Microcontroller–Based Lighting Control System

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Abstract**:** The work presented here outlines the development of a microcontroller-based lighting control system. The inconveniences cost encountered in electricity bills have called for an immense search for solutions. The microcontroller-based lighting control system offers everything necessary to put an end to these inconveniences as it incorporates an intelligent device (microcontroller). Specifically, the system described in this paper monitors room occupancy, the entrance and exit, and specific occupied zones in the room to enable switching of lamps. The lighting control system senses any persons entering the room. It automatically counts the persons and displays the total room occupancy at whichever time. The system then switches the lamps in the room based on the position the persons sit as long as the display shows a number other than zero. Lamps are switched ON and remain on as long as the spaces are occupied. If there is no occupancy, the lamps are switched off after a short duration. As soon as the room is empty, all lamps are switched off since the count will be indicating zero value. The lighting control system developed in this project is unique in the sense that it is controlled by software which can be modified at any time the system demands a change. The focus of this project was on classroom environment because it has received relatively little attention to date, and it was found that the electrical energy usage within classrooms is nor well controlled at present. Through literature review, various efficient lighting control methods and technologies were studied, and different energy saving opportunities was identified. In the design implementation of this project, different technologies options were studied to determine their technical and economic performance; and the design of the project based on the microcontroller technology was undertaken. The software testing made use of the MPLAB Simulation features as well as the PIC Simulator IDE both of which are freely available from the Internet. The hardware prototype was also provided to experiment on the actual control strategy designed, and considered the impact of the design change options in classroom occupancy. The results of this study allowed some general conclusions to be reached and confirmed the benefits associated with these technologies.

Keywords-- *Lighting control system, Microcontroller, Occupancy, Software*

I. INTRODUCTION

This project "Microcontroller–Based Lighting Control Systems" is a reliable circuit that takes over the task of controlling the room lights as well as counting number of persons/visitors in the room very accurately. When someone enters the room then the counter is incremented by one and the light in the room will be switched ON and when anyone leaves the room, the counter will be decremented by one. The light will not be switched OFF until all the persons in the room leave. The total number of persons inside the room will also be displayed on the seven segment displays. All these tasks are the responsibility of the microcontroller. It receives the signals from the sensors and this signal is operated under the control of software which is stored in the microcontroller.

In the recent decades, technological development has increasingly automated these functions and allowed integration of devices into larger, more flexible systems. The result is significantly expanding energy-saving opportunities, flexibility, reliability and interoperability between devices from different manufacturers.

One thing remains the same: A good lighting design includes a good control design. The goal of an effective control system is to support the lighting application goals which often translate to eliminating energy waste while providing a productive visual environment.

Integrating lighting controls can significantly improve building performance, energy efficiency, and enhance occupant comfort and satisfaction with the built environment [1]. While previous research has shown that simple lighting controls such as occupancy sensors are effective at reducing the amount of electrical energy used for lighting in buildings, advanced lighting control strategies have the potential to achieve even greater energy savings and offer many advantages over simple control, [2], [3], and [4]. [5] Reports that lighting industry has slowly started transitioning from a primarily analogue world to a digital one which effectively facilitates for development of digital control systems, which the microcontroller and microprocessor come in to support.

According [6], lighting control system or device is viewed as an apparatus that, receives information, decides what to do with that information, and changes the operation of the lighting system.

The lighting control system is not a security device and not be construed as one. It provides convenient access and intelligent features that makes it distinct from all other lit rooms which bring it so close to a security device.

II. GENERAL OVERVIEW OF THE SYSTEM

The research work presented here is the design and development of a microcontroller – based lighting control system. As a monitoring and control system, the microcontroller was used to read in data values from the input device and interact with the outside world. The system senses, switches on and off the lamps, counts, registers and displays the number of room occupancy (both for entrance and exit) and triggers actuation for lamps in the room based on position where persons choose to sit. Once triggered, the lamp remains switched on till the occupancy ceases. The lighting control system comprises a sensor unit, CPU module, display unit, a lamp trigger circuitry (actuation circuit), and the power supply unit as shown in the block diagram in Figure 1.

The sensor provides an input signal to the system. It is an optical sensor which, when light rays are focused on it, has a low resistance and hence, causes the input to the direction detection circuitry to be held "LOW". But, when a person interrupts the beam, the resistance increases and reaches its dark resistance, thus, the input to the direction detection circuitry is held "HIGH". The direction detection circuitry serves as an Analogue – to – Digital converter (ADC), which produces a HIGH signal when the beam is interrupted.

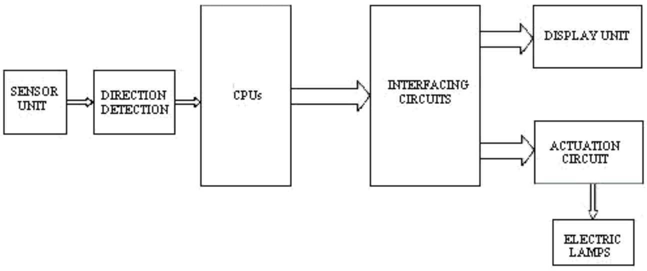

Figure 1: Block Diagram of the System

The direction detection circuitry sends a signal to the microcontroller input port; hence no interfacing is required at this point. The software causes the microcontroller to check its input port for the sensor status information (the outputs of the direction detection circuitry). A HIGH value on input port pin 1 causes the microcontroller to send a signal to its output port through the interface circuitry made up of resistors in order to activate the actuation circuitry to control the lamps (switch on and switch off). It equally sends a signal to the display unit for counting the number of people entering or exiting from the room. A zero value on the display will never activate the control of lamps. False triggering is taken care of by the direction detection circuitry which performs debouncing to be certain of entry or exit.

III. HARDWARE & SOFTWARE DESIGN CONSIDERATIONS

Certain specifications, parameters, and methods of implementation must be considered in system design and construction in order to give the expected result. The implementation of the design involves segmenting the overall system design into subsystem/modules/units, which are individually designed and tested before the integration of the various subsystems. The system design is divided into: Hardware Design consisting of: Sensor Unit, Direction Detection Circuit, CPU Module, Display Unit, Actuation, and Software.

A. Hardware Design

a. Sensor Unit

This module makes use of an optical sensor, specifically a light dependent resistor (photo conductive cell), whose resistance changes with the intensity of light. The type used is ORP12 and it has a dark resistance of 3 MΩ. The sensor unit is shown in Figure 2. When light rays are focused on the LDR, the resistance becomes very low (20kΩ - 200kΩ) but when the rays are interrupted, the resistance increases to dark resistance.

A pair of sensors (2 in total) were used for the entire system for sensing the entry or exit, a third sensor was used as the reference to both sensors; each pair of sensors for entry and exit and the outputs from the sensor units and is part of the direction detection circuitry. The sensor unit is arranged in such a way that it consists of two pairs of LDRs to provide signals for the direction detection circuitry whenever there is an obstruction due to entry to or exit from the room. For the design, two conditions are considered: first, when light rays are focused on the LDR, and secondly, when the rays are being interrupted.

When light rays of great intensity are focused on the LDR, the output voltages, VO1 and VO2 are low (approximately 0V). When the light beams are interrupted, the output voltages increase to 5V approximately. The circuit has the ability to detect the passage of objects the size of an average human being. Each pair of sensors are separated by a reasonable distance to create the quadrature effect.

To avoid false triggering, the two sensors must be interrupted at interval equivalent to 90 degrees out of phase for any effective triggering to take place. This is made up of a Schmitt-trigger, Quad two-input NAND gates, to form a debounced switch circuit. It accepts the output of the two sensor units. Its function is to NAND the two inputs from the sensing unit, clip, and shape the pulse into square waves. It is configured in such a way that only when there is an output from the two sensing units will the output go HIGH, else it remains at LOW level.

The Schmitt-trigger accepts slow changing signals and produces an output that has oscillation-free transitions. When traffic interrupts the light beams of the sensor units, the voltage at that output of the Schmitt-trigger goes HIGH. The circuit resets to a LOW voltage level when the interrupt is removed.

b. Direction Detection

To determine the direction of the movement requires building a special quadrature decoder circuit, and for this it is important to recall knowledge of computer memory. Computers store information in millions (sometime billions) of small devices called flip-flops. The purpose of a flip-flop is to store a single bit (either a 1 or 0) until requested to change. One of the simplest types of flip-flops is called a D-type flip-flop. The functioning of a flip-flop is actually pretty simple: a piece of data is stored at (and can be read from) port Q until a clock pulse is received at CLK port.

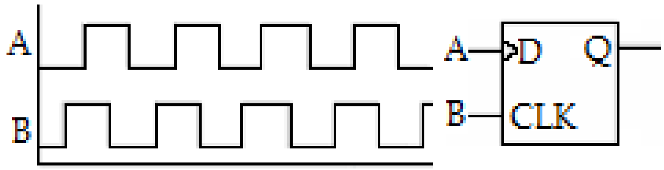

Figure 2: Sensor circuit with Schmitt-trigger

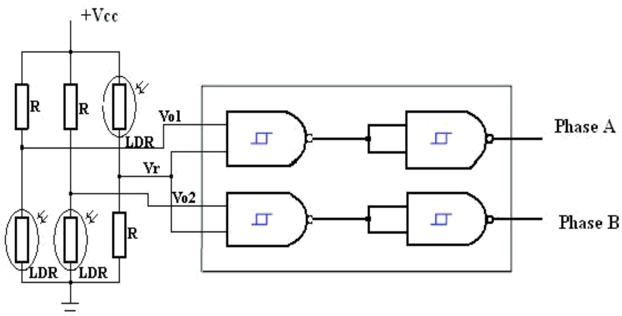

Figure 3: Inputs A and B applied to the D – Flip-flop

Table 1: Truth table showing the output from the D flip-flop with the input waveforms shown in Figure 3.

Denote contact closure to common	A	0	0	1	1	0	0	1	1	0	0	1	1	0	0	1	1
	B	0	1	1	0	0	1	1	0	0	1	1	0	0	1	1	0
Output	Q	0	0	1	1	0	0	1	1	0	0	1	1	0	0	1	1
	$\bar{Q}$	1	1	0	0	1	1	0	0	1	1	0	0	1	1	0	0

The quadrature decoder circuit will make use of data storage capability of the flip-flop. As can be seen from the figure a signal is fed from pin A of the decoder into the D port and the B signal into the CLK port. If the pulses from pin A lead those of pin B, the D port will be in a high state whenever the clock port sees a rising edge – hence Q will remain high. Conversely, if the B pulses lead, Q will remain low. In this way the output at Q provides a means of decoding the direction of movement.

The circuit makes use of the NAND gates in the CD4011 chip. The NAND gates are used to combine the constant high or low signals from Q with the pulse train from the encoder to provide pulses to the microcontroller input pins to facilitate count up or countdown of one of the microcontroller registers. If Q1 is high the CLK UP port will receive the pulse train and if Q2 is high the CLK DN port will receive the pulse train. Since we would like to make use of protective clocking to the microcontroller, the output is passed through an inverter gate formed from NAND, and then fed to the input port of the microcontroller.

These two signal outputs from the decoder are connected directly to the input port of the microcontroller. They are used by the microcontroller to increment or decrement one of the microcontroller's internal registers which is used as a counter. For entry to the room, the CLK UP pulse makes the microcontroller to increment the counter. For an exit from the room, the CLK DN will cause the microcontroller to decrement the counter value.

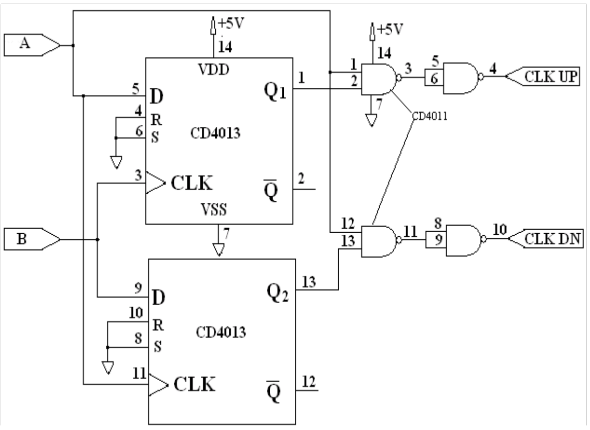

Figure 4: Quadrature Circuit

c. CPU Module

This module provides the system clock, reset, and access provision to address, data and control bus architecture. Since a microcontroller is used in this case, very few additional circuitries are needed for the PIC 16F84 CPU to perform its functions since most of the facilities are internal to the microcontroller.

d. Display Unit

One of the most popular methods for displaying information (numerical data) in a form that can be understood readily by the user or operator uses a 7-segment configuration to form the decimal characters 0 through 9 and sometimes the hex characters A through F. the display unit comprises the LED 7-segment display only as the display driver is just but the program from the microcontroller.

The PIC 16F84/A used in the display unit provides one 8-bit I/O port and one 5-bit I/O port, which have been programmed as output port and input port respectively. The outputs of port B can be fed directly to the 7-segment display through resistors, therefore it does not need any device drivers. The microcontroller sends signals to the display each time a person crosses the sensors.

A BCD-to-7segment decoder is in the program form and provides the outputs that will pass through the appropriate segments to display the decimal digits.

IV. SOFTWARE DESIGN

A. Software Development Procedures

Designing software for the microcontroller-based lighting control system was not a trivial task. In the development cycle of a microcontroller-based system, decisions are made on the parts of the system to be realized in the hardware design and the parts to be implemented in software.
The software is decomposed into modules so that each module can be individually tested as unit and debugged before the modules are integrated and tested as a software system in order to ensure that the software design meets its specification.

The program for the system is written in assembly language for speed optimization. Assembly code represents halfway position between machine code and a high level language.

The assembly code is usually a mnemonic derived from the instruction itself, i.e. MOVLW is derived from MOVe Literal to Working register. Assembly code is thus very easy to remember and use when writing programs. When entering an assembly program into a microcontroller, the assembly code must first be converted into machine code [7]. For short programs, of a few lines, this is relatively easy and usually requires that the programmer constructs a table which contains the assembly mnemonics and the equivalent machine code.

This technique is known as Hand Assembly and is limited to programs of about one hundred lines or less. For longer programs, a separate program called assembler is used to convert the assembly code into machine code, which is placed directly into the microcontroller memory.

The program modules are segmented into:

1. Main program
2. Sensor subroutine
3. Digit separation Macro
4. Display subroutine
5. Actuation program (Lamp Control Program)

The software was designed using the following steps:
1. Algorithm
2. Flow chart
3. Assembly Language Codes

A. Test Procedures

The testing of the entire circuit was carried out in stages:

1. Each of the components was first tested using a multimeter in order to check for their state of performance and accurate values.
2. The connection of each component on the vero board was then tested. This was done in order to assess the continuity, which is meant for proper connection of the circuit, and to detect any wrong connections.
3. The sensor unit circuitry was tested to ascertain the degree of sensitivity. An object was placed between the two pairs of the photoconductive cell to obstruct light rays. The voltage levels at the output were

observed with the aid of a digital multimeter.

4. The outputs of the trigger circuitry were tested by connecting an LED across the circuit to check if it lights or not. A light indicates the presence of HIGH logic while a no-light indicate the presence of LOW logic.
5. Also, the lighting control system was tested by applying logic 1 or 0 to points A and B of the circuit, and the processor responded as expected.
6. After the peripherals were tested and found to be in working order, the entire circuit was tested. A series of programs (software) were written and tested before the working program was finally achieved.

V. RESULTS

This project consists of two programs running independent of each other although the outcome of the first program affects the operation of the other. The two programs were tested by MPLAB SIM simulator and were found to be working as required. The Simulator is a program that runs from the Integrated Development Environment. It takes the assembly results and pretends to be a PIC microcontroller. It interprets the PIC microcontroller codes and does what they say to do, as if it were a PIC microcontroller. In spite of the fact that a personal computer is probably 100 times faster than a PIC, the simulator runs many times slower than a real PIC.

The counting part of the program was run on a PIC Simulation IDE and it was perfect. Figure 5 is a snap-shot showing the results of the simulation that displays two digit numbers as was stated in the design specifications. This display will display numbers from 00 (zero) to 99 (ninety nine).

By applying the MPLAB IDE Simulator, the program showed high performance in terms of responding to input changes, by multiplexing the digits on the LED display. It also responded by sending actuation signal to the output pin responding for exciting the action on the microcontroller to prepare lighting up lamps. If the pin assigned to receiving the actuation signal is high, then any pins assigned to the occupancy sensors when pressed, displays a high output meaning that the program was running fine. When any of the sensor pins are made low, the output will go low after a short duration showing that there will be no occupancy at the assigned spaces.

Figure 5: Snap-shot for a simulation producing two digits of the count using PIC Simulator IDE – Evaluation Copy

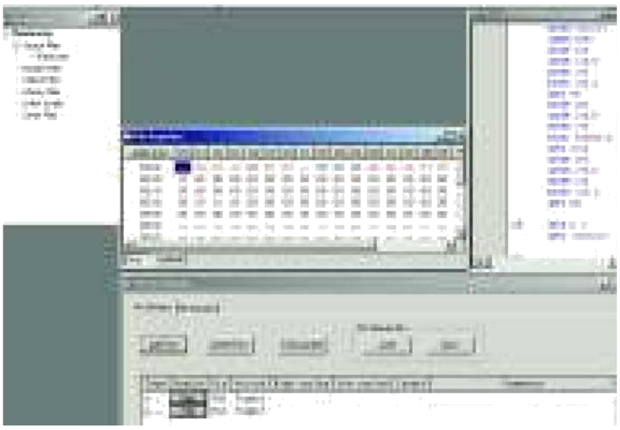

Figure 6: Snap-shot showing the simulation by MPLAB IDE Simulator.

CONCLUSION

The design and implementation of a microcontroller-based lighting control system was achieved in its entirety. This design can easily be adopted to any electrically controlled appliances and any form of control which requires the use of sensors. To effectively design this kind of system, it is necessary to understand the basic sensor characteristics, microcontroller input and output interfacing, and assembly language principles, utilized in the system plan. Sensors serve as transducers for people detection while the programming language is fundamental to software design based on the system requirements, specifications and planned operation of the system. There is total agreement between the system designed and the required operation of the system.

Every good project has limitations; the limitation of this design lies in the effectiveness of the sensors. The sensors will work most effectively if operated under high intensity light. The microcontroller-based lighting control system designed in this research can be employed in organisations, public car parks, residential parking lots, stadia and automobile termini where no form of security measure is required.

RECOMMENDATIONS

For an improved, effective and security room system to be implemented and achieved, the following suggestions should be considered for further research work.

1. A form of personal identification should be provided for security purposes. For instance, a biometric system may be employed to widen and improve the applicability of the system.
2. Better sensors should be considered to achieve new functionality. For instance, a suitable sensor such as infrared sensors should be used in place of LDR sensors which only operate in the presence of light. Infrared sensors are suitable in all situations as they do not depend on the light but the heat coming from the people entering the rooms
3. To achieve full automation, a real time system should be employed and a Closed Circuit Television (CCTV) system provided for proper monitoring and security purposes. This can be helpful in detecting the presence of individuals before the system is activated.
4. Upgrading the system using higher bit microprocessor/microcontroller for speed optimization. With the revolutionary impact that microprocessors/microcontrollers have had on the

electronic industry, it is not unreasonable to expect that everyone working in electronics and related areas will have to become knowledgeable with the operation and integration of microprocessors.

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