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Hardware Design of A ZIGBEE Smart Energy Implementation for Energy Efficient Building

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Abstract

This paper gives the brief information regarding the implementation of a smart system for energy efficient building. The hardware design of the proposed system is mainly focused in this paper. The proposed system is elaborated along with the associated software, schematics, implementation logic and few snapshots. This paper also discusses the complete process and step wise execution of the proposed system. Each section of the hardware is described using schematics and flow diagram. To visualize the controlling and monitoring of the proposed work, a graphical user interface is also discussed. The idea of utilising the energy in an efficient way is cleared using the proposed system.

Keywords: ARM7, ATmega8, µVision, MATLAB, ZigBee.

Introduction

Homes, buildings and residential apartments together represents the maximum load on the electric grid. Recent advances in ubiquitous technologies rises the energy consumption and therefore produces a potential source for energy savings. A smart energy system is required to utilise the energy in an efficient manner.

This paper gives the idea of a smart system for the efficient use of the energy. The detailed hardware design is discussed in this paper. Various appliances are connected to the microcontroller unit along with the auxiliary load (ex. washing machine, grinders etc.). The measurement of the power values of the auxiliary load is done using the microcontroller unit. Depending upon these power values, the appliances are switched on and off according to the priority given to them in the user specified modes. Priorities to the appliances should be assigned by the user according to the usage. A ZigBee communication module is used to communicate between the user and the device section.

Statistics at a Glance

Residential and commercial buildings together consumes 73% of our electricity [6]. In Europe, buildings are responsible for 40% of total energy consumption [7], which is more than the demand of industry or transportation. In India, the residential consumption of electricity can be estimated statistically from the following figures [8].

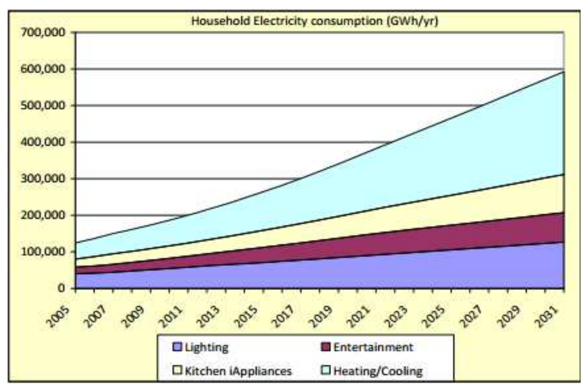

Figure 1: Total Power Consumed by Appliances

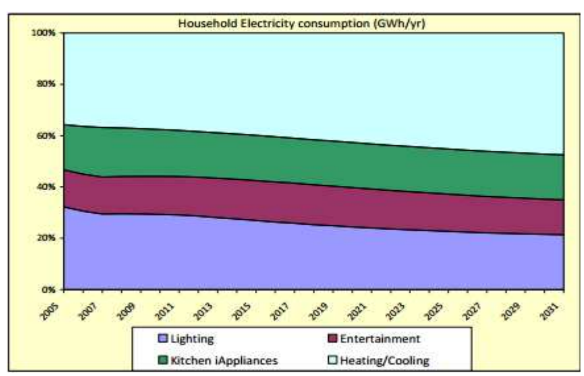

Figure 2: Distribution of Power Consumed by Appliances

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Related Work

Paper [1] discusses the self-adapting intelligent gateway and the self-adapting intelligent sensor for the development of a self-adapting intelligent system for building energy saving and context aware smart services. The implementation of the smart energy management system is discussed in paper [2] by using a test-bed in which a comparison of the power consumption is discussed by using a motion sensor, a common power strip and setting time of power usage. Paper [3] proposed a system using a smart node and the sensors. The kruskal's algorithm for wireless network is also discussed in brief. Paper [4] proposed a system using a client and a server. The client is provided with a real time monitoring sub system and an on-off control panel using a smart phone. The server uses the ZigBee network with video devices and sub-system. Paper [5] proposed a system using a smart node with various sensors.

Implementation of the System

The proposed system consists of the Device Section and the Monitoring Section. Both the sections can be explained as follows.

A. Device Section
Software used for Schematic : EAGLE 6.4.0

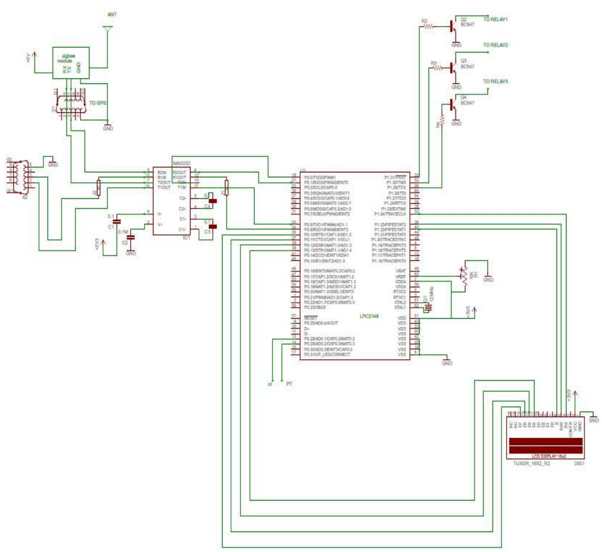

Figure 3: Device Section

The device section mainly consists of the LPC2148 microcontroller. It is a 16-bit/32-bit ARM7TDMI-S microcontroller with 64 pins. It also consists of two 10-bit inbuilt ADCs. The relay are connected to the respective port pins for switching of the appliances. To measure the current and voltage values of the auxiliary load, a current transformer and potential transformer is connected to pin 13 and pin 14 respectively. The power calculation is done in Embedded C using Keil µVision. A ZigBee module is connected through the MAX232 to the Tx (transmitter) Rx (receiver) pins to communicate the power values to the Monitoring Section. Remaining port pins are connected to the LCD as shown in the figure 3.

B. Monitoring Section
Software used for Schematics : EAGLE 6.4.0

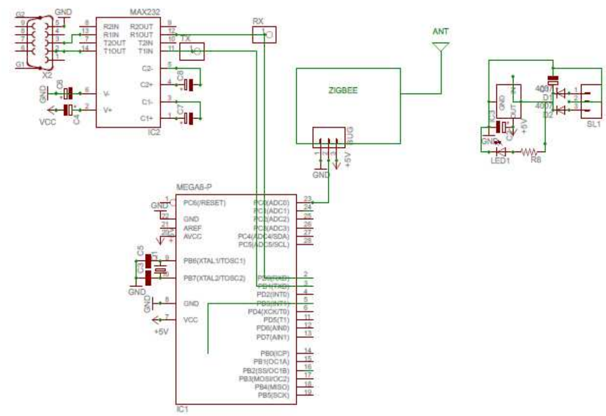

Figure 4: Monitoring Section

The Monitoring Section consists of the ATMEL ATmega8 microcontroller. It is a high performance, low power AVR 8-bit microcontroller. It is a 28-pin microcontroller for PDIP package. A 10-bit inbuilt ADC is also provided for this microcontroller. The TXD (transmitter) and RXD (receiver) pins of the microcontroller are connected through the MAX232 along with a ZigBee module as shown in the figure 4. A PC/Laptop is provided for monitoring purpose.

Execution

A. The execution starts with the initialisation of the port pins of LPC2148 microcontroller.
B. The current and voltage values of the auxiliary load are measured using a current and voltage transformers respectively.
C. After reading these values, the power calculation is done using Embedded C programming.
D. This power value is then compared with the reference value of the wattage. For an auxiliary load, 100W is kept as the reference level. This reference level generates two possibilities.
   1. If the auxiliary load value goes beyond the reference level (100W) then the specified priority modes of the relays should be switched.

2. If the auxiliary load value remains equal to or below the reference value (100W) then the default status of the relays should be retained.

Priorities to the appliances should be assigned by the user according to the usage.

Using four relays, a total 16 combination of modes are possible with the on/off switching status. The facility to switch the relays on and off and the selection of modes are provided at the monitoring section by using a graphical user interface (GUI) designed in MATLAB. In this paper we are using four modes randomly to reduce the length and complexity of the programme. They are tabulated below as follows.

Relays / Modes	R1	R2	R3	R4
M1	ON	ON	OFF	OFF
M2	OFF	ON	OFF	OFF
M3	ON	OFF	ON	OFF
M4	ON	ON	ON	OFF

Table 1 : Priority Modes along with Switching Status of Relays

Modes should be programmed according to usage of the appliances. Higher priority should be given to those appliances which are more necessary to use while less priority should be given to those which are less important. The appliance like motor pumps, mixer grinder, washing machine, microwave oven etc. are to be considered as an auxiliary load. These appliances are utilised occasionally with variable load values.

E. Flow Chart :

The step wise execution can be elaborated using a flow chart as shown in figure 5. Initialisation of port pins, inbuilt ADC and UART are initial steps of execution. Reading the priority mode is the next step for execution. The current and voltage readings are taken and power calculations are done subsequently. The comparison of obtained power value is done with the reference value. The appliances are either switched or retained with default status accordingly.

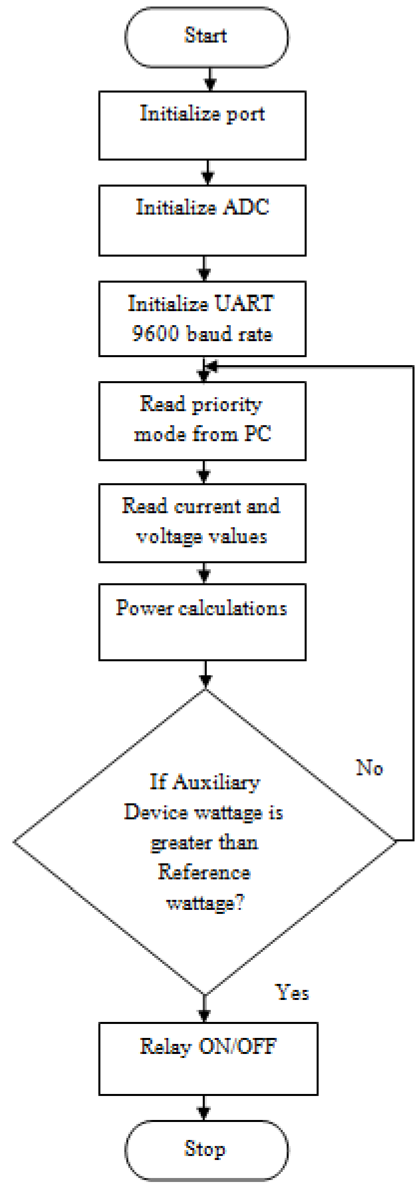

Figure 5 : Flow Chart

Result and Conclusion

The efficient energy management of the building is achieved by using a smart system. The ZigBee communication plays an important role for the communication between the user and device section. For selection of the modes and switching the relays, a graphical user interface is designed in MATLAB 10.0 as shown in figure 6.

Software: MATLAB 10.0

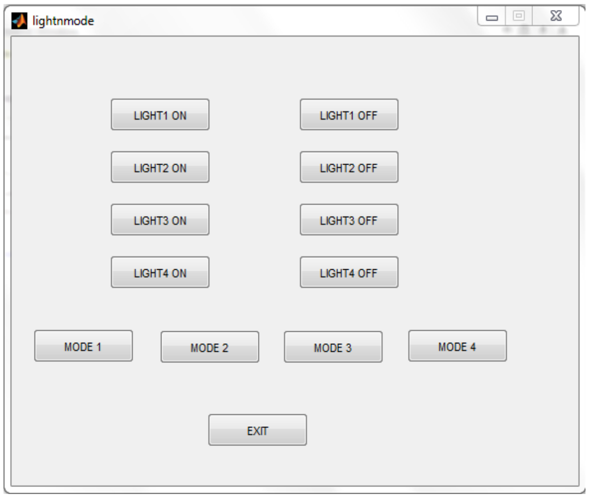

Figure 6 : A MATLAB based GUI

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