National conference on Engineering Innovations and Solutions (NCEIS – 2018)
International Journal of Scientific Research in Computer Science, Engineering and Information Technology
© 2018 IJSRCSEIT | Volume 4 | Issue 6 | ISSN : 2456-3307

Development of Energy Monitoring and Control System for Smart Home

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ABSTRACT

Energy saving is important because energy use effects the environment and everyone in it. When conservation of energy is done, savings on the cost of living is achieved. Energy efficiency is a goal to reduce the amount of energy required to provide products and services. The first step for saving energy is in home environment. This is possible by automating the home, so that energy saving can be done. This paper proposes a development of energy monitoring and control system for smart home. To full fill the purpose of every day energy consumption monitoring and home appliances control to full fill the purpose of prevention of energy wastage when appliances are not in use. The Data collector collects the data from energy monitoring, motion & temperature monitoring modules and the status of the home appliances from Opto-isolator TRIAC driver circuit module. The collected data is sent to the cloud through MODBUS to GPRS gateway. This data can be viewed in web application. For easy control and monitoring of the system mobile application is used, to which data is sent using Bluetooth and Wi-Fi modules. This helps in local as well as remote control of home appliances. Control of home appliances is achieved using Opto-isolator TRIAC based driver circuit with Zero Crossing Detection(ZCD) feature. This proposed system will help to improve the efficient use of electricity by monitoring the everyday consumption as well as controlling the usage of electricity by home appliances, which in turn helps in energy saving.

Keywords: Smart Home, Gateway, Wi-Fi, Bluetooth, PIR sensor, Opto-isolator TRIAC driver, Microcontroller.

I. INTRODUCTION

Home automation is a kind of automation which provides assistance to carry out the household activities through automatic solutions. Home automation may include centralized control of lighting, HVAC (Heating, Ventilation and Air Conditioning), appliances, and other systems, to provide improved convenience, comfort, energy efficiency and security. The concept of home automation has been around for a long time and products have been on the market for decades, though no one solution has broken through to the mainstream yet [1].

In this century homes will turn out to be increasingly self-controlled and robotized because of the comfort it gives, particularly when utilized in a private home. Many existing, settled home automation frameworks depend on wired communication. This does not represent an issue until the framework is arranged well ahead of time and installed during the physical development of the building. But for already existing building the usage cost goes high. Interestingly, Remote frameworks

can be of extraordinary help for automation systems. With the progression of remote technologies, for example, Wi-Fi, cloud network in the current past, remote frameworks are utilized each day and all around [2].

This paper proposes design and implementation of energy monitoring and control system for IoT based smart home. Overall system block diagram is shown in figure 1.

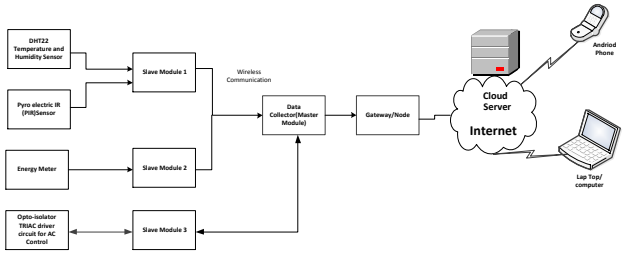

Figure 1. Block Diagram of the Overall System

It consists of (DHT 22) Temperature and Humidity sensor, Pyroelectric IR (PIR) sensor, Domestic energy meter, Opto-isolator TRIAC driver circuit which are physically connected to the Slave modules which will read sensors data and send it to the Data collector wirelessly. From the Data collector information about all the salve modules will be sent to cloud using gateway. Here temperature and humidity sensor is used to get the ambient temperature of the surrounding environment in real time. PIR sensor is used to detect the movement of human/ intruder/person. Domestic energy meters which are used mainly for billing the consumed energy is interfaced to slave module through RS 485 connection. This is done in order to get the real time electricity consumption data of the house. Control of fan, light, water pump and other home appliances is done using Opto-isolator TRIAC driver circuit.

The protocol used for communication between the modules which collects the data from all the sensors and the gateway is MODBUS protocol. The mode of communication can be Bluetooth, Wireless Radio-Frequency and Wi-Fi. The data collected by gateway is sent to cloud server with the help of GPRS connectivity. That collected data can be viewed in Web application/Mobile application from any place and at any time.

II. OBJECTIVE

1. Real time domestic energy monitoring, in order to keep track of everyday day consumption of electricity.
2. Motion detection using Pyroelectric IR sensor.
3. To design user friendly, safe system to control home appliances such as fan, lights, water pumps etc
4. Controlling all home appliances such as fan, lights, motors etc using smart phone.
5. Power saving and improving overall power efficiency.

III. PROBLEM STATEMENT

Most conventional power meters currently installed in households only display the total real time usage of power and the amount of electricity available. There is no possibility of back tracking complete energy consumption up to 6 months and often these energy meters are placed in an inconvenient location which makes regular inspection difficult. Energy consumption control along with the consumed energy tracking will help in energy saving.

IV. PROPOSED SYSTEM

The fundamental building blocks of this proposed system are Microcontroller, Sensors (DHT22, PIR), Wireless RF module, Wi-Fi module, Bluetooth module, Gateway (Modbus to GPRS). Proposed system shown in figure 2 is divided into three different modules such as: module for energy monitoring, module for detecting the motion of human or intruder and module for AC control system for home appliance control.

The three modules are explained below:

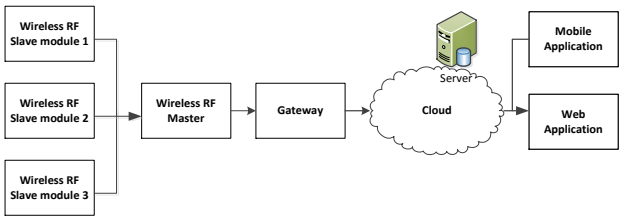

Figure 2. Proposed System

A. Domestic Energy Consumption Monitoring

This module is developed to keep track of every day consumption of energy. The user will be able to view energy parameters such as voltage, current, power factor, power (KWH), frequency. This information is extracted from the domestic energy meters using RS485 communication protocol. This will help the user to keep track of every day energy consumption there by getting to know the reason for excess of energy usage. User will also be able to know energy consumption pattern i.e, user will be able to know during which time of the day the consumption was more/less. This will help the user to manage the energy consumption during peak hours, thereby saving money.

Figure 3. Block Diagram of Energy Monitoring

As shown in the above figure 3 the Energy meter is interfaced to wireless RF slave module 1. Data collector send MODBUS command to the meter and get the response through wireless RF master and slave modules.

B. Motion Detection using PIR sensor

PIR sensor is used to detect the motion of human/ intruder/person. Pyroelectric IR (PIR) sensors belong to the class of thermal detectors. Thermal detectors can measure incident radiation by means of a change in their temperature. When an appropriate absorbing material is applied to the detectors element surface, they can be made responsive over a selected range of wavelengths. PIR sensors are designed to detect human bodies, thus the wavelengths of interest are mainly in the range of the IR window, in which the IR emission of bodies at 37°C also peaks. HC-SR501 is the PIR motion sensor that is being used in this module. This sensor can be connected to any microcontroller easily and this can also be used as standalone motion detector. DHT22 temperature and humidity sensor is also used to measure the ambient temperature and humidity of the home environment. These two sensors are interfaced to one module. This module will be continuously reading the PIR sensor data. When any motion is detected by the sensor, the module will read the change and send it to the Data collector.

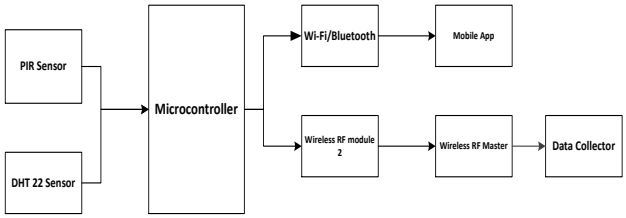

Figure 4. Block Diagram of Motion Detection Module

As shown in the above block diagram figure 4 the PIR and DHT22 sensors are interfaced to microcontroller. The sensor data from the controller is communicated to mobile application through Wi-Fi or Bluetooth. The same data is sent to Data collector with wireless RF master and slave module.

C. AC Control System for Home Appliance

This module is designed and developed for on and off control along with phase angle control of the AC voltage. On and off control is used to switch on and off the home appliances. Whereas phase angle control of the AC voltage is done in order to vary the intensity of light, controlling speed of fan and motor, controlling electric heater etc. This AC control system is designed with zero-crossing opto-isolator TRIAC driver which will drive the TRIAC for AC voltage control.

TRIAC, triode for alternating current, is a generic trademark for a three terminal electronic component that conducts current in either direction when triggered. TRIAC based AC control system is designed because of the bidirectional current

conduction characteristic of it. The circuit diagram of zero-crossing detection along with Opto-isolator TRIAC driver is shown in below figure 5.

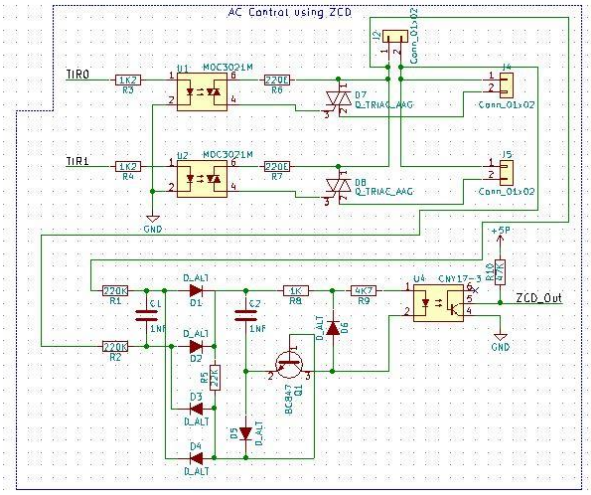

Figure 5. Zero-Crossing Detection Along With Opto-Isolator Triac Driver Circuit

Zero Crossing detection is used to synchronise the firing angle of a TRIAC (or other switching device) to achieve dimming or speed control. Zero cross switching is used so that the switch action occurs when there is no voltage across the load and thus no current through the load. This prevents fast rise time current flow as what would occur if the switch closed or opened when the voltage was high. Zero Crossing Detection will reduce EMI (Electro Magnetic Interference). In the circuit shown the "hot" side of the line is switched and the load connected to the cold or ground side.

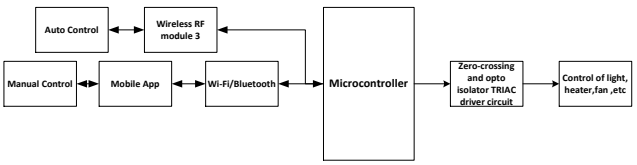

Figure 6. Block Diagram of AC Control System Module

The above figure 6 shows the details of AC Control System module. Here the controlling is done in two ways: one is manual control and one more is auto control. In manual control the user will do on off control and phase angle control using mobile app. Whereas in the auto control based on the PIR sensor data the controlling action is taken automatically. Auto control data is given to the controller through wireless RF module. For manual control, control commands are given through Wi-Fi or Bluetooth module.

V. METHODOLOGY

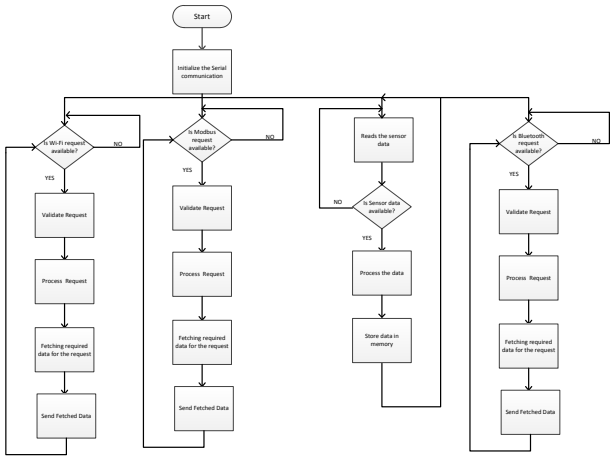

Figure 7. Flow Chart of Slave Module

Figure 7 shows the flow chart of slave module. At the start all the communication ports are initialized to defined baud rate and also the output and input pins are assigned. Processes starts working where one will check for the data availability at the serial port, whereas the other process starts reading the sensor data. In the second process PIR sensor status and the AC Control Circuit read and write operation is done. After each operation the data which is resulted from it is stored in the memory. This process is done continuously in an infinite loop.

Whenever the Modbus, Bluetooth or Wi-Fi request is available, validation of the received data is done. After validation required processing is done on the data to get the proper information. Based on the information the sensor data which is stored in the memory is fetched and sent back to the same serial port in the format defined as per the protocol (Modbus Protocol).

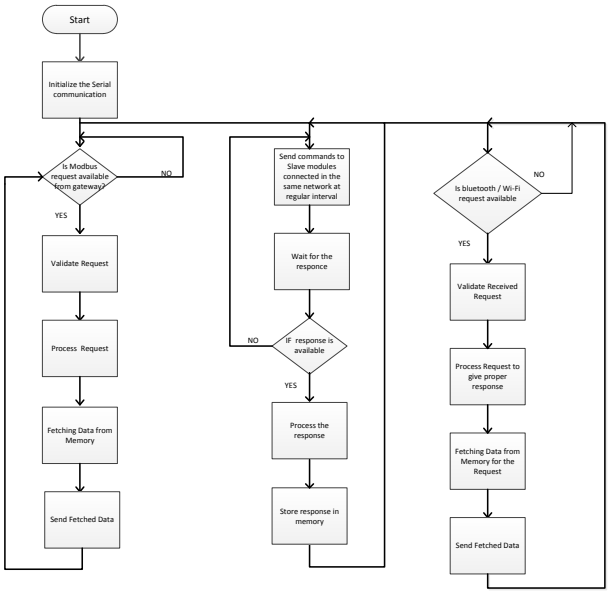

Figure 8. Flow Chart of Master Module (Data Collector)

Figure 8 shows the flow chart of Master module. At the beginning, initialization of the ports, pin assignments are being done and the Master starts sending the read command to the devices/slave modules which are connected in the same network at regular time interval. After sending the command it waits for small amount of time for the response. If the device won't respond, it sends command to the next device address. This process is also run in an infinite loop. At the same time, it keeps checking for any data available from the data availability from the server(gateway). Server data availability, will indicate the changes that has to be done by the master or the changes that occurred in the network in which the master is connected.

Master will update the changes indicated by the server and stores those changes in memory for next operation. After the operation is done it sends back confirmation of modification, by responding back to server with an acknowledgement. Suppose request is available from Bluetooth/Wi-Fi, validation of the received request is done. After validation processing of the request is carried out and based on the processing data is fetched from the memory and response is sent back.

VI. HARDWARE DESIGN

This section focus on the hardware construction of control board. The design of the hardware is done using KiCad software. It is an open source software suite for Electronic Design Automation (EDA). It facilitates the design of schematics for electronic circuits and their conversion to PCB designs. KiCad has five main parts: KiCad – the project manager, Eeschema – the schematic capture editor, Pcbnew – the PCB layout program. It also has a 3D view. GerbView – the Gerber viewer. Bitmap2Component – tool to convert images to footprints for PCB artwork. Using this software, design of all three modules which were mentioned in the previous section is carried out.

In the hardware designing single controller board is designed to which the three different module sensors are designed as add-on cards. The schematic of main controller board is shown below figure 9.

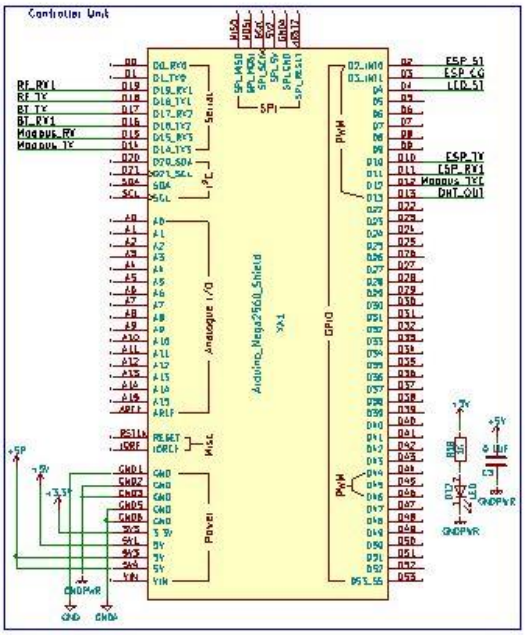

Figure 9. Schemtic view of controller

The Main Controller is interfaced to Wireless RF module, Bluetooth, Wi-Fi shield. So the pins of controller are assigned to all these interfacing devices. The three modules from which the required

information is collected, will be energy meter monitoring, motion detection and AC control system.

Next section is the wireless radio frequency module along with Wi-Fi, Bluetooth and Modbus is shown in figure 10.

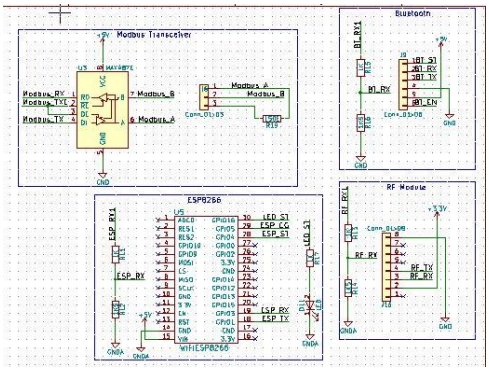

Figure 10. Schematic view of the Wireless RF, Wi-Fi, Bluetooth and Modbus Unit

The different communication modules such as Wireless RF, Bluetooth, Wi-Fi and Modbus are connected to the controller for easy accessibility of the data. These modules work at different supply voltages. So the required power supply is given by the controller.

Next section consists of sensor connection to the slave module controller. Integration of sensor module in the design is shown in figure11.

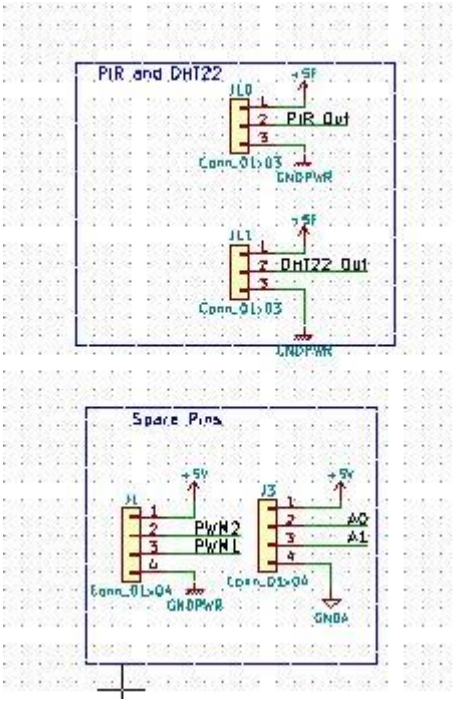

Figure 11. Schematic View of Sensor Connection

This unit also consists of spare pins for future application/use. DHT22 and PIR sensors are connected to the controller. Each sensor has three pins, which are mapped to three pins of controller. The 3D view of the PCB design is shown in figure 12 and 13.

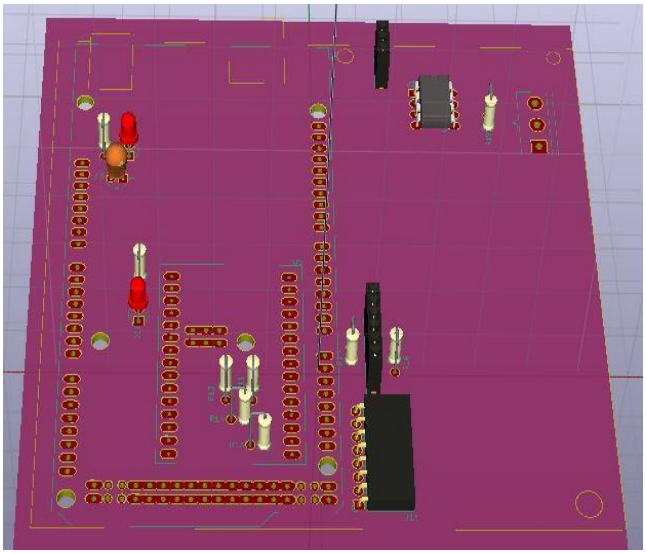

Figure 12. 3D view of the Printed Circuit Board of the Main controller board

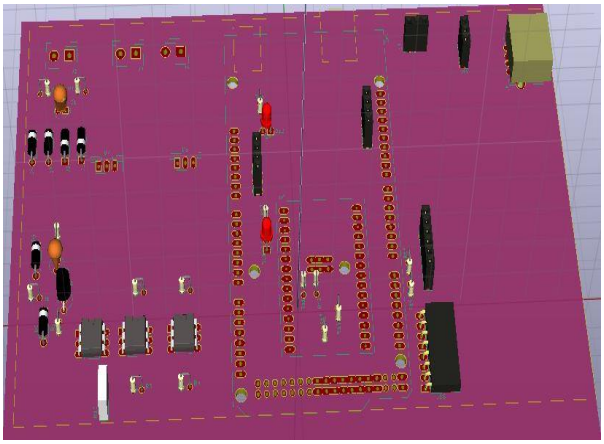

Figure 13. 3D view of the Printed Circuit Board of the slave controller board

The 3D view of the design consists of all the sections which are explained in the previous section. The hardware is designed for single layer.

VII. RESULTS

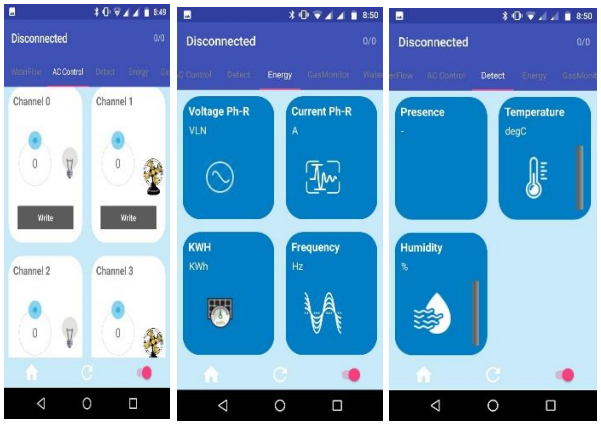

Figure 14. Mobile Application Interface for Energy Monitoring and Control System

Figure 14 shows the user interface of mobile application for energy monitoring. This data is read from the energy meter. This data can be viewed in the graphical format also for easy understanding along with timestamp. This data will be stored in the database and can be viewed at any time. The same data is viewed in the web application.

For motion detection and AC control graphical user interface is designed along with SMS alerts which indicate the user about the present condition of home.

VIII. CONCLUSIONS

This paper presents the new circuit topology for monitoring and controlling the home electrical devices by using the flexible home-based Android smart phone and implemented by wireless transceiver and customized hardware design. The Controller as well as android app is used for system control configuration. The proposed new circuit topology is used in a quiet based web services in an interoperable application layer for communication between the remote user and the home device.

This approach proves the requirement of real time monitoring of domestic energy in order to keep track of everyday consumption of electricity and also controlling of home appliances such as fans, lights, water pumps etc.

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