: ATMEGA 328 Pin Configuration.

Output Unit

The motor/gear system, sliding door (DVD tray), and the liquid crystal display (LCD) makes up the output unit. The liquid crystal display indicates the status of access (if it is granted or denied). The gear/motor system and the DVD tray make up the sliding door system. Two relays connected to the micro-controller system via a transistor array IC ULN2003 (U3) controls the motor system. The micro-controller will forward or reverse bias the motor system to control the opening and closing of the door by rotating the motor in the clockwise or anti-clockwise direction respectively. If the key pressed in the phone matches the code stored in the microcontroller, the door will slide open. A program burnt into the microcontroller tells the microcontroller what to do with each code.

The LCD receives data from the micro-controller using the data pins d3-d7. The four terminals of the data pins are connected to the micro-controller pins 25-28. The communication between the LCD and the microcontroller is a 4bit (nibble) parallel communication. 4bit is used in transferring information or ASCII character from the microcontroller to the LCD. This is so as to use only four terminals of the microcontroller pin outs instead of eight pins for eight bit. The RS (register select) and the EN (enable terminals) of the LCD are used to receive commands from the microcontroller and also in controlling the display of the data received from the microcontroller.

The uln2003 (U4) is connected to the micro-controller pin 3 and 6. The output of the IC (U4) is connected to the two relays (RL1 and RL2). The relays are switched on by the micro-controller via the IC (U4). When access is granted by the micro-controller, the micro-controller sends signal to the relay via the IC. When relay (RL1) is turned on and relay (RL2) is off, the door slides open (the motor is reverse biased). When relay (RL2) is turned on and relay (RL1) is off, the door slides close (the motor is forward biased).

The complete circuit diagram is shown in figure 4.

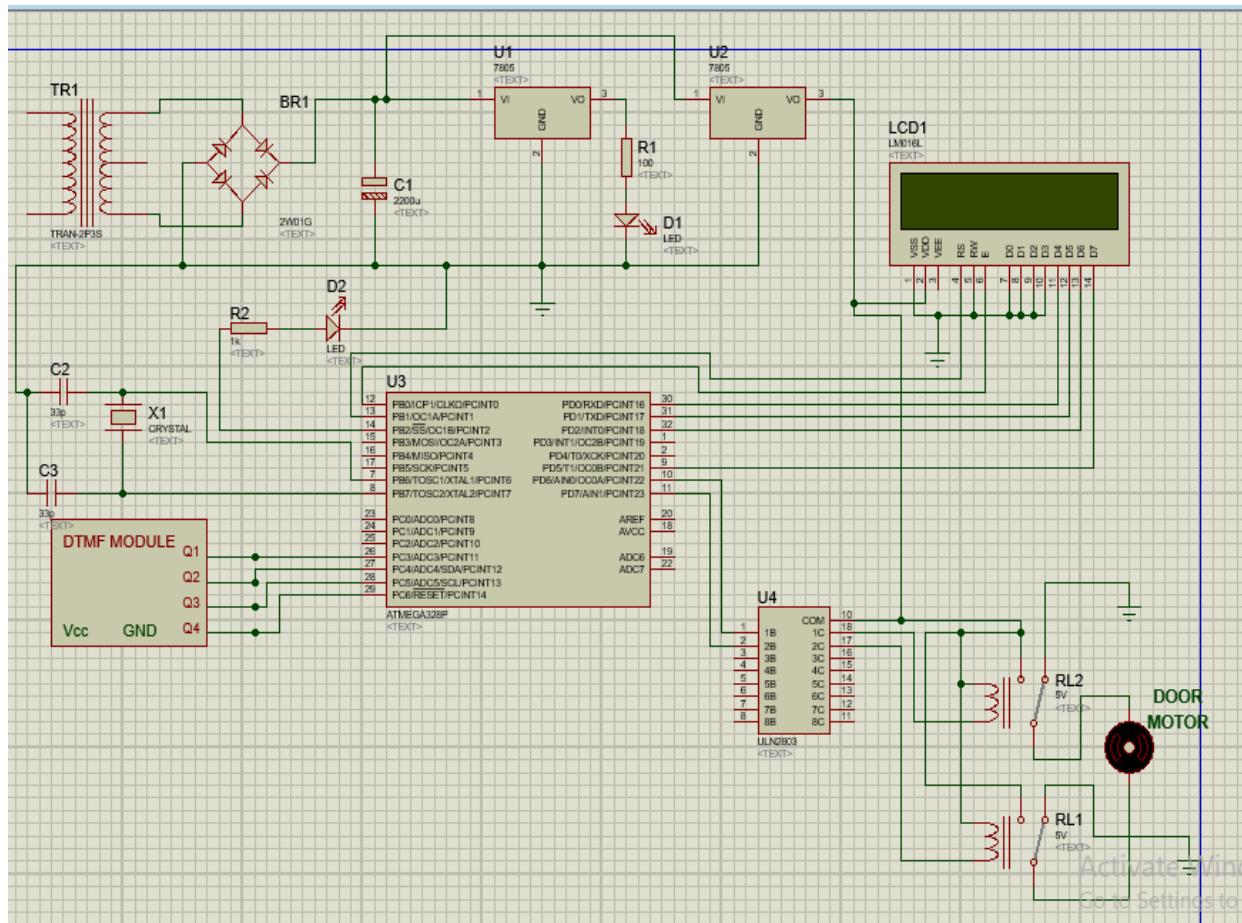


Figure 3.3: Circuit Diagram of the Complete System.

TEST AND RESULTS

The On the course of building this project, two stages of testing were involved:

- i. Testing before implementation
- ii. Testing after implementation

Testing before Implementation

This is where tests carried out on the components before they are soldered onto the Vero board. This was to ensure that each and every one of the components was in good working condition before using them. Two groups of components were used in this design.

1. Discrete components e.g. resistors, light emitting diodes, capacitors, transistors, etc.
2. Integrated circuit components.

The individual components were searched and bought in the markets. The discrete components were tested for continuity with a multi-meter by switching the meter to the required value or range corresponding to each discrete component.

Testing after Implementation

Different sections of the completed system were also tested after the circuit has been implemented on a project board. This was done to ensure that they were in good operating condition. Proper calculations were done after designing the circuit to ascertain the workability of the project.

Testing the Components

The following procedures were considered while carrying out this project.

- i. Circuit analysis was done.
- ii. Drafting out a schematic circuit diagram.
- iii. Purposing of the entire materials/components needed.
- iv. Simulation of the designed schematic circuit diagram.
- v. Acquisition of the various components needed as per the simulated circuit.
- vi. Testing the components to be used in building the circuit.
- vii. Construction of the designed circuit.
- viii. Testing the completed work.
- ix. Casing of the final tested construction.

After the circuit design and analysis was done, the components for building the circuit was bought from the market. Each component for each section of the circuit was assembled and tested before being soldered onto a veroboard. Continuity tests were carried out for each component to ensure that they were in good working condition. Tests were also carried out prior to supplying power to the circuit. Finally, power was supplied to the circuit at the

voltage shown in table 2, after troubleshooting has been done on the whole circuit. Visual observation was then carried out to observe the components and ensure they do not burn out.

Testing the Circuit

The circuit was designed in an electrical drawing studioenvironment (Proteus version 7.8). This was used to simulate some of the part of the circuit so as to show if the design will work. The construction of the circuit started from the power supply unit. The power supply unit was first built, followed by the input unit, control unit and lastly the output unit. The power supply unit was tested and a supply voltage of 5VDC was achieved as expected. The input devices and the DTMF module were tested before proceeding to the control unit. The microcontroller IC, the display unit and the door system were also tested and confirmed working. Soldering iron and soldering leads were used to attach the components of the circuit onto the veroboard. During and after construction, the circuit was tested properly using a digital multimeter to check for continuity and other variables on the veroboard.

After all the tests and observations were carried out as explained above, the results were noted and the project was certified ready for packaging.

The following tables show the results of the parameters measured and tested at different parts of the circuit. The tests were carried out using a digital multimeter set at voltage measurement, current measurement, etc.

Table 2: The Status of outputs on pressing keys on the gsm keypad.

Power Output	Expected Values	Measured Values
7805 regulator	+5V	+5.02V
ATMEGA 328		
Current	20mA	19.8mA
Voltage	+5V	+4.99V
Input Voltage		
PHCN	220VAC	218.14VAC

Table 3: Functions of The Buttons In The System.

Buttons	Expected Values
3	This is used to open the garage door
7	This is used to close the garage door

Table 4 Results From Testing Of The System.

Key Pressed	LCD Display	Action
3	Door Opening	Door slides open
7	Door Closing	Door slides close

The results in Table 2, 3 and 4 shows that the prototyped circuit worked as required.

CONCLUSION

The research and construction of the garage door controlled by DTMF cell phone was successful. The mobile phone system controlled the opening and the closing of the sliding door system. The keypad of a DTMF enabled cell phone generates different tones and frequency when pressed. These frequencies can be decoded using a DTMF module. The 4 binary bits of the DTMF module can be configured together with a microcontroller to switch a set of relays. These relays turned the motor in the clockwise or anti-clockwise direction to either open or close the door respectively.

This approach can be used in home automation systems where a mobile phone will be used to control the switching of electrical and electronic appliances in a building, be it a home, school or an office.

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