Automatic Control and Monitoring of Electrical Energy Consumption Using PIR Sensor Module.

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Abstract: Low power consumption is a very good advantage in this energy hungry world. A microcontroller-based Automatic Light Control is designed and constructed to save the usage of electrical energy and to avoid wastage using a room as a study. This project takes over the task of controlling the room light. When a person enters the room, the lights are switched on automatically while it is switched off as the last person leaves. A Passive Infrared sensor is placed near the door and used to detect the presence of human beings. The output from this sensor is sent to the PIC16F84 microcontroller, which then controls the room lights via a relay. A pilot test carried out suggested a saving in the energy comsumption.

Index Terms: Energy Consumption, Control, Passive Infrared sensor, Microcontroller, Occupancy sensor.

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1 INTRODUCTION

Electricity has assumed a prime position as a form of energy for mankind. As human activities increase and inventions are made, the importance of electricity continued to be on the ascendance. Based on increase in human activity, there has been astronomic rise in the demand for electricity. Indeed the level of electricity consumption has become a major index being used in measuring the level of development of nations of the world nowadays. However despite the importance attached to electricity, it has remained one of the most wasted and abused resources especially in the third world countries. It is not uncommon to see lightings left ON in unoccupied classrooms, offices, and homes for many hours.

It is estimated that approximately 45% of the electricity generated in most third world countries (including Nigeria) is wasted. This is due to poor energy conservation policy (of the country) or and lack of public awareness of need for efficient utilization of electricity. Nigeria's electricity demand is growing faster than the country's population. The electricity per capita of Nigeria, which is 137.2 KWh per capita, is one of the lowest in the world. Lighting constitutes about 18% of the total power generated as compared to 8 – 10% in developed countries [1].

Energy conservation is an important element of energy policy. A well-thought-out Energy conservation policy helps in reducing energy consumption and demand per capita. This in turn increases the energy supply needed to keep up with population growth. In addition, it goes a long way in reducing energy costs and the need for new power plants [2].

Lighting accounts for 30% to 50% of a building's electrical energy use [2]. Energy conservation and considerable savings can be achieved by the application of intelligent control technologies in existing buildings [3]. Llighting usage is about 19% of the electricity used in the world. The emission of CO_2, which is also related to electricity production for lighting, is approximated to be 1,775 billion ton per year [4]. The emission of CO_2, causes Green House Effect, which in turn depletes the ozone layer.

2 REVIEW OF LIGHTING CONTROL SYSTEMS.

There are six most common strategies used in advanced lighting control to reduce electricity consumption viz; daylight harvesting, occupancy sensing, personal control, time scheduling, task tuning, and variable load control [5],[6],[7].

ABB carried out series of tests to examine the specific potential saving values of implementing constant lighting control. The tests were performed in an office building with seminar rooms. Constant lighting control were used – in contrast to a lighting that is fully switched ON– the required lighting intensity in the room is achieved by the continuous and controlled addition of "artificial lighting" required to maintain a defined level of brightness (in these measurements: 500 Lux). Only the amount of energy that was necessary for the artificial lighting was consumed.

Results from experiments has shown that a high-level of potential energy savings is possible with constant lighting control and constant light control always yielded savings of more than 25 % in comparison to manual lighting operation [8].

2.1 ENERGY SAVINGS DUE TO OCCUPANCY SENSORS

Passive Infrared Sensor (PIR): The pyroelectric sensor is made of a crystalline material that generates a surface electric charge when exposed to heat in the form of infrared radiation. When the amount of radiation striking the crystal changes, the amount of charge also changes and can then be measured with a sensitive FET device built into the sensor. The job of the passive infrared is to sense the presence of human body within a particular radius (in this case 5m).

The application of occupancy sensors has many motivations over other methods mention above. The prominent among which are listed below:

People do not occupy spaces for a large percentage of time, and are not diligent about controlling the lighting in their spaces both during the workday, and after hours and weekends. This applies to both public spaces as well as personal spaces [6].

For lighting energy conservation and peak demand savings, the most important issue is not the installed lighting power density, but how lightings are utilized.

Ultrasonic sensors generate an inaudible signal at 20 to 40 kHz which is put out into a space. The signal bounces off surfaces and returns to a receiver unit within the sensor, similar to radar. When there is motion in the space, the signal returns to the unit at a slightly different frequency which triggers the sensor to open the lighting circuit in what is reffered to as the Doppler effect.They have limited sensitivity around obstacles such as walls or cubicles. Ultrasonic sensors cover the entire space and do not need a line of sight. As a result, they can detect people behind obstacles. They also are more sensitive to minor motions, such as hand movements. Small hand motions can be detected up to 6 m away [9].

The other variant of sensors used are the infrared sensors. Infrared occupancy sensors respond to occupancy by detecting changes in temperature and movement of humans. They're designed to detect the peak wavelengths of heat that are emitted by humans, not other heat-generating objects such as computers and copiers.A passive infrared sensor detects heat only within its "line of sight." It cannot detect the heat through walls or other obstacles. They detect motion within a fan shaped pattern. The sensor's ability to detect motion also depends on the distance between the sensor and the location of the motion. At short distances, within

3 m, the sensor can detect very small motions such as hand movement. As the distance between movement and the sensor increases, larger motions are required to trigger the sensor. When a person is 9 m to 12 m away from the sensor, it will only detect large movements such

as a person walking around [6].Infrared sensors have a lot of advantage compare with other sensors. This sensor is simple, reliable, highly resistant to false triggering, quite inexpensive and do not emit ultrasound or microwaves" [9].

3 SYSTEM DESIGN AND IMPLEMENTATION
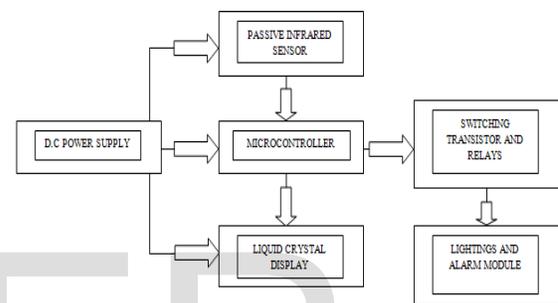
3.1 MICROCONTROLLER STAGE

A microcontroller PIC 16F84 is at the heart of the system design . It housed the program that

controls the functionalities of other sub-systems that are coupled with it. The flow chart codes that monitor the operation of the PIC is given in figure 2A.

The design uses a Passive Infrared detector (PIR detector) to detect human presence in the

room. The PIR output is fed to PORTA0 of the PIC16F84 microcontroller (configured as inputs). Once the signal is received in the PIC microcontroller, the lines of instructions to switch the lightings ON are called. These instructions are converted to an electrical signal, which drives the transistor to saturation, so that the relay is energized to switch ON the lightings. If there is still detection of human in the room, the process repeats itself, creating a loop in the program. Until the sensor output gives a zero (i.e. empty room), and the loop is broken to trigger the lights OFF. When a human is sensed, the

same process is repeated. Also, the alarm switch is fed into PORT A1 of the PIC microcontroller. When the switch is ON, it sends a high to the PIC microcontroller meaning that the person detected by the PIR is an intruder. The alarm subroutine function is called up, which would trigger the alarm module ON for 1 min after which the alarm module goes OFF. If another intruder or the same intruder breaks in, the process repeats itself. If the alarm switch is OFF, the alarm will not be triggered if the PIR detector detects a human. The microcontroller does all the timing and control functions. PORT A is configured as input for the PIR and alarm switch,

Figure 1: System Design block diagram

while PORTB is configured as output, which is responsible for switching the transistors and interfaces the Liquid Crystal

Display.

3.2 LIQUID CRYSTAL DISPLAY OUTPUT

A 16 x 2-line Hitachi HD44780 Liquid Crystal display is used in the circuit design. It is used to display read/written inputted data, in this case, from the microcontroller. The LCD is to communicate every action of the microcontroller. The **LCD REQUIRES** three control lines from the Microcontroller:

Enable Line: This allows access to the display through the R/W and RS lines. When this line is low, the LCD is disabled and ignores signals from R/W and RS. When (E) line is high, the LCD checks the state of the two control lines and responds accordingly.

Read Write Line: This line determines the direction of data between the LCD and microcontroller. When it is low, data is written to the LCD. When it is high, data is read from the LCD.

Register select (RS): With the help of this line, the LCD interprets the type of data on data lines. When it is low, an instruction is being written to the LCD. When it is high, a character is being written to the LCD.

The lines connected to the output port of the microcontroller (RBO – RB3) are the Data Lines, while the line connected to RB4 is the Register select and RB5 is Enable Line.
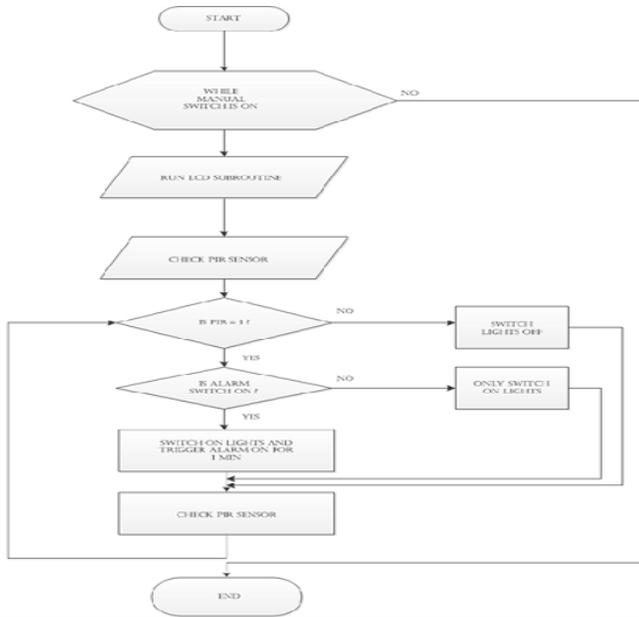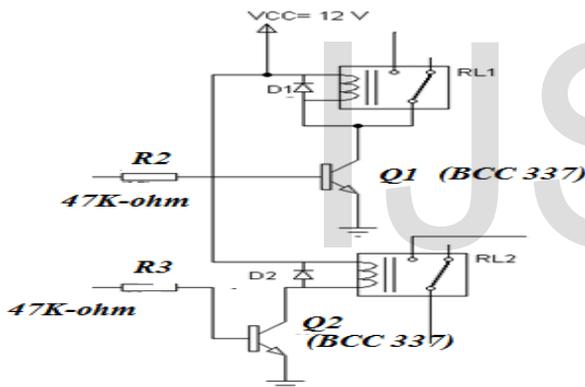
Fig 2A: PIC Program Flow Chart

Fig 2B: Transistor Switching Circuit

3.3 TRANSISTOR SWITCHING DESIGN

Transistors Q1 and Q2 are BCC337 which are operated as swiches for relays RL1 and RL2. The relays are rated 12V DC, 30mA and a resistance of 400Ω.

Diodes D1 and D2 protect the transistors from back emf that might be induced due to the inductance of the coil, after the voltage across the coil is zero. The resistances of the two relay coils(400Ω) act as the collector resistances of both transistors.

12V, relay voltage from the supply

$V_{BE} = 0.7V$ (silicon)

$V_{IN} = 5V$ (from microcontroller)

$H_{fe} = 300$ (data sheets for BC337)

$RC = 400Ω$ (resistance of the coil of the relay will be the collector resistance)

$$V+ = I_c R_c + V_{CE} \qquad (1)$$
$$V_{IN} = I_B R_B + V_{BE} \qquad (2)$$
$$H_{fe} = \frac{I_c}{I_B}$$

from (2),

$$R_B = \frac{V_{IN} - V_{BE}}{I_B} \qquad (3)$$

where,

IC = collector current,IB = base current, VIN = input voltage, V+ = supply voltage

VCE = collector-emitter voltage = 0V (At Saturation Mode)

Hfe = current gain.

from (1),

$$I_c = \frac{12 - 0}{400}$$
$$= 0.03A$$

From (3)

$$I_B = \frac{0.03}{300}$$
$$= 100\mu A$$
$$R_B = \frac{5 - 0.7}{100 \text{ X } 10^{-6}}$$
$$= 43k\Omega$$

47kΩ was chosen as it was readily available.

RB=R2=R3=47K in the circuit diagram

The circuit diagram of the switching stage is shown in figure 2B.

4 RESULTS AND ANALYSIS

The system packaged as a module which is integrated into electrical wiring design of a building was tested by installing the PIR at the entrances/doors to monitor and control the swicthing ON and OFF of the lighting points in the hall. The result obtained showed a great improvement over the manual switching as many a time the last occupant oftentime forget to put OFF the light. It was equally adapted to control the Fan reguraltors such that the ceiling Fans came up on sensing that people are in the hall and switch off when nobody is around. The switch (fan regulator) was however restricted to a certain speed as there was no provsion for speed regulation.

In the following anaylsis, table 1 indicate the status of the lighting sources in the hall when there are occupiers and when nobody is inside. The device gives a time delay of one minutes for switching from ON position to OFF position while the change from OFF to On position is instantaneous.

Table 1: Availability and the status of the light in the Hall using PIR sensor Module

	Availabilty/number of person(s) in the Hall (y)	STATUS OF LIGHT	
		ON	OFF
1.	NIL	X	
2.	$1 < y \leq \propto$		X

Table 2: Comparism of PIR Sensor Module with Manual Switching (50% Negligence in manual switching)

S/N	TIME (3hours)	PIR SENSOR MODULE		MANUAL SWITCH	
		ON	OFF	ON	OFF
1.	2.00 - 2.30		X		X
2.	2.30 - 3.00	X			X
3.	3.00 - 3.30		X		X
4.	3.30 – 4.00	X		X	
5.	4.00 – 4.30		X		X
6.	4.30 - 5.00	X		X	

Using PIR sensor module (i.e when PIR sensor module is installed)

Total number of hours in ON position = 1hr, 33minutes
   (1hr, 30minutes
   + 3minutes of delayed transition to OFF position)
Total number of hours in OFF position = 1hr, 27minutes
   %of hours in ON position = 51.7%
   %of hours in OFF position = 48.3%

Using Manual Switch solely (i.e without PIR sensor module)
   Total number of hours in ON position = 2hrs
   Total number of hours in OFF position = 1hr
   %of hours in ON position = 66.7%
   %of hours in OFF position = 33.3%

Saving in energy
   % of hours wasted = 66.7 − 51.7 = 15%
   % of hours saved = 48.3 − 33.3 = 15%

Assuming average working life of 1000 hours for incandescent lamp, and 4000 hours for Flourescent lamp, 150 hours of the active working hours of incandescent lamp and 600 hours of ative working hours of Flourescent lamp are wasted .

5 CONCLUSION

The paper presents one of the simple and effective ways of saving energy automatically in any room of any building or organization. This was achieved by the application of the microcontroller PIC 16F84 and Passive Infra-red sensor as the major building blocks. A randomly selected test for a duration of 3 hours using the module showed a 15% saving in the energy consumption and the translation to the number of active woking hours of lighting type used. This is based on the premise that the manual control switches are operated with 50% accuracy.

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