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Remote Control of Home Appliances Using Mobile Phone: A Polymorphous Based System

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Abstract

The current trend in computing has launched us into a world of numerous, easily accessible computing devices connected to each other and to an increasingly ubiquitous network infrastructure which has created new opportunities in Information Technology. This trend has proven to be a solution to electricity costs which has experienced geometric increase in some countries. Leaving electronic devices on at home while away for work or when you embark on a trip has its inherent dangers, as well as rising energy consumption which amounts to waste. This paper presents a smart space of networked devices which is programmed with a mobile phone. We used object-oriented methodology to model the home appliances. The end-user can monitor and control his home appliances with his mobile phone from any location at any time. We examined some existing one-to-one based systems which assumed that the devices must have a mobile phone attached to the controller which leverages on the components of the 'second' phone to complete communication with the device. Here the system depended on the already built component of the used phone and if the second phone is removed the system will fail. In our research, we developed a polymorphous based system (one-to-many), which uses only a single phone. The user phone requires no other phone at the receiving end and can communicate with a controller with multiple ports making it polymorphous. We also developed custom-made module for reception of signals independent of the second phone. The system was implemented using Arduino microprocessor and a GSM module which forms the server

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side of the system. A prototype of our system was carried out successfully. With our system, multiple appliances could be switched OFF or ON simultaneously compared with the existing ones that are capable of handling one appliance at a time.

***Keywords**: Ubiquitous computing; smart homes; microcontroller; remote control; mobile device.*

INTRODUCTION

Pervasive (ubiquitous) computers monitor and control the physical world through the use of sensors and actuators [1]. Smart living involves the remote control of consumer devices and media sharing. The new trend in Information and Communication technology is the provision of ubiquitous access to the networked electrical gadgets in the home using mobile phone. Most people nowadays have access to mobile phones and thus the world indeed has become a global village. At any given moment, any particular individual can be contacted with the mobile phone [2].

Today's smart phones are mobile always on networked computers that are with us all the time, they are already part of the digital home ecosystem. They resemble the consumer notion of universal remote controls, but are also personal and much more capable (e.g. processing, storage, multimedia, networking) and with support for a multitude of user interaction modalities (e.g. GUI, voice, gestures, touch). The emergence of smart spaces in the computer world is going to change users' experiences with the computers.

Smart spaces are intelligent environments that are able to acquire and apply knowledge about its inhabitants and their surroundings in order to adapt to the inhabitants and meet the goals of comfort and efficiency [3]. These goals of comfort and efficiency are met through the use of mobile phones in the remote control of the smart spaces. These capabilities rely upon effective prediction, decision making, robotics, wireless and sensor networking, mobile computing, databases, and multimedia technologies.

There are a number of benefits inherent to Smart Homes. First, for many, it's an important consideration - a Smart Home can save money. This is achieved through savings in heating, cooling, water, and

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other utility costs. Additionally, smart homes offer more enhanced security measures, reduce a number of rote tasks, and offer an increase in entertainment [4]. The smart environment perceives the state of the home through sensors and intelligently acts upon the environment through controllers.

The smart home is equipped with sensors that record inhabitant interactions with many different devices, medicine-taking schedules, movement patterns, and vital signs. Smart environments can sense their own well-being and can request repair or notify inhabitants of emergencies. This paper focuses on remote monitoring and control of home electronic appliances through the use of mobile cell phone. The notion of smart spaces cannot be real without mentioning pervasive computing. Pervasive computing has launched us into a world of numerous, easily accessible computing devices connected to each other and to an increasingly ubiquitous network infrastructure. The vision of pervasive computing emerged from seamlessly integrating technologies into the fabric of everyday life [5]. Pervasive computing allows users to access and manipulate information anywhere at any time while in control of some privacy issues [6].

In this paper, a ubiquitous system is developed using Arduino microprocessor and a GSM module which forms the server side of the system. The Arduino is not just a controller but a single board microcomputer dedicated to embedded control applications. Therefore, the complexity of the system is managed on the software side; this ensures lower component size and increased system reliability. We developed a customized message system that communicates with a smart home, electrical gadgets via a GSM interconnection with a SIM card. A prototype of our system was carried out successfully. With our system, multiple appliances could be switched OFF or ON simultaneously compared with the existing ones that are capable of handling one appliance at a time.

RELATED WORKS

A smart house is usually a computer-assisted dwelling unit that allows the occupants freedom and flexibility to live a safe and comfortable life. Such homes save money and time and use energy efficiently [7]. Smart space technology is still at its infancy stage with a lot of research going on for its advancement. However, success has been recorded in this field as some working smart homes are available. The features in the Aware

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Home Research Institute of Technology Georgia include:

1. ***Gator Tech Smart House [8]:*** This smart house is situated in the University of Florida. It is designed to assist older persons and the disabled in maximizing independence and maintaining a high quality life. UF Gator-Tech features a home security monitor that continuously watches the doors and windows of the house. It transmits the security status of the doors and windows to the occupants e.g. "Locked door", "Unlocked window" etc.

2. ***Aware Home [9]*** in Institute of Technology, Georgia): Aware stands for the Alliance Working for Antiobiotic Resistance Education initiated by the California Medical Association (CMA) Foundation. The Aware Home Research Initiative (AHRI) at Georgia Institute of Technology is an interdisciplinary research endeavour aimed at addressing the fundamental technical, design, and social challenge for people in a home setting. Aware Home Research Initiative (Automatic Blind and Light System) uses simple sensors and actuators to maintain the optimal lighting for a room that is also energy efficient. Light sensors detect what the current light settings are for the room and motion sensors detect if people are in the room. This information is combined with the time of the day to determine the optimal light setting. Actuators automatically adjust the lights and the blinds to obtain the optimal light setting [10]. The features expected in the Aware Home research in the institute of Technology Georgia include:

- Thermostat with Intelligent Real-time Location (TWIRLs) designed to track your location (i phone app), then intelligently adjust your home temperature for you.

- Assistive Robotics for the Home: To investigate the assistive capabilities of robots; to understand how older adults wish to interact with the robot and what "chores" they would like the robot to do.

- Future Tool for the Home: Understanding how current home tools fit into the work of the home in order to shed light on how to design the next generation of domestic robots.

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- Digital Entertainment and Media Technologies have the potential to reduce health care costs, by allowing people to live independently in their own homes, rather than being forced into institutional care facilities.

- Chronic Care Management in the Home:

- The deaf 911 system emulates a TTY (teletypewriter) in a cell phone providing deaf users with direct and easy access to emergency services. Deaf users can dial 911 from a cell phone and communicate with the 911 operator through an instant messaging style interface.

- Diet-related chronic diseases can be managed by providing a class of tools that use information and communication technology to translate complex medical guidelines into contextually relevant medical advice.

- Early Detection of Developmental Delay: Helps parents and healthcare providers to detect developmental delays such as autism, deafness earlier, which can improve the effects of intervention.

- Formerly "Talk to the Hand," the Helping Hand device was originally designed as a wireless device worn on the hand to help people learn languages, especially on objects around the home. After understanding some of the other possibilities, the device could also help people with visual impairment recognize objects and improve hand-eye co-ordination.

- The Cook's Collage supports a cook's memory of which ingredients have been added how many times for any recipe.

3. ***iRoom [11]:*** iRoom is a specialist provider of both wireless and hardwired Internet into hotspot locations including resorts, hotels, motels, clubs, accommodation providers, student accommodation, hospitals and cafes. iRoom offer a high speed Wireless Broadband Hotspot Service, allowing their customers to become their own ISP. iRoom manages the system, providing technical support and equipment maintenance so that even non-technical persons without computer skills can operate it.

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4. ***Bartech:*** Bartech is an intelligent fridge. In addition to advanced system of automated mini-bar provides connection to other room devices through a special microprocessor which has I/O connectors for external control. When a guest checks out at the front desk, the hotel property manager (PMS) sends the C-O to Bartech's computer and the Bartech software locks the door of the fridge. At pre-set time (determined by the hotel) other devices such as TV set, air conditioner, telephone, fax or light can be switched off.

5. ***Onity System***: This is an energy management system that makes use of sensostat. Sensostat is an energy management device capable of sensing the occupancy status of a room. It has a setback controller. It uses a passive infrared (PIR) sensor and a flush-mouthed door switch. innPulse is the window-based software system used. The sensostat interfaces with virtually all types of HVAC (Heating, Ventilation and air-conditioning) systems.

In the paper of [2], the development and implementation of a Global System for Mobile Communication (GSM) based control system for electrical appliances was presented. The internal GSM module was used for receiving short message service (SMS) from user's mobile phone attached to the device which enables 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. Figure 1 shows a block diagram of GSM based control system for electrical appliances with controller. The system was designed with the first mobile phone being used as a transmitting section from which the subscriber sends text messages that contain commands and instructions to the second mobile phone which is based on a specific area where the control system is located. The mobile phone as indicated in the block diagram is a Nokia 6100 mobile set. The received SMS message is stored in the SIM memory of the phone and then extracted by the microcontroller and processed accordingly to carry out specific operations. The relay driver (BUFFER ULN2003) is used to drive the relay circuits which switches the different appliances connected to the interface. The LED is used to indicate the status of the operation performed by the microcontroller.

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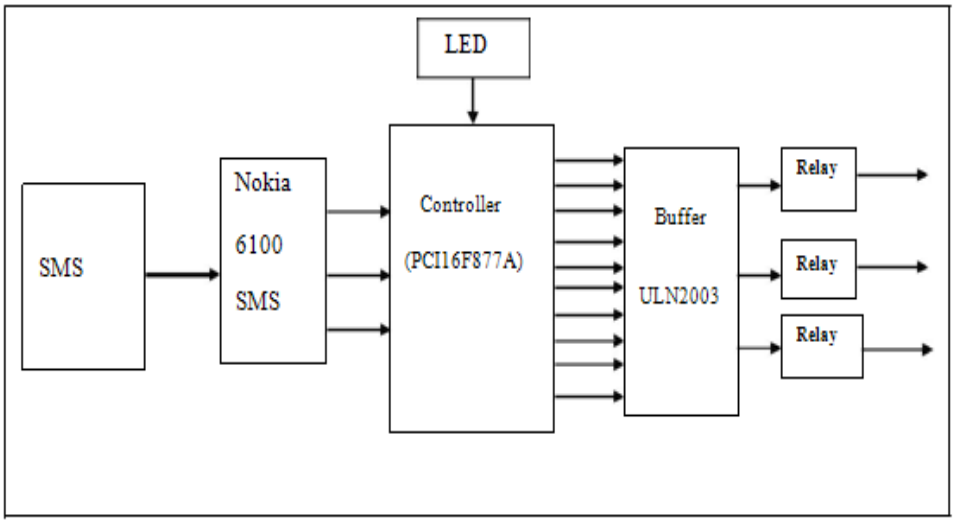


Figure 1: A block diagram of GSM based control system for electrical appliances with controller Source: Oke et al [2].

CHALLENGES OF THE EXISTING SYSTEM

The existing system developed by [2], assumed that the devices must have a mobile phone attached to the controller which leverages on the components of the 'second' phone to complete communication with the device. Here the system depended on the already built component of the used phone. If the second phone is removed the system will fail.

The other system reviewed is based also on one phone to another - which makes the system one-to-one based. In these systems, the controller has a single port. On the other hand, our system uses only a single phone. The user phone requires no other phone at the receiving end and can communicate with a controller with multiple ports making it polymorphous (one-to-many based). This also made us develop custom-made module for reception of signals independent of the second phone.

PROPOSED SYSTEM

In our proposed system, we developed a software module different from the phone messaging system to enable us control the port or group of ports where we may need the message to be channeled, this way, an ubiquitous environment for the smart space to operate is provided. The software in addition provides a user-friendly interface on the mobile phone of the user. Figure 2 shows a block diagram of the proposed system

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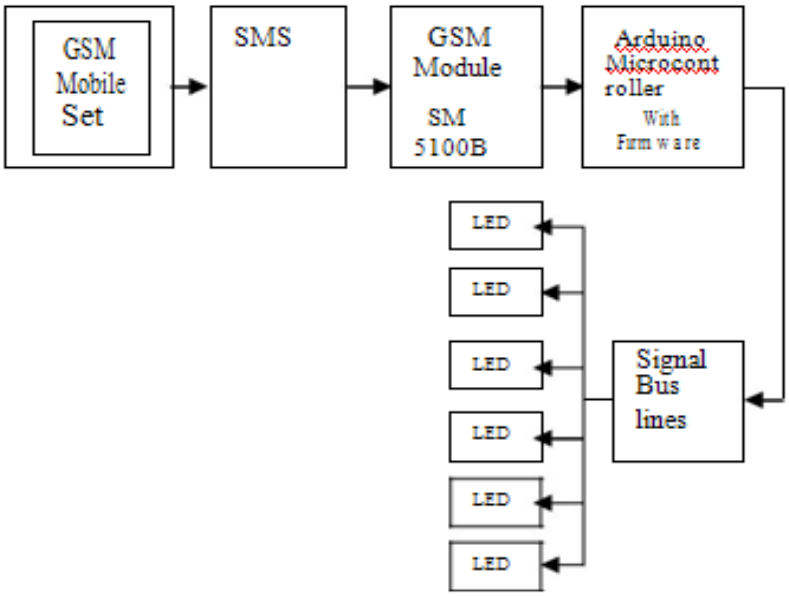


Fig. 2: Block diagram of the proposed system

Electronic Design of the Proposed System

The specification is broken down into smaller more manageable parts. The version of the functional diagram which shows the least detail is called the "Top-Level" functional diagram. Figure 3 shows top-level functional diagram. At the top-level, the simplest is to divide the product into their major constituent sub-assemblies. The sub-assembly partitioning method is adopted. In this case, the breakdown followed the convention of separating electronics from mechanics. The power supply is separated because it can be designed by a team which specializes on the design and development of power supplies.

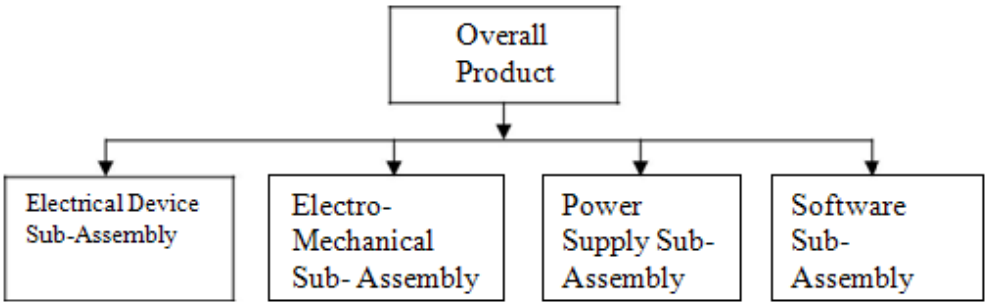


Fig 3: Top-Level Functional Diagram

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Smart Home System Specifications

1. Performance

- Input Signal

Low-level: 0 to 0.8 V

High-level: 3 to 5.0 V.

- ***Output Signal:*** Low-Level: 0 to 0.8 V High-level: 3 to 5.0 V

2. Power Supply Interface Unit

- Electronics- AC to DC source obtained from a rectifier power supply
- Step-down transformation
- Voltage regulation from 5V and 12V IC regulators
- Special 3.3v-4.2v regulation for GSM cellular module (SM5100B)

3. Sensor Interface Unit

- Light Dependent Resistors (LDR)
- Comparator
- GSM Cellular Module

4. Timing and Control Unit

- Microprocessor-based (Arduino ATmega328P, with java bootloader)
- BJT Driver connected to port b.0 of microcontroller
- Input from Comparator

5. Electro-Mechanical Unit

- 12v /240V Relay

6. Environment

- Temperature – 0 to 40o C
- Vibration - Transportation vibration only
- Humidity- IP1

7. Production

- Target Volume- 1
- Production Rate – 3hrs to 6hrs
- Estimated Production Cost - #285, 000.

System Block Diagram

Given a system broken down into modules, each with a formal requirement specification, the separate modules can be certified. To build the product effectively from the modules requires a carefully planned integration plan. Figure 4 shows the block diagram of Smart Home System which is broken down into modules.

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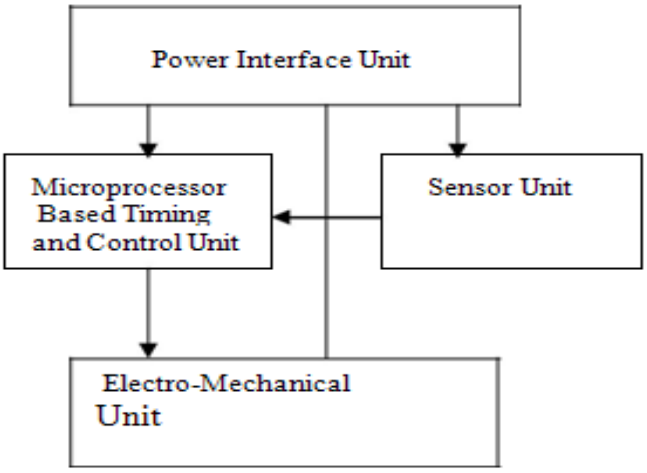


Fig. 4: Block diagram of Smart Home System

Each module (or block) has a test specification to enable its performance from other modules to be verified. Having tested each module for functionality, all functional modules are integrated and the system is ready, and could be switched on.

Functions of the Modules

Module 1: The Power Source is responsible for furnishing Dc power to the microprocessor-based timing and control unit, electro-mechanical unit and of course the sensor unit.

Module 2: The Microprocessor-based Timing and Control Unit. This is the heart of the entire system. It consists of an Arduino microcontroller-based on the AVR core architecture [12] with the necessary firmware for generating the timing and control signals and a BJT amplifier driver to amplify the signals so generated for proper operation of the electro-mechanical system. The Arduino is programmed using Wiring-based language with syntax and libraries similar to C++ with some slight simplifications and modifications, and a Processing-based integrated development environment based on java.

Module 3: Is the Sensor Unit. It is made up of light dependent resistors (LDR's) and furnishes the required variation in resistance and hence voltage for actuating the comparator.

Module 4: Electromechanical Unit. This unit is responsible for actual control of load. It consists of a 12V-relay and protection diode to protect against counter electromotive force (CEMF).

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The Circuit Design

The design of the circuit is based on the usual voltage divider equations to obtain the required current and voltage specifications for the Smart home circuit. **Figure 5** shows the smart home transmitter schematic design.

In Figure 5, the transmitter schematic design is presented. This system receives signal from the user via the user interface and transmits the interpreted diagram into electronic format that can be received and interpreted by the receiving circuit on the receiving gadget within the smart space. In ***figure 6***, the electronic design of the receiver is equally presented. The receiver gets the electronic signal sent from the transmitter and translates it into the corresponding triggers which the electronic gadgets within the smart space environment will execute or react to.

The receiver uses the wireless technology to accept the signal presented to it via the signal points in both the transmitter and receiver. The signal point is implemented as sensor points that are capable of accepting communication signal within a radio signal radius which is always dependent on the signal strength and the area of coverage of the smart space.

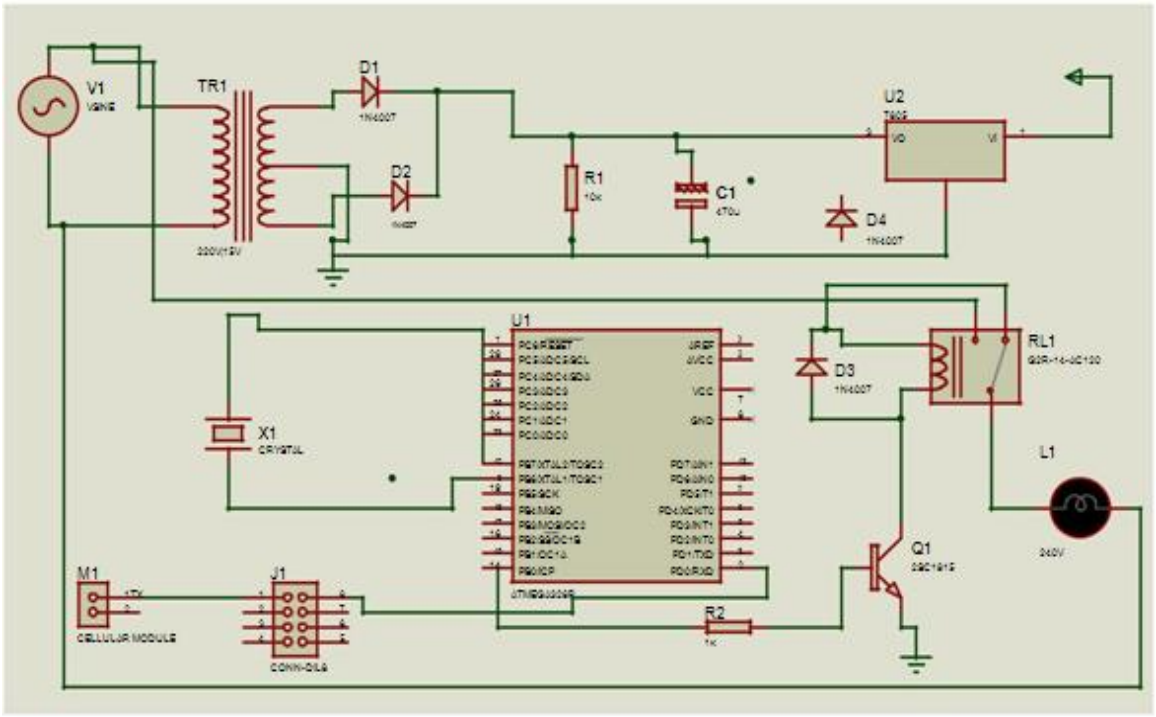


Fig 5: Smart Home Transmitter Schematic Design

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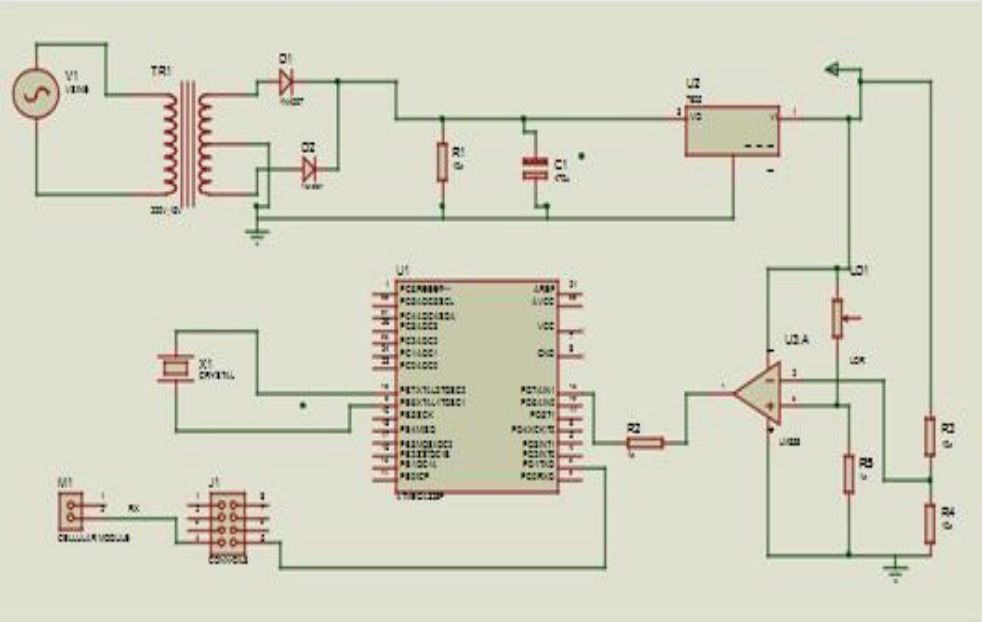


Fig 6: Smart Space Receiver Schematic Design

The Power Supply Unit:

This is based on the popular bridge rectifier configuration. Thus before a bridge rectifier should be built the current and voltage demands must be met. For the microcontroller and operational amplifier, a 15mA and 3mA current is specified respectively and for the LED and GSM module current (peak) of 5mA is specified. Also the transistor current is specified as 100mA.

The resistance in voltage divider fashion will typically draw a minimal amount current so a current of 5mA is specified. The current demand can be estimated by specifying likely current demands from the ratings of the components used:

I_L = Im+ I_R + I_{UC} + I_{module}+ I_{OPAMP}+ I_{LED} + I_{QC} ---- (1)

Where, IL = Total load requirements for the system

Im = peak relay current

IR = Net resistance current demand

Iuc = peak microcontroller current demand

IOPAMPS = peak operational amplifier current demand

Imodule = peak GSM module current

ILED = peak LED display current

IQC = peak transistor collector current

These currents must be multiplied by the total number of components for each case:

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Thus, the current demands are as follows:
Im = 0.24A

IR = 0.005A x 11 (Resistors) = 0.055A Iuc = 0.015A

IOPAMPS = 0.003A x 3 = 0.009A
Imodule = 2.005A

ILED = 0.005A x 14 (LED segments) = 0.07A IQC = 0.1 x 7 = 0.7A

Hence, **IL** = 1.094A

Thus the power supply should be able to produce a current of at least 2.5A at a voltage of 12V. The 5V required for the electronics can be obtained from a 5V I.C Regulator chip. From the estimated current and specified voltage, one can obtain the required component ratings. These components ratings include a determination of the Peak Inverse Voltage (PIV) per diode, the diode current (ID) capacitor size and of course the transformer rating:

With reference to the full-wave capacitive-input bridge rectifier topology:

$PIV = 1.41 * Vrms$ ---------- (2)

$I_D = 0.5 * I_L$ ----------(3)

For the capacitor sizing, the value of capacitance (C) in microfarads and the working voltage (V cap) is required:

$$C = \frac{I_L}{2 * f_{ac} * V_{p-p}} \quad \text{-------} \quad (4)$$

And the working voltage is:

$$V_{cap} = 1.414 * V_{rms} \quad \text{-------} \quad (5)$$

Where f ac = mains supply frequency = 50H

Vp-p = the peak- to- peak ripple in volts (typically 1V) and

V r.m.s = root-mean-square secondary voltage = 12V dc

Hence from equations (2) to (5) we obtain the following values:

PIV = 16.92V
ID = 0.55A
C = 1100uF and
V cap = 16.92V.

The required components for the power supply are 1N4001 for the rectifier diodes and 1000uF; 25V for the capacitor.

Next, the bleeder resistance (Ir) is selected such that capacitor is discharged when

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power supply circuit is disconnected. Making Ir >> 1kΩ solves this problem and prevents the storage of high currents.

The complete power supply is obtained by selecting a suitable transformer size of 15V and 2.5A from the list of readily available standard transformers in stock.

Voltage Regulators

Figure 7 shows a typical adjustable regulator circuit. Two integrated circuit (I.C) voltage regulators are employed. The first is a 7805 regulator supplying the necessary voltage and current requirements (5A and maximum 100mA respectively) for the microcontroller while the other is a LM317T Adjustable IC regulator furnishing the 3.3v to 4.2v, and a peak 2A current supply to the GSM Module. The design for the adjustable regulator circuit is based on some few calculations:

i. Specify working voltage, Vo = 3.5v

ii. Compute calibration resistance Rc from: R2 = ((Vout/1.25)-1)*240 -Ω --------(6).

Thus for a full-wave bridge rectifier the capacitance value can be obtained from the relation,

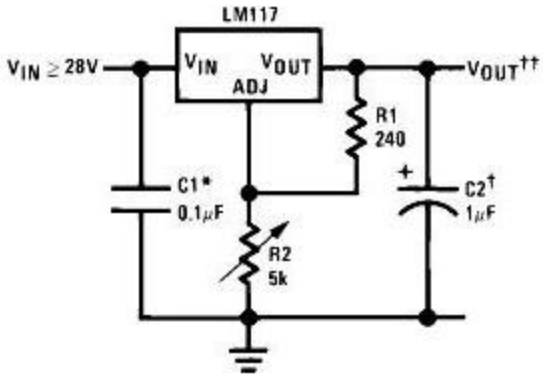


Figure 7: Typical Adjustable regulator circuit

The Microcontroller Section

The microcontroller must run from 5v and current limitation should be between 10mA and 30mA. The output is taken from the port B.0 of the Arduino microcontroller (ATmega328P, with java bootloader) which is supplied from a 5V source, thus a supply of about 5V is guaranteed for the microcontroller. The microcontroller current specifications must not be exceeded. Thus the amount of current to be supplied is limited by the microcontroller maximum current capability.

Specifying a current limitation, IB of about 5mA for the BJT relay driver we compute:

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$$R_{B1} = \frac{V_0 - V_{BE}}{I_{B1}} \ (\Omega) \ldots\ldots\ldots\ldots (7)$$

And

$$I_{C1} = hFE \times I_{B1} \ (mA) \ldots\ldots\ldots\ldots (8)$$

Where,

V_{BE} = emitter – base drop of Q_1= 0.7V

I_{C1} = collector current of Q_1

IL = IC =125mA; Voh = 5V

$$R1 = V_{CC} * h_{FE} / I_C \text{ ---------- } (9)$$

R1 = 1000 Ω which is a preferred value.

User Interface Design

User interface design is the specification of an interaction between the system user and the computing device. This interaction generally results in either input or output or possibly both. There are different types of user interface styles but the one that we created in this paper is the one that suits the mobile device on which the application developed in this system will need to run on within the mobile screen which is friendly to users. In figure 8, the user interface designed for the system is clearly shown with the option buttons indicating Send or Menu. The Destination textbox is provided for the user to enter the gadget code which is the smart card number of the gadget. The default port number is 5000. However, if there is a separate port number, it can be entered in the textbox provided for the port. The message is what the user types and sends out by pressing send button. The coding is where the end-user programming comes in each code has special meaning which the end-user understands.

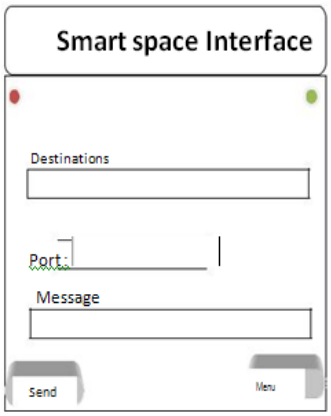


Fig 8: GUI User interface Design for the Smart Space

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For instance #a1 may mean ON and #b0 may mean OFF, #a1b1 may mean Multiple ON and #a0b0 may also mean Multiple OFF. The code may be configured by the developer in a way that it will be easy for the end-user to program. The codes are hexadecimal numbers and can be easy for the end-user to code or program. On the bottom of the user interface lies two command buttons: the Send button that sends the message to the device where ever it is located. The second button, the Menu button that carry out the operation that is desired by the user. The title of the system is neatly centered at the top of the user interface. Snapshots of prototype of our system are shown in Figures 9a and 9b respectively.



Fig. 9a: Snapshot of prototype



Fig. 9b: Snapshot of prototype

CONCLUSION

This paper has presented a remote control of home appliances using a mobile phone in an ubiquitous environment. The paper has been able to provide a polymorphous based system (one-to-many), which uses only a single phone. The user phone requires no other phone at the receiving end and can communicate with a controller with multiple ports making it polymorphous. With our system, multiple appliances could be switched OFF or ON simultaneously compared with the existing ones that are capable of handling one appliance at a time.

The paper has been able to provide a standard and easy to understand framework for developing and using electronic devices in our homes in such a way that energy is not wasted. The system also presents another dimension of developing a control agent of our environment. The mobile phone as the control agent has satisfactorily contributed in the achievement of the goals of comfort and efficiency desired in smart living.

RECOMMENDATIONS

We recommend the work in this paper to the Nigerian power organizations and companies for exploitation in developing

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real life systems that can be used in controlling traffic lights from a single point across the cities and towns in a given geographical area.

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