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Design and Construction of a Global System for Mobile Communication (GSM) Based Home Devices Control System

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Abstract
This paper presents the design and construction of a Global System for Mobile Communication (GSM) Based Home Devices Control System for electrical appliances that enables the complete control of the interface on which it is based. GSM module was used for receiving short message service (SMS) from user's mobile phone that automatically enable the controller to take further action like switching ON and OFF electrical appliances such as fan, air conditioner, light etc. The system was integrated with microcontroller and GSM network interface. The system is activated when user sends the SMS to the controller at home. Upon receiving the SMS command, the microcontroller unit then automatically controls the electrical appliances. This saves time used in switching ON or OFF the device manually since the electrical appliance can be controlled from this remote system.

Keywords: *GSM, Microcontroller, SMS,*

Introduction

In recent times, the increasing role of advanced electronic Systems, Mobile networks, wireless communications and digital technologies affects many methods used in remotely controlled Systems. One of these methods is the GSM Based Control System Design, which is practical and applicable in real-time development. The advances in the innovations identified with remote correspondence has prompted the rise of a few building plans to help the human necessities (Amit and Singh. 2011). The utilization of power is imperative as one of the fundamental wellspring of vitality that is the key in today present day life. A few sorts of system utilizing accessible innovation could be utilized to diminish wastage in power use. Accordingly a model in view of a microcontroller gadget utilizing SMS is created. It is a more straightforward, multipurpose, financially save plan that can naturally control any electrical hardware at home remotely utilizing cell phone. Subsequently the electrical vitality sparing in day by day life can be made more productive and successful. "GSM based Control System" executes the rising utilizations of the GSM innovation. Utilizing GSM systems, a control framework has been recommended that will go about as an inserted framework which can screen and control machines and different gadgets locally utilizing worked in info and yield peripherals. Remotely the framework enables the client to adequately screen and control the house/office machines and hardware's through the cell phone set by sending orders as SMS messages and accepting the apparatuses status. The primary idea driving the venture is accepting the sent SMS and preparing it further as required to play out a few operations. The kind of the operation to be performed relies upon the idea of the SMS sent. The main concept behind the project is receiving the sent SMS and processing it further as required to perform several operations. The type of the operation to be performed depends on the nature of the SMS sent. The rule in which the venture is based is genuinely basic. First, the sent SMS is stored and polled from the receiver mobile station and then the required command signal is generated and sent to the intermediate hardware that have been designed according to the command received in form of the sent message. Messages are sent from the portable handset that contains instructions in written form which are then processed accordingly to perform the required task. A microcontroller based system has been proposed for the venture.

The new age of technology has redefined communication. Most people nowadays now have access to mobile phones and thus the world indeed has become a global village. (Ganiyu. Arulogun. Adetunji. (2011). Many researchers have worked in the field of home appliances automation with many contributing in a useful way. Oyediran M.O and Akande N.O (2016), this paper presents a GSM based electronic appliances monitoring and controlling system. This enables individuals to connect their home or office electronic appliances to the developed system which in turn enables them to remotely monitor and control these appliances though a Short Message Service (SMS). In remotely controlling the connected electronic appliances, users can determine the status of the electronic appliances remotely and decide whether to either switch any of the connected electronic appliances on or off. The uniqueness of the approach introduced further revealed in a way the GSM module developed system was integrated with the PIC 16877 microcontroller to give a single and more compact system. Oke A.O., Emuoyibofarhe J.O., and Adetunji A.B (2013), this paper presents the development and implementation of a Global System for Mobile Communication (GSM) based control system for electrical appliances that enables the complete control of the interface on which it is based. GSM module was used for receiving short message service (SMS) from user's mobile phone that automatically enable the controller to take further action like switching ON and OFF electrical appliances such as fan, air- conditioner, light etc. The system was integrated with microcontroller and GSM network interface using C language. MPLAB software was utilized to accomplish the integration. The system is activated when user sends the SMS to the controller at home (regarded as Smart Home). Upon receiving the SMS

command, the microcontroller unit then automatically controls the electrical appliances by switching ON or OFF the device according to the user's order. In other word, it reads message from the mobile phone and respond to control the devices according to the received message. Anamul Haque S. M., Kamruzzaman and AshrafulIslam M. D. (2006). A system for smart home control of appliances based on timer and speech interaction is presented. The paper review two major approaches to control home appliances, the first involves controlling home appliances using timer option whereby the expected time within which the electronic appliances will work would have been set. The second approach is to control home appliances using voice command. Nhivekar G. S. and Mudholkar R. R. (2011), designed and implemented an infrared (IR) remote control signal decoder which can be used for various home control applications. The approach introduced improved on the distance within which the electronic appliances can be controlled. A Telephone Based Wireless Remote Controller for Home Appliances was designed by Kailash Patil et al. (2011). The system developed used a telephone as the remote controller; the telephone generates a Dual Tone Multifrequency (DTMF) signal corresponding to each dialled digit which is converted to a BCD code by the Telephone interface circuit.

This is given as input to the transmitter module which is then used to control various home appliances through a receiver module. Data processing stages of the transmitter and receiver modules was implemented using digital components, thereby avoiding possible use of conventional devices like monostable multivibrators. Ganiyu R. et al (2011) developed a GSM based household power management system which allows users to control connected electronic appliances remotely. In their work, a Nokia 6100 phone was interfaced with a microcontroller and an SMS received by the Nokia phone will be interpreted by the microcontroller which in turns carried out the specified instruction contained in the SMS sent by the users. Armando Roy Delgado, Rich Picking and Vic Grout (2012), studied various remote controlled home automation systems with different network technologies and submitted that the best home automation systems must be flexible and must be controllable from any distance and they submitted that an IP based remote control system is preferable. Basil Hamed (2012), designed and implemented a smart house control system using LABVIEW. The smart house has two interfaces, computer interfacing, and remote control unit interfacing. Computer device that provided with LabVIEW software is the main controller unit for all systems in the house. It receives data from house sensors, process information and updates data for the difference systems, and transmit controlling signal to house systems and switching output devices. Vini Madan and S.R.N Redd (2012), carried out detailed survey of various remote monitoring and control systems with the classification based on various parameters and the design of a GSM-Bluetooth based remote monitoring and control system with Automatic light controller has been proposed. This system has an advantage of using both GSM and Bluetooth technology which thereby eliminates the cost of network usage to a great extent by using Blue tooth when in the range of few meters with the devices.

The comfort of being able to take control of devices from one particular location has become imperative as it saves a lot of time and effort. The proposed system is to automate a control system. The application of the system comes in handy when people who forget to do simple things such as turn ON or OFF devices at their home or in their office, they can now do so without their presence by the transmission of a simple text message from their mobile phone. This development, will ultimately save a lot of time especially when people don't have to come back for simple things such as to switch ON/OFF switches at their home or at their office once they set out for their respective work. This research work goes beyond a paper work, the design and implementation was actually carried out and tested.

Circuit Design and Analysis

The design of the GSM based home devices control system involves two parts namely: software and hardware parts. The software is a programme containing sets of commands programmed into the memory location of the microcontroller. The software extracts the sent message from the SIM location at a regular interval and processes it to control the different appliances connected within the interface. The hardware part of the work involves the circuitry design that receives information from the phone and act on it to turn it ON or OFF the home appliances depending on the request. The circuitry design involves the power supply, GSM modem, micro-controller, relay switches, LCD (liquid crystal display), transistors, lead wire and panel boards on which the circuit is built. The power supply circuit consists of a transformer, bridge diode, capacitors and a regulator that steps down the alternating input voltage to produce a stable DC voltage for the microcontroller. The microcontroller controls the relay with its output terminals and receives its input from the GSM modem through SMS sent to the modem. The relay acts as an electrical switch that powers the device based on the signal sent to it from the microcontroller. However, the various components used in the system designed are as enumerated in the block diagram of Figure 1.

Power Supply

The power supply circuit employed in this project consists of the following components:

- *The transformer: It steps down or step up input signal. The transformer used in this project work is a step down transformer that converts 220 ac volts to 12 ac volts by the principle of electromagnetic induction.*
- *The bridge diode: This component converts an alternating (AC voltage) to a direct (DC voltage). It performs a full wave rectification of output voltage from the transformer.*
- *Capacitor: This component stores charge. It filters the voltage output of bridge diode to eliminate the ripple in the output signal.*
- *Regulator: This component regulates the input signal to a stable unchanging voltage. It has 3 terminals. For this work, the regulator converts the input voltage to a constant 5v that is eventually connected to the controller.*

- *Wire: This an important component that creates a communication channels between each of the components. They are conductors that convey electric signal from one terminal to the other.*

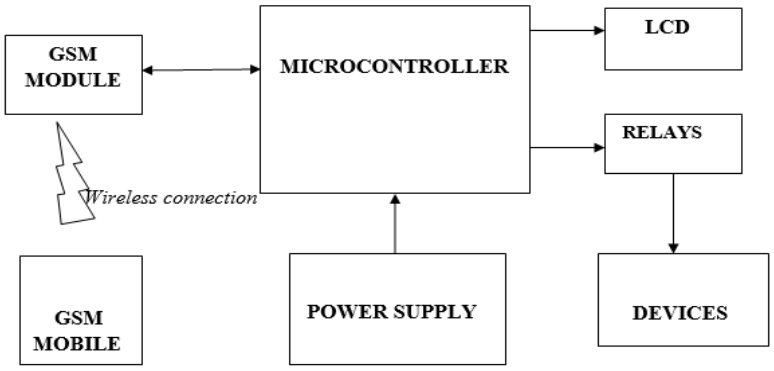

Fig.1 Block diagram of the GSM based home devices control system

The circuit diagram of the regulated power supply is shown in Fig.2 below. The alternating input signal (220V ac) is fed into the primary side of the transformer and the voltage is stepped down to 12V which is the required voltage for the circuit. This 12V is then rectified using a full wave rectifying device (i.e. the bridge diode); capacitor is used to remove ripples in the output voltage. The essence of this is to convert the AC voltage from the main source to DC voltage because the micro-controller is powered by a DC source. The microcontroller requires just 5V for its operation and hence, a regulator is required. The filtered output is then supplied to the regulator that gives a constant output of 5V required by the microcontroller.

The step-down transformer reduces the AC input from 220V to 12V. The AC 12V is then rectified using bridge rectifier to convert it to DC. After the conversion, the DC value is as given below:

$let\ AC\ voltage = Vac$
$DC\ voltage = Vdc$
$Diode\ voltage = Vd$
$Then\ the\ Dc\ voltage\ Vdc = \sqrt{2} - 2Vd$
$from\ the\ circuit\ diagram, Vac = 12v\ and\ Vd = 0.7v$
$Vd\ is\ the\ diode\ forward\ bias\ voltage.$
$In\ forward\ bias\ and\ reverse\ biasof\ the\ bridge\ diode, only\ the\ two\ of\ the\ four\ diodes\ conducts. Hence, 2Vd\ is\ used.$

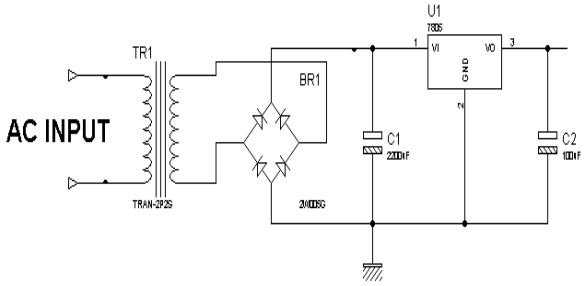

Fig. 2 Circuit diagram of the regulated power supply

$$Vdc = 12\sqrt{2} - 2(0.7)$$
$$Vdc = 15.57$$

Also, 2200µF capacitor is used to produce a large and fairly steady dc voltage. It charges up to the peak (maximum) value of the applied ac voltages and then discharges slowly depending on the time-constant. The value of this capacitor is chosen based on the calculation below.

Recall, $I = \frac{Cdv}{dt}$ $using$ $T = \frac{1}{f}$

Where:

$F = 50Hz$ (The ac frequency in Nigeria)
$T = 0.02s$ (T is the time to complete one cycle)

dt is the time for the capacitor to discharge up to when it will start to charge up again, Hence, $dt = 10ms = 0.01s.$

$d\,v = Vdc$ - expected voltage

Choosing 10V as the expected voltage to the regulator 7805, then

$$Dv = 15.57 - 10$$
$$Dv = 5.57v$$

I is the total current required by the circuit to power the 7 relays, microcontroller and regulator and other components

Current for microcontroller = $30mA$ (Given in the data sheet)
Current for the regulators = $5mA$
Current for $relays = 420mA\ (60mA\ for\ each\ relay)$
Total current required = 455mA

$$C = I\,dV/dt$$
$$C = 816\mu F$$

GSM Module (SIM900)

SIM900 is a quad band module that works on frequencies GSM 850MHz, EGSM 900MHz, DCS 1800MHz and PCS 1900MHz. It has a tiny configuration of 24*24*3mm but meet almost all space requirements in user applications such as M2M, smart phone, PDA and other mobile devices. It has 68 SMT pads and provides all hardware interfaces between the module and an external circuit. It also have a programmable general purpose input and output unit, audio channels which include microphone inputs and receiver outputs.

This paper work is based on SMS only. Therefore only the serial communication feature of the module is used in the design. The GSM module receives the SMS sent by the user and then transmits an acknowledgement or status to the user mobile. The module is an AT modem and has a valid SIM card, UART interface and support most of AT command instructions. The AT commands are instructions used to control the module. It is specific command language originally develop for the Hayes smart modem. The command set consist of a series of short text strings which combine together to produce complete commands for operations such as dialing, read SMS, compose SMS, send SMS, delete SMS and changing the parameters of connection. The module is attached to the microcontroller through its receiver (RXD) and transmitter (TXD) pins (pin 10 and 11 respectively). It only needs three wires (TR, TX, and GND) to interface with the microcontroller. This gives the flexibility to put the GSMmodule into operation no matter what baud rate the host application is configured to. 9600bps is used as the baud rate in this paper. Fig. 3 shows the serial connections between the GSM module and the microcontroller, powering the module and antenna and network light. The pin 1 of the module is the power pin. This is used by the microcontroller to switch ON/OFF the GSM module. The module is turned ON or OFF according to the logical level applied. The power line of the module is equipped with an internal pull up resistor and is active at logical zero. Therefore, in order to switch ON the module, microcontroller sets PWR at high logical level by supplying high level signal of 5v to transistor (T2) and causes it to saturate, this transistor then sets the PWR LINE at low level. The power ON/OFF signal to the module is only a pulse of about two seconds. So when the GSM Based Home Devices controller system is switch ON, it supplies a high level voltage of 5v to the module (pin one; PWRKEY) for two seconds which the turn ON the module. NETLIGHT (pin 52) of the module is used to drive the network light indicator. Transistor T1 is locally used to control the module network reception LED. The base of the transistor is polarized from the current logical level on pin 52 of the module (NETLIGHT), the transistor collector is then connected to the LED which indicates the presence of GSM network as well regarding the connection status of the module. When the modem is not working, the LED will be off but will come on when the module is running. When the modem fails to register network, the LED comes on 64sm and off 800ms. When it is registered to a network, it comes on 64ms and off 3000ms.

The Microcontroller

Microcontrollers (also known as embedded controllers) are microcomputers. Unlike personal computers, microcontrollers are computers that are designed to carry out a specific function. In the design of the GSM Based Household Device Controller system, PIC16F877A micro-controller is employed. The PIC16F877A is one of the most popular PIC micro-controllers. It comes in a 40-pin dual in-line package (DIP) with internal peripherals. The 40 pins make it easier to use the peripherals as the functions are spread out over the pins. PIC16F877A is a powerful (200 nanosecond instruction execution) easy-to-program (only 35 single word instructions) CMOS FLASH-based 8-bit micro-controller. It is upward compatible with the PIC16C5X, PIC12CXXX and PIC16C7X devices. The PIC16F877A is characterized by 256 bytes of EEPROM data memory, self-programming, an ICD, 2 comparators, 8 channels of 10-bit Analog-to-Digital (A/D) converter, 2 capture/ compare/PWM functions, the synchronous serial port which can be configured as either 3-wire Serial Peripheral Interface (SPI) or the 2-wire Inter-Integrated Circuit (PC) bus and a Universal Asynchronous Receiver Transmitter (USART).

All of these features make it ideal for more advanced level A/D applications automotive, industrial, appliances and consumer applications. One of the main advantages is that each pin is only shared between two or three functions although an external crystal oscillator chip is required to generate the required clock signal. The pin diagram of the microcontroller and the circuit connection are shown in Figs.4.

System Architecture

The GSM modem is integrated with the microcontroller (PIC16F877A). The modem receives SMS message from user Mobile Phone and sends a command to controller to control whether to turn ON or OFF the output. The operation process and status of the devices are shown on the LCD.

The structure of the system is working with following steps:

1. *The remote user sends text messages (SMS) including authentication information and commands to the receiver.*
2. *GSM modem receives messages sent from user cell phone or mobile phone and send.*

3. *GSM modem decodes the sent message and sends the commands to the microcontroller.*
4. *The microcontroller issues commands to the appliances.*
5. *Microcontroller issues commands to the appliances and the devices connected will switch ON/OFF.*
6. *The Microcontroller checks for completion status and apply operation on Electrical Devices*
7. *The microcontroller composes SMS as regards the status of the device and sends to the remote mobile phone through the GSM modem.*
8. *GSM modem informs the remote user of the outcome of their request by sending a completion status message back to remote user in the form of another SMS message.*

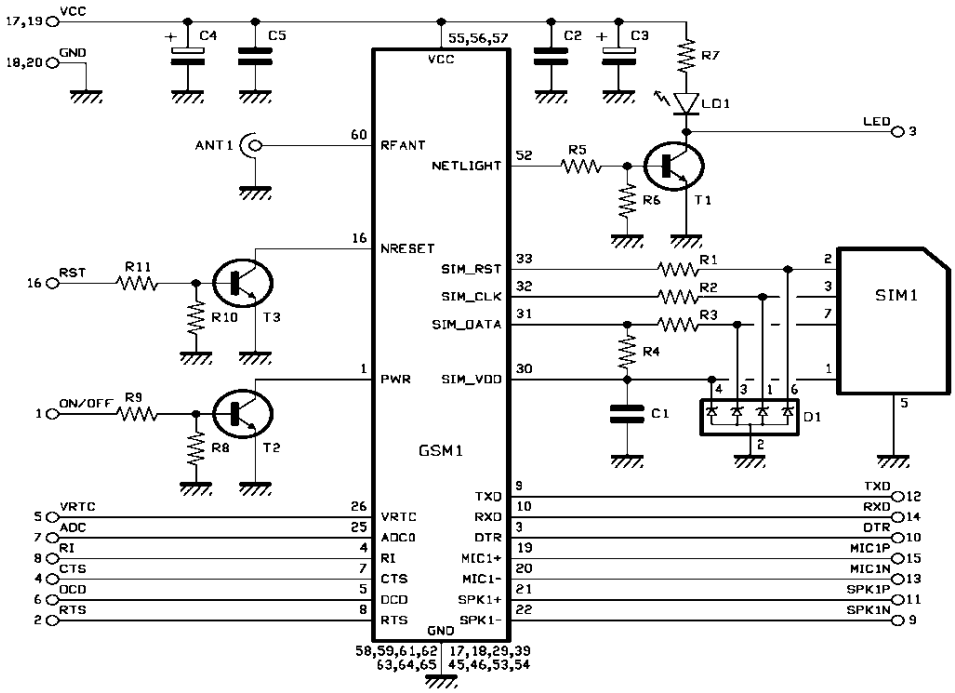

Fig. 3: Circuit diagram of SIM900 (GSM module)

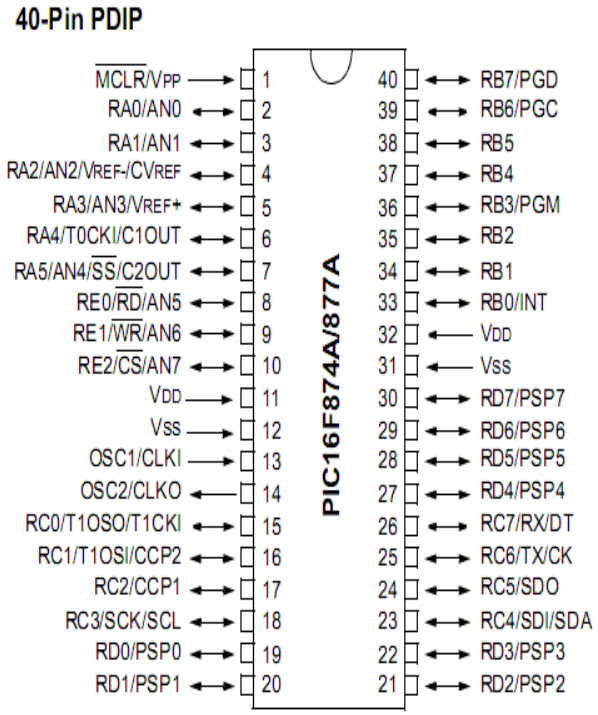

Fig. 4: The pin diagram of PIC16f877A (Microcontroller)

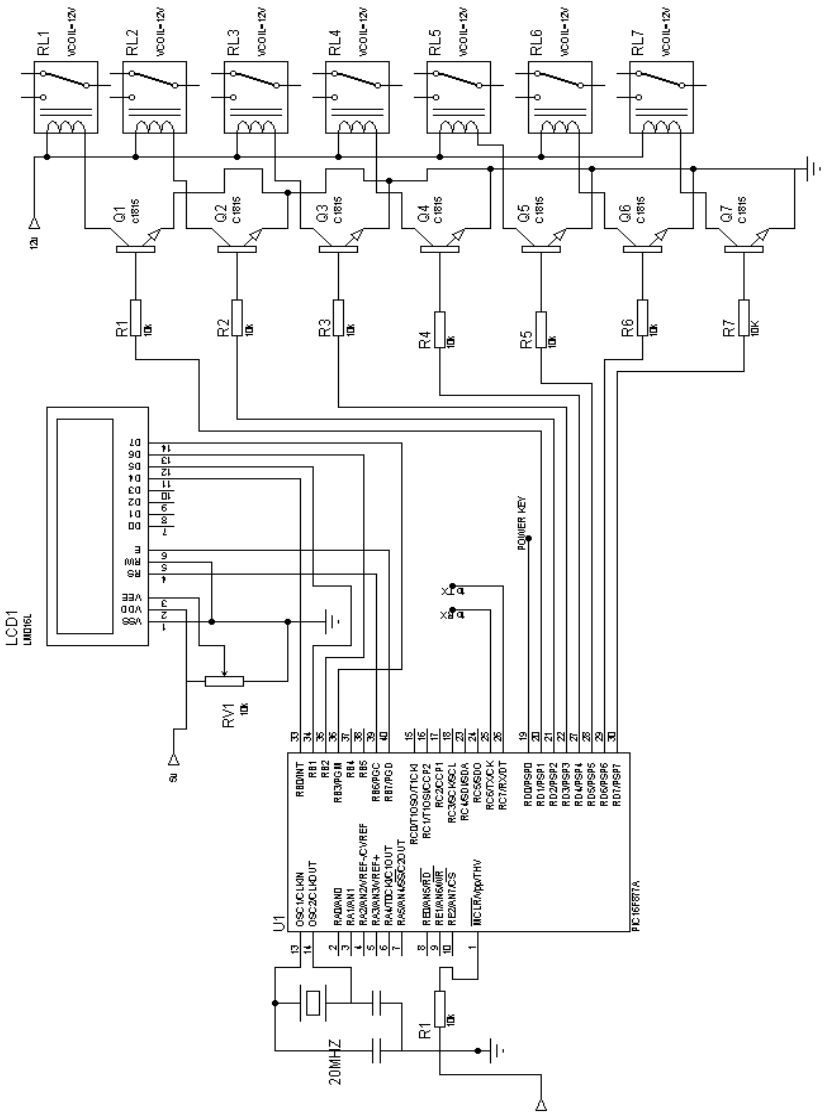

Fig.5: Circuit diagram of the GSM Based Home Devices control system

The Design and Implementation

The major components used in the design include both the microcontroller and the relay.The microcontroller controls the relay which performs the switching. The Microcontroller requires 5V (DC) for its operation while the relay needs a minimum of 9V (DC) for its electromagnet to be energized. Thus, a rectifier circuit is needed. The main 220V ac voltage source is connected to the transformer which steps down the 220V to 12V ac volts. But a DC volt is required; hence the need for rectification and a bridge diode used. The output of the bridge diode is connected to a capacitor to remove the ripples in the signal. The stable 12V is connected to the DC terminals of all the 10 relays which require the minimum of 9v for its electromagnet to be energized and the same 12V is also connected to a regulator that produces a constant output of 5V for the microcontroller. The microcontroller is programmed to trigger the relay into the action based on its output i.e. either low or high.

The programming event was such that the microcontroller reads the SMS from the phone; if the command specify ON for a particular device the microcontroller will give a high output for the relay switching the device and if the acknowledgement is high the microcontroller will send message about the status of the microcontroller output to the phone that sends message to the phone connected to the microcontroller.

A 220V ac volt is connected to the NO terminal of the entire 10 relays and the NC terminal is connected to the live terminal of the device to be powered. The action is such that when the microcontroller gives a high output to the input of the relay, the electromagnet of the relay becomes energized thereby attracting the pole to bridge the connecting between the NO and the NC terminal of the relay thereby powering the device. The connection remains until the microcontroller receives a message to OFF the corresponding device.

When a text message is sent to the phone (Modem), it checks for the instruction. If the instruction is meant to turn ON any of the outlets, then it sends a voltage that is approximately equal to 5V to the transistor. This makes the transistor to output zero (0) volt at the collector, thereby serving as ground. The relay then conducts and the pole switches to NC. Then “life” flows to the socket is

on. However, if the text message is to OFF the socket, a voltage of zero (0) volt is sent to the transistor. Hence, a voltage of nearly 5V remains at the collector and the relay pole returns to NO. Therefore, "life" is cut off from the socket.
The socket is then turn OFF.
The format of the message to be sent to the system is as follows:

To switch on device one – '1on'
To switch off device one – '1off'
To switch on device two – '2on'
To switch off device two –'2off'
To switch on device three – '3on'
To switch off device three – '3off'
To switch on device four – '4on'
To switch off device four - '4off'
To switch on device five – '5on'
To switch off device five – '5off'
To switch on device six - '6on'
To switch off device six - '6off'
To switch on device seven – '7on'
To switch off device seven – '7off'
To switch ON all at the same time – 'all'
To switch OFF all at the same time – 'clear'
To check for the present status – 'status'

The GSM module (Figure 6) shows the GSM modem soldered on a PCB together with the SIM holder which holds the SIM card. The antenna is linked to this board with a connecting wire. The network light is also connected from this board to the casing. The relay interface module shown in the Figure 7 consist of the relay driver circuit, relay connection and the devices status LEDs. They are soldered on vero board. Wires are used to loop the driver transistors to the outputs of the microcontroller and the normal open pin (NO) and common pin (COM) of each relay to their respective output sockets. Figure 8 shows the controller modules. This module consists of the microcontroller circuit that controls all other part of the device.


Fig 6: GSM module

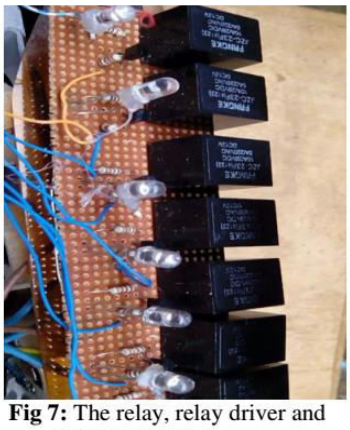
Fig 7: The relay, relay driver and indicator module

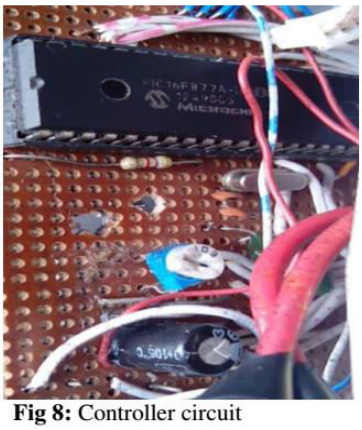
Fig 8: Controller circuit

Testing and result
After construction the system was put to test and the result of the test shows that the device is a modern development which can effectively be used to remotely control home devices as it portraits the following features when tested;

1. *Convenience – SMS technology is easy to use and learn and can be accessed easily when needed.*
2. *Accessibility – instructions are sent to the microcontroller to be controlled and monitored from any location provided there is the existence of an active GSM network or control from anywhere in world if cellular coverage is available.*
3. *Portability – a microcontroller can be controlled and monitored from any GSM phone that supports SMS. Considering the fact that most GSM phones support SMS, the system is therefore highly portable.*
4. *Saves Time – an SMS based remote monitoring and control system saves time as the user is not required to gain access to an internet connection or make a dedicated connection to the computer to be controlled as opposed to a Bluetooth-based system or an Internet based system.*
5. *Cost effective – SMS services are generally cheap and are sometimes provided for free (at least for certain periods) by service providers. Furthermore, most service providers do not charge users for receiving SMS.*
6. *Mobility – User and/or system administrators are more likely to have their phones with them at all times than they are likely to physically be in front of their computers. An SMS based system therefore enables them have ubiquitous access to the computer to be controlled and monitored.*
7. *Acknowledgement about execution of command from system to user.*

The GSM Based Home Devices Control System if plugged to the mains source and switched ON. It initializes and soon is ready to receive message. A message is sent to it in the format shown below to switch off all the sockets. "CLEAR"

The unit receives the message and processes it to switch OFF all loads. (The processing duration for every message received is approximately thirty seconds). The liquid crystal display screen displayed "OUTPUT LOADS", "0000000". The seven zeros show that all loads are in OFF position.

The loads to be controlled and monitored are connected to the outputs of the device. While testing, an electric standing fan was connected to socket labeled 1, a freezer to 2, a computer system to 3, a phone charger to 4 and a computer printer to 5. An SMS was then sent to switch ON the desired socket. The desired socket was switch ON and a message was displayed on the LCD screen showing the status of the device.

An example is when a message to turn ON socket 5 was sent, when the device received the message, it displayed "message received" and then processed the command for almost thirty seconds. It then changed the display content to the present status of the device –"OUTPUT LOADS", "0000100". Showing that load at socket 5 was ON while others were in OFF position. The device is very effective as it can be used to control and monitor any electrical appliance from a remote location around the world over GSM communication, provided there is an active GSM network at the sending and receiving end of the SMS.

Conclusion and Future Work

This paper work is focused on controlling home appliances with wireless technology which has revolutionized our way of living. Home owners can come to an ideal environment coming from their daily activities. The switching system which is a microcontroller-based GSM controlled switching device was designed and constructed to switch ON/OFF devices with AC load of 220V±5% supply. The result achieved in this process is actually a move away from the manual mode of switching to that of automation.

It is a location independent system being GSM dependent for the ease of user. The extensive capabilities of this system are what make it so interesting. From the convenience of a simple cell phone, a user is able to control virtually any home devices. This makes it possible for users to rest assured that their belongings are secure. The system can be modified to achieve a complete Home Automation System which will then create a platform for the user to interface between himself and his household. The system can still be modified to use voice command instead of SMS or both in controlling and monitoring.

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