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DESIGN AND IMPLEMENTATION OF ENERGY EFFICIENT AUTOMATIC ELECTRICAL UTILITY CONTROL SYSTEM

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Abstract- *This paper presents the design, construction, control and evaluation of an automatic electrical load controlling system. This is an intelligent step in smart automatic load controlling system than those which are already taken. Intelligent technology is the kind of smart technology that delivers new insights and revolutionizes how we live. The system makes a use of intelligent technology to sense the illumination as well as the ambient temperature of surrounding using special sensors and automatically controls the electrical utilities at home by keeping the number of running loads under a fixed limit and thus helps to save energy. This automatic system presented in this paper is designed to fulfill the requirement of advanced technology of today in a very cost effective way. This smart system not only saves energy but also ensures comfort of the users as the sensors provide information about users' requirement by evaluating the ambient conditions continuously. The system contains mainly combination of sensors, controller, driver and relays with integration of embedded controlled programming.*

Keywords: Relay, Sensors, Microcontroller, Load Controller, Relay Driver.

1. INTRODUCTION

Load control and energy efficiency has become one of the important topics in Bangladesh. The demand of electricity is growing with growing technology. The electricity demand of Bangladesh is more than its electricity generation. Although the production of electricity has doubled, with 55 power plants adding over 3870MW of electricity to the national grid in the last four years, it still falls short of the ever-rising consumer demand [1].

In the summer of 2008, the country faced about 800MW of load shedding when it generated about 3300-3400MW against a demand of 4000-4200MW. At present in 2013, there is a deficit of 1600-1700MW, with an average of 6200MW production against a demand of 7500MW [1]. We are in the middle of an energy crisis and each of us needs to contribute for saving energy to ensure that we have electricity in future.

This paper provides us with an idea to save energy by controlling the electrical utilities at home automatically while ensuring comfort of the user at maximum extent. Automation plays an increasingly important role in the world economy and in daily experience. Automatic systems are being preferred over manual system [2]. In this paper, automatic load control system is implemented as a result of which power is saved to some extent. This Paper makes the use of embedded system, since all of its operations are controlled by software inside the micro-controller. Technology used as microcontrollers are the core of the today's digital circuit design in industry, this system uses it for the centralized operation and digital processing.

The common utilities that are used frequently in home are mainly light (CFLs/LFLs etc.), fan, television, computer, refrigerator, washing machine, iron, etc. Among them some loads are used for fixed time in a day and other loads are used occasionally which depends mainly on the necessity of the user. The use of television varies from user to user. The use of utilities like light or fan depends mainly on the surrounding conditions of room like illumination and temperature respectively.

The best way to control such loads like fan and light is using light and temperature measuring sensors. The sensors will automatically turn off the loads which are not required for the time being and thus save energy efficiently.

Besides, the system is designed in such a way that it always keeps the number of running loads under a set limit. Hence it makes the users conscious of saving energy. Thus, the system is developed to save energy in an efficient way by controlling the loads automatically.

2. SYSTEM HARDWARE DESIGN

For developing energy efficient automatic utility control system, the device consists of temperature monitoring unit for measuring ambient temperature and the illumination measuring unit to provide information about light. Both the data of ambient condition are continuously sent to the microcontroller. The microcontroller is pre-programmed to check the number of running loads all the time. If number of running loads crosses a certain limit (the limit is preset by the embedded program in microcontroller. In this case, the maximum limit is set at three loads) then one of the loads will be disconnected automatically. The purpose of switching on or off of each load is controlled by the switching control unit. The decision of which load will be disconnected is taken by the microcontroller evaluating the ambient data sent by the sensors. Let, three loads (a light, a fan and a television) are running at a time. When a fourth load is switched on or added, the number of running loads may cross the set limit and if the combined loads crosses a set limit, one of the loads will be disconnected automatically to save energy depending upon priority of the load. If there is enough daylight, the light will be off sensing that the light will not be necessary during day time. Similarly, if the ambient temperature is not hot, the fan will be forced to turn off. So, the system considers about users' comfort. Figure 1 displays the block diagram of the system.

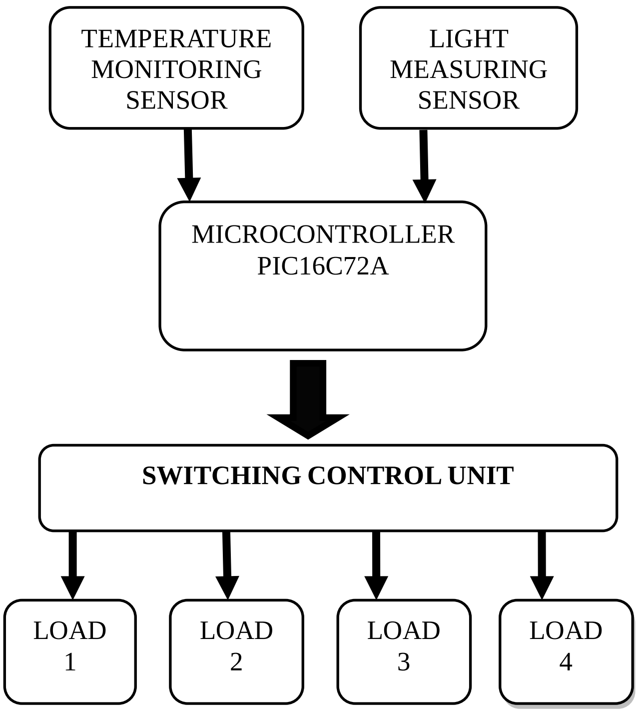

Figure 1: Block diagram showing design of the system

2.1 Temperature Measuring Unit

This unit consists of a temperature sensor to measure the temperature of the room which connects directly to the microcontroller.. The temperature sensor used in this system is LM35 which is an analog sensor. The LM35 is a temperature sensor, which shows output voltage that is linearly proportional to the Celsius temperature as shown in figure 2.

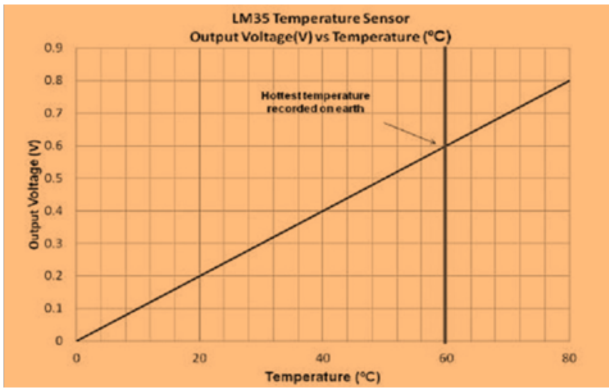

Figure 2: V_{OUT} Vs Temperature curve of LM35

The output voltage varies by 10mV in response to every degree C rise/fall in ambient temperature, i.e. its scale factor is $0.01V/^{O}C$ [3]. The analog voltage produced by LM35 is fed to Analog to Digital Converter (ADC) of microcontroller to convert it into digital form so that the digital equivalent voltage can be used by the microcontroller for further processing, until then it keeps the data in its memory. The temperature measuring unit is shown in figure 3.

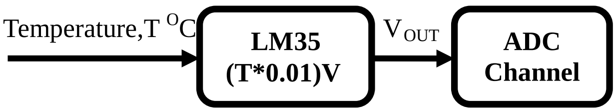

Figure 3: The temperature measuring unit

2.2 Temperature Sensor

The LM35 is a precision integrated circuit temperature sensor that is used here to measure temperature. The electrical output voltage of LM35 is linearly proportional to the celsius or centgrade temperature[3]. The LM35 has an advantage over linear temperature sensors calibrated in degree Kelvin, as it is not required to subtract a large constant voltage from its output to obtain convenient Centigrade scaling. Besides, the LM35 does not require any external calibration or trimming to provide typical accuracies of +_-1/4 degree C at room temperature and +- 8/4 degree C. The trimming and calibration is done at wafer level. So, it is an inexpensive device. It can be used with single power supplies, or with plus and minus supplies. As it draws only 60µA from it s supply, it has very low self-heating, less than 0.10 in still air[4]. Thermistor can also be used for temperature measuring. Another reason for using LM35 is that it accurately measures the temperature than thermistor and it is not subjected to oxidation as the sensor circuitry is sealed [5]. Besides, the output voltage of LM35 does not need to be amplified. The low output impedance, linear output, and precise inherent calibration of the LM35 make it interfacing to control circuitry that is a microcontroller here very easy. Moreover, the LM35 is rated to operate over a -55^{o}C to +150^{o}C temperature range.

For measuring temperature, the left pin of LM35 is connected to the power (5V) and the right pin is connected to the ground. The middle pin will give us an analog voltage that is directly proportional (linear) to the temperature. The analog voltage is independent of the power supply. Thus, the middle pin is connected to the microcontroller PIC16C72A at port A (pin 2) for further processing Thus, ambient temperature is measured by LM35 and is converted into analog voltage which is then fed to microcontroller by the middle pin of LM35. The microcontroller has ADC in it and it keeps the digital data in the memory.

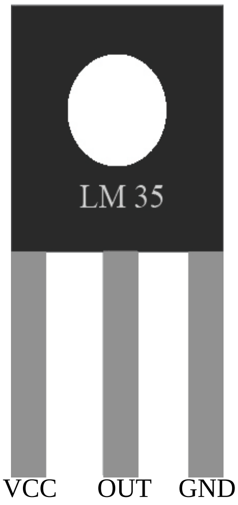

Figure 4: Temperature sensor (LM35)

2.3 Light Sensing Unit

The light measurement is performed by a special light sensitive device called light dependent resistor (LDR). The light sensing unit uses the LDR along with another reference resistor and together they work as a voltage divider [6]. The essential circuit of that voltage divider is shown in figure 5.

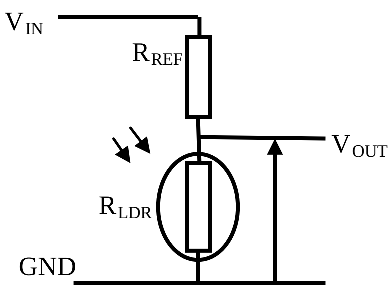

Figure 5: The voltage divider as light sensing unit

The output voltage is across LDR and it is given by the following equation:

$$V_{out} = \frac{R_{LDR} \times V_{in}}{R_{LDR} + R_{REF}} \cdots\cdots\cdots (1)$$

The V_{OUT} is high when the LDR is lightened and V_{OUT} is low when the LDR is in the shade. Thus the light sensing unit measures the amount of light of the room and sends the information to the PIC microcontroller. The microcontroller keeps the data in its memory for further processing and decision making.

2.4 Light Sensor

This device mainly varies its resistance inversely depending upon the light intensity [6]. It is actually, whenever light falls on the LDR, electrons in valence band are excited and move to the conduction band. The movement of free electrons and holes causes the current flow in the LDR with decrease in resistance. When there is enough light, the resistance is minimum about 100 ohms. But at dark state, the resistance can be increased as much as 1Mohms. Figure 6 shows the LDR.

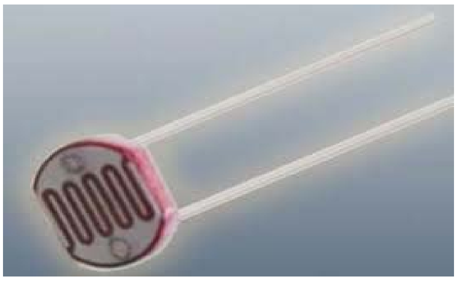

Figure 6: The LDR

Suppose, at bright light the LDR has a minimum resistance of R_{MIN} =0.5K and in the shade the maximum resistance is, R_{MAX} =1000K. The R_{REF} is set as the threshold of the light intensity [7]. R_{REF} is calculated as:

$$R_{REF} = \sqrt{(R_{MIN} \times R_{MAX})} \quad (2)$$

When LDR is under bright light the Output voltage according to equation 1 is 0.015V and in the dark state it is 3.76V. The output voltage is then sent to the microcontroller and is kept in its memory. The output voltage is measured continuously.

2.5 Microcontroller Unit

Microcontroller is the heart of the system. Every action taken is under the control of the Microcontroller. The microcontroller used here is PIC16C72A. It is an 8-bit low power high performance PIC micro-controller. It has 1024 Bytes of RAM and 28K words of program memory. The program for controlling the system is written in the micro-controller. The temperature measuring unit, the light sensing unit, the switching control unit etc. are interfaced with the microcontroller. Microcontroller communicates with the different sections and performs the action according to the set program in it. The program is rewritable according to the requirement.

2.6 Switching Control Unit

This unit serves to switch on or off the loads. The unit consists of manual switches, Relay driver ULN2003A and 12V relays. The loads are switched on manually. When the manual switches are pressed the relays switch on the loads and disconnect the load according to the microcontroller's decision.

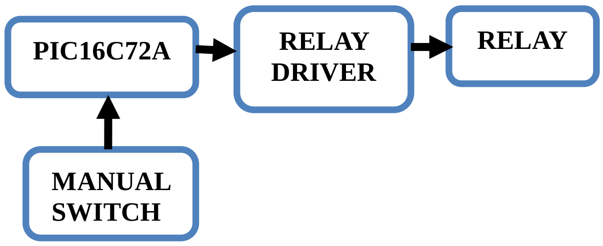

Figure 7: Switching control unit

2.7 Relay

Relay is an electromagnetic switch which is used to switch High Voltage/Current using Low power circuits. Relay isolates low power circuits from high power circuits. It is activated by energizing a coil wounded on a soft iron core. Generally relay coils are designed to operate from a particular voltage often its 5V or 12V [8]. The relay in this system is 12V and it opens and closes under the control of PIC16C72A microcontroller. The relay switch connections are usually labeled as Common (COM), Normally Closed (NC) and Normally Open (NO). The circuit is connected to COM and NO if it is switched to ON when relay coil in ON while to switch OFF the circuit connect the COM and NC together and then the relay coil is in OFF state. Therefore, the output was connected to COM and NO [8]. As a result the relay contacts when it detect signal from the PIC circuit.

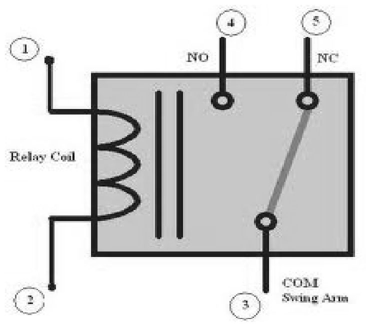

Figure 8: The switch connection of a Relay

In the designed system the utilities are AC loads and run at a very high voltage 220V. So, the low voltage 12V relays operate the 220V loads here. The 12V supply energizes the relay coil by normally closed contact. When the coil is fully energized the normally open contact closes and thus the load gets connected to the AC 220V supply.

2.8 Relay Driver

A microcontroller is not able to supply current required for the working of a relay. The maximum current, I_{MAX} that a PIC Microcontroller can source or sink is 25mA while a relay needs about 50 – 100mA current. That's why a relay is not directly connected to the microcontroller rather than through a driving circuit. The driving circuit amplifies the microcontroller current to a necessary level sufficient to turn on the relay. It also prevents the negative voltage that is produced in a relay due to its back EMF which might cause the working of the microcontroller to be stopped. As relay driver one can use transistor, ULN2003A or ULN2803. Transistor should not be used if there are more relays in the system [9]. In the system ULN2003A is used.

2.9 Power Supply Unit

The Power supply circuit is built to supply the power or voltage to the circuit. For this system, the circuit needs 5V voltage supply and the relays need 12V supply. So, Input supply for this circuit consists of 12V DC. Therefore Voltage regulator is used to provide 5V DC regulated voltage from the unregulated 12V input voltage. LM7805 is used as the voltage regulator for the circuit. The LM7805 acts as a filter to the 5V voltage for the circuits. A voltage regulator is actually an electrical regulator designed to automatically maintain a constant voltage level. The capacitors are used to stabilize the voltage supply and to reduce the ripples of the voltage source. The power supply circuit is shown in Figure 9.

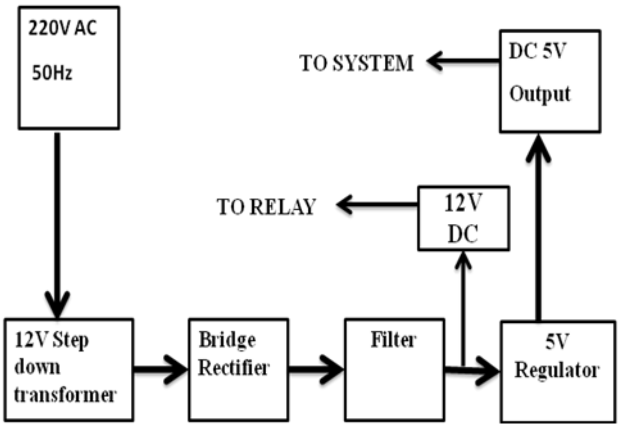

Figure 9: Power supply Unit

3. FLOW CHART

The Flow chart describes the implementation of program written using C language. All the ports used in the program are initialized at starting. The system first checks the activated number of loads. If the number crosses the set limit it then checks for the current ambient data in the controller and disconnect one load as decision given by the controller according to the logic conditions set in the program.

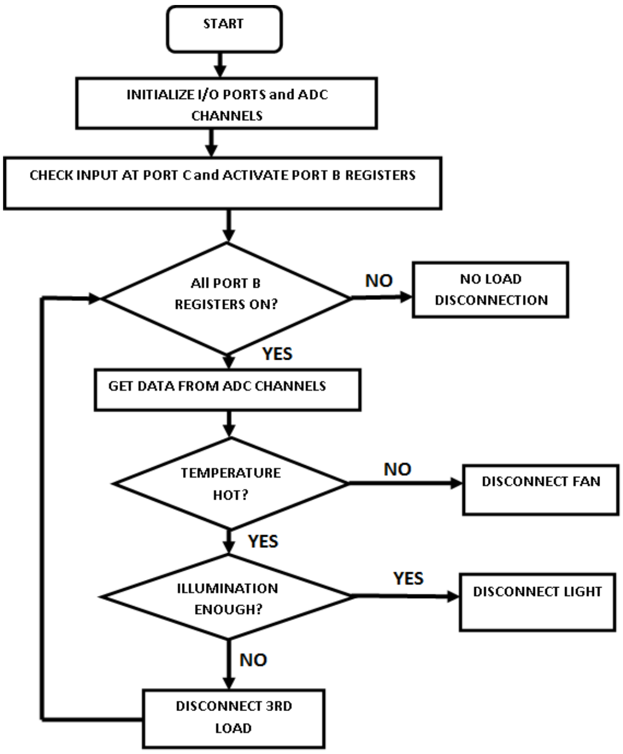

Figure 10: System Flow chart

4. SIMULATION

The system is simulated using Proteus Software and the complete simulation diagram is shown in figure 11.

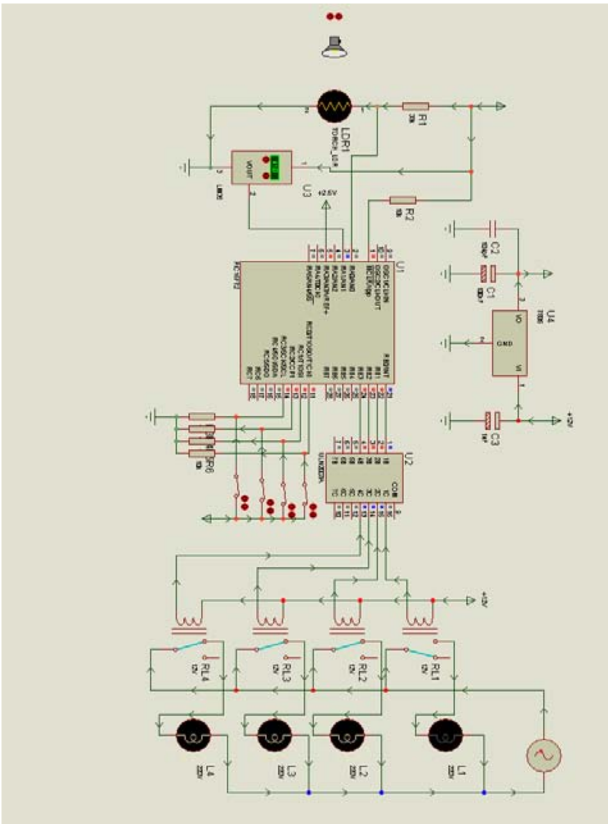

Figure 11: Complete Simulation Diagram

5. SYSTEM IMPLEMENTATION

The system is implemented successfully. The different loads are shown using 4 bulbs. The orange one indicates the fan, the yellow one indicates light, and the other two bulbs refer to load3 and load4 respectively as shown in figure 12. As the system is turned on, an LED turns on first to indicate that the system is activated. The utilities can be turned on or off using manual switches. While 3 utilities are switched on no automatic disconnection is occurred. While 4 loads are turned on at a time, one load is disconnected automatically considering the ambient conditions. Figure 13 shows that the fan is switched off automatically due to low ambient temperature.

Figure 12: The automatic utility control system

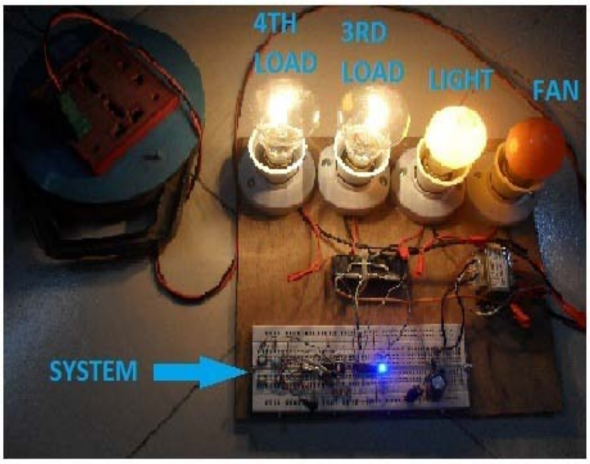

Figure 13: The system working

6. RESULTS

This section describes the output of the implemented system to check if it works successfully. Several testing has been made for various ambient conditions and the results were checked if they are intended. When 3 loads are running at a time no load will be switched off. When another 4th load is switched on the following conditions occurred which is shown in table1.

Table1: System Output at different ambient conditions

Ambient condition	Load 1 (Light)	Load 2 (fan)	Load 3	Load 4
Temperature is high, Bright light	OFF	ON	ON	ON
Temperature is low, light is low	ON	OFF	ON	ON
Temperature is high, light is low	ON	ON	OFF	ON
Temperature low, Bright light	ON	OFF	ON	ON

7. CONCLUSION

In the case of energy savings human behavior can increase the contribution much more. Human behavior, ignorance and comfort in households and industry are a huge cause of energy inefficiency. It has been found that users do not contribute towards buying and installation of energy efficient products or system [10] and this automatic utility controller can encourage energy efficient behavior as it will help the users not to exceed a certain energy limit by limiting the number of running utilities. The system can be designed to work with other energy efficient technologies. Software is easily adaptable to work with any number of loads that could be managed more efficiently. The system will save the utility cost along with energy efficiency along with encouraging customers to be more alert towards energy efficiency as they will be part of the process, choices and savings offered by the system.

8. FUTURE WORKS

1. A modification may enable the system to turn off more than one load at a time so that more energy can be saved.
2. The system can be modified for Industrial load controlling purpose.
3. The system can be expanded and developed to control various other loads. E.g. A single temperature sensor can be used to control both air conditioner and fan by defining different control range of temperature, a level sensor can be added which may help to turn off pump automatically
4. The system can be integrated with home security system. E.g. A smoke sensor and an alarm can be added to secure home from fire.

9. REFERENCES

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10. NOMENCLATURE

Symbol	Meaning	Unit
V	Voltage	(Volt)
R	Resistance	(Ohm)
I	Current	(Amp)
T	Temperature	(^{O}C)