Development of a GSM Based Household Power Management System

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ABSTRACT

Household power management system provides a means of controlling home appliances remotely using mobile phone. In this paper, we mainly focus on design and implementation of a GSM based household power management system to remotely control at most ten home appliances via a mobile phone connected to an automated device's microcontroller using wireless technology. The developed system allows the user to start or stop appliances from afar and sends back a message to acquaint the user of the status (on/off) of all the devices under consideration. Thus, from the design and implementation of the GSM based household power management system, users can control their household appliances outside their abodes using mobile phones, manage their power consumptions and prevent unauthorized individuals from controlling their appliances.

Keywords: Remote control, Home appliances, Short Message Service (SMS), Global System for Mobile Communication (GSM), Microcontroller.

1. INTRODUCTION

The Global System for Mobile Communication (GSM) has been proven to be an effective and efficient communication device over a long distance using the telecommunication satellite. Evidently, GSM can communicate with any equipment being designed to be compatible with. As a result, GSM phone can be used in household power management to turn ON or OFF devices via a command in a Short Message Service (SMS) sending to the mobile phone connected to the automated device's controller.

Furthermore, to remotely control home appliances, the system to be developed would consists of a mobile phone and a microcontroller, which is characterized by input, and output terminals that can be utilized as communication channel to send message between the microcontroller and the devices being controlled. The message is a data made up of address and command from microcontroller to the device being controlled. Conclusively, this paper is aimed at developing a GSM based household power management system that could be used to remotely control at most ten household appliances when the user is away from home.

2. RELATED WORK

Conte and Scaradozzi (2003) view home automation systems as multiple agent systems (MAS). In the paper, home automation system has been proposed that includes home appliances and devices that are controlled and maintained for home management. The major task is to improve performance.

Potamitis *et al*. (2003) suggest the use of speech to interact remotely with the home appliances to perform a particular action on behalf of the user. The approach is inclined for people with disability to perform real-life operations at home by directing appliances through speech. Voice separation strategy is selected to take appropriate decision by speech recognition.

Alkar and Buhur (2005) propose an Internet Based Wireless Home Automation System for Multifunctional Devices. This paper proposes a low cost and flexible web-based solution but this system has some limitations such as the range and power failure.

Delgado *et al*. (2006) consider the problems with the implementation of home automation systems. Furthermore the possible solutions are devised through various network technologies. Several issues affecting home automation systems such as lack of robustness, compatibility issue and acceptability among the old and disabled people are discussed.

Ciubotaru-Petrescu *et al.* (2006) present a design and implementation of SMS based control for monitoring systems. The paper has three modules involving sensing unit for monitoring the complex applications. A processing unit that is microcontroller and a communication module that uses GPRS modem or cell phone via serial port RS-232. The SMS is used for status reporting such as power failure.

Murthy (2008) explores primary health-care management for the rural population. A solution proposes the use of the mobile web-technologies providing the PHC services to the rural population. The system involves the use of SMS and cell phone technology for information management, transactional exchange and personal communication.

Jawarkar *et al*. (2008) propose remote monitoring through mobile phone involving the use of spoken commands. The spoken commands are generated and sent in the form of text SMS to the control system and then the microcontroller on the basis of SMS takes a decision of a particular task.

Malik *et al.* (2009) focuses on the controlling of home appliances remotely and providing security when the user is away from the place. The system is SMS based and uses wireless technology to revolutionize the standards of living. This system provides ideal solution to the problems faced by home owners in daily life. The system is wireless therefore more adaptable and cost-effective. The HACS system provides security against intrusion as well as automates various home appliances using SMS. The system uses GSM technology thus providing ubiquitous access to the system for security and automated appliance control.

Ahmad *et al.* (2011) describes how to manage and control home appliances using mobile phone, people can use this system to do things in their home from a far place before they reach home. To control an appliance the user sends a command in form of SMS from his/her mobile phone to a computer which is connected to the appliance, once the message is received the computer will send the command to a microcontroller for controlling the appliance appropriately.

3. METHODOLOGY

The method employed for the development of a GSM Based Household Power Management System is divided into two parts: Software and Hardware parts.

3.1 Software

Basically the microcontroller is a device that cannot act on it own; it is a device that can be tailored to perform a specific function. The response of the microcontroller to the signal or message from the phone is controlled through a program written in mikro C IDE language. The mikro C programme was written to create links between the micro-controller and the phone (modem).

3.2 Hardware

The hardware part of the work involves the circuitry design that receives information from the phone and act on it to switch ON or OFF the home appliances depending on the request. The circuitry design involves the microcontroller, relays, transformer, bridge diode, capacitors, regulator, lead wire and panels on which the circuit is built. The transformer, bridge diode, capacitors and regulator constitute the rectifier circuit 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 mobile phone through SMS sent to the phone. 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 below.

3.2.1 The Rectifier Circuit

As shown in Figure 1.1, the rectifier circuit employed in the system designed consists of the following components:

- ***The transformer***: This is the component that either steps down or step up input signal. For this work a step down transformer is used to convert 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 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.

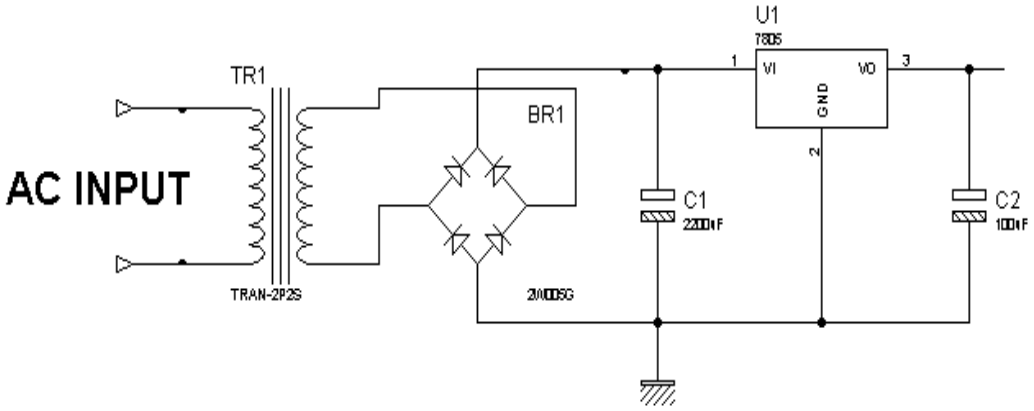

Figure 1.1: Rectifier Circuit

In terms of operation, the alternating input signal 220V 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 (an alternating voltage) 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 inputted to the regulator that gives a constant output of 5V required by the V_{cc} of the microcontroller.

3.2.2 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. However, microcontrollers are not used on their own; they are embedded in other computer or machine. They carry out their functions by taking inputs from the devices they are incorporated into. For example, in this work, the input is obtained from the mobile phone. Information is sent to the microcontroller for execution. The microcontroller has the ability of turning the appliances ON and OFF based on the SMS sent to the phone connected to the microcontroller.

Furthermore, in the design of the GSM based household power management 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. Figure 1.2 shows the PIC16F877A pin diagram for the DIP. 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.

Nevertheless, as used in the system design, the functions of the microcontroller are as follows:

- It reads the information on the phone (modem) from the user.
- It acts as either to switch on or off any outlets (device). This done through the relay by either sending a high or low signal through any of its out terminal to the relay.
- It acknowledges the user on request if a particular device is ON or OFF and deletes the message sent to the phone (modem) from the user.

3.2.3 Relay Switches

Relay is an electrically operated switch. Many relays use an electromagnet to operate a switching mechanism. Relay is applicable where it is necessary to control a circuit requiring a low power signal or where several circuits must be controlled by one signal. The parts of every relay include the following:

- Electromagnet which becomes a magnet when it receives an electric signal.
- Armature that can be attracted by the electromagnet.
- Spring which pulls the armature when the electromagnet is demagnetized.
- Sets of electrical contacts.

Relay consists of two separate and complete independent circuits. The first circuit is at the bottom which drives the electromagnet. In this circuit, a switch is controlling power to the electromagnet. When the switch is ON, the electromagnet is ON so as to attract the armature. The armature is acting as a switch in the second circuit. When the electromagnet is energized, the armature completes the second circuit and the output device is powered. When the electromagnet is not energized, the spring pulls the armature away and the circuit is not complete. In this case, the output device is not powered. The most important features considered in the choice of the relay used are as follows:

- The voltage and current required to activate the armature.
- The number of contacts for the armature. (One in this case).
- Whether the contact is either normally open (NO) or normally closed (NC)

Also, they usually have five terminals which include DC terminals, Normally Open (NO), Normally Close (NC) and Pole (P).

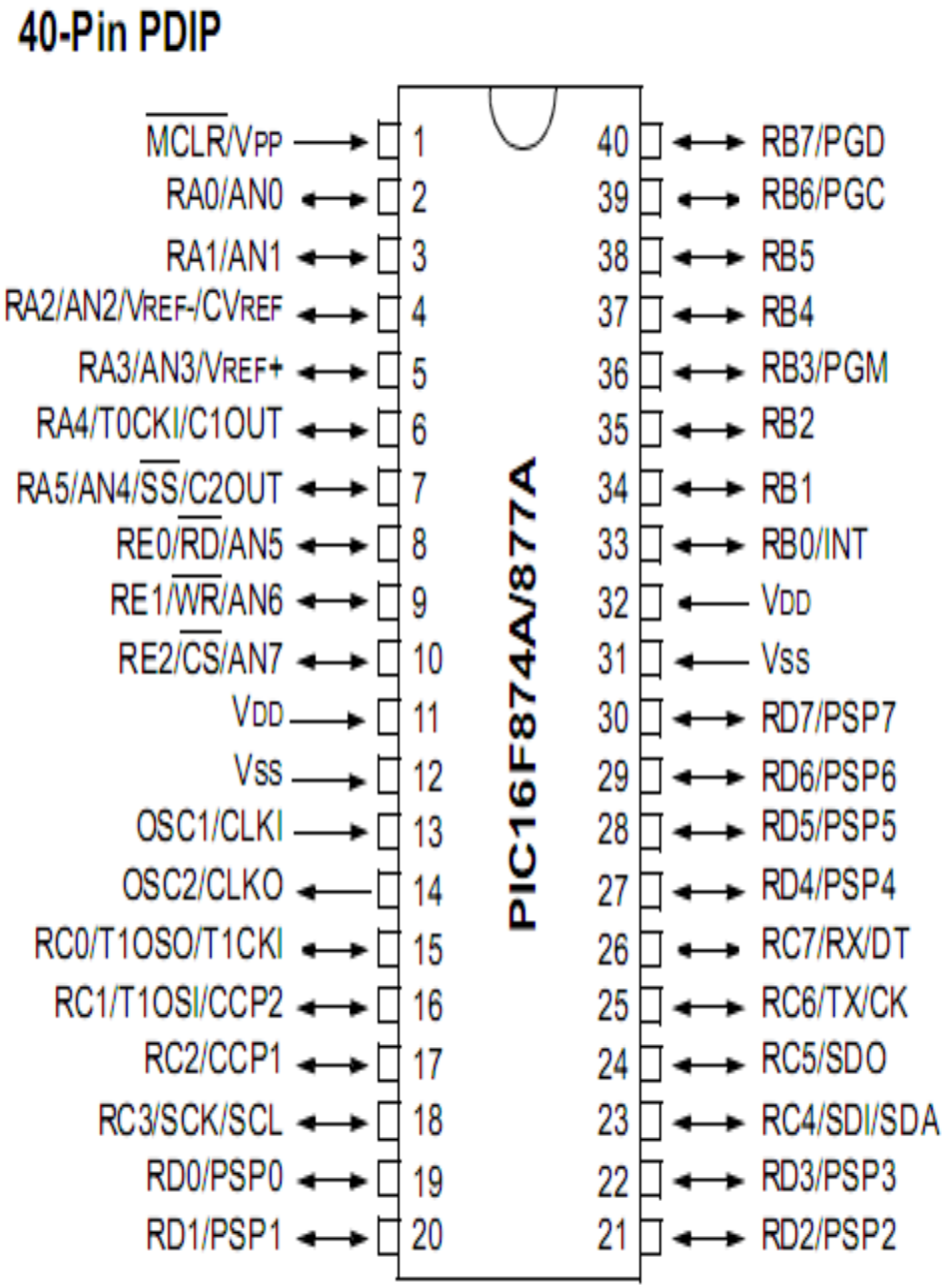

Figure 1.2: Pin configuration of PIC 16F877A (Micro-Controller)

3.2.4 Resistor

This component provides an opposition to the flow of electric current and thereby protecting the component connected to it. In this work, it is used in the input terminal of the relay and the light emitting diode (LED).

3.2.5 Light emitting diode (LED)

The light emitting diode (LED) is a diode that gives off visible light when it is energized through the process of electroluminescence. It is used as an indicator showing the operation of each device. 12 LEDs are used in this design. 10 of the LEDs are used to indicate if any of the devices is in operation i.e. 1 for each device. One is used for the operation of the microcontroller while the other is used to indicate if the phone (modem) is connected to the microcontroller.

3.2.6 The Switch

The toggle switch is used to switch on and off the automated device. It initializes the operation of the microcontroller.

3.2.7 Battery

This is a backup battery which keeps the memory of the microcontroller so as to know the device that is ON and OFF in case there is a power failure. It helps the microcontroller to continue its operation as it is before the power failure.

3.2.8 PVC Cable and Plug

The pvc cable is used to bring power to the entire system. The cable is connected to the plug through which a connection to the main source is achieved by plugging the plug to the socket.

3.2.9 The GSM Phone

This is the device that enables the remote connection of user to the home appliances. It is the modem that is interfaced to the microcontroller so as to trigger its operation. The mobile telephony has the 2G and 3G wireless ability and it support full-duplex of transmission. The phone used to achieve the design is Nokia 6100. The Nokia 6100 phone and its pin configuration are as depicted in Figure 1.3. The 6100 has a 'modem' option under 'Connectivity' (Menu option 11). Selecting this option allows another device (such as a Palm, Pocket PC or Psion) to get connected to the Internet using infrared. The 6100 can be connected to a PC via infrared or USB cable. If your PC does not support IR, then you may consider buying an adapter that can be plugged into your computer's USB or Serial port. The ability to interface the mobile phone makes it possible to implement the design using a GSM phone with an associated Short Message Service feature.

Pin Number	Pin Name
1	Gnd
2	Rx
3	MBUS
4	Tx
5	Vpp
C	Gnd
B	BSI
A	Vbatt

Figure 1.3: Nokia 6100 phone and its pin configuration

3.2.10 Short message service

This uses the basis of paging; that is, a page is delivered from a GSM cell phone to the other GSM cell phone. It is an exchange of messages between the GSM network and the mobile set. SMS is composed of message entry features, administrative features and message transmission capabilities. Entry features provide interface for the users to set short messages, destination address of the message and the delivery option for transmission.

3.2.11 Data-Cable

This is the cable that connects the modem (GSM phone) to the microcontroller. It is a communication channels between the GSM phone and the microcontroller.

3.2.12 Power Supply Part

This part deals with supplying the circuit with a regulated power. It consists of a step-down transformer that reduces the AC 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 be V_{ac} and DC voltage be V_{dc}

Let diode voltage be V_d, then

$V_{dc}=V_{ac}\sqrt{2}+2V_d$

Using the above circuit shown in Figure 1.4, $V_{ac}=12V$; $V_d=0.7V$

Note: V_d is the diode forward bias voltage. In forward bias and reverse bias of the bridge diode, two (2) of the four diodes conduct. Hence, $2V_d$

$V_{dc}=12\sqrt{2}-2\ (0.7)$

$V_{dc}=15.57V$

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=C dv/dt
Using T=1/f
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.

$dv=V_{dc}$ - 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 our circuit include 10 relays, microcontroller and regulator.

I (controller) = 30mA (Given in the datasheet
I (regulators) = 5mA
I (relays) = 600mA (60mA for each relay)
I (total) = 635mA
C=I dv/dt
$C=6350 \times 10^{-6} \times 10 \times 10^{-3}$
C=1140µF

So, the minimum capacitor that can be used is 1140µF. But we choose 2200µF to cater for any exceptional that can be caused by the manufacturer, temperature and others. The 7805 regulator is chosen so as to provide a perfectly steady 5V to the microcontroller. The microcontroller uses 5V voltage to work effectively.

3.3 The Design and Implementation Issues

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 220 ac voltage source is connected to the transformer which steps down the 220v to 12 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 220 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. A battery is connected to the microcontroller to keep the memory of its operation in case there is a power failure. That is, when there is a power failure, the microcontroller will continue its normal operation. Thus, one would be able to switch ON or OFF devices using the relay controlled by the microcontroller through the SMS sent to the phone connected to the microcontroller. The schematic diagram

of the design, the flow diagram of the activities of the microcontroller and the circuit diagram of the GSM based household power management system are depicted in Figures 1.4, 1.5 and 1.6 respectively.

Using the circuit diagram of the GSM based household power management system shown in Figure 1.4, when a text message is sent to the phone (modem), it checks for the instruction. If the instruction is meant to 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 message sent to the phone (modem) follows the format: device0*command.device1*command…end*d#.

- device 0 to 9 represents the ten appliance(s).
- command – represents the kind of operation to perform. It can either be 0 or 1 to represent "OFF" or "ON" respectively.
- end indicates that the command is to be terminated at the point to avoid un-terminated loop.
- d – Means acknowledgement. If it is set to 1, the phone (modem) send message back to the user phone informing him/her about the condition of each appliances whether "ON" or "OFF".

For example, the message (0*1.1*1.2*1.3*1.4*1.end*1#) switches ON appliances 1 to 5 and sends back a message to acquaint the user of the conditions of all the considered devices. The message sent to the user appears as follows:

HA
1 ON
2 ON
3 ON
4 ON
5 ON
6 OFF
7 OFF
8 OFF
9 OFF
10 OFF

However, if the message sent is 0*1.1*1.2*1.3*1.4*1.end*0#, this will switch ON appliances 1 to 5 and no acknowledgement message will be sent. The phone connected to the microcontroller must have some amount of credits if an acknowledgement message of the status of appliances is required.

4. CONCLUSION AND FUTURE WORK

Through this medium, we have been able to describe how to develop a GSM Based Household Power Management System that can be utilized to remotely control up to ten home appliances. The developed system allows the user to start or stop appliances from afar and sends back a message to acquaint the user of the status (on/off) of all the devices under consideration. Thus, this paper has achieved its target using the architecture of a household power management system that remotely controls home appliances through a common mobile device. From the design and the implementation of the system presented, users can control their household appliances from anywhere their using their mobile phones, manage their power consumptions and prevent unauthorized person from controlling their appliances. Nevertheless, with this

system, user cannot control more than ten devices. Future research may be geared towards developing a GSM Based Household Power Management System that can be used to remotely control more than ten home appliances in case of a large household.

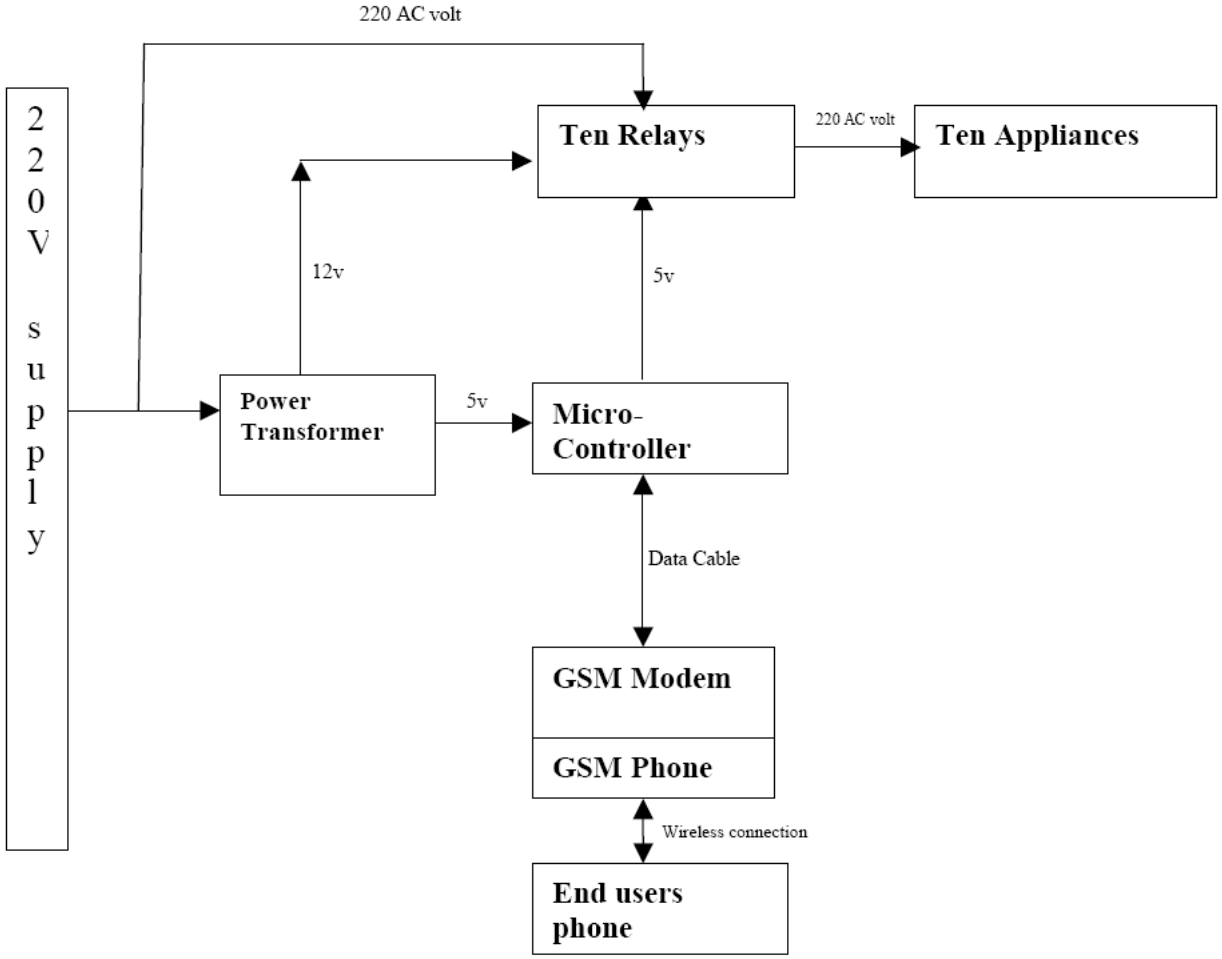

Figure 1.4: The schematic diagram of the design

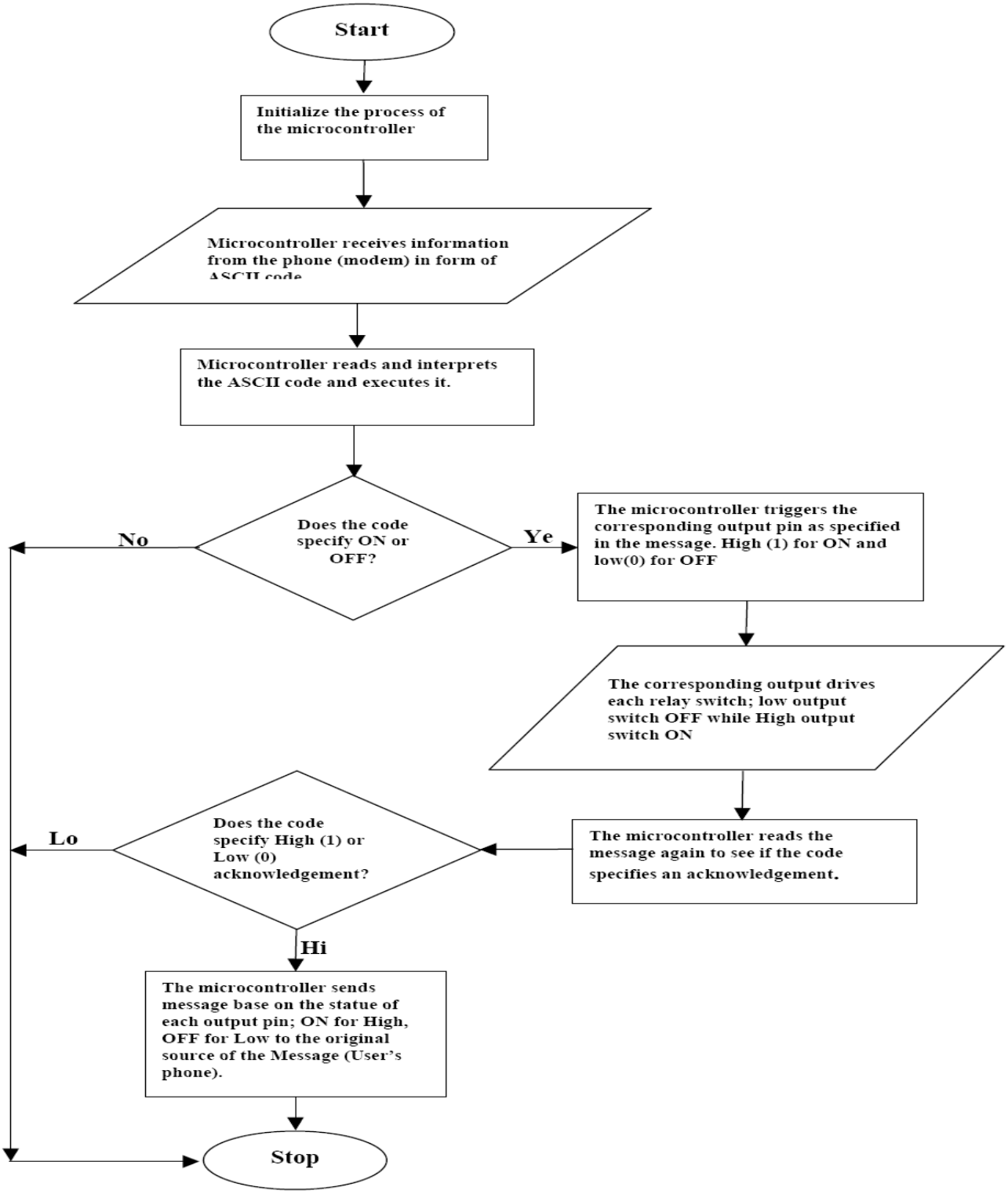

Figure 1.5: Flow diagram of the program activities of the microcontroller

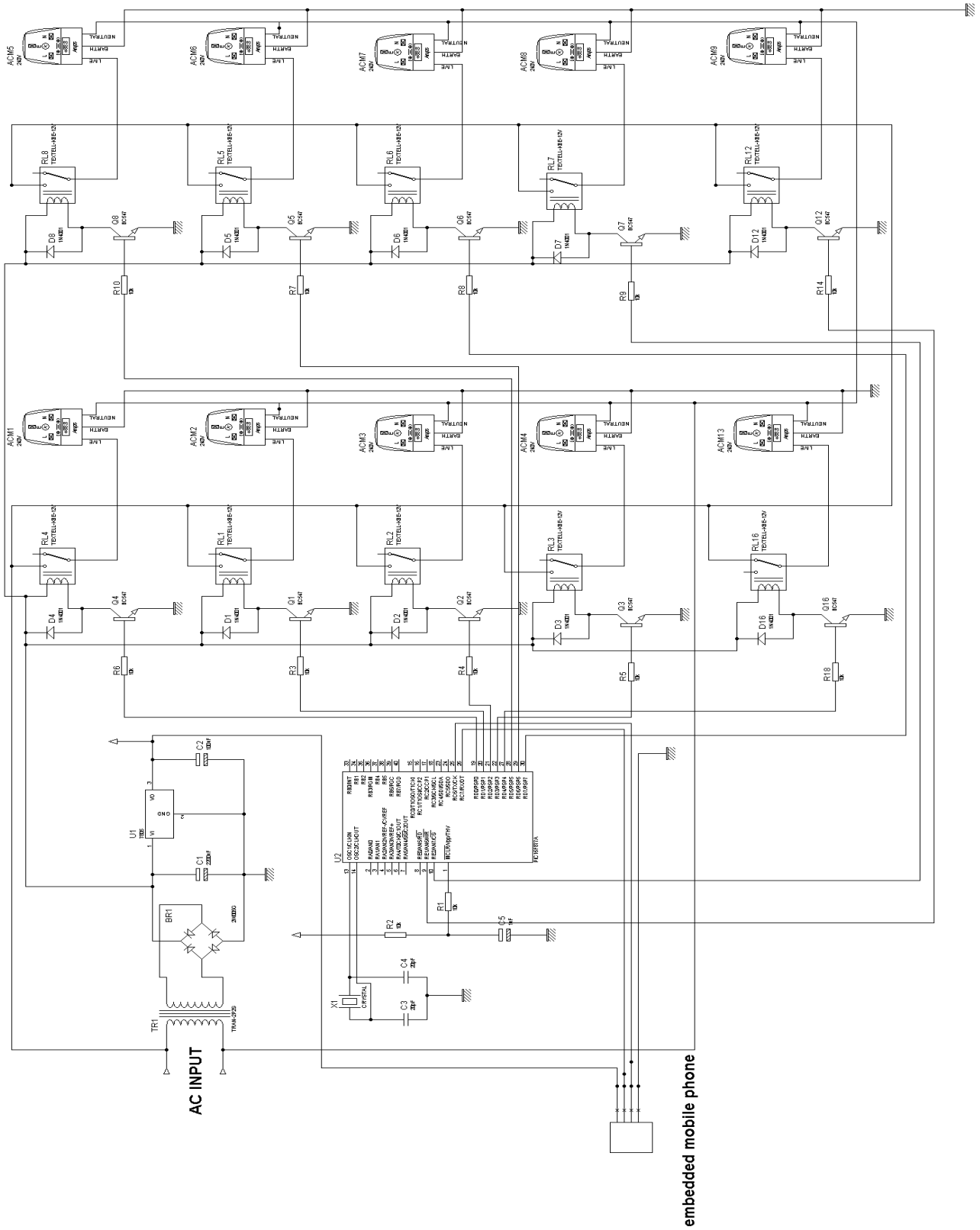

Figure 1.6: Circuit diagram of the GSM based household power management system

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