Communication in Physical Sciences, 2023, 9(4): 585-606

Design And Construction of an Automatic Shutdown Device Using Programmable PIC16F844A Micro-Controller

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Recieved 29 April 2023/Accepted 13 September 2022/Published online: 29 September 2023

Abstract:: This study presents a design for the construction of an automatic programmed audio shut-off device. Theproposed system employs the use of a programmed timer consisting of time ranges that can be selected based on the user's choice. The power source for the device is the direct current (AC)AC supply which is rectified and stepped-down to supply the discrete components of the device. Also, the shut-down is activated by the instruction from the programmed PIC16F844A micro-controller which in turn is used to control the relay action. The idea of this research was aimed at improving the reliability of home-based appliances, providing a well secured alternative for emergencies at residential, commercial and recreational centres and of providing an easy way of switching and controlling devices when the user is unavailable or incapacitated to do so. The desined circuit offers flexibility of repair, avoidance of redundant components and ease of utility by users. Relevant components employed ranges from 220/12V step-down transformer, rectifier, 12 V relay and push buttons for initiating the control and accessing the features incorporated in the design. At the end of the project the device was tested and found to be capable of initiating the intended shut-down in record time as designed. With full optimism, the proper application of this research work will save alot in our community and if more researches are directed towards this area of electrical engineering, security of lives and properties would be greatly improved. This concept is found to be incorporated in the latest design of the i-stereo speaker unit, which shuts down automatically if there is no audio signal detected for few minutes

Keywords: *Device, Audio, Micro-controller, Circuit, Relay, Transformer, Appliances.*

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1.0 Introduction

In an industrial and domestic environments, ensuring the safety of habitants, personnels and equipments are of paramount importance (Usman et al., 2021). Automatic shutdown systems play a crucial role in preventing accidents and minimizing damages in scenarios where process parameters deviate from safe operating limits (Johnson et al., 2020). These systems are designed to swiftly detect abnormal conditions and initiate shutdown procedures to mitigate potential hazards (Shawnet al., 2019). This research paper presents an approach to automatic shutdown system design by introducing an innovative Automatic Shutdown Device (ASD) that integrates advanced sensor technology, intelligent control mechanisms(ICM), and responsive actuation systems.

The integration of advanced sensor technology allows the ASD to continuously monitor various critical process parameters in real-time. Sensors such as temperature, pressure, and flow sensors provide precise data that is then processed by a microcontroller unit (MCU) (Ayinde et al., 2021). The MCU acts as the brain of the ASD, processing incoming sensor data and making real-time decisions based on predefined safety thresholds (Odat et al., 2017). When these thresholds are exceeded, the MCU triggers the shutdown sequence to prevent any further escalation of abnormal conditions (Adelakun et al.,2014).

The actuation system of the ASD comprises a set of mechanisms that execute the shutdown actions. This system includes solenoid valves, motorized dampers, and emergency stop mechanisms, depending on the specific application requirements (Mohammed et al., 2020). These mechanisms ensure that the shutdown process is executed swiftly and accurately, minimizing the potential for accidents or damages.

This research is an explorer into the "unexplored gold mine of the sense of hearing". Most area of study on audio addresses amplification or analysis on hi-fi (high frequency HF) power amplifiers and other related works. However, the perculiarity of this research work is seen in its unconventional approach as regards the direction taken by several researches in the field of electronics engineering.

Oftentimes, the issue of abrupt shut-off is attributed to the mal-functioning of a system especially when it directly affects home-based appliances – this may actually be true most often when reasoned logically. However, in this design, this fact is opposed by a deliberate structure that permits a programmed shut-off on the audio player within a set time, with the aims of securing and protecting our home-based appliances. This concept is found to be incorporated in the latest design of the i-stereo speaker unit, which shuts down automatically if there is no audio signal detected for few minutes (Source: youtube.com/i-stereotechnology).

Reliability and compatibility are paramount in the design of the ASD. Redundancy measures are incorporated to avoid single points of failure and enhance system reliability (Clark & Green, 20RR). Moreover, the ASD is engineered to seamlessly integrate with the existing plant control infrastructure, facilitating coordinated communication with other safety systems (Ehiabhili et al., 2021)

Several works have been carried out. But until now researchers have failed to discover an efficient and cost-effective means of making life easier for residential and recreational activities. This research takes the case study of music as a means of effecting shut-down and thus providing comfort and convenience to music lovers and consumers of other related services. This work can be said to be an explorer into the field of electronics engineering, therefore it can be best described as unique.

In 2020, Ehiabhili et. al., created a wireless Bluetooth-based automated home control system connecting electrical appliance switches to Android smartphones. However, their emphasis was on automation rather than energy conservation. Meanwhile, in 2015, Iromini et al., 2021 developed an automatic switch controller for office lighting. This controller turns on the lights when the room illumination is insufficient, without accounting for the presence of office occupants.

Bitrus (2007), constructed a similar auto-shut off device with a supply voltage of 12V and the load rating of the device was estimated to range from 1.0KW to 1.2KW. His work was great, however an improvement is needed to augment power supply for the device as ripples and disturbances were not adequately filtered using a convenient filter capacitor. This is to enable the device to be adequately supplied with the sufficient power to operate on any device it is connected to.

This research is actually an improvement to his unpublished work. The use of a programmed micro-controller and a visual interface has replaced the analogue and archaic design of the previous work, (which made use of several comparators and capacitors) thereby making it more compact, portable and affordable. This work was able also to solve the problem of power limitation, as a result of inhibited voltage drops accross the various components of the circuit that was encountered by the previous work. This was achieved by using a voltage regulator to regulate the input voltage to the sensitive parts of the device and also designing with reliability in mind, hence avoiding redundancy of component parts. In other words, the circuitry was simple and was not cumberssome. By so doing, the internal characteristics and ratings of the components used were also improved and modified to meet the demand.

Onome, (2010) in a related work embarked on a construction with design intention to satisfy and control home appliances by the use of GSM and a SMS feedback was incorporated in the design to feed the user with information. However good the design has worked, the tendency for network failure or delay in network stands true especially in a growing world like ours. The design in this project gives higher reliability of automation due to the default timing programmed for a reliable home-based appliance, say an audio playing device. which is the surest and most effective way of curbing fire out-breaks at home, offices, recreational and tourist centres.

Sambo (2009), in his work on high fidelity 100W audio amplifier. Although, he employed the use of heat-sink as a means of dissipating heat generated by certain components of the device, he also gave the blue-prints on the several driver stages that ranges from pre-amplification to the output of the hi-fi amplifier. He failed to describe the feedback of the various driver stages, which could have afforded him the proper description of a design that incorporates audio de-amplification and shut-down if the device was to follow the reversed path of the stages. His work, however informative could not account for the eventualities associated with household appliances.

Hsuan-Huei Shih (2004), was good in the area of adjusting the output of the audio-player. The work was intended to see to the comfort of the consumer, this is the basis of this research as well. However, the importance of shutting down the system cannot be over-stressed; this is because, the volume control still entails that the device is still ON and that does not stop the dissipation of heat and other related risks from within the player or appliance.

This research therefore, stands alone in this regards concerning similar works on audio devices shut-down and other household appliance automation.

The significance of this research is to provide a useful solution to one of the major problem we face in Nigeria, as well as any other developing nations of the world which is that of regulating power supply to serve rather than to cause undesirable effects such as fire out-break. Another advantage of this project is that it mitigates the problem of noise and environmental pollution which is a direct consequence of noise especially at night when the user of an electrical appliance say for instance a music player, is asleep.

The uses of the confusion that exist as an art to solve the problem that may emanate from these terms that have been modelled and engineered in this work in other to address the problem statement.

Noise

This is any sound that causes disturbance, and that poises unpleasant sound to the ears. In any environment, noise is an unacceptable phenomena. However, noise is a relative term, because what may be pleasant (music) to one party may actually be unpleasant to the other (noise). This is exactly what gives backbone to this research at hand with useful household applications that promotes safety at home.

Music

This term is used to refer to a pleasant sound that attracts hearing. In otherwords, music is directly opposed to noise- which is rather not appropriate to the hearing of the parties involved. Music, according to the ancient maxim, is the food to the soul, this however, does not apply at times. Simply because there is time for everything. Usually, at the appropriate time music really serve as a source of relaxation and refreshment for the mind, but when the individual has derived the maximum utility from it, any additional factor, be as it may fractionally constitutes a noise. This explains the general principles that applies in economics, referred to as the law of marginal utility. In the expatiation of this principle above, satisfaction gets to a point where it retards and give rise to diminishing returns.

A precise picture is painted in the scenario of a lullaby, which is a device intended to make one (especially babies) to dose-off at night or whenever the need arises. When the consumer has derived the maximum satisfaction from the lullaby, the device is not designed to turn-off by itself, i.e it is not self-sustaining, as per automation. This therefore ends up constituting a nuisance when it truncates the sleep that has been induced initially, which is undesirable to the comfort and convenience of the consumers.

1.1 Description of components

With particular reference to this research, the following components were used in the design and construction stage of this research. Among the list are resistors, capacitors, diodes, switches/push buttons, voltage regulator, relays, biopolar tramsistor, transformer, micro-controller (PIC161877A), alphanumeric LCD display, buzzers and vero board and jumper wires. es

1.1.1 Resistors

A resistor is an electrical component that limits or regulates the flow of electrical current in an electronic circuit. Resistors can also be used to provide a specific voltage for an active device such as a transistor. The intrinsic ability of a resistor to resist the flow of electric current in an electric circuit is called the resistance. The value of the resistance of a resistor is measured in ohms (Ω) (Muawiya et al., 2022; Changde et al., 2022; Andarawus et al., 2022; Abdulbariu et al., 2023).

Any electrical wire has resistance depending on the material that such a resistor is made of, as well as its length and diameter. The unique resistive charateristic behaviour of a given material is called its resistivity ρ. The mathematical relationship between the resistivity ρ, the resistance R, length L and cross sectional area A of a material is given by equation 1,

$$\rho L = RA \qquad (1)$$

As seen from the relation above, it implies that the Wires that must conduct very heavy currents must have larger diameters to reduce resistance. The power dissipated by a resistive circuit carrying electric current is in the form of heat. Practical circuits must take power into account.

All other factors being equal, in a direct-current (DC) circuit, the current through a resistor is inversely proportional to its resistance, and directly proportional to the voltage across it. This is the well-known Ohm's Law. In alternating-current (AC) circuits, this rule also applies as long as the resistor does not contain inductance or capacitance.

$$I = \frac{E}{R} \qquad (2)$$

Circuit resistance can be calculated from current flow and the voltage.

$$R = \frac{E}{I} \qquad (3)$$

Resistors in series

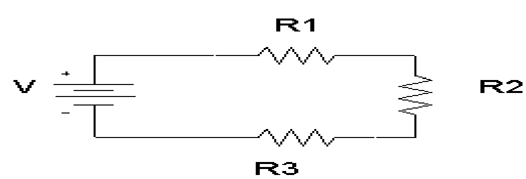


Fig.1: Network of resistors in series

The total equivalent resistance of resistors in series Rtotal is the sum of the individual resistance values:

$$R_{total} = R_1 + R_2 + R_3 + ... \qquad (4)$$

So when resistors are in series, the total resistance is increased ie the equivalent resistance (Rtotal) is greater than the largest resistance of the individual resistors.

Resistors in parallel

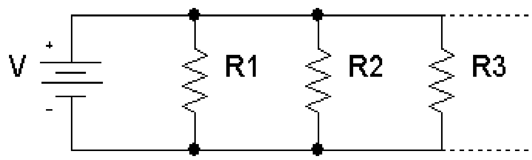


Fig. 2 : Network of resistors in parallel

The total equivalent resistance of resistors in parallel Rtotal is given by

1/Rtotal = 1/R1 + 1/R2 + 1/R3 + … (5)

So when resistors are in parallel, the total resistance is decreased ie the equivalent resistance (Rtotal) is less than the least resistance of the individual resistors(Archa et al., 2002).

1.1.2 Capacitors

A capacitor is an electronic device that is used to store charges in an electrostatic field. Capacitors are widely used to filter or remove AC signals from a variety of circuit. In a DC circuit, they can be used to block the flow of direct current while allowing AC signals to pass. A capacitor's capacity to store energy is called its capacitance, C, which is measured in farad, it can have any value from pf to uf.

Capacitors in an AC circuit behave as "short circuits" to AC signals. They are widely used to filter or remove AC signals from a variety of circuits; AC ripples in DC supplies, AC noise from computer circuits. The use of capacitor to couple one circuit to another is a common practice.

Capacitors take a predictable time to charge and discharge and can be used in a variety of time-delay circuits. They are similar to inductors and are often used with them for this purpose.

The basic construction of all capacitor involves two metal plates separated by an insulator. Electric current cannot flow through the the insulator, so more electron pile up on one plate than the other. The result is a difference in voltage level from one plate to the other. The stored charge in the capacitor is calculated as;

$$Q = CV \quad (6)$$

Where C is the capacitance of the capacitor and V is the potential difference between the two parallel plates. From the above we can calculate the current through the capacitor as follows: recal that:

$$i = \frac{dq}{dt} \quad (7)$$

but since $q = cv$, therefore we can write:

$$i = \frac{d(cv)}{dt} \quad (8)$$

but since it is a known fact that the capacitance of the capacitor is constant therefore the current through a capacitor is often represented as:

$$I = C\frac{dV}{dt} \quad (9)$$

The schematic representation of a capacitor is shown in the figure below

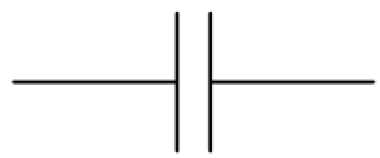


Fig. 3: Symbol of a capacitor

There are different types of capacitors which includes: ceramic capacitors, tantalum capacitors, electrolytic capacitors, mica capacitors, paper capacitors, plastic film capacitors, etc.

1.1..3 Diodes

A diode is an electronic component that possesses the intrinsic ability of allowing the free flow of electrons only in one direction known as the forward bias direction. Diode exhibits a number of useful characteristics, such as predictable capacitance (that can be voltage controlled) and a region of very stable voltage. They can therefore, be used as switching devices, voltage-controlled capacitors (varistors) and reference voltage (zener diode).

Because diodes will conduct current easily in only one direction, they are used extensively as power rectifiers, converting AC signals to pulsating DC signals, for both power applications and radio receivers.

Diode behave as voltage-controlled switches and have replaced mechanical switches and relays in many applications requiring remote signal switching. Even indicator lamps are now replaced with diodes (LEDS) that emit light in a variety of colors when conducting.

A special form of diode, called Zener diode is useful for voltage regulation. (Job 2008). While, a special form of diode which operates only in the forward-biased direction by blocking opposite passage of current, is called a Fly-wheel diode.

The schematic representation of a diode is shown in Fig. 4.

1.1.4 Switch and push button

A switch is a device which is used to power the circuit “ON” or “OFF”. When the switch is in its position {ON} current will flow, (i.e when the resistance of the switch contact is very small). However when the switch is in its open position {OFF} it does not allow the flow of current because of the high resistance between the switch contact. In this project the switch was used for establishing the connection between the device and the A.C mains supply.

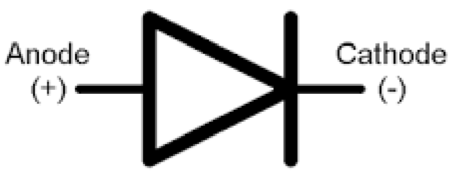
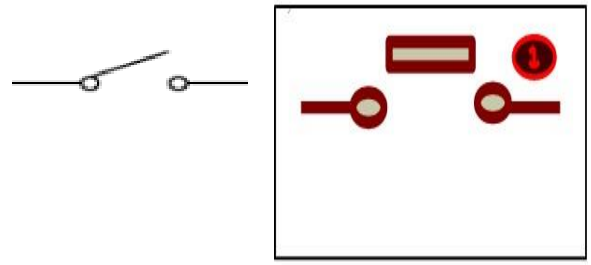


Fig. 4: Symbol of Diode

The push buttons on the other hand, is a special switch that has a predefined state maintained by default and will change to the opposite state only when the button is pressed and relapse back to the default state when the button is released. In this project, the pushbuttons were used extensively as the local buttons on the device to toogle between the variety of the operating features of the device. It is quick to recommend the use of the remote control instead, which could readily replace the push buttons; however, the cost implications and other reliability studies shows the merits of the push buttons over the remote controller, thus the reason for utilising it in the construction of this work.

The schematic diagram below illustrates the difference between a switch and a push button:



Symbol of a Switch

(b) Symbol of a Push Button

Fig. 5 : Contrast between a Switch and Push button

1.1.5 Voltage Regulators

A voltage regulator is an electronic component (integrated circuit), which converts varying input voltage to produce a constant regulated output voltage. Voltage regulators usually have three terminals and are available in a variety of outputs. The most common part numbers start with the numbers 78 or 79 and finish with two digits indicating the output voltage. The number 78 represents positive voltage and 79 negative one. The 78XX series of voltage regulators are designed for positive input and the 79XX series is designed for negative input. For example a +5V DC regulator is named LM7805 or MC7805, a -5V DC regulator is named LM7905 or MC7905, a +8V DC regulator is named LM7808 etc.

The LM78XX series typically has the ability to drive current up to 1A. For application requirements up to 150mA, 78LXX can be used. As mentioned above, the component has three terminals namely:

Input terminal: this can hold up to 36VDC.

Common terminal (GROUND = 0V)

Output terminal, which has the regulator's voltage.

For maximum voltage regulation, adding a capacitor in parallel between the common leg and the output is usually recommended. Typically a 0.1uF capacitor is used. This eliminates any high frequency AC voltage that could otherwise combine with the output voltage. Fig. 6 shows the schematic diagram of a voltage regulator.

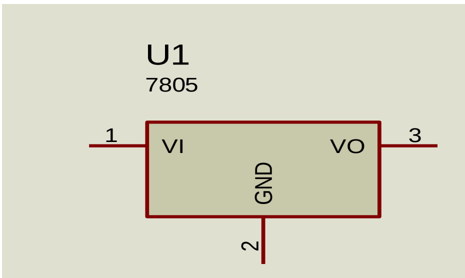


Fig. 6 A Schematic diagram of a voltage regulator

As a general rule the input voltage should be atleast 2 to 3 volts above the output voltage in order to ensure proper voltage regulation at the output of a given voltage regulator. However, care should also be taken so that the input voltage does not get in excess of 12-15 volts of the rated value of a given voltage regulator. The LM78XX series can handle up to 36 volts input. The power difference between the input and output appears as heat therefore if the input voltage is unnecessarily high, the regulator will overheat. Unless sufficient heat dissipation is provided through heat sinking, the regulator will shut down (Eidusa, 2015). Perculiar to the automatic shut off device, is the 7805 voltage regulator, which supplies a steady 5V from the normal 12V input to the micro-controller and other sections of the device.

1.1.6 Relays

A relay is an electrical switch, which uses an electromagnet to operate a switching mechanism mechanically. Relays are used where it is necessary to control a circuit by a low-power signal (with complete electrical isolation between control and controlled circuits), or where several circuits must be controlled by one signal. In the operation of the relay, current flowing through the coil of the relay creates a magnetic field, which attracts a lever and changes the switch contacts. The coil current can be on or off so relays have two switch positions and most have double throw (changeover) switch contacts. The circuit symbol for a relay is shown in Fig. 7 below.

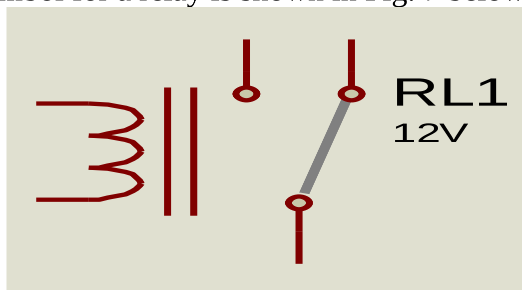


Fig. 7: Circuit symbol of a relay.

As shown in Fig. 7, the relay's switch connections are usually labelled COM, NC and NO.

COM = Common: The Mains is always connected to this terminal and it is the moving part of the switch.

NC = Normally Closed: The COM is connected to this when the relay coil is OFF.

NO = Normally Open: The COM is connected to this when the relay coil is ON.

Note: COM is connected to NO when it is desired to let the switched circuit be ON when the relay coil is ON while COM is connected to NC when it is desired to let the switched circuit to be ON when the relay coil is OFF.

Since relays are switches, the terminology applied to switches is also applied to relays. A relay will switch one or more poles, each of whose contacts can be thrown by energizing the coil in one of three ways:

Normally-open (NO) contacts connect the circuit when the relay is activated; the circuit is disconnected when the relay is inactive. It is also called a Form A contact or "make" contact. NO contacts can also be distinguished as "early-make" or NOEM, which means that the contacts will close before the button or switch is fully engaged.

Normally-closed (NC) contacts disconnect the circuit when the relay is activated; the circuit is connected when the relay is inactive. It is also called a Form B contact or "break" contact. NC contacts can also be distinguished as "late-break" or NCLB, which means that the contacts will stay closed until the button or switch is fully disengaged.

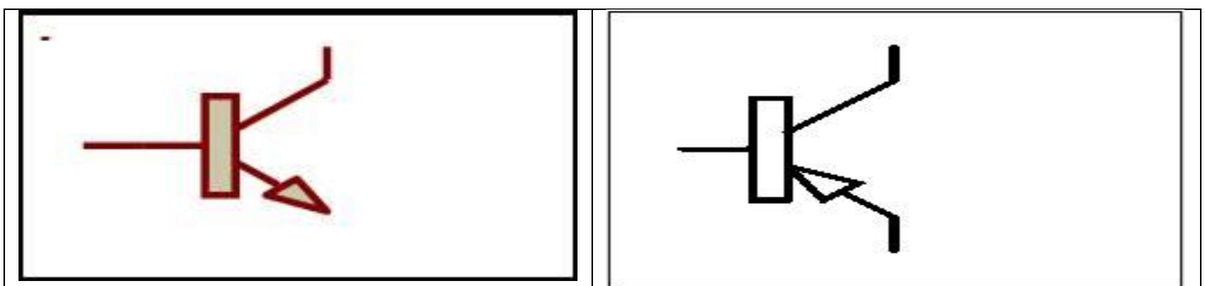
Change-over (CO), or double-throw (DT), contacts control two circuits: one normally-open contact and one normally-closed contact with a common terminal. It is also called a Form C contact or "transfer" contact ("break before make"). If this type of contact utilizes a "make before break" functionality, then it is called a Form D contact.

1.1.7 Bipolar Transistors

The generic bipolar transistor is the common transistor type in use. It is made up of basically two types which are the NPN and PNP bipolar transistor. One of the major difference between the bipolar transistor and the Power MOSFET transistors is the fact that bipolar transistors are current controlled semiconductor electronic devices while the Power MOSFETs are voltage controlled. However, in terms of power handling capability, the MOSFETs are preferrably employed in designs than their counterparts (Rishama, 2015).

Where lower switch speed as well as lower power amplification is required then the better transistor type required is the generic type bipolar transistor. And in this project the bipolar transistor have been used to basically achieve the switching of the relays and for other switching operations within the circuit.

The schematic block diagram of a bipolar NPN and PNP transistor is shown Fig 8(a) and (b) respectively below:



(a) **(b)**

Fig. 8 (a) A bipolar NPN transistor (b) A bipolar PNP transistor

1.1.8 Transformer

A transformer can be said to be a static machine used for transforming power from one circuit to another without changing the frequency. Usually, the generation of electrical power in low voltage level is very much cost effective. Hence, electrical power is generated in low voltage level. Theoretically, this low voltage level power can be transmitted to the receiving end. But if the voltage level of a power is increased, the current of the power is reduced which causes a corresponding reduction in ohmic or I2R losses in the system. Because of these, low level power must be stepped up for efficient power transmission. In this project, a step-down transformer was used to reduce or regulate the normal supply voltage from the mains, rated about 220V to 24V when the input voltage is applied through the primary winding of the transformer. This 24V, is what is used as the supply voltage to power the auto shut-off device and the entire circuit therein. A current transformer, does the function of stepping down the input current into ratings that are compactible with the circuit components for their safe and smooth operation without failing.

A schematic block diagram of a simple two winding transformer is shown in Fig. 9.

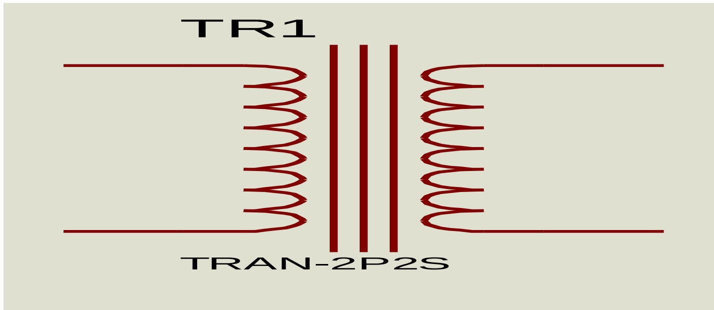


Fig. 9: A Simple Transformer

1.1.9 The micro-controller (PIC16F877A)

This can be looked as the brain of the device that integrates the other sections of the entire circuitry and serving the major function of monitoring some of the processes taking place in the automation of the device like measurement of voltage level, giving of command to the hardware section of the device, and the controlling the connected audio input. It is responsible for interpreting the signals received at the remote control receiver pins as well as those of the local buttons. It also controls the inverter display, the oscillator IC (SG3525) during automatic shutdown, and two out of the four relays which are used for automatic full charge battery cuttoff, and for automatically controlling the AC ouput power. The schematic diagram that illustrates the microcontroller (PIC 16f877A) IC is shown in Fig. 10.

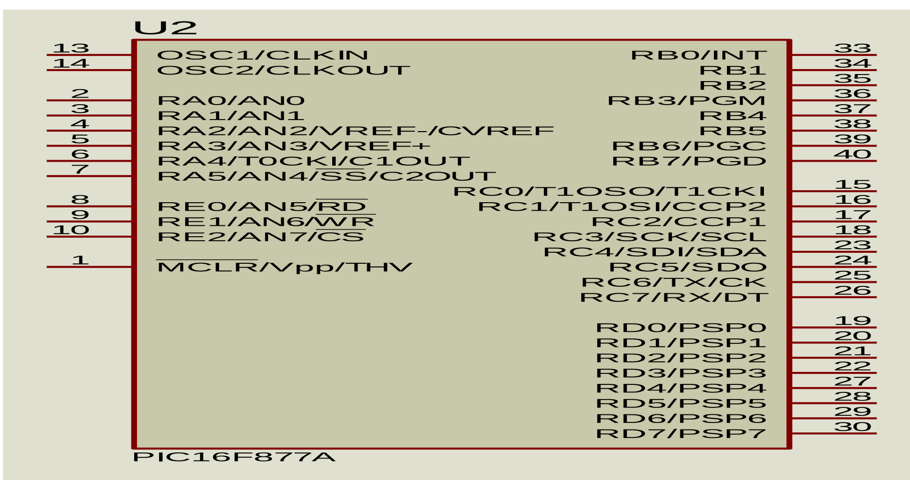


Fig. 10: Block diagram showing the pin outs of a PIC 16f877A programmable IC

1.1.10 16 by alphanumeric display

The 16 by 2 alphanumeric display is the digital display that provides an interractive platform for the user to operate and manupulate some of the useful features of the automatic shut-off device. It gives the user the access to visualize the menus as well as the available options which acts as the sub functions associated to each of those individual menus. All these menus and sub funtions can be accessed using either the remote buttons or the local buttons which are situated at the front panel of the automatic device, actually on the keypad.

A schematic representation of the alphanumeric display is shown below:

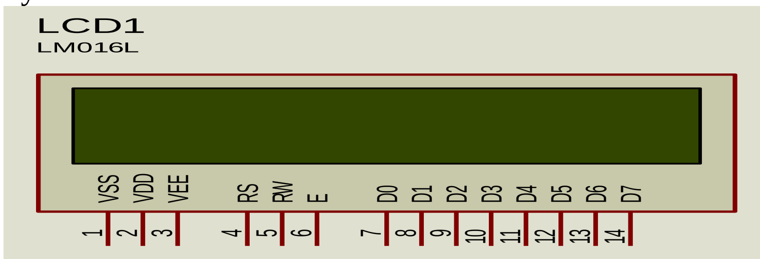


Fig. 11: A Schematic Representation of a 16 by 2 Alphanumeric Display

1.1.11 Buzzer

Buzzer is simply an electronic device which makes a hum or beep sound when it is activated by a small current by the aid of a switch, say a transistor. A simple HYDZ 3-30V buzzer alarm is used in this project to activate the operational tone of the device while the user is scrolling down the menu of the device. It also has the following features:

High performance buzzer that uses piezoelectric element is easily incorporated into various circuit operation.

It features extremely low power consumption in comparison with electromagnetic unit because the buzzer is designed for external excitation, as the same part can act as both musical tone oscillator and a buzzer.

It can be used as an automatic inserter and it is moisture- resistant in an electronic device.

The buzzer used in this project has two pins which are simply connected to the NPN transistor, to allow the base current of the transistor to trigger a sound. The other pin is connected to a 5V regulated power supply. The buzzer is set into operation according to the signal it receives from the microcontroller by the transistor which acts as a switch.

Fig. 12 the symbol diagram of a buzzer.

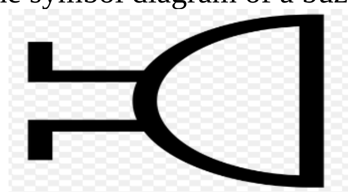
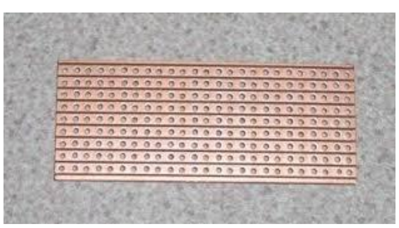


Fig. 12:Electrical Symbol of a Buzzer.

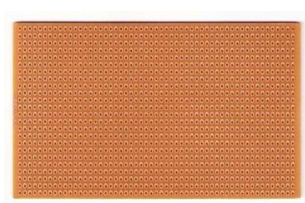
1.1.12 Vero board and Jumper wires

The vero board is the solid frame where the permanent soldering of components in the project was done. The two basic types based on the conducting layout are the dotted and the straight through which do usually comes in various sizes. The jumper wires on the other hand was used to cross-link the conducting path of a circuit from one point to another. By so doing, the lead solder comes into play in holding the jumper wire in position on the vero board when implementing the cicuit on a permanent construction. Specifically, the straight through board was used in this project work due to the advantage of easy conduction.

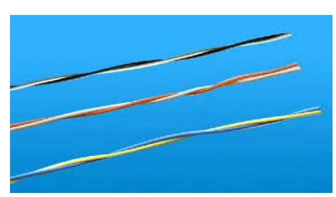
Fig 13 (a) shows the picture of a straight through vero board, Fig 13 (b) shows the picture of a dotted vero board while Fig 13 (c) shows that of the jumper wires as illustrated below:



(a) Straigh Through Vero Board



(b) Dotted Vero Board



(c)Jumper Wires

Fig 13 Materials used for the Circuit Construction

1.2 Design and calculation

The auto audio shut-off device is essentially a device that turns-off the audio system from continously working out, especially at a time when the user is not in the position to do so. This is also with the perspective of protecting electrical systems from undue abrupt damage, which consequently enhances audio-system reliabilty and of course dispatch maintainability. (B.S Dhillon, 1999)

The research at hand, is the design of a portable device which performs the function of regulating the above mentioned. The device is internally powered by a 12V DC after rectifying the 220V from its mains power source.

The working principles of this device is depicted in a block diagram as shown below in Fig 14:

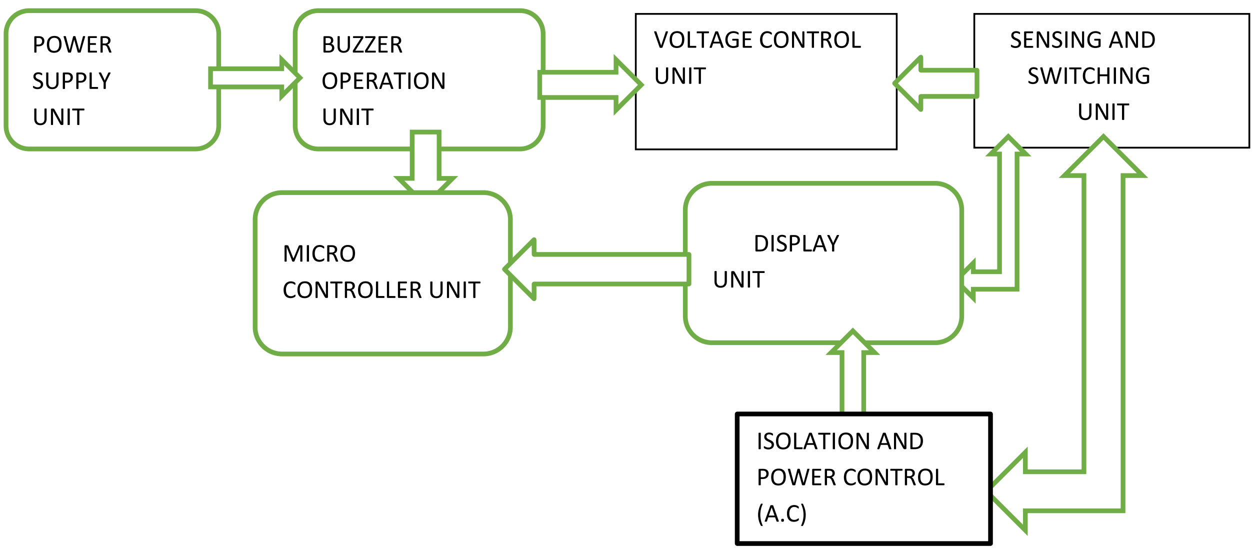


Fig. 14: A Block diagram showing the working principle of the project

2.0 Material and Methods

2.1 Design and calculations of hardware unit

The hardware section of this research, is categorised into eight major parts which gives the clear description of the circuit diagram that makes up the auto shut-off device;

DC Power Supply Unit
Buzzer Operation Unit
Voltage Control Unit
Sensing and Switching Unit
Micro-controller Unit
Display unit

Design and calculation of the power supply unit

The power supply unit consists of:

A 240/12V 500mA step down transformer.
A full wave bridge rectifier.
A capacitor.
A voltage regulator.

The Power Supply Unit Design is depicted in Fig. 15 below,

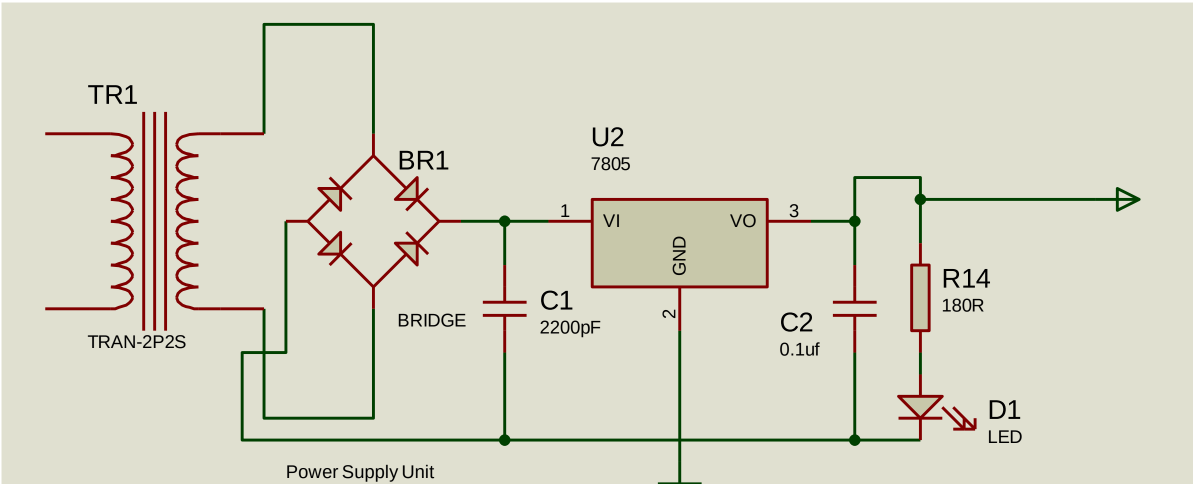


Fig. 15: Power Supply Unit Circuit

2.1.1 Transformer selection calculation

In any design, the selection of a transformer is dependent on the total maximum current of the components involved in accordance with their ratings. The current and voltage ratings of the basic component used in the project from their respective data sheets are shown in 1 below.

Table 1: Maximum Current and Voltage Ratings of Components used

Components	Maximum CURRENT (mA)	TYPICAL VOLTAGE rating RATING (V)
LED	30	4
Transistor	100	5-12
Microcontroller (PIC)	3.6	5
Relay	30	12
Power diode	20	0.7
Buzzer	15	12
LCD	1.5	5

Total= 200.1mA

Based on the total current value calculated, a transformer rating of 240/12V, Voltage rating; 500mA Current demand, and 50Hz operating Frequency was considered to be appropriate for stepping down AC voltage from 240V to 12V

in order to power the device without causing damage to its internal components.

Hence, the turn ratio of the transformer is calculated as follows:

$$K = \frac{N_2}{N_1} = \frac{V_2}{V_1} \qquad (10)$$

Where: K is turns ratio.
N_1 is number of turns on the primary winding.
N_2 is number of turns on the secondary winding.
V_1 is voltage applied to the primary side.
V_2 is voltage at the secondary side.

It follows from equation 10 above that,

$K = \frac{240}{12} = 20:1$

Also, the power rating of a transformer is expressed by equation 11 below:

$$P = I_{rms}V_{rms} \qquad (11)$$

Where: P is average power rating of a transformer.
I_{rms} is the root mean square value of the total output current from the rectifier.
V_{rms} *is* the root mean square value of the total output voltage from the rectifier.

It follows thus, that the maximum safest power range of the transformer to perform is 6 watts from:

$P = 500 * 10^{-3} * 12 = 6W$

2.2 1 Selection of the bridge rectifieriodes

The diodes used were selected were so done based on the following calculations as follows: The Peak Inverse Voltage (PIV) of the diode is expressed thus:

$PIV = V_m$ (12)

But

$V_m = \sqrt{2}\, V_{rms}$ (13)

Therefore, the substitution of 12V rms as the value of the voltage leads to the following expression

$$PIV = \sqrt{2} * 12 = 17V$$

PIV is the maximum reverse voltage, above which the break down occurs causing large current to flow in the reverse direction. Hence for the purpose of rectification the IN 4002 diode types whose PIV are less than 17V are suitable and were selected for AC voltage rectification for this project work.

2.2.2 Design of the buzzer unit

The design of the buzzer operation unit, was done in view of the ease of operation of the device. It was noted, that devices are known to be operating when it either beeps out a sound or it emits light, i.e from a Light Emitting Diode (LED).

In this project work, the sound-emitting or the buzzer unit consists of the following components:

12V DC Rectified Output

Transistor as a Switch

A Voltage Regulator

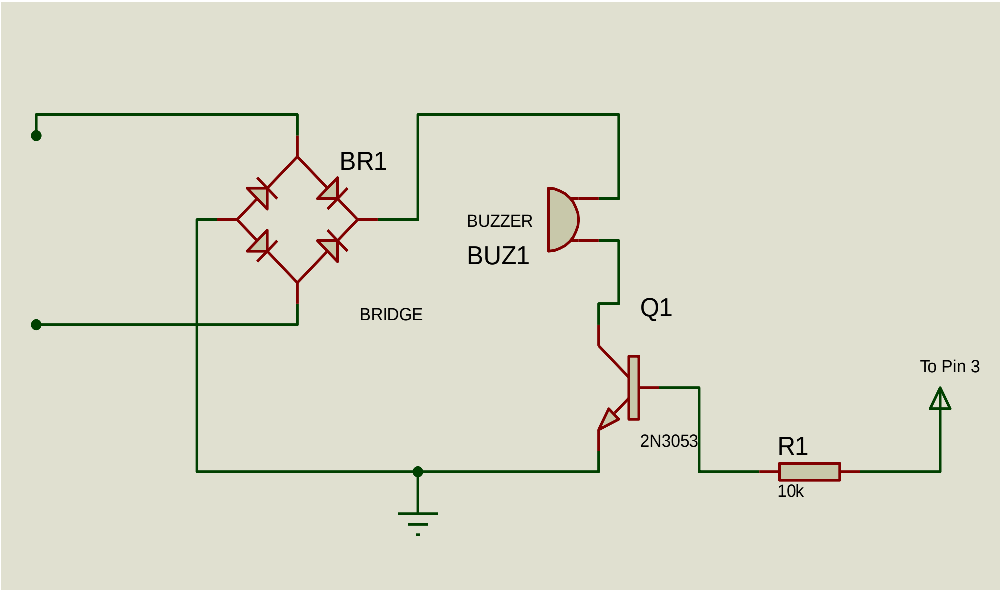


Fig. 16 :Circuit schematic of the Buzzer unit

2.3 Rectifier output design

From the circuit diagram above in (14) above, the output of the bridge rectifier which is initially 12V DC is connected to the input terminal of the voltage regulator (7805), from whose output the 5V is taken. It is from this node that a connection is made to the buzzer for its operation.

In otherwords, the buzzer can take up to a maximum of 12V or more for its normal operation.From the design of the device, the value of the filter capacitor is derived from:

The capacitor used as the filter is selected based on the following calculations of its capacitance

$C_1 = \frac{I_{dc}}{4F(V_m - V_{dc})}$ (14)

where: I_{dc} is the output DC current of the rectifier, F is the frequency of the rectifier, V_m is the maximum voltage at the load, V_{dc} is the output DC voltage of the rectifier, But respective parameter values in equation (14) are calculated as:

$V_m = \sqrt{2}\, V_{rms}$ (15)

$$V_m = \sqrt{2} \times 12 = 16.97V$$

$$V_{dc} = \frac{2V_m}{\pi} \qquad (16)$$

$$V_{dc} = 2 * \frac{16.67}{3.142} \quad V_{dc} = 10.8\text{V}$$

$$I_{dc} = \frac{2I_m}{\pi} \qquad (17)$$

$$I_{dc} = \frac{2 * \sqrt{2} * 500}{3.142} = 450mA$$

Therefore from equation (14) above, the values are calculated for C_1:

$$C_1 = \frac{450 * 10^{-3}}{4 * 50 * (16.67 - 10.80)} = 900\mu F$$

The value of capacitance, determines the harmonics or ripples that may permeate it. Thus, a 1000µF capacitor was used as an approximate value of the capacitance.

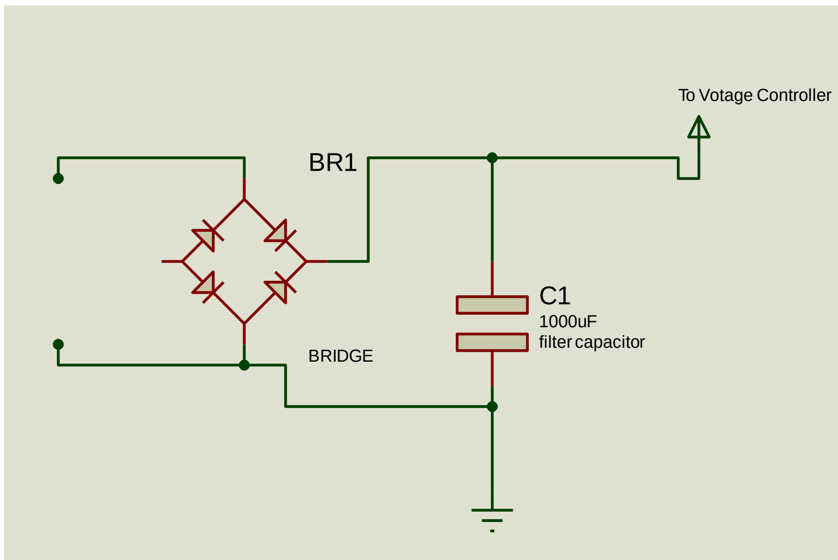


Fig. 17: Circuit Schematic For the Filter Capacitor Design

2.4 Design of transistor as a switch

The buzzer, is connected to an NPN transisitor, of value 2N3053 obtained from datasheet of transistors and then the connection is grounded via its emitter terminal. The transistor in this case receives set of instructions from the PIC Micro-controller and executes its functions as a switch to either activate the buzzer in ON or OFF mode by pressing the buttons attached to the casing of the device.

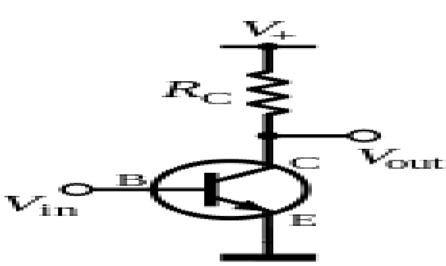


Fig. 18: A Transistor as a switching device

$$I_B = \frac{V_{BB} - V_{BE}}{R_B} \cong \frac{V_{BB}}{R_B} \qquad (18)$$

$$I_C = \beta I_B \qquad (19)$$

$$V_{CE} = V_{CC} - I_C R_L \qquad (20)$$

The transistor is said to be in cut off condition when it does not conduct any current, signifying that the buzzer is LOW or OFF.

As the value of I_B increases by increasing V_{BB} then I_C also increases because $I_C = \beta I_B$. This increases drop across R_L, as result of which V_{CE} is decreased because $V_{CE} = V_{CC} - I_C R_L$

A certain value of I_C is reached when $I_C R_L$ becomes equal to V_{CC} and this state the transistor is said to be in saturation (full conducting state).

The load line diagram and operating point of a transistor, is shown below:

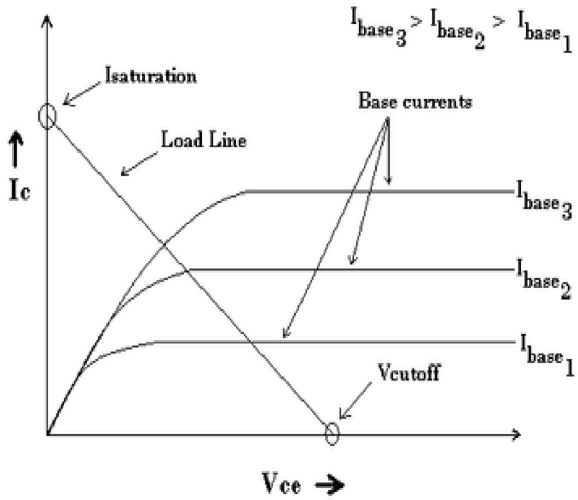


Fig. 19: DC load line of the common emitter circut of a transistor

In this reseach, the assigned pin that does this work on the micro-controller has been defined to be pin 3, and the buzzer had been connected to the micro-controller by the means of a pull-up resistor of value 10kΩ to regulate the pulse sent to the micro-controller and also to keep the sound at the instant the press button is toggled. The programme for this operation has been embedded in the software unit of this work through the aid of a micro-controller.

DESIGN OF THE VOLTAGE CONTROL UNIT.

The key component in this unit, is the 7805 voltage regulator which is used to keep the supply at the input terminal of the PIC micro-controller at exactly 5V, rated.

The importance of the 7805 Voltage Regulator IC, is to regulate the 12V DC and to fix the supply of the positive terminal of supply to a lesser and consumable voltage by chiefly, the press-button switches and micro-controller (Dennis, B. 1999).

2.5 Design of the sensing and switching unit

The design of the sensitive part of this project was carried out in this unit. The time lag and delay for responding to the command given from the micro-controller, was carried out by the following components below:

A 12V DC Electro-mechanical Relay

The Blocking Diode

A BC547 Transistor

A 1kΩ Resistor

Design of the micro-controller unit

This design unit represents the brain box for controlling the whole process and functionality of the hardware section of this project.

The PIC microcontrollers are commonly employed in the following applications;

Household Appliances: This include washing machines, remote controls, light control video games, TV tuners, interim and sewing machines.

Office Equipment: Such as telephones, fax machines, printers and security systems.

Instrument: These include digital thermometers, level meters and multi-meters.

Motor Control: Speed control of AC and DC motors, position control using servo-motors and stepper motors.

Peripheral Devices: Keyboard controllers, modems and plotters.

Industry Application: Process control systems and automobile applications.

The design of the micro-controller, is an internal design which has been internally fabricated. The layout consists of 40 pins and other ports, which are used for description of various actions and function assigned to them. However, this is dependent on the complexity of the work described.

In this research, about 15-20 pins were defined and assigned to perform the overall process of the shut-down and also to programme the beeping of the buzzer and other ancillary functions.

The internal architecture of the PIC16F877A which was used for this work, is given in Fig. 20

Device	Program FLASH	Data Memory	Data EEPROM
PIC16F874	4K	192 Bytes	128 Bytes
PIC16F877	8K	368 Bytes	256 Bytes

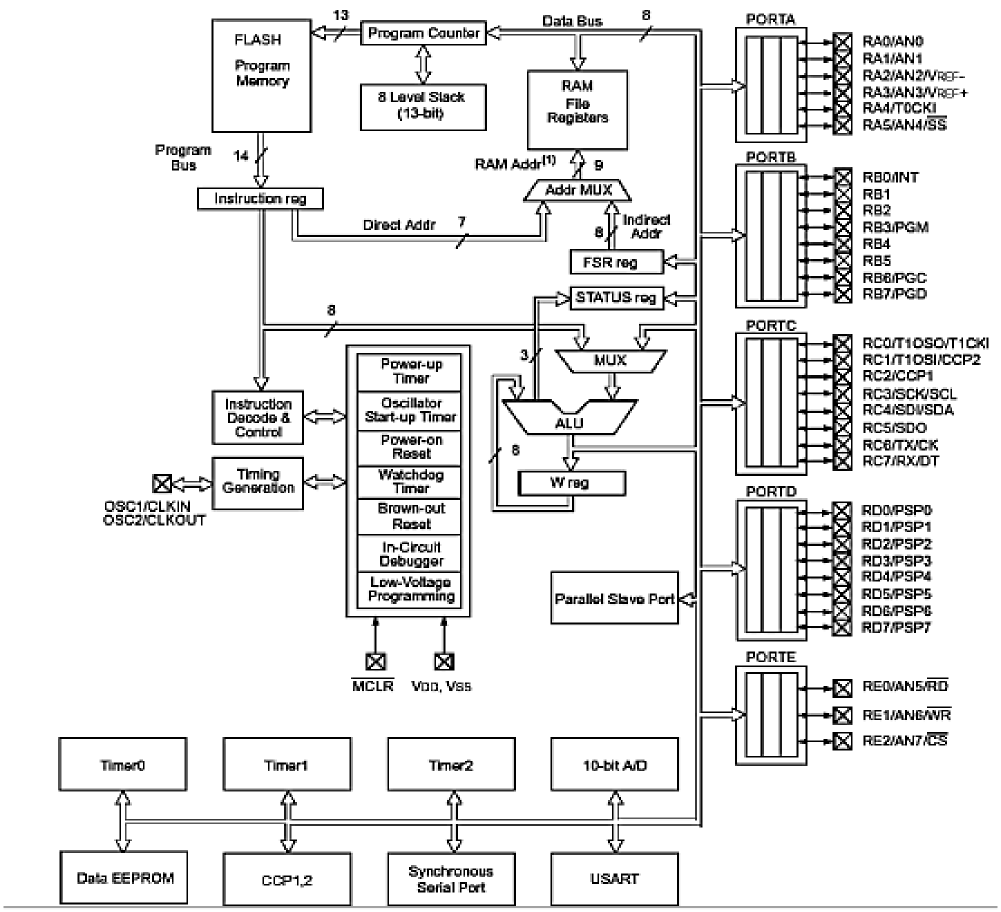


Fig. 20: Internal architecture of PIC16F877A micro-controller

2.6 Design of the interface unit

The design of this unit consists of the following components which served as the ey to either directly enhancing the performance of the codes encrypted inside the PIC micro-controller or by rather displaying the information from its output.

By this classification, the natural category in this unit are the following two components:

The Crystal Oscillator, and

The 16 by 2 Alphanumeric Display (LCD)

2.7 The crystal oscillator

From the description above, the crystal oscillator is a speed processing device, which determines at what frequency the micro-controller would run the programmed codes to run the device at a well suited time condition.

In the design of this project, due to the complexity of the codes and also the multi-functions that have been assigned to the micro-controller, it was recommended that a higher value of the crystal oscillator is to be used to effectively run the source code without any slack time or delay, which may lead to an eventual inefficiency of the device to be able to shut-down at the stipulated time.

Common values of crystal oscillators available in the market ranges from 4MHz to 20MHz. Also, they are usually connected to pins 12 and

13 of the micro-controller, used to run the programme.

2.8 The 16 by 2 alphanumeric display

For this project work, a portable 16 by 2 display aid has been used in order to show case the operation of the device. This component part gives the user an idea of the device at first use by scrolling the press-buttons and visually accessing the corresponding response. However, with the theory of use and dis-use, the user becomes familiar with the features and mode of operation of the device which is the goal of every designer.

In this work, the 16 x 2 display was used which entails that 16 rows are displayed in two columns. By implication, it means that only 32 characters are permitted to be displayed at once on this design.

The overall design of the hardware unit as described, is depicted in Fig. 21: below:

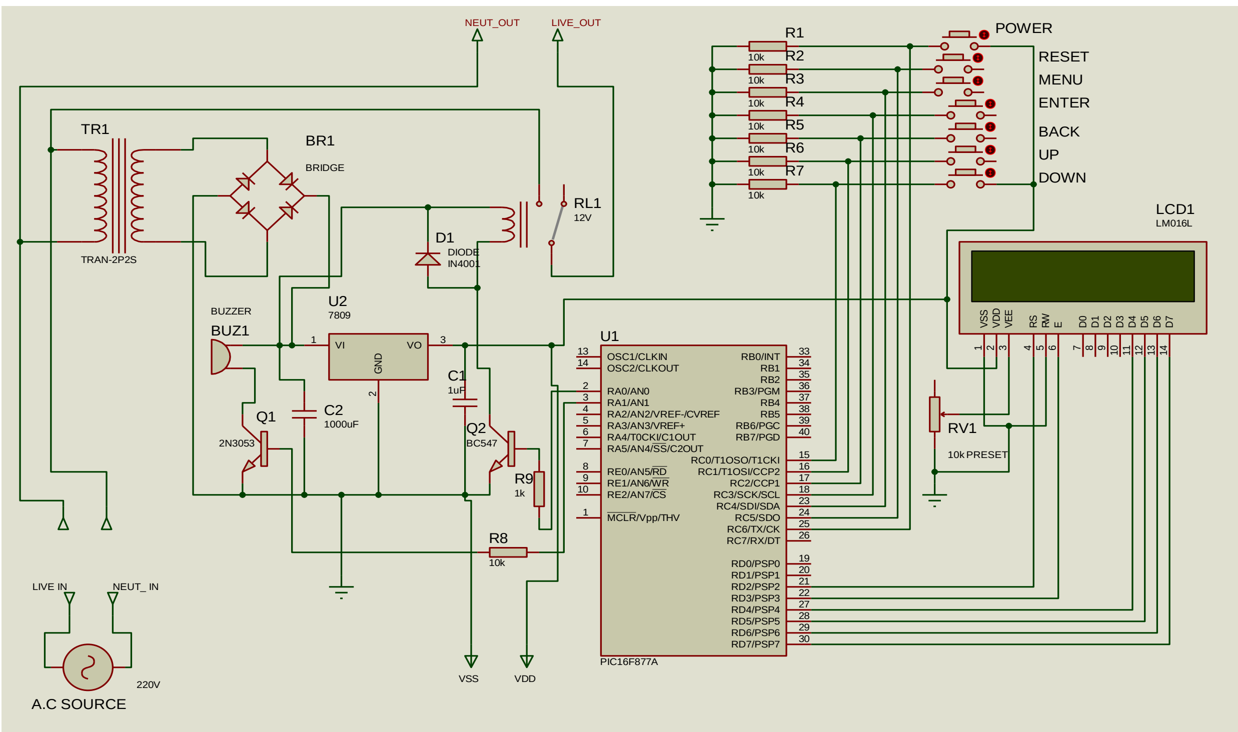


Fig. 21: The Complete Circuit Schematic of the Hardware Section of the Device

2.9 Design and programming of the software unit

The software design of this research, involved the use of an application was used in simulating the circuit and writing the programming codes for the system design. This computer application is the PROTON COMPILER and PROTEUS 8 PROFESSIONAL which uses C-programming as the assembly language for its compilation.

The micro-controller (PIC16F844A) served as the brain on which this codes were written and compiled. Thus, by incorporating the codes on the micro-controller chip the circuit design was expected to work as planned or rather as the codes were compiled to the chip.

The apparatus used to write the codes on the memory block of the micro-controller, is the PIC-KIT 3 PROGRAMMER SOFTWARE the hardware on which the configuration is done.

3.0 Results and Discussion

3.1 Research onstruction and testing

The details on the testing and the result obtained from the device after the design and the construction has been achieved and the list of tools used in the course of the construction phase have been highlighted

3.2 Body design and construction

The main body part of the device gives shape to it and serves not only as mechanical support or protection to the delicate design part, but also gives beauty and aesthetical appeal. It was necessary to make the enclosed casing simple and portable as possible, this is for the purpose of convenience and for easy mobility of the device.

3.3 Circuit construction

The construction of this project was carried out in two phases namely the temporal and permanent constructions. The former was implemented first in other to have an over-view function of the device before finally implementing the latter.

3.3.1 Temporary construction

The temporal construction was achieved on a bread board and ensured to be working, before finally transferring the working circuit to be soldered on a permanent frame. The temporary phase of the construction is depicted in the picture as shown below:

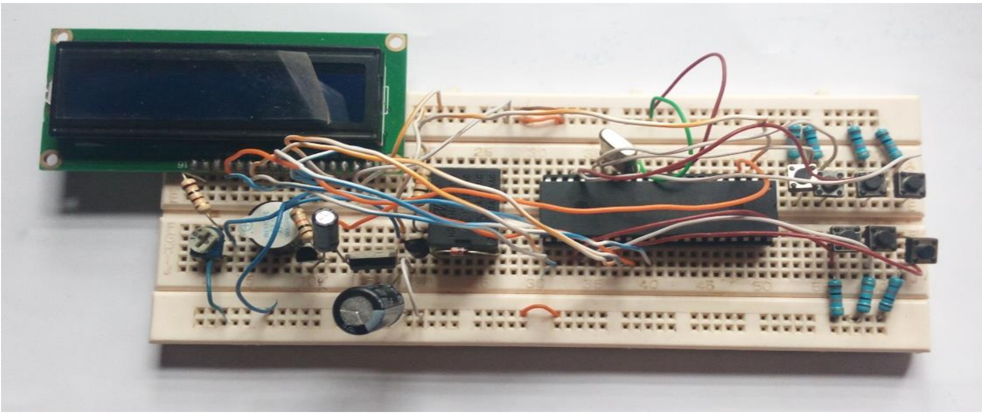


Plate 1 The temporary construction on a bread board

3.3.2 Permanent construction

On a permanent frame the circuit was constructed on the vero-board after testing it on the breadboard. The circuit was constructed in logical order, this was done in other to avoid the overlapping of solder lead and also to give independence to each working section that makes up the device.

The device in its completion phase, is shown in the plate 2. Irrespective of the maintenance and care during the construction work, some components had it rough during the soldering action and consequently, they had to be replaced.

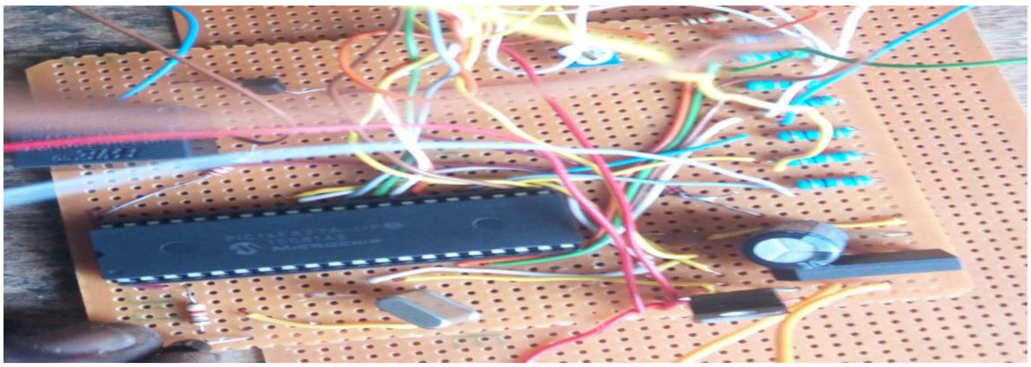


Plate 2: The Permanent construction on a vero-board

3.4 Enclosure construction and casing fabrication

The casing used was made of poly vinyl chloride (PVC) material which have an advantage of easy recycling. The reason for using the plastic casing, is to avoid all forms of short-cicuit and risk of damage that may be posed to the device.

The press buttons, buzzer, outlet socket point and other external connection points were neatly fabricated on the casing. While internal connections were ensured to be held firmly by means of screws which were fabricated within the device.

3.5 Assembling

The tools that were involved in the assembly of the completed work were drillers, hand hack-saw, screw drivers and pair of solid cutters. The assembly process was carefully carried out in other to give shape and aesthetic appeal before presenting the work to the public. The screw points were also driven through the plastic enclosure neatly and was well coupled.

3.6 Circuit testing

After the device had been constructed and the assembling process was finished, it was tested to ensure that it meets the requirements and that the problem definition had been achieved to its maximum. The point of test used, was the socket outlet of the device.

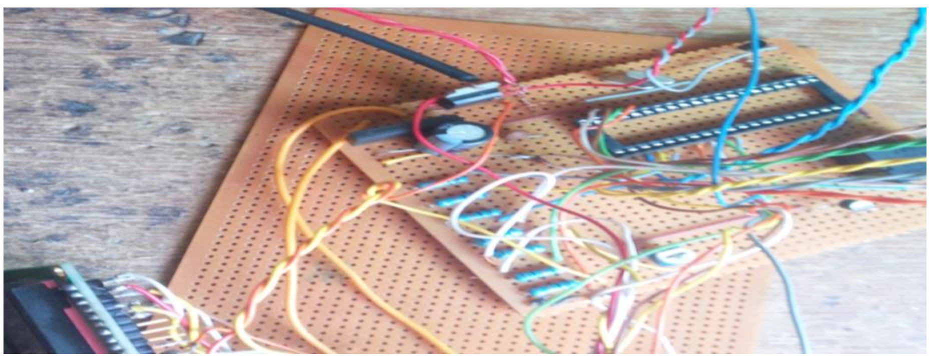


Plate 3: A picture view of the device during testing

3.6.1 Operational mechanism

It is clear from the elaborate circuitry of the device, that the power source to the device is fed from an ac mains supply which is usually between the ranges of 200-230V. However, many applications that indulges electronic components requires lesser voltage rating of DC values between the ranges of 5V-12V mostly, under normal working condition. Therefore, several processes of rectification and filteration takes place at the power supply unit, before finally supplying well suited voltages to the hardware units and sections. The reason for the full-wave bridge rectifier, is to ensure that the 220V AC is fully rectified to 12V DC before being fed into the discrete electronics component to avoid the problems of over-voltage and consequent irrepairable damages to the device. The buzzer unit is connected to a bipolar transistor which acts as a switch to activate its beep sound during the operation of the device. This feature is so achieved by the interface between the micro-controller section and the buzzer hardware unit, which basically consists of the programming codes. From the circuit design, 12V DC power is fed into the buzzer which is a convenient voltage for its smooth operation as indicated in the datasheet. It is hence connected to a bipolar transistor which acts as a switch to the buzzer and the other terminal in turn, is connected to ground.

The other components used, such as the push-buttons, electromagnetic relays and the LCD or display unit requires voltages that are less than the rectified 12V supplied from the rectifier output terminal. It is due to this variation in voltage levels, that a 3-terminal called the voltage regulator (7805 model) was introduced. It is fed from the rectified 12V DC and supplies 5V DC at its output terminal and the third terminal (middle) is connected to ground.

The press-buttons are used to toogle between the various features that have been incorporated into the design of the device to ensure that the users are conversant in operating the device without difficulty.

When a the signal is not sensed by the micro-controller, this condition is detected by pin 2. Normally, the device is programmed to be ready to turn-off under this condition; however, the relay does not go to the normally open position immediately. The program includes a delay time before turn-off of 5seconds which is to ensure that the user is actually asleep or incapacitated before finally actuating the shut-down of the music player (or any other appliance connected to it).

The device on test, satisfied the designed requirement for which it was intended to perform. However, the time of displaying the features on the LCD was observed to be slow.

4.0 Conclusion

Having successfully gone through the different phases of this research, which cover the objective of designing and construction of an automatic appliance shut-down device with programmable features which controls switching time, the results of the testing phase showed that the performance of the device met design specifications. For the above inpediments; More research work be channel on the design and construction of home-based automation systems, that would be cost-effective and affordable to an average citizen; More features could be incorporated in the design as well, such as remote control aided operation for comfort and convenience; A feedback loop can also be incorporated in the designed to turn an appliance (or an equipment) ON, whenever it senses a supply or under a controlled condition. This finds useful application in industrial settings where precision is highly required.

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Declarations

The authors declare that they have no conflict of interest.

Data availability

All data used in this study will be readily available to the public.

Consent for publication

Not Applicable

Availability of data and materials

The publisher has the right to make the data Public.

Competing interests

The authors declared no conflict of interest.

Funding

There is no source of external including

Authors' contributions