DESIGN AND CONSTRUCTION OF AN AUTOMATIC LIGHT CONTROLLER WITH OCCUPANCY COUNTER

BY

OSAKWE JOY NWAYIBUIFE
(2003/15454EE)

A THESIS SUBMITTED TO THE DEPARTMENT OF ELECTRICAL AND COMPUTER ENGINEERING, FEDERAL UNIVERSITY OF TECHNOLOGY, MINNA.

NOVEMBER, 2008.

DEDICATION

This project is dedicated to God Almighty who has been with me from the beginning till now, to my parents Chief and Mrs C.U Osakwe and to Mr Oyedemi.

DECLARATION

I, Osakwe Joy Nwayibuife, declare that this project is an original work of mine under the supervision of Mallam Zubair.S of the Electrical and Computer Engineering Department, Federal University of Technology, Minna. The information Derived from published and unpublished work has been acknowledged.

I also hereby relinquish the copyright to the Federal University of Technology, Minna .

Osakwe Joy Nwayibuife	Mallam Zubair.S
-------------------------------	-------------------------------
(Name of student)	(Name of supervisor)
-------------------------------	------------------------------- 12-11-08
(Signature and date)	(Signature and date)
Dr Adediran .Y.A	
-------------------------------	-------------------------------
(Name of H.O.D)	(Name of External Examiner)
-------------------------------	-------------------------------
(Signature and date)	(Signature and date)

ACKNOWLEGEMENT

My everlasting thanks go to God Almighty for seeing me through this program, to him be the glory.

I would like to express my special thanks to my supervisor Mr Zubair. S for his valuable time, comments and contribution.

My profound gratitude to the Head of department, Dr Adediran, Engr Eronume, Dr Tsado, Mr Abolarinwa, Mrs Caroline Alenoghena and the entire staff of electrical and Computer Engineering Department. I sincerely appreciate all your advice in the course of my program.

I would also like to appreciate my dear friends and colleagues.

My profound gratitude to my parents Chief and Mrs C.U.Osakwe and my beloved brothers - Osakwe Ifeanyi, Osakwe Azubike, Osakwe Chika and Osakwe Ikenna.

I really appreciate your financial and moral support.

A lot of hard work has gone into this project and a lot of people have helped me behind the scene. This project would not have been possible if not for their help.

ABSTRACT

This project is a report on the design and construction of an automatic light controller with occupancy counter using a microcontroller. It is a reliable circuit that takes over the task of controlling the lights as well as counting number of persons/visitors in the room very accurately. When somebody enters into the room, the counter increments by one and light in the room will switch ON automatically, when someone leaves the room, the counter decrements by one.

The light will only be switched OFF when all the persons inside the room go out. The total number of persons inside the room will also be displayed on the light crystal Display (LCD).

The microcontroller receives the signals from the sensors and the signal operates under the control of software which is stored in the ROM. Microcontroller continuously monitors the infrared receivers, then the IR rays falls on the receiver which is obstructed, the obstruction is sensed by the microcontroller.

TABLE OF CONTENTS

LIST OF ABBREVIATIONS USED

1. MCU – Microcontroller
2. LDR – Light Dependant Resistor
3. CFL – Compact Fluorescent Lamp
4. GLS – General Lighting Service (Incandescent Lamp)
5. IR – Infra Red
6. ADC – Analog to Digital Converter
7. ZCD – Zero Crossing Detector
8. ISR – Interrupt Service Routine
9. IC– Integrated circuit
10. PWM – Pulse Width Modulation
11. CRO – Cathode Ray Oscilloscope
12. PC – Personal computer
13. LED-Light Emitting Diode
14. AC-Alternating current
15. DC-Direct current
16. IR- Instruction Register
17. DDRAM-Display Data R
18. CGRAM-Character Generator Random Access Memory
19. PIR-Passive Infrared
20. BF-Busy flag
21. GND-Ground
22. USART-Universal Synchronous and Asynchronous Receiver and Transmitter

LIST OF FIURES

LIST OF TABLES

CHAPTER ONE

GENERAL INTRODUCTION

1.1 INTRODUCTION

Energy is essential to life but with rising fuel and energy costs, energy conservation has become an absolute necessity. Starting with the incandescent lamps (Household bulbs) and xenon lamps, illumination technology has come a long way. But lamp life extension still plays a major role.

Using Nigeria as a case study, the situation is so poor that we hardly have enough for domestic or industrial consumption. The limited energy provided for use is being wasted.

For instance in Minna, the incandescent lamps in people's shops and houses are always on during the day when it is meant to be switched off. Also in commercial buildings up to 50% of the energy costs are for lighting. Much of this energy is wasted either the area illuminated in the building is unoccupied or is sufficiently illuminated during daylight hours by sunlight passing through windows.

The automated system hence proposed adjusts the amount of electrically generated illumination in response to the ambient sunlight available and automatically turn off the light when the room or area is unoccupied.

A simple form of automated control employs computers and timers to turn the lights on and off. This occurs so that after working hours, the lights are not accidentally left on. It is also necessary to have the lights on at night for maintenance and cleaning personnel, as well as for regular employees who must work late.

However, what will be good for Nigeria in general would be a device that controls the turning on and turning off the incandescent lamps and the xenon lamps when it is unoccupied. This will create more energy that would be available for other regions in the country.

Energy efficiency is not a lost cause rather a reality that we must face. Hence, I proposed a system, which incorporates both occupancy detection and light detection into the control system.

1.2 AIMS AND OBJECTIVES

The aim of this project is to integrate energy conservation and lamp life extension by providing control solutions using a microcontroller so as to reduce energy costs and also extend lamp life. The fully functional system automatically controls the light in a room as well as counting the number of persons/visitors in the room very accurately. The innovative automatic mode operates under the energy saving strategy.

1.3 MOTIVATION

For my final semester project, I was interested in creating a system that u utilized all the elements I have learned throughout the eight semesters and apply that knowledge into a working prototype.

I wanted to get hands on experience on the applications of microcontrollers in designing practical systems. Use of microcontrollers in providing control solutions is very efficient because of its low power consumption and small size and in-built peripherals.

The driving force behind the idea of my project stems from the premise that the need of the hour is conservation and preservation of energy. The system proposed can be used to reduce energy consumption due to lighting fixtures manifold over. The fully automated lighting control system designed automatically controls the light in a room as well as counting the number of persons/visitors in the room or area.

1.4 METHODOLOGY

Automatic room light controller with visitors counter in its scope describes how the microcontroller continuously monitors the infrared sensors A and B as well as controls lights. When any object passes through the infrared sensors either A or B, then the infrared rays falls on it which will be obstructed, the obstruction is sensed by the microcontroller.

This device is able to detect the number of people in a room, turns on when there is somebody in the room and turns off when there is nobody in the room. On entry, an individual walks in and breaks the infrared to the room (sensor A), by so doing, a beam is broken. From the infrared to the photodiode, an up/down counter is clocked and counts 1, at the same time the other infrared and photodiode in the room (sensor B) is deactivated for three (3) seconds, thus making sensor B non-functional.

The purpose which is to avoid clocking of the up/down counter by the breaking of sensor B by the same person who is entering the room .The two sensors A and B are placed to each other; so that the individual breaks the first beam and passes before three (3) seconds elapses.

If another individual enters the room again, the counter counts in an ascending order.

On exit, if an individual leaves the room, the individual breaks sensor B's beam first, so it clocks the counter and it counts down. Thus, if for instance the count in the room was three (3), it would count down to two (2), this will continue in descending order, until it gets to the last count down which is zero (0).At the same time, sensor A is deactivated for three (3) seconds, so the person passes sensor A and goes out without

affecting the count. The light in the room only goes out if the count is zero (0), so if the last person leaves, the count reduces to zero and the light goes off automatically.

CHAPTER TWO

THEORETICAL BACKGROUND

2.1 LITERATURE REVIEW

The need for automation has come to stay and these dates back to 1500 years ago when the first water pump for metal working rolling mills for coinage strips was developed from then till date the automation world has continued to grow tremendously. Automation is the art of making processes or machines self-acting or self-moving, it also pertains to the technique of making a device, machine, process or procedure more fully automatic.

Automation is characterized by two major principles:

1. Mechanization: That is machines are self-regulated so as to meet predetermined requirements (a simple example of self-regulation can be found in the operation of a thermostatically controlled furnaces).
2. Continuous process: That is production facilities are linked together, thereby integrating several separate elements of productive process into a unified whole

Automation in the electrical, electronics and computing world has grown rapidly of which it dates back to 1940 when the first electronics computing machine was developed.

This has aided humans as it basically reduces/eliminates human intervention, of which automatic light switching also makes the list of automation in the electro-computing world.

Switches which are the bases of this project may be the most ubiquitous mechanical devices in our technological society. Most machines needs to be turned on or turned off at some point, and that's typically done by activating a switch. There are different varieties of switches. One major switch manufacturer alone produces more than three million different switches; digital and computerized switches are becoming more common both home and workplace, especially for automatic applications.

Some switches work automatically, incorporating a tiny microprocessor that turns the machine on (off) according to preset instructions. An example of a low-tech (pre-digital age) automatic switch is the thermostat used to maintain a set temperature in a home or building. These switches use a vial (small glass bottle) containing a drop of mercury. When the temperature indicator moves beyond a certain level, a drop of mercury will move into contact with metallic contact points that extends into the vial. Mercury switches are used rarely nowadays and they should be disposed.

Another example of switch that works automatically but a high tech one is an automatic room light system, which ranges from sound automatic room light system, infrared automatic room light system, temperature automatic room light system, in addition to the base principle stated above, the principle behind theses automatic room light system is that the light turns ON and OFF automatically which is sensor dependent.

2.2 PRINCIPLE OF OPERATION

For this project, the central element of the system is the AT89C51 8-bit microcontroller.

It continuously takes in information from the Infrared Sensors to make decisions on turning ON and turning OFF the lights. It also takes in information from the user through the push buttons. The Infra red Sensors (Sensor A and Sensor B), mounted on the doors of the room, communicâte to the microcontroller when they are toggled, indicating that somebody passed through the door. Depending on the direction of movement, the microcontroller determines if someone came into or left the room. The microcontroller keeps count of the number of persons in the room and when room is unoccupied, lights are switched off to maintain an optimum level of illuminance inside the room if the room is occupied.

This is done under the energy-saving objective i.e. if sufficient amount of natural light is available outside the room, then the light automatically goes dim utilization of natural light. If this light is not sufficient only then the artificial light source will be utilized.

2.3 POSSBLE METHODS OF IMPLEMENTATION AND THEIR COMPARISM

The different approaches are:

i. PC based solution.

ii. Microprocessor based solution.

iii. Microcontroller based solution.

The main drawbacks of the PC based solution and microprocessor based solutions are:-

i. Bulky in size.

ii. Higher power consumption in case of PC.

iii. In order for a microprocessor to be used, other components such as memory, or peripherals for receiving and sending data must be added to it.

These drawbacks are overcome in a microcontroller-based system because it is compact in size and has low power consumption. In a microcontroller no other external components are needed for its application because all necessary peripherals are already built into it. Thus, i saved the time and space needed to construct devices. Moreover if the system needs to be interfaced to a PC it can be done through the USART (pin) of the MCU.

2.4 CHOICE OF IMPLEMENTATION SCHEME

The drawbacks of PC based and Microprocessor based systems are overcome in a Microcontroller-based system. Hence I decided to use a microcontroller based system.

The microcontroller selected is At89C51 by Atmel Corporation. This was selected because of the following advantages:

i. Zero crossing can be detected without using any external components except current limiting resistors using the MCU interrupt.

ii. It has an inbuilt ADC. So no external ADC was required to be built.

iii. Instructions within the At89C51 are sent to a pipeline, allowing most instructions to execute in a single clock cycle. Thus Execution is very fast and efficient.

iv. It has 256 Powerful Instructions. Hence programming is easier and program size also reduces.

v. The internal memory can be reprogrammed over 1000 times, making them easy to experiment.

CHAPTER THREE

DESIGN AND IMPLEMENTATION

3.1 FUNCTIONAL BLOCK DIAGRAM

As shown in Fig3.1 below, the occupancy detector keeps a check on people entering and leaving the room. When the first person enters the room he/she toggles sensor A first and then sensor B, however, sensor B is deactivated whenever sensor A is activated, and vice-versa. This order helps the MCU understand that someone has entered or exited the room. When he/she leaves the room, he toggles sensor B first and then sensor A. In this manner, the MCU keeps count of the people inside the room and displays it on the liquid crystal display (LCD). [17]

Now, once the room is occupied, the MCU gets the digital interpretation of the light available inside and outside the room through the light sensors. If there is enough daylight available, the MCU automatically let light into the room. It then checks if the optimum brightness level is reached inside the room.

Once it has been reached, the MCU constantly keeps a check on the light inside, If the light level outside falls and it becomes very dark outside, the lamp brightness increases so as to maintain an optimum level.
And once the light outside again increases the lamps dim accordingly. [9]

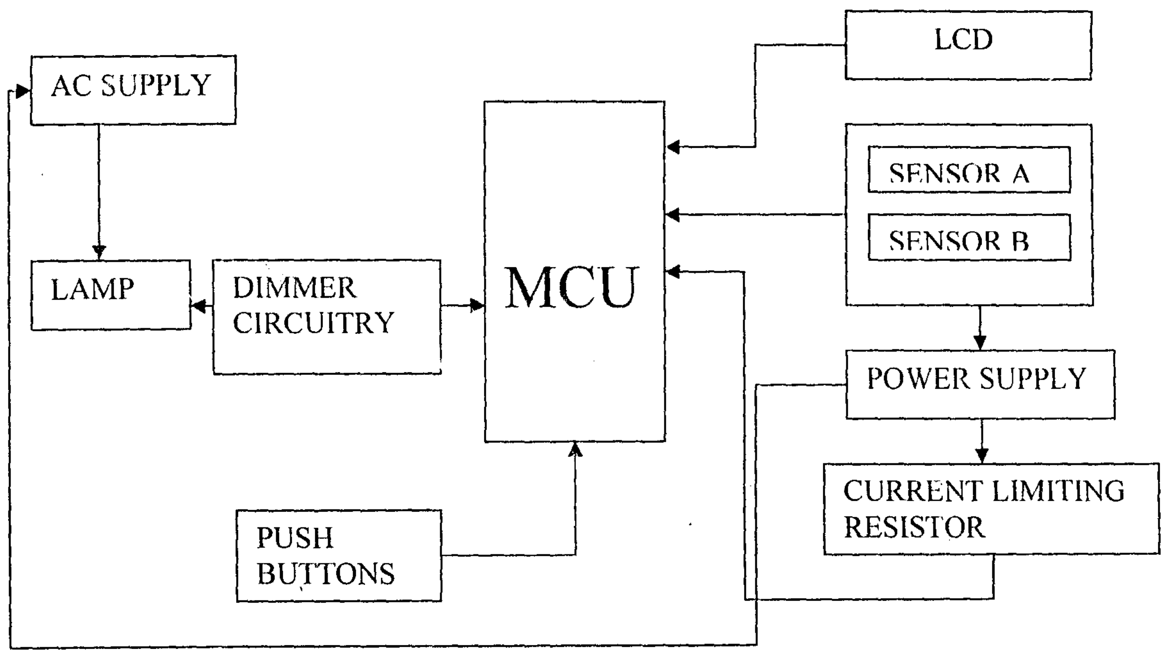


Fig 3.1: functional Block Diagram

3.2 ELECTRICAL CIRCUIT DESCRIPTION

This section describes the Electrical and Electronics part of the system.

3.2.1 POWER SUPPLY UNIT

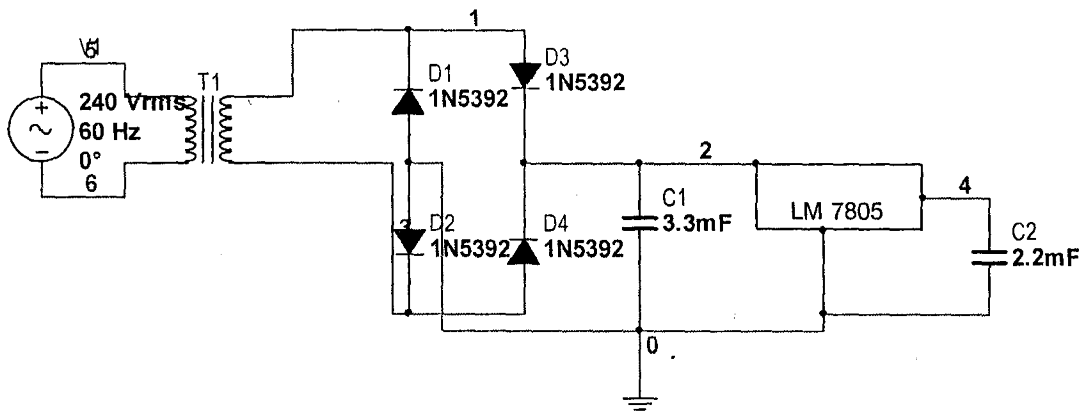


Fig 3.2: Power Supply Unit

The system has three different voltage requirements. The MCU, dimmer circuitry and light sensor, and IR detectors run on 5V DC. The IR transmitters run on 9V DC. Hence i had to use a 230/12V step-down transformer which can supply 3 amps. The secondary of the transformer was rectified using a diode bridge and a filter capacitor was added in parallel with them.The required 5v DC was then obtained by using a LM7805 regulator IC with filter capacitors added for filtering the supply. The circuit diagram of the power supply unit is shown in figure 3.2.The lamp in the dimmer circuit receives 230V 50Hz AC directly from the mains and the MCU unit receives 5V DC from the transformer secondary through a bridge rectifier.

3.2.2 OCCUPANCY DETECTOR

3.2.2.1 TIMER (NE/SA 555)

3.2.2.2 DESCRIPTION

The 555 monolithic timing circuits is a highly stable controller capable of producing accurate time delays, or oscillation. In the time delay mode of operation, the time is precisely controlled by one external resistor and capacitor.

For a stable operation as an oscillator, the free running frequency and the duty cycle are both accurately controlled with two external resistors and one capacitor. The circuit may be triggered and reset on falling waveforms, and the output structure can source or sink up to 200mA. [16]

FEATURES

i. Turn-off time less than 2ms

ii. Max. operating frequency greater than 500kHz

iii. Timing from microseconds to hours

iv. Operates in both astable and monostable modes

v. High output current

vi. Adjustable duty cycle

vii. TTL compatible

viii. Temperature stability of 0.005% per °C

APPLICATIONS

i. Precision timing

ii. Pulse generation

iii. Sequential timing

iv. Time delay generation

v. Pulse width modulation

3.2.2.3 TRANSMITTER:

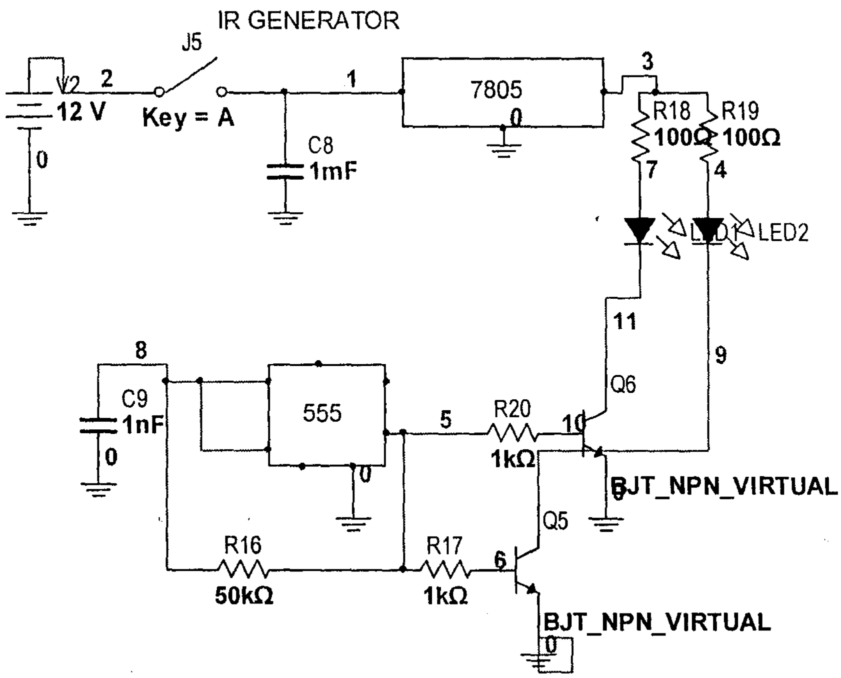


Fig 3.3: IR transmitter

Thus using the free running mode of the 555 timer, the transmitter keeps transmitting Infrared rays continuously. [7] The transmitter emits a non-modulated infrared light beam, which is invisible to the naked eye.

A 555 timer is used to make the transmitter emit modulated IR beam at 38 KHz. The 555 timer works as an astable multivibrator, also called free-running multivibrator, and is a rectangular wave generating circuit. It does not require an external trigger to change the state of the output. The time during which the output is held low or high is determined by the resistors and the capacitor connected to it as shown in figure 3.3.

3.2.2.4 RECEIVER:

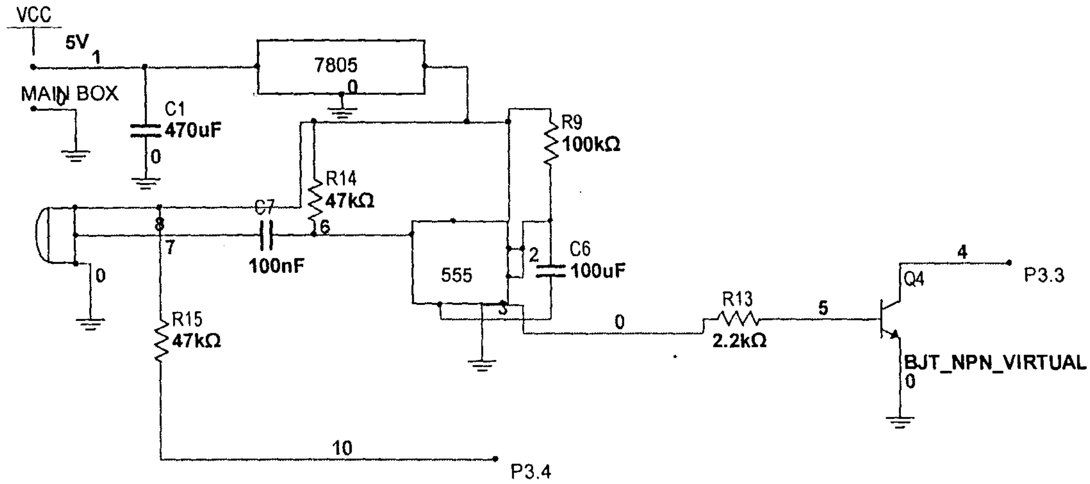


Fig 3.4: IR Receiver

In the receiver section of the occupancy detector, the IR receivers constantly receive the modulated IR beams transmitted by the IR transmitter. This signal is amplified, inverted and then fed to an LED (L2) as seen in figure 3.3. When somebody enters or leaves the room, he/she blocks the path of the IR rays from the transmitter and thus the IR receiver stops receiving the IR rays, pulsing its output low and toggling an interrupt input on the controller. [7]

3.2.2.5 INTERFACING THE OCCUPANCY DETECTOR WITH THE MICROCONTROLLER

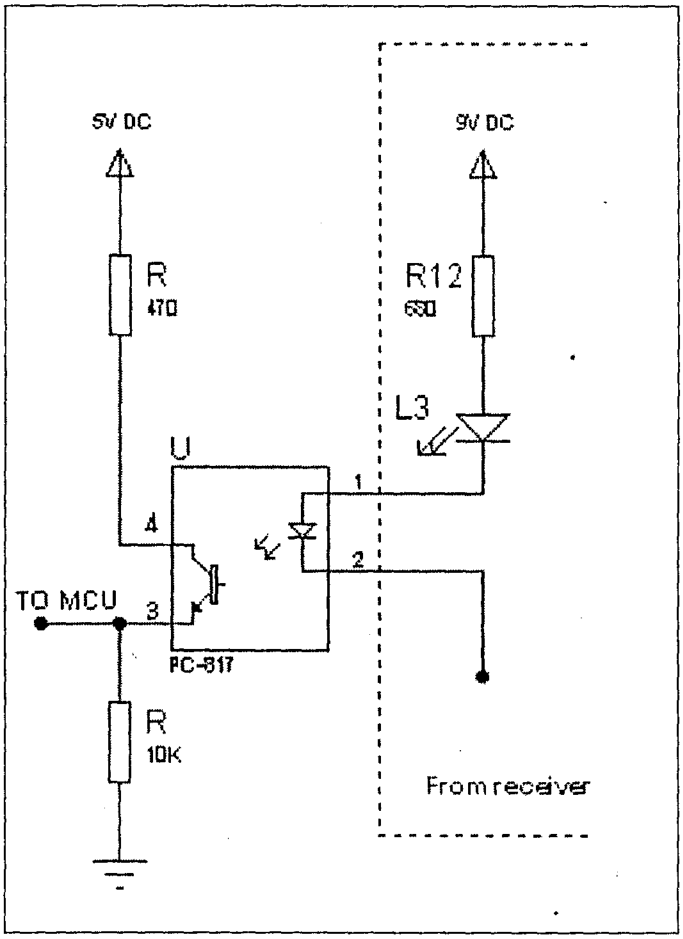


Fig 3.5: Interfacing the Receiver to the MCU

The infra red detectors were interfaced with the system controller via monostables. The monostables were included in the design to provide a lock-out time for the separate detectors. The monostables were pre-programmed for a time-delay of about three seconds, this being the lock-out time for the sensors.

The first sensor to be activated deactivates the second sensor, preventing the second sensor from generating an interrupt on the microcontroller input and negating the initial presence count generated by the first triggered sensor. The monostables were designed around 555 timers with an RC network that determined the duration of high time of the output pulse width.

The monostable outputs were connected to the interrupt inputs of the 8951 controller to prevent missing any event occasioned by changes in the sensors' outputs. [5]

3.2.3 MICROCONTROLLER

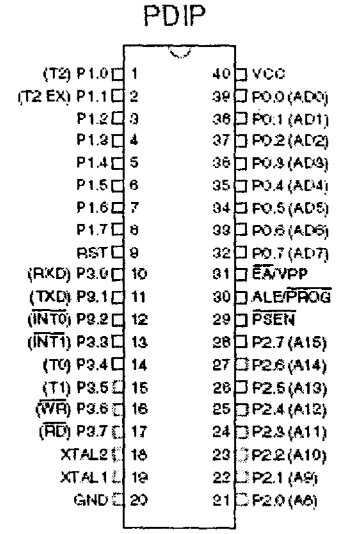


Fig 3.6: Microcontroller Unit

The 8051 microcontroller from Atmel Corporation has an operating voltage between 2.7-5.5V, please refer figure 3.6 for pin configuration. Vcc and AVcc is connected to +5V. GND is connected to the analog ground of the transformer through a current limiting resistor of 4.7KΩ which is discussed in detail in the Zero crossing detector section (Refer 3.2.3.1 and 3.3). Pin9(reset pin) is left open. Under circumstances where a reset is required without the mains being switched off this has to be pulled low for MCU reset. But in this system if a reset is required, only the mains need to be switched off, hence Pin9 is left open. I am using the external oscillator of 12MHz. Hence Pins12, 13 (XTAL2, XTAL1) are left open, though slots are made on the PCB to add an oscillator and the associated capacitors on the PCB.Pin 21(p2.0) is connected to the dimmer circuitry to provide the triggering pulse to the triac, which turns on the lamp at the appropriate time of the mains cycle.Pin16, 17 (INT0, INT2) are connected to the receivers of sensor A and sensor B respectively through their interfaces. These are interrupts of the MCU, which are configured to interrupt on falling edges of the receiving signals.

Port 1 was interfaced with an 8-bit analog to digital converter ADC0804 which was in turn interfaced with an LDR. The ADC was set up with a reference voltage of 5volts, and was run on a clock source of about 900 kHz. This was deduced from the expression:

F= 1/1.1RC .... (1)

R is the resistance between pin19 and pin4, C is the capacitance between pin4 and ground. R is a 10k resistance specified in the datasheet. C was made a 100pF capacitance.

F= 1/1.1*10000*100*10^-12. = 909 kHz. [10].

3.2.3.1 ZERO CROSSING DETECTOR (ZCD HARDWARE):

This part explains the hardware part of the Zero crossing detection. The software part of the ZCD will be explained in detail later in the software section (refer 3.3).

HARDWARE:

The zero-crossing detector was placed across the unsmoothened output of the rectifier. The ZCD therefore produces two pulses for every AC cycle since the frequency of the output waveform of the detector is a 100Hz square waveform as compared with the 50Hz mains frequency.

As the square wave signal is in phase with the AC mains, using the falling edge will tell very accurately where the zero crossing happens. By using this signal the controller can be programmed to be a very accurate zero cross detector. [8]

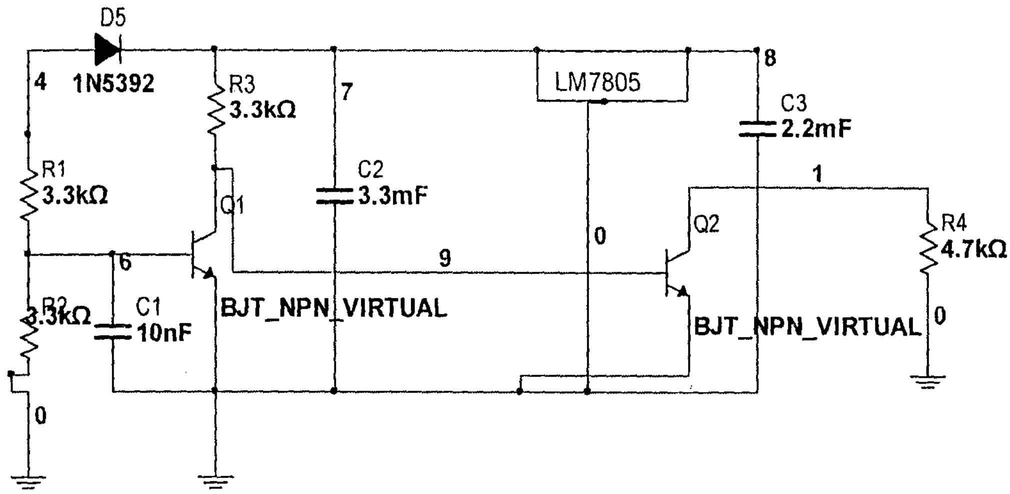


Fig 3.7: Zero Crossing Detector

3.2.4 DIMMER CIRCUITRY

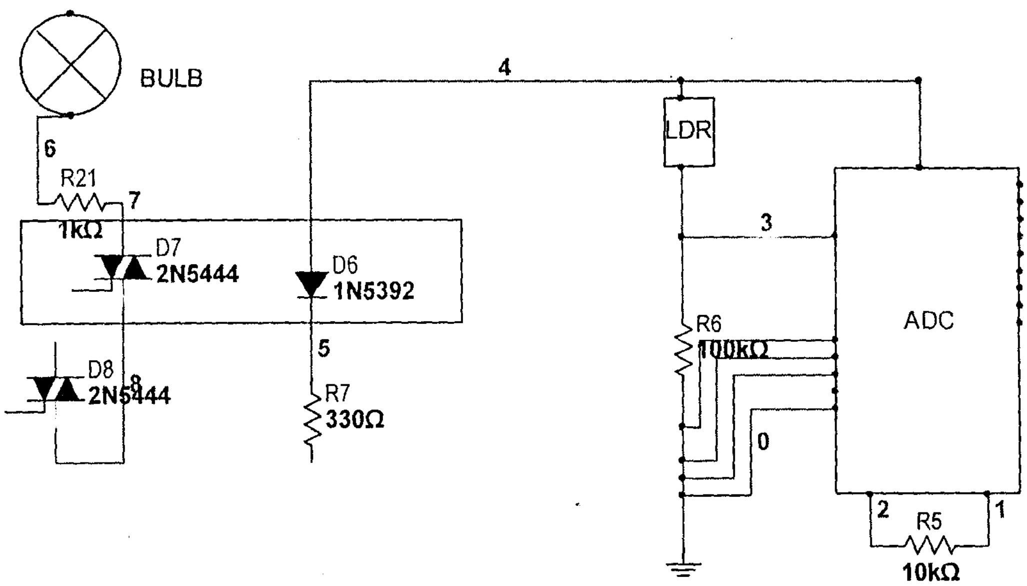


Fig 3.8: Dimmer Circuitry

The dimming of the lamp is done using phase control of the triac, which is discussed in detail in section 3.2.4.1. The MCU sends the gate trigger signal to the gate of the triac at the appropriate time after the zero crossing of the mains cycle for the corresponding brightness level of the lamp. This signal cannot be sent directly to the triac gate because the current from the I/O port of the lamp is not enough to drive the gate. Hence this current has to be amplified before it can be sent to the triac.

The amplified signal is isolated before being applied to the gate of the triac through an opto-triac which is discussed in detail in Section 3.2.7. [3]

3.2.4.1 TRIAC

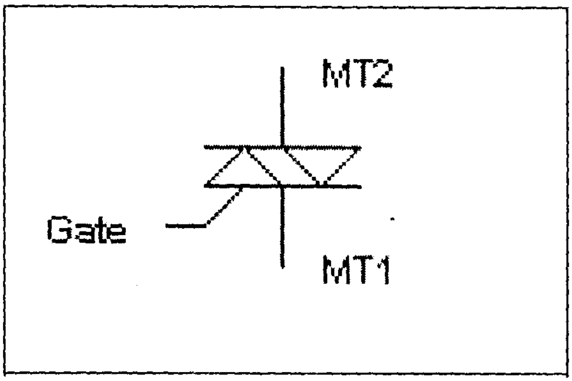


Fig 3.9: Triac

A Triac is a three terminal electronic device designed to control large alternating currents with a small current. It is a member of a family of electronic components known as Thyristors, of which SCRs are another member. The names of the terminals on a Triac are MT1, Gate, and MT2 as shown in figure 3.9. Specifications of the triac's operation are referenced with respect to MT1.

A current flow between GATE and MT1 will allow a larger current flow between MT2 and MT1. Once current flow is established between MT2 and MT1, current flow will continue even if the current flow between GATE and MT1 stops. Thus, controlling the gate cannot turn the current flow off. When current flow stops on its own the Triac commutates. Further current flow between MT2 and MT1 will be blocked. This typically happens at zero cross. Current flow cannot restart until another gate pulse occurs.

The current flow through the gate can be in either direction to start current flow between MT1and MT2. Because the current flow between GATE and MT1 can be in either direction and because current flow between MT2 and MT1 can be in either direction, four triggering conditions exist for the Triac. The specifications for each of these four conditions, known as quadrants, are all different. Hence the triacs are known have a 4-Quadrant operation. By convention they are defined as shown in table 3.1 below:

Table 3.1: Triac 4-Quadrant Operation

Gate- MT1	MT2-MTI	Quadrant
Positive	Positive	QI
Negative	Positive	Q2
Negative	Negative	Q3
Positive	Negative	Q4

The triac's operation can be defined by a set three specifications. These are rating current (I_G), Latching Current (I_L), and Holding current (I_H). Each Quadrant has its own set and all are affected by temperature.

i. **Gating Current (I_G)** - This is the current that must flow between GATE and MTI for the triac to fire.

ii. **Latching Current (I_L)** - This is the current that must be flowing between MT2 and MT1 when the gate current turns off to maintain current flow.

iii. **Holding Current (I_H)** - This is the current that must be flowing between MT2 and MT1 to prevent commutation and the stopping of current flow [13].

3.2.4.2 PHASE CONTROL:

In phase control the Thyristors are used as switches to connect the load circuit to the input ac supply, for a part of every input cycle. That is the ac supply voltage is chopped using Thyristors during a part of each input cycle.The Thyristors is turned on for a part of every half cycle, so that input supply voltage appears across the load and then turned off during the remaining part of input half cycle to disconnect the ac supply from the load. By controlling the phase angle or the trigger angle 'α' (delay angle), the output RMS voltage across the load can be controlled.

The trigger delay angle 'α' is defined as the phase angle (the value of ωt) at which the Thyristors turns on and the load current begins to flow. Thyristors ac voltage controllers use ac line commutation or ac phase commutation. Thyristors in ac voltage controllers are line commutated (phase commutated) since the input supply is ac.

When the input ac voltage reverses and becomes negative during the negative half cycle the current flowing through the conducting Thyristors decreases and falls to zero. Thus the ON Thyristors naturally turns OFF, when the device current falls to zero. Triacs are available to meet the voltage and current ratings of our particular application that is 4A, 400Volts. [13]

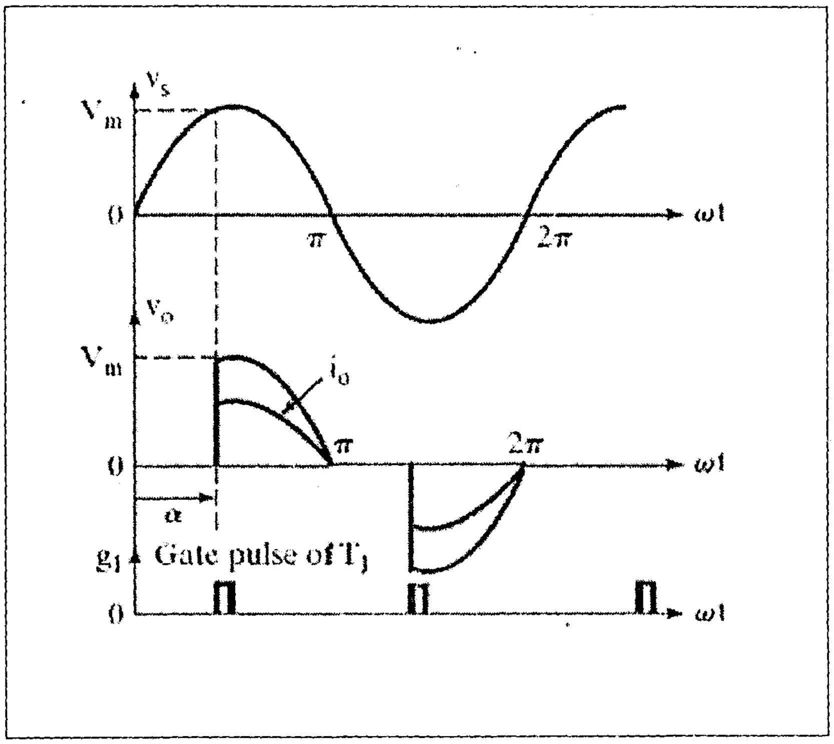


Fig 3.10: Phase Control

At the proper time in the half cycle, the microcontroller will gate the triac allowing current flow as illustrated in figure 3.10. By blocking the current flow for a short time after zero cross, more power is delivered to the load. A delay for a longer time delivers less power. Delay for the full half cycle will deliver no power to the load.

In phase control gating very close to zero cross is avoided to prevent false triggering of the Triac.

3.2.5 LIGHT SENSOR

The Light sensors were made using a readily available Light Dependant Resistor (LDR), also known as a photo resistor. It is made of a high-resistance semiconductor. If light falling on the device is of high enough frequency, photons absorbed by the semiconductor give bound electrons enough energy to jump into the conduction band.

The resulting free electron (and its hole partner) conduct electricity, thereby lowering resistance. [4]

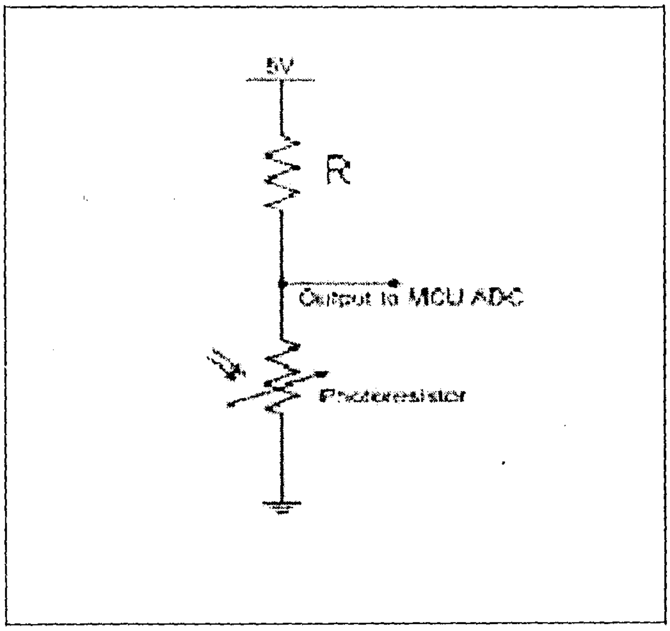


fig 3.11 : Light Sensor

The light sensor unit was implemented in the form of a voltage divider circuit as shown in figure 3.11 above. When light intensity falling on the LDR increases, its resistance decreases and hence its voltage drops down according to the equation:

$V_{LDR} = (V_{CC} \times R_{LDR}) / (R + R_{LDR})$ .... (2)

Hence the voltage across the LDR varies according to the light falling on it and this signal is constantly being received by the ADC of the MCU. As the light intensity increases, the analog voltage signal being received by the ADC decreases and this is then converted into digital value by the ADC. The digital value is in the range of 0-255 for the 5V signals. Hence we get a digital interpretation of the light available inside and outside the room. [15]

3.2.6 USER INTERFACE (PUSHBUTTONS)

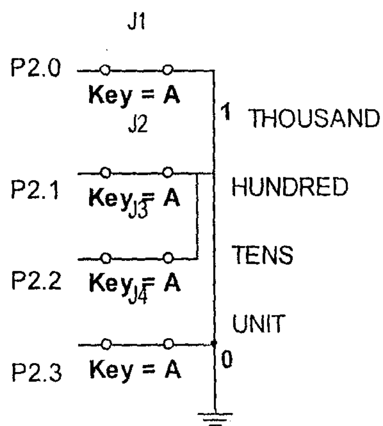


Fig 3.12: Pushbutton Bank

Four pushbuttons were provided on the system for presetting the initial presence level in case presence detection is not desired to commence counting from 0.The four buttons were used for presetting the thousands, hundreds, tens, and units.

3.2.7 OPTO-TRIAC

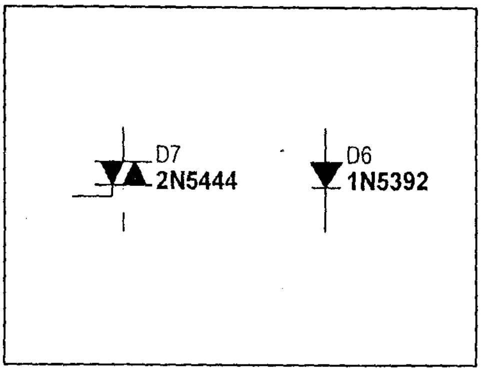


Fig 3.13: Opto-triac

For safety reasons and also to keep the digital circuitry isolated from the mains an MOC3032 isolator shown in figure 3.13 was used. It consists of an internal LED and a triac. When there is a current flow between the pins 1 and 2 (anode and cathode of internal LED), the light emitted by the LED provides the gating current of the triac, which then allows current flow between MT1 and MT2. Thus the triggering pulses are isolated from the mains supply. [15]

3.3. ZERO CROSSING (ZCD SOFTWARE):

The transformer secondary is connected to the INT2 pin through a current limiting resistor as already explained in the hardware section of the ZCD (refer 3.2.3.1). Initially the INT2 is disabled. But when an increase in lamp brightness is desired, then it is first enabled and configured to interrupt on falling edge. So when the square wave at the INT pin falls below zero, the MCU [11] is interrupted and control is transferred to the INT2 vector address where a jump statement then transfers the control to the Interrupt Service Routine for INT2 (Iservive2).

Here, the necessary operations for sending the triggering signal to the triac after an appropriate delay are carried out and before returning back from the ISR, the interrupt is configured as rising edge to take care of the rising edge of the mains cycle. [5]

The MCU is interrupted during the rising edge and similar operations are carried out and once again the interrupt is configured as falling edge before returning from the ISR. In this way both the rising and falling edges of the mains cycle are detected using only two current limiting resistors to the microcontroller. [13] Note that once the MCU is interrupted the level at the INT pin is sampled 5 times so as to neglect voltage spikes.

3.3.1 INCREASING AND DECREASING BRIGHTNESS IN STEPS:

Firing of the triac is avoided very close to the actual zero crossing. Hence for each half cycle of 10ms, only 9.5ms is used for control. 0.25ms at the beginning and at the end of the cycle is always avoided. The 9.5ms available for control provides us with ability to control the brightness from a minimum level of 7.5% to a maximum level of 97.6875%.

The dimming is divided into 194 steps using the following calculations:

Total time period of each half cycle = 10ms.

Time period neglected to avoid firing close to zero crossing = 0.25ms at each end

Pulse width of the triggering signal = 0.5ms.

Therefore time delay required once zero cross is detected before firing the first triggering pulse = 9.25ms.

This time delay is divided into 200 steps.

Thus one delay step = 9.25/200 = 46.25μs.

This delay step is called 200 times for the first brightness level of the lamp.

For the last brightness level, 0.25ms has to be again discarded close to the zero cross. Hence the number of times the delay has to be called before maximum brightness has been achieved = 0.25ms/46.25μs = 5.405 times = 5 times(approx) If the delay is called 5 times for maximum brightness, then the time of mains cycle at which triac is triggered = 5 x 46.25μs = 0.23125ms .Therefore Maximum brightness = 100 – ((0.23125/10) x 100) = 97.6875% .And Minimum brightness = ((0.75/10) x 100) = 7.5%.Thus the minimum brightness level is obtained by triggering the triac after nearly 9.25ms of the mains cycle and the maximum is obtained by triggering at approximately 0.231ms of the mains cycle.

3.4 OCCUPANCY DETECTOR:

When a person enters the room, he toggles sensor A first and when he leaves the room he toggles sensor B first.

When entering, the control of the MCU is transferred to ISR0. Here it checks if sensor B has already toggled or not. As it has not been toggled already, that indicates to the MCU that the person is entering and it.waits for the sensor B to toggle before which INT0 is disabled. This is done to avoid reading the pulsating signals obtained during actual toggling of the sensors (that is, the signal coming into the microcontroller is a series of pulses due to irregular shapes of human bodies). Once the sensor B is toggled, the ISR checks if sensor A has already occurred or not. If it has already occurred, that means the person is entering and then the count of number of people is incremented and the interrupts controlling it is disabled for a time delay to avoid pulsating signals at sensor B. After the time delay both the interrupts are enabled again.

When leaving, the control of the MCU is transferred to ISR1. Here it checks if sensor A has already toggled or not. As it has not been toggled already, that indicates to the MCU that the person is leaving and it waits for the sensor A to toggle before which INT1 is disabled. Once the sensor A is toggled, the ISR checks if sensor B has already occurred or not. Since it has already occurred, that means the person is leaving and then the count of number of people is decremented and the interrupts disabled for a time delay. After the entire time delay, both interrupts are enabled again. [7]

3.5 ANALOGUE-TO-DIGITAL CONVERTERS:

The LDR voltage varied between 0 – 5V. This was converted by the ADC into a value between 0-255. The reference voltage fed to the ADC was 5V. [15]
Hence the digital value was given by:

VLDR (digital) = (VLDR x 255)/5.. (3)

3.6 LIQUID CRYSTAL DISPLAY (LCD)

3.6.1 FUNCTION DESCRIPTION

The LCD display Module is built in a LSI controller, the controller has two 8-bit registers, an instruction register (IR) and a data register (DR). The IR stores instruction codes, such as display clear and cursor shift, and address information for display data RAM (DDRAM) and character generator (CGRAM). The IR can only be written from the MPU. The DR temporarily stores data to be written or read from DRAM or CGRAM.

When address information is written into the IR, then data is stored into the DR from DDRAM or CGRAM. By the register selector (RS) signal, these two registers can be selected.

Table 3.2: LCD Operation

RS	R/W	OPERATION
0	0	IR writes as an internal operation(display clear, etc)
0	1	Read busy flag DB7 and address counter(DB0 to DB7)
1	0	Write data to DDRAM or CGRAM(DR to DDRAM or CGRAM)
1	1	Read data from DDRAM or CGRAM(DDRAM or CGRAM to DR)

i. Busy flag (BF)

When the busy flag is 1, the controller LSI is in the internal operation mode and the next instruction will not be accepted. When RS=0 and R/W=1, the busy flag is output

to DB7.The next instruction must be written after ensuring that the busy flag is 0.

ii. Address Counter (AC)

The address counter (AC) assigns addresses to both DDRAM and CGRAM

iii. Display Data RAM (DDRAM)

This DDRAM is used to store the display data represented in 8-bit character codes. Its

extended capacity is 80×8 bits or 80 characters. Below figure is the relationship between DDRAM addresses and positions on the liquid crystal display.

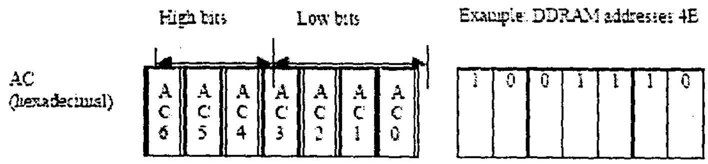


Fig 3.14 DDRAM addresses and positions on LCD

3.6.2 PRECAUTIONS IN USE OF LCD MODULES

(1) Avoid applying excessive shocks to the module or making any alterations or modifications to it.

(2) Don't make extra holes on the printed circuit board, modify its shape or change the

components of LCD module.

(3) Don't disassemble the LCM.

(4) Don't operate it above the absolute maximum rating.

(5) Don't drop, bend or twist LCM.

(6) Soldering: only to the I/O terminals.

(7) Storage: please storage in anti-static electricity container and clean environment. [17]

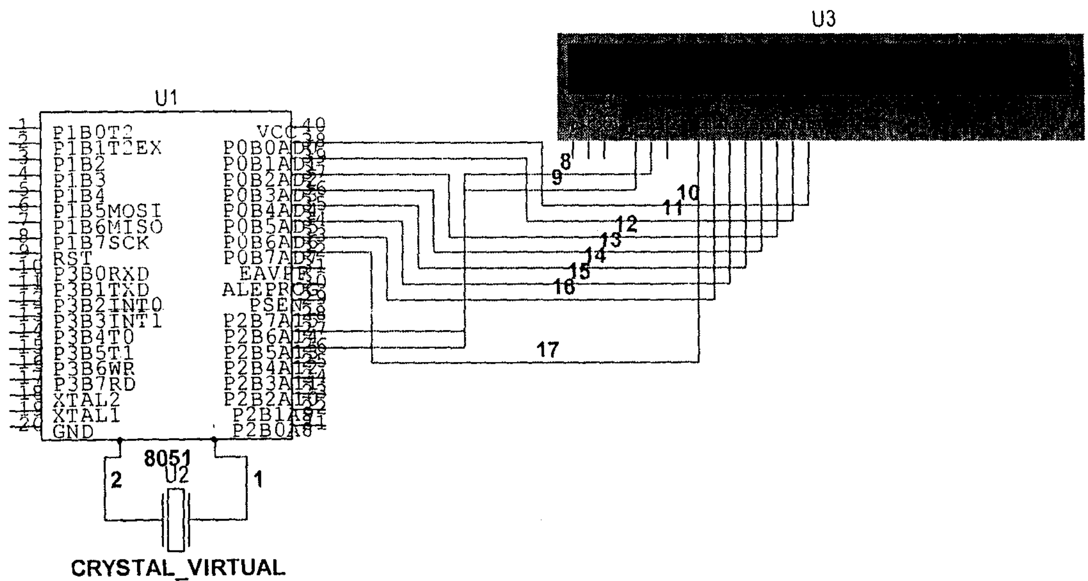


Fig 3.15: Interfacing the LCD to the MCU

CHAPTER FOUR

CONSTRUCTION, TESTING AND RESULTS

4.1 CONSTRUCTION TOOLS AND MATERIALS

The tools and materials as well as instrument used during the testing and the construction of the project are briefly described below:

(1) **The simulation**: The circuit diagram was tested on the computer using multisim10 software for simulation analysis of DC operating points transients and parameters sweep.

(2) **Analogue/Digital multi meter:** This was used for the measurement of electrical quantities such as resistance, voltage and current. They were also used to test the circuit sections for continuity. The digital multi meter gave a digital output display of measured quantities, while the analogue meter gave an indication of the value of measured quantities on a scale, the value of which is read on the position the pointer on the scale.

(3) **The vero board:** This is a perforated board on which electronics components can be inserted and soldered permanently. It was used for the permanent construction of the project prototype.

(4) **Wires and connectors**: Wires were used during the testing stage of the project on the breadboard to connect the components together as well as the different sub-units of the circuit, copper wires were also used during the soldering of components on the Vero board .

(5) **IC Sockets**: This is a device used to hold ICs in position; the IC socket was first soldered on the Vero board before the IC chip was fixed on it to protect the IC from the heat of the soldering iron.

(6) **Wire cutters/strippers:** They were used to cut wires to the desired size before use, as well as to strip off insulation in other to expose the conductor for proper and neat soldering.

(7) **Soldering Iron**: This is a low power heating element typically in the range of 40 Watts. It provides the heat needed to melt the lead, so that it can be used for connection of the components permanently on the Vero board. It is usually powered from the ac mains.

(8) **Soldering Lead:** This is a wire (lead) of low melting point. It is used to electrically connect components and wires in a fixed position on the Vero board.

(9) **Lead Sucker**: This is used to suck off excess molten lead from the Vero board to prevent short circuit (bridging) or undesirable connections.

4.2 CONSTRUTION DETAILS

The circuit was laid out on the breadboard to observe its operational response and ensure that it is in line with required objectives. Then it was dismantled. The circuit was finally constructed on a Vero board. The components were inserted in the holes on the board properly to ensure that it is out on the other side of the board where the copper tracks are. All coppers and connecting wires were inserted in place before soldering. The MCU chip is very sensitive to heat and so was protected by the use of IC socket. The socket was first soldered on the Vero board before inserting the IC. [1]

4.2 CONSTRUCTION PRECAUTIONS

(1) All soldered joints (points) were tested for continuity so as to avoid unnecessary open circuits.

(2) All the excess leads were removed to avoid bridges (short circuits) on the board. Polarities of the electrolytic capacitors and LEDS were properly checked to be correctly positioned before connecting (soldering) on the Vero board.

(3) ICs were mounted on the IC socket to avoid heating them during soldering by soldering the IC socket first on the Vero board.

(4) Excessive heating of the components was avoided so that they do not burn by making the soldering process to a component very brief.

4.3 PROBLEMS ENCOUNTERED

(1) The specific components were not easily obtained in the local markets. This resulted to waste of limited time for the project as the component had to be complete

before commencement.

(2) Erratic power supply also slowed down the pace of the project.

(3) Dimmer circuit:

Initially it was decided to directly connect the I/O port of the lamp to the triac gate, but the current from the I/O port is not enough to drive the gate.

When the output of the port pin was observed, a pulse was obtained at different times of the mains cycle for different brightness levels. Amplifying the current before it can be sent to the triac in the final dimmer. This did not solve the problem.

4.5 TESTING AND RESULTS

Each of the units of the system was tested separately before assembling the final prototype.

4.5.1 POWER SUPPLY UNIT

The power supply unit was tested to check the voltages being obtained before applying these to the other units. The voltages obtained was regulated 5V DC.

4.5.2 OCCUPANCY DETECTOR

The occupancy detector was able to detect any opaque or non-transparent object placed in between the transmitter and receiver. I was able to obtain a good range of about 3-4metres.

4.5.3 ZERO CROSSING DETECTOR (ZCD)

Initially a ZCD was built using LM324 Op-amp. But that required a power supply with negative potential. On discovering that a ZCD could be built directly by the MCU just by using current limiting resistors, it was decided to discard the ZCD circuit using LM324.

The zero crossing detector was tested using the MCU by sending a pulse at one of the port pins immediately after zero cross. It gave a satisfactory response where the detection of the cross was very close to the actual zero cross. [8]

4.5.4 DIMMER CIRCUITRY

The dimmer circuit finally built was arrived at after a long struggle of interfacing the triac control with the microcontroller through the opto-triac. The final dimmer circuit was first tested using a PWM generated by the MCU port pin. After it gave a satisfactory response, further tests were carried out to see the ranges of dimming/brightness levels possible. The theoretical calculations (Refer 3.3.1) showed 0.23125% - 92.5% dimming i.e. 97.6875% maximum and 7.5% minimum brightness. [3]

During actual testing, flickering was observed during triggering at close to zero cross and a bright spark was observed during the first level (minimum) of brightness. To eliminate this we had to decrease the range of control marginally which eliminated the flicker yet did not affect the performance of the dimming.

The output of the lamp and the output of the triac were observed under different dimming levels on a cathode ray oscilloscope (CRO). The triac output with respect to the gating pulse for 50% can be seen in figure 4.1. The corresponding load voltage is shown in figure 4.2. The maximum brightness load voltage can be seen in figure 4.3.

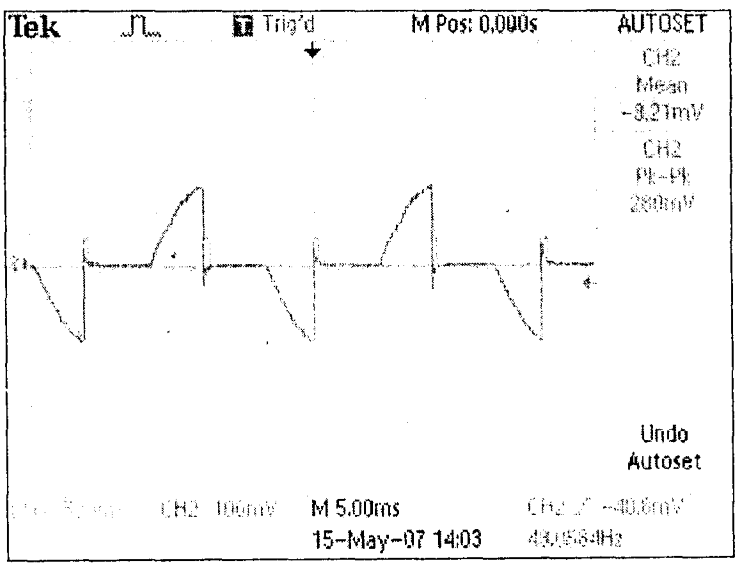


Fig 4.1: Triac output at 50% brightness

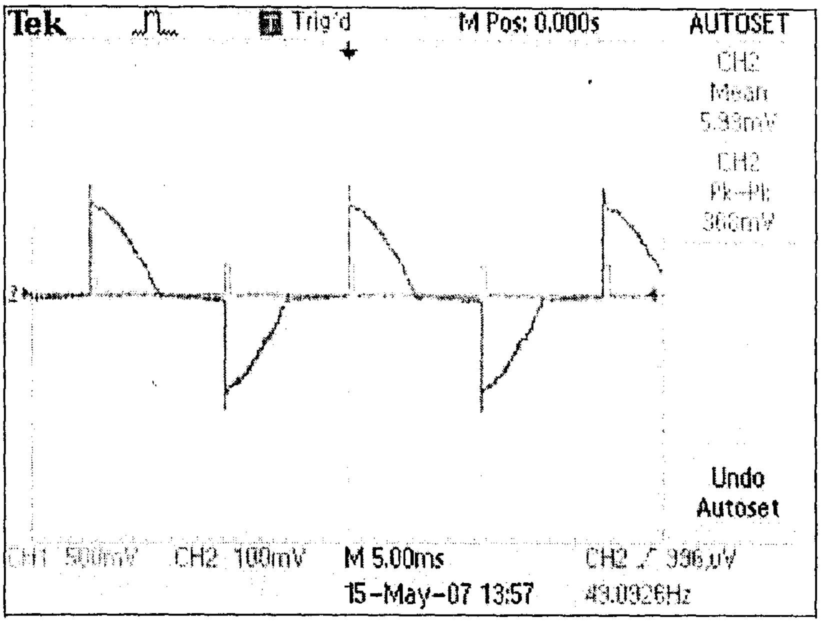


Fig 4.2: Load voltage at 50% brightness

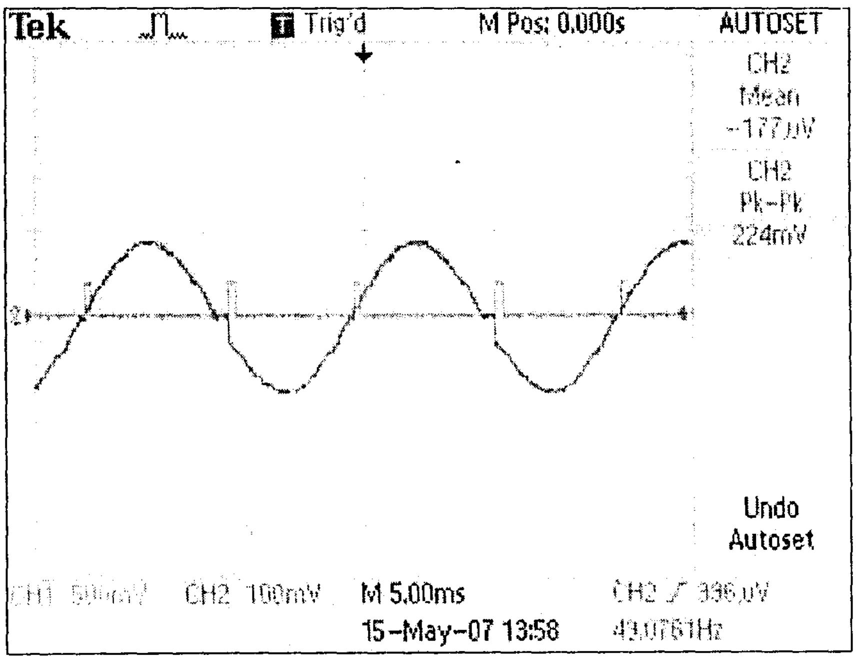


Fig 4.3: Load voltage at 97% brightness

4.5.4.1 DIMMING USING INCANDESCENT LAMPS

The dimmer circuit was tested on an incandescent lamp as well. It gave a considerable amount of flicker during low voltages as well as a sudden rise in brightness was observed during the first level of brightness. Thereafter brightness control was possible and was achieved. To eliminate the flicker, the program code was modified so that if the user requires to use a incandescent lamp, then all he needs to do is turn on the incandescent lamp switch on the button bank. The program for the incandescent lamp mode was modified so that the first brightness level (minimum brightness) occurred quite far away from the actual zero. A considerable amount of dimming was achieved using the incandescent lamp.

4.5.5 LIGHT SENSOR

To decide the value of resistance to be used in series with the LDR to form the voltage divider circuit the following test was conducted.

Firstly the dark resistance of the LDR was measured. The LDR was then connected as shown in figure 4.4 and the voltage across the LDR was measured in light and dark. The resistance at which maximum range was obtained was the most optimum for the LDR tested. The different resistances tested can be seen in table 4.1

Dark resistance was measured to be = 1.8 MΩ

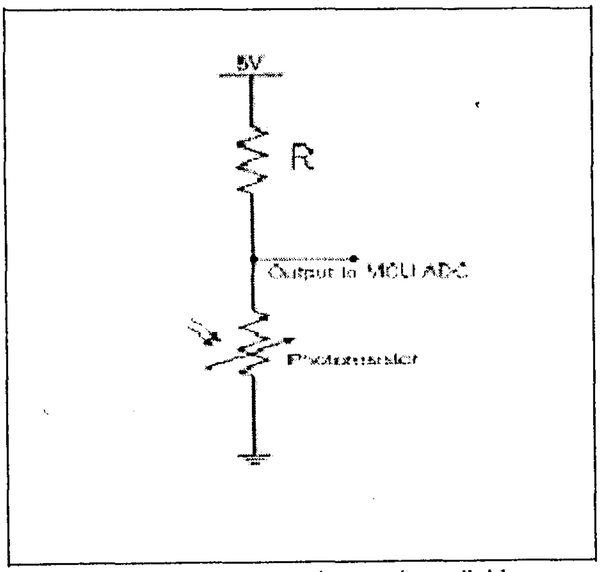


Fig 4.4: LDR connected as a voltage divider

Table 4.1: VLDR in light and in dark

$R(\Omega)$	V_o in Light (Volts)	V_o in Dark (Volts)
100	3.670	4.92
1K	0.100	4.91
10K	0.142	4.60
100K	0.014	2.00
1M	0.001	1.50

The widest range was available when the series resistance connected to the LDR was $1K\Omega$.Hence it was chosen to be included in the light sensor circuit. The LDR voltage varied between 0 – 5V. This was converted by the ADC to its corresponding digital value as already discussed in 3.3.2.

The voltage in digital value is between 0 and 255.

4.5.6 USER INTERFACE (PUSH BUTTONS)

The pushbutton interface was used to manually test the presence level starting from zero. It was also test with a value higher than zero to see if the counts will continue from the chosen initial value.

4.5.7 ELECTRICAL SAFETY

Because of high voltages (AC mains potential) used in the dimmer, the dimmer must adhere to electrical safety guidelines. Galvanic isolation must be provided between any component connected to the AC line and the rest of the circuitry and interfaces that are not. Isolation is provided by using the MOC3032 opto- triac and the transformer.

CHAPTER FIVE

CONCLUSION AND RECOMMENDATION

5.1 Performance

The final prototype was a working model of how to integrate daylight saving into lighting systems. The control method used was very efficient. The entire program used up only 5% of the total memory space available in the microcontroller due to efficient programming and better utilization of memory resources. It yielded a satisfactory response to varying light intensities outside.

5.2 LIMITATIONS

i. The dimmer yielded exceptional performance using incandescent lamp. But CFL lamp in itself is highly inefficient and is being replaced in most countries by better efficient light sources like incandescent lamps.

ii. The prototype could easily be integrated to households where most of the lamps are GLS, but it is not easy to integrate the developed system in offices, which usually have FTL lamps.

iii. The dimming obtained in incandescent lamps was limited by the starting voltage. Though flickering was more or less eliminated, the dimming aspect needs to be further improved.

iv. The dimming process by cutting a part of the voltage mains cycle introduces harmonics. If inductive loads are also connected to the mains, this could cause problems.

v. The infrared sensor used detects anything that passes through it, such human beings,
animals and any non-living thing.

5.3 RECOMMENDATION

The following are recommended for future work on the device:

i. The most immediate refinement to the system could be to integrate an IR remote control to the system using RC5 coding to replace the manual push buttons.

ii. RS-232 interface could be added to the existing system to integrate the control with laptops and PCs using the USART of the MCU.

iii. For further applications like theatrical light control, DMX-512 interface could be added..

iv. More features like temperature control (air-conditioner) could be added with more time, money and materials.

v. The use of a passive infrared (PIR 325) and FreeCell lens could be used which detects human beings unlike the infrared sensor used in this project that detects any solid body that passes through it.

REFERENCES

Books:

[1] Ramakant A. Gayakwad, "Op-Amps and Linear Integrated Circuits", 4th ed, Prentice-Hall of India Private Ltd, 2003, pp. 315-322, pp. 400-411.

[2] Raj Kamal, "Embedded Systems Architecture, programming and design", 5th ed, Tata-McGraw Hill, 2003.

Technical reports:

[3] Ed Maste, "Microcontroller based Multichannel Light Dimmer", University of Waterloo Available: http://jem.dhs.org/~ed/ece499/

[4] Abhijeet Agarwal, Marcelo Garza Moreira, Eric Matsumoto Okawa, "Loucetios Lighting Control System", Cornell University Available: http://instruct1.cit.cornell.edu/courses/ee476/finalprojects/s2006/aa338_mg266_emo29/0aa338_mg266_emo29/index.htm

[5] MacKenzie Scott. The 8051 Microcontroller, Prentice Hall. 3rd. Ed., 1999

Yeralan and Ahluwalia. Programming and Interfacing the 8051 Microcontroller. Addison-Wesley. 1995.

[6] U.L. Server (Shared folder)

Go to 'Network Neighborhood', then 'Entire Network', then pick Domain 'Intel_Data_Comm' and choose the server 'Intel_Comm'. In the folder 'ET4514' you will find the required information

Patents:

[7] William Kahl,, Brookfield; Richard Settani, Bethel, "Lighting Control system with Infrared Detector", U.S. Patent 4 703 171, Oct. 27, 1987.

Websites:

[8] 8051 Atmel Corporation, "Zero Cross Detector"

[9] Alberto Ricci Bitti project web page: http://www.riccibitti.com/tinyplanet/tiny

intro.html.

[10] 8052 Microcontroller website. http://www.8052.com/tut8052.phtml

[11] 8051 Tutorial by Donal haffernan, University of limerick, May 2002.

[12] 8052 tutorial information by Vault Information Services: http://www.8052.com

Intel's site for 8051 based products: http://developer.intel.com/design/mcs51/

[13] Philips' site for 8051 based products:

http://www-us.semiconductors.philips.com/microcontrol/ Infineon (formerly Siemens) site for 8051 based products:

http://www.infineon.com/products/micro/micro.htm

[14] Keil development tools:http://www.keil.com/home.htm

[15] Information on Analog Devices ADuC812 (8051/8052 compatible processor): www.analog.com/microconverter

[16] National semiconductor: www.national.com

[17] Crystalfontz America, Inc.12412 East Saltese Avenue

Spokane Valley, WA 99216-0357

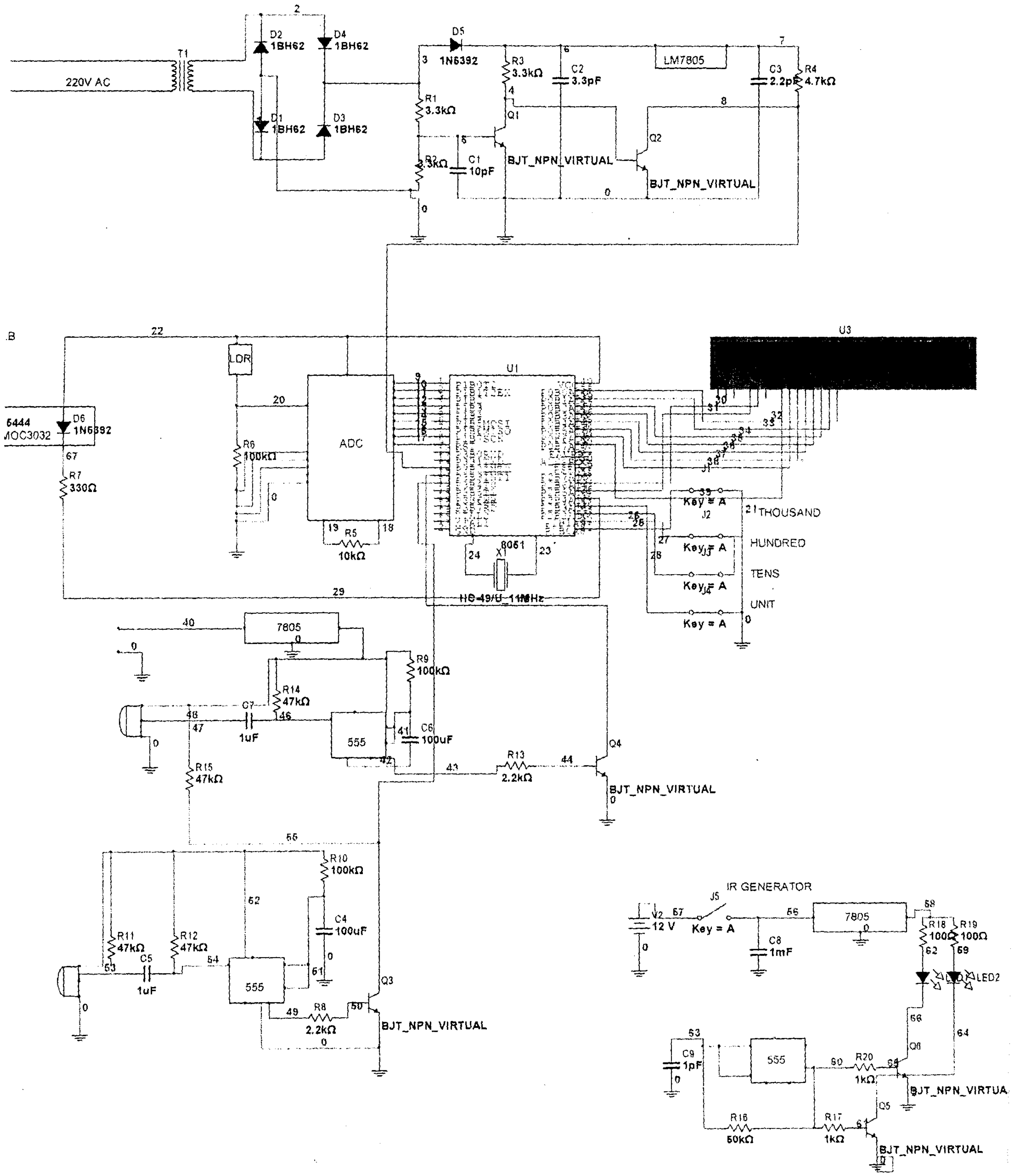
Phone: (888) 206-9720

Fax: (509) 892-1203

Email: techinfo@crystalfontz.com

URL: www.crystalfontz.com

APPENDIX A



220V AC
T1
D2 1BH62
D4 1BH62
D1 1BH62
D3 1BH62
D5 1N5392
R1 3.3kΩ
R3 3.3kΩ
C2 3.3pF
LM7805
C3 2.2pF
R4 4.7kΩ
C1 10pF
BJT_NPN_VIRTUAL
LDR
ADC
U1
8051
U3
D6 1N5392
MOC3032
R6 100kΩ
R7 330Ω
R5 10kΩ
X1
HC-49/U_11MHz
THOUSAND
HUNDRED
TENS
UNIT
Key = A
7805
R9 100kΩ
R14 47kΩ
C7 1uF
555
C6 100uF
R15 47kΩ
R13 2.2kΩ
Q4
R10 100kΩ
C4 100uF
R11 47kΩ
R12 47kΩ
C5 1uF
R8 2.2kΩ
Q3
IR GENERATOR
V2 12 V
J5
C8 1mF
R18 100Ω
R19 100Ω
LED2
C9 1pF
R20 1kΩ
Q6
Q5
R16 50kΩ
R17 1kΩ

APPENDIX B

PIN CONFIGURATIONS