Lighting Control System for Energy Saving

Anuradhi Welhenge
School of Engineering and Technology
Asian Institute of Technology
Thailand
anuradhi@live.co.uk

***Abstract*— The surge of consumer electronics market has placed a heavy burden on the already stretched energy demand. In view of the depleting fossil fuel reserves and the scarcity of non renewable resources, Engineers face a challenge to conserve energy at the design stage and at the utilization stage. Since consumers are pre occupied with their professions they need automated systems to take care of the energy consumption and make their life easy. This projects aim is to develop an energy saving device using a microcontroller for a room in which lights and other utilities are used. The sensors which provide inputs to the microcontroller detect the occupancy and other environmental conditions and logically control the output circuits. The program is written so that the inputs and outputs are controlled to optimize the energy consumption by switching the lighting and equipment appropriately by cutting off energy wasted. Collected data showed that this device helps to reduce the energy consumption. Though the prototype is demonstrated with LEDs indicating outputs, the actual product include peripheral components which meet the load ratings of the equipment to which the control system is connected.This paper presents one of such systems implemented using microcontrollers and embedded programming.**

Keywords-Microcontrollers, Embedded systems, Energy saving, Consumer electronics, Automate

I. INTRODUCTION

As the living standards of people around the world improve with the continuous development of technology, the needs of the people also increase. Engineers play a vital role in the process to satisfy these ever-increasing needs. This has resulted in the introduction of many new machines, equipment and devices to increase comfort and reduce human effort. The surge of consumer electronics market has placed a heavy burden on the already stretched energy demand. In view of the depleting fossil fuel reserves and the scarcity of non renewable resources, Engineers face an unprecedented challenge to conserve energy at the design stage of electrical equipment and components and also at the utilization stage. This problem will be more pronounced in the future due to the ever increasing population.

Consumption of electrical energy in residential and commercial buildings will be doubled in 20 years [1]. If energy saving methods are not implemented it will be difficult to supply the electrical energy to satisfy the demand, as the gap between supply and demand is increasing every year [2]. Therefore studies are conducted to find energy saving techniques.

Ambient intelligence was used in one of the systems designed [3] to encourage residents to reduce energy usage by showing the methods energy is wasted and the amount of energy loss.

PLC/RF ENergy Information System (ENIS) is another system which helps customers to use the energy flexibly by providing the access to energy information and showing the energy saving profile. An energy meter and energy information display is designed and it communicates the information using broadband network and power line communication network (PLC) [4]. Parabolic dish collector designed using Scheffler technology to use solar energy to replace part of electricity generation is also proven successful [5].

Since at the utilization stage the control is always in the hands of the consumer, though this may be achieved through consumer awareness programs and introduction of energy tariff to compel the consumer to improve energy efficiency, their minds are already pre occupied with their professions and have only a little time left to concentrate on events taking place around them. Therefore they need automated systems to take care of the energy consumption and make their life easy.

This research’s aim is to develop an energy saving device for a room in which lights and other utilities are used. The device detects the occupancy and other environmental conditions, and logically controls the energy consumption by switching the lighting and equipment appropriately cutting off energy wasted.

II. SYSTEM DESIGN

Main component of this system is the microcontroller board with ARM Cortex processor. Inputs and outputs are connected to this processor. The software program was written to the chip to compare inputs and delivering the necessary output and recording all activities. Figure 1 shows the system overview and the state diagram.

The Lighting Control System for Energy Saving is comprised of the room lighting control and utilities control. The lighting control system uses a LDR to measure the illumination level and a passive motion detector to identify the presence of a person in the room to control the ”on” state and ”off” state of the room lights. Figure 2(a) shows

978-1-4799-6487-1/14 $31.00 © 2014 IEEE
DOI 10.1109/AMS.2014.21

the overview of this system. The utilities control system uses a manual switch for the room user to indicate the wish to use the utilities and a passive motion detector to identify the presence of a person in the room to control the ”on” state and ”off” state of the utilities. Figure 2(b) shows the overview of this system.

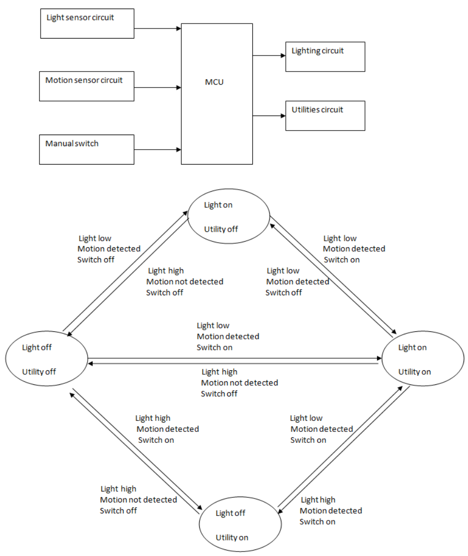
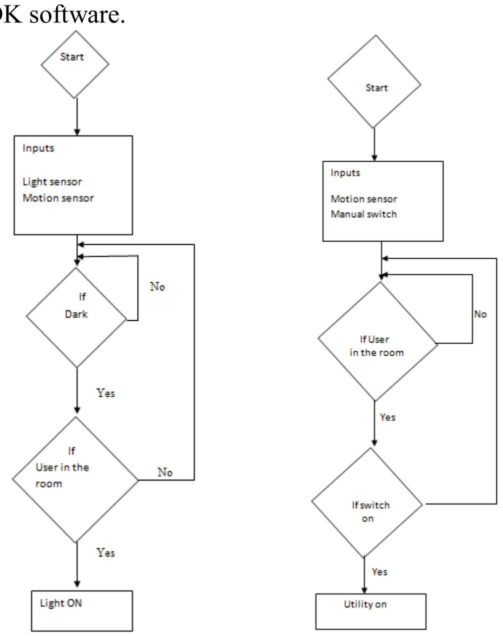


Figure 1. System overview and state diagram

To logically control the output devices, based on the signals given by the input devices, a STM32F0 Discovery board is used. Program for the board was written using Keil MDK software.



(a) (b)

Figure 2. Overview of the (a) lighting system, (b) utilities system

A Light-to- voltage converter which is mounted on the PCB was selected to measure the illumination level. It is supplied with 5V supply which is shared with the motion sensor. This device is a combination of a photodiode and transimpedence amplifier in which the output voltage is linear with light intensity over a wide range. The irradiance responsivity is 246 mV / (W/cm2) which is suitable for the normal reading illumination level of 250 - 500 Lux. (36.6-73.2 W/cm2).

To detect the presence of the occupants in the room, a passive IR type motion sensor was selected. The detection distance was selected as 10 m and a detection zone was selected as a cone of 45 degrees. The sensor used is of low current type and operates on a 5V supply generating a digital output.

The lighting circuit of the room is switched “on” and “off” depending on the output of the MCU, which is determined by the illumination level available from the day light and the presence of a person inside the room. There is no intervention required by the room user. The Utilities (power sockets) circuit of the room is switched ”on” and “off” depending on the output of the MCU, which is determined by the presence of a person inside the room and the occupants intervention (which is the manual switch) to keep the utilities “on” or “off”.

The output of the Light sensor, which is an analog signal need to be proportioned using a voltage divider before feeding the MCU, which also acts as a pull down for the input. The signal is fed to one of the ADC channels. The output of the Motion sensor, which is a digital signal also need to be proportioned using a voltage divider before feeding the MCU, which also acts as a pull down for the input. The MCU detects the rising edge of the motion sensor output.

The Lighting and Utilities circuits, which are directly connected to the AC mains, must be isolated from the DC components. For this purpose optocoupler circuits using TLP 621 were deployed in both outputs. Recommended forward current of 20mA through the optocoupler LEDs were achieved using appropriate circuits. The optocouplers in each output circuit drive the LEDs.

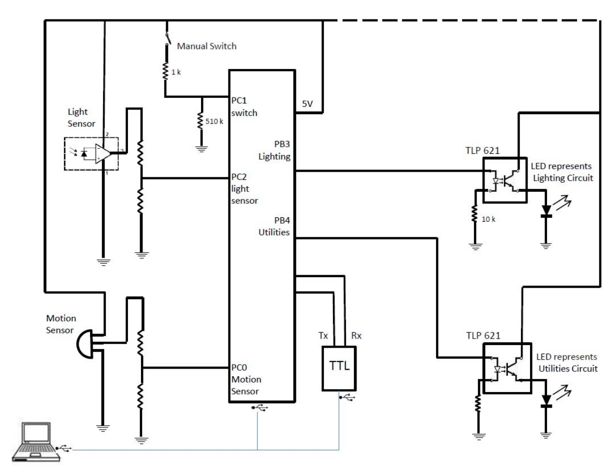


Figure 3. Full system overview

III. EVALUATION

The light sensor was mounted on the PCB. It keeps on giving a continuous output because of the lights in the surroundings. Even after covering the sensor, it detects sufficient light to prevent the MCU from switching on the lighting circuit. So, input level of the MCU was adjusted to defeat the sensor.

The motion sensor was mounted on the PCB. Hence the sensor was in a direction facing the ceiling. The detection zone was above the table and hence the movements of the room occupants were not registered by the sensor. In a second trial the PCB was supported vertically so that the detection cone was projected horizontally across the room.

In the microcontroller Pin PC 0 is chosen as a digital input pin since the output from the motion sensor is a digital output and PC 1 is chosen for the manual switch while PC 2 are chosen for the light sensor it gives analog signals. PB 3 is chosen as the digital output pin to the lighting circuit and PB 4 for the utilities circuit and it is connected via a relay to the output pin. Voltage divider circuits are used to protect the microcontroller. In the code, GPIO is configured for each pin according to their characteristics. Then USART communication channel is configured with 9600 baud rate. To convert analog signals to digital ADC converter on the board is configured in single conversion mode. GPIO is connected to the AHB bus while ADC and USART are connected to the APB bus. Clocks relevant to these buses are also turned on.

The Lighting Control System for Energy Saving was installed in the Lab and the performance was monitored during a day. To record the lighting and utility "on", "off" data for the room during a specified period, a TTL board was connected to the computer to generate an activity log.

The data collected showed that the system was detecting the inputs correctly and logical outputs were generated. LEDs were used to indicate the output signal of the board and the "on", "off" state of the AC circuit was indicated by a lamp.

The "on", "off" periods of each output was extracted from the activity log and the percentage reduction of energy consumption was calculated.

IV. DATA ANALYSIS

$$Energy\ saving = Power\ rating \times \left(\sum_{i=0}^{n} (Off\ time)_n\right) \quad (1)$$

Using (1) amount of energy saved can be calculated. No. of samples should be collected in order to get a more accurate analysis.

V. CONCLUSION

Though the results indicate that there is a power saving of 97.6% from using this system, the trials were conducted inside the laboratory during vacation. Therefore the actual occupancy was not available for the trial. The trial was conducted 25% of the full time. The results could have been more realistic if the trials were conducted during 24 hours and on many different working days.

Since this device is designed for the use of general public the trials which were conducted in an access restricted room may not give the realistic results.

VI. FUTURE WORK

Instead of using a long range motion sensor with its detection zone horizontally projected at the expense of sensitivity, two or more short range sensors could be mounted on the ceiling to cover the entire floor area of the room and the code should be extended with a suitable algorithm. An algorithm can be used to operate a distributed lighting arrangement within the room.

In a real product relays should be used to drive the lights and utilities. If the total load of the utilities cannot be taken by the relay it is proposed to have a circuit breaker cascaded with the relay.

If this is going to be marketed as a consumer product, light sensors and motion sensors should not be integral parts of the PCB. The sensing units should be mounted appropriately at discrete locations.

ACKNOWLEDGMENT

The success of this research depends largely on the encouragement and guidelines of many others. I would like to show my greatest appreciation to Dr. Mongkol Ekpanyapong, Dr. Apinun Tunpan, Dr. Supachai Vorapojpisut for being my supervisors. I take this opportunity to express my gratitude to the people who have been supportive hands in doing this research.

REFERENCES

[1] Y. Chen and J. K. Hwang, "A reliable energy information system for promoting voluntary energy conservation benefits", IEEE Trans. Power Del., vol. 21, no. 1, pp. 102 – 107, January 2006.

[2] G. Kamalapur and R. Udaykumar "Electrical energy conservation in india – challenges and achievements"in int. conf. Control, Automation, Communication and Energy Conservation, 2009, pp. 1 - 5.

[3] J. Kidhen et al.,"Development of energy conservation programs for residential and small commercial buildings in Thailand" in IEEE first conf. Clean Energy and Technology, 2011, pp. 104 -109.

[4] K. Kobayashi et al.,"Ambient intelligence for energy conservation" in IEEE/SICE int. symp. on System Integration (SII), 2011, pp. 375 - 380.

[5] M. Patwardhan,"Use of solar energy for electrical energy conservation: A case study" in Nirma University int. conf. Engineering (NUiCONE), 2011 pp. 1 -5.