Occupancy Based Load Switching using Microcontroller

A Project report submitted in partial fulfillment
of the requirements for the degree of B. Tech in Electrical Engineering

by

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CERTIFICATE

To whom it may concern

This is to certify that the project work entitled **OCCUPANCY BASED LOAD SWITCHING USING MICROCONTROLLER**is the bonafide work carried out by**PRANTAR DUTTA (11701616048), ARITRA MALLICK (11701616063), RAJDEEP RAJBANSHI (11701616042)** and**SAGAR CHANDRA BAURI (11701616038)**, the students of B.Tech in the Department of Electrical Engineering, RCC Institute ofInformation Technology (RCCIIT), Canal South Road, Beliaghata, Kolkata-700015,affiliated to MaulanaAbulKalam Azad University of Technology (MAKAUT), WestBengal, India, during the academic year 2019-20, in partial fulfillment of therequirements for the degree of Bachelor of Technology in Electrical Engineeringand that this project has not submitted previously for the award of any otherdegree, diploma and fellowship.

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ACKNOWLEDGEMENT

It is our great fortune that we have got opportunity to carry out this project work under the supervision of **Mr. BudhadityaBiswas**in the Department of Electrical Engineering, RCC Institute of Information Technology (RCCIIT), Canal South Road, Beliaghata, Kolkata-700015, affiliated to MaulanaAbulKalam Azad University of Technology (**MAKAUT**), West Bengal, India. We express our sincere thanks and deepest sense of gratitude to our guide for his constant support, unparalleled guidance and limitless encouragement.

We would also like to convey our gratitude to all the faculty members and staffs of the Department of Electrical Engineering, RCCIIT for their whole hearted cooperation to make this work turn into reality.

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To

The Head of the Department
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Respected Sir,

In accordance with the requirements of the degree of Bachelor of Technology in the Department of Electrical Engineering, RCC Institute of Information Technology, We present the following thesis entitled "**Occupancy Based Load Switching using Microcontroller**". This work was performed under the valuable guidance of Mr. BudhadtiyaBiswas, Assistant Professor in the Dept. of Electrical Engineering.

We declare that the thesis submitted is our own, expected as acknowledge in the test and reference and has not been previously submitted for a degree in any other Institution.

Yours Sincerely,

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ABBREVIATIONS AND ACRONYMS

BT–Bluetooth
***IC* -** Integrated Circuit
PCB – Printed Circuit Board
μC – Micro Controller
***BJT* -** Bi-polar Junction Transistor
***SPDT* -** Single Pole Double Throw
***NO* -** Normally Open
***NC* -** Normally Closed
COM – Common
LCD – Liquid Crystal Display
***LED* -** Light Emitting Diode
POT – Potentiometer
SMPS – Switch Mode Power Supply
IR–Infrared
ISM – Industrial, scientific and medical
***TDR* –** Time Delay Relay

ABSTRACT

Lighting accounts for a significant amount of electrical energy consumption in buildings, up to 45% of the total consumed. This energy consumption can be reduced by as much as 60% through an occupant dependent lighting control strategy.

With particular focus on institutional classrooms, where the application of this strategy is more challenging to apply due to differences in individual occupancy patterns,. Linking a light system with occupancy sensors is a cost-effective and easy solution for reducing lighting energy use. The concept is based on the design of a smart classroom, where on the basis of the entry of an individual the connected load will be active and on the exit the connected loads will get switched off automatically. When the candidates enters the classroom the number of candidates entering the class room will be displayed on a LCD display, for the design of such energy efficient lighting system the persons entering the classrooms should sit on after the other and not in a haphazard way, since the design will be implemented such that after the fulfillment of a row the 2nd row lights will glow on. In this way the light of the respective rows glows on and lights gets turned off when they leaves the classrooms

The sitting arrangement light control is to be done in such a way that the synchronization of the students entering the room is maintained and also energy efficiency is improved.

CHAPTER 1

(Introduction)

1.1 INTRODUCTION

Lighting controls are making their way into increasing numbers of buildings, but the potential for application of these technologies is still far from fully being achieved. A key element for decision makers in choosing lighting control technologies is evidence that these technologies will be effective in reducing rising energy costs. This long-term study adds to the small but growing body of literature describing the potential savings from occupant sensors and time scheduling controls in large open office areas. Occupancy sensing has been shown to be an effective means of reducing lighting energy use in private offices . Time scheduling can also save significant energy in similar large spaces.

With particular focus on institutional classrooms, where the application of this strategy is more challenging to apply due to differences in individual occupancy patterns,. Linking a light system with occupancy sensors is a cost-effective and easy solution for reducing lighting energy use. The concept is based on the design of a smart classroom, where on the basis of the entry of an individual the connected load will be active and on the exit the connected loads will get switched off automatically. When the candidates enters the classroom the number of candidates entering the class room will be displayed on a LCD display, for the design of such energy efficient lighting system the persons entering the classrooms should sit on after the other and not in a haphazard way, since the design will be implemented such that after the fulfillment of 1^{st} row the 2^{nd} row lights will glow on. In this way the light of the respective rows glows on and light gets turned off when they leaves the classrooms.

1.2 Sensors can be used for two types of lighting control strategies:

Occupancy Sensors (auto on/auto off): With this strategy, the sensor automatically turns on the lights when someone enters the space and turns off the lights after a user-designated time period if no movement is detected.

PIR sensors, which work on heat difference detection, measuring infrared radiation. Inside the device is a pyroelectric sensor which can detect the sudden presence of objects (such as humans) that radiate a temperature different from the temperature of the background, such as the room

Vacancy Sensors (manual on/auto off): With this strategy, the person entering the room manually switches on the lights. If they are left on when the person leaves the room, after a certain amount of time with no movement, the sensor will turn off the lights.

Working of an occupancy sensors

An occupancy sensor is an indoor motion detecting device used to detect the presence of a person to automatically control lights or temperature or ventilation systems. The sensors use infrared, ultrasonic, microwave, or other technology. Occupancy sensors are typically used to save energy, provide automatic control, and comply with building codes

Motion sensors are often used in indoor spaces to control electric lighting. If no motion is detected, it is assumed that the space is empty, and thus does not need to be lit. Turning off the lights in such circumstances can save substantial amounts of energy. In lighting practice occupancy sensors are sometime also called "presence sensors" or "vacancy sensors".

1.3 IR SENSOR

Infrared technology addresses a wide variety of wireless applications. The main areas are sensing and remote controls. In the electromagnetic spectrum, the infrared portion is divided into three regions: near infrared region, mid infrared region and far infrared region.

The wavelengths of these regions and their applications are shown below.

- Near infrared region — 700 nm to 1400 nm — IR sensors, fiber optic
- Mid infrared region — 1400 nm to 3000 nm — Heat sensing
- Far infrared region — 3000 nm to 1 mm — Thermal imaging

The frequency range of infrared is higher than microwave and lesser than visible light.

For optical sensing and optical communication, photo optics technologies are used in the near infrared region as the light is less complex than RF when implemented as a source of signal. Optical wireless communication is done with IR data transmission for short range applications.

An infrared sensor emits and/or detects infrared radiation to sense its surroundings.

The working of any Infrared sensor is governed by three laws: Planck’s Radiation law, Stephen – Boltzmann law and Wien’s Displacement law.

Planck’s law states that “every object emits radiation at a temperature not equal to 0^0K”. Stephen – Boltzmann law states that “at all wavelengths, the total energy emitted by a black body is proportional to the fourth power of the absolute temperature”. According to Wien’s Displacement law, “the radiation curve of a black body for different temperatures will reach its peak at a wavelength inversely proportional to the temperature”.

The basic concept of an Infrared Sensor which is used as Obstacle detector is to transmit an infrared signal, this infrared signal bounces from the surface of an object and the signal is received at the infrared receiver.

There are five basic elements used in a typical infrared detection system: an infrared source, a transmission medium, optical component, infrared detectors or receivers and signal processing. Infrared lasers and Infrared LED’s of specific wavelength can be used as infrared sources. The three main types of media used for infrared transmission are vacuum, atmosphere and optical fibers. Optical components are used to focus the infrared radiation or to limit the spectral response.

Optical lenses made of Quartz, Germanium and Silicon are used to focus the infrared radiation. Infrared receivers can be photodiodes, phototransistors etc. some important specifications of infrared receivers are photosensitivity, directivity and noise equivalent power. Signal processing is done by amplifiers as the output of infrared detector is very small.

1.4 Types of IR Sensors

Infrared sensors can be passive or active. Passive infrared sensors are basically Infrared detectors. Passive infrared sensors do not use any infrared source and detects energy emitted by obstacles in the field of view. They are of two types: quantum and thermal. Thermal infrared sensors use infrared energy as the source of heat and are independent of wavelength. Thermocouples, pyroelectric detectors and bolometers are the common types of thermal infrared detectors.

Quantum type infrared detectors offer higher detection performance and are faster than thermal type infrared detectors. The photosensitivity of quantum type detectors is wavelength dependent. Quantum type detectors are further classified into two types: intrinsic and extrinsic types. Intrinsic type quantum detectors are photoconductive cells and photovoltaic cells.

Active infrared sensors consist of two elements: infrared source and infrared detector. Infrared sources include an LED or infrared laser diode. Infrared detectors include photodiodes or phototransistors. The energy emitted by the infrared source is reflected by an object and falls on the infrared detector.

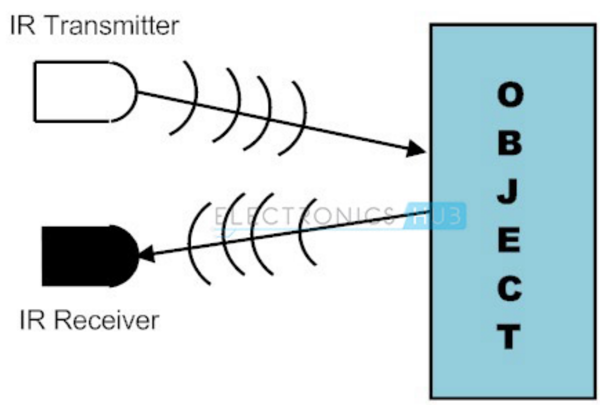


Figure 1: IR objective detection principle

1.4.1 IR Transmitter

Infrared Transmitter is a light emitting diode (LED) which emits infrared radiations. Hence, they are called IR LED’s. Even though an IR LED looks like a normal LED, the radiation emitted by it is invisible to the human eye.

The picture of a typical Infrared LED is shown below.

Figure 2: IR Transmitter

There are different types of infrared transmitters depending on their wavelengths, output power and response time.

A simple infrared transmitter can be constructed using an infrared LED, a current limiting resistor and a power supply. The schematic of a typical IR transmitter is shown below.

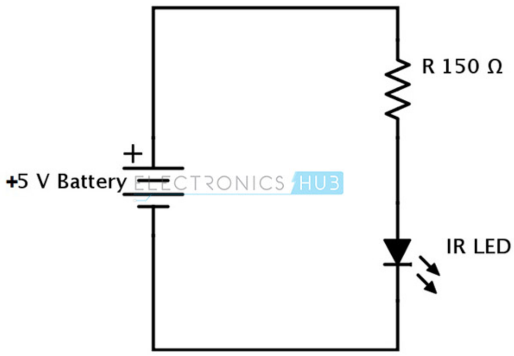


Figure 3: IR LED (transmitter) connection

When operated at a supply of 5V, the IR transmitter consumes about 3 to 5 mA of current. Infrared transmitters can be modulated to produce a particular frequency of infrared light. The most commonly used modulation is OOK (ON – OFF – KEYING) modulation.

IR transmitters can be found in several applications. Some applications require infrared heat and the best infrared source is infrared transmitter. When infrared emitters are used with Quartz, solar cells can be made.

1.4.2 IR Receiver

Infrared receivers are also called as infrared sensors as they detect the radiation from an IR transmitter. IR receivers come in the form of photodiodes and phototransistors. Infrared Photodiodes are different from normal photo diodes as they detect only infrared radiation. The picture of a typical IR receiver or a photodiode is shown below.

Figure 4: IR Receiver

Different types of IR receivers exist based on the wavelength, voltage, package, etc. When used in an infrared transmitter – receiver combination, the wavelength of the receiver should match with that of the transmitter.

A typical infrared receiver circuit using a phototransistor is shown below.

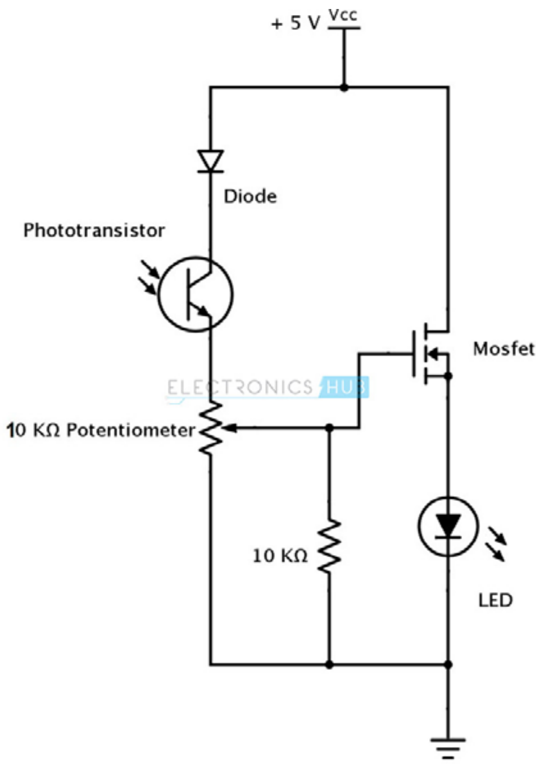


Figure 5: IR Receiver connection

It consists of an IR phototransistor, a diode, a MOSFET, a potentiometer and an LED. When the phototransistor receives any infrared radiation, current flows through it and MOSFET turns on. This in turn lights up the LED which acts as a load. The potentiometer is used to control the sensitivity of the phototransistor.

1.4.3 Principle of Working

The principle of an IR sensor working as an Object Detection Sensor can be explained using the following figure. An IR sensor consists of an IR LED and an IR Photodiode; together they are called as Photo – Coupler or Opto – Coupler.

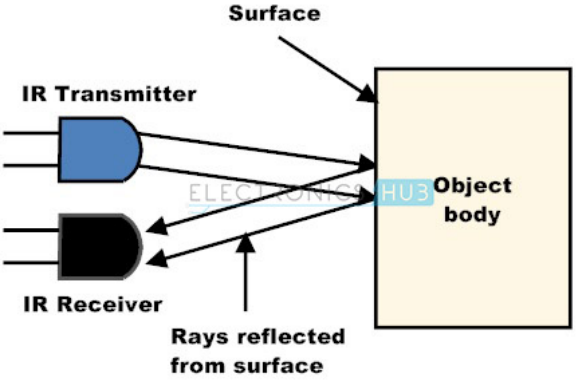


Figure 6: IR objective detection principle

When the IR transmitter emits radiation, it reaches the object and some of the radiation reflects back to the IR receiver. Based on the intensity of the reception by the IR receiver, the output of the sensor is defined.

1.4.4 Obstacle Sensing Circuit or IR Sensor Circuit

A typical IR sensing circuit is shown below.

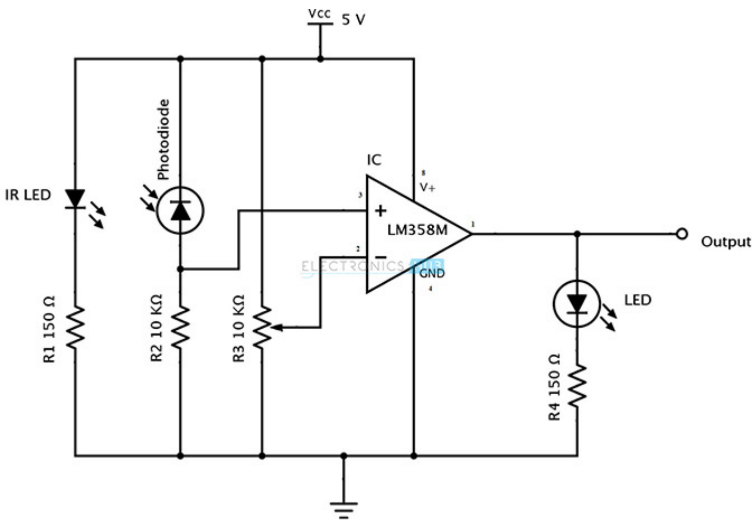


Figure 7: IR obstacle sensing circuit

It consists of an IR LED, a photodiode, a potentiometer, an IC Operational amplifier and an LED.

IR LED emits infrared light. The Photodiode detects the infrared light. An IC Op – Amp is used as a voltage comparator. The potentiometer is used to calibrate the output of the sensor according to the requirement.

When the light emitted by the IR LED is incident on the photodiode after hitting an object, the resistance of the photodiode falls down from a huge value. One of the input of the op – amp is at threshold value set by the potentiometer. The other input to the op-amp is from the photodiode's series resistor. When the incident radiation is more on the photodiode, the voltage drop across the series resistor will be high. In the IC, both the threshold voltage and the voltage across the series resistor are compared. If the voltage across the resistor series to photodiode is greater than that of the threshold voltage, the output of the IC Op – Amp is high. As the output of the IC is connected to an LED, it lightens up. The threshold voltage can be adjusted by adjusting the potentiometer depending on the environmental conditions.

The positioning of the IR LED and the IR Receiver is an important factor. When the IR LED is held directly in front of the IR receiver, this setup is called Direct Incidence. In this case, almost the entire radiation from the IR LED will fall on the IR receiver. Hence there is a line of sight communication between the infrared transmitter and the receiver. If an object falls in this line, it obstructs the radiation from reaching the receiver either by reflecting the radiation or absorbing the radiation.

1.4.5 Distinguishing Between Black and White Colors

It is universal that black color absorbs the entire radiation incident on it and white color reflects the entire radiation incident on it. Based on this principle, the second positioning of the sensor couple can be made. The IR LED and the photodiode are placed side by side. When the IR transmitter emits infrared radiation, since there is no direct line of contact between the transmitter and receiver, the emitted radiation must reflect back to the photodiode after hitting any object. The surface of the object can be divided into two types: reflective surface and non-reflective surface. If the surface of the object is reflective in nature i.e. it is white or other light color, most of the radiation incident on it will get reflected back and reaches the photodiode. Depending on the intensity of the radiation reflected back, current flows in the photodiode.

If the surface of the object is non-reflective in nature i.e. it is black or other dark color, it absorbs almost all the radiation incident on it. As there is no reflected radiation, there is no radiation incident on the photodiode and the resistance of the photodiode remains higher allowing no current to flow. This situation is similar to there being no object at all.

The pictorial representation of the above scenarios is shown below.

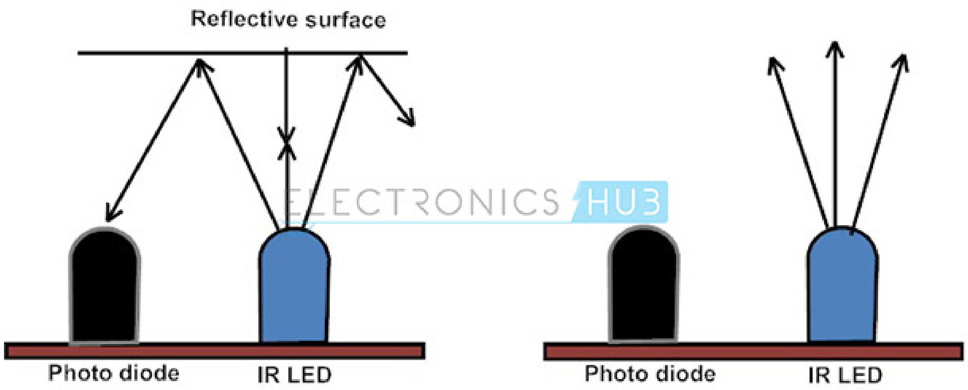
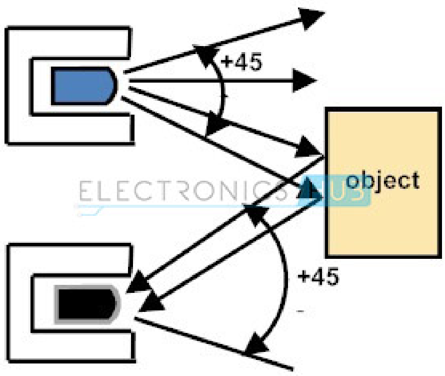


Figure 8: Distinguishing Between Black and White Colors using IR Sensor

The positioning and enclosing of the IR transmitter and Receiver is very important. Both the transmitter and the receiver must be placed at a certain angle, so that the detection of an object happens properly. This angle is the directivity of the sensor which is +/- 45 degrees.

The directivity is shown below.



In order to avoid reflections from surrounding objects other than the object, both the IR transmitter and the IR receiver must be enclosed properly. Generally the enclosure is made of plastic and is painted with black color.

1.5 Overview and benefits of the project

Remote Control Technology’s line of dependable, durable wireless remote switching systems can and will make money for you and your business. Wireless remote control benefits include:

No legal issues
Obtaining access to or traversing properties with hard lines is extremely difficult.

No copper wire to steal
As the price of copper increases, so does the possibility that your wire will be stolen. Using a wireless remote system means no wire for thieves to steal.

Extended range

Unlike much of the equipment on the market, Remote Control Technology's wireless remote equipment has long-range communication capabilities — up to 5 miles.

Eliminate the need for wire and conduit

Wire and conduit are expensive and high maintenance. Typical wear-and-tear, digging, rodent damage, theft, etc., are all examples of problems that can damage wire. RCT's wireless remote systems put an end to these drawbacks of wired technology.

Higher profits

Wireless remote switching systems eliminate the costly, labor-intensive process of trenching and laying wire. As a result, the contractor can enjoy an increased profitability of 200 percent or more in this facet of the job.

No FCC licensing required

RCT equipment does not require FCC licensing, whereas much of the other equipment on the market does. This is a significant benefit, as the FCC licensing process alone may take up to 8 weeks.

Less maintenance and servicing

In many states a contractor is obligated by law to maintain pumping systems for up to a year after its installation. RCT switching systems eliminate a majority of these maintenance and servicing issues by automating the job. Fewer service calls mean higher profits.

Reliability and compatibility

All of the components that a contractor puts into a project must interface with one another and have the utmost reliability. RCT wireless remote equipment has proven to be highly compatible with standard equipment used in most industries, as well as offering unparalleled reliability in use with programmable logic controllers (PLCs), various switches and relays, etc.

1.6 Organisation of thesis

The thesis is organised into five chapters including the chapter of introduction. Each chapter is different from the other and is described along with the necessary theory required to comprehend it.

Chapter 2 deals with the literature reviews. From this chapter we can see before our project who else works on this topic and how our project is different and advance from those projects.

Chapter 3 deals with the theory required to do the project. The basic of operation of Infrared sensor and how to interface with AT89c51 microcontroller are described there.

Chapter 4 deals with the hardware modelling of the projects. The main features, photographs, step by step operation of the prototype, component listing and the hardware interfacing of the required components are described here.

Chapter 5 describes the operation of the prototype circuit. A flow chart is presented on the actions which describes the principle of Infrared sensor detection. Once the number of persons are measured by the sensor the controller display it over a 16X2 LCD screen and switch on the light of the classroom according to the number of persons present in the classroom.

Chapter 6 concludes the work performed so far. The possible limitations in proceeding research towards this work are discussed. The future work that can be done in improving the current scenario is mentioned. The future potential along the lines of this work is also discussed.

Chapter 7 References are listed in this chapter

Appendix A, B & C Hardware description, software coding and datasheets are listed here.

CHAPTER 2

(Literature Review)

- *M.-C. Dubois, A. Blomsterberg, "**Energy saving potential and strategies for electric lighting in future**" North European, low energy office buildings: a literature review, Energy Build. 43 (2011) 2572e2582*

Energy-efficient building is rapidly gaining acceptance in South Korea to achieve the goals of sustainability in the building industry. The building sector in Korea currently consumes about 25% of the nation's total energy output and is also responsible for generating about 25% of its greenhouse gas emissions, even though this portion of building sector was expected to increase to 40% based on the trends in other developed countries (Park, 2013a, 2013b). The Korean Government passed legislation entitled the "**Framework Action Low Carbon, Green Growth**" in 2010 in order to reduce the country's energy and greenhouse gas emissions and support economic growth. In 2013, a subsequent law to encourage green and energy-efficient building was implemented that covered the following areas of the building sector: green building rating system, energy-efficient renovation, energy-efficient building system, incentives, research development, education and training forenergy-efficient building and several energy-saving pilot projects(National Assembly, 2010; Park, 2013a, b).

In the building sector, the Korean construction industry with the support of the government developed and implemented the Korean Green Building Certification System (K-GBCS) in 2002 to reduce energy consumption and environmental pollutants across the life cycle of the building (Son,Kim, & Kim, 2012). K-GBCS was later renamed the Green Standardfor Energy and Environmental Design (G-SEED) to accomplish sustainable development and also encourage resource conservative and environmentally-friendly buildings (Mok, Cho, & Park, 2014).

- *M. Magno, T. Polonelli, L. Benini, "**A low cost, highly scalable wireless sensor network solution to achieve smart LED light control for green buildings**", IEEE Sensors (2015) 2963e2973. http://ieeexplore.ieee.org/xpls/abs_all.jsp? Arnumber 6994782 (accessed 22 June 2016)*

This paper proposed reducing energy demand in the residential and industrial sectors is an important challenge worldwide. In particular, lights account for a great portion of total energy consumption, and unfortunately a huge amount of this energy is wasted. Light-emitting diode (LED) lights are being used to light offices, houses, industrial, or agricultural facilities more efficiently than traditional lights. Moreover, the light control systems are introduced to current markets, because the installed lighting systems are outdated and energy inefficient. However, due to high costs, installation issues, and difficulty of maintenance; existing light control systems are not successfully applied to home, office, and industrial buildings. This paper proposes a low cost, wireless, easy to install, adaptable, and smart LED lighting system to automatically adjust the light intensity to save energy and maintaining user satisfaction. The system combines motionsensors and light sensors in a low-power wireless solution using Zigbee communication. This paper presents the design and implementation of the proposed system in a real-world deployment. Characterization of a commercial LED panel was performed to evaluate the benefit of dimming for this light technology. The proposed smart lighting system reduces total power consumption in the application scenario by55% during a six month period and up to 69% in spring months.

- *F. Manzoor, D. Linton, M. Loughlin*, ***" Occupancy monitoring using passive RFID technology for efficient building lighting control"****, RFID Technol.(EURASIP)(2012)83e88. http://ieeexplore.ieee.org/xpls/abs_all.jsp?arnumber¼6353853 (accessed 14 December 2015).*

  The proposed methodology provides an estimated 13% of electrical energy savings in one open plan office of a University campus building. Practical implementation of RFID gateways provide real-world occupancy profiling data to be fused with PIR sensing towards analysis and improvement of building lighting usage.

  The control of artificial lighting is a key parameter to be considered in buildings towards energy and cost savings. Efficient, need-based control of building lighting through occupancy detection using Passive Infrared (PIR) sensors has become a reliable and well established approach. However, the use of only PIR sensors for occupancy monitoring does not offer much savings and depends upon a building's type and use, and its occupancy levels. Accuracy of occupancy monitoring greatly affects building lighting control strategy and hence, percentage savings. Besides considering lighting control based on occupancy detection using PIR sensors, this paper presents a data fusion approach of passive RFID based occupancy monitoring with PIR.

- *Z. Nagy, M. Hazas, M. Frei, D. Rossi, A. Schlueter, "****Illuminating adaptive comfort: dynamic lighting for the active occupant,"*** *in: Proc. 8th Wind. Conf. Count. Cost Comf. A Chang. World, 2014*

  The proposed idea of this paper focused particularly on open-plan offices, where the application of this strategy is more challenging to apply due to differences in individual occupancy patterns, this paper covers (1) to which extent individual occupancy-based lighting control has been tested, (2) developed, and (3) evaluated. Search terms were defined with use of three categories, namely 'occupancy patterns', 'lighting control strategy', and 'office'. Relevant articles were selected by a structured search through key online scientific databases and journals. The 24 studies identified as eligible were evaluated on six criteria: (1) study characteristics, (2) office characteristics, (3) lighting system characteristics, (4) lighting control design, (5) post-occupancy evaluation, and (6) conclusions, and this was used to answer the research questions. It was concluded that the strategy has not been tested yet with field studies in open plan offices, but that it needs further development before it can be applied in these type of offices. Although lighting currently tends to be controlled at workspace level, many aspects of the strategy can be further developed; there is potential to further increase energy savings on lighting within open-plan office spaces. Individual occupancy-based lighting control requires further validation, focussing on the factors influencing its energy savings, on its cost effectiveness, and on its acceptability for users.

CHAPTER 3

(Theory)

3.1 IR LED | Infrared LED | Infrared Sensor

An Infrared light emitting diode (IR LED) is a special purpose LED emitting infrared rays ranging from 700 nm to 1 mm wavelength. Different IR LEDs may produce infrared light of differing wavelengths, just like different LEDs produce light of different colours.

IR LEDs are usually made of gallium arsenide or aluminium gallium arsenide. In complement with IR receivers, these are commonly used as sensors.

The appearance of IR LED is same as a common LED. Since the human eye cannot see the infrared radiations, it is not possible for a person to identify if an IR LED is working. A camera on a cell phone camera solves this problem. The IR rays from the IR LED in the circuit are shown in the camera.

3.2 Pin Diagram of IR LED

An IR LED is a type of diode or simple semiconductor. Electric current is allowed to flow in only one direction in diodes. As the current flows, electrons fall from one part of the diode into holes on another part. In order to fall into these holes, the electrons must shed energy in the form of photons, which produce light.

It is necessary to modulate the emission from IR diode to use it in electronic application to prevent spurious triggering. Modulation makes the signal from IR LED stand out above the noise. Infrared diodes have a package that is opaque to visible light but transparent to infrared. The massive use of IR LEDs in remote controls and safety alarm systems has drastically reduced the pricing of IR diodes in the market.

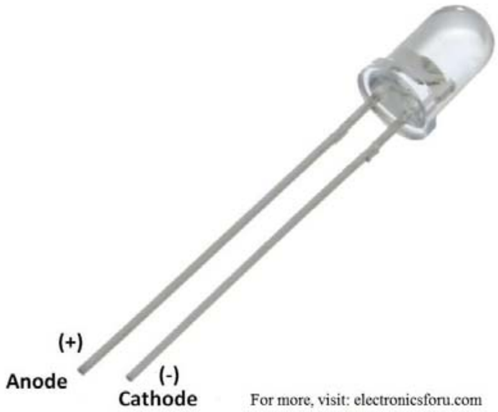


Figure 9: Pin configuration of IR LED

3.3 IR sensor

An IR sensor is a device that detects IR radiation falling on it. Proximity sensors (used in touch screen phones and edge avoiding robots), contrast sensors (used in line following robots) and obstruction counters/sensors (used for counting goods and in burglar alarms) are some applications involving IR sensors.

3.3.1 Principle of Working

An IR sensor consists of two parts, the emitter circuit and the receiver circuit. This is collectively known as a photo-coupler or an optocoupler.

The emitter is an IR LED and the detector is an IR photodiode. The IR phototdiode is sensitive to the IR light emitted by an IR LED. The photo-diode's resistance and output voltage change in proportion to the IR light received. This is the underlying working principle of the IR sensor.

The type of incidence can be direct incidence or indirect incidence. In direct incidence, the IR LED is placed in front of a photodiode with no obstacle in between. In indirect incidence, both the diodes are placed side by side with an opaque object in front of the sensor. The light from the IR LED hits the opaque surface and reflects back to the photodiode.**DS18B20 Block Diagram**

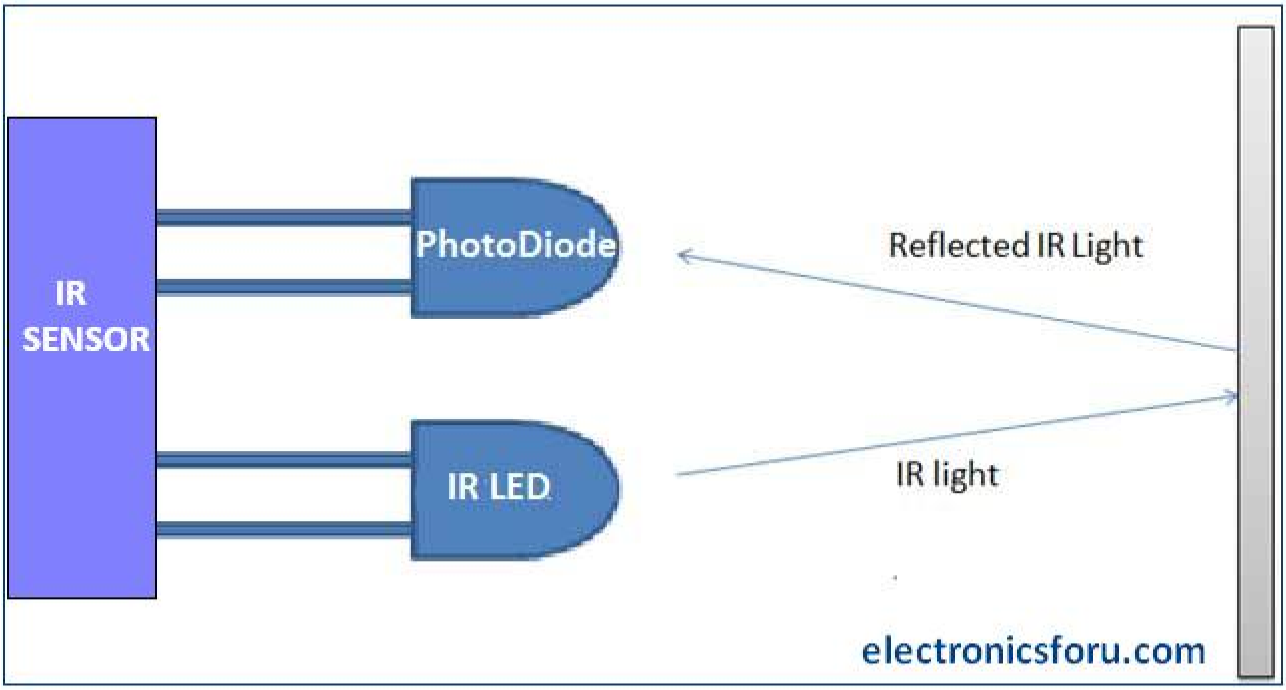


Figure 10: Working Principle of IR LED (Obstacle detection)

3.4 Variety of applications of IR Sensors

Proximity Sensors

Proximity sensors employ reflective indirect incidence principle. The photodiode receives the radiation emitted by the IR LED once reflected back by the object. Closer the object, higher will be the intensity of the incident radiation on the photodiode. This intensity is converted to voltage to determine the distance. Proximity sensors find use in touch screen phones, among other devices. The display is disabled during calls, so that even if the cheek makes contact with the touch screen, there is no effect.

Line Follower Robots

In line following robots, IR sensors detect the color of the surface underneath it and send a signal to the microcontroller or the main circuit which then takes decisions according to the algorithm set by the creator of the bot. Line followers employ reflective or non-reflective indirect incidence. The IR is reflected back to the module from the white surface around the black line. But IR radiation is absorbed completely by black color. There is no reflection of the IR radiation going back to the sensor module in black color.

Item Counter

Item counter is implemented on the basis of direct incidence of radiation on the photodiode. Whenever an item obstructs the invisible line of IR radiation, the value of a stored variable in a computer/microcontroller is incremented. This is indicated by LEDs, seven segment displays and LCDs. Monitoring systems of large factories use these counters for counting products on conveyor belts.

Burglar Alarm

Direct incidence of radiation on the photodiode is applicable in burglar alarm circuit. The IR LED is fit on one side of the door frame and the photodiode on the other. The IR radiation emitted by the IR LED falls on the photodiode directly under normal circumstances. As soon as a person obstructs the IR path, the alarm goes off. This mechanism is used extensively in security systems and is replicated on a smaller scale for smaller objects, such as exhibits in an exhibition.

IR Music Transmitter and Receiver

Using IR transmitter/receiver & music generator, audio musical notes can be generated and heard up to a distance of 10 metres. The IR music transmitter works off a 9V battery, while the IR music receiver works off regulated 9V to 12V.

Playing With IR Sensors

There are various applications of IR sensors such as TV remote controllers, burglar alarms and object counters. Here we have used IR sensors (infrared LEDs) to make an object-detection circuit and also a proximity sensor for path-tracking robots.

3.5 INTERFACING THE IR SENSOR WITH THE MICROCONTROLLER

Infrared is light that has a wavelength longer than visible red light. The ranges of infrared include near infrared, mid infrared and far infrared, spanning wavelengths from about 710 nanometers (near infrared) to 100 micrometers (far infrared).

All objects emit light according to their temperature–this is called “black body radiation.” The hotter the object, the shorter wavelength of light it emits. The Earth emits infrared light at a peak of about nine to 10 micrometers–and so do warm-blooded animals like humans. This light can be used to detect motion or warmth.

3.5.1 IR Sensor Module

Infrared Obstacle Sensor Module has builtin IR transmitter and IR receiver that sends out IR energy and looks for reflected IR energy to detect presence of any obstacle in front of the sensor module. The module has on board potentiometer that lets user adjust detection range. The sensor has very good and stable response even in ambient light or in complete darkness.

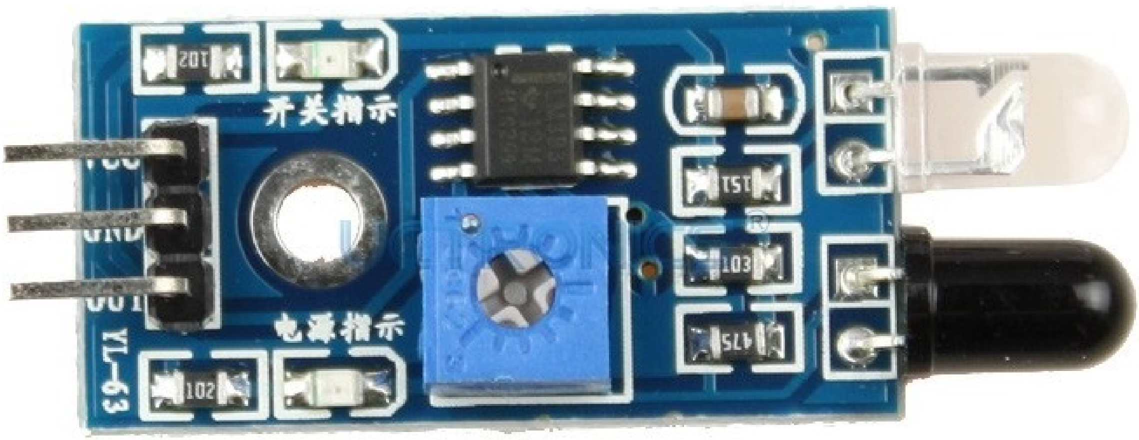


Figure 11: IR Sensor Module

3.5.2 Specifications

- Operating Voltage: 3.0V – 5.0V
- Detection range: 2cm – 30cm (Adjustable using potentiometer)
- Current Consumption:at 3.3V : ~23 mA,at 5.0V: ~43 mA
- Active output level: Outputs Low logic level when obstacle is detected
- On board Obstacle Detection LED indicator

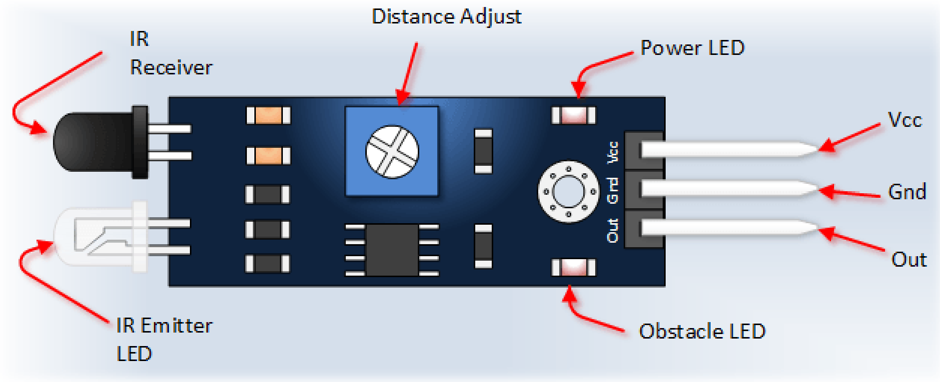


Figure 12: IR Sensor Module pin configuration

3.5.3 Working Principle of IR Obstacle Sensor

An IR sensor consists of an IR LED and an IR Photodiode; together they are called as Photo–Coupler or Opto–Coupler. As said before, the Infrared Obstacle Sensor has builtin IR transmitter and IR receiver. Infrared Transmitter is a light emitting diode (LED) which emits infrared radiations. Hence, they are called IR LED's. Even though an IR LED looks like a normal LED, the radiation emitted by it is invisible to the human eye.

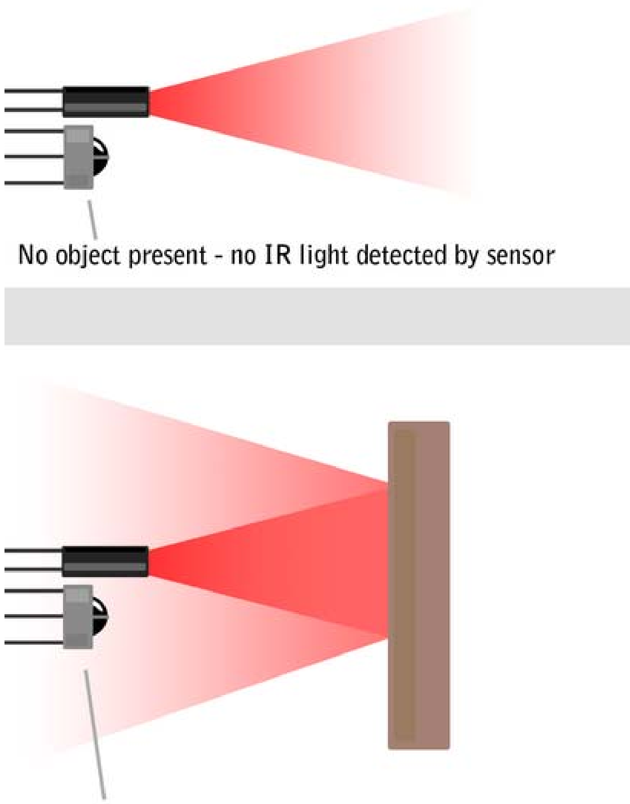


Figure 13: IR sensor Interfacing with microcontroller

Infrared receivers are also called as infrared sensors as they detect the radiation from an IR transmitter. IR receivers come in the form of photodiodes and phototransistors. Infrared

Photodiodes are different from normal photo diodes as they detect only infrared radiation. When the IR transmitter emits radiation, it reaches the object and some of the radiation reflects back to the IR receiver. Based on the intensity of the reception by the IR receiver, the output of the sensor is defined.

3.6 IR Sensor Interfacing with 8051

IR Sensor Connection
Vcc – 5v
Gnd – Ground
Vout – P1.0

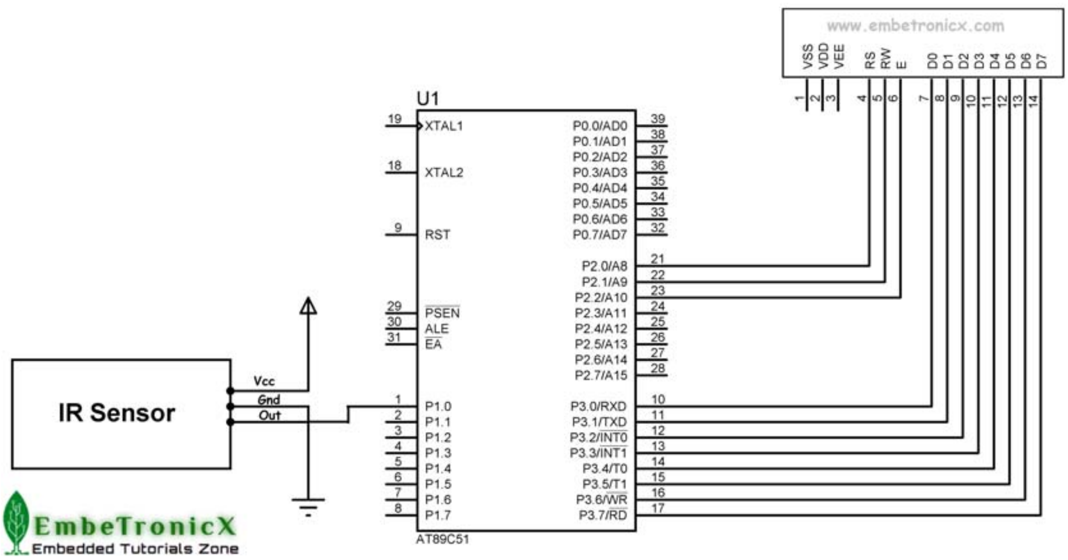


Figure 14: IR sensor connection with 8051 microcontroller

3.6.1 Source Code

If it is detecting any object in front of this sensor, LCD will display "Obstacle Detected".

```
#include<reg51.h>
#define lcd P3

sbit IR=P1^0;

sbit rs=P2^0; //register select
sbit rw=P2^1; //RW
sbit en=P2^2; //enable

void lcd_init();
void cmd(unsigned char);
void dat(unsigned char);
void delay();
```

```
void lcd_string(char *s);

void main()
{
    lcd_init();
    lcd_string("  EmbeTronicX   ");
    while(1) {
        if(IR == 0) {
            cmd(0xc0);
            lcd_string("Obstacle Detected");
            delay();
        } else {
            cmd(0xc0);
            lcd_string("                ");
        }
    }
}

void lcd_init()
{
    cmd(0x38);
    cmd(0x0e);
    cmd(0x06);
    cmd(0x01);
    cmd(0x80);
}

void cmd(unsigned char a)
{
    lcd=a;
    rs=0;
    rw=0;
    en=1;
    delay();
    en=0;
}

void dat(unsigned char b)
{
    lcd=b;
    rs=1;
    rw=0;
    en=1;
    delay();
    en=0;
}
```

```
void lcd_string(char *s)
{
   while(*s) {
      dat(*s++);
    }
}

void delay()
{
   unsigned int i;
   for(i=0;i<20000;i++);
}
```

If you want to sense more distance you can use below IR sensor. You can also adjust the distance using this. IR Sensor Interfacing With 8051This is an Infrared Transmitter and receiver which together make up a photoelectric sensor. The sensor has a long detection distance, and has less interference by visible light because it uses modulated Infrared light. This sensor has a screwdriver adjustment to set the detected distance, then gives a digital output when it senses something within that range. This sensor does not return a distance VALUE.

3.7 Interfacing 16×2 LCD with 8051

LCD display is an inevitable part in almost all embedded projects and this article is about interfacing a 16×2 LCD with 8051 microcontroller. Many guys find it hard to interface LCD module with the 8051 but the fact is that if you learn it properly, its a very easy job and by knowing it you can easily design embedded projects like digital voltmeter / ammeter, digital clock, home automation displays, status indicator display, digital code locks, digital speedometer/ odometer, display for music players etc etc. Thoroughly going through this article will make you able to display any text (including the extended characters) on any part of the 16×2 display screen. In order to understand the interfacing first you have to know about the 16×2 LCD module.

16×2 LCD module

16×2 LCD module is a very common type of LCD module that is used in 8051 based embedded projects. It consists of 16 rows and 2 columns of 5×7 or 5×8 LCD dot matrices. The module were are talking about here is type number JHD162A which is a very popular one. It is available in a 16 pin package with back light, contrast adjustment function and each dot matrix has 5×8 dot resolution. The pin numbers, their name and corresponding functions are shown in the table below.

Table 1: LCD module Pin Configuration

Pin No:	Name	Function
1	VSS	This pin must be connected to the ground
2	VCC	Positive supply voltage pin (5V DC)

3	VEE	Contrast adjustment
4	RS	Register selection
5	R/W	Read or write
6	E	Enable
7	DB0	Data
8	DB1	Data
9	DB2	Data
10	DB3	Data
11	DB4	Data
12	DB5	Data
13	DB6	Data
14	DB7	Data
15	LED+	Back light LED+
16	LED-	Back light LED-

VEE pin is meant for adjusting the contrast of the LCD display and the contrast can be adjusted by varying the voltage at this pin. This is done by connecting one end of a POT to the Vcc (5V), other end to the Ground and connecting the center terminal (wiper) of of the POT to the VEE pin. See the circuit diagram for better understanding.

The JHD162A has two built in registers namely data register and command register. Data register is for placing the data to be displayed, and the command register is to place the commands. The 16×2 LCD module has a set of commands each meant for doing a particular job with the display. We will discuss in detail about the commands later. High logic at the RS pin will select the data register and Low logic at the RS pin will select the command register. If we make the RS pin high and the put a data in the 8 bit data line (DB0 to DB7) , the LCD module will recognize it as a data to be displayed . If we make RS pin low and put a data on the data line, the module will recognize it as a command.

R/W pin is meant for selecting between read and write modes. High level at this pin enables read mode and low level at this pin enables write mode.

E pin is for enabling the module. A high to low transition at this pin will enable the module.

DB0 to DB7 are the data pins. The data to be displayed and the command instructions are placed on these pins.

LED+ is the anode of the back light LED and this pin must be connected to Vcc through a suitable series current limiting resistor. LED- is the cathode of the back light LED and this pin must be connected to ground.

3.7.1 16×2 LCD module commands.

16×2 LCD module has a set of preset command instructions. Each command will make the module to do a particular task. The commonly used commands and their function are given in the table below.

Table 2: LCD module Command Sets

Command	Function
0F	LCD ON, Cursor ON, Cursor blinking ON
01	Clear screen
02	Return home
04	Decrement cursor
06	Increment cursor
0E	Display ON ,Cursor blinking OFF
80	Force cursor to the beginning of 1st line
C0	Force cursor to the beginning of 2nd line
38	Use 2 lines and 5×7 matrix
83	Cursor line 1 position 3
3C	Activate second line
08	Display OFF, Cursor OFF
C1	Jump to second line, position1
OC	Display ON, Cursor OFF
C1	Jump to second line, position1
C2	Jump to second line, position2

3.7.2 LCD initialization

The steps that have to be done for initializing the LCD display is given below and these steps are common for almost all applications.

Send 38H to the 8 bit data line for initialization

Send 0FH for making LCD ON, cursor ON and cursor blinking ON.

Send 06H for incrementing cursor position.

Send 01H for clearing the display and return the cursor.

Sending data to the LCD.

The step for sending data to the LCD module is given below. I have already said that the LCD module has pins namely RS, R/W and E. It is the logic state of these pins that make the module to determine whether a given data input is a command or data to be displayed.

Make R/W low.

Make RS=0 if data byte is a command and make RS=1 if the data byte is a data to be displayed.

Place data byte on the data register.

Pulse E from high to low.

Repeat above steps for sending another data.

3.7.3 Circuit diagram

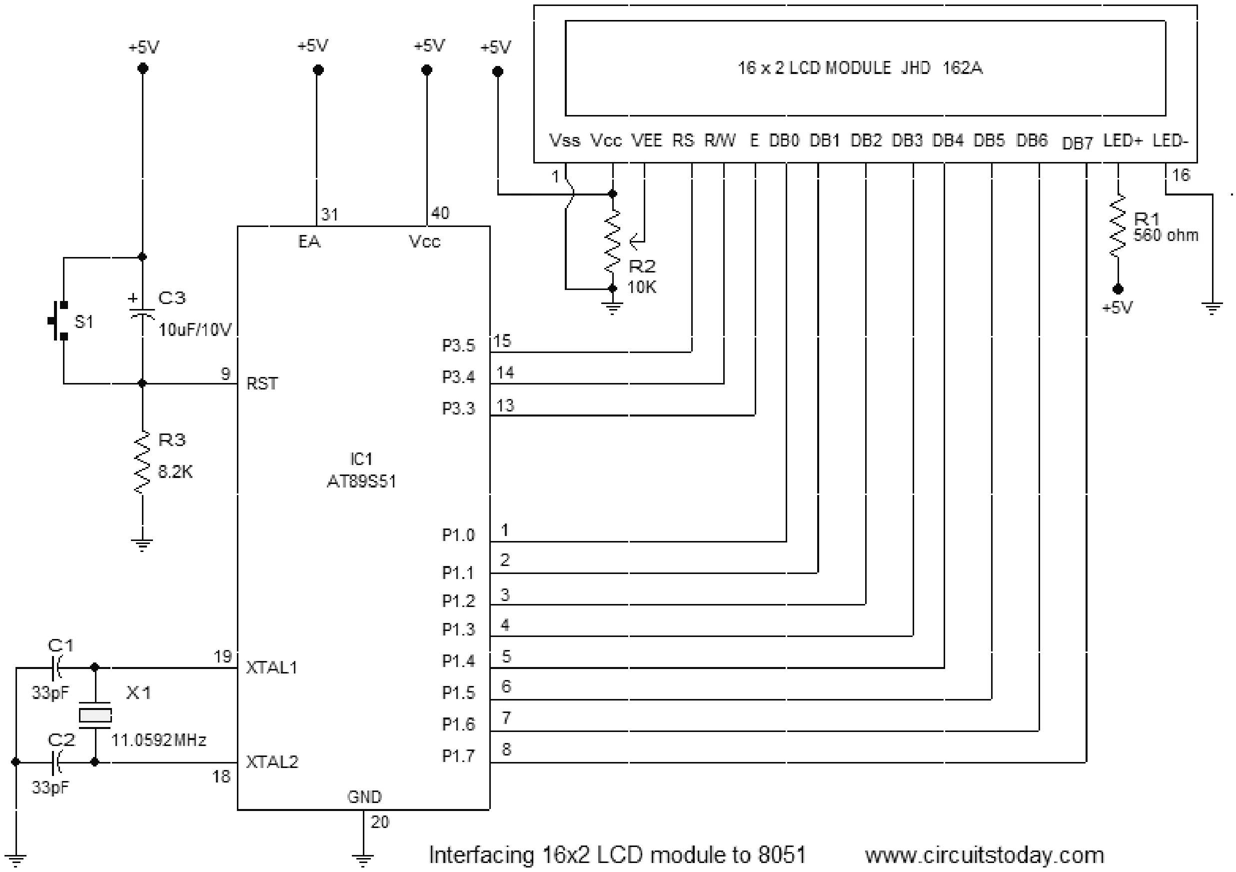


Figure 15: Interfacing 16x2 LCD module with the microcontroller (8 bit mode)

The circuit diagram given above shows how to interface a 16×2 LCD module with AT89S1 microcontroller. Capacitor C3, resistor R3 and push button switch S1 forms the reset circuitry. Ceramic capacitors C1,C2 and crystal X1 is related to the clock circuitry which produces the system clock frequency. P1.0 to P1.7 pins of the microcontroller is connected to the DB0 to DB7 pins of the module respectively and through this route the data goes to the LCD module. P3.3, P3.4 and P3.5 are connected to the E, R/W, RS pins of the microcontroller and through this route the control signals are transferred to the LCD module. Resistor R1 limits the current through the back light LED and so do the back light intensity. POT R2 is used for adjusting the contrast of the display. Program for interfacing LCD to 8051 microcontroller is shown below.

3.7.4 Program

```
MOV A,#38H // Use 2 lines and 5x7 matrix
ACALL CMND
MOV A,#0FH // LCD ON, cursor ON, cursor blinking ON
ACALL CMND
MOV A,#01H //Clear screen
ACALL CMND
MOV A,#06H //Increment cursor
```

```
ACALL CMND
MOV A,#82H //Cursor line one , position 2
ACALL CMND
MOV A,#3CH //Activate second line
ACALL CMND
MOV A,#49D
ACALL DISP
MOV A,#54D
ACALL DISP
MOV A,#88D
ACALL DISP
MOV A,#50D
ACALL DISP
MOV A,#32D
ACALL DISP
MOV A,#76D
ACALL DISP
MOV A,#67D
ACALL DISP
MOV A,#68D
ACALL DISP

MOV A,#0C1H //Jump to second line, position 1
ACALL CMND

MOV A,#67D
ACALL DISP
MOV A,#73D
ACALL DISP
MOV A,#82D
ACALL DISP
MOV A,#67D
ACALL DISP
MOV A,#85D
ACALL DISP
MOV A,#73D
ACALL DISP
MOV A,#84D
ACALL DISP
MOV A,#83D
ACALL DISP
MOV A,#84D
ACALL DISP
MOV A,#79D
ACALL DISP
MOV A,#68D
ACALL DISP
```

```
MOV A,#65D
ACALL DISP
MOV A,#89D
ACALL DISP

HERE: SJMP HERE

CMND: MOV P1,A
CLR P3.5
CLR P3.4
SETB P3.3
CLR P3.3
ACALL DELY
RET

DISP:MOV P1,A
SETB P3.5
CLR P3.4
SETB P3.3
CLR P3.3
ACALL DELY
RET

DELY: CLR P3.3
CLR P3.5
SETB P3.4
MOV P1,#0FFh
SETB P3.3
MOV A,P1
JB ACC.7,DELY

CLR P3.3
CLR P3.4
RET

END
```

Subroutine CMND sets the logic of the RS, R/W, E pins of the LCD module so that the module recognizes the input data (given to DB0 to DB7) as a command.

Subroutine DISP sets the logic of the RS, R/W, E pins of the module so that the module recognizes the input data as a data to be displayed.

3.7.5 Interfacing LCD Module to 8051 in 4 Bit Mode (using only 4 pins)

The microcontroller like 8051 has only limited number of GPIO pins (GPIO – general purpose input output). So to design complex projects we need sufficient number of I/O pins. An LCD module can be interfaced with a microcontroller either in 8 bit mode (as seen above) or in 4 bit mode. 8 bit mode is the conventional mode which uses 8 data lines and RS, R/W, E pins for functioning. However 4 bit mode uses only 4 data lines along with the control pins. This will saves the number of GPIO pins needed for other purpose.

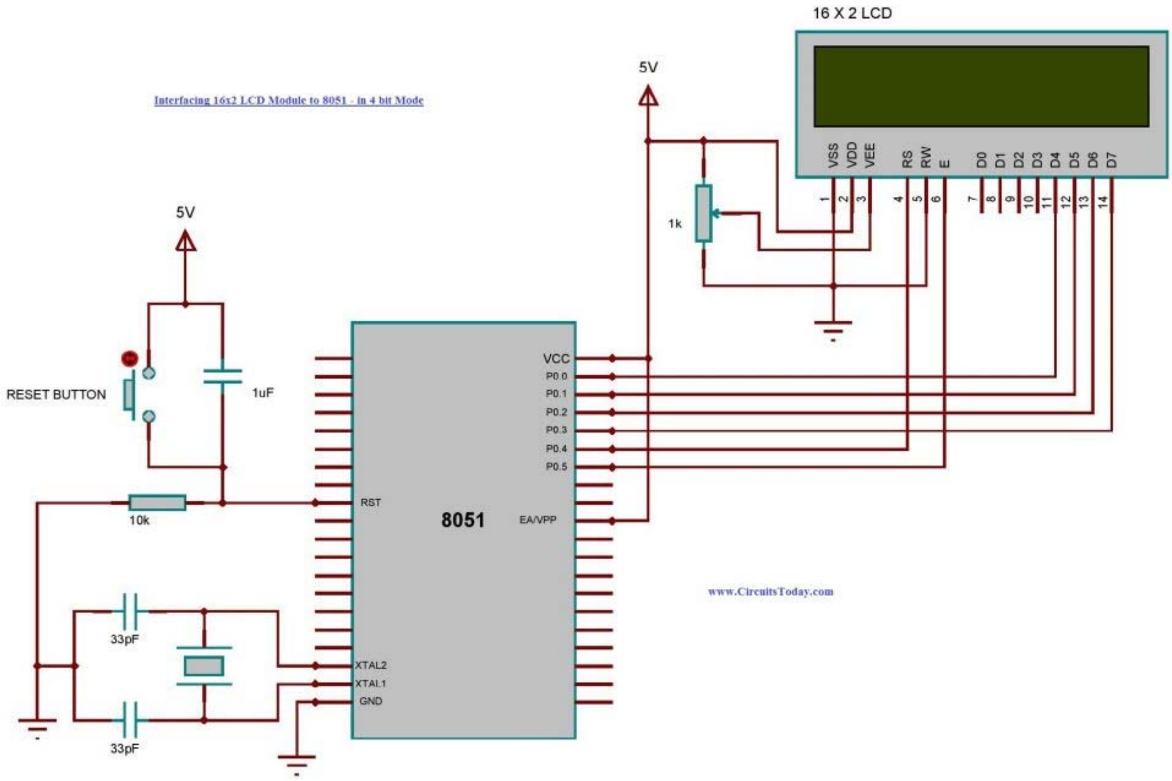


Figure 16: Interfacing 16x2 LCD module with the microcontroller (4 bit mode)

As shown in the circuit diagram, port 0 of the controller is used for interfacing it with LCD module. In 4 bit mode only 4 lines D4-D7, along with RS, R/W and E pins are used. This will save us 4 pins of our controller which we might employ it for other purpose. Here we only need to write to the LCD module. So the R/W pin can be ground it as shown in the schematic diagram. In this way the total number of pins can be reduced to 6. In 4 Bit mode the data bytes are split into two four bits and are transferred in the form of a nibble. The data transmission to a LCD is performed by assigning logic states to the control pins RS and E. The reset circuit, oscillator circuit and power supply need to be provided for the proper working of the circuit.

3.7.6 Program – Interface LCD Module to 8051 – 4 Bit Mode

RS EQU P0.4
EN EQU P0.5
PORT EQU P0
U EQU 30H

```
L EQU 31H
ORG 000H

MOV DPTR,#INIT_COMMANDS
ACALL LCD_CMD
MOV DPTR,#LINE1
ACALL LCD_CMD
MOV DPTR,#TEXT1
ACALL LCD_DISP
MOV DPTR,#LINE2
ACALL LCD_CMD
MOV DPTR,#TEXT2
ACALL LCD_DISP
SJMP $

SPLITER: MOV L,A
ANL L,#00FH
SWAP A
ANL A,#00FH
MOV U,A
RET

MOVE: ANL PORT,#0F0H
ORL PORT,A
SETB EN
ACALL DELAY
CLR EN
ACALL DELAY
RET

LCD_CMD: CLR A
MOVC A,@A+DPTR
JZ EXIT2
INC DPTR
CLR RS
ACALL SPLITER
MOV A,U
ACALL MOVE
MOV A,L
ACALL MOVE
SJMP LCD_CMD
EXIT2: RET


LCD_DATA: SETB RS
ACALL SPLITER
MOV A,U
```

```
ACALL MOVE
MOV A,L
ACALL MOVE
RET

LCD_DISP: CLR A
MOVC A,@A+DPTR
JZ EXIT1
INC DPTR
ACALL LCD_DATA
SJMP LCD_DISP
EXIT1: RET

 DELAY: MOV R7, #10H
L2: MOV R6,#0FH
L1: DJNZ R6, L1
DJNZ R7, L2
RET

INIT_COMMANDS: DB 20H,28H,0CH,01H,06H,80H,0
LINE1: DB 01H,06H,06H,80H,0
LINE2: DB 0C0H,0
CLEAR: DB 01H,0

TEXT1: DB " CircuitsToday ",0
TEXT2: DB "4bit Using 1Port",0

END
```

3.7.7 Important aspects of the program

The programming part is done in assembly language instead of embedded C. As mentioned earlier the 8 bit data is breaks into two 4 bit data and send to LCD. A subroutine called “SPLITTER” is used in the program for slicing 8 bit data into nibbles. It uses two memory location ‘U’ and ‘L’ for storing the upper and lower nibbles. The subroutine named “MOVE” is used to put the upper and lower nibbles into the data pins of the LCD by making a high to low pulse at the E pin of the LCD module. If we need to send a command, “LCD_CMD” is used. In this subroutine the RS pin of the LCD is cleared in order to notify the LCD that the byte at its data pins is a command. And subroutine labeled “LCD_DISP” is used for sending data. Here the RS pin is set which will notify the LCD that the byte arrived is a data for displaying. The necessary commands for the LCD initialization are defined at the end part of the program. Along with that the text to be displayed is also defined there with a label “TEXT1”. “LINE1” AND “LINE2” labels contain the commands for selecting the 1st and 2nd rows of the LCD respectively.

CHAPTER 4

(Hardware Modeling)

4.1 Main features of the prototype

The features of the developed prototype are:

- IR sensors are used so that no external light source are required
- LCD display (showing the number of persons inside the classroom)
- Separate Buzzer indication for entry and exit
- 7 independent load can be controlled (ON/OFF control)
- 5 Volt operation (both control board and ON & OFF relay)
- Automatically switch off all the loads if no persons inside.
- Switch on the loads sequentially as the number of persons increased
- Cost effective (Rs 670/- approx)

4.2 Overview of the Project

Working process of the project is described in figure 17. This prototype can control all the loads inside the classroom automatically. Based on the number of persons entered inside the classroom the loads can be switch on sequentially. Here it is designed that if the number of persons inside the classroom is between 1 to 5, then the light 1 (Figure 17) is switch on. For

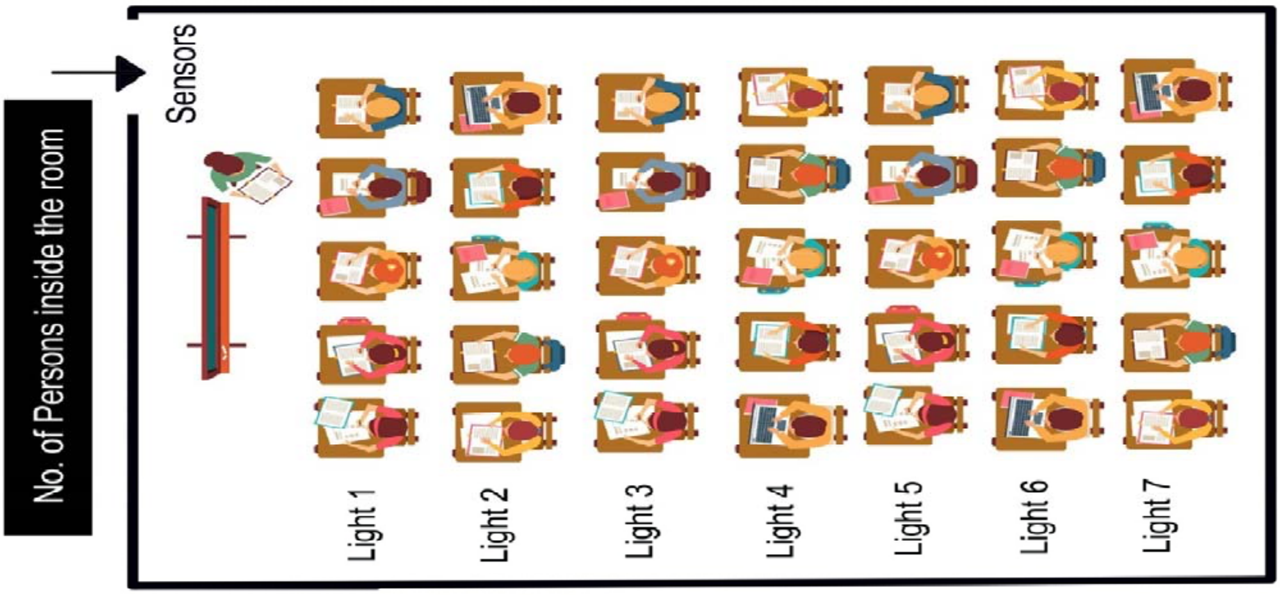
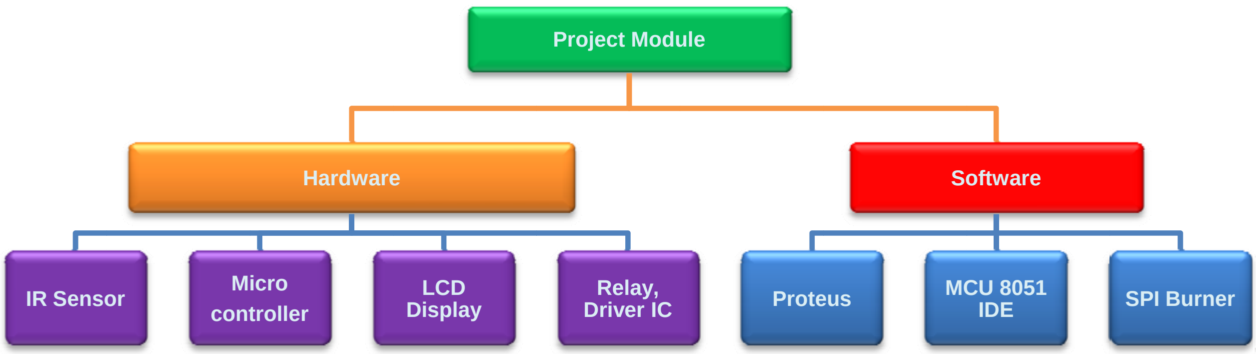


Figure 17: Overview of the projects

persons between 6 to 10, the second row light is switch on. In this way the students have to seat in the front of the class and the lower row lights are switch off if the students inside the class are less. This will save the electricity as well as the energy of the teacher because the teacher may not be so loud if the students are less inside the classroom. The prototype also switch off all the light loads if everybody leaves the classroom.

4.3 Project layout



4.4 Control logic

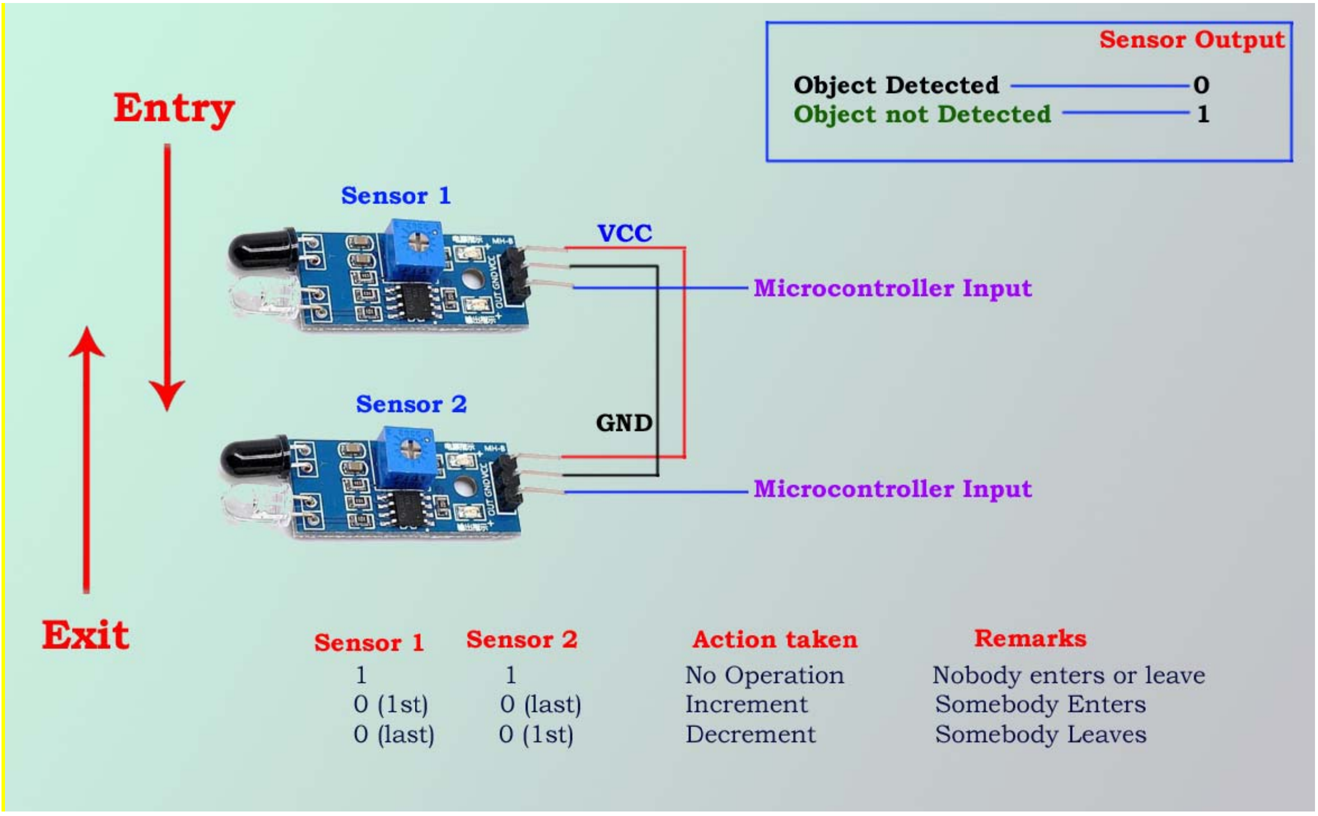


Figure 18: Control logic of the IR sensor

4.5 Time Frame

Table 3: Time frame of the project work

Task	Week	Status
To understand the project	1	Done
Literature Survey	2	Done
Component Listing	3	Done
Purchase from market	4	Done
Implement the circuit in BB	5-6	Done
Solder the circuit in PCB	7-10	Done
Testing and Correction	11-12	Done
Implement the relay board	13	Done
Interfacing the LCD Module	14	Done
Check circuit status	15	Done
Making a model	16	Done
Final assembling & Testing	17-20	Done
Suggestive Implementation	21-22	Done
Report Writing	rest	Done

4.6 Components required

Table 4: Component listing

Sl. No.	Component	Qtn
1.	AT89c51 µC	1
2.	11.0592 MHz Crystal	1
3.	33 pf Capacitor	2
4.	General PCB	1
5.	Jumper wire	10
6.	330 Ω Resistance	8
7.	Piezo Buzzer	1
8.	16 pin IC base	1
9.	Wire striper	1
10.	Soldering Iron	1
11.	40 pin IC base	1
12.	10µF Capacitor	2
13.	ULN 2003 A IC	1
14.	Static Relay (5 volt)	7
15.	16x2 LCD Module	1
16.	5 mm LED (Red/Green)	8
17.	Single strand wire	3m
18.	Wire nipper	1
19.	De-soldering pump	1
20.	Soldering material	1

4.7 Cost estimation of the prototype

Table 5: Cost estimation of the project

Sl. No.	Component	Qtn	Price (Rs)
	IR Sensor module	2	100
1.	AT89c51 μC	1	60
2.	11.0592 MHz Crystal	1	10
3.	33 pf Capacitor	2	5
4.	General PCB	1	40
5.	Jumper wire	10	50
6.	330 Ω Resistance	8	10
7.	Piezo Buzzer	1	20
8.	16 pin IC base	1	2
9.	40 pin IC base	1	5
10.	10μF Capacitor	2	5
11.	ULN 2003 A IC	1	20
12.	Static Relay (5 volt)	7	140
13.	16x2 LCD Module	1	180
14.	5 mm LED (Red/Green)	8	10
15.	Single strand wire	3m	30
TOTAL COST (Estimated)			680 /-

4.8 Hardware connection

4.8.1 16 × 2 LCD Module interfacing

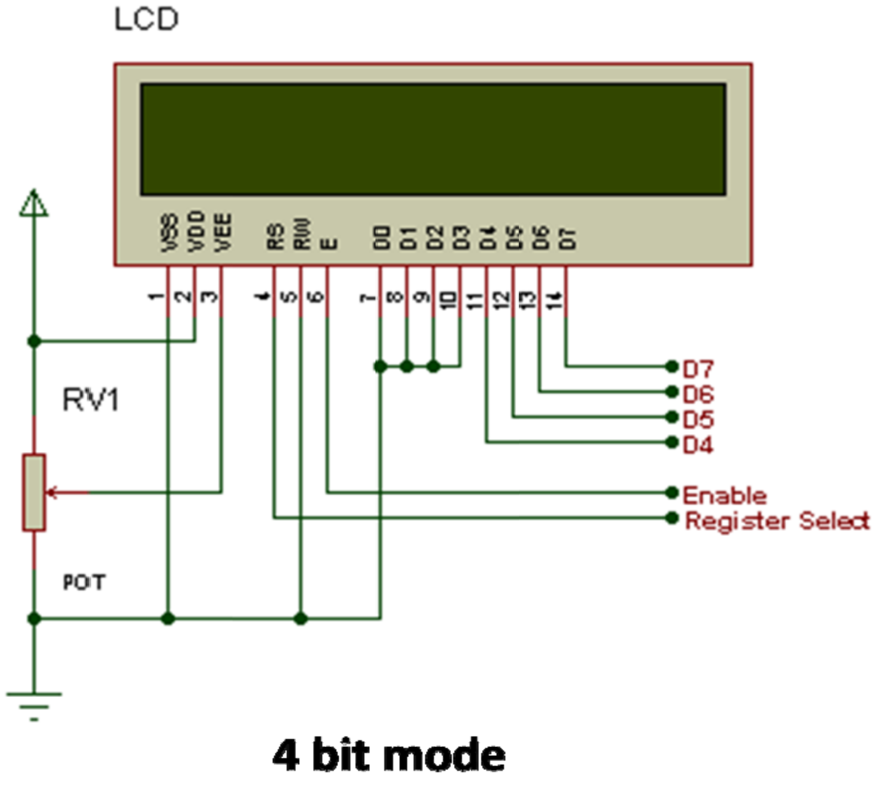


Figure 19: 4 bit mode LCD Interfacing

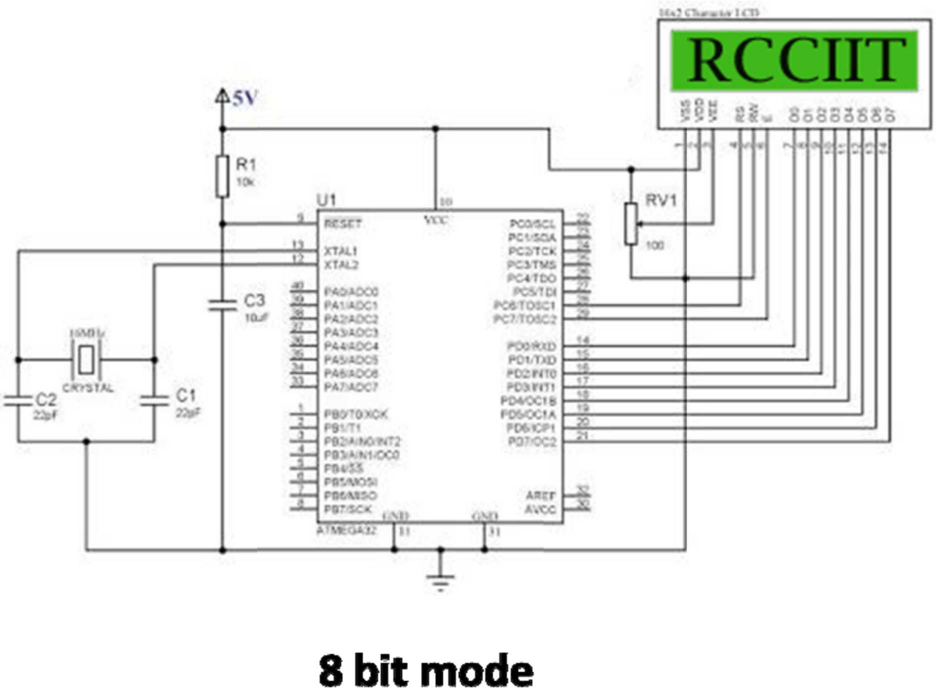


Figure 20: 8 bit mode LCD Interfacing

4.8.2 LCD AT Commands

Table 6: LCD Attention (AT) Command

Code (Hex)	Command to LCD Instruction Register
1	Clear display screen
2	Return home
4	Decrement cursor (shift cursor to left)
6	Increment cursor (shift cursor to right)
5	Shift display right
7	Shift display left
8	Display off, cursor off
A	Display off, cursor on
C	Display on, cursor off
E	Display on, cursor blinking
F	Display on, cursor blinking
10	Shift cursor position to left
14	Shift cursor position to right
18	Shift the entire display to the left
1C	Shift the entire display to the right
80	Force cursor to beginning to 1st line
C0	Force cursor to beginning to 2nd line
38	2 lines and 5x7 matrix

4.8.3 LCD Reset subroutine in AT89c51

```
lcd_reset:                  ;LCD reset sequence
        mov lcd_port, #0FFH
        mov delay,#20       ;20mS delay
        acall delayms
        mov lcd_port, #83H  ;Data = 30H, EN = 1, First Init
        mov lcd_port, #03H  ;Data = 30H, EN = 0
        mov delay,#10       ;Delay 10mS
        acall delayms
        mov lcd_port, #83H  ;Second Init, Data = 30H, EN = 1
        mov lcd_port, #03H  ;Data = 30H, EN = 0
        mov delay,#1        ;Delay 5mS
        acall delayms
        mov lcd_port, #83H  ;Third Init
        mov lcd_port, #03H
        mov delay,#1        ;Delay 5mS
        acall delayms
        mov lcd_port, #82H  ;Select Data width (20H for 4bit)
```

```
        mov lcd_port, #02H      ;Data = 20H, EN = 0
        mov delay,#1            ;Delay 5mS
        acall delayms
ret
```

4.8.4 LCD Initialization subroutine in AT89c51 (4 bit mode)

```
 lcd_init:
        mov a,#28H              ;4-bit, 2 line, 5x7 dots
        acall CMND
        mov a,#0CH              ;LCD_DATAlay ON cursor OFF
        acall CMND
        mov a,#06H              ;Set entry mode (Auto increment)
        acall CMND
        mov a,#80H              ;Bring cursor to line 1
        acall CMND
 ret
```

4.8.5 LCD Command subroutine in AT89c51 (4 bit mode)

```
 CMND:                  ;LCD command Routine
        mov temp,a              ;Save a copy of command to temp
        swap a                  ;Swap to use higher nibble
        anl a,#0FH              ;Mask the first four bits
        add a,#80H              ;Enable = 1, RS = 0, RW = 0
        mov lcd_port,a          ;Move it to lcd port
        mov delay,#3            ;5mS delay
        acall delayms
        CLR EN

        mov a,temp              ;Reload the command from temp
        anl a,#0FH              ;Mask first four bits
        add a,#80H              ;Enable = 1
        mov lcd_port,a          ;Move to port
        mov delay,#3            ;5mS delay
        acall delayms
        CLR EN
 ret
```

4.8.6 LCD Display subroutine in AT89c51 (4 bit mode)

```
 DISP:                          ;LCD data Routine
        mov temp,a              ;Keep copy of data in temp
        swap a                  ;We need higher nibble
        anl a,#0FH              ;Mask first four bits
        add a,#0A0H             ;Enable = 1, RS = 1, RW = 0
```

```
        mov lcd_port,a        ;Move to lcd port
        mov delay,#3          ;5mS delay
        acall delayms
        clr en                ;Enable = 0

        mov a,temp            ;Reload the data from temp
        anl a,#0FH            ;we need lower nibble now
        add a,#0A0H           ;Enable = 1, RS = 1, RW = 0
        mov lcd_port,a        ;Move to lcd port
        mov delay,#3          ;5mS delay
        acall delayms
        clr en                ;Enable = 0
ret
```

4.8.7 Relay Driver interfacing with microcontroller

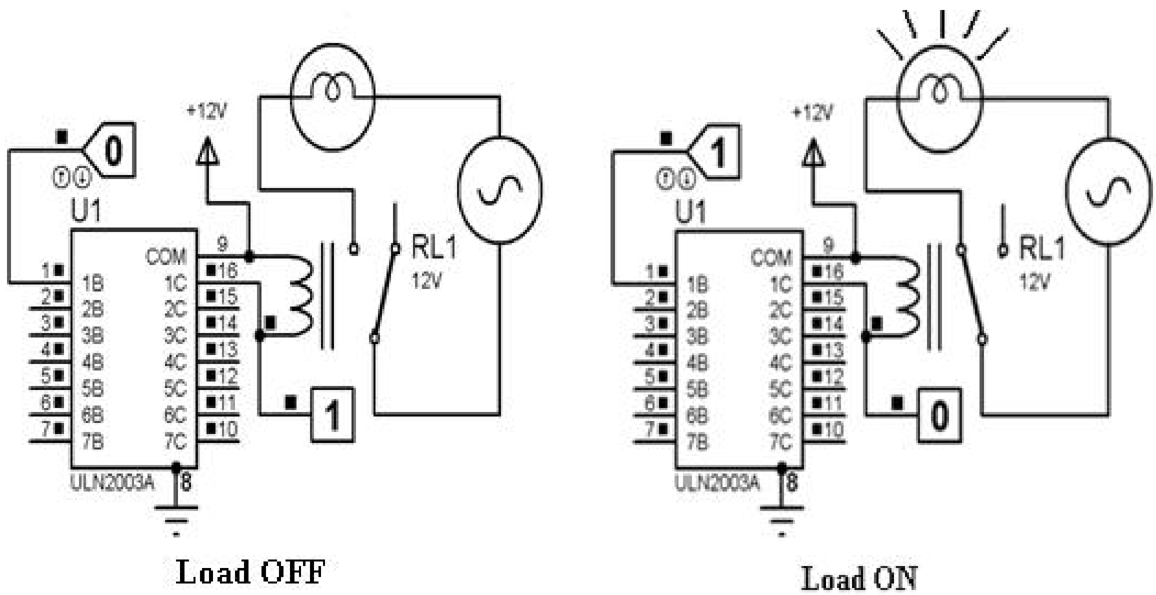


Figure 21: ULN2003A interfacing with microcontroller

The ULN2003A is a active high relay driver. 7 relays are controlled by this relay driver. Pin 1-7 are for controlling the relay which are connected to pin 10-16. For a ‘0’ from microcontroller the corresponding relay is turned off and a ‘1’ from microcontroller is turned on the relay.

CHAPTER 5

(Logic & Operation)

5.1 INTRODUCTION

After assembling the system, what remains is to observe its operation and efficiency of the system. The total system is divided in several sub systems, like

- IR sensor section
- Relay with driver
- LCD section

The operation of the whole circuit is depending on every sections performance.

5.2 Connection diagram of the prototype

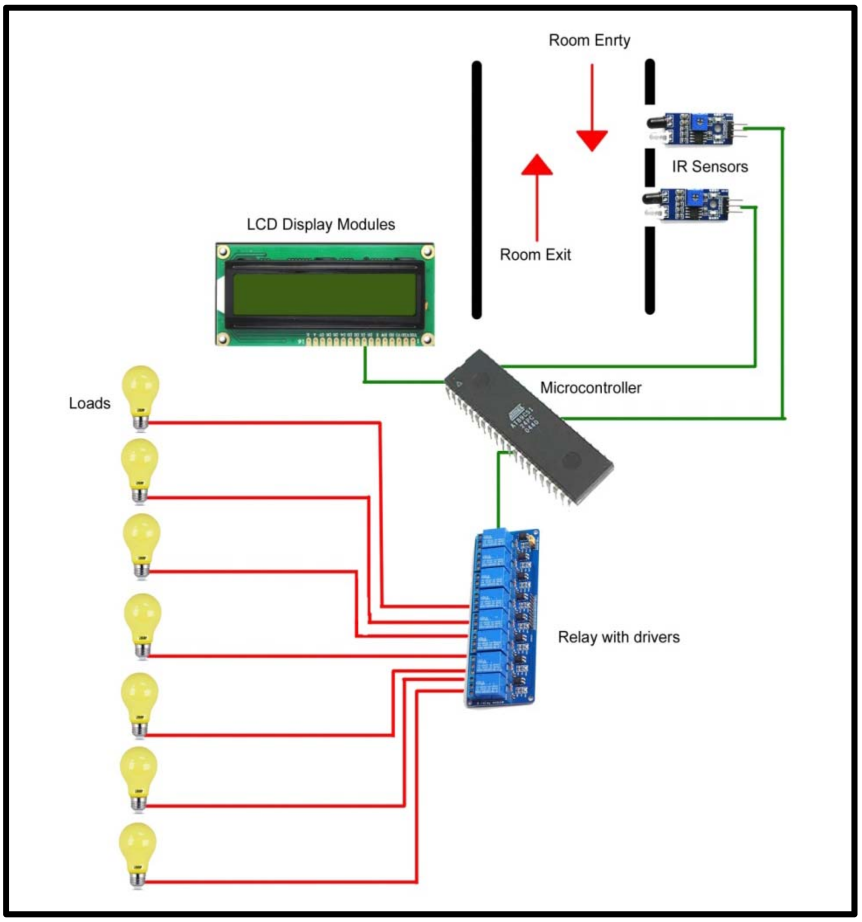


Figure 22: Connection diagram of the prototype

5.3 Principle & Operations

Working process of the project is described in figure 23. This prototype can control all the loads inside the classroom automatically. Based on the number of persons entered inside the classroom the loads can be switch on sequentially. Here it is designed that if the number of persons inside the classroom is between 1 to 5, then the light 1 (Figure 23) is switch on. For persons between 6 to 10, the second row light is switch on. In this way the students have to seat in the front of the class and the lower row lights are switch off if the students inside the class are less. This will save the electricity as well as the energy of the teacher because the teacher may not be so loud if the students are less inside the classroom. The prototype also switch off all the light loads if everybody leaves the classroom.

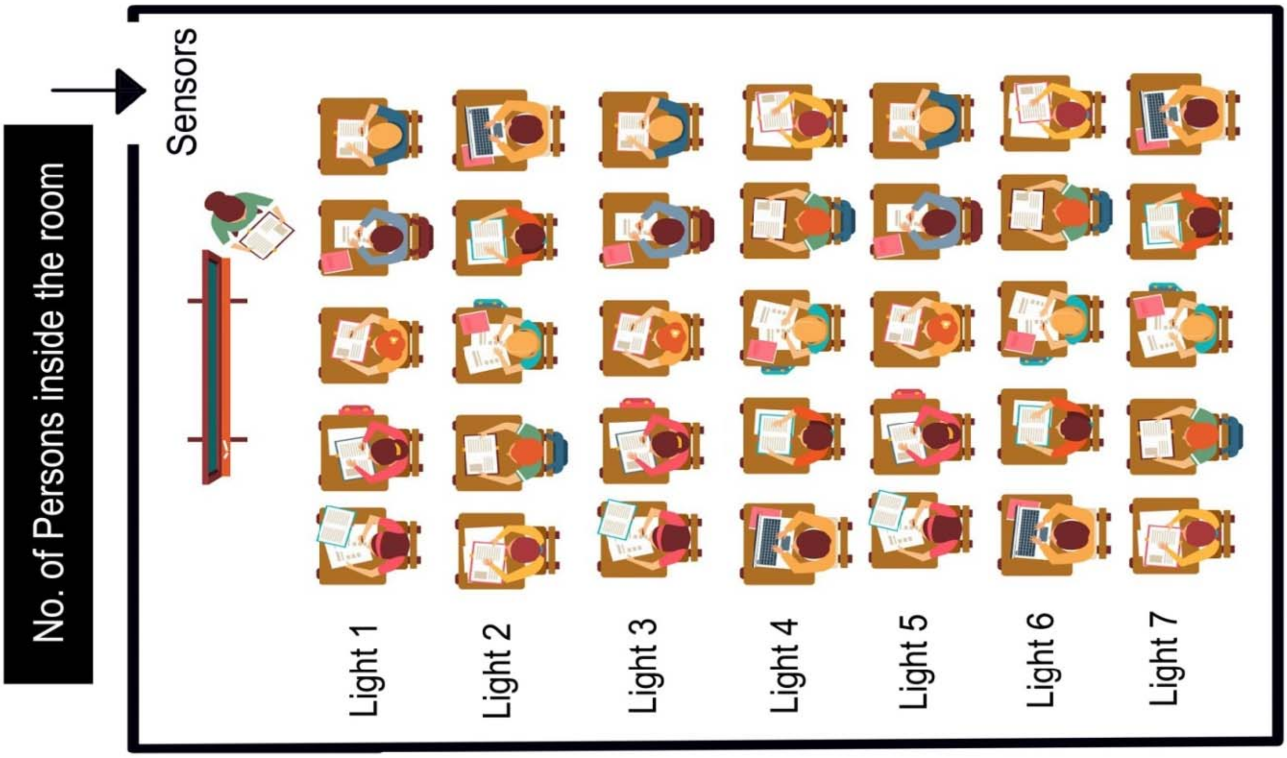


Figure 23: Working principle of the prototype

5.4 Advantages of the project

- IR sensors are used so that no external light source are required
- LCD display shows the number of persons inside the room
- Separate Buzzer indication for entry and exit
- 5v operation for control circuit
- Separate relay board with the same power supply
- 250V, 7A ac load may be connected.

5.5 Disadvantages

- Limited range of the IR sensors (1 – 1.5 meter)
- Large electrical load cannot be handled by the circuit (250V, 7A max)**

** it may be overcome if we replace the static relay by electrical contactor.

5.6 Flow chart of the program

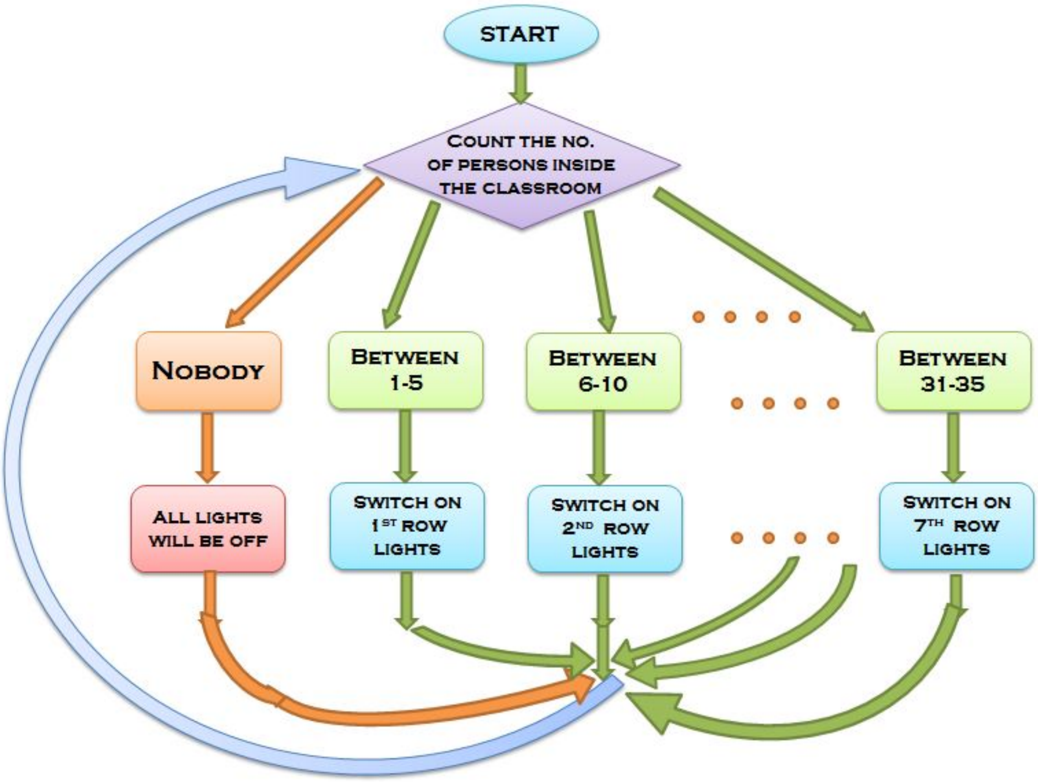


Figure 24: Flowchart of the program

5.7 Photographs of the prototype

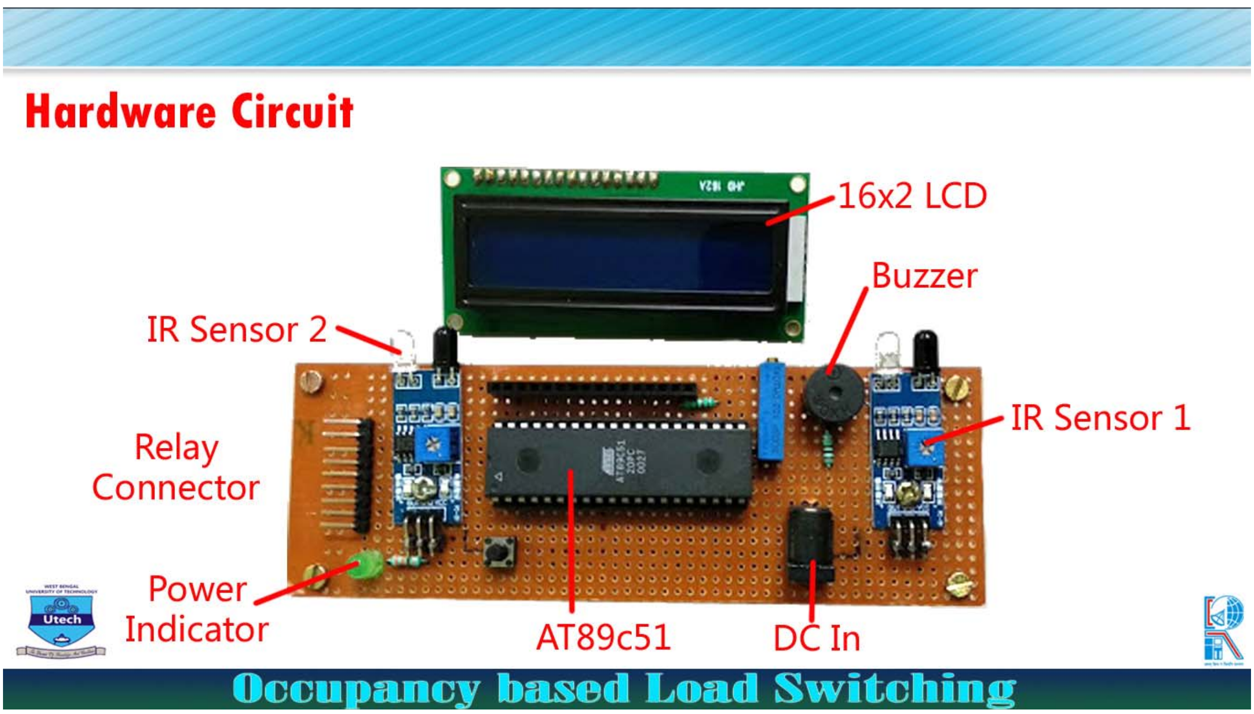


Figure 25: Main controller board with IR sensor

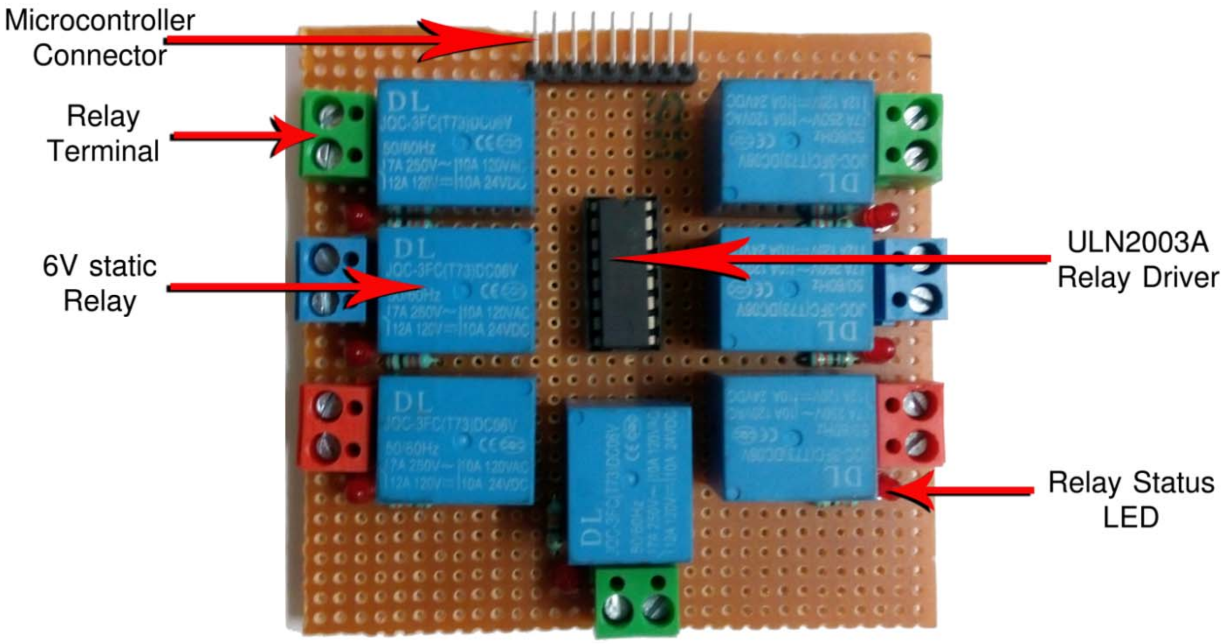


Figure 26: Relay Driver Board

5.8 Circuit diagram

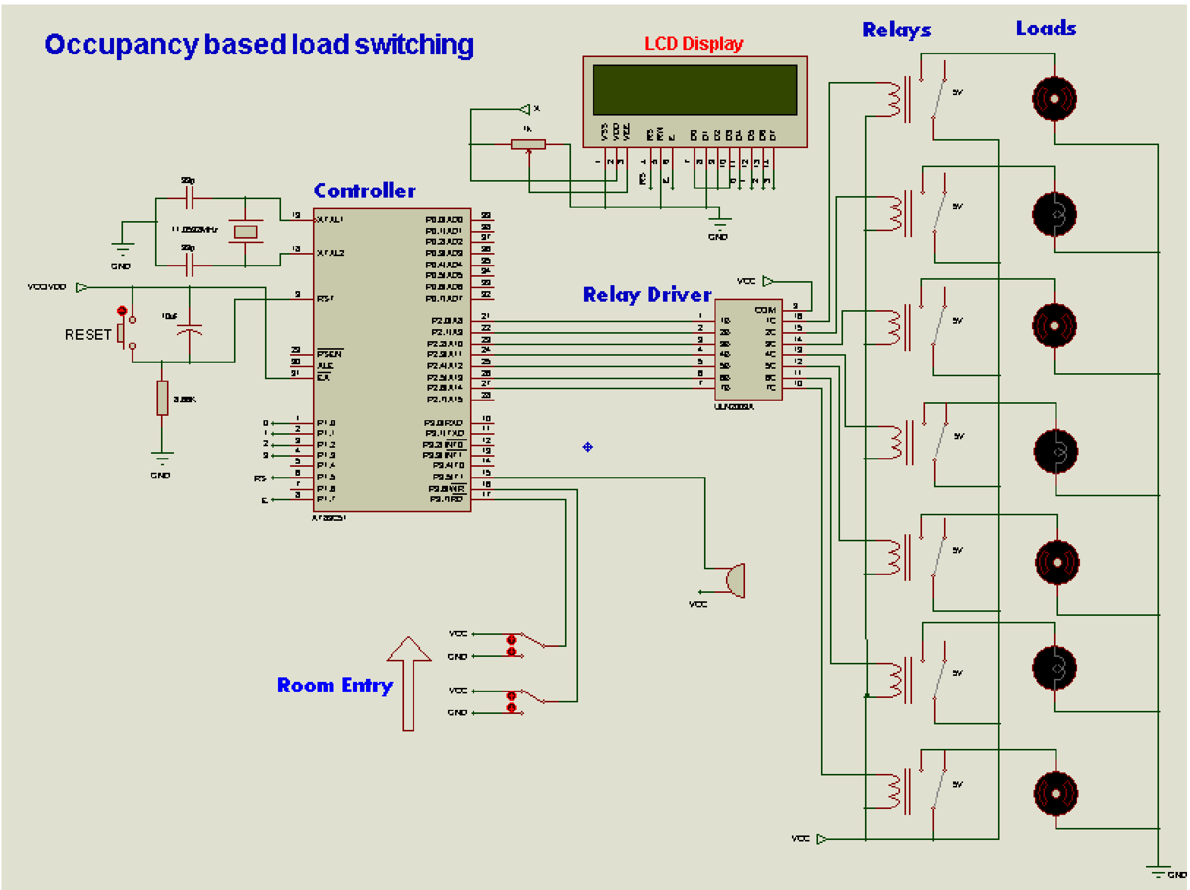


Figure 27: Circuit diagram of the prototype

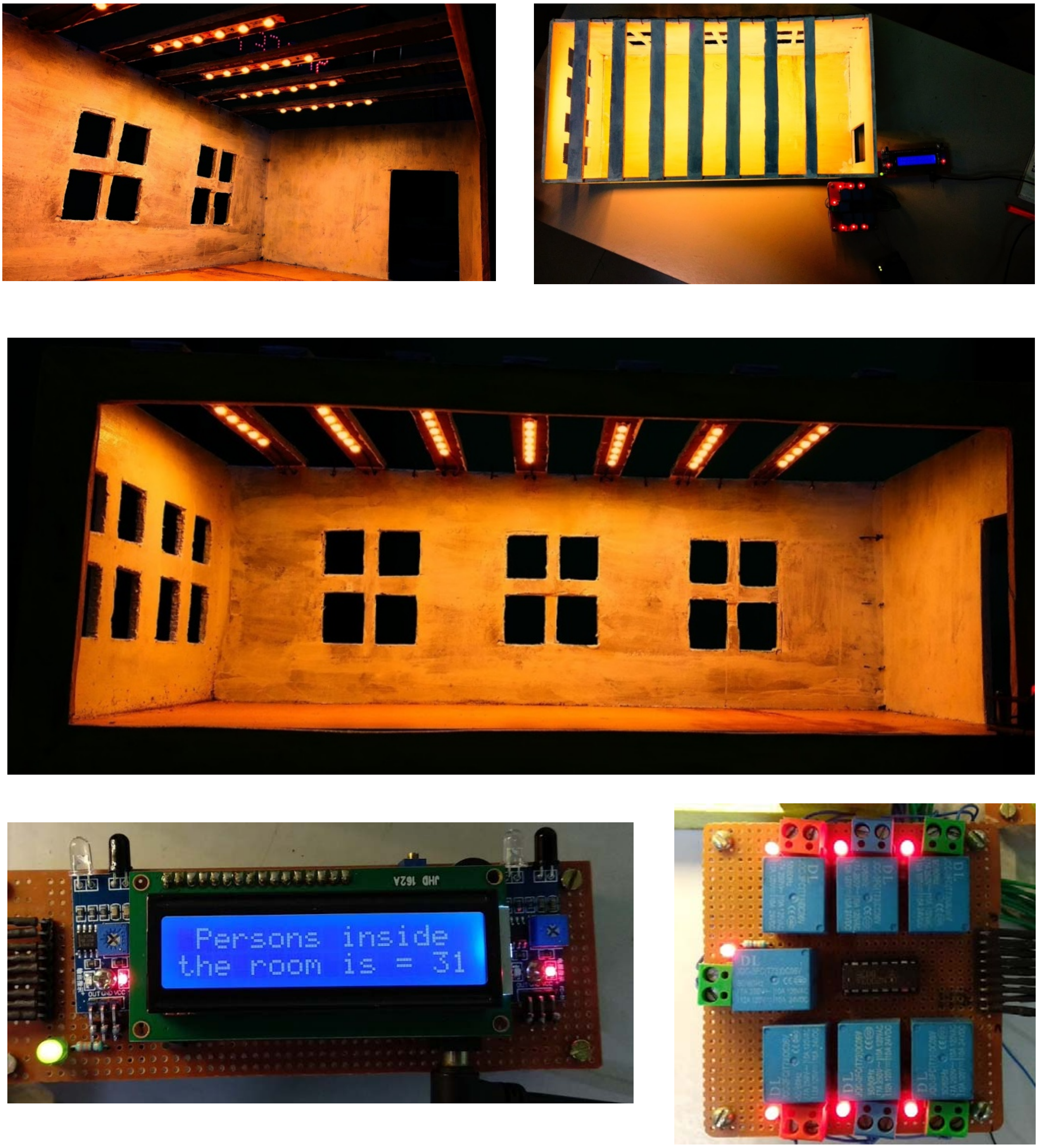


Figure 28: Some more glimpses of the project

Chapter 6

(Conclusion & Future Scope)

6.1 CONCLUSION

Here we have developed an energy saving lighting system for the classroom using IR sensor and digital visitor counter principle.

In this project we use Infrared Sensor which senses entry and exit of the students in the classroom. A piezo electric buzzer gets activated whenever a student enters in or exit from the classroom. Separate buzzer indications are there for entry or exit. Based on the number of persons entered inside the classroom the loads can be switch on sequentially. Here it is designed that if the number of persons inside the classroom is between 1 to 5, light 1 is switch on. For persons between 6 to 10, the second row light is switch on. In this way the students have to seat in the front of the class and the lower row lights are switch off if the students inside the class are less. This will save the electricity as well as the energy of the teacher because the teacher may not be so loud if the students are less inside the classroom. The prototype also switch off all the light loads if everybody leaves the classroom.

6.2 RESULTS

The experimental model was made following the circuit diagram and the desired results were obtained .Every time the student enters the classroom the buzzer sounds and loads are switch on accordingly the program. For exit the loads are switched off and for empty room all loads are switched off.

6.3 FUTURE WORK

In future the prototype may be modified to take the attendance of the students using radio frequency Infrared (RFID) sensor. Also the number of students in a particular classroom can be send to a remote server using IoT so that authority can monitor the presence of the student in the classroom.

Chapter 7

(References)

1. M.-C. Dubois, A. Blomsterberg, “**Energy saving potential and strategies for electric lighting in future**” North European, low energy office buildings: a literature review, Energy Build. 43 (2011) 2572e2582,

2. M. Magno, T. Polonelli, L. Benini, “**A low cost, highly scalable wireless sensor network solution to achieve smart LED light control for green buildings**”, IEEE Sensors (2015) 2963e2973. http://ieeexplore.ieee.org/xpls/abs_all.jsp? Arnumber 6994782 (accessed 22 June 2016)

3. Z. Nagy, M. Hazas, M. Frei, D. Rossi, A. Schlueter, “**Illuminating adaptive comfort: dynamic lighting for the active occupant,”** in: Proc. 8th Wind. Conf. Count. Cost Comf. A Chang. World, 2014

4. F. Manzoor, D. Linton, M. Loughlin**, “ Occupancy monitoring using passive RFID technology for efficient building lighting control”**, RFID Technol. (EURASIP) (2012) 83e88. http://ieeexplore.ieee.org/xpls/abs_all.jsp?arnumber¼6353853 (accessed 14 December 2015).

5. [M.-C. Dubois, Å. Blomsterberg, “**Energy saving potential and strategies for electric lighting in future**” North European, low energy office buildings: a literature review, Energy Build. 43 (2011) 2572e2582,

6. M. Magno, T. Polonelli, L. Benini, “**A low cost, highly scalable wireless sensor network solution to achieve smart LED light control for green buildings**”, IEEE Sensors 15 (5) (2015) 2963e2973. http://ieeexplore.ieee.org/xpls/abs_all.jsp? arnumber¼6994782 (accessed 22 June 2016)

Appendix A

(Hardware description)

Transformer less AC to DC power supply circuit using dropping capacitor

Production of low voltage DC power supply from AC power is the most important problem faced by many electronics developers and hobbyists. The straight forward technique is the use of a step down transformer to reduce the 230 V or 110V AC to a preferred level of low voltage AC. But *SMPS* power supply comes with the most appropriate method to create a low cost power supply by avoiding the use of bulky transformer. This circuit is so simple and it uses a voltage dropping capacitor in series with the phase line. Transformer less power supply is also called as capacitor power supply. It can generate 5V, 6V, 12V 150mA from 230V or 110V AC by using appropriate zener diodes.

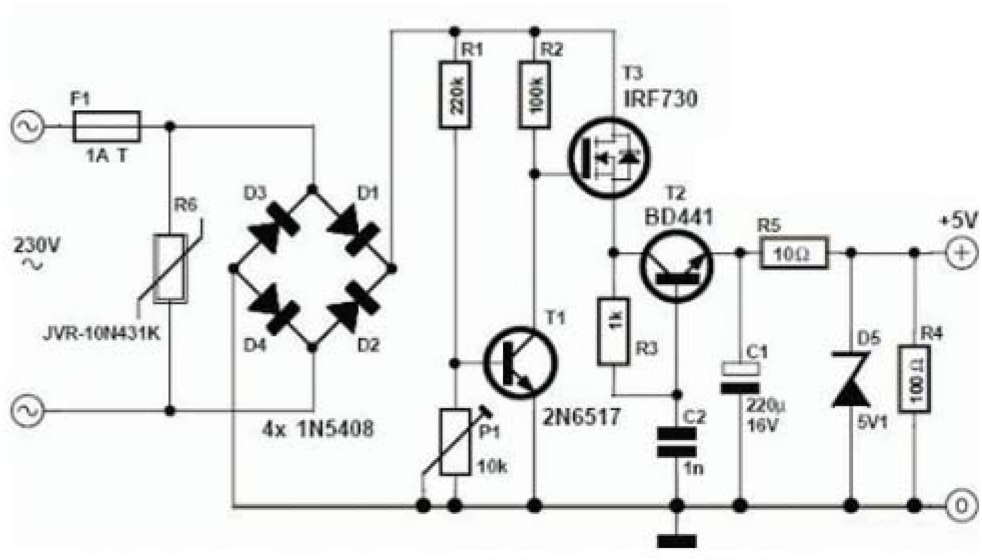


Figure 29: Transformer less SMPS 5 volt power supply

Working of Transformer less capacitor power supply

- This transformer less power supply circuit is also named as capacitor power supply since it uses a special type of AC capacitor in series with the main power line.
- A common capacitor will not do the work because the mains spikes will generate holes in the dielectric and the capacitor will be cracked by passing of current from the mains through the capacitor.
- X rated capacitor suitable for the use in AC mains is vital for reducing AC voltage.
- A X rated dropping capacitor is intended for 250V, 400V, 600V AC. Higher voltage versions are also obtainable. The dropping capacitor is non polarized so that it can be connected any way in the circuit.
- The 470kΩ resistor is a bleeder resistor that removes the stored current from the capacitor when the circuit is unplugged. It avoids the possibility of electric shock.
- Reduced AC voltage is rectified by bridge rectifier circuit. We have already discussed about bridge rectifiers. Then the ripples are removed by the 1000µF capacitor.

- This circuit provides 24 volts at 160 mA current at the output. This 24 volt DC can be regulated to necessary output voltage using an appropriate 1 watt or above zener diode.

- Here we are using 6.2V zener. You can use any type of zener diode in order to get the required output voltage.

AT 89c51 Microcontroller

AT89C51 is an 8-bit microcontroller and belongs to Atmel's 8051 family. **ATMEL 89C51** has 4KB of Flash programmable and erasable read only memory (PEROM) and 128 bytes of RAM. It can be erased and program to a maximum of 1000 times.

In 40 pin AT89C51, there are four ports designated as P_1, P_2, P_3 and P_0. All these ports are 8-bit bi-directional ports, *i.e.*, they can be used as both input and output ports. Except P_0 which needs external pull-ups, rest of the ports have internal pull-ups. When 1s are written to these port pins, they are pulled high by the internal pull-ups and can be used as inputs. These ports are also bit addressable and so their bits can also be accessed individually.

Port P_0 and P_2 are also used to provide low byte and high byte addresses, respectively, when connected to an external memory. Port 3 has multiplexed pins for special functions like serial communication, hardware interrupts, timer inputs and read/write operation from external memory. AT89C51 has an inbuilt UART for serial communication. It can be programmed to operate at different baud rates. Including two timers & hardware interrupts, it has a total of six interrupts.

PIN Diagram:

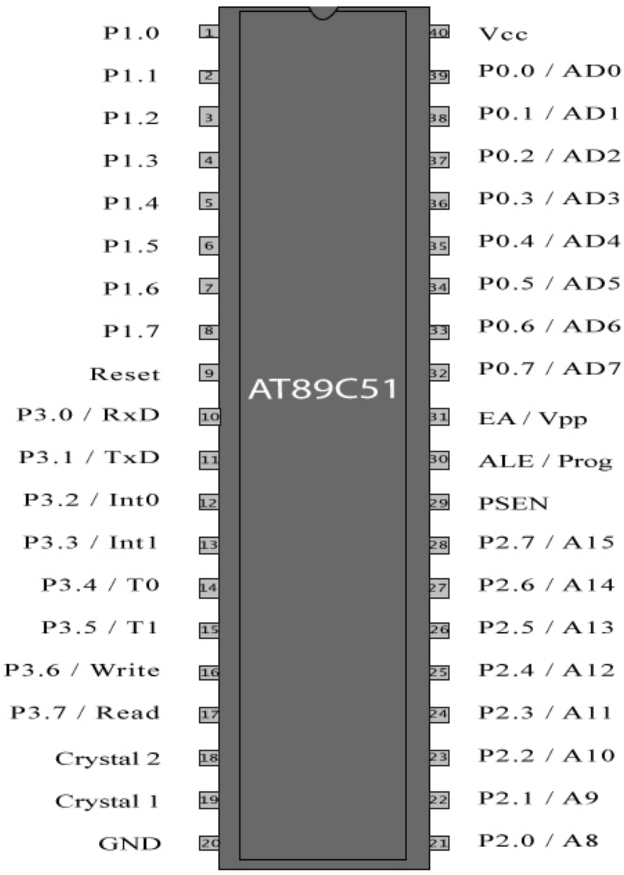


Figure 30: 89c51 Microcontroller Pin Diagram

PIN Description:

Pin No	Function			Name
1	8 bit input/output port (P_1) pins			$P_1.0$
2				$P_1.1$
3				$P_1.2$
4				$P_1.3$
5				$P_1.4$
6				$P_1.5$
7				$P_1.6$
8				$P_1.7$
9	Reset pin; Active high			Reset
10	Input (receiver) for serial communication	RxD	8 bit input/output port (P_3) pins	$P_3.0$
11	Output (transmitter) for serial communication	TxD		$P_3.1$
12	External interrupt 1	Int0		$P_3.2$
13	External interrupt 2	Int1		$P_3.3$
14	Timer1 external input	T_0		$P_3.4$
15	Timer2 external input	T_1		$P_3.5$
16	Write to external data memory	Write		$P_3.6$
17	Read from external data memory	Read		$P_3.7$
18	Quartz crystal oscillator (up to 24 MHz)			Crystal 2
19				Crystal 1
20	Ground (0V)			Ground
21	8 bit input/output port (P_2) pins / High-order address bits when interfacing with external memory			$P_2.0/ A_8$
22				$P_2.1/ A_9$
23				$P_2.2/ A_{10}$
24				$P_2.3/ A_{11}$
25				$P_2.4/ A_{12}$
26				$P_2.5/ A_{13}$
27				$P_2.6/ A_{14}$
28				$P_2.7/ A_{15}$
29	Program store enable; Read from external program memory			PSEN
30	Address Latch Enable			ALE
	Program pulse input during Flash programming			Prog
31	External Access Enable; Vcc for internal program executions			EA
	Programming enable voltage; 12V (during Flash programming)			Vpp
32	8 bit input/output port (P_0) pins Low-order address bits when interfacing with external memory			$P_0.7/ AD_7$
33				$P_0.6/ AD_6$
34				$P_0.5/ AD_5$
35				$P_0.4/ AD_4$
36				$P_0.3/ AD_3$
37				$P_0.2/ AD_2$
38				$P_0.1/ AD_1$
39				$P_0.0/ AD_0$
40	Supply voltage; 5V (up to 6.6V)			Vcc

Table 7: Pin Description of 89c51 microcontroller

16x2 LCD Module:

- 16 character 2 lines display
- 4 bit and 8 bit data transfer mode
- display alpha numeric display
- backlight compatible
- contrast adjustment
- backlight intensity adjustment
- 5 volt operation
- compatible to almost every microcontroller

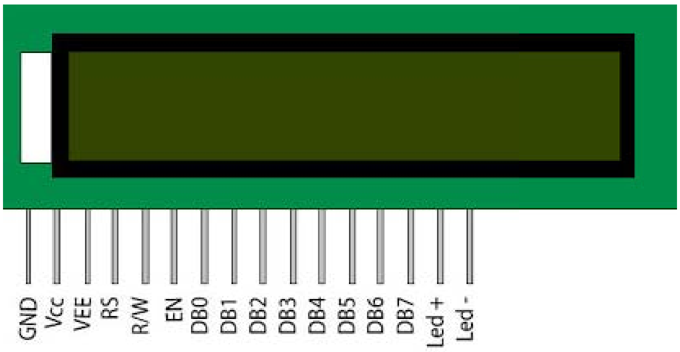


Figure 31: 16X2 LCD Module

LCD Pin outs

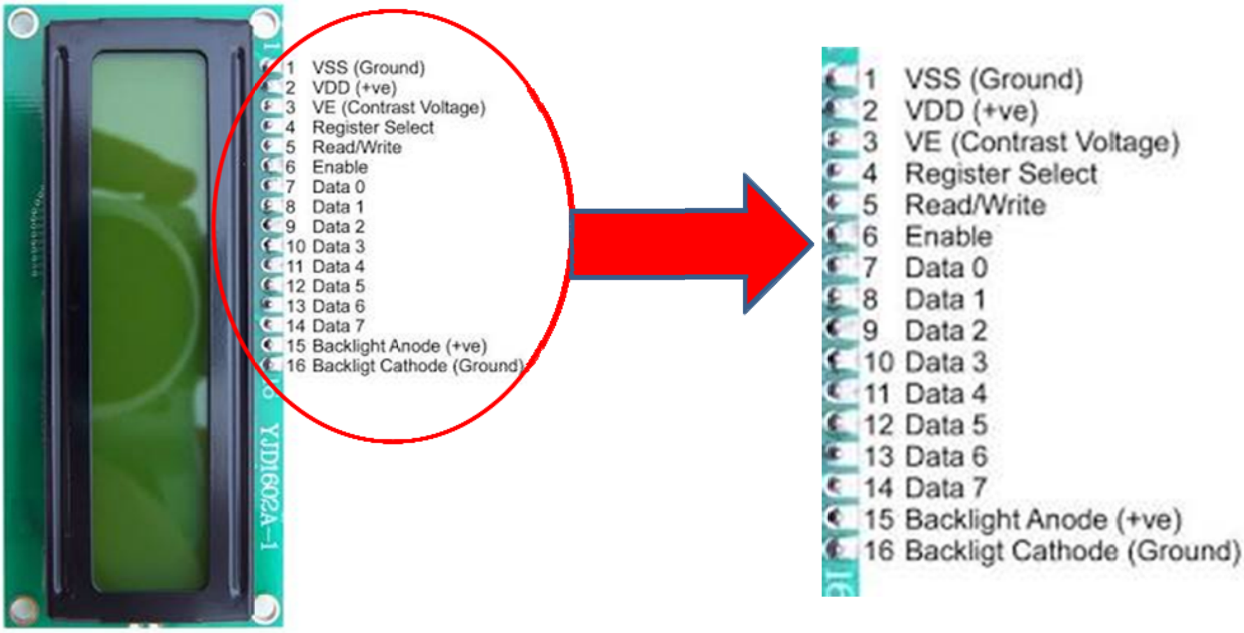


Figure 32: LCD Pin Diagram

Relay Driver

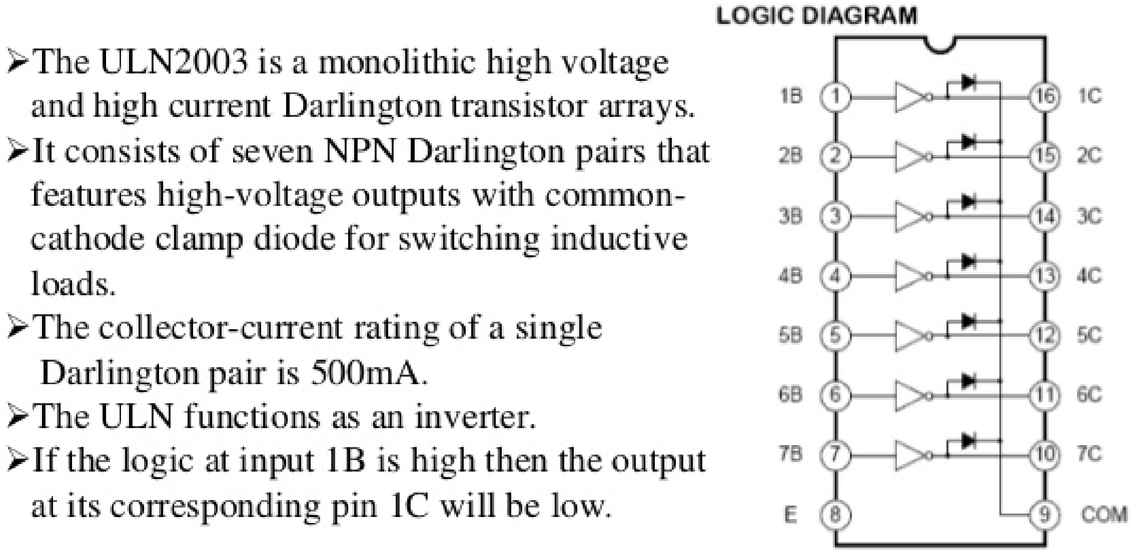


Figure 33: ULN2003A Internal Block Diagram

Resistor

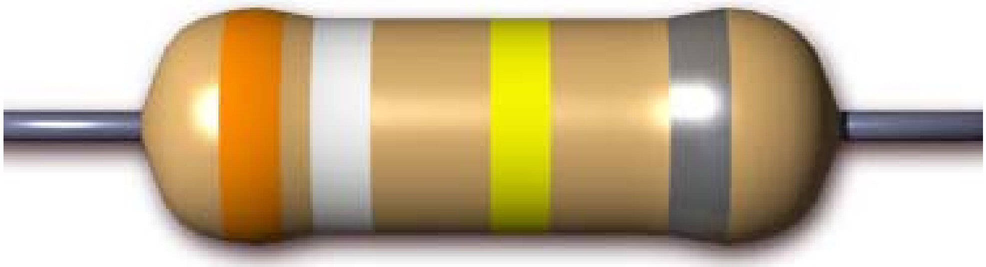


Figure 34: Resistor

Resistance is the opposition of a material to the current. It is measured in Ohms Ω. All conductors represent a certain amount of resistance, since no conductor is 100% efficient. To control the electron flow (current) in a predictable manner, we use resistors. Electronic circuits use calibrated lumped resistance to control the flow of current. Broadly speaking, resistor can be divided into two groups viz. fixed & adjustable (variable) resistors. In fixed resistors, the value is fixed & cannot be varied. In variable resistors, the resistance value can be varied by an adjuster knob. It can be divided into (a) Carbon composition (b) Wire wound (c) Special type. The most common type of resistors used in our projects is carbon type. The resistance value is normally indicated by color bands. Each resistance has four colors, one of the band on either side will be gold or silver, this is called fourth band and indicates the tolerance, others three band will give the value of resistance (see table). For example if a resistor has the following marking on it say red, violet, gold. Comparing these colored rings with the color code, its value is 27000 ohms or 27 kilo ohms and its tolerance is ±5%. Resistor comes in various sizes (Power rating).The bigger the size, the more power rating of 1/4 watts. The four color rings on its body tells us the value of resistor value.

Color Code of the resistor

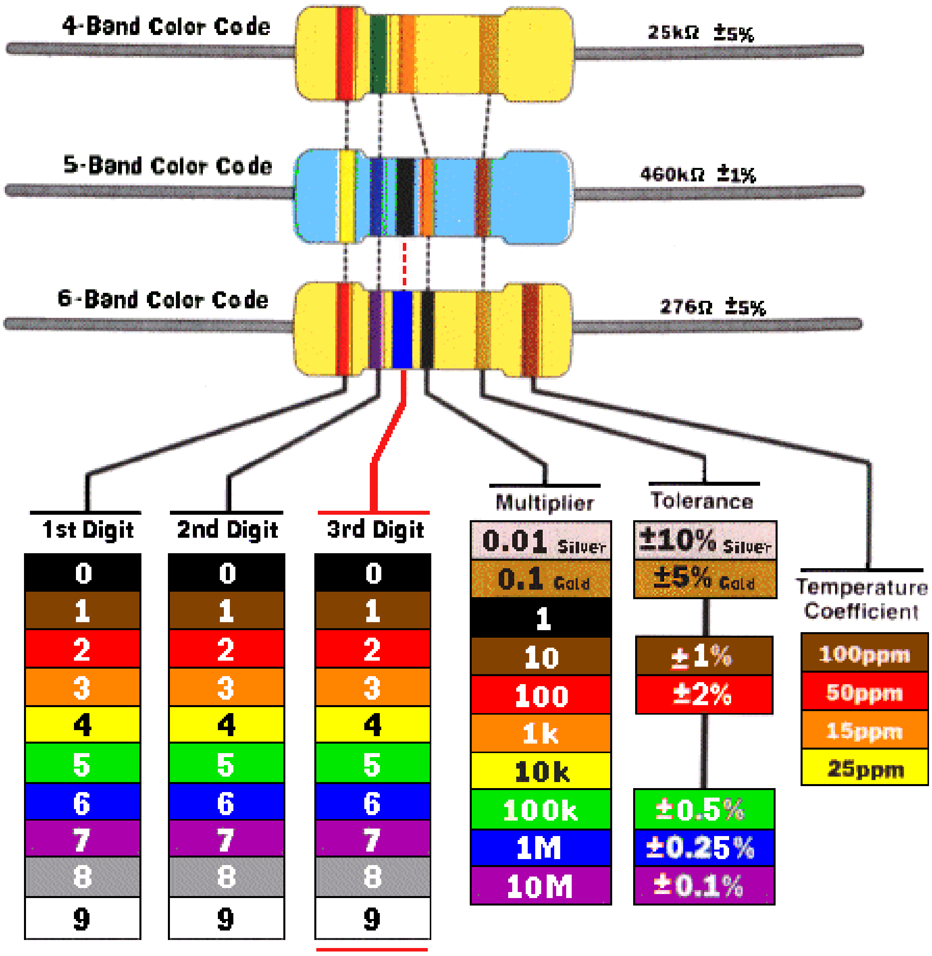


Figure 35: Color Code for resistance

RELAY

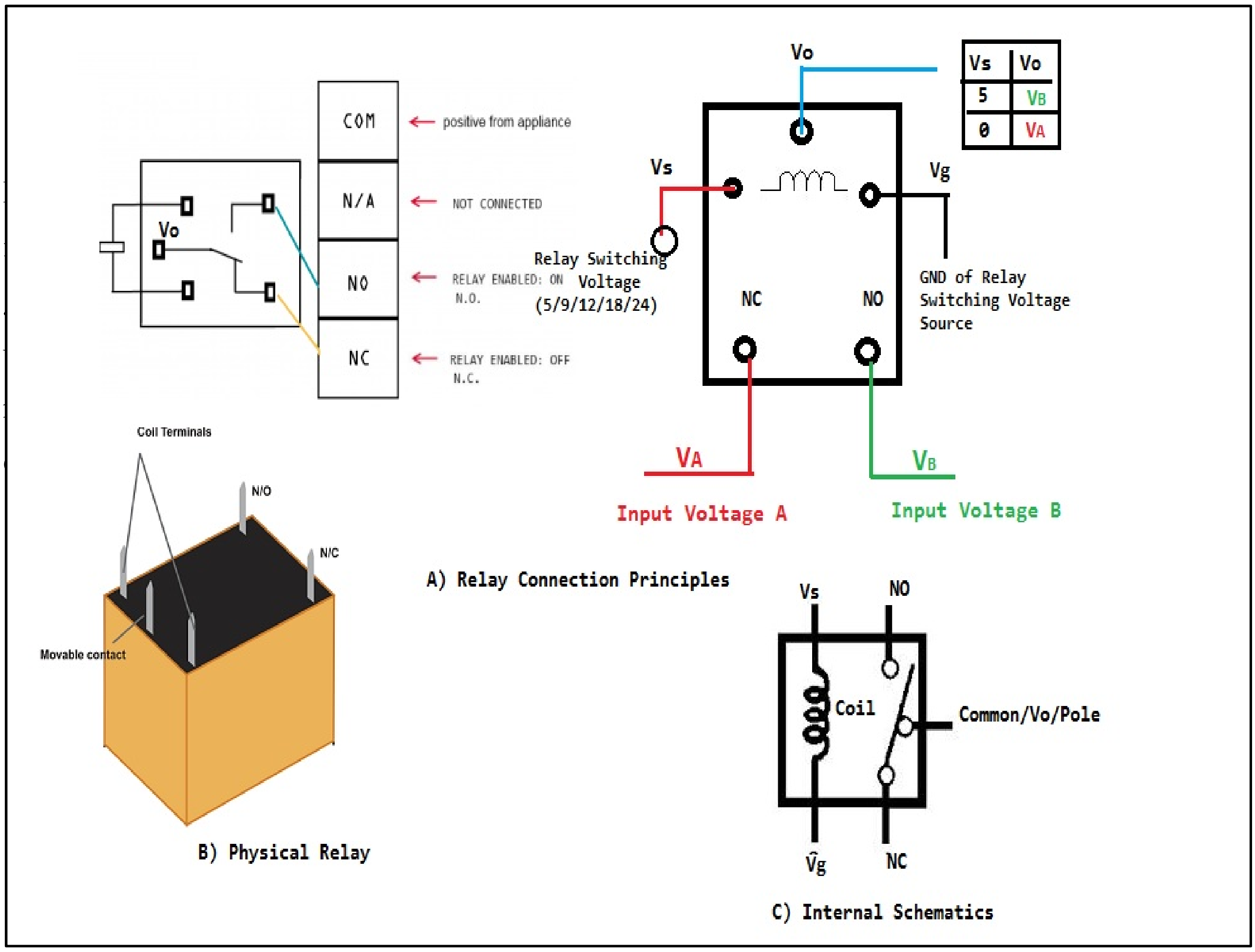


Figure 36: 6 volt Cube Relay

A relay is an electrically operated switch. Current flowing through the coil of the relay creates a magnetic field which attracts a lever and changes the switch contacts. The coil current can be on or off so relays have two switch positions and they are double throw (changeover) switches.

The relay's switch connections are usually labeled COM (POLE), NC and NO:

COM/POLE= Common, NC and NO always connect to this, it is the moving part of the switch.

NC = Normally Closed, COM/POLE is connected to this when the relay coil is not magnetized.

NO = Normally Open, COM/POLE is connected to this when the relay coil is MAGNETIZED and vice versa.

Capacitors

It is an electronic component whose function is to accumulate charges and then release it.

To understand the concept of capacitance, consider a pair of metal plates which all are placed near to each other without touching. If a battery is connected to these plates the positive pole to one and the negative pole to the other, electrons from the

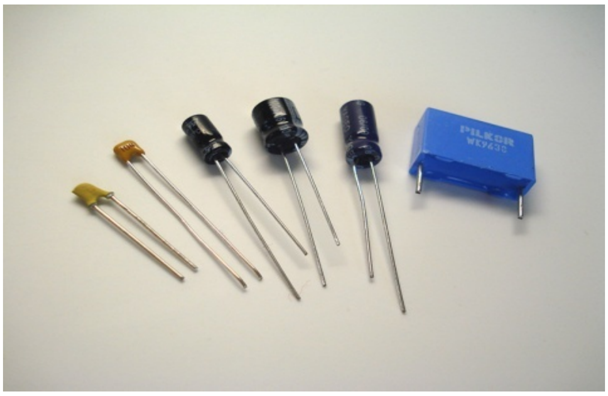


Figure 37: Types of capacitors

battery will be attracted from the plate connected to the positive terminal of the battery. If the battery is then disconnected, one plate will be left with an excess of electrons, the other with a shortage, and a potential or voltage difference will exists between them. These plates will be acting as capacitors. Capacitors are of two types: - (1) **fixed type** like ceramic, polyester, electrolytic capacitors - these names refer to the material they are made of aluminum foil. (2) **Variable type** like gang condenser in radio or trimmer. In fixed type capacitors, it has two leads and its value is written over its body and variable type has three leads. Unit of measurement of a capacitor is farad denoted by the symbol F. It is a very big unit of capacitance. Small unit capacitor are pico-farad denoted by pf (1pf=1/1000,000,000,000 f) Above all, in case of electrolytic capacitors, it's two terminal are marked as (-) and (+).

Crystal Oscillator

A crystal oscillator is an electronic oscillator circuit that uses the mechanical resonance of a vibrating crystal of piezoelectric material to create an electrical signal with a precise frequency. This frequency is commonly used to keep track of time, as in quartz wristwatches, to provide a stable clock signal for digital integrated circuits, and to stabilize frequencies for radio transmitters and receivers. The most common type of piezoelectric resonator used is the quartz crystal, so oscillator circuits incorporating them became known as crystal oscillators, but other piezoelectric materials including polycrystalline ceramics are used in similar circuits.

Figure 38: Crystal Oscillator

Quartz crystals are manufactured for frequencies from a few tens of kilohertz to hundreds of megahertz. More than two billion crystals are manufactured annually. Most are used for consumer devices such as wristwatches, clocks, radios, computers, and cell phones. Quartz crystals are also found inside test and measurement equipment, such as counters, signal generators, and oscilloscopes.

Piezo buzzer

A buzzer or beeper is an audio signaling device, which may be mechanical, electromechanical, or piezoelectric. Typical uses of buzzers and beepers include alarm devices, timers and confirmation of user input such as a mouse click or keystroke. A piezoelectric element may be driven by an oscillating electronic circuit or other audio signal source, driven with a piezoelectric audio amplifier. Sounds commonly used to indicate that a button has been pressed are a click, a ring or a beep.

Figure 39: Piezo Buzzer

Blank PCB

A **printed circuit board** (**PCB**) mechanically supports and electrically connects electronic components using conductive tracks, pads and other features etched from copper sheets laminated onto a non-conductive substrate. PCBs can be *single sided* (one copper layer), *double sided* (two copper layers) or *multi-layer* (outer and inner layers). Multi-layer PCBs allow for much higher component density. Conductors on different layers are connected with plated-through holes called vias. Advanced PCBs may contain components - capacitors, resistors or active devices - embedded in the substrate.

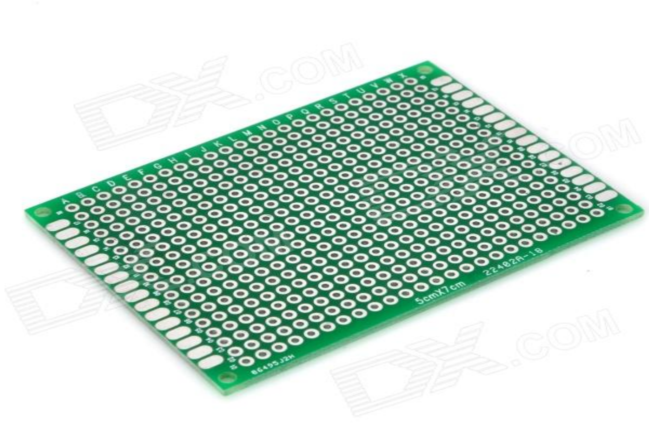


Figure 40: Blank glass epoxy PCB Board

FR-4 glass epoxy is the primary insulating substrate upon which the vast majority of rigid PCBs are produced. A thin layer of copper foil is laminated to one or both sides of an FR-4 panel. Circuitry interconnections are etched into copper layers to produce printed circuit boards. Complex circuits are produced in multiple layers.

Printed circuit boards are used in all but the simplest electronic products. Alternatives to PCBs include wire wrap and point-to-point construction. PCBs require the additional design effort to lay out the circuit, but manufacturing and assembly can be automated. Manufacturing circuits with PCBs is cheaper and faster than with other wiring methods as components are mounted and wired with one single part. Furthermore, operator wiring errors are eliminated.

Appendix B

(Software coding)

PROGRAM CODE:

```
;		Occupancy based load switching (energy saver)
;-------------------------------------------------------------------
		lcd_port equ P1		;LCD connected to Port1
		en equu P1.7		;Enable connected to P1.7
		var1 equ 30H
		temp equ 31H
;		temp1 equ 32H
		delay equ 33H
ORG 00H
mov P2, #00H			; initially off the loads
SETB P3.6			; sensors input
SETB P3.7			; sensors input
;CLR P3.5			; Buzzer (active low))
START:
;-------------------------------------------------------------------
;				Initial Message Section
;-------------------------------------------------------------------
; LCD module is connected at Port 1 (data), Controls are
connected at port P1.7 (E)
; P1.5 (RS) - 4 bit mode
;-------------------------------------------------------------------
		ACALL LCD_RESET		;4 bit LCD RESET
(software reset)
		acall lcd_init		;4 bit mode LCD
initialization
MOV A, #80H
ACALL CMND
MOV DPTR, #MYDATA		;'Occupancy Based'
display
H_1:	CLR A
		MOVC A, @A+DPTR
		JZ b_1
		ACALL DISP
		INC DPTR
		SJMP H_1
b_1:
MOV A,#0C1H			;Jump to second line, position 2
ACALL CMND
		MOV DPTR, #MYDATA1		;'load
switching' display
H_2:	CLR A
		MOVC A, @A+DPTR
		JZ b_2
		ACALL DISP
		INC DPTR
		SJMP H_2
b_2:	MOV DELAY, #250
		ACALL DELAYmS
		MOV DELAY, #250
		ACALL DELAYmS
		MOV DELAY, #250
		ACALL DELAYmS

MOV A,#01H				;Clear screen
ACALL CMND
MOV A,#82H				;Cursor line one ,
position 2
ACALL CMND
		MOV DPTR, #MYDATA2		;'Using 89c51'
display
H_3:	CLR A
		MOVC A, @A+DPTR
		JZ b_3
		ACALL DISP
		INC DPTR
		SJMP H_3
b_3:
MOV A,#0C0H			;Jump to second line, position 1
ACALL CMND
		MOV DPTR, #MYDATA3		;'Micro
Controller' display
H_4:	CLR A
		MOVC A, @A+DPTR
		JZ b_4
		ACALL DISP
		INC DPTR
		SJMP H_4
b_4:	MOV DELAY, #250
		ACALL DELAYmS
		MOV DELAY, #250
		ACALL DELAYmS
		MOV DELAY, #250
		ACALL DELAYmS

MOV A,#01H			;Clear screen
ACALL CMND
MOV A,#82H			;Cursor line one , position 4
ACALL CMND
		MOV DPTR, #MYDATA4		;'Developed
by' display
H_5:	CLR A
		MOVC A, @A+DPTR
		JZ b_5
		ACALL DISP
		INC DPTR
		SJMP H_5
b_5:
MOV A,#0C4H			;Jump to second line, position 1
ACALL CMND
		MOV DPTR, #MYDATA5		;'student
name' display
H_6:	CLR A
		MOVC A, @A+DPTR
		JZ b_6
		ACALL DISP
		INC DPTR
		SJMP H_6
b_6:	MOV DELAY, #250
```

```
        ACALL DELAYmS
        MOV DELAY, #250
        ACALL DELAYmS
        MOV DELAY, #250
        ACALL DELAYmS
XX:
MOV A,#01H                  ;Clear screen
ACALL CMND
MOV A,#81H          ;Cursor line one , position 4
ACALL CMND
        MOV DPTR, #MYDATA6          ;'The room is
Empty' display
H_7:    CLR A
        MOVC A, @A+DPTR
        JZ b_7
        ACALL DISP
        INC DPTR
        SJMP H_7
b_7:
MOV A,#0C0H         ;Jump to second line, position 1
ACALL CMND
        MOV DPTR, #MYDATA7          ;'All light is
OFF' display
H_8:    CLR A
        MOVC A, @A+DPTR
        JZ b_8
        ACALL DISP
        INC DPTR
        SJMP H_8
b_8:    MOV DELAY, #250
        ACALL DELAYmS
        MOV DELAY, #250
        ACALL DELAYmS
        MOV DELAY, #250
        ACALL DELAYmS

;----------------------------------------------------------------------
; main program
;----------------------------------------------------------------------
        MOV R1, #00H
X2:     MOV DELAY, #250
        ACALL DELAYmS
        JB P3.6, X1
        SJMP K1
X1:     JB P3.7, X2
        SJMP L1

k1:
        JNB P3.6, $
        MOV DELAY, #250
        ACALL DELAYmS
        JB p3.7, k3
        SJMP K2
k3:     JNB P3.6, X2
        sjmp k1
k2:     inc R1
        MOV A, R1
        ANL A, #0FH
        CJNE A, #0AH, D1        ; for hex to decimal
conversion
        MOV A, R1
        ADD A, #06H
        MOV R1, A

D1:
MOV A,#01H                  ;Clear screen
ACALL CMND
MOV A,#81H          ;Cursor line one , position 4
ACALL CMND
        MOV DPTR, #MYDATA8          ;'Person
Entered' display
H_9:    CLR A
        MOVC A, @A+DPTR
        JZ b_9
        ACALL DISP
        INC DPTR
        SJMP H_9
b_9:    ACALL BEEP
        CLR P3.5
        MOV DELAY, #250
        ACALL DELAYmS
        SETB P3.5

ACALL MSG_DISPLAY
ACALL LOAD_SWITCH
SJMP X2

L1:                 ; person leaving section
        JNB P3.7, $
        MOV DELAY, #250
        ACALL DELAYmS
        JB p3.6, L3
        SJMP L2
L3:     JNB P3.7, X2
        sjmp L1

L2:     DEC R1
        MOV A, R1
        ANL A, #0FH
        CJNE A, #0FH, D2        ; for hex to decimal
conversion
        MOV A, R1
        SUBB A, #06H
        MOV R1, A

D2:
MOV A,#01H                  ;Clear screen
ACALL CMND
MOV A,#81H          ;Cursor line one , position 4
ACALL CMND
```

```
        MOV DPTR, #MYDATA11          ;'Person
Leaving' display
H_12:   CLR A
        MOVC A, @A+DPTR
        JZ b_12
        ACALL DISP
        INC DPTR
        SJMP H_12
b_12:   ACALL Beep
        MOV DELAY, #250
        ACALL DELAYmS
        ACALL BEEP
        CJNE R1, #00H, L4
        MOV P2, #00H
        LJMP XX
L4:
ACALL MSG_DISPLAY
ACALL LOAD_SWITCH
LJMP X2
;--------------------------------------------------------------------
;       LOAD switching section
;--------------------------------------------------------------------
LOAD_SWITCH:
        MOV A, R1
        CJNE A, #00H, ON0
        MOV P2, #00H
        SJMP LAST
ON0:    MOV A, R1
        SUBB A, #06H
        JNC ON1
        MOV P2, #01H
        SJMP LAST
ON1:    MOV A, R1
        SUBB A, #11H
        JNC ON2
        MOV P2, #03H
        SJMP LAST
ON2:    MOV A, R1
        SUBB A, #16H
        JNC ON3
        MOV P2, #07H
        SJMP LAST
ON3:    MOV A, R1
        SUBB A, #21H
        JNC ON4
        MOV P2, #0FH
        SJMP LAST
ON4:    MOV A, R1
        SUBB A, #26H
        JNC ON5
        MOV P2, #1FH
        SJMP LAST
ON5:    MOV A, R1
        SUBB A, #31H
        JNC ON6
        MOV P2, #3FH
        SJMP LAST
ON6:    MOV A, R1
        SUBB A, #36H
        JNC Last
        MOV P2, #7FH
        SJMP LAST
LAST: RET
;--------------------------------------------------------------------
MSG_display:
MOV A,#01H                    ;Clear screen
ACALL CMND
MOV A,#81H              ;Cursor line one , position 4
ACALL CMND
        MOV DPTR, #MYDATA9            ;'Persons
Inside' display
H_10:   CLR A
        MOVC A, @A+DPTR
        JZ b_10
        ACALL DISP
        INC DPTR
        SJMP H_10
b_10:
MOV A,#0C0H                   ;Jump to second line,
position 0
ACALL CMND
        MOV DPTR, #MYDATA10          ;'the room is =
' display
H_11:   CLR A
        MOVC A, @A+DPTR
        JZ b_11
        ACALL DISP
        INC DPTR
        SJMP H_11
b_11:
MOV A,#0CEH             ;Jump to second line, position
14
ACALL CMND
        MOV A, R1
        SUBB A, #10D
        JNC S1
        MOV A, R1
        ADD A, #30H
        ACALL DISP
        ret
S1:
        MOV A, R1
        ANL A, #0F0H
        SWAP A
        ADD A, #30H
        ACALL DISP
        MOV A, R1
        ANL A, #0FH
        ADD A, #30H
        ACALL DISP
        RET
;--------------------------------------------------------------------
```

```
lcd_reset:                  ;LCD reset sequence
        mov lcd_port, #0FFH
        mov delay,#20       ;20mS delay
        acall delayms
        mov lcd_port, #83H      ;Data = 30H, EN = 1,
First Init
        mov lcd_port, #03H   ;Data = 30H, EN = 0
        mov delay,#10       ;Delay 10mS
        acall delayms
        mov lcd_port, #83H    ;Second Init, Data = 30H,
EN = 1
        mov lcd_port, #03H   ;Data = 30H, EN = 0
        mov delay,#1        ;Delay 5mS
        acall delayms
        mov lcd_port, #83H   ;Third Init
        mov lcd_port, #03H
        mov delay,#1        ;Delay 5mS
        acall delayms
        mov lcd_port, #82H     ;Select Data width (20H
for 4bit)
        mov lcd_port, #02H   ;Data = 20H, EN = 0
        mov delay,#1        ;Delay 5mS
        acall delayms
ret
;--------------------------------------------------------------------
lcd_init:
        acall lcd_reset     ;Call LCD Reset sequence
        mov a,#28H          ;4-bit, 2 line, 5x7 dots
        acall CMND
        mov a,#0CH            ;LCD_DATAlay ON cursor
OFF
        acall CMND
        mov a,#06H                ;Set entry mode (Auto
increment)
        acall CMND
        mov a,#80H          ;Bring cursor to line 1
        acall CMND
ret
;--------------------------------------------------------------------
CMND:           ;LCD command Routine
        mov temp,a            ;Save a copy of command to
temp
        swap a          ;Swap to use higher nibble
        anl a,#0FH        ;Mask the first four bits
        add a,#80H        ;Enable = 1, RS = 0, RW = 0
        mov lcd_port,a     ;Move it to lcd port
        mov delay,#3      ;5mS delay
        acall delayms
        CLR EN

        mov a,temp            ;Reload the command from
temp
        anl a,#0FH        ;Mask first four bits
        add a,#80H        ;Enable = 1
        mov lcd_port,a     ;Move to port
        mov delay,#3      ;5mS delay
        acall delayms
        CLR EN
ret
;--------------------------------------------------------------------
DISP:                   ;LCD data Routine
        mov temp,a          ;Keep copy of data in temp
        swap a            ;We need higher nibble
        anl a,#0FH          ;Mask first four bits
        add a,#0A0H         ;Enable = 1, RS = 1, RW = 0
        mov lcd_port,a      ;Move to lcd port
        mov delay,#3        ;5mS delay
        acall delayms
        clr en            ;Enable = 0

        mov a,temp          ;Reload the data from temp
        anl a,#0FH          ;we need lower nibble now
        add a,#0A0H         ;Enable = 1, RS = 1, RW = 0
        mov lcd_port,a      ;Move to lcd port
        mov delay,#3         ;5mS delay
        acall delayms
        clr en            ;Enable = 0
ret
;--------------------------------------------------------------------
BEEP:
        CLR P3.5
        MOV DELAY, #100
        ACALL DELAYmS
        SETB P3.5
RET
;--------------------------------------------------------------------
delayms:
        mov var1,#200             ;changed from 230
d:
        nop
        nop
        djnz var1,d
        djnz delay,delayms
        ret
;--------------------------------------------------------------------
MYDATA:                 DB 'Occupancy  Based', 0
MYDATA1:    DB 'Load Switching', 0
MYDATA2:    DB 'Using 89c51', 0
MYDATA3:    DB 'Micro Controller', 0
MYDATA4:    DB 'Developed By', 0
MYDATA5:    DB ' P-R-A-S', 0
MYDATA6:    DB 'Room is Empty', 0
MYDATA7:    DB 'All light is OFF', 0
MYDATA8:    DB 'Person Entered', 0
MYDATA9:    DB 'Persons inside',0
MYDATA10:   DB 'the room is = ', 0
MYDATA11:   DB 'Person Leaving', 0
MYDATA12:   DB 0DH, '       WRONG PASSWORD',
0
MYDATA13:   DB 'Enter Password', 0
;--------------------------------------------------------------------
END
```

Appendix C

(Data sheets)

Features

- Compatible with MCS-51™ Products
- 2K Bytes of Reprogrammable Flash Memory
  - Endurance: 1,000 Write/Erase Cycles
- 2.7V to 6V Operating Range
- Fully Static Operation: 0 Hz to 24 MHz
- Two-level Program Memory Lock
- 128 x 8-bit Internal RAM
- 15 Programmable I/O Lines
- Two 16-bit Timer/Counters
- Six Interrupt Sources
- Programmable Serial UART Channel
- Direct LED Drive Outputs
- On-chip Analog Comparator
- Low-power Idle and Power-down Modes

8-bit Microcontroller with 2K Bytes Flash

AT89C2051

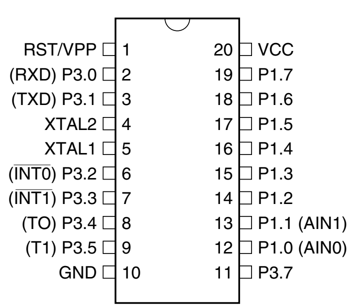
Description

The AT89C2051 is a low-voltage, high-performance CMOS 8-bit microcomputer with 2K bytes of Flash programmable and erasable read only memory (PEROM). The device is manufactured using Atmel's high-density nonvolatile memory technology and is compatible with the industry-standard MCS-51 instruction set. By combining a versatile 8-bit CPU with Flash on a monolithic chip, the Atmel AT89C2051 is a powerful microcomputer which provides a highly-flexible and cost-effective solution to many embedded control applications.

The AT89C2051 provides the following standard features: 2K bytes of Flash, 128 bytes of RAM, 15 I/O lines, two 16-bit timer/counters, a five vector two-level interrupt architecture, a full duplex serial port, a precision analog comparator, on-chip oscillator and clock circuitry. In addition, the AT89C2051 is designed with static logic for operation down to zero frequency and supports two software selectable power saving modes. The Idle Mode stops the CPU while allowing the RAM, timer/counters, serial port and interrupt system to continue functioning. The power-down mode saves the RAM contents but freezes the oscillator disabling all other chip functions until the next hardware reset.

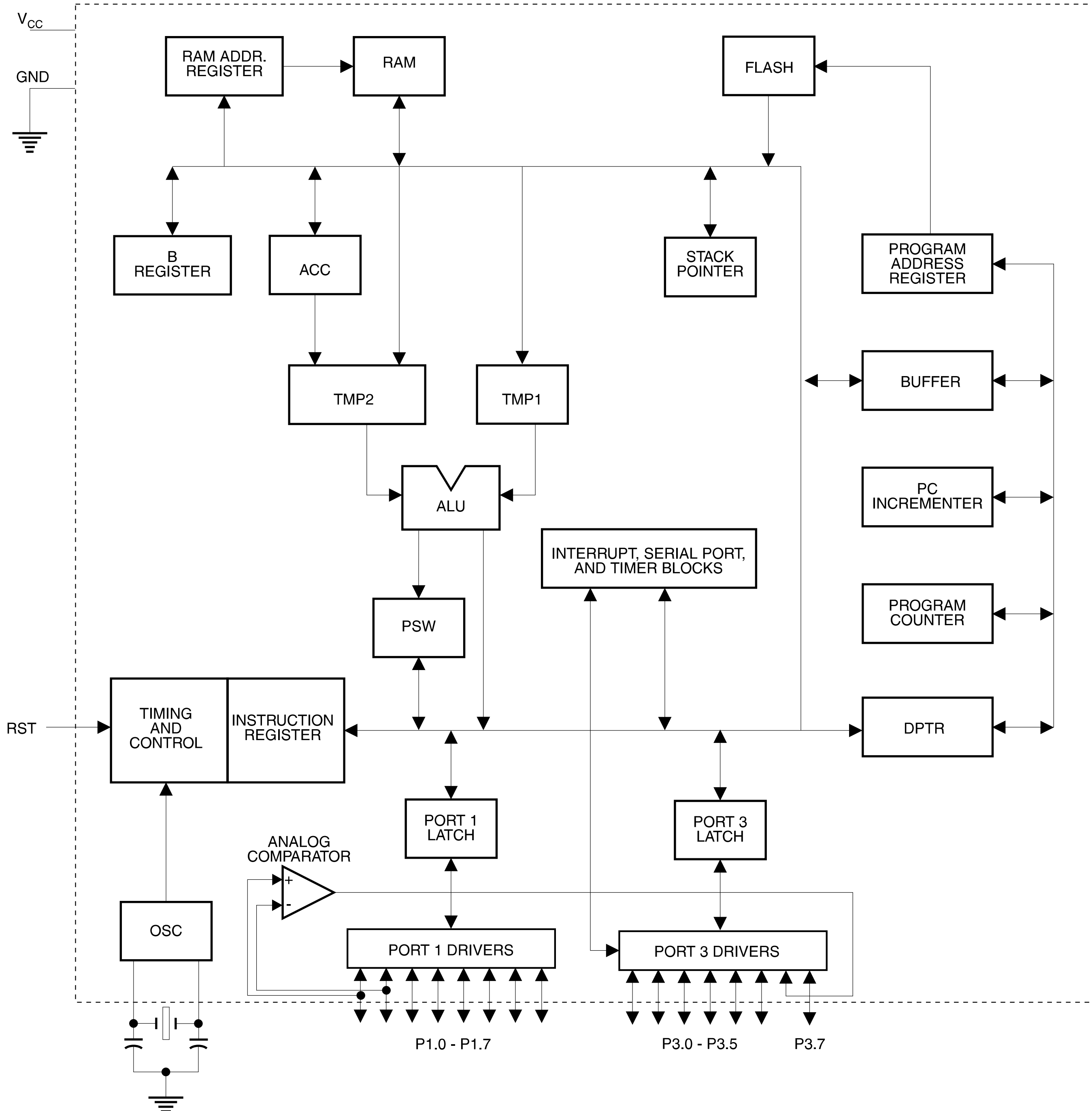
Pin Configuration

PDIP/SOIC



Rev. 0368E–02/00

Block Diagram



Pin Description

VCC

Supply voltage.

GND

Ground.

Port 1

Port 1 is an 8-bit bi-irectional I/O port. Port pins P1.2 to P1.7 provide internal pullups. P1.0 and P1.1 require external pullups. P1.0 and P1.1 also serve as the positive input (AIN0) and the negative input (AIN1), respectively, of the on-chip precision analog comparator. The Port 1 output buffers can sink 20 mA and can drive LED displays directly. When 1s are written to Port 1 pins, they can be used as inputs. When pins P1.2 to P1.7 are used as inputs and are externally pulled low, they will source current (I_{IL}) because of the internal pullups.

Port 1 also receives code data during Flash programming and verification.

Port 3

Port 3 pins P3.0 to P3.5, P3.7 are seven bi-irectional I/O pins with internal pullups. P3.6 is hard-wired as an input to the output of the on-chip comparator and is not accessible as a general purpose I/O pin. The Port 3 output buffers can sink 20 mA. When 1s are written to Port 3 pins they are pulled high by the internal pullups and can be used as inputs. As inputs, Port 3 pins that are externally being pulled low will source current (I_{IL}) because of the pullups.

Port 3 also serves the functions of various special features of the AT89C2051 as listed below:

Port Pin	Alternate Functions
P3.0	RXD (serial input port)
P3.1	TXD (serial output port)
P3.2	$\overline{\text{INT0}}$ (external interrupt 0)
P3.3	$\overline{\text{INT1}}$ (external interrupt 1)
P3.4	T0 (timer 0 external input)
P3.5	T1 (timer 1 external input)

Port 3 also receives some control signals for Flash programming and verification.

RST

Reset input. All I/O pins are reset to 1s as soon as RST goes high. Holding the RST pin high for two machine cycles while the oscillator is running resets the device.

Each machine cycle takes 12 oscillator or clock cycles.

XTAL1

Input to the inverting oscillator amplifier and input to the internal clock operating circuit.

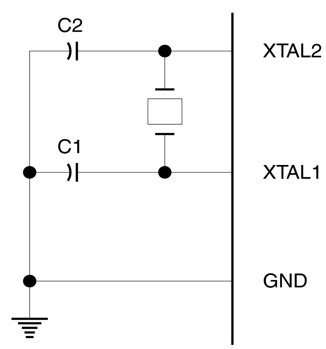
XTAL2

Output from the inverting oscillator amplifier.

Oscillator Characteristics

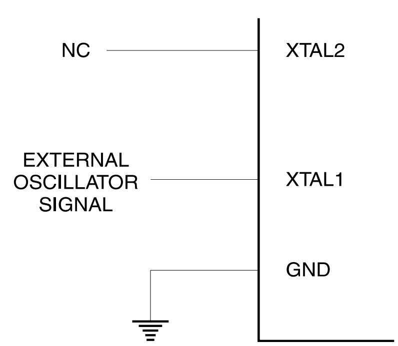
XTAL1 and XTAL2 are the input and output, respectively, of an inverting amplifier which can be configured for use as an on-chip oscillator, as shown in Figure 1. Either a quartz crystal or ceramic resonator may be used. To drive the device from an external clock source, XTAL2 should be left unconnected while XTAL1 is driven as shown in Figure 2. There are no requirements on the duty cycle of the external clock signal, since the input to the internal clocking circuitry is through a divide-by-two flip-flop, but minimum and maximum voltage high and low time specifications must be observed.

Figure 1. Oscillator Connections



Note: C1, C2 = 30 pF ± 10 pF for Crystals
= 40 pF ± 10 pF for Ceramic Resonators

Figure 2. External Clock Drive Configuration



Special Function Registers

A map of the on-chip memory area called the Special Function Register (SFR) space is shown in the table below.

Note that not all of the addresses are occupied, and unoccupied addresses may not be implemented on the chip. Read accesses to these addresses will in general return random data, and write accesses will have an indeterminate effect.

User software should not write 1s to these unlisted locations, since they may be used in future products to invoke new features. In that case, the reset or inactive values of the new bits will always be 0.

Table 1. AT89C2051 SFR Map and Reset Values

0F8H									0FFH
0F0H	B 00000000								0F7H
0E8H									0EFH
0E0H	ACC 00000000								0E7H
0D8H									0DFH
0D0H	PSW 00000000								0D7H
0C8H									0CFH
0C0H									0C7H
0B8H	IP XXX00000								0BFH
0B0H	P3 11111111								0B7H
0A8H	IE 0XX00000								0AFH
0A0H									0A7H
98H	SCON 00000000	SBUF XXXXXXXX							9FH
90H	P1 11111111								97H
88H	TCON 00000000	TMOD 00000000	TL0 00000000	TL1 00000000	TH0 00000000	TH1 00000000			8FH
80H		SP 00000111	DPL 00000000	DPH 00000000				PCON 0XXX0000	87H

Restrictions on Certain Instructions

The AT89C2051 and is an economical and cost-effective member of Atmel's growing family of microcontrollers. It contains 2K bytes of flash program memory. It is fully compatible with the MCS-51 architecture, and can be programmed using the MCS-51 instruction set. However, there are a few considerations one must keep in mind when utilizing certain instructions to program this device.

All the instructions related to jumping or branching should be restricted such that the destination address falls within the physical program memory space of the device, which is 2K for the AT89C2051. This should be the responsibility of the software programmer. For example, LJMP 7E0H would be a valid instruction for the AT89C2051 (with 2K of memory), whereas LJMP 900H would not.

1. Branching instructions:

LCALL, LJMP, ACALL, AJMP, SJMP, JMP @A+DPTR

These unconditional branching instructions will execute correctly as long as the programmer keeps in mind that the destination branching address must fall within the physical boundaries of the program memory size (locations 00H to 7FFH for the 89C2051). Violating the physical space limits may cause unknown program behavior.

CJNE [...], DJNZ [...], JB, JNB, JC, JNC, JBC, JZ, JNZ With these conditional branching instructions the same rule above applies. Again, violating the memory boundaries may cause erratic execution.

For applications involving interrupts the normal interrupt service routine address locations of the 80C51 family architecture have been preserved.

2. MOVX-related instructions, Data Memory:

The AT89C2051 contains 128 bytes of internal data memory. Thus, in the AT89C2051 the stack depth is limited to 128 bytes, the amount of available RAM. External DATA memory access is not supported in this device, nor is external PROGRAM memory execution. Therefore, no MOVX [...] instructions should be included in the program.

A typical 80C51 assembler will still assemble instructions, even if they are written in violation of the restrictions mentioned above. It is the responsibility of the controller user to know the physical features and limitations of the device being used and adjust the instructions used correspondingly.

Program Memory Lock Bits

On the chip are two lock bits which can be left unprogrammed (U) or can be programmed (P) to obtain the additional features listed in the table below:

Lock Bit Protection Modes(1)

Program Lock Bits	LB1	LB2	Protection Type
1	U	U	No program lock features.
2	P	U	Further programming of the Flash is disabled.
3	P	P	Same as mode 2, also verify is disabled.

Note: 1. The Lock Bits can only be erased with the Chip Erase operation.

Idle Mode

In idle mode, the CPU puts itself to sleep while all the on-chip peripherals remain active. The mode is invoked by software. The content of the on-chip RAM and all the special functions registers remain unchanged during this mode. The idle mode can be terminated by any enabled interrupt or by a hardware reset.

P1.0 and P1.1 should be set to “0” if no external pullups are used, or set to “1” if external pullups are used.

It should be noted that when idle is terminated by a hardware reset, the device normally resumes program execution, from where it left off, up to two machine cycles before the internal reset algorithm takes control. On-chip hardware inhibits access to internal RAM in this event, but access to the port pins is not inhibited. To eliminate the possibility of an unexpected write to a port pin when Idle is terminated by reset, the instruction following the one that invokes Idle should not be one that writes to a port pin or to external memory.

Power-down Mode

In the power down mode the oscillator is stopped, and the instruction that invokes power down is the last instruction executed. The on-chip RAM and Special Function Registers retain their values until the power down mode is terminated. The only exit from power down is a hardware reset. Reset redefines the SFRs but does not change the on-chip RAM. The reset should not be activated before V_{CC} is restored to its normal operating level and must be held active long enough to allow the oscillator to restart and stabilize.

P1.0 and P1.1 should be set to “0” if no external pullups are used, or set to “1” if external pullups are used.

Programming The Flash

The AT89C2051 is shipped with the 2K bytes of on-chip PEROM code memory array in the erased state (i.e., contents = FFH) and ready to be programmed. The code memory array is programmed one byte at a time. *Once the array is programmed, to re-program any non-blank byte, the entire memory array needs to be erased electrically.*

Internal Address Counter: The AT89C2051 contains an internal PEROM address counter which is always reset to 000H on the rising edge of RST and is advanced by applying a positive going pulse to pin XTAL1.

Programming Algorithm: To program the AT89C2051, the following sequence is recommended.

1. Power-up sequence:
   Apply power between V_{CC} and GND pins
   Set RST and XTAL1 to GND
2. Set pin RST to "H"
   Set pin P3.2 to "H"
3. Apply the appropriate combination of "H" or "L" logic levels to pins P3.3, P3.4, P3.5, P3.7 to select one of the programming operations shown in the PEROM Programming Modes table.

To Program and Verify the Array:

4. Apply data for Code byte at location 000H to P1.0 to P1.7.
5. Raise RST to 12V to enable programming.
6. Pulse P3.2 once to program a byte in the PEROM array or the lock bits. The byte-write cycle is self-timed and typically takes 1.2 ms.
7. To verify the programmed data, lower RST from 12V to logic "H" level and set pins P3.3 to P3.7 to the appropiate levels. Output data can be read at the port P1 pins.
8. To program a byte at the next address location, pulse XTAL1 pin once to advance the internal address counter. Apply new data to the port P1 pins.
9. Repeat steps 5 through 8, changing data and advancing the address counter for the entire 2K bytes array or until the end of the object file is reached.
10. Power-off sequence:
    set XTAL1 to "L"
    set RST to "L"
    Turn V_{CC} power off

$\overline{\text{Data}}$ Polling: The AT89C2051 features $\overline{\text{Data}}$ Polling to indicate the end of a write cycle. During a write cycle, an attempted read of the last byte written will result in the complement of the written data on P1.7. Once the write cycle has been completed, true data is valid on all outputs, and the next cycle may begin. $\overline{\text{Data}}$ Polling may begin any time after a write cycle has been initiated.

Ready/$\overline{\text{Busy}}$: The Progress of byte programming can also be monitored by the RDY/$\overline{\text{BSY}}$ output signal. Pin P3.1 is pulled low after P3.2 goes High during programming to indicate BUSY. P3.1 is pulled High again when programming is done to indicate READY.

Program Verify: If lock bits LB1 and LB2 have not been programmed code data can be read back via the data lines for verification:

1. Reset the internal address counter to 000H by bringing RST from "L" to "H".
2. Apply the appropriate control signals for Read Code data and read the output data at the port P1 pins.
3. Pulse pin XTAL1 once to advance the internal address counter.
4. Read the next code data byte at the port P1 pins.
5. Repeat steps 3 and 4 until the entire array is read.

The lock bits cannot be verified directly. Verification of the lock bits is achieved by observing that their features are enabled.

Chip Erase: The entire PEROM array (2K bytes) and the two Lock Bits are erased electrically by using the proper combination of control signals and by holding P3.2 low for 10 ms. The code array is written with all "1"s in the Chip Erase operation and must be executed before any non-blank memory byte can be re-programmed.

Reading the Signature Bytes: The signature bytes are read by the same procedure as a normal verification of locations 000H, 001H, and 002H, except that P3.5 and P3.7 must be pulled to a logic low. The values returned are as follows.

(000H) = 1EH indicates manufactured by Atmel
(001H) = 21H indicates 89C2051

Programming Interface

Every code byte in the Flash array can be written and the entire array can be erased by using the appropriate combination of control signals. The write operation cycle is self-timed and once initiated, will automatically time itself to completion.

All major programming vendors offer worldwide support for the Atmel microcontroller series. Please contact your local programming vendor for the appropriate software revision.

SLRS027O – DECEMBER 1976 – REVISED JANUARY 2016

ULN200x, ULQ200x High-Voltage, High-Current Darlington Transistor Arrays

1 Features

- 500-mA-Rated Collector Current (Single Output)
- High-Voltage Outputs: 50 V
- Output Clamp Diodes
- Inputs Compatible With Various Types of Logic
- Relay-Driver Applications

2 Applications

- Relay Drivers
- Stepper and DC Brushed Motor Drivers
- Lamp Drivers
- Display Drivers (LED and Gas Discharge)
- Line Drivers
- Logic Buffers

3 Description

The ULx200xA devices are high-voltage, high-current Darlington transistor arrays. Each consists of seven NPN Darlington pairs that feature high-voltage outputs with common-cathode clamp diodes for switching inductive loads.

The collector-current rating of a single Darlington pair is 500 mA. The Darlington pairs can be paralleled for higher current capability. Applications include relay drivers, hammer drivers, lamp drivers, display drivers (LED and gas discharge), line drivers, and logic buffers. For 100-V (otherwise interchangeable) versions of the ULx2003A devices, see the SLRS023 data sheet for the SN75468 and SN75469 devices.

The ULN2002A device is designed specifically for use with 14-V to 25-V PMOS devices. Each input of this device has a Zener diode and resistor in series to control the input current to a safe limit. The ULx2003A devices have a 2.7-kΩ series base resistor for each Darlington pair for operation directly with TTL or 5-V CMOS devices.

The ULx2004A devices have a 10.5-kΩ series base resistor to allow operation directly from CMOS devices that use supply voltages of 6 V to 15 V. The required input current of the ULx2004A device is below that of the ULx2003A devices, and the required voltage is less than that required by the ULN2002A device.

Device Information[(1)]

PART NUMBER	PACKAGE	BODY SIZE (NOM)
ULx200xD	SOIC (16)	9.90 mm × 3.91 mm
ULx200xN	PDIP (16)	19.30 mm × 6.35 mm
ULN200xNS	SOP (16)	10.30 mm × 5.30 mm
ULN200xPW	TSSOP (16)	5.00 mm × 4.40 mm

(1) For all available packages, see the orderable addendum at the end of the data sheet.

Simplified Block Diagram

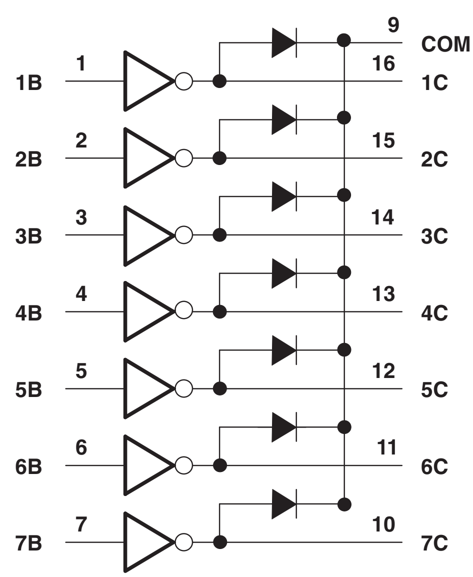


Table of Contents

4 Revision History

NOTE: Page numbers for previous revisions may differ from page numbers in the current version.

Changes from Revision N (June 2015) to Revision O	Page
• Changed Pin Functions table to correct typographical error.	3

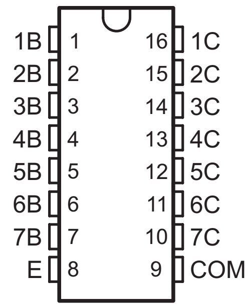
Changes from Revision M (February 2013) to Revision N	Page
• Added *Pin Configuration and Functions* section, *ESD Ratings* table, *Feature Description* section, *Device Functional Modes*, *Application and Implementation* section, *Power Supply Recommendations* section, *Layout* section, *Device and Documentation Support* section, and *Mechanical, Packaging, and Orderable Information* section	1
• Deleted *Ordering Information* table. No specification changes.	1
• Moved *Typical Characteristics* into *Specifications* section.	8

Changes from Revision L (April 2012) to Revision M	Page
• Updated temperature rating for ULN2003AI in the ORDERING INFORMATION table	1

Changes from Revision K (August 2011) to Revision L	Page
• Removed reference to obsolete ULN2001 device.	1

5 Pin Configuration and Functions

D, N, NS, and PW Package
16-Pin SOIC, PDIP, SO, and TSSOP
Top View



Pin Functions

PIN		I/O[(1)]	DESCRIPTION
NAME	NO.		
1B	1	I	Channel 1 through 7 Darlington base input
2B	2		
3B	3		
4B	4		
5B	5		
6B	6		
7B	7		
1C	16	O	Channel 1 through 7 Darlington collector output
2C	15		
3C	14		
4C	13		
5C	12		
6C	11		
7C	10		
COM	9	—	Common cathode node for flyback diodes (required for inductive loads)
E	8	—	Common emitter shared by all channels (typically tied to ground)

(1) I = Input, O = Output

6 Specifications

6.1 Absolute Maximum Ratings

at 25°C free-air temperature (unless otherwise noted)[1]

			MIN	MAX	UNIT
V_{CC}	Collector-emitter voltage			50	V
	Clamp diode reverse voltage[2]			50	V
V_I	Input voltage[2]			30	V
	Peak collector current, See Figure 4 and Figure 5			500	mA
I_{OK}	Output clamp current			500	mA
	Total emitter-terminal current			–2.5	A
T_A	Operating free-air temperature range	ULN200xA	–20	70	°C
		ULN200xAI	–40	105	
		ULQ200xA	–40	85	
		ULQ200xAT	–40	105	
T_J	Operating virtual junction temperature			150	°C
	Lead temperature for 1.6 mm (1/16 inch) from case for 10 seconds			260	°C
T_{stg}	Storage temperature		–65	150	°C

(1) Stresses beyond those listed under *Absolute Maximum Ratings* may cause permanent damage to the device. These are stress ratings only, and functional operation of the device at these or any other conditions beyond those indicated under *Recommended Operating Conditions* is not implied. Exposure to absolute-maximum-rated conditions for extended periods may affect device reliability.
(2) All voltage values are with respect to the emitter/substrate terminal E, unless otherwise noted.

6.2 ESD Ratings

			VALUE	UNIT
$V_{(ESD)}$	Electrostatic discharge	Human body model (HBM), per ANSI/ESDA/JEDEC JS-001[1]	±2000	V
		Charged device model (CDM), per JEDEC specification JESD22-C101[2]	±500	

(1) JEDEC document JEP155 states that 500-V HBM allows safe manufacturing with a standard ESD control process.
(2) JEDEC document JEP157 states that 250-V CDM allows safe manufacturing with a standard ESD control process.

6.3 Recommended Operating Conditions

over operating free-air temperature range (unless otherwise noted)

		MIN	MAX	UNIT
V_{CC}	Collector-emitter voltage (non-V devices)	0	50	V
T_J	Junction temperature	–40	125	°C

6.4 Thermal Information

THERMAL METRIC[1]		ULx200x D (SOIC) 16 PINS	ULx200x N (PDIP) 16 PINS	ULx200x NS (SO) 16 PINS	ULx200x PW (TSSOP) 16 PINS	UNIT
$R_{\theta JA}$	Junction-to-ambient thermal resistance	73	67	64	108	°C/W
$R_{\theta JC(top)}$	Junction-to-case (top) thermal resistance	36	54	n/a	33.6	°C/W
$R_{\theta JB}$	Junction-to-board thermal resistance	n/a	n/a	n/a	51.9	°C/W
ψ_{JT}	Junction-to-top characterization parameter	n/a	n/a	n/a	2.1	°C/W
ψ_{JB}	Junction-to-board characterization parameter	n/a	n/a	n/a	51.4	°C/W

(1) For more information about traditional and new thermal metrics, see the *Semiconductor and IC Package Thermal Metrics* application report, SPRA953.

6.5 Electrical Characteristics: ULN2002A

T_A = 25°C

PARAMETER		TEST FIGURE	TEST CONDITIONS		ULN2002A MIN	TYP	MAX	UNIT
$V_{I(on)}$	ON-state input voltage	Figure 14	V_{CE} = 2 V,	I_C = 300 mA			13	V
V_{OH}	High-level output voltage after switching	Figure 18	V_S = 50 V, I_O = 300 mA		V_S – 20			mV
$V_{CE(sat)}$	Collector-emitter saturation voltage	Figure 12	I_I = 250 µA,	I_C = 100 mA		0.9	1.1	V
			I_I = 350 µA,	I_C = 200 mA		1	1.3	
			I_I = 500 µA,	I_C = 350 mA		1.2	1.6	
V_F	Clamp forward voltage	Figure 15	I_F = 350 mA			1.7	2	V
I_{CEX}	Collector cutoff current	Figure 9	V_{CE} = 50 V,	I_I = 0			50	µA
		Figure 10	V_{CE} = 50 V, T_A = 70°C	I_I = 0			100	
				V_I = 6 V			500	
$I_{I(off)}$	OFF-state input current	Figure 10	V_{CE} = 50 V,	I_C = 500 µA	50	65		µA
I_I	Input current	Figure 11	V_I = 17 V			0.82	1.25	mA
I_R	Clamp reverse current	Figure 14	V_R = 50 V	T_A = 70°C			100	µA
			V_R = 50 V				50	
C_i	Input capacitance		V_I = 0,	f = 1 MHz			25	pF

6.6 Electrical Characteristics: ULN2003A and ULN2004A

T_A = 25°C

PARAMETER		TEST FIGURE	TEST CONDITIONS		ULN2003A MIN	TYP	MAX	ULN2004A MIN	TYP	MAX	UNIT
$V_{I(on)}$	ON-state input voltage	Figure 14	V_{CE} = 2 V	I_C = 125 mA						5	V
				I_C = 200 mA			2.4			6	
				I_C = 250 mA			2.7				
				I_C = 275 mA						7	
				I_C = 300 mA			3				
				I_C = 350 mA						8	
V_{OH}	High-level output voltage after switching	Figure 18	V_S = 50 V, I_O = 300 mA		V_S – 20			V_S – 20			mV
$V_{CE(sat)}$	Collector-emitter saturation voltage	Figure 13	I_I = 250 µA,	I_C = 100 mA		0.9	1.1		0.9	1.1	V
			I_I = 350 µA,	I_C = 200 mA		1	1.3		1	1.3	
			I_I = 500 µA,	I_C = 350 mA		1.2	1.6		1.2	1.6	
I_{CEX}	Collector cutoff current	Figure 9	V_{CE} = 50 V,	I_I = 0			50			50	µA
		Figure 10	V_{CE} = 50 V, T_A = 70°C	I_I = 0			100			100	
				V_I = 6 V						500	
V_F	Clamp forward voltage	Figure 16	I_F = 350 mA			1.7	2		1.7	2	V
$I_{I(off)}$	Off-state input current	Figure 11	V_{CE} = 50 V, T_A = 70°C,	I_C = 500 µA	50	65		50	65		µA
I_I	Input current	Figure 12	V_I = 3.85 V			0.93	1.35				mA
			V_I = 5 V						0.35	0.5	
			V_I = 12 V						1	1.45	
I_R	Clamp reverse current	Figure 15	V_R = 50 V				50			50	µA
			V_R = 50 V	T_A = 70°C			100			100	
C_i	Input capacitance		V_I = 0,	f = 1 MHz		15	25		15	25	pF

6.7 Electrical Characteristics: ULN2003AI

T_A = 25°C

PARAMETER		TEST FIGURE	TEST CONDITIONS		ULN2003AI MIN	TYP	MAX	UNIT
$V_{I(on)}$	ON-state input voltage	Figure 14	V_{CE} = 2 V	I_C = 200 mA			2.4	V
				I_C = 250 mA			2.7	
				I_C = 300 mA			3	
V_{OH}	High-level output voltage after switching	Figure 18	V_S = 50 V, I_O = 300 mA		V_S – 50			mV
$V_{CE(sat)}$	Collector-emitter saturation voltage	Figure 13	I_I = 250 µA,	I_C = 100 mA		0.9	1.1	V
			I_I = 350 µA,	I_C = 200 mA		1	1.3	
			I_I = 500 µA,	I_C = 350 mA		1.2	1.6	
I_{CEX}	Collector cutoff current	Figure 9	V_{CE} = 50 V,	I_I = 0			50	µA
V_F	Clamp forward voltage	Figure 16	I_F = 350 mA			1.7	2	V
$I_{I(off)}$	OFF-state input current	Figure 11	V_{CE} = 50 V,	I_C = 500 µA	50	65		µA
I_I	Input current	Figure 12	V_I = 3.85 V			0.93	1.35	mA
I_R	Clamp reverse current	Figure 15	V_R = 50 V				50	µA
C_i	Input capacitance		V_I = 0,	f = 1 MHz		15	25	pF

6.8 Electrical Characteristics: ULN2003AI

T_A = –40°C to 105°C

PARAMETER		TEST FIGURE	TEST CONDITIONS		ULN2003AI MIN	TYP	MAX	UNIT
$V_{I(on)}$	ON-state input voltage	Figure 14	V_{CE} = 2 V	I_C = 200 mA			2.7	V
				I_C = 250 mA			2.9	
				I_C = 300 mA			3	
V_{OH}	High-level output voltage after switching	Figure 18	V_S = 50 V, I_O = 300 mA		V_S – 50			mV
$V_{CE(sat)}$	Collector-emitter saturation voltage	Figure 13	I_I = 250 µA,	I_C = 100 mA		0.9	1.2	V
			I_I = 350 µA,	I_C = 200 mA		1	1.4	
			I_I = 500 µA,	I_C = 350 mA		1.2	1.7	
I_{CEX}	Collector cutoff current	Figure 9	V_{CE} = 50 V,	I_I = 0			100	µA
V_F	Clamp forward voltage	Figure 16	I_F = 350 mA			1.7	2.2	V
$I_{I(off)}$	OFF-state input current	Figure 11	V_{CE} = 50 V,	I_C = 500 µA	30	65		µA
I_I	Input current	Figure 12	V_I = 3.85 V			0.93	1.35	mA
I_R	Clamp reverse current	Figure 15	V_R = 50 V				100	µA
C_i	Input capacitance		V_I = 0,	f = 1 MHz		15	25	pF