SMART AUTOMATED HOME

MEGAT IZZUDDIN BIN MEGAT AB MANAP

MAY 2008

"I hereby declared that I have read through this report and found that it has comply the partial fulfillment for awarding the degree of Bachelor of Electrical Engineering (Control, Instrumentation & Automation)"

Signature	:	…………………………………
Supervisor's Name	:	Jurifa Bt Mat Lazi
Date	:	6 May 2008

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This Report Is Submitted In Partial Fulfillment of Requirements for the Degree of Bachelor in Electrical Engineering (Control, Instrumentation & Automation)

Faculty of Electrical Engineering
Universiti Teknikal Malaysia Melaka

May 2008

DECLARATION

"I hereby declared that this report is a result of my own work except for the excerpts that have been cited clearly in the references."

Signature : ………………………………………

Name : MEGAT IZZUDDIN BIN MEGAT AB MANAP

Date : 6 MAY 2008

DEDICATION

For my beloved father, Megat Abd Manap Bin Megat Husain and mother, Arbaah Bte Mat Said, my brother and sister

ACKNOWLEDGEMENTS

First of all, I would like to express my thankfulness to Allah S.W. T who has given me the strength, knowledge and capability to implement and complete my Projek Sarjana Muda and also to complete this report.

I would like to express my highest and foremost gratitude to my project supervisor, Puan Jurifa Bt Mat Lazi for her guidance, help and advices to complete this project. Next, I would like to thank Malaysian Coal Integrated Engineering Services (MCIE), the company which I had my industrial training attachment with for their sponsorship of equipments and devices which I used for my project. I would also like to thank the Faculty of Electrical Engineering (FKE), Universiti Teknikal Malaysia Melaka (UTeM) for giving me the opportunity to implement and complete my project.

Next, I would like to thank my parents for their financial and support and also to my fellow friends in 4BEKC. Last but not least, I would like to thank everyone who is directly and indirectly involved in this project. Their support and encouragement has given me the strength and effort to complete this project. Thank you.

ABSTRACT

This project is about the construction of an automated control system for a smart home to control critical house parameters, which includes the indoor and outdoor lightings, indoor ventilation, garbage management, garden watering, garage/parking and events alert. The outdoor lightings are automatically activated when the day gets dark by using a dark detection circuit. The indoor lightings are equipped with dimmers and the switches are relocated to more strategic locations. The indoor ventilation is connected to a temperature sensing circuit which controls a pair of ventilation fans to lower the indoor temperature. The garbage management automatically takes care of the garbage according to the collection schedule. The garden watering will be automatically activated according the time. The garage/parking system are designed to be safer and more convenient for the occupants while the event alert warns its occupant of possible danger. The operation for each parameters are represented on a scale model. The system utilizes the use of Programmable Logic Controller (PLC) and Integrated Circuit (IC) to create an interconnected control system. Each system are connected with other common input and output devices such as motors, switches, sensors, lights, relays etc.

ABSTRAK

Projek ini adalah berkenaan tentang pembinaan suatu sistem kawalan automatik utk rumah pintar untuk mengawal bahagian-bahagian penting rumah termasuklah lampu dalaman dan lampu luaran, ventilasi dalam rumah, pengurusan sampah, pengairan taman, tempat letak kereta dan juga amaran awal. Lampu luar boleh dihidupkan secara automatik mengunakan litar mengesan kepekaan cahaya. Lampu dalaman pula telah dilengkapi dengan pemalap dan suis akan ditempatkan semula di tempat yang lebih strategik. Ventilasi dalam rumah akan disambungkan dengan litar pengesan kepekaan haba yang mengawal sepasang kipas ventilasi utk menurunkan suhu di dalam rumah. Pengurusan sampah pula menguruskan sampah mengikut waktu kutipan sampah. Pengairan taman juga akan dihidupkan secara automatik mengikut waktu. Tempat letak kereta akan direka untuk menjadi lebih selamat dan lebih mudah untuk penghuni manakala amaran awal memberi amaran tentang bahaya yang bakal menimpa. Operasi untuk setiap bahagian diwakilkan pada model skala. Sistem ini akan mengaplikasikan pengunaan Pengawal Logik Aturcara (PLC) dan Litar terbina dalam (IC) untuk mencipta suatu sistem kawalan. Setiap sistem disambungkan dengan input dan output seperti motor, suis, sensor, lampu, geganti dan lain-lain.

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ABBREVIATIONS	MEANING
CCTV	Closed circuit television
DC	Direct current
AC	Alternating current
IC	Integrated circuit
LCD	Liquid crystal display
LDR	Light dependant resistor
LED	Light emitting diode
PLC	Programmable logic controller
PIC	Programmable interface controller
PWM	Pulse Width Modulation
NO	Normally open
NC	Normally close

CHAPTER 1

INTRODUCTION

1.1 Project Background

This chapter provides the necessary background for this project, which explains the basic principle of PLC and IC control system.

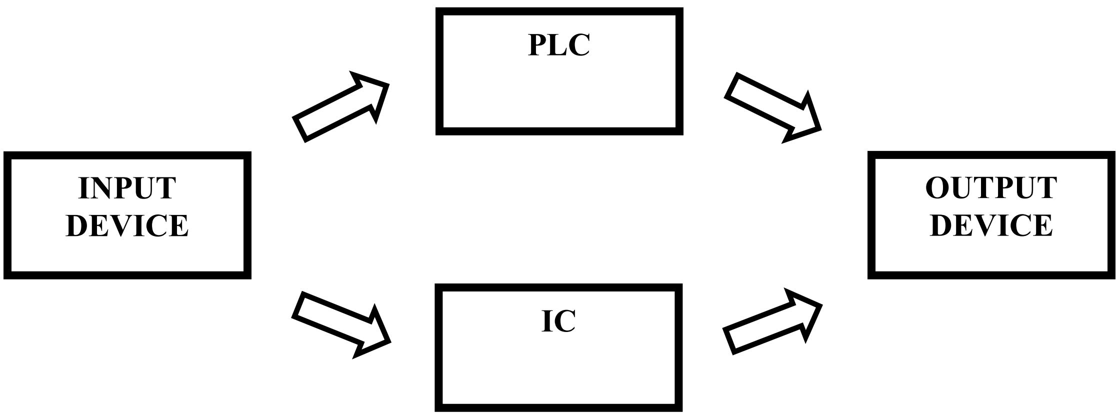


Figure 1.1: Block Diagram of control system using PLC and IC

To create a control system, it must have 3 basic components which are input, process and output. The process consists of the PLC and IC which acts as input signal processing device to control the output. A brief introduction to the concept of application is given to provide basic understanding of this project.

The input device comes in the form of ordinary on/off limit switches, push buttons, variable resistors, photo-electric sensors, proximity sensor, light dependent resistors (LDR) and thermistors. These devices provide the activation signal in the form of analog or digital signal to the control unit.

The controller part which is the PLC and the IC acts as the primary control unit for this project. In this system, the PLC controller used is the Omron ZEN micro PLC unit. The input signals are transmitted digitally into the PLC and an appropriate “decision” will be made by the PLC according to the programmed ladder logic diagram. The PLC will then produce a digital signal in the form of relay output. The PLC is chosen over PIC to provide control for this project due to its multiple inputs and output arrangements and also its easy and user friendly programming using ladder logic diagram. The key feature for the PLC that is used is the built in daily, weekly and monthly timer capability which provides useful control for time controlled operation.

The IC is used for analog signal processing which involves decision making through logic gates combination and comparing two or more sets of input signals. There are two main advantages of ICs over discrete circuits which is the cost and performance. Cost is low because the chips, with all their components, are printed as a unit by photolithography and not constructed a transistor at a time. Performance is high since the components switch quickly and consume little power, because the components are small and close together.

For this project, the control is divided into two control devices which are the PLC and the IC. The purpose for this design is to fully utilize the advantages of both devices. The PLC has the advantage of easy programming, multiple relay outputs and enables systematic & organized wiring to be implemented. The IC on the other hand has the advantage of miniature size, low costs and provides tons of function according to the circuit it is connected. By combining two forms of these widely used devices, a good and reliable control system can be created to cater the project’s needs.

The output device will be in the form of relays, buzzer, DC motors, tweeter, lights, LEDs and fans. These devices receive activation signal from the PLC, IC or directly from the input device and perform various functions including illumination, cooling and etc.

1.2 Problem Statement

This project like all others is created to solve problems that we humans encounter everyday. Upon completion of this project, the problems that we face will hopefully be solved or at least reduced. To make it easier to explain regarding the problem statements, they are divided into two parts, which is general aspect and detailed according to the system arrangements

1.2.1 General Problem Statement

- There is no training kit that emphasizes the combination between PLC and electronics based circuits.
- Most training kit available focuses on industrial system but not home automation system.
- Available home automation has limited control over devices/system and costly.
- Normal homes are inconvenience, not safe and not economical.

1.2.2 Detailed Problem Statement

- For the indoor lightings, the lights switches are located far away, not easily to access locations and the lights cannot be dimmed.
- The outdoor lights needs to be turned on and off manually at day & night and sometimes the occupant forgot to turn them off. This causes wastage in electricity bills.
- The temperature inside (indoor) are hot and unpleasant. The hot/warm air is trapped inside house due to poor ventilation
- The occupant missed the weekly garbage collection time and the garbage spilled when bringing it outside the house. Furthermore, the odor from the garbage attracts flies & disease.
- Plants at the garden die due to lack of watering and the gardens are infected by pests.
- Accidentally hit the garage wall/children while reversing the vehicle and sometimes the occupant forgets to close the garage door
- House does not have fire and flood warning system.

1.3 Project Objective

The objective of this project is to design & construct a control system which consists of home automation and lighting control that can be used for various purpose especially teaching & learning and home application.

The lighting control is used to control the illumination and brightness for the indoor and outdoor lightings while the home automation is used to control the indoor ventilation, garbage disposal, garden management, garage/car park and events alert.

1.4 Project Scope

Scope and limitations for this project:

- Design and construction of a control system consist of home automation and lighting control.
- Constructed using PLC, Electronic circuits, DC motors, sensors, switches, relays etc.
- The model design & construction consists of small scale model that represents the connection and function of the system.
- System powered by DC source through switching power supply and voltage regulators.
- Lighting
  i. Indoor
  ii. Outdoor
- Home automation
  i. Ventilation (Indoor)
  ii. Garbage disposal
  iii. Garden management
  iv. Garage/car park
  v. Events alert

1.5 Project Advantages & Benefits

There are many advantages and benefits for the implementation of this project. A simple yet effective lighting control and home automation system is created. The control and automation system is easy to troubleshoot for problems and easy to improve or upgrade the system in the future. The system is also user friendly and safe that is usable by all ages including children as a system should be easy to control and handled by everyone. The system creates a low cost home automation system that is affordable by everyone so that everyone can experience the advancement in modern technology.

The system also makes efficient use of electricity by optimizing and minimizing the usage hours of lightings and ventilations system through automatic turn on and turn off system. Electricity bills and power wastage will be reduced and ensures a prolonged life span of electrical devices through optimized working hours. Lights and fans turn on only when needed.

This project is also aimed as an educational tool in the classroom which provides a more interesting approach and better understanding on the application of automation for homes.

CHAPTER 2

LITERATURE REVIEW

2.1 Case Study

The case study for this project is based on the Home Depot Smart Home constructed by Duke's Pratt School of Engineering.

2.1.1 The Home Depot Smart Home

Figure 2.1(a): The Home Depot Smart Home

The Home Depot Smart Home is a 6,000 square foot live-in research laboratory operated by Duke's Pratt School of Engineering. The Home Depot Smart Home, part of a Duke Smart Home Program, creates a dynamic "living laboratory" environment that contributes to the innovation and demonstration of future residential building technology. The central concept of this project is our belief that smart homes can improve that quality of life for people of all ages and incomes.

The Home Depot Smart Home provides students at Duke's Pratt School of Engineering, Trinity School of Arts and Sciences and Nicholas School for the Environment and Earth Sciences with an opportunity for practical hands- on engineering outside of the classroom in a living and learning community. In addition, the partnering with industry to strengthen the residential market for integrated technology, and helping homeowners make their own ideas for smart homes a reality.

The goals for the residents of The Home Depot Smart Home are to:

a) Commit to and explore an energy efficient lifestyle,
b) Compare, use and develop smart and sustainable technology, and
c) Provide insight to homeowners for "do-it-yourself" technology integration and control.

2.1.2 The purpose of building the Home Depot Smart Home at Duke

Other universities already have smart homes, so why build another one at Duke? One of the most important aspects of this project is that it is a living laboratory--students will actually reside in The Home Depot Smart Home, and live with the benefits and consequences of their technology design and deployment decisions. This up close and personal approach to technology development will have a profound impact on the students--and on industry as Pratt engineers graduate and launch their own careers. The intention is to share the experiences and technology innovations and draw upon the experiences of other university Smart Home projects. The long term goal is to influence the national market for residential technology integration, and to help educate homeowners about the latest technologies.

2.1.3 The Duke Smart Home Program

The Duke Smart Home Program is a research-based approach to smart living sponsored by the Pratt School of Engineering. Primarily focused on undergraduates, the program encourages students from different academic disciplines to form teams and explore smart ways to use technology in the home. The emphasis on 'smart' means finding the best technology answer for a particular problem--not just finding the high tech solution or the latest gadget on the market. This approach naturally leads students to identify 'gaps' in the marketplace--problems that just aren't being addressed through commercially available technology. These gaps then become the basis for exploration.

The Duke Smart Home Program encompasses a 6,000 sq. ft. residential dorm and research laboratory called the Home Depot Smart Home; a thriving student club of Duke students who explore smart home technology design and prototyping (some projects are directly related to the dorm), a growing core of faculty to conduct research that parallels the goals of the Duke Smart Home Program, and an enthusiastic community of members of industry who see this program as a unique way to cultivate the next generation of employees and to augment their own consumer technology R&D efforts. Hopefully, others will see sustainable living research at Duke continue expand to include students from all disciplines of academic study. In addition, to stimulate faculty across Duke to participate in research focused on technology adoption, energy efficiency, and environmental sustainability.

The Duke Smart Home Program fosters strong relationships with industry through collaborative projects, tours and interviews, guest lectures and internships. Hopefully, to not only strengthen the market for integrated technology, but to also help homeowners make their own ideas for smart home a reality. The central concept of this project is the belief that smart homes can improve that quality of life for people of all ages and incomes.

The Duke Smart Home Program provides students with outlets for:

a) Hands-on technology exploration and optimization,
b) Project management, team building and design experience,
c) Study of technology adoption and design refinement,
d) Study of product marketability, economics and practical engineering aspects of product design, and exploring the gap between commercial versus consumer technology and shaping the future of smart residential living.

2.1.4 Benefits of the Duke Smart Home Program

a) Provides Practical Design Experience - One of the biggest challenges for universities is involving students in hands-on engineering experiences early in the curriculum. Design and application of design is the most fundamental skill of engineering, yet at many universities, exposure to design is often limited until senior year. Multiple Duke engineering classes already are using data from the various Smart Home projects to teach students in tangible ways.
b) Project Management and Communications Experience - Students in the program hold responsibility for creating their own project proposals and managing project teams as well as interacting with corporations. Students gain valuable experience in project management, budgeting, and communication in addition to the technical skills of engineering research and design.

c) Exposure to Cross-disciplinary teamwork - The Home Depot Smart Home project is inherently cross-disciplinary--incorporating civil and environmental engineering, electrical and computer engineering, materials science and mechanical engineering and even biomedical engineering. The project also draws on computer science, environmental science and human factors disciplines. Project teams are specifically designed to bridge the gap across the disciplines and give students exposure and experience in field outside their own specialties. With all these disciplines involved, student teams gain a unique support network unavailable to most entrepreneurs and this will promote the future success of our students.

d) Intellectual Property Awareness - This project increases intellectual property awareness on campus and serves as an invaluable resource for those wanting to prepare themselves for the technical world of product design and development. Whereas major corporations prefer to put on expensive shows to convince consumers to buy their products, using a different approach, educating the engineer before the consumer. The Home Depot Smart Home is a living laboratory for useful products and designs that may ultimately result in patents and publications of research for the university.

e) University/Industry Test Bed - The Home Depot Smart Home has the potential to be a powerful test bed for marketable university and industry derived technologies. With 10 students living in and monitoring all actions of the house, The Home Depot Smart Home becomes an effective venue for driving change in the marketplace. Testing designs and optimizing systems in The Home Depot Smart Home environment will be a major component of research. By remaining small, the house also has the added advantage of being flexible in design and operation. Successes and failures on this scale will be extremely beneficial to the university at a minimum cost risk.

f) Corporate Relations - The Home Depot Smart Home program is already serving as a bridge between academia and industry, bringing to campus corporate interest in the high tech community that will lead to future sponsorships and partnerships. In addition, an industry-relevant education is the best thing we can provide for our students. Through The Home Depot Smart Home industry relationships, students will have new opportunities for internships, mentoring and future employment.

g) Community Relations - The Home Depot Smart Home will serve as a new forum for community outreach and education. Among the various methods of community outreach will be technology seminars, The Home Depot Smart Home tours, publications and learning opportunities via the web site. We hope to help homeowners make sound decisions, and make their own dream of a smart home a reality.

2.1.5 Accessibility in The Home Depot Smart Home

Universal design promotes –products and environments usable by all people to the greatest extent possible without the need for adaptation or specialized design." Research will address the problem of second floor accessibility alternatives to an elevator, new audible and visual components of systems, adjustable and rotating counters and shelves, front loading and accessible machines, and heights of equipment.

2.1.6 Cooling Systems for The Home Depot Smart Home

In partnership with SolarFrost, The Home Depot Smart Home is developing a new technology that enables ammonia absorption cooling to take place at lower temperatures. A bypass loop allows hydrogen to absorb more ammonia from the water ammonia solution. With no moving parts, this system requires far more in labor than in parts to be built, making it ideal for third world applications.

2.1.7 Daylighting

Daylighting can significantly reduce the lighting power density without reducing measured lighting levels. It also helps reduce a building owner's electricity consumption during the utility's peak demand periods and reduce heating and cooling costs. It may also reduce the loss of worker productivity during power failures.

2.1.8 Fire Safety

With advanced in-home communication, common fire detection devices can be coupled with new reporting mechanisms to pinpoint locations of fires in relation to home occupants, to relay that information to authorities, and to determine the optimal escape route from any location.

2.1.9 Geothermal Pump

Geothermal heat pumps operate using the principle that the ground temperature below the frost line remains at nearly constant temperature throughout the year. The heat pump uses the differences between the constant temperature and the temperature within the building to either transfer energy from the house to the ground (cooling mode) or transfer energy from the ground to the building (heating mode). Multiple compressors increase system efficiency by better meeting varying load requirements. Waste heat from the compressors can be used to pre-heat water for use in showers and dishwashers.

2.1.10 Indoor Air Quality Monitoring

Students will develop real-time monitors of indoor environmental quality to create a low-toxin, low-pathogen environment. Airborne pollutants such as bacteria, dust mites, mold, pollen and biologicals as well as carbon dioxide levels will provide new data that could shed light on air quality control of conditioned spaces.

2.1.11 Leadership in Energy and Environmental Design (LEED)

Growing concern for the environment has caused a rise in what has come to be called "green building." The United States Green Building Council has been developing over the past 4 years the "Leadership in Energy and Environmental Design," or LEED green building rating system, with the purpose of accelerating the implementation of green building practices and establishing a standard for the certification of environmentally conscious buildings. The rating system is based on credits awarded in 6 categories: Sustainable Sites, Water Efficiency, Energy and Atmosphere, Materials and Resources, Indoor Environmental Quality, and Innovation and Design. The Home Depot Smart Home intends to achieve a Platinum rating.

2.1.12 Media-on-Demand

Students are working to create an all encompassing entertainment solution for the house so that media can be recorded, streamed and played back from a central server on any TV or computer using a special high bandwidth network optimized for media.

2.1.13 Photovoltaic System Design

The Home Depot Smart Home photovoltaic system will tie together PV modules, batteries, a flywheel, charge controller, and an AC inverter for selling power back to the grid. Multicrystalline and thin-film modules will face true south and reside at a tilt angle of Durham's latitude of 36° in order to maximize annual output. Initially, power consumption will cover 20 percent of The Home Depot Smart Home demand but could increase as the experiment with newer technologies utilizing monocrystalline material or laser-etched photovoltaics.

2.1.14 Protecting Public Health - UV Disinfection of Drinking Water

In addition to degrading organics, Ultra Violet light is currently highly researched for drinking water treatment. It has successfully deactivated both Cryptosporidium and Giardia oocysts and leaves no disinfection byproducts that are often a problem in highly chlorinated water. Atrazine, an s-triazine solid organic herbicide used for weed control throughout the mid-western United States, is the most widely used herbicide in the United States. Irradiation by Ultra Violet light is also on target to be approved by the EPA in the near future.

2.1.15 Recycling

Automated sorting and compacting of the entire range of recyclable materials will make recycling more convenient and efficient in The Home Depot Smart Home. Weight and dimensions distinguish a discarded object so that it can be distributed into the appropriate container. The compression mechanism can withstand pressure of 400 pounds in compliance with local recycling centers. Reclaimed water cleans and drains the compactor while not in use. The prototype was designed to reasonably fit within a dishwasher-sized kitchen cabinet. The ability to use this station as a one-stop-shop for both recyclables and general trash makes recycling more convenient and more likely.

2.1.16 Retractable Roof

The roof above the courtyard will contain a retractable skylight that can by opened or closed as desired. The action of the skylight will be controlled by a computer program that has access to internal and external environmental conditions information. The roof will provide research opportunities with daylighting, airflow and indoor air quality

2.1.17 RFID Technology

Coupled with face recognition technology, radio frequency identification will be used to track users throughout the house and store preferences for automated room temperature, media, lighting, and security control on an individual level.

2.1.18 Security

Moving beyond traditional lock and key for building access technologies in The Home Depot Smart Home may advance the science of keyless entry and biometric identification. Fingerprint scanners offer versatility, security, cost-effectiveness, reliability, customizability, and cutting-edge technology. Identification via hand-print geometry or iris scanning is neither feasible nor cost-effective for our purposes.

2.1.19 Soundproofing and Acoustic Suggestions

Students are researching methods of creating localized spaces of silence that already include hypersonic speakers, sand, air gaps, and resilient channels as well as actively processing noise signals to create new corrective signals for the human listener in real-time.

2.1.20 Water Catchment, Purification/Rainwater Harvesting

A rainwater catchment system reduces the amount of potable water used in irrigation and common household purposes. Grey-water systems isolate black-water, leaving gray-water available for reuse. Research is underway for new techniques of UV treatment rather than residual chlorine purification.

2.1.21 Adaptive Digital Signal Processing - Active Noise Filtering

Adapts to a room environment and uses the LMS algorithm to filter out unwanted background noise at known frequencies, which often interfere with voice-activated commands given to the home automation system.

2.1.22 Facial Recognition

In order to adequately determine the identity and location of a person in The Home Depot Smart Home, in-house security cameras perform face recognition analysis. Students have experimented with both Lowe's SIFT algorithm and Intel's OpenCV library as references for first identifying a face in a room and then determining the identity of that person. Light and viewing angle were the main system constraints, and the team dealt with issues such as data bandwidth, system reliability, and privacy concerns.

2.1.23 Advanced HVAC Control and Artificial Intelligence Controllers

This controller grows smarter as its neural network learns the relationship between occupant behavior patterns and room temperature fluctuations to recommend the most efficient and cost effective heating/cooling scheme.

2.1.24 LED Lighting

LED lights are a high output, low energy alternative to conventional lights that are compatible with conventional light sockets and can be customized to provide different output tones through color mixing.

2.1.25 Residential Piezoelectric Energy Sources

The Home Depot Smart Home is going to have a large number of sensors and microelectronic devices located throughout the house. These devices will need a clean, reliable source of energy that will not need constant maintenance. The goal of this project is to utilize piezoelectric energy sources to provide power to sensor and other low-power applications in the house.

2.1.26 Sensor Platform

Monitoring and reporting is central to The Home Depot Smart Home. The sensors that drive this process must be placed on an extensible and comprehensive network that can report readings from multiple sensor types and provide relevant data to all other systems for processing. Interconnectivity is vital in order to implement a decentralized network where devices can talk to each other and share information. Flexibility is also vital to The Home Depot Smart Home for research purposes. Logging takes place as 1-wire data is imported into an SQL database, and PHP web-based reports can be generated to alert occupants based on pre-set alarm levels.

2.1.27 Shower Heat Recovery

Students designed a concentric counter-flow heat exchanger, with the draining hot-water flowing on the outside and the incoming cold water flowing in the opposite direction, to salvage heat from wastewater for re-use in air and water heating applications. Initial efficiency recovery results were as high as 88%.

2.1.28 Sleep Monitoring

Sensors monitors occupant sleep patterns via external health indicators such as brain waves, heart rates, and REM to promote the best sleep possible and optimal wake-up times.

2.1.29 Home Automation

The Home Depot Smart Home’s planned home automation system will include the ability to remotely command by voice, devices such as lights, home theater, a centralized music library, and temperature control, in addition to providing a system for monitoring power and household events and managing security concerns.

2.2 Conclusion

Based upon the case study conducted on the Duke's Pratt School of Engineering Smart Home, their smart home has a much more advanced and sophisticated modules and systems fitted to the house. Comparing that with the project, there is more emphasize on simple and low cost workable modules and system of a smart home.

CHAPTER 3

METHODOLOGY

3.1 Overview

3.1.1 Literature review

The literature review is the where the project is referred to another project by another project party. The purpose of literature review is to provide guidance and objective for the current project. All the research and reference materials are also collected at this point.

3.1.2 Design the modules and circuits

A basic sketching on the idea and planning for the modules and circuits
are created to provide a basic idea or theory on the proposed project. The circuits are designed during this phase and any further improvements or corrections can be added later.

3.1.3 Simulate circuits

The designed circuit is assembled virtually using a simulation program (Multisim 7, Proteus 6 and ZEN support software).

3.1.4 Redesign circuits

The circuits that failed to be simulated during the simulation stage are corrected and the circuit is redesigned until the simulation is successful.

3.1.5 Purchase components

The parts and components needed are purchased according to the simulation. The purchasing process may continue in the future as some components may prove faulty or got damaged. The total cost for the implementation of this project is RM814.40. The cost does not include the price for the Omron ZEN PLC, optical distance sensor and the inductive proximity sensor which was sponsored.

3.1.6 Assemble circuits

The circuits are assembled according to the simulation.

3.1.7 Test operation

The assembled circuits are tested for operation

3.1.8 Troubleshoot

Should any of the circuits may experience operation failure, the circuit is checked to determine the cause of the problem. The circuit will be corrected and any faulty components are replaced.

3.1.9 Assemble the modules

As soon as the circuits are completed, they will be connected to their respective input and output devices such as sensors, fans, relay, motors etc. Only then, they will form a working and functioning module.

3.1.10 Test operation

Each of the following modules will be tested after they are connected to their input/output devices to make sure that they are functioning perfectly.

3.1.11 Improvements, modifications and additions

As the modules are working perfectly, any improvements, modifications and additions is made during this phase to make the modules perform better and at its best.

3.1.12 Analysis

Analysis on the circuit is carried out t determine their input/output behavior and characteristics. The output signal especially is monitored upon changes to the rating of the circuit (resistance, capacitance, input voltage etc).

3.1.13 Connect the assembled modules

The assembled modules are connected with each other to create the smart home system.

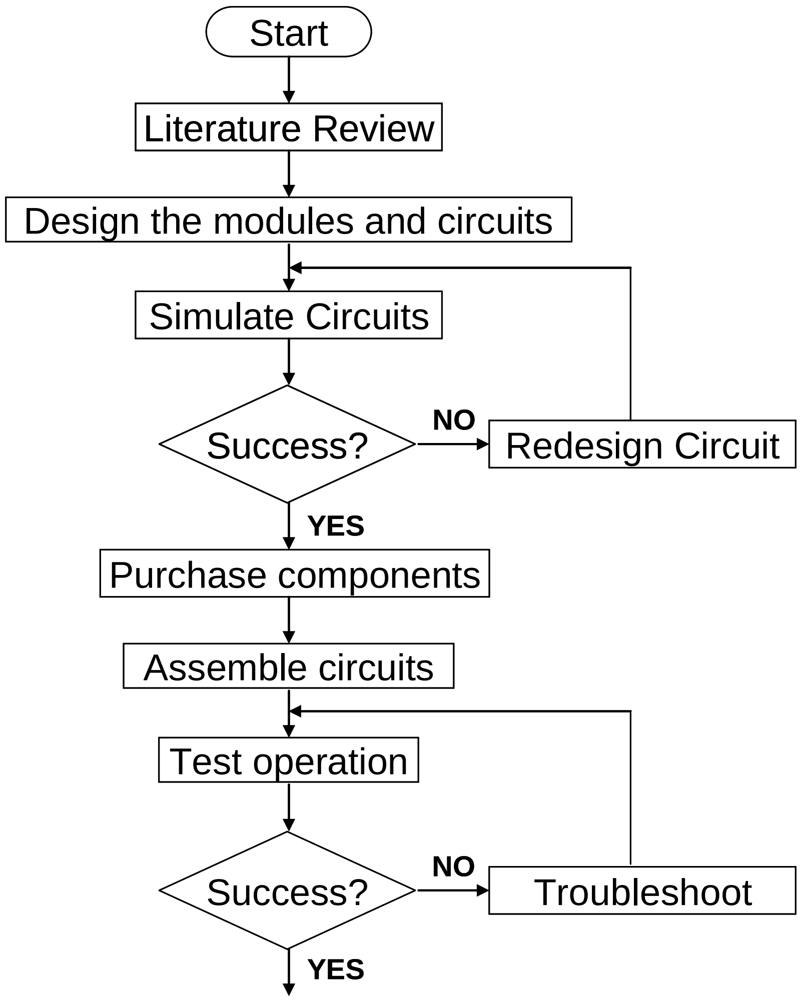
3.1.14 Test operation

The project is tested for the last time and should any problem persists, troubleshooting is carried out again.

3.1.15 Finalize

The project is finalized by adding, improving or repairing the circuits, hardware or equipments. The project is arranged nicely and presented to the panel for evaluation.

3.2 Flow Chart



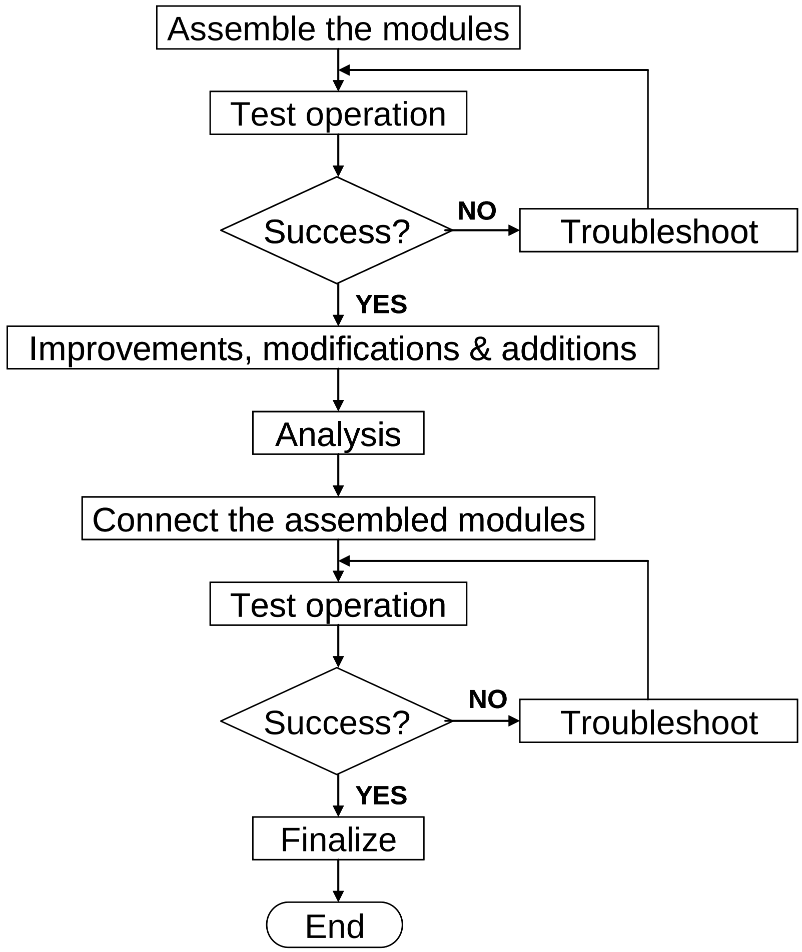


Figure 3.2: Project flow chart

3.3 Gantt Chart

PERANCANGAN PROJEK *PROJECT PLANNING*													
Senaraikan aktiviti-aktiviti utama bagi projek yang dicadangkan. Nyatakan jangka masa yang diperlukan bagi setiap aktiviti. *List major activities involved in the proposed project. Indicate duration of each activity to the related month(s).*													
	2007							**2008**					
Aktiviti Projek *Project's Activities*	**J**	**J**	**A**	**S**	**O**	**N**	**D**	**J**	**F**	**M**	**A**	**M**	**J**
▪ **Literature review & research**		■	■										
▪ **Design the modules & circuits**			■	■									
▪ **Simulate circuits using simulation software**			■	■	■								
▪ **Purchase components needed**				■	■								
▪ **Assemble circuit**					■	■	■						
▪ **Test & troubleshoot**					■	■	■						
▪ **Assemble modules**							■	■					
▪ **Test & troubleshoot**							■	■	■				
▪ **Improvements, modifications & additions**									■	■			
▪ **Analysis**									■	■	■		
▪ **Connect the assembled modules**										■	■		
▪ **Test & troubleshoot**										■	■		
▪ **Finalize & completion**											■	■	

Figure 3.3: Gantt Chart

CHAPTER 4

PROJECT BACKGROUND

4.1 Introduction

4.1.1 Smart Home

What is a Smart Home? A Smart Home is an integration of various systems at home such as security, home automation, lighting control, CCTV and entertainment system which is coordinated by a smart home controller and controlled by users using various centralized command interfaces such as touch screens, keypads, universal remote controllers, internet browser, telephone and LCD TV screen.

Figure 4.1(a): A smart home system

4.1.1.1 Functions of smart home system

The functions and details of a smart home system based on Figure 3.1(a):

- Motion Detection – serves a dual purpose for security for intrusion and automatic lighting.
- Pool & Spa – controls filters, timers, heating temperatures and solar control.
- Vehicle Detection – Announces visitors, turn on lights, and switch on TV to view driveway, etc.
- Lighting & Appliances – Automatic lighting and appliances control to simulate ―lived-in" look to deter burglary. Also capable of one touch button to create optimum scene for movie time, dining, romantic scene & etc.
- Irrigation – control and automate irrigation for lawn sprinklers, plus inputs for rain sensing.
- Surveillance Camera – To safeguard compound of the house. Capable of internet surveillance, automatic video recording & notification via email, etc.
- Enhanced Entertainment – Coordinate multiple AV system to bring the best of entertainment.

- Environment Control – Control indoor & outdoor temperature and humidity level to create the most comfortable environment for indoor & outdoor living.
- Front Line Security Layer – Using invisible photobeam sensors & radar type motion sensor to safeguard the perimeter of the house.
- Communication – Control the whole house via any phone at home or away. Get a call to advise on security, temperature and more.
- Internet & Home Networking HAI Weblink II allows the occupant to control and see status of the house from anywhere via the Internet browser or PDA.

4.1.1.2 Benefits of smart home system

The benefits of a Smart Home are its ―convenience at your finger tip" and it's comfortable and fun. The down stair living lights can be automatically turned on, turn on the perimeter lights, draw the curtains, and arm security to night mode with just one touch button from the comfort of the bedroom. The system can create the perfect mood for relaxation, movie, party night, romantic dinner or even easy listening with just one touch of a button.

4.2 Project Background

4.2.1 Indoor Lighting

4.2.1.1 Overview

The lights switches are located far away and not easily accessible locations and the lights inside the house cannot be dimmed according to the resident's moods.

To solve this problem, the lights switches are relocated to a closer and easy to reach locations. Light dimmer circuit is connected between the switch and the lights to vary and control the lights brightness.

4.2.1.2 Design

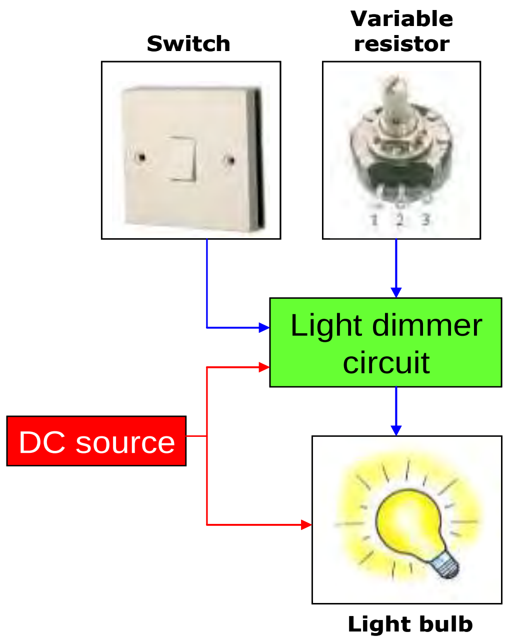


Figure 4.2.1(a): Block diagram for Indoor Lighting

A pulse width modulator (PWM) is a device that may be used as an efficient light dimmer or DC motor speed controller. A PWM circuit works by making a square wave with a variable on-to-off ratio, the average on time may be varied from 0 to 100 percent. In this manner, a variable amount of power is transferred to the load. The main advantage of a PWM circuit over a resistive power controller is the efficiency, at a 50% level, the PWM will use about 50% of full power, almost all of which is transferred to the load, a resistive controller at 50% load power would consume about 71% of full power, 50% of the power goes to the load and the other 21% is wasted heating the series resistor. Load efficiency is almost always a critical factor in solar powered and other alternative energy systems.

The additional advantage of pulse width modulation is that the pulses reach the full supply voltage and will produce more torque in a motor by being able to overcome the internal motor resistances more easily. Finally, in a PWM circuit, common small potentiometers may be used to control a wide variety of loads whereas large and expensive high power variable resistors are needed for resistive controllers.

The main disadvantages of PWM circuits are the added complexity and the possibility of generating radio frequency interference (RFI). RFI may be minimized by locating the controller near the load, using short leads, and in some cases, using additional filtering on the power supply leads.

4.2.1.3 Circuit

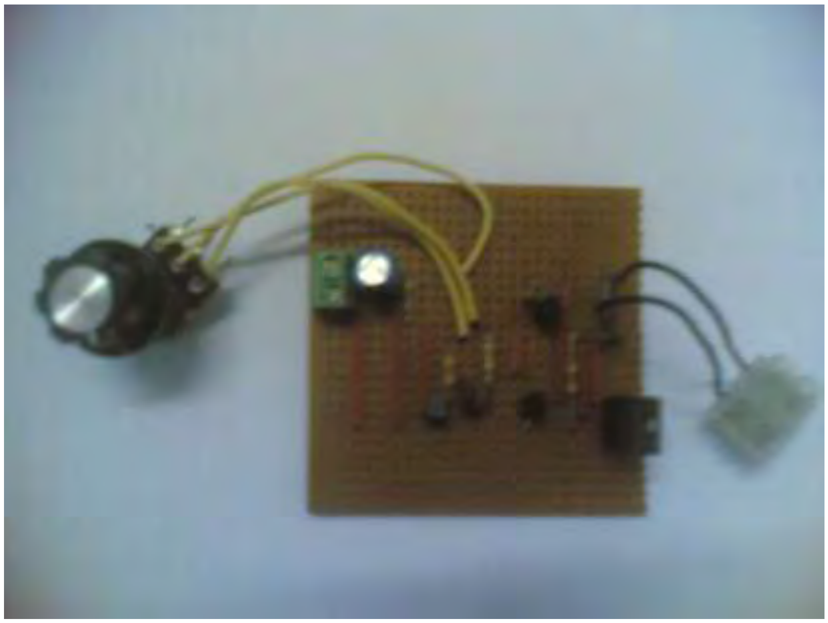


Figure 4.2.1(b): Assembled circuit for the Indoor Lighting

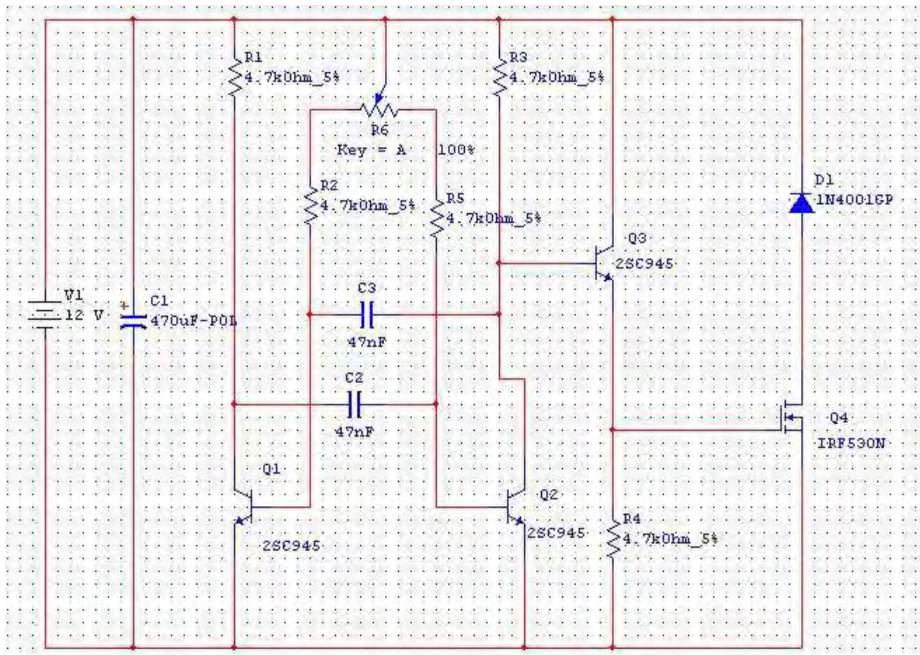


Figure 4.2.1(c): Light dimmer circuit using PWM control method

The PWM circuit requires a steadily running oscillator to operate. The transistors C945 provides an oscillating frequency of 150-450 MHz. Resistors R2 and R5 are used to set the end points of the R6 control, the values shown allow the control to have a full on and a full off setting within the travel of the potentiometer. These part values may be varied to change the behavior of the potentiometer. Q1 is the power switch, it receives the modulated pulse width voltage on the gate terminal and switches the load current on and off through the Source-Drain current path. When Q1 is on, it provides a ground path for the load, when Q1 is off, the load's ground is floating. Diode D1 is a flywheel diode that shorts out the reverse voltage kick from inductive motor loads.

4.2.1.4 Hardware and software

Listed below are the components used to construct the circuit. The software used for simulation is Multisim 7. The circuit is then connected to the output device which consists of 12VDC light bulbs. A manual latching pushbutton acts as an on/off switch for the circuit.

Components	**Label**	**Quantity**
470µF electrolytic capacitor	C1	1
47nF ceramic disc capacitor	C2, C3	2
4.7kΩ resistor	R1-R5	5
100kΩ potentiometer	R6	1
C945 NPN transistor	Q1-Q3	3
IRF530 N-Channel MOSFET	Q4	1
IN4001 diode	D1	1
12VDC 3W screw type light bulbs		2
Pushbutton (Latching type)		1

4.2.2 Outdoor Lighting

4.2.2.1 Overview

The outdoor lights needs to be turned on and off manually at day and night. To solve this problem, the outdoor lights are connected to a light/dark sensing circuit so that the lights automatically turn on at night and turns off at daytime.

4.2.2.2 Design

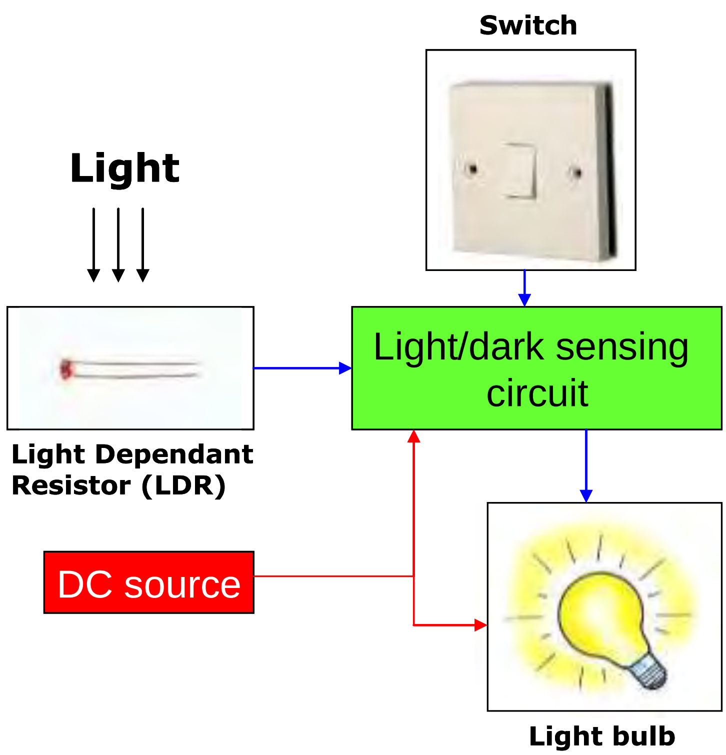


Figure 4.2.2(a): Block diagram for Outdoor Lighting

This module is used to illuminate the outdoor areas of the house automatically. This is made possible by using a light/dark sensing circuit. The circuit uses a regular Cadmium-Sulphide Light Dependant Resistor (LDR) which is a variable resistor whose value decreases with increasing incident light intensity. This circuit is used to sense the absence of light and produces an output to energize the relay coils. This will close the contacts and activates the lights where it is connected.

4.2.2.3 Circuit

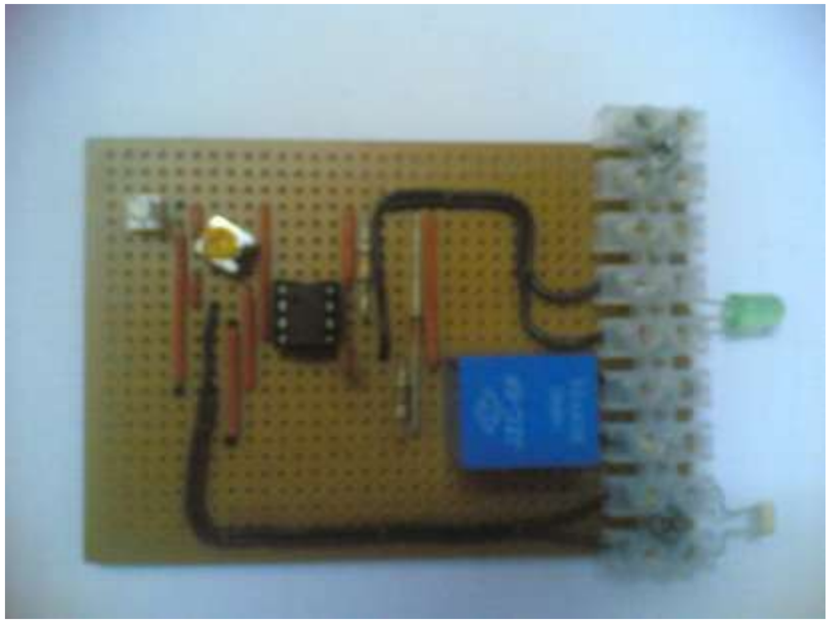


Figure 4.2.2(b): Assembled circuit for the Outdoor Lighting

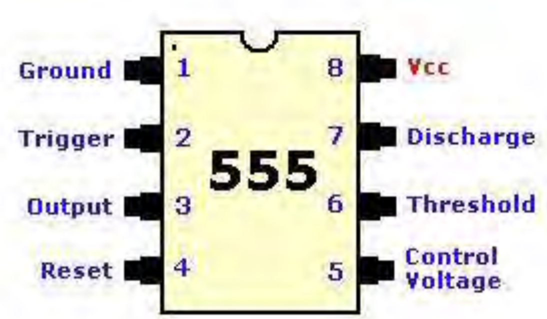


Figure 4.2.2(c): IC 555 Timer pin allocations

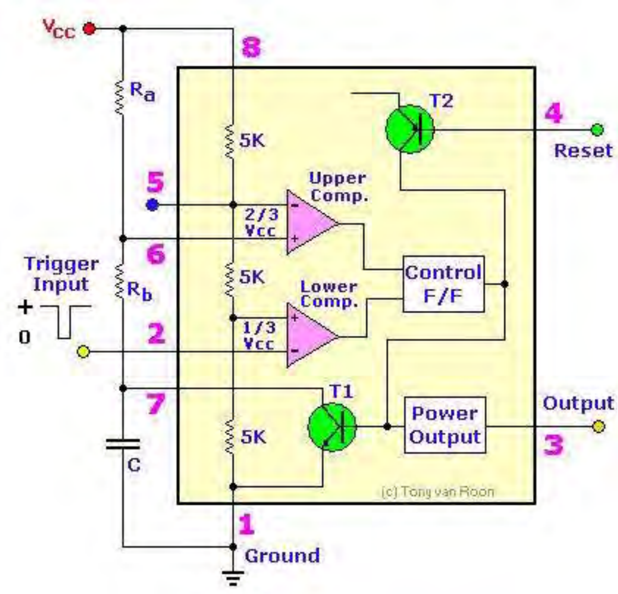


Figure 4.2.2(d): Internal circuit for IC 555 Timer

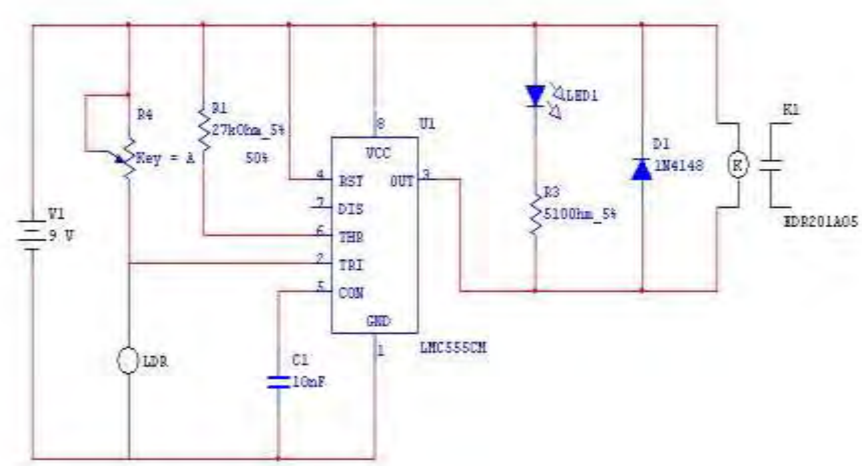


Figure 4.2.2(e): Light/dark sensing circuit for Outdoor Lighting

Pin 1 is connected to ground and Pin 8 is connected to the voltage source of 9V. Pin 2 is the input for lower comparator and is used to set the latch, which in turn causes the output to go high. The LDR and the potentiometer are connected to this pin to provide the ―turn on" signal. Pin 3 is the output which turns on the LED and energizes the relay coil. Pin 4 is used to reset the latch and return the output to low state. Pin 5 is the control voltage which provides the reference level for the upper comparator. It is bypassed to ground for noise immunity using a 10nF capacitor. Pin 6 is one input to the upper comparator and is used to reset the latch which causes the output to go low.

In bright light the resistance of the LDR can be as low as 80 ohm and at 50lux (darkness) the resistance increases to over 1 MΩ. The 1MΩ potentiometer control should provide a wide range for light intensities, if not its value may be increased. The timer senses the voltage difference between pins 2 and 6. The control R4 is adjusted so that the relay is off.

When light falls, the resistance of the LDR increases and the difference in input voltage is compared by the timer, the output will swing towards full supply and drives the LED and 5V relay.

4.2.2.4 Hardware and software

Listed below are the components used to construct the circuit. The software used for simulation is Multisim 7. The output from the relay is connected to 9VDC light bulbs. The module can be activated automatically using the LDR sensing or manually using a pushbutton.

A 2-way switch provides selection for auto/manual function. The LED indicates that the circuit is operational and the potentiometer provides calibration for the circuit's sensitivity according to the LDR's location.

Components	**Label**	**Quantity**
Timer	LM555	1
1MΩ potentiometer	R4	1
27kΩ resistor	R1	1
510Ω resistor	R3	1
10nF ceramic disc capacitor	C1	1
Light Emitting Diode	LED 1	1
Light Dependant Resistor	LDR	1
IN4148 diode	D1	1
5V Relay	K1	1
9VDC 3W screw type light bulbs		3
Screw type sockets		3
Pushbutton (latching type)		1
2-way selector switch		1

4.2.3 Indoor Ventilation

4.2.3.1 Overview

The indoor temperature is high during a hot day causing the resident to feel uncomfortable and sweaty. The warm air is trapped inside the house due to poor indoor ventilation. To solve this problem, an air circulatory system consists of intake & exhaust fans is connected to improve the indoor ventilation. These fans are controlled using temperature sensing circuit.

4.2.3.2 Design

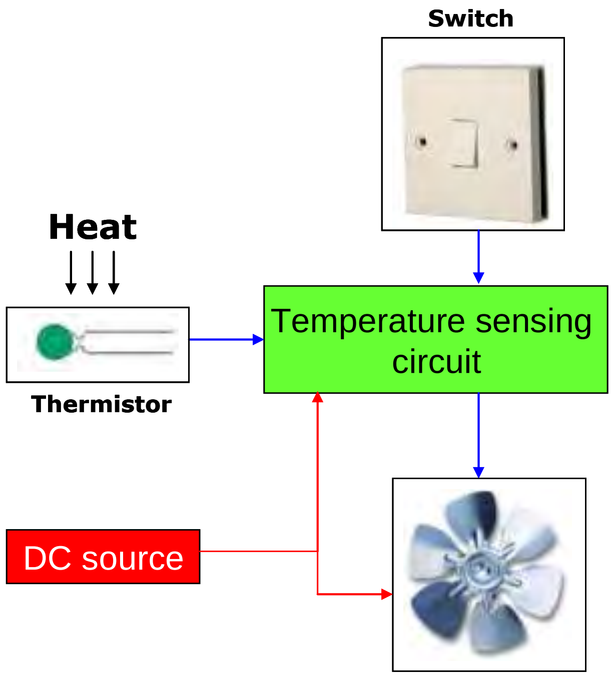


Figure 4.2.3(a): Block diagram for Indoor Ventilation

Temperature measurement is the most common application for NTC thermistors. The high sensitivity of thermistors and the ability to manufacture components with tightly controlled temperature accuracy has made the NTC thermistor an ideal device for low cost temperature measurement.

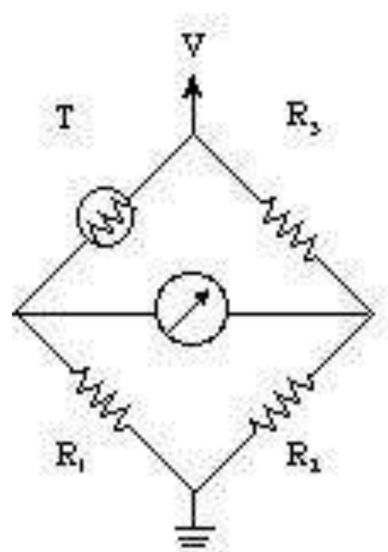


Figure 4.2.3(b): Wheatstone Bridge

The method of utilizing a thermistor to measure temperature is to use a Wheatstone bridge with the thermistor as one leg of the bridge. The circuit is one example of a circuit that utilizes a thermistor to sense temperature. As temperature increases, the voltage output increases. The selection of R1, R2 and R3 will determine the sensitivity of the circuit as well as the temperature range for which the circuit is best suited.

The ventilation fans will be activated when the temperature of the house rises above a pre-determined level. For this case we take a nominal room temperature of 27°C. When the temperature increases beyond this value, the circuit will activate the relay which activates the ventilation fans located on the above of the house. The ventilation fan purpose is to maintain and lower down the rooms temperature by extracting in the cool air from the outside (intake fan) and discharges the hot air (exhaust fan) from inside the house. When the temperature returns to its nominal value, the ventilation fans stops and returns to its idle state. This value can be changed according to the user preference.

4.2.3.3 Circuit

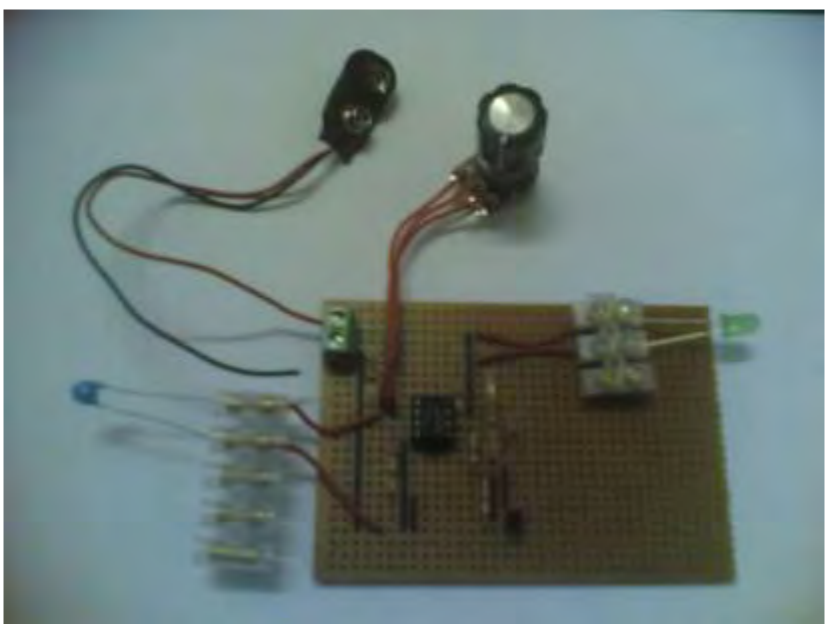


Figure 4.2.3(c): Assembled circuit for Indoor Ventilation

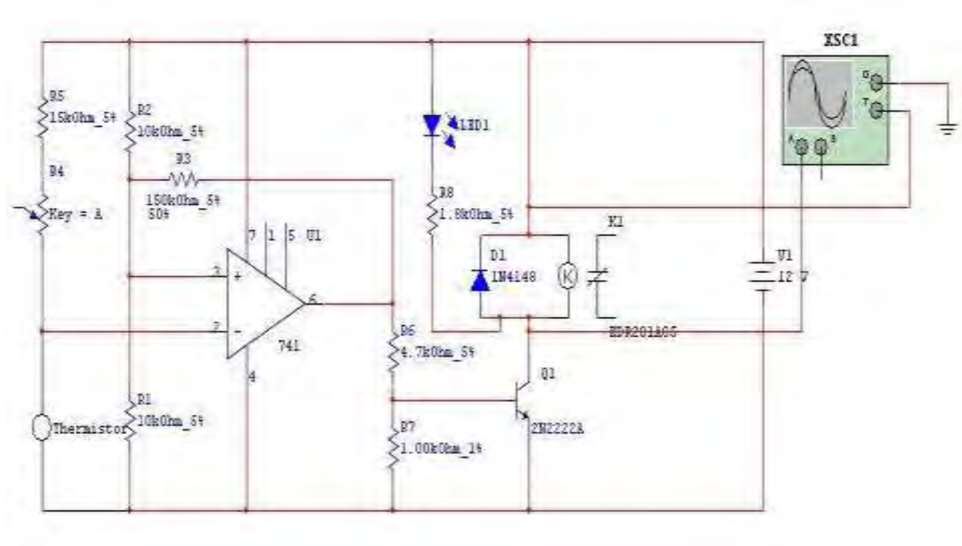


Figure 4.2.3(d): Temperature sensing circuit for Indoor Ventilation

The IC 741 is an operational amplifier used as a differentiator using the values of R1, R2, R5 and the thermistor on both side of the bridge. The 47kΩ thermistor above was rated at 25°C with a tolerance of 10%. The thermistor is also known as Negative Temperature Coefficient (NTC) which means that the resistance will decrease when the surrounding temperature increases. R4 is a regular 100kΩ trimmer potentiometer for adjusting over a wide range of temperature. The transistor Q1 acts as the switch for the relay. There will be 2 units of ventilation fans used for the ICTC. One will serve as an intake fan and the other will be the exhaust fan. The fans used are 12VDC rated at 0.13A. The fans will be interconnected to each other via a ventilation shafts which runs through all the rooms in the house. The LED is used to indicate the operation of the circuit. The output of the circuit will be connected to the PLC or an external off-delay timer so that when the circuit is deactivated, the ventilation fans will continue running for 2-3 minutes to make sure that the idle nominal temperature is steadily achieved.

4.2.3.4 Hardware and software

Listed below are the components used to construct the circuit. The software used for simulation is Multisim 7. The output of the relay is connected to a 12VDC fan taken from a CPU cooler. The module can be activated automatically using the thermistor sensing or manually using a pushbutton. A 2-way switch provides selection for auto/manual function. The LED indicates that the circuit is operational and the potentiometer provides calibration for the circuit's sensitivity according to the thermistor's location. An independent temperature display unit provides the user with the current ambient temperature inside the house.

Figure 4.2.3(e): 12VDC CPU fan rated at 0.13A

Figure 4.2.3(f): Temperature display unit

Components	**Label**	**Quantity**
IC 741 Op Amp	741	1
47kΩ@25°C thermistor	Thermistor	1
15kΩ resistor	R5	1
10kΩ resistor	R1, R2	2
150kΩ resistor	R3	1
4.7kΩ resistor	R6	1
1kΩ resistor	R7	1
1.8kΩ resistor	R8	1
100kΩ potentiometer	R4	1
2N2222 transistor	Q1	1
IN4148 diode	D1	1

5V Relay	K1	1
Pushbutton (latching type)		1
2-way selector switch		1
12VDC 0.13A CPU fan		1
Temperature display unit		1

4.2.4 Garbage disposal

4.2.4.1 Overview

The residents sometimes missed the garbage collection time. The garbage spilled when bringing it outside the house and the odor from the garbage attracts flies & brings unwanted disease. To solve this problem, the PLC manages the disposal according to time. A garbage route runs in the underground level of the house and a ventilation system handles the unpleasing odor.

4.2.4.2 Design

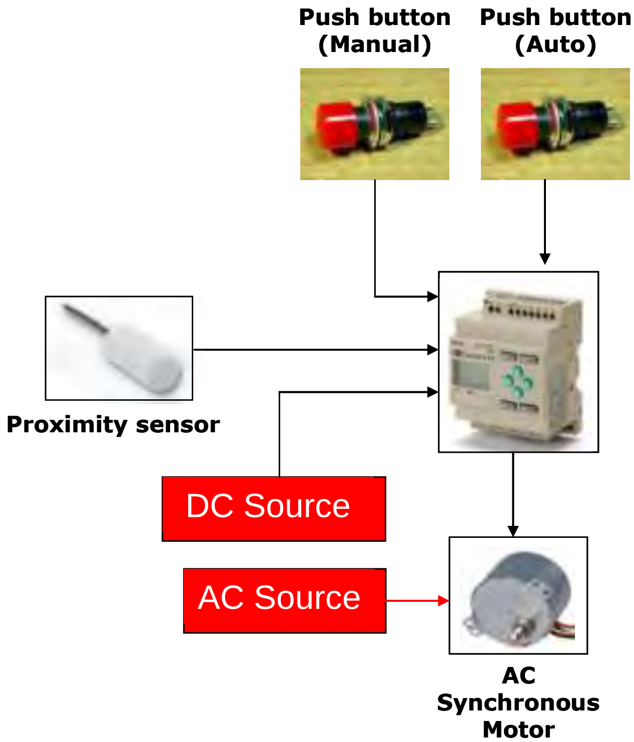


Figure 4.2.4(a): Block diagram for garbage disposal

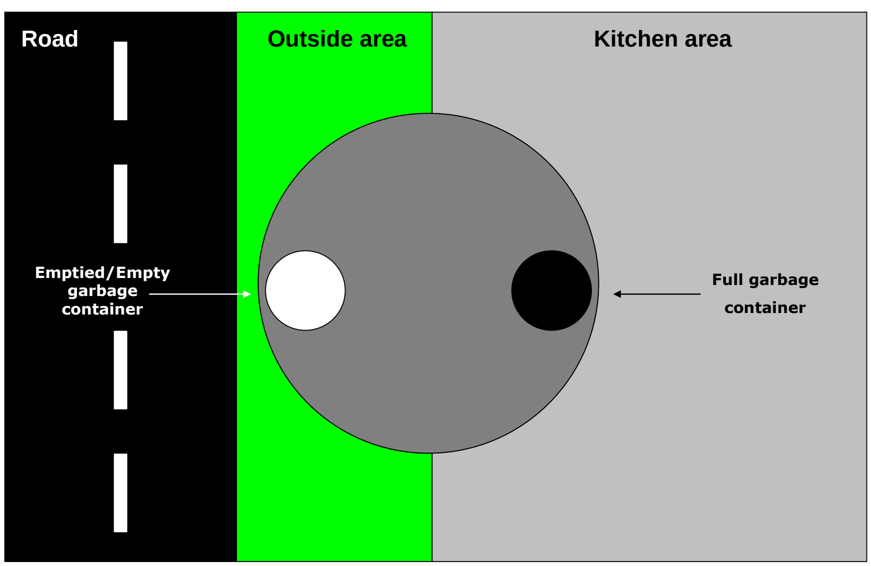


Figure 4.2.4(b): Concept diagram for garbage disposal

To create the rotating platform at the underground level, there are two important parameters that need to be controlled, which is the motor's speed and direction. The motor speed needs to be maintained at an optimal speed so that the load is not moving to fast or else it will spill on the platform.

The motor moves in a single direction since the platform rotates in a single direction. Even if the motor rotates in the opposite direction (which happened sometimes), there is no problem as long as the 180 degrees rotation is achieved. The motor speed is rated at 5-6 rpm which is suitable enough to provide the rotating functions.

The platform can be rotated automatically or manually according to the situation. The automatic function is achieved using the latching function from the PLC while the manual function is achieved using a manual bypass connection over the PLC relay output. Both functions is activated using pushbuttons.

4.2.4.3 Circuit

There is no circuit used for this module as the module fully utilizes the function of the PLC and the combination of input and output devices.

4.2.4.4 Hardware and software

The input devices for this module include, non-latching pushbuttons and a PNP type inductive proximity sensor used to detect when the platform is in its idle position (180 degrees). The sensor has an optimal sensing range of 5mm and a maximum sensing range of 8mm.

The output devices for this module include, LEDs used to indicate the platform is in home/idle position and also an AC synchronous motor rated at 6VAC 50/60Hz 1.5/2W 5/6rpm which provides a steady speed and torque rotation for the platform.

The application of PLC makes it possible to reduce the amount of relay used since it has multiple input and output arrangements. The most useful function of the PLC is its latching capability. Listed below are the I/O designations for the PLC.

Input	**Device**	**Designation**
Rotate Command (Auto)	Pushbutton	I0
Platform Position	Proximity Sensor	Ib

Output	**Device**	**Designation**
In Position/Ready indicator	LED	Q0
Rotating indicator	LED	Q1
Rotating platform motor	Synchronous motor	Q4

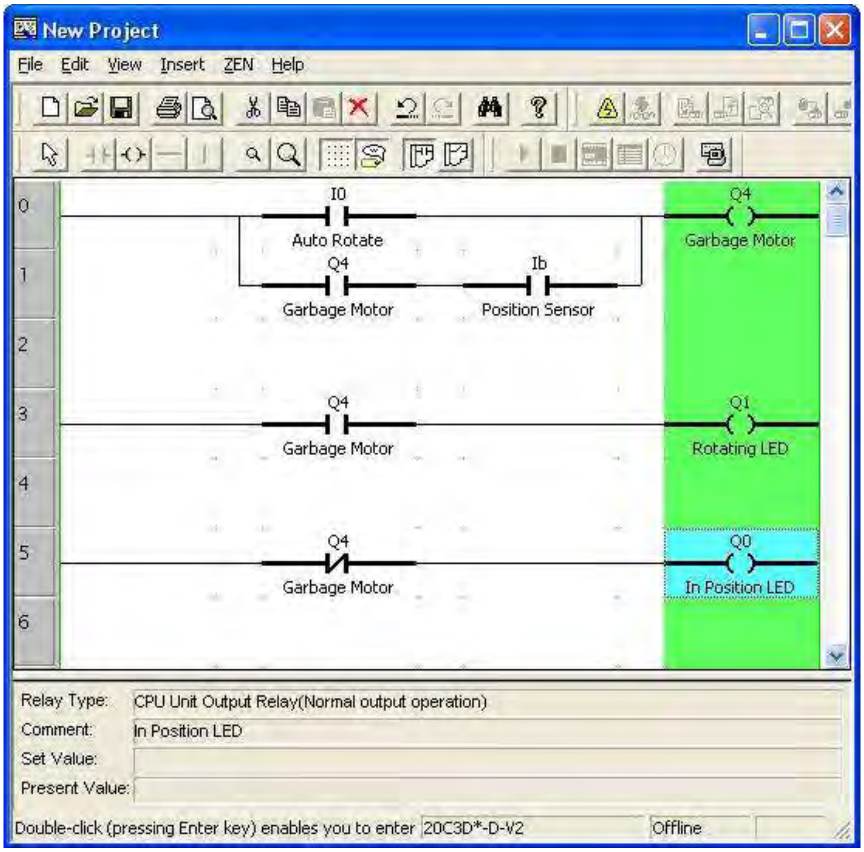


Figure 4.2.4(c): Ladder diagram for overall Garbage Disposal module

Figure 4.2.4(d): Inductive proximity sensor used for platform position

Figure 4.2.4(e): AC Synchronous motor used for platform rotation

Listed below are the components used to construct the circuit. The software used for simulation is Zen Support Software. This software is used by creating ladder diagrams before programmed into the PLC unit via a communication cable.

Components	**Quantity**
Omron Zen PLC	1
Push buttons	2
Inductive proximity sensor	1
LED	2
6VAC synchronous motor	1
6VAC adapter	1

4.2.5 Garage and car park

4.2.5.1 Overview

Residents accidentally hit the wall or children while reversing the vehicle and sometimes forget to close the garage door after they left the house. To solve this problem, the car park will automatically rotate the vehicle facing the front and the garage doors will close automatically after a while.

4.2.5.2 Design

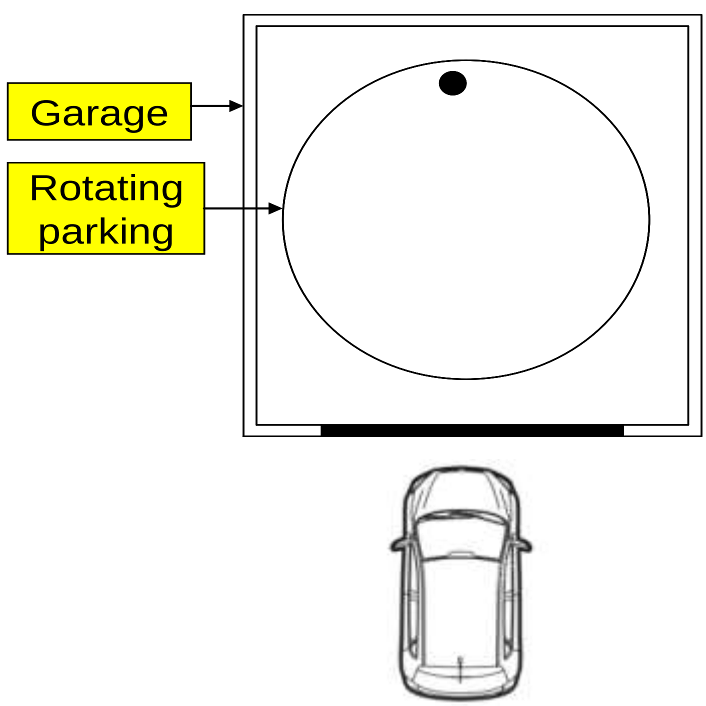


Figure 4.2.5(a): Concept diagram for garage and car park

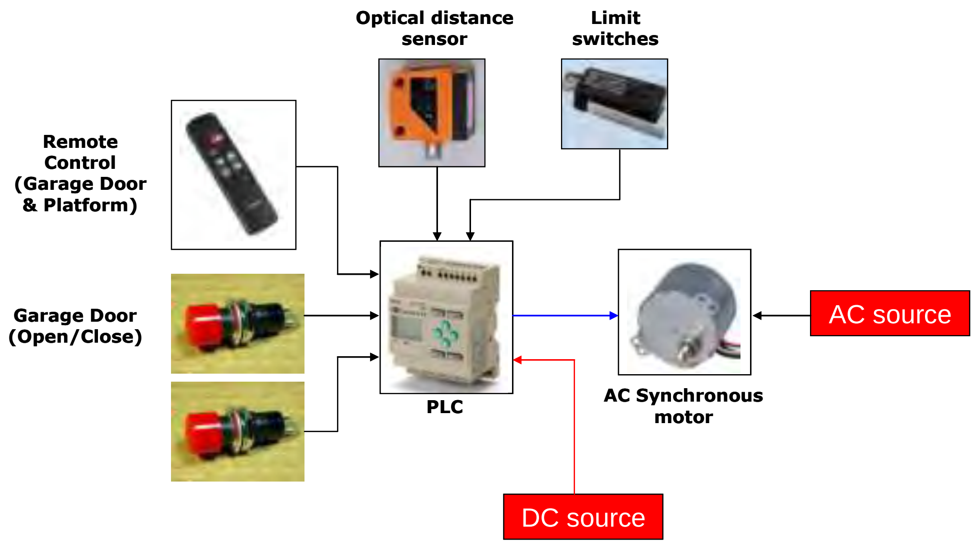


Figure 4.2.5(b): Block diagram for garage and car park

The garage/car park system is identical to the garbage disposal system. There are also two important parameters that need to be controlled, which is the motor's speed and direction. The motor speed needs to be reduced to an optimal speed so that the car is rotated at a suitable safe speed. A high speed would cause the car to fall of from the platform.

The motor direction is not important as long as the motor turns the platform to achieve 180 degrees. To detect the 180 degrees rotation, a limit switch is used in conjunction with a triangular marker. The marker actuates the limit switch when the 180 degrees turn has been completed.

Figure 4.2.5(c): Limit switch and triangular marker

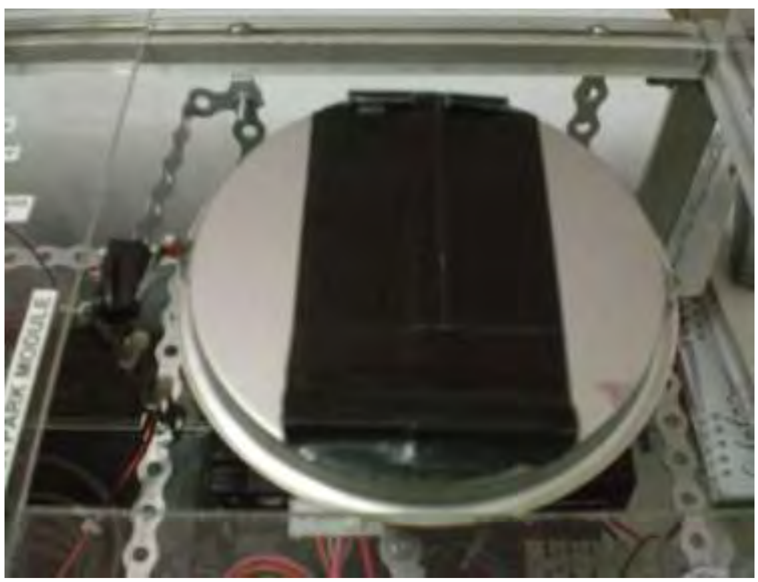


Figure 4.2.5(d): Rotating platform

The garage and car park system operates using many sensors and switches. The optical distance sensor is used to detect when the car is in position to enter the garage. The garage door opens and actuates the maximum door limit switch which activates a 10 second timer. Within the allocated time, the vehicle must enter the garage and the garage door automatically closes.

When the vehicle wishes to leave the garage, the user can open the garage door manually (by pressing the open door pushbutton) or by pressing the ―unlock" button on the remote control.

4.2.5.3 Circuit

There is no circuit used for this module as the module fully utilizes the function of the PLC and the combination of input and output devices.

4.2.5.4 Hardware and software

The input devices for this module include, non-latching pushbuttons, PNP type optical distance sensor used to detect when the car is in entry position and limit switches The optical distance sensor is programmable to suite any range within 0.2 meters and up to 10 meters. The limit switches is used to detect the platform position and also to detect the garage door position.

Figure 4.2.5(e): Optical distance sensor

The output devices for this module include, LEDs used to indicate the platform is in home/idle position or rotating, an AC synchronous motor rated at 6VAC 50/60Hz 1.5/2W 5/6rpm which provides a steady speed and torque rotation for the platform and also 12VDC light bulbs to indicate the garage door coil is open or close.

The application of PLC makes it possible to reduce the amount of relay used since it has multiple input and output arrangements. The most useful function of the PLC is its latching capability. Listed below are the I/O designations for the PLC.

Input	Device	Designation
Rotate command (Auto)	Pushbutton	I1
Reset/Stop rotate	Pushbutton	I2
Maximum door position	Limit switch	I4
Minimum door position	Limit switch	I5
Rotate command (Remote)	Remote	I6
Platform position	Limit switch	I7
Open door command	Pushbutton/Remote	I8
Close door command	Pushbutton/Remote	I9
Close door command (Delayed)	Optical distance sensor	Ia

Output	Device	Designation
In Position/Ready indicator	LED	Q2
Rotating indicator	LED	Q3
Rotating platform motor	Synchronous motor	Q5
Open garage door coil	12VDC light bulb	Q6
Close garage door coil	12VDC light bulb	Q7

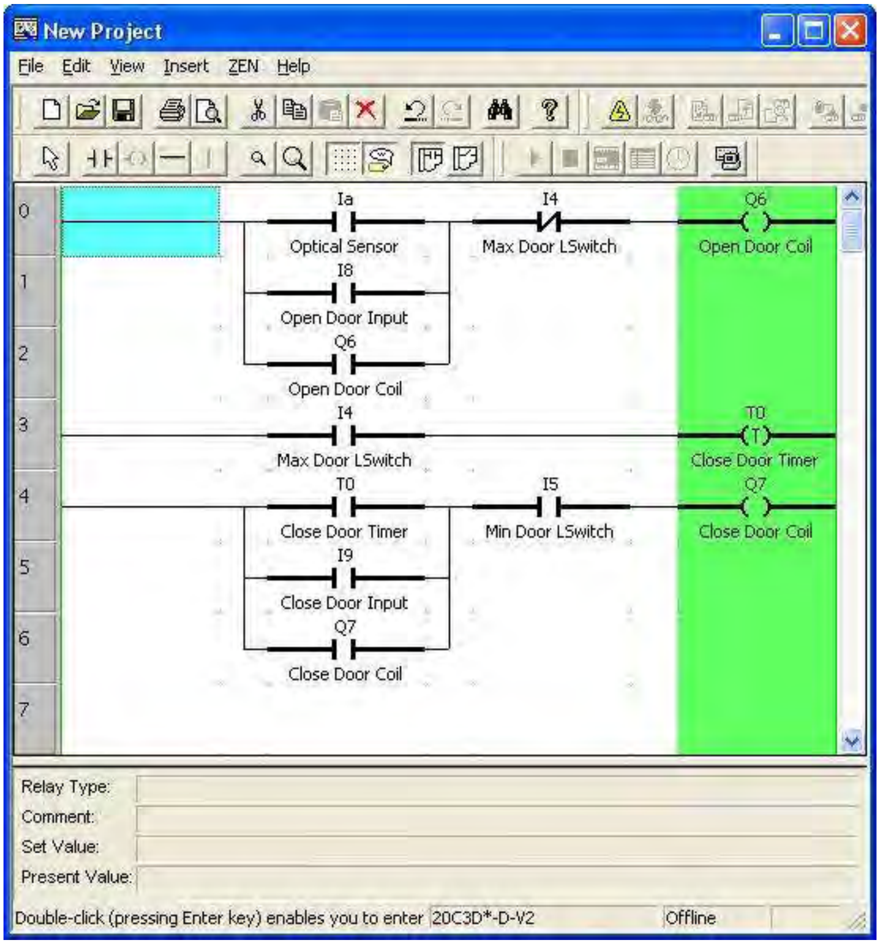


Figure 4.2.5(f): Ladder diagram for garage door

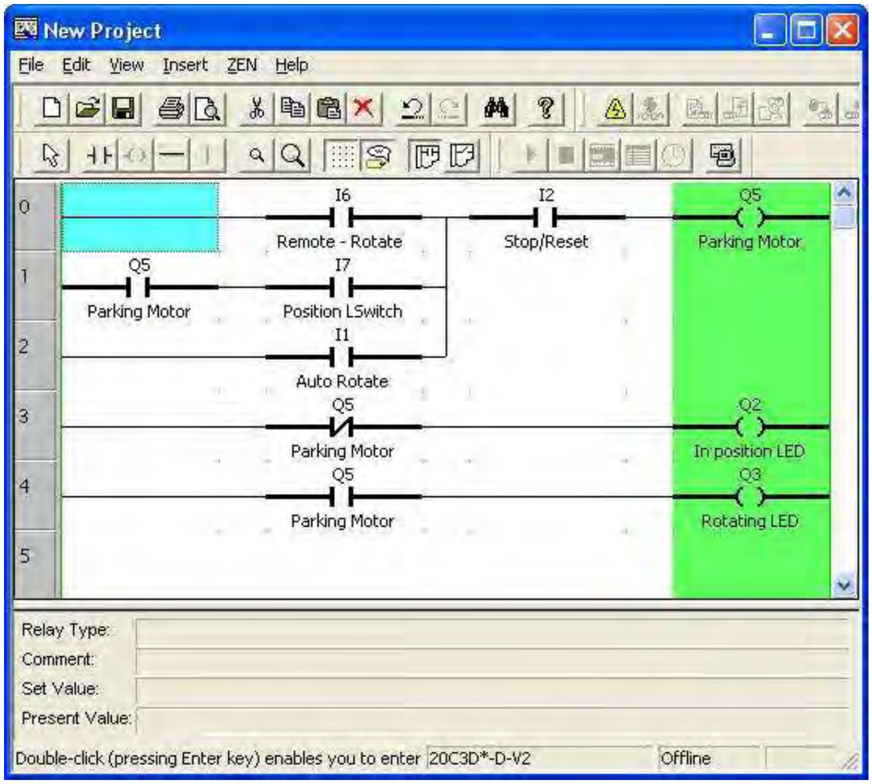


Figure 4.2.5(g): Ladder diagram for rotating platform

Listed below are the components used to construct the circuit. The software used for simulation is Zen Support Software. This software is used by creating ladder diagrams before programmed into the PLC unit via a communication cable.

Components	**Quantity**
Omron Zen PLC	1
Push buttons	5
Optical distance sensor	1
LED	2
6VAC synchronous motor	1
6VAC adapter	1
Limit switches	3
12VDC light bulbs	2

Light bulbs socket 2

4.2.6 Events alert

4.2.6.1 Overview

Normal house does not have fire and flood detection system to alert the occupants of danger and disaster. To fix this problem, a heat & smoke sensor is added for fire detection and a water level sensor is added for flood detection.

4.2.6.2 Design

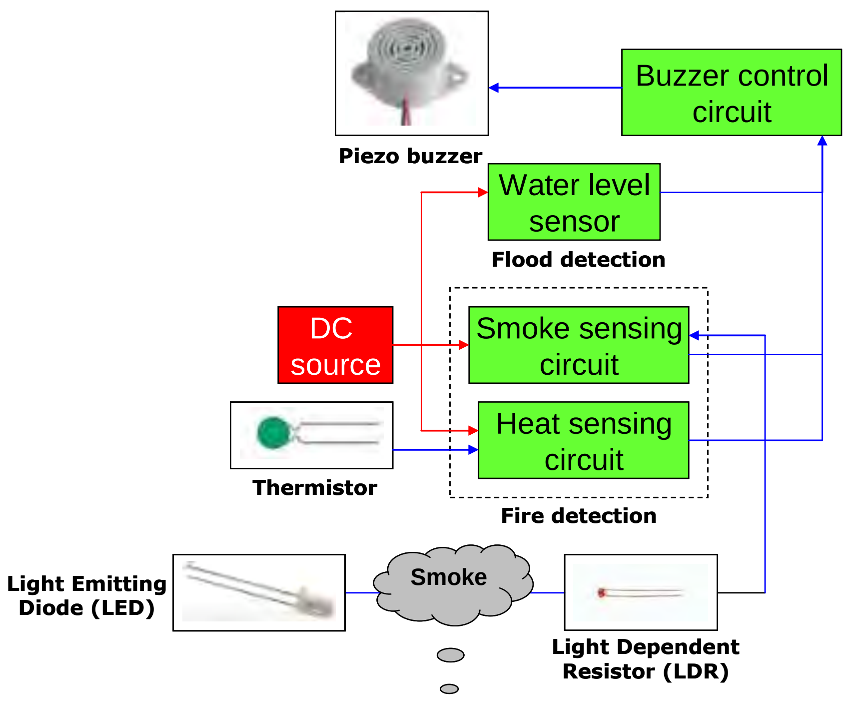


Figure 4.2.6(a): Block diagram for Events Alert

This module combines 4 circuit to create a house event alert module. The heat sensing circuit and smoke sensing circuit combines together to create the fire detection system. The heat circuit is similar as the ones used for the indoor ventilation module. The difference lies in its activation threshold which detects a higher temperature before it activates the buzzer circuit. The smoke sensor detects smoke produced from the fire.

The water level sensor acts as the flood detector which monitors water level in drainage. The buzzer control circuit is used to vary the interval between beeps as user's reference.

4.2.6.3 Circuit

4.2.6.3.1 Water Level Sensor

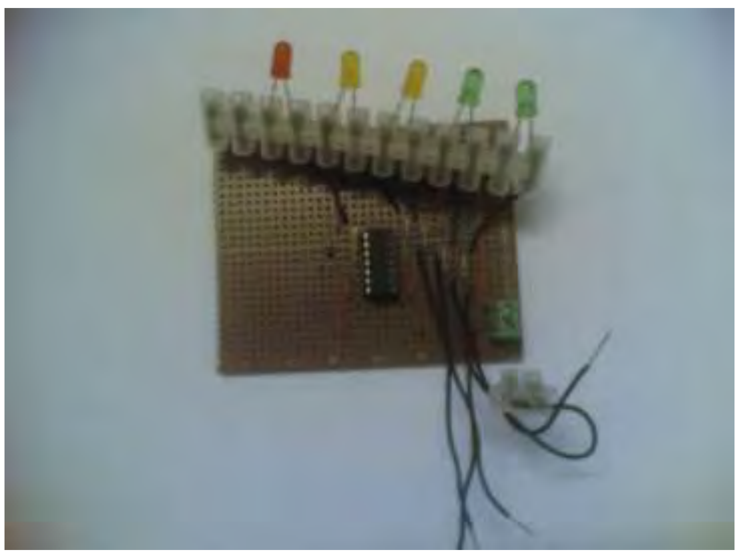


Figure 4.2.6(b): Assembled circuit for Water Level Sensor

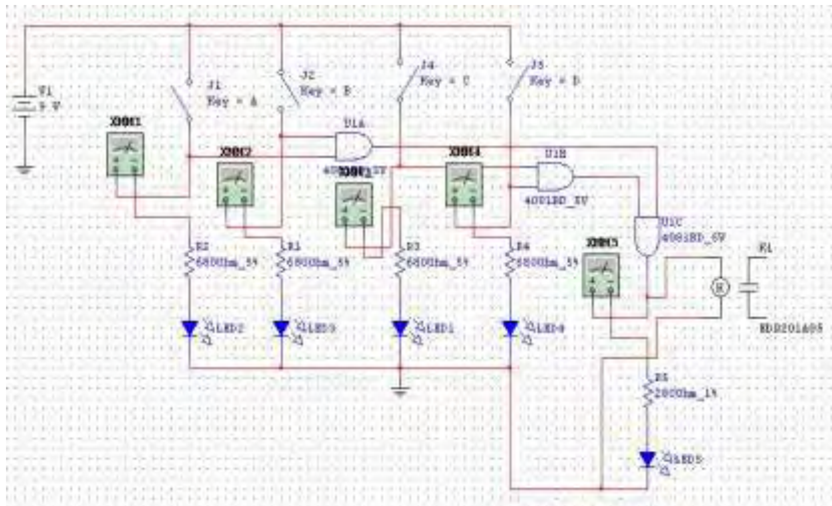


Figure 4.2.6(c): Water Level Sensor circuit for Events Alert

This circuit indicates the water level and produces an alarm when the high level is reached. The circuit uses a pair of AND gates from the CMOS 4081 operating on logic inputs (0 or 1) to indicate the water level through LEDs. When the water is empty the wires in the tank are open circuited and this pulls the switch low hence opening the switch and LEDs are OFF. As the water starts filling up, first the wire in the tank connected to J1 and the + supply are shorted by water. This turns the LED 2 on. As the water level continues to rise, the LED 3, 1 and 4 lights up gradually. As the inputs are HIGH, this causes LED 5 to turn on and the relay is activated.

4.2.6.3.2 Heat Sensing

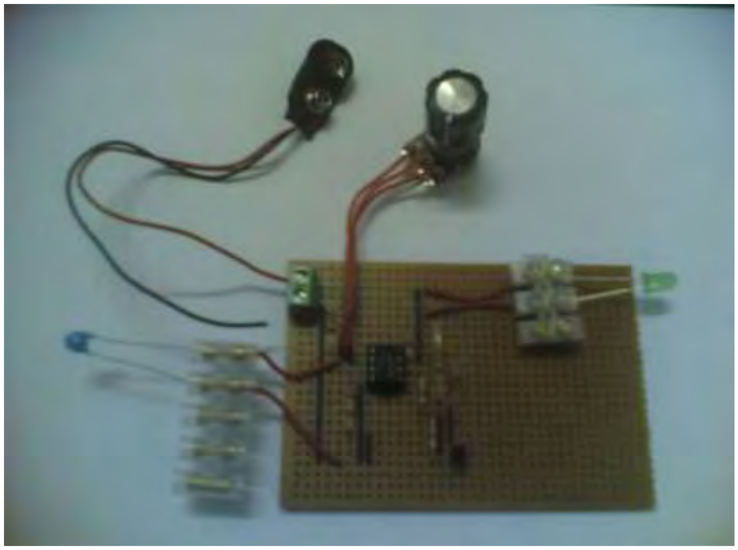


Figure 4.2.6(d): Assembled circuit for Heat Sensing

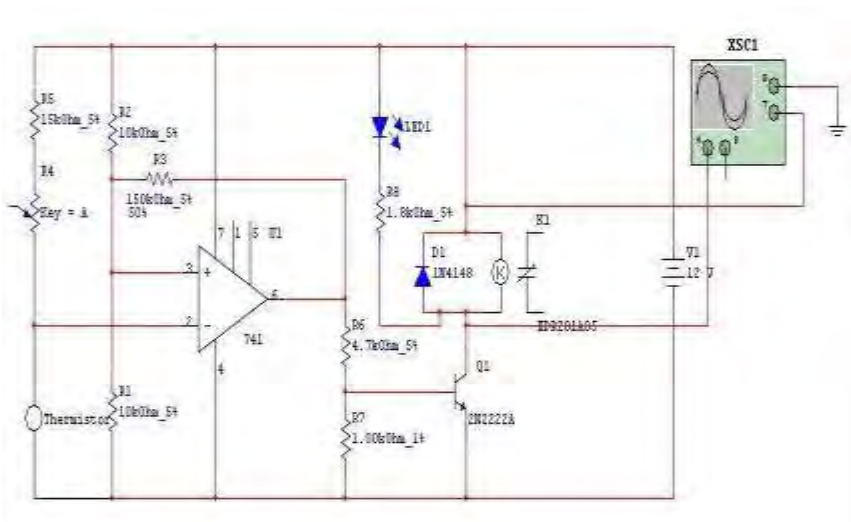


Figure 4.2.6(e): Heat Sensing circuit for Events Alert

The IC 741 is an operational amplifier used as a differentiator using the values of R1, R2, R5 and the thermistor on both side of the bridge.The 47kΩ thermistor above was rated at 33°C with a tolerance of 10%. The thermistor is also known as Negative Temperature Coefficient (NTC) which means that the resistance will decrease when the surrounding temperature increases. R4 is a regular 1MΩ trimmer potentiometer for adjusting over a wide range of temperature. The transistor Q1 acts as the switch for the relay. The LED is used to indicate the operation of the circuit. The output of the circuit is connected to the buzzer interval circuit and the buzzer will sound when a heat from fire is detected.

4.2.6.3.3 Smoke Sensor

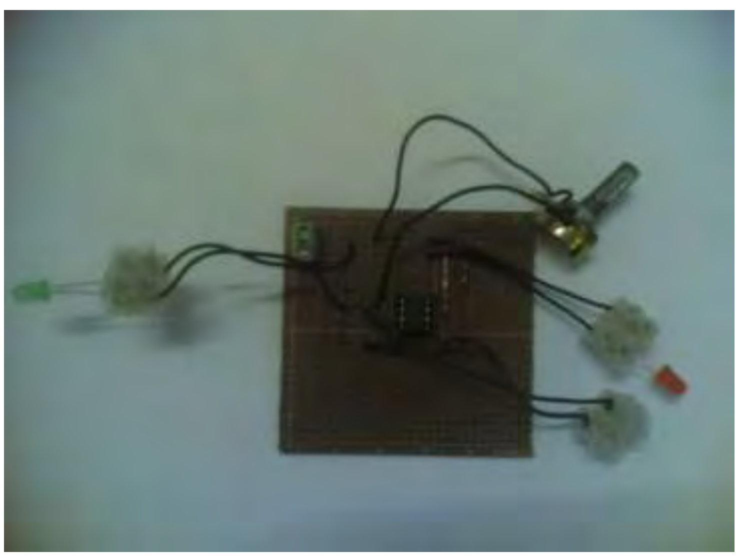


Figure 4.2.6(f): Assembled circuit for Smoke Sensor

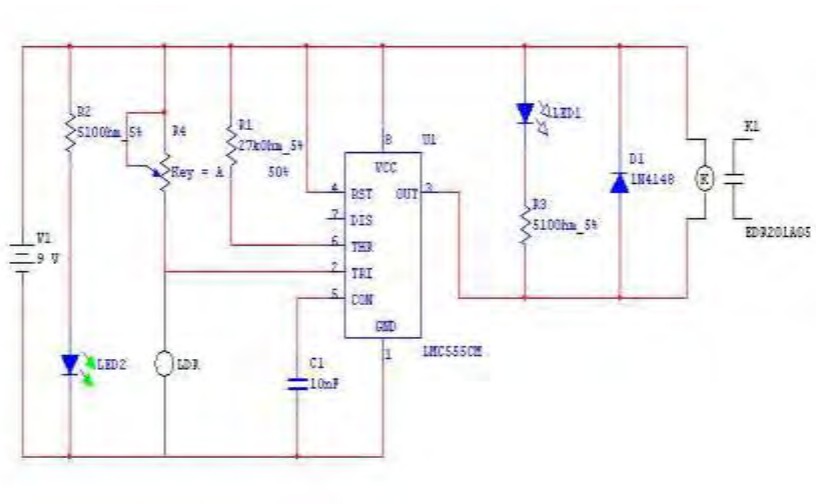


Figure 4.2.6(g): Smoke Sensor circuit for Events Alert

This circuit is similar as the light/dark sensing circuit for the Outdoor Lighting module with some modifications to allow it to function as a smoke detector. A LED or any suitable light source is placed in parallel with the Light Dependant Resistor (LDR). When a fire occurs, the smoke will fill the gap between the LED 2 and the LDR. The amount of light falling on the LDR decreases and the resistance of the LDR increases thus activating the relay.

4.2.6.3.4 Buzzer Interval

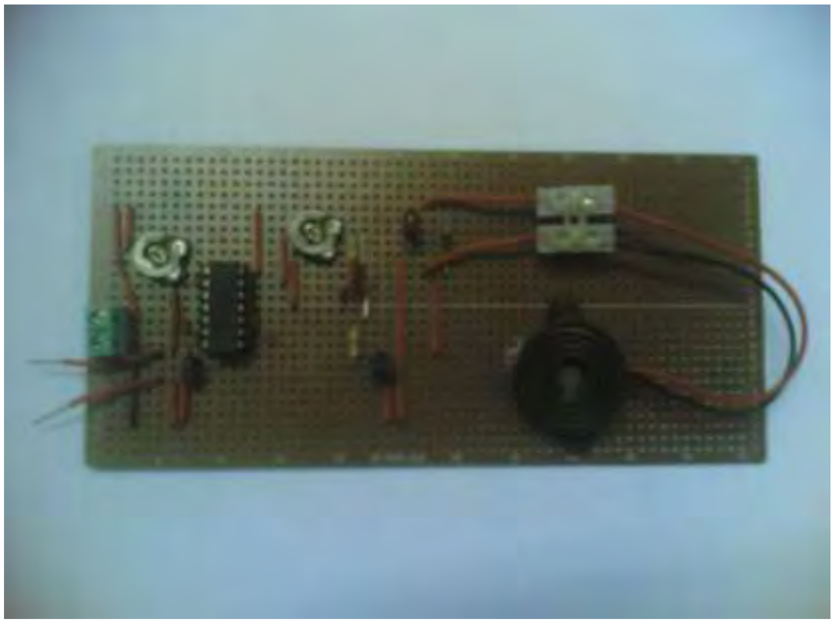


Figure 4.2.6(h): Assembled circuit for Buzzer Interval

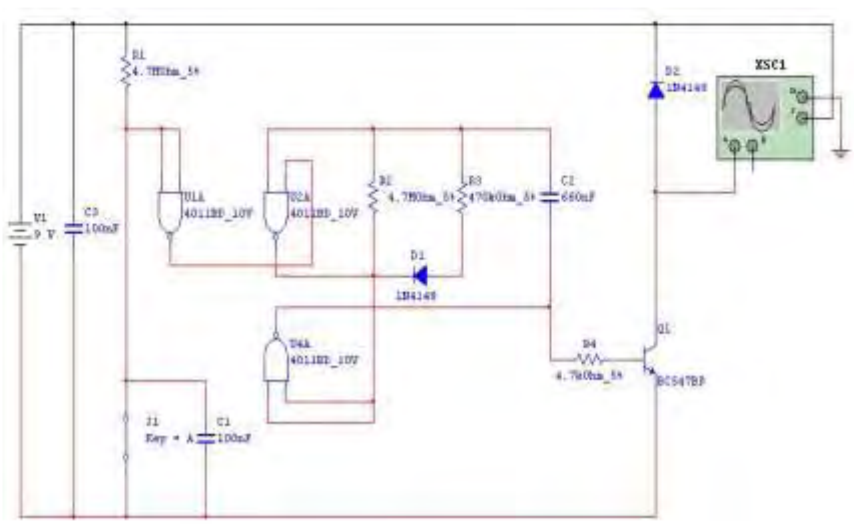


Figure 4.2.6(i): Buzzer Interval circuit for Events Alert

While J1 remains open, the circuit uses virtually no current. When the switch is closed, the buzzer produces a series of beeps at a certain intervals. R3 & C2 sets the length of beeps while R4 & C2 sets the delay between the beeps. If the initial values are doubled, then the interval would double as well. Gates 5 & 6 of the CMOS 4011 is not used in the circuit. When the oscillator is running, pin 10 keeps switching back and forth between high to low. Pin 11 supplies base current to Q1 - through R4. As pin 10 switches on and off - the transistor switches on and off. While the transistor is on - it connects the negative lead of the Buzzer to ground - and the Buzzer sounds. To keep the standby current low - the value of 4.7MΩ was chosen for R1 and the current through R1 is flowing to ground through the switch. This means that Pin 1 & 2 is low - and C1 is discharged. And while pin 10 remains low, the Buzzer is silent.

4.2.6.4 Hardware and software

Listed below are the components used to construct the circuit. The software used for simulation is Multisim 7.

Water Level Sensor

Components	**Label**	**Quantity**
CMOS 4081 Quad AND gates	4081	1
680Ω resistor	R1-R4	4
280Ω resistor	R5	1
Light Emitting Diode	LED1-5	5
5V Relay	K1	1

Heat Sensing

Components	Label	Quantity
IC 741 Op Amp	741	1
33kΩ@25°C thermistor	Thermistor	1
15kΩ resistor	R5	1
10kΩ resistor	R1, R2	2
150kΩ resistor	R3	1
4.7kΩ resistor	R6	1
1kΩ resistor	R7	1
1.8kΩ resistor	R8	1
100kΩ potentiometer	R4	1
2N2222 transistor	Q1	1
Light Emitting diode	LED 1	1
IN4148 diode	D1	1
5V Relay	K1	1

Smoke Sensor

Components	Label	Quantity
555 Timer	LM555	1
1MΩ potentiometer	R4	1
27kΩ resistor	R1	1
510Ω resistor	R2, R3	2
10nF ceramic disc capacitor	C1	1

Light Emitting Diode	LED 1, 2	2
Light Dependant Resistor	LDR	1
IN4148 diode	D1	1
5V Relay	K1	1

Buzzer Interval

Components	**Label**	**Quantity**
CMOS 4011 Quad NAND gates	4011	1
680nF ceramic disc capacitor	C2	1
100nF ceramic disc capacitor	C1, C3	2
4.7MΩ resistor	R1, R2	2
470kΩ resistor	R3	1
4.7kΩ resistor	R4	1
IN4148 diode	D1, D2	2
BC547 NPN transistor	Q1	1

4.2.7 Garden Management

4.2.7.1 Overview

The plant in the garden dies due to lack of watering and the gardens are infected by pests. PLC manages the garden's water sprinkler and the garden is equipped with ultrasonic pest repellant to ward of the pests.

4.2.7.2 Design

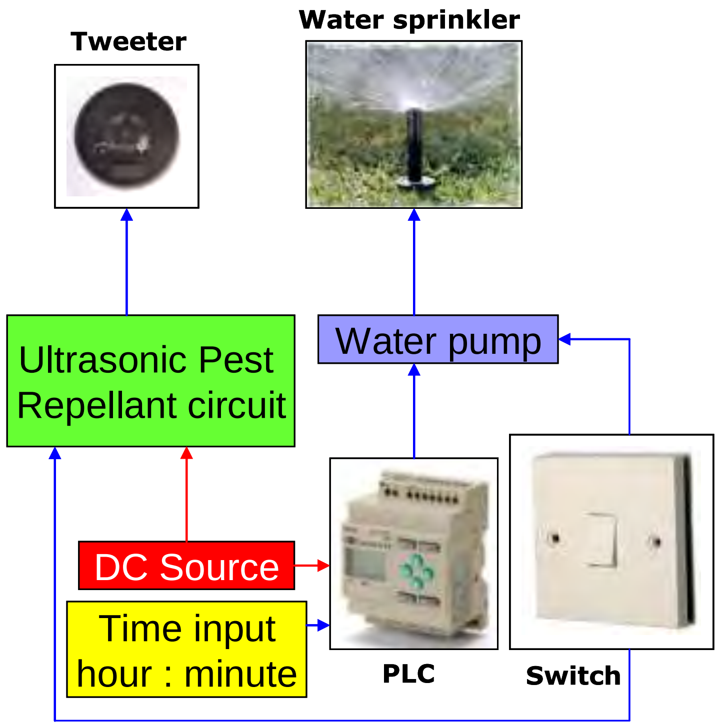


Figure 4.2.7(a): Block diagram for Garden Management

It is well know that pests like rats, mice etc are repelled by ultrasonic frequency in the range of 30 kHz to 50 kHz. Human beings can't hear these high-frequency sounds. Unfortunately, all pests do not react at the same ultrasonic frequency. While some pests get repelled at 35 kHz, some others get repelled at 38 to 40 kHz. Thus to increase the effectiveness, frequency of ultrasonic oscillator has to be continuously varied between certain limits.

The ultrasonic pest repellant circuit sends out a range of ultrasonic (inaudible to humans) waves that frighten away a large variety of pests. It emits sound pitches specific to different animals, to repel certain pests without scaring the pets.

Unlike some pest controls that use dangerous, sometimes poisonous means of ridding pests, this circuit uses ultrasonic sound frequency that are slightly audible to humans to scare away animals and insects. It is a humane option to fixing the pest problem. Say goodbye to rat poison, harmful chemicals or worrying about the children and pets.

4.2.7.3 Circuit

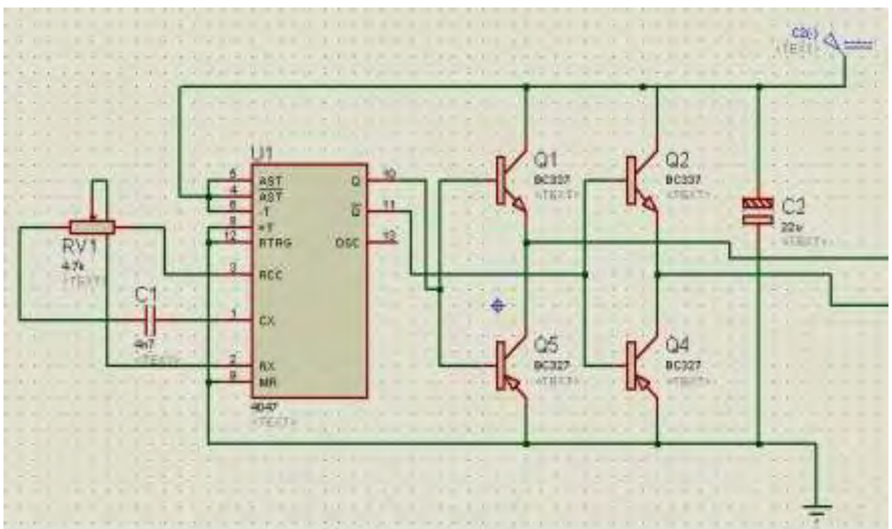


Figure 4.2.7(b): Ultrasonic pest repellant circuit for Garden Management

The circuit consists of a phase locked loop (CMOS 4047) wired as a 22 KHz oscillator. The output is amplified by a pair of complimentary output transistors and drives a piezoelectric tweeter. The current drain is estimated at around 120mA so an external power supply is required. The frequency is varied using the 4.7kΩ potentiometer. The piezoelectric tweeter acts as the ultrasonic frequency transmitter.

4.2.7.4 Hardware and software

Listed below are the components used to construct the circuit. The software used for simulation is Proteus 6.

Components	**Label**	**Quantity**
CMOS 4047 Monostable/Astable Multivibrator	4047	1
4.7kΩ potentiometer	RV1	1
4.7nF ceramic disc capacitor	C1	1
22nF electrolytic capacitor	C2	1
BC337 NPN Epitaxial Silicon Transistor	Q1, Q2	2
BC327 PNP Epitaxial Silicon Transistor	Q3, Q4	2
Piezoelectric tweeter		1

4.3 Components

4.3.1 Programmable Logic Controller (PLC)

4.3.1.1 Introduction to PLC

A programmable logic controller (PLC), or programmable controller is a digital computer used for automation of industrial processes, such as control of machinery on factory assembly lines. Unlike general-purpose computers, the PLC is designed for multiple inputs and output arrangements, extended temperature ranges, immunity to electrical noise, and resistance to vibration and impact. Programs to control machine operation are typically stored in battery-backed or non-volatile memory. A PLC is an example of a real time system since output results must be produced in response to input conditions within a bounded time, otherwise unintended operation will result.

Figure 4.3.1(a): PLC and input/output arrangements

4.3.1.2 Features of PLC

Figure 4.3.1(b): Control Panel with PLC

The main difference from other computers is that PLC are armored for severe condition (dust, moisture, heat, cold, etc) and have the facility for extensive input/output (I/O) arrangements. These connect the PLC to sensors and actuators. PLCs read limit switches, analog process variables (such as temperature and pressure), and the positions of complex positioning systems. Some even use machine vision. On the actuator side, PLCs operate electric motors, pneumatic or hydraulic cylinders, magnetic relays or solenoids, or analog outputs. The input/output arrangements may be built into a simple PLC, or the PLC may have external I/O modules attached to a computer network that plugs into the PLC.

PLCs were invented as replacements for automated systems that would use hundreds or thousands of relays, cam timers, and drum sequencers. Often, a single PLC can be programmed to replace thousands of relays. Programmable controllers were initially adopted by the automotive manufacturing industry, where software revision replaced the re-wiring of hard-wired control panels when production models changed.

Many of the earliest PLCs expressed all decision making logic in simple ladder logic which appeared similar to electrical schematic diagrams. The electricians were quite able to trace out circuit problems with schematic diagrams using ladder logic. This program notation was chosen to reduce training demands for the existing technicians. Other early PLCs used a form of instruction list programming, based on a stack-based logic solver.

The functionality of the PLC has evolved over the years to include sequential relay control, motion control, process control, distributed control systems and networking. The data handling, storage, processing power and communication capabilities of some modern PLCs are approximately equivalent to desktop computers. PLC-like programming combined with remote I/O hardware, allow a general-purpose desktop computer to overlap some PLCs in certain applications. Under the IEC 61131-3 standard, PLCs can be programmed using standards-based programming languages. A graphical programming notation called Sequential Function Charts is available on certain programmable controllers.

4.3.1.3 Comparing PLC with other control systems

PLCs are well-adapted to a certain range of automation tasks. These are typically industrial processes in manufacturing where the cost of developing and maintaining the automation system is high relative to the total cost of the automation, and where changes to the system would be expected during its operational life. PLCs contain input and output devices compatible with industrial pilot devices and controls; little electrical design is required, and the design problem centers on expressing the desired sequence of operations in ladder logic (or function chart) notation. PLC applications are typically highly customized systems so the cost of a packaged PLC is low compared to the cost of a specific custom-built controller design. On the other hand, in the case of mass-produced goods, customized control systems are economic due to the lower cost of the components, which can be optimally chosen instead of a "generic" solution, and where the non-recurring engineering charges are spread over thousands of sales.

For high volume or very simple fixed automation tasks, different techniques are used. For example, a consumer dishwasher would be controlled by an electromechanical cam timer costing only a few dollars in production quantities.

A microcontroller-based design would be appropriate where hundreds or thousands of units will be produced and so the development cost (design of power supplies and input/output hardware) can be spread over many sales, and where the end-user would not need to alter the control. Automotive applications are an example; millions of units are built each year, and very few end-users alter the programming of these controllers. However, some specialty vehicles such as transit busses economically use PLCs instead of custom-designed controls, because the volumes are low and the development cost would be uneconomic.

Very complex process control, such as used in the chemical industry, may require algorithms and performance beyond the capability of even high-performance PLCs. Very high-speed or precision controls may also require customized solutions; for example, aircraft flight controls.

PLCs may include logic for single-variable feedback analog control loop, a "proportional, integral, derivative" or "PID controller." A PID loop could be used to control the temperature of a manufacturing process, for example. Historically PLCs were usually configured with only a few analog control loops; where processes required hundreds or thousands of loops, a distributed control system (DCS) would instead be used. However, as PLCs have become more powerful, the boundary between DCS and PLC applications has become less clear-cut.

4.3.1.4 Programming

Early PLCs, up to the mid-1980s, were programmed using proprietary programming panels or special-purpose programming terminals, which often had dedicated function keys representing the various logical elements of PLC programs. Programs were stored on cassette tape cartridges. Facilities for printing and documentation were very minimal due to lack of memory capacity. More recently, PLC programs are typically written in a special application on a personal computer, then downloaded by a direct-connection cable or over a network to the PLC. The very oldest PLCs used non-volatile magnetic core memory but now the program is stored in the PLC either in battery-backed-up RAM or some other non-volatile flash memory.

Early PLCs were designed to be used by electricians who would learn PLC programming on the job. These PLCs were programmed in "ladder logic", which strongly resembles a schematic diagram of relay logic. Modern PLCs can be programmed in a variety of ways, from ladder logic to more traditional programming languages such as BASIC and C. Another method is State Logic, a Very High Level Programming Language designed to program PLCs based on State Transition Diagrams.

Recently, the International standard IEC 61131-3 has become popular. IEC 61131-3 currently defines five programming languages for programmable control systems: FBD (Function block diagram), LD (Ladder diagram), ST (Structured text, similar to the Pascal programming language), IL (Instruction list, similar to assembly language) and SFC (Sequential function chart). These techniques emphasize logical organization of operations.

While the fundamental concepts of PLC programming are common to all manufacturers, differences in I/O addressing, memory organization and instruction sets mean that PLC programs are never perfectly interchangeable between different makers.

Even within the same product line of a single manufacturer, different models may not be directly compatible.

4.3.2 Omron ZEN

4.3.2.1 Features

Achieve small-scale automatic control with a single ZEN. The ZEN provides relay, timer, counter, and time switch functions. The relay, timer, and other functions do not need to be wired separately, greatly reducing wiring work. This also helps to reduce installation space requirements.

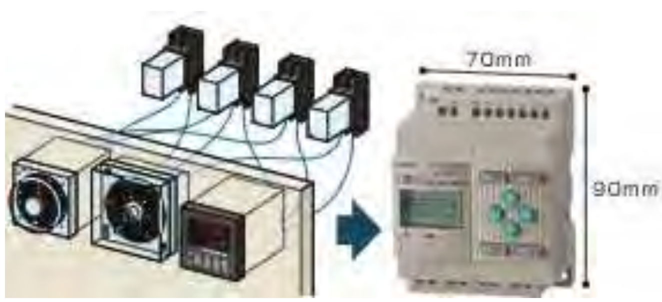


Figure 4.3.2(a): Multi function and space saving features

4.3.2.2 Programming

Ladder programming is simple with the LCD and 8 operation buttons. The LCD has a backlight, making it easier to see when the ZEN is used in dark locations.

Figure 4.3.2(b): Programming the Omron ZEN

4.3.2.3 Functions

- Flexible power supply voltage between 12 and 24VDC or 100 and 240VAC
- Economy CPU Units have been added to the series.
- An 8-digit comparator has been added.
- Use of a Memory Cassette makes it easy to copy and save programs.
- Password function provides security.
- Multi-language display in six languages (English, Japanese, German, French, Spanish, and Italian).
- User-set messages can be displayed using the display function.

4.3.2.4 Expansion

Up to three Expansion I/O Units can be easily connected if there are not enough I/O points. Expansion I/O Units are only 35 mm wide, which helps to save space.

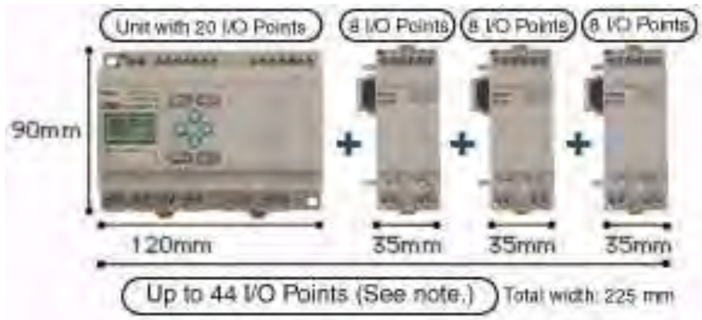


Figure 4.3.2(c): Expansion units

4.3.2.5 Support software

Programs can be easily written and saved using a personal computer. A simulation function has been added to enable checking program operation on the computer before wiring.

Figure 4.3.2(d): Support software

4.3.3 Integrated Circuit (IC)

4.3.3.1 Introduction

In electronics, an integrated circuit (also known as IC, microcircuit, microchip, silicon chip, or chip) is a miniaturized electronic circuit (consisting mainly of semiconductor devices, as well as passive components) that has been manufactured in the surface of a thin substrate of semiconductor material.

A hybrid integrated circuit is a miniaturized electronic circuit constructed of individual semiconductor devices, as well as passive components, bonded to a substrate or circuit board.

4.3.3.2 History of ICs

Integrated circuits were made possible by experimental discoveries which showed that semiconductor devices could perform the functions of vacuum tubes, and by mid-20th-century technology advancements in semiconductor device fabrication. The integration of large numbers of tiny transistors into a small chip was an enormous improvement over the manual assembly of circuits using discrete electronic components. The integrated circuit's mass production capability, reliability, and building-block approach to circuit design ensured the rapid adoption of standardized ICs in place of designs using discrete transistors.

Figure 4.3.3: Integrated circuit

4.3.3.3 Advantages of ICs

There are two main advantages of ICs over discrete circuits: cost and performance. Cost is low because the chips, with all their components, are printed as a unit by photolithography and not constructed one transistor at a time. Performance is high since the components switch quickly and consume little power, because the components are small and close together. As of 2006, chip areas range from a few square mm to around 350 mm^2, with up to 1 million transistors per mm^2.

4.3.3.4 Popularity of ICs

Only a half century after their development was initiated, integrated circuits have become ubiquitous. Computers, cellular phones, and other digital appliances are now inextricable parts of the structure of modern societies. That is, modern computing, communications, manufacturing and transport systems, including the Internet, all depend on the existence of integrated circuits. Indeed, many scholars believe that the digital revolution—brought about by the microchip revolution—was one of the most significant occurrences in the history of humankind.

4.3.3.5 Classifications of ICs

Integrated circuits can be classified into analog, digital and mixed signal (both analog and digital on the same chip).

Digital integrated circuits can contain anything from a few thousand to millions of logic gates, flip-flops, multiplexers, and other circuits in a few square millimeters. The small size of these circuits allows high speed, low power dissipation, and reduced manufacturing cost compared with board-level integration. These digital ICs, typically microprocessors, DSPs, and micro controllers work using binary mathematics to process "one" and "zero" signals.

Analog ICs, such as sensors, power management circuits, and operational amplifiers, work by processing continuous signals. They perform functions like amplification, active filtering, demodulation, mixing, etc. Analog ICs ease the burden on circuit designers by having expertly designed analog circuits available instead of designing a difficult analog circuit from scratch.

ICs can also combine analog and digital circuits on a single chip to create functions such as A/D converters and D/A converters. Such circuits offer smaller size and lower cost, but must carefully account for signal interference

4.3.4 555 Timer IC

4.3.4.1 Introduction

The 8-pin 555 timer must be one of the most useful ICs ever made and it is used in many projects. With just a few external components it can be used to build many circuits, not all of them involve timing!

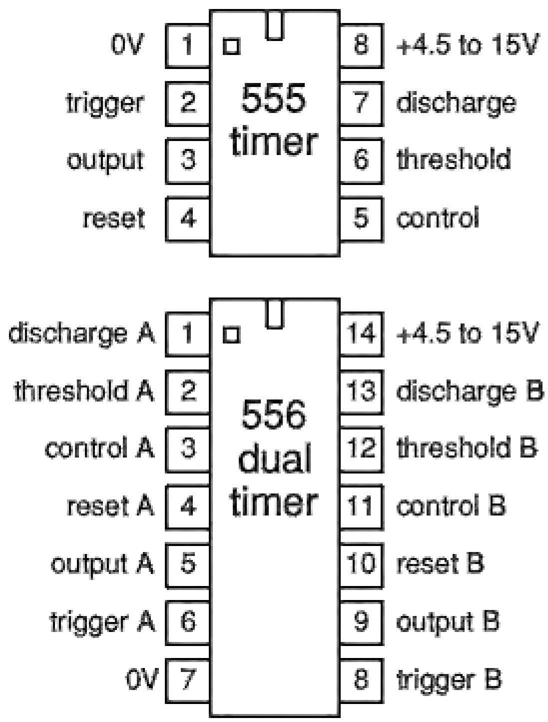


Figure 4.3.4(a): Actual pin arrangements

A popular version is the NE555 and this is suitable in most cases where a '555 timer' is specified. The 556 is a dual version of the 555 housed in a 14-pin package, the two timers (A and B) share the same power supply pins. The circuit diagrams on this page show a 555, but they could all be adapted to use one half of a 556.

Low power versions of the 555 are made, such as the ICM7555, but these should only be used when specified (to increase battery life) because their maximum output current of about 20mA (with a 9V supply) is too low for many standard 555 circuits. The ICM7555 has the same pin arrangement as a standard 555.

The circuit symbol for a 555 (and 556) is a box with the pins arranged to suit the circuit diagram: for example 555 pin 8 at the top for the +Vs supply, 555 pin 3 output on the right. Usually just the pin numbers are used and they are not labelled with their function.

The 555 and 556 can be used with a supply voltage (Vs) in the range 4.5 to 15V (18V absolute maximum).

Standard 555 and 556 ICs create a significant 'glitch' on the supply when their output changes state. This is rarely a problem in simple circuits with no other ICs, but in more complex circuits a smoothing capacitor (i.e. 100µF) should be connected across the +Vs and 0V supply near the 555 or 556.

The input and output pin functions are described briefly below and there are fuller explanations covering the various circuits:

- Astable - producing a square wave
- Monostable - producing a single pulse when triggered
- Bistable - a simple memory which can be set and reset
- Buffer- an inverting buffer (Schmitt trigger)

4.3.4.2 Inputs of 555

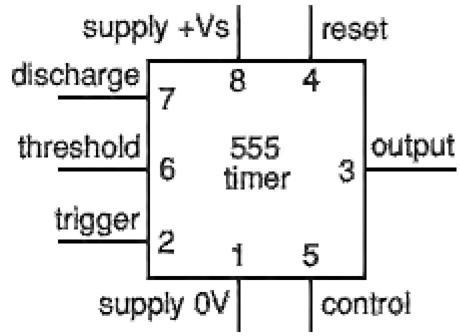


Figure 4.3.4(b): Example circuit symbol

Trigger input: when < $^1/_3$ Vs ('active low') this makes the output high (+Vs). It monitors the discharging of the timing capacitor in an astable circuit. It has a high input impedance > 2MΩ.

Threshold input: when > $^2/_3$ Vs ('active high') this makes the output low (0V)*. It monitors the charging of the timing capacitor in astable and monostable circuits. It has a high input impedance > 10MΩ. Providing the trigger input is > $^1/_3$ Vs, otherwise the trigger input will override the threshold input and hold the output high (+Vs).

Reset input: when less than about 0.7V ('active low') this makes the output low (0V), overriding other inputs. When not required it should be connected to +Vs. It has an input impedance of about 10kΩ.

Control input: this can be used to adjust the threshold voltage which is set internally to be $^2/_3$ Vs. Usually this function is not required and the control input is connected to 0V with a 0.01µF capacitor to eliminate electrical noise. It can be left unconnected if noise is not a problem.

The discharge pin is not an input, but it is listed here for convenience. It is connected to 0V when the timer output is low and is used to discharge the timing capacitor in astable and monostable circuits.

4.3.4.3 Outputs of 555

The output of a standard 555 or 556 can sink and source up to 200mA. This is more than most ICs and it is sufficient to supply many output transducers directly, including LEDs (with a resistor in series), low current lamps, piezo transducers, loudspeakers (with a capacitor in series), relay coils (with diode protection) and some motors (with diode protection). The output voltage does not quite reach 0V and +Vs, especially if a large current is flowing.

The ability to both sink and source current means that two devices can be connected to the output so that one is on when the output is low and the other is on when the output is high.

4.3.4.4 555 Astable

An astable circuit produces a 'square wave', this is a digital waveform with sharp transitions between low (0V) and high (+Vs). Note that the durations of the low and high states may be different. The circuit is called an astable because it is not stable in any state: the output is continually changing between 'low' and 'high'.

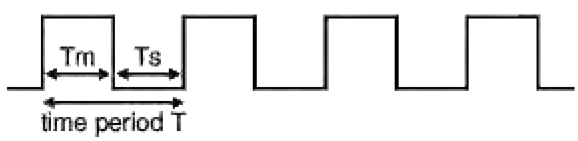


Figure 4.3.4(c): 555 Astable output, a square wave

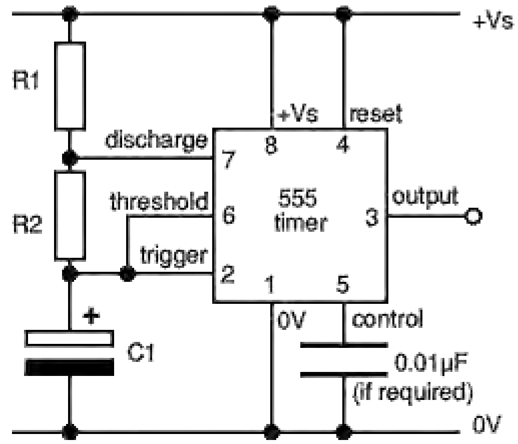


Figure 4.3.4(d): 555 Astable circuit

4.3.5 741 Op-Amp IC

4.3.5.1 Introduction

An operational amplifier IC is a solid-state integrated circuit that uses external feedback to control its functions. It is one of the most versatile devices in all of electronics. The term 'op-amp' was originally used to describe a chain of high performance dc amplifiers that was used as a basis for the analog type computers of long ago. The very high gain op-amp IC's our days uses external feedback networks to control responses. The op-amp without any external devices is called 'open-loop' mode, referring actually to the so-called 'ideal' operational amplifier with infinite open-loop gain, input resistance, bandwidth and a zero output resistance. However, in practice no op-amp can meet these ideal characteristics. And as you will see, a little later on, there is no such thing as an ideal op-amp. Since the LM741/NE741/uA741 Op-Amps are the most popular one, this tutorial is direct associated with this particular type. Nowadays the 741 is a frequency compensated device and although still widely used, the Bi-polar types are low-noise and replacing the old-style op-amps.

4.3.5.2 Definition of 741 pin functions

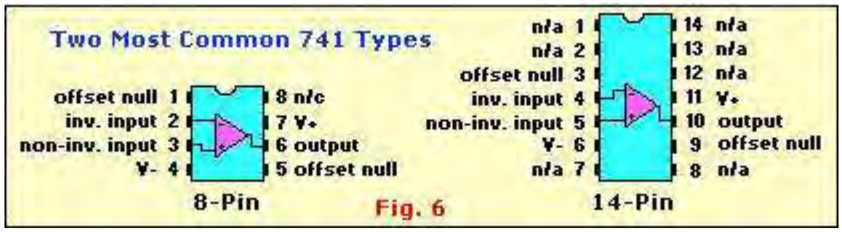


Figure 4.3.5: 741 Op Amp pin functions

Pin 1 (Offset Null): Offset nulling. Since the op-amp is the differential type, input offset voltage must be controlled so as to minimize offset. Offset voltage is nulled by application of a voltage of opposite polarity to the offset. An offset null-adjustment potentiometer may be used to compensate for offset voltage. The null-offset potentiometer also compensates for irregularities in the operational amplifier manufacturing process which may cause an offset. Consequently, the null potentiometer is recommended for critical applications.

Pin 2 (Inverted Input): All input signals at this pin will be inverted at output pin 6. Pins 2 and 3 are very important (obviously) to get the correct input signals or the op amp can not do its work.

Pin 3 (Non-Inverted Input): All input signals at this pin will be processed normally without inversion. The rest is the same as pin 2.

Pin 4 (-V): The V- pin (also referred to as Vss) is the negative supply voltage terminal. Supply-voltage operating range for the 741 is -4.5 volts (minimum) to -18 volts (max), and it is specified for operation between -5 and -15 Vdc. The device will operate essentially the same over this range of voltages without change in timing period. Sensitivity of time interval to supply voltage change is low, typically 0.1% per volt.

Pin 5 (Offset Null): See pin 1

Pin 6 (Output): Output signal's polarity will be the opposite of the input's when this signal is applied to the op-amp's inverting input. For example, a sine-wave at the inverting input will output a square-wave in the case of an inverting comparator circuit.

Pin 7 (posV): The V+ pin (also referred to as Vcc) is the positive supply voltage terminal of the 741 Op-Amp IC. Supply-voltage operating range for the 741 is +4.5 volts (minimum) to +18 volts (maximum), and it is specified for operation between +5 and +15 Vdc. The device will operate essentially the same over this range of voltages without change in timing period. Actually, the most significant operational difference is the output drive capability, which increases for both current and voltage range as the supply voltage is increased. Sensitivity of time interval to supply voltage change is low, typically 0.1% per volt.

Pin 8 (N/C): The 'N/C' stands for 'Not Connected'. There is no other explanation. There is nothing connected to this pin, it is just there to make it a standard 8-pin package.

4.4 Project Costs & Expenses

Provided in the table below are the total cost for the hardware used to build this project.

Table 4.3(a): Purchased hardware total cost

Item	Cost (RM)	Total (RM)
Electric & Electronic related	524.50	524.50
Aluminium railings	40.00	564.50
Acrylic sheets	135.00	699.50
Screws, nuts & bolts	42.70	742.20
Others	72.20	814.40
TOTAL		**814.40**

The implementation of this project could not be made possible without a few devices and equipments especially the Omron ZEN PLC unit, inductive proximity sensor and also the optical distance sensor. The actual overall cost for the hardware are provided below.

Table 4.3(b): Sponsored hardware total cost

Item	Cost (RM)	Total (RM)
Omron ZEN PLC unit	640.00	640.00
Optical distance sensor	1200.00	1840.00
Inductive proximity sensor	250.00	2090.00
Others	100.00	2190.0
TOTAL		**2190.00**

By combining the total cost from both table 3.3a and 3.3b, the total cost for the implementation of this project is obtained.

Table 4.3(c): Total cost for purchased and sponsored hardware

Item	Cost (RM)	Total (RM)
Purchased hardware total cost	814.40	814.40
Sponsored hardware total cost	2190.00	3004.40
TOTAL		**3004.40**

CHAPTER 5

RESULT & DISCUSSION

5.1 Result

The result achieved from the implementation of this project is the design and construction of home automation and lighting control applicable for homes and also teaching purpose. The stated objectives for this project has been achieved almost fully with only the garden management module could not be completed due to various problems and challenges.

During the implementation of the project, there has been problems arising but all of them were solved using troubleshooting techniques. The implementation of this project are also successful according to the Gantt chart and also the flow chart.

Figure 5.1: Completed project

5.2 Discussion

Home automation is a field within building automation, specializing in the specific automation requirements of private homes and in the application of automation techniques for the comfort and security of its residents. Although many techniques used in building automation (such as light and climate control, control of doors and window shutters, security and surveillance systems, etc.) are also used in home automation, additional functions in home automation include the control of multi-media home entertainment systems, automatic plant watering and pet feeding, and automatic scenes for dinners and parties.

The main difference between building automation and home automation is, however, the human interface. In home automation, ergonomics is of particular importance: the control should be largely image-based and self-explanatory.
Although home automation makes it easy and comfortable for the residents, not everyone could afford such systems especially for the low income residents. The main challenge for this project is to design and develop a system that is cost effective.

5.2.1 Problems & Challenges

The implementation of the project is not a simple and easy one as imagined by many when the idea for a smart home project was proposed as many would be looking into the simplicity and basic functions of the circuits rather than the importance of the circuits arrangements on the house module.

Certain components that need to be used for the circuit are unavailable in the simulation software. 3 softwares are used, which are Multisim 7, Proteus 7 and ZEN support for PLC to solve this problem. Troubleshooting the circuit created during simulation stage is another hard part. Sometimes the circuit could not be simulated properly due to human error and probably the computer's malfunction or the connection problems. Acquiring the components needed for the circuits is not as easy as it may sound as certain components have a specific value and to fix this, another component with a closer value or identically the same is replaced.

Another important thing is to make sure that the total load does not exceed the maximum rating of power supply. The switching power supply provides a power of a maximum 2.1 Amps for the 24V and 3A for the 12V power supply. The circuits have to be designed to use the most minimum power from the power supply. Designing a low cost project is one of the hardest part as the cost for each components have to be kept low. Arrangement also needs to be planned accordingly. Any mistake here would cost waste of time, energy and difficulties in the future as sometimes the same works have to be carried out twice.

The Garden Management module was not completed due to a few reasons. There was a problem finding the components and parts needed especially the tweeter to transmit ultrasonic frequency. The designed circuit was not functioning and the troubleshooting failed and there was insufficient time and budget for this module.

CHAPTER 6

CONCLUSION & RECOMMENDATIONS

6.1 Recommendations

The modules that form this project is just a simple circuit connected with each other to form an automation system. There are many rooms to improve the existing ones to make it perform better in the future. For example, we will use the indoor ventilation control that uses the temperature sensing circuit. The circuit detects the change in the temperature by using a NTC type thermistor which is the most basic device in temperature measurement. This circuit can be improved by probably using an air humidity sensor and can be added with a temperature display so that the current temperature is shown to the user.

Other than that, each designed module can be upgraded easily. Other automation system can also be added to improve the current system. Hopefully someone will make good use of this project and make a better one of it in the near future.

To make it better especially cost saving, the PLC can be replaced with the application of PIC. This is especially true since PICs are robust, compact and smaller in size. The application of PLC is also suitable but as a small scale application demands, it is better to go with the PIC. The reason for this project to continue with the use of PLC despite the better use of PIC is because the PLC is obtained for free.

6.2 Conclusion

It can be concluded that up to date, all the objectives are not far away to be achieved. The project is well going and proceeding according to the flow chart and Gantt chart planning or probably even faster than expected. There are various problems and challenges faced but so far each and every one is solved with the guidance of the project supervisor and with the help of my fellow collegues. This project has undoubtly improved my understanding in electrical devices, circuit and increased my ability in project managing and planning. Hopefully, upon the completion of this project, the field of home automation will be a major aspect in universities in Malaysia as the current homes have a good potential to be converted into smart homes. This will reflect Malaysia as a modern and technologically advanced country.

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National Semiconductor

July 2006

LM555
Timer

General Description

The LM555 is a highly stable device for generating accurate time delays or oscillation. Additional terminals are provided for triggering or resetting if desired. In the time delay mode of operation, the time is precisely controlled by one external resistor and capacitor. For astable operation as an oscillator, the free running frequency and duty cycle are accurately controlled with two external resistors and one capacitor. The circuit may be triggered and reset on falling waveforms, and the output circuit can source or sink up to 200mA or drive TTL circuits.

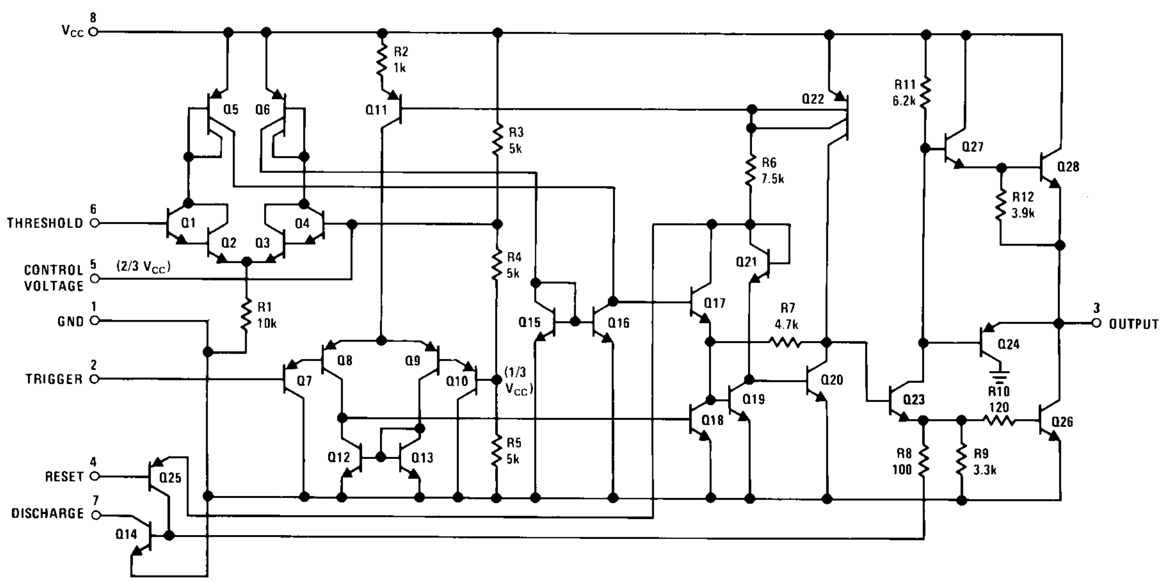
Features

- Direct replacement for SE555/NE555
- Timing from microseconds through hours
- Operates in both astable and monostable modes
- Adjustable duty cycle
- Output can source or sink 200 mA
- Output and supply TTL compatible
- Temperature stability better than 0.005% per ˚C
- Normally on and normally off output
- Available in 8-pin MSOP package

Applications

- Precision timing
- Pulse generation
- Sequential timing
- Time delay generation
- Pulse width modulation
- Pulse position modulation
- Linear ramp generator

Schematic Diagram



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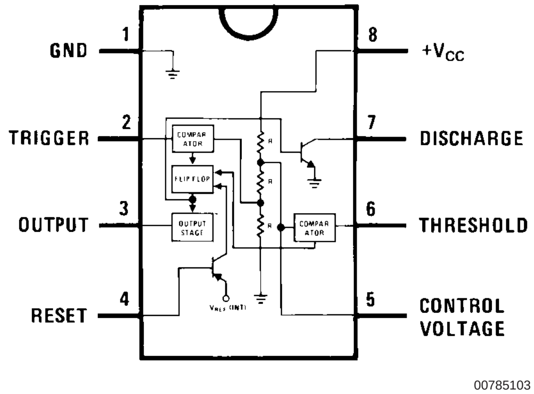
Connection Diagram

Dual-In-Line, Small Outline and Molded Mini Small Outline Packages



Top View

Ordering Information

Package	Part Number	Package Marking	Media Transport	NSC Drawing
8-Pin SOIC	LM555CM	LM555CM	Rails	M08A
	LM555CMX	LM555CM	2.5k Units Tape and Reel	
8-Pin MSOP	LM555CMM	Z55	1k Units Tape and Reel	MUA08A
	LM555CMMX	Z55	3.5k Units Tape and Reel	
8-Pin MDIP	LM555CN	LM555CN	Rails	N08E

Absolute Maximum Ratings (Note 2)

If Military/Aerospace specified devices are required, please contact the National Semiconductor Sales Office/ Distributors for availability and specifications.

Supply Voltage	+18V
Power Dissipation (Note 3)	
LM555CM, LM555CN	1180 mW
LM555CMM	613 mW
Operating Temperature Ranges	
LM555C	0˚C to +70˚C
Storage Temperature Range	−65˚C to +150˚C

Soldering Information	
Dual-In-Line Package	
Soldering (10 Seconds)	260˚C
Small Outline Packages (SOIC and MSOP)	
Vapor Phase (60 Seconds)	215˚C
Infrared (15 Seconds)	220˚C

See AN-450 “Surface Mounting Methods and Their Effect on Product Reliability” for other methods of soldering surface mount devices.

Electrical Characteristics (Notes 1, 2)

(T_A = 25˚C, V_{CC} = +5V to +15V, unless othewise specified)

Parameter	Conditions	Limits			Units
		LM555C			
		Min	Typ	Max	
Supply Voltage		4.5		16	V
Supply Current	V_{CC} = 5V, R_L = ∞ V_{CC} = 15V, R_L = ∞ (Low State) (Note 4)		3 10	6 15	mA
Timing Error, Monostable					
Initial Accuracy			1		%
Drift with Temperature	R_A = 1k to 100kΩ, C = 0.1µF, (Note 5)		50		ppm/˚C
Accuracy over Temperature			1.5		%
Drift with Supply			0.1		%/V
Timing Error, Astable					
Initial Accuracy			2.25		%
Drift with Temperature	R_A, R_B = 1k to 100kΩ, C = 0.1µF, (Note 5)		150		ppm/˚C
Accuracy over Temperature			3.0		%
Drift with Supply			0.30		%/V
Threshold Voltage			0.667		x V_{CC}
Trigger Voltage	V_{CC} = 15V V_{CC} = 5V		5 1.67		V V
Trigger Current			0.5	0.9	µA
Reset Voltage		0.4	0.5	1	V
Reset Current			0.1	0.4	mA
Threshold Current	(Note 6)		0.1	0.25	µA
Control Voltage Level	V_{CC} = 15V V_{CC} = 5V	9 2.6	10 3.33	11 4	V
Pin 7 Leakage Output High			1	100	nA
Pin 7 Sat (Note 7)					
Output Low	V_{CC} = 15V, I_7 = 15mA		180		mV
Output Low	V_{CC} = 4.5V, I_7 = 4.5mA		80	200	mV

Electrical Characteristics (Notes 1, 2) (Continued)

($T_A = 25^{\circ}C$, V_{CC} = +5V to +15V, unless othewise specified)

Parameter	Conditions	Limits			Units
		LM555C			
		Min	Typ	Max	
Output Voltage Drop (Low)	V_{CC} = 15V				
	I_{SINK} = 10mA		0.1	0.25	V
	I_{SINK} = 50mA		0.4	0.75	V
	I_{SINK} = 100mA		2	2.5	V
	I_{SINK} = 200mA		2.5		V
	V_{CC} = 5V				
	I_{SINK} = 8mA				V
	I_{SINK} = 5mA		0.25	0.35	V
Output Voltage Drop (High)	I_{SOURCE} = 200mA, V_{CC} = 15V		12.5		V
	I_{SOURCE} = 100mA, V_{CC} = 15V	12.75	13.3		V
	V_{CC} = 5V	2.75	3.3		V
Rise Time of Output			100		ns
Fall Time of Output			100		ns

Note 1: All voltages are measured with respect to the ground pin, unless otherwise specified.

Note 2: Absolute Maximum Ratings indicate limits beyond which damage to the device may occur. Operating Ratings indicate conditions for which the device is functional, but do not guarantee specific performance limits. Electrical Characteristics state DC and AC electrical specifications under particular test conditions which guarantee specific performance limits. This assumes that the device is within the Operating Ratings. Specifications are not guaranteed for parameters where no limit is given, however, the typical value is a good indication of device performance.

Note 3: For operating at elevated temperatures the device must be derated above 25˚C based on a +150˚C maximum junction temperature and a thermal resistance of 106˚C/W (DIP), 170˚C/W (S0-8), and 204˚C/W (MSOP) junction to ambient.

Note 4: Supply current when output high typically 1 mA less at V_{CC} = 5V.

Note 5: Tested at V_{CC} = 5V and V_{CC} = 15V.

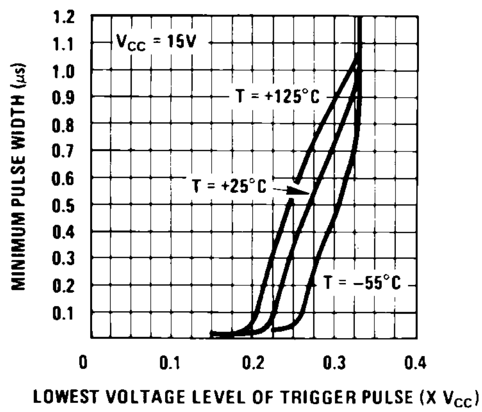
Note 6: This will determine the maximum value of $R_A + R_B$ for 15V operation. The maximum total ($R_A + R_B$) is 20MΩ.

Note 7: No protection against excessive pin 7 current is necessary providing the package dissipation rating will not be exceeded.

Note 8: Refer to RETS555X drawing of military LM555H and LM555J versions for specifications.

Typical Performance Characteristics

Minimuim Pulse Width Required for Triggering



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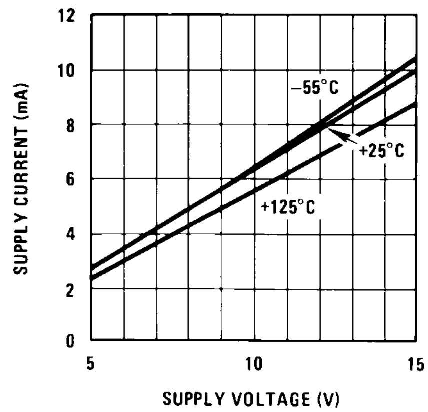
Supply Current vs. Supply Voltage



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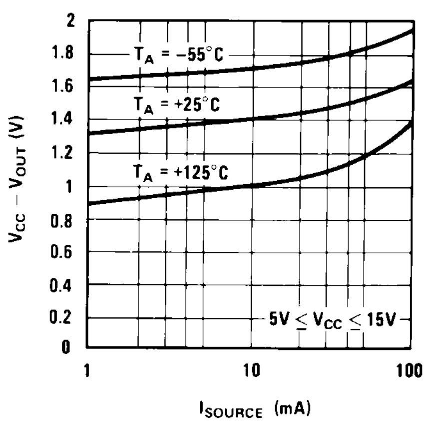
High Output Voltage vs. Output Source Current



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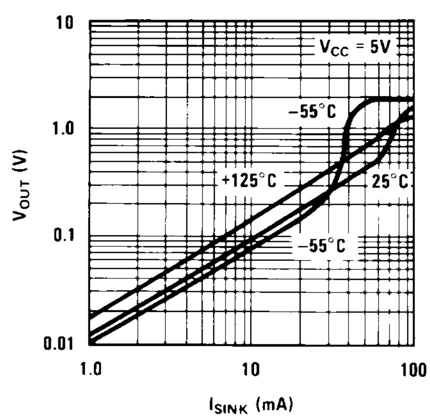
Low Output Voltage vs. Output Sink Current



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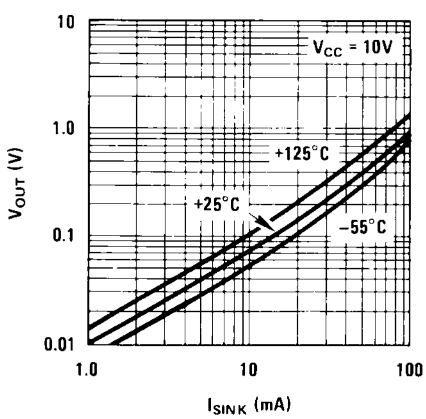
Low Output Voltage vs. Output Sink Current



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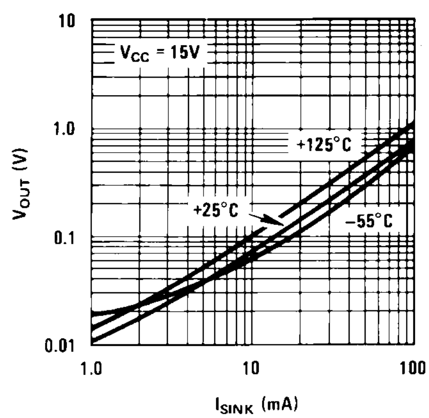
Low Output Voltage vs. Output Sink Current



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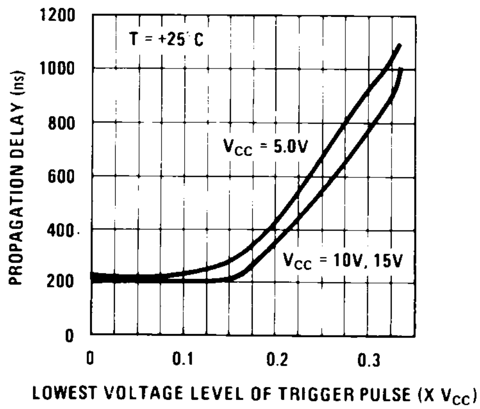
Typical Performance Characteristics (Continued)

Output Propagation Delay vs. Voltage Level of Trigger Pulse



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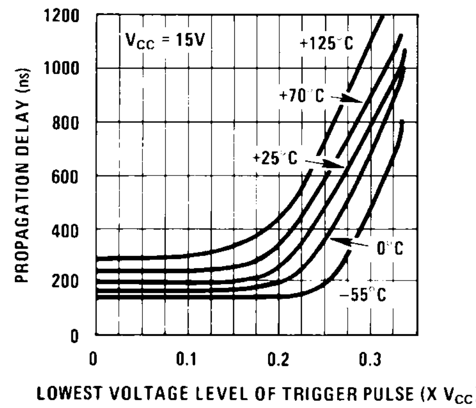
Output Propagation Delay vs. Voltage Level of Trigger Pulse



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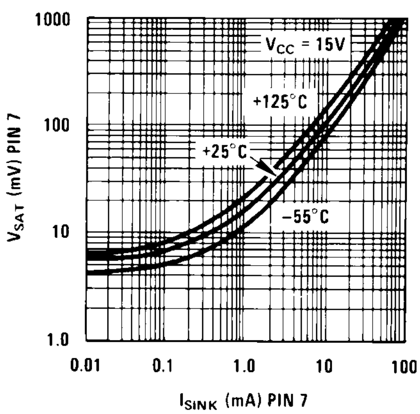
Discharge Transistor (Pin 7) Voltage vs. Sink Current



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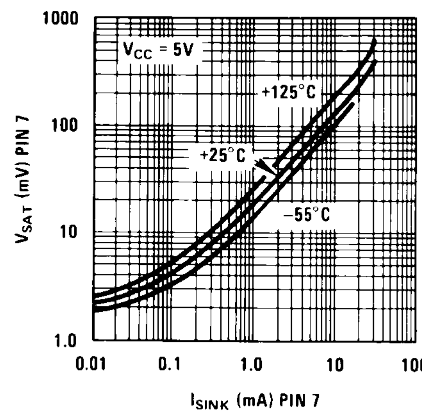
Discharge Transistor (Pin 7) Voltage vs. Sink Current

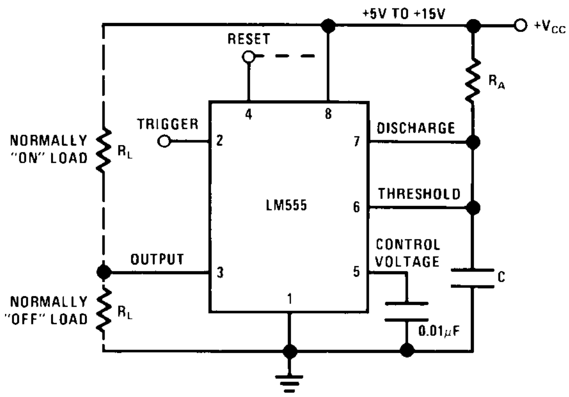


00785127

Applications Information

MONOSTABLE OPERATION

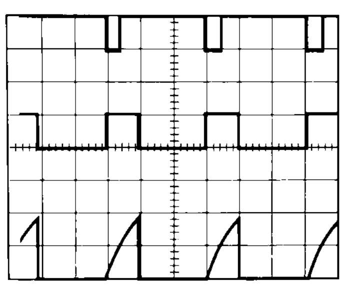
In this mode of operation, the timer functions as a one-shot (*Figure 1*). The external capacitor is initially held discharged by a transistor inside the timer. Upon application of a negative trigger pulse of less than 1/3 V_{CC} to pin 2, the flip-flop is set which both releases the short circuit across the capacitor and drives the output high.



00785105

FIGURE 1. Monostable

The voltage across the capacitor then increases exponentially for a period of t = 1.1 R_A C, at the end of which time the voltage equals 2/3 V_{CC}. The comparator then resets the flip-flop which in turn discharges the capacitor and drives the output to its low state. *Figure 2* shows the waveforms generated in this mode of operation. Since the charge and the threshold level of the comparator are both directly proportional to supply voltage, the timing interval is independent of supply.



00785106

V_{CC} = 5V Top Trace: Input 5V/Div.
TIME = 0.1 ms/DIV. Middle Trace: Output 5V/Div.
R_A = 9.1kΩ Bottom Trace: Capacitor Voltage 2V/Div.
C = 0.01μF

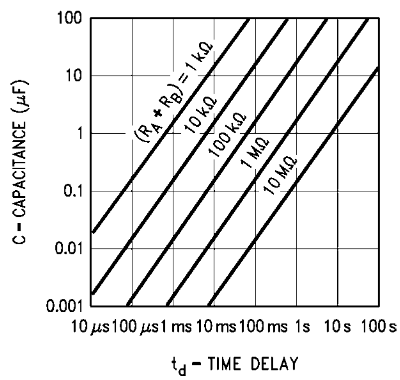
FIGURE 2. Monostable Waveforms

During the timing cycle when the output is high, the further application of a trigger pulse will not effect the circuit so long as the trigger input is returned high at least 10μs before the end of the timing interval. However the circuit can be reset during this time by the application of a negative pulse to the reset terminal (pin 4). The output will then remain in the low state until a trigger pulse is again applied.

When the reset function is not in use, it is recommended that it be connected to V_{CC} to avoid any possibility of false triggering.

Figure 3 is a nomograph for easy determination of R, C values for various time delays.

NOTE: In monostable operation, the trigger should be driven high before the end of timing cycle.

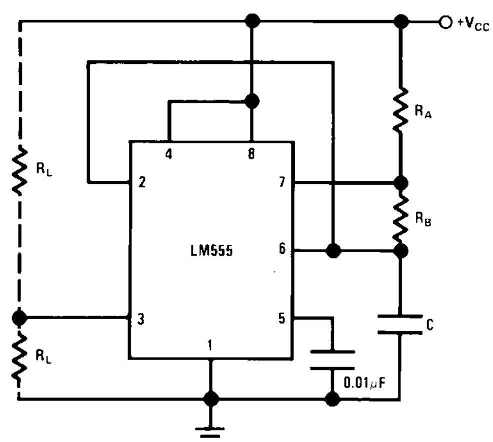


00785107

FIGURE 3. Time Delay

ASTABLE OPERATION

If the circuit is connected as shown in *Figure 4* (pins 2 and 6 connected) it will trigger itself and free run as a multivibrator. The external capacitor charges through R_A + R_B and discharges through R_B. Thus the duty cycle may be precisely set by the ratio of these two resistors.



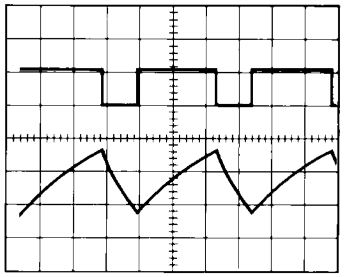
00785108

FIGURE 4. Astable

In this mode of operation, the capacitor charges and discharges between 1/3 V_{CC} and 2/3 V_{CC}. As in the triggered mode, the charge and discharge times, and therefore the frequency are independent of the supply voltage.

Applications Information (Continued)

Figure 5 shows the waveforms generated in this mode of operation.



00785109

V_{CC} = 5V Top Trace: Output 5V/Div.
TIME = 20µs/DIV. Bottom Trace: Capacitor Voltage 1V/Div.
R_A = 3.9kΩ
R_B = 3kΩ
C = 0.01µF

FIGURE 5. Astable Waveforms

The charge time (output high) is given by:

$$t_1 = 0.693\ (R_A + R_B)\ C$$

And the discharge time (output low) by:

$$t_2 = 0.693\ (R_B)\ C$$

Thus the total period is:

$$T = t_1 + t_2 = 0.693\ (R_A + 2R_B)\ C$$

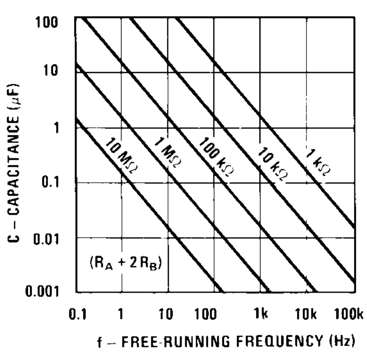
The frequency of oscillation is:

$$f = \frac{1}{T} = \frac{1.44}{(R_A + 2\,R_B)\,C}$$

Figure 6 may be used for quick determination of these RC values.

The duty cycle is:

$$D = \frac{R_B}{R_A + 2R_B}$$

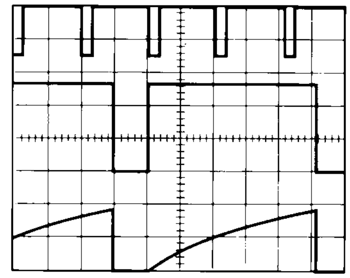


00785110

FIGURE 6. Free Running Frequency

FREQUENCY DIVIDER

The monostable circuit of *Figure 1* can be used as a frequency divider by adjusting the length of the timing cycle. *Figure 7* shows the waveforms generated in a divide by three circuit.



00785111

V_{CC} = 5V Top Trace: Input 4V/Div.
TIME = 20µs/DIV. Middle Trace: Output 2V/Div.
R_A = 9.1kΩ Bottom Trace: Capacitor 2V/Div.
C = 0.01µF

FIGURE 7. Frequency Divider

PULSE WIDTH MODULATOR

When the timer is connected in the monostable mode and triggered with a continuous pulse train, the output pulse width can be modulated by a signal applied to pin 5. *Figure 8* shows the circuit, and in *Figure 9* are some waveform examples.

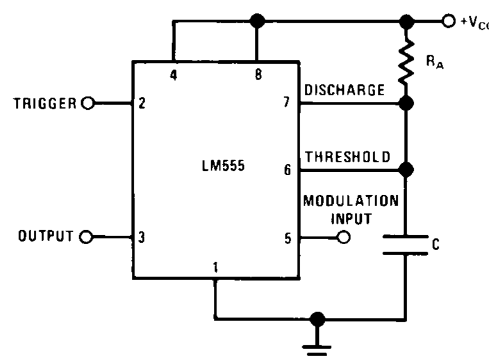


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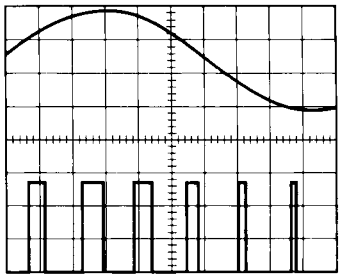
FIGURE 8. Pulse Width Modulator

Applications Information (Continued)



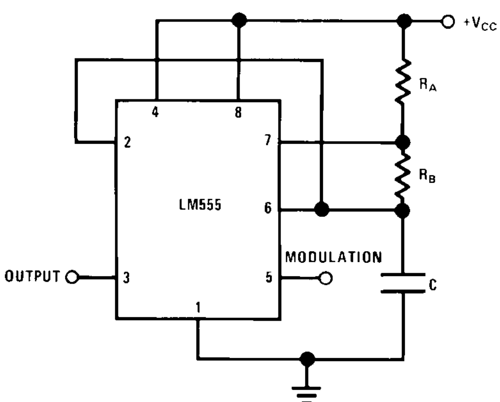
00785113

V_{CC} = 5V   Top Trace: Modulation 1V/Div.
TIME = 0.2 ms/DIV.   Bottom Trace: Output Voltage 2V/Div.
R_A = 9.1kΩ
C = 0.01µF

FIGURE 9. Pulse Width Modulator

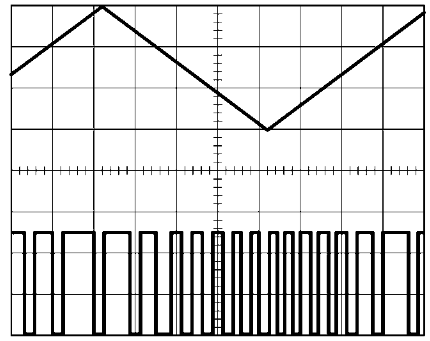
PULSE POSITION MODULATOR

This application uses the timer connected for astable operation, as in *Figure 10*, with a modulating signal again applied to the control voltage terminal. The pulse position varies with the modulating signal, since the threshold voltage and hence the time delay is varied. *Figure 11* shows the waveforms generated for a triangle wave modulation signal.



00785114

FIGURE 10. Pulse Position Modulator



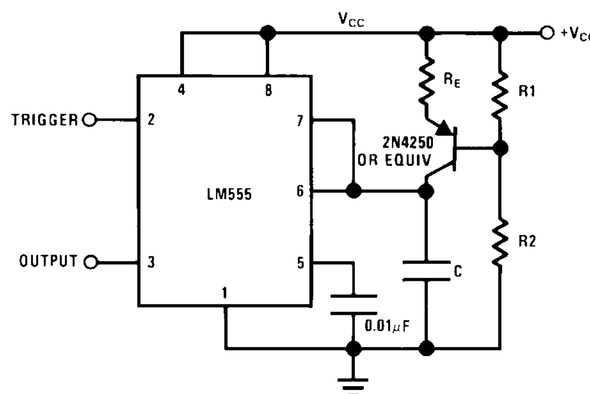
00785115

V_{CC} = 5V   Top Trace: Modulation Input 1V/Div.
TIME = 0.1 ms/DIV.   Bottom Trace: Output 2V/Div.
R_A = 3.9kΩ
R_B = 3kΩ
C = 0.01µF

FIGURE 11. Pulse Position Modulator

LINEAR RAMP

When the pullup resistor, R_A, in the monostable circuit is replaced by a constant current source, a linear ramp is generated. *Figure 12* shows a circuit configuration that will perform this function.



00785116

FIGURE 12.

Figure 13 shows waveforms generated by the linear ramp.

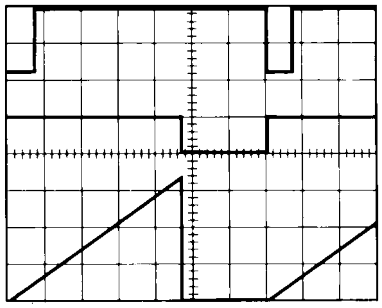
The time interval is given by:

$$T = \frac{2/3\ V_{CC}\ R_E\ (R_1 + R_2)\ C}{R_1\ V_{CC} - V_{BE}\ (R_1 + R_2)}$$

$$V_{BE} \cong 0.6V$$

$$V_{BE} \simeq 0.6V$$

Applications Information (Continued)



00785117

V_{CC} = 5V   Top Trace: Input 3V/Div.
TIME = 20µs/DIV.   Middle Trace: Output 5V/Div.
R_1 = 47kΩ   Bottom Trace: Capacitor Voltage 1V/Div.
R_2 = 100kΩ
R_E = 2.7 kΩ
C = 0.01 µF

FIGURE 13. Linear Ramp

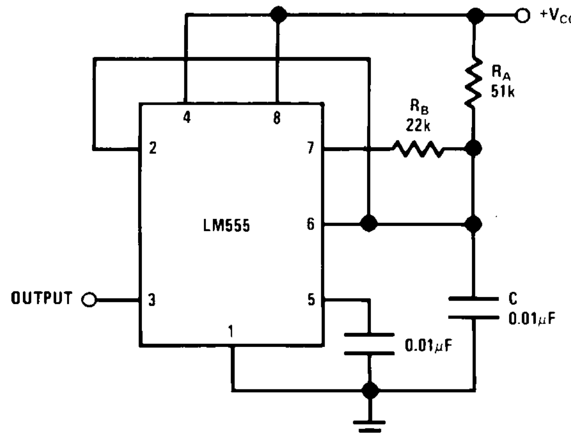
50% DUTY CYCLE OSCILLATOR

For a 50% duty cycle, the resistors R_A and R_B may be connected as in *Figure 14*. The time period for the output high is the same as previous, t_1 = 0.693 R_A C. For the output low it is t_2 =

$$\left[(R_A R_B)/(R_A + R_B)\right] C \,\ell n \left[\frac{R_B - 2R_A}{2R_B - R_A}\right]$$

Thus the frequency of oscillation is

$$f = \frac{1}{t_1 + t_2}$$



00785118

FIGURE 14. 50% Duty Cycle Oscillator

Note that this circuit will not oscillate if R_B is greater than 1/2 R_A because the junction of R_A and R_B cannot bring pin 2 down to 1/3 V_{CC} and trigger the lower comparator.

ADDITIONAL INFORMATION

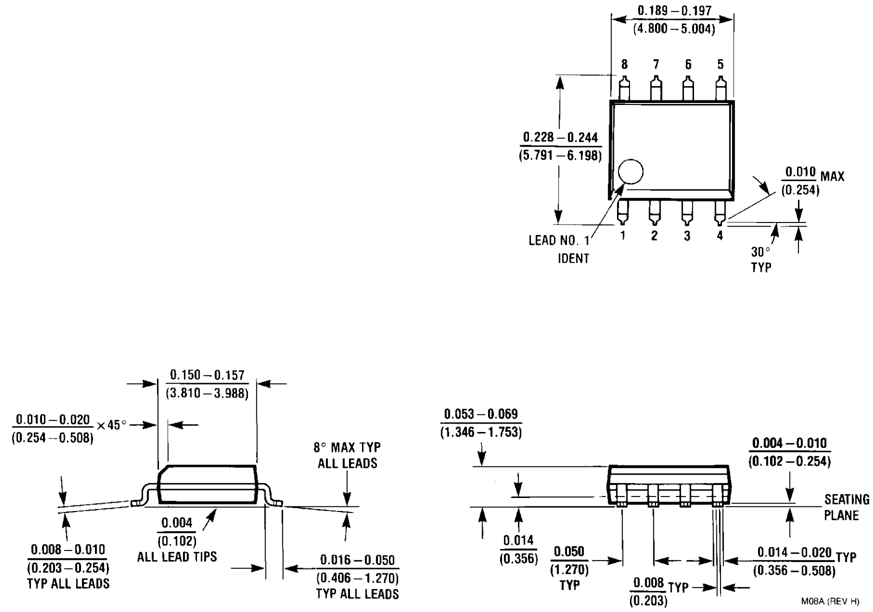
Adequate power supply bypassing is necessary to protect associated circuitry. Minimum recommended is 0.1µF in parallel with 1µF electrolytic.

Lower comparator storage time can be as long as 10µs when pin 2 is driven fully to ground for triggering. This limits the monostable pulse width to 10µs minimum.

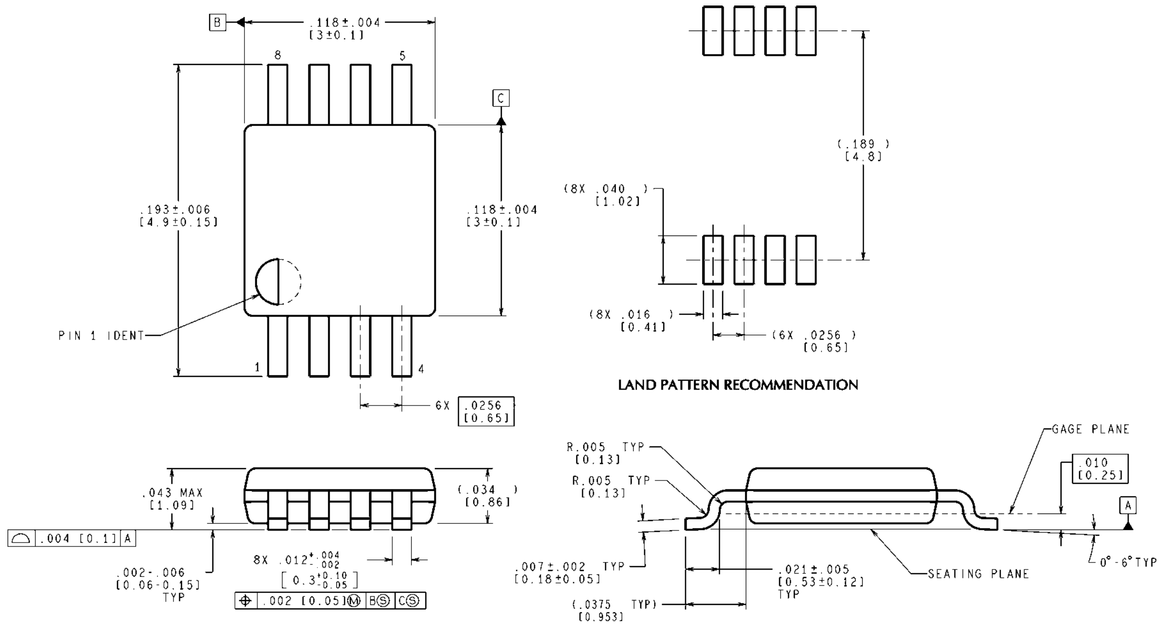
Delay time reset to output is 0.47µs typical. Minimum reset pulse width must be 0.3µs, typical.

Pin 7 current switches within 30ns of the output (pin 3) voltage.

Physical Dimensions inches (millimeters) unless otherwise noted



Small Outline Package (M)
NS Package Number M08A

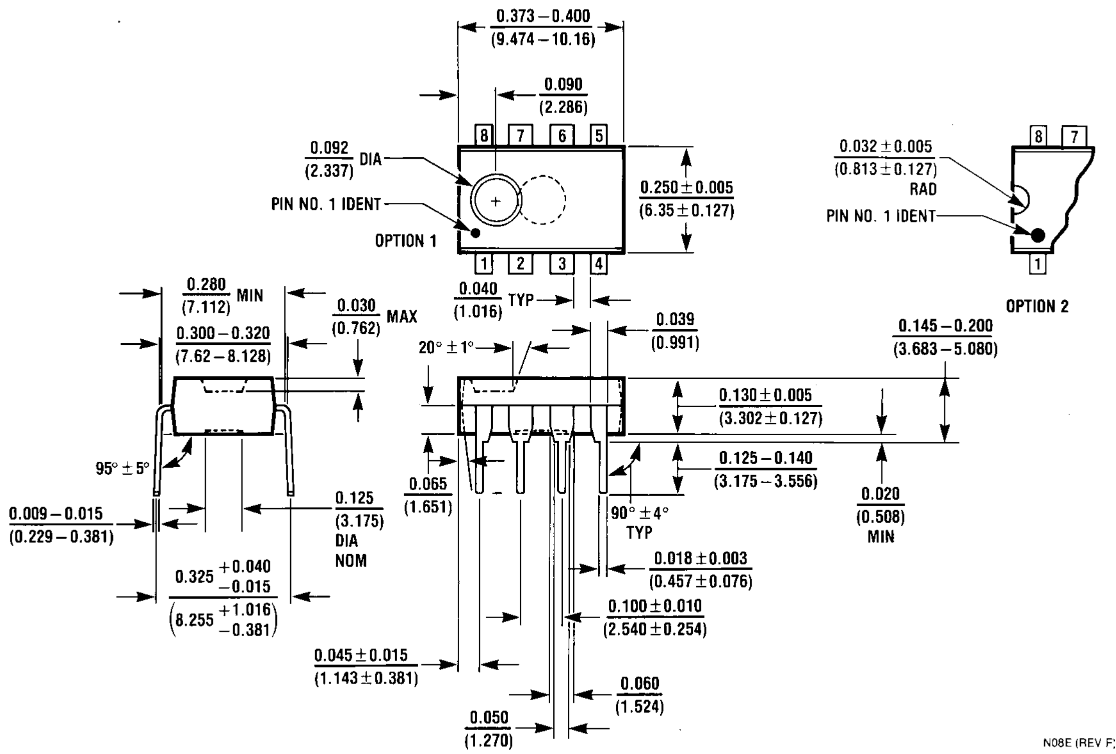


CONTROLLING DIMENSION IS INCH
VALUES IN [ ] ARE MILLIMETERS

MUA08A (Rev E)

8-Lead (0.118” Wide) Molded Mini Small Outline Package
NS Package Number MUA08A

Physical Dimensions inches (millimeters) unless otherwise noted (Continued)



Molded Dual-In-Line Package (N)
NS Package Number N08E

National does not assume any responsibility for use of any circuitry described, no circuit patent licenses are implied and National reserves the right at any time without notice to change said circuitry and specifications.

For the most current product information visit us at www.national.com.

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National Semiconductor

August 2000

LM741
Operational Amplifier

General Description

The LM741 series are general purpose operational amplifiers which feature improved performance over industry standards like the LM709. They are direct, plug-in replacements for the 709C, LM201, MC1439 and 748 in most applications.

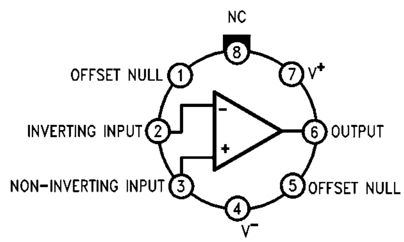
The amplifiers offer many features which make their application nearly foolproof: overload protection on the input and output, no latch-up when the common mode range is exceeded, as well as freedom from oscillations.

The LM741C is identical to the LM741/LM741A except that the LM741C has their performance guaranteed over a 0˚C to +70˚C temperature range, instead of −55˚C to +125˚C.

Features

Connection Diagrams

Metal Can Package

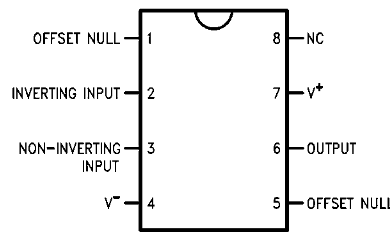


00934102

Note 1: LM741H is available per JM38510/10101

Order Number LM741H, LM741H/883 (Note 1)**,**
LM741AH/883 or LM741CH
See NS Package Number H08C

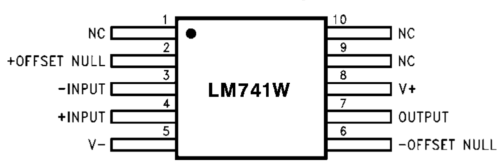
Dual-In-Line or S.O. Package



00934103

Order Number LM741J, LM741J/883, LM741CN
See NS Package Number J08A, M08A or N08E

Ceramic Flatpak

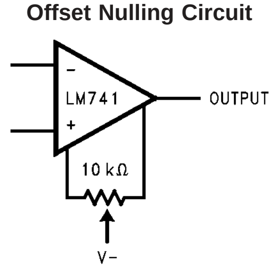


00934106

Order Number LM741W/883
See NS Package Number W10A

Typical Application

Offset Nulling Circuit



00934107

Absolute Maximum Ratings (Note 2)

If Military/Aerospace specified devices are required, please contact the National Semiconductor Sales Office/ Distributors for availability and specifications.

(Note 7)

	LM741A	LM741	LM741C
Supply Voltage	±22V	±22V	±18V
Power Dissipation (Note 3)	500 mW	500 mW	500 mW
Differential Input Voltage	±30V	±30V	±30V
Input Voltage (Note 4)	±15V	±15V	±15V
Output Short Circuit Duration	Continuous	Continuous	Continuous
Operating Temperature Range	−55˚C to +125˚C	−55˚C to +125˚C	0˚C to +70˚C
Storage Temperature Range	−65˚C to +150˚C	−65˚C to +150˚C	−65˚C to +150˚C
Junction Temperature	150˚C	150˚C	100˚C
Soldering Information			
N-Package (10 seconds)	260˚C	260˚C	260˚C
J- or H-Package (10 seconds)	300˚C	300˚C	300˚C
M-Package			
Vapor Phase (60 seconds)	215˚C	215˚C	215˚C
Infrared (15 seconds)	215˚C	215˚C	215˚C

See AN-450 “Surface Mounting Methods and Their Effect on Product Reliability” for other methods of soldering
surface mount devices.

ESD Tolerance (Note 8)	400V	400V	400V

Electrical Characteristics (Note 5)

Parameter	Conditions	LM741A			LM741			LM741C			Units
		Min	Typ	Max	Min	Typ	Max	Min	Typ	Max	
Input Offset Voltage	T_A = 25˚C										
	$R_S \leq 10\ k\Omega$					1.0	5.0		2.0	6.0	mV
	$R_S \leq 50\Omega$		0.8	3.0							mV
	$T_{AMIN} \leq T_A \leq T_{AMAX}$										
	$R_S \leq 50\Omega$			4.0							mV
	$R_S \leq 10\ k\Omega$						6.0			7.5	mV
Average Input Offset Voltage Drift				15							μV/˚C
Input Offset Voltage Adjustment Range	T_A = 25˚C, V_S = ±20V	±10				±15			±15		mV
Input Offset Current	T_A = 25˚C		3.0	30		20	200		20	200	nA
	$T_{AMIN} \leq T_A \leq T_{AMAX}$			70		85	500			300	nA
Average Input Offset Current Drift				0.5							nA/˚C
Input Bias Current	T_A = 25˚C		30	80		80	500		80	500	nA
	$T_{AMIN} \leq T_A \leq T_{AMAX}$			0.210			1.5			0.8	μA
Input Resistance	T_A = 25˚C, V_S = ±20V	1.0	6.0		0.3	2.0		0.3	2.0		MΩ
	$T_{AMIN} \leq T_A \leq T_{AMAX}$, V_S = ±20V	0.5									MΩ
Input Voltage Range	T_A = 25˚C							±12	±13		V
	$T_{AMIN} \leq T_A \leq T_{AMAX}$				±12	±13					V

Electrical Characteristics (Note 5) (Continued)

Parameter	Conditions	LM741A			LM741			LM741C			Units
		Min	Typ	Max	Min	Typ	Max	Min	Typ	Max	
Large Signal Voltage Gain	T_A = 25˚C, $R_L \geq$ 2 kΩ										
	V_S = ±20V, V_O = ±15V	50									V/mV
	V_S = ±15V, V_O = ±10V				50	200		20	200		V/mV
	$T_{AMIN} \leq T_A \leq T_{AMAX}$,										
	$R_L \geq$ 2 kΩ,										
	V_S = ±20V, V_O = ±15V	32									V/mV
	V_S = ±15V, V_O = ±10V				25			15			V/mV
	V_S = ±5V, V_O = ±2V	10									V/mV
Output Voltage Swing	V_S = ±20V										
	$R_L \geq$ 10 kΩ	±16									V
	$R_L \geq$ 2 kΩ	±15									V
	V_S = ±15V										
	$R_L \geq$ 10 kΩ				±12	±14		±12	±14		V
	$R_L \geq$ 2 kΩ				±10	±13		±10	±13		V
Output Short Circuit	T_A = 25˚C	10	25	35		25			25		mA
Current	$T_{AMIN} \leq T_A \leq T_{AMAX}$	10		40							mA
Common-Mode	$T_{AMIN} \leq T_A \leq T_{AMAX}$										
Rejection Ratio	$R_S \leq$ 10 kΩ, V_{CM} = ±12V				70	90		70	90		dB
	$R_S \leq$ 50Ω, V_{CM} = ±12V	80	95								dB
Supply Voltage Rejection	$T_{AMIN} \leq T_A \leq T_{AMAX}$,										
Ratio	V_S = ±20V to V_S = ±5V										
	$R_S \leq$ 50Ω	86	96								dB
	$R_S \leq$ 10 kΩ				77	96		77	96		dB
Transient Response	T_A = 25˚C, Unity Gain										
Rise Time			0.25	0.8		0.3			0.3		µs
Overshoot			6.0	20		5			5		%
Bandwidth (Note 6)	T_A = 25˚C	0.437	1.5								MHz
Slew Rate	T_A = 25˚C, Unity Gain	0.3	0.7			0.5			0.5		V/µs
Supply Current	T_A = 25˚C					1.7	2.8		1.7	2.8	mA
Power Consumption	T_A = 25˚C										
	V_S = ±20V		80	150							mW
	V_S = ±15V					50	85		50	85	mW
LM741A	V_S = ±20V										
	$T_A = T_{AMIN}$			165							mW
	$T_A = T_{AMAX}$			135							mW
LM741	V_S = ±15V										
	$T_A = T_{AMIN}$					60	100				mW
	$T_A = T_{AMAX}$					45	75				mW

Note 2: "Absolute Maximum Ratings" indicate limits beyond which damage to the device may occur. Operating Ratings indicate conditions for which the device is functional, but do not guarantee specific performance limits.

Electrical Characteristics (Note 5) (Continued)

Note 3: For operation at elevated temperatures, these devices must be derated based on thermal resistance, and T_j max. (listed under "Absolute Maximum Ratings"). $T_j = T_A + (\theta_{jA} P_D)$.

Thermal Resistance	Cerdip (J)	DIP (N)	HO8 (H)	SO-8 (M)
θ_{jA} (Junction to Ambient)	100˚C/W	100˚C/W	170˚C/W	195˚C/W
θ_{jC} (Junction to Case)	N/A	N/A	25˚C/W	N/A

Note 4: For supply voltages less than ±15V, the absolute maximum input voltage is equal to the supply voltage.

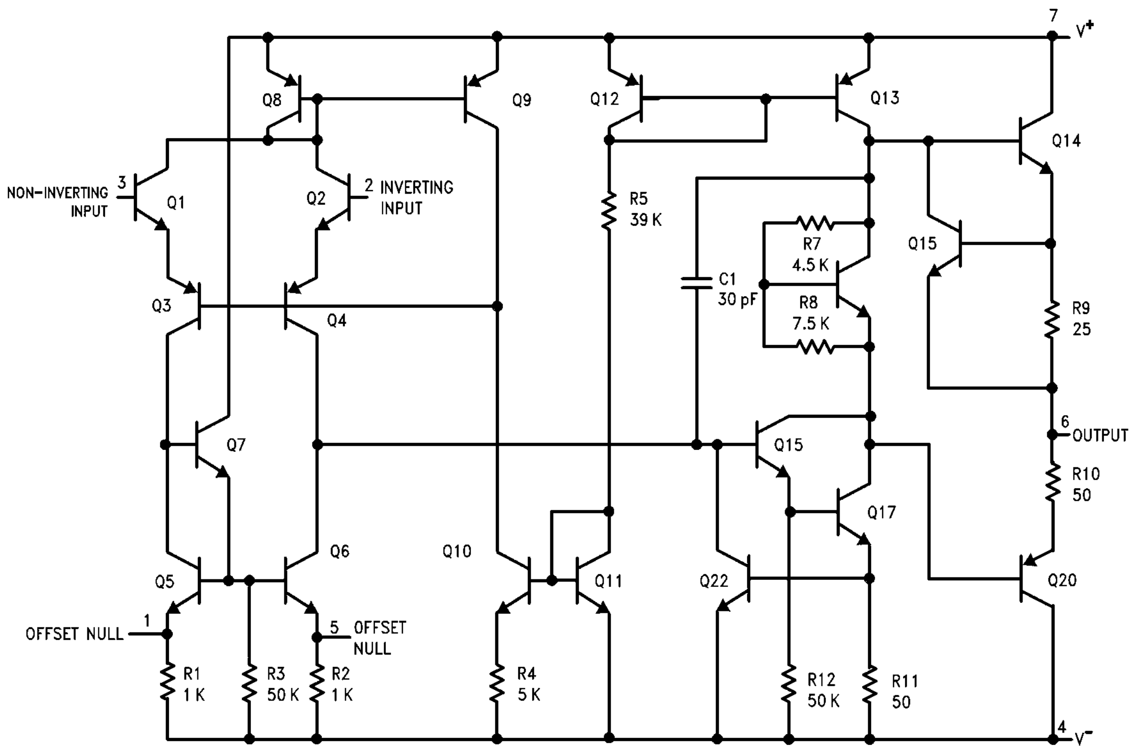
Note 5: Unless otherwise specified, these specifications apply for V_S = ±15V, −55˚C ≤ T_A ≤ +125˚C (LM741/LM741A). For the LM741C/LM741E, these specifications are limited to 0˚C ≤ T_A ≤ +70˚C.

Note 6: Calculated value from: BW (MHz) = 0.35/Rise Time(µs).

Note 7: For military specifications see RETS741X for LM741 and RETS741AX for LM741A.

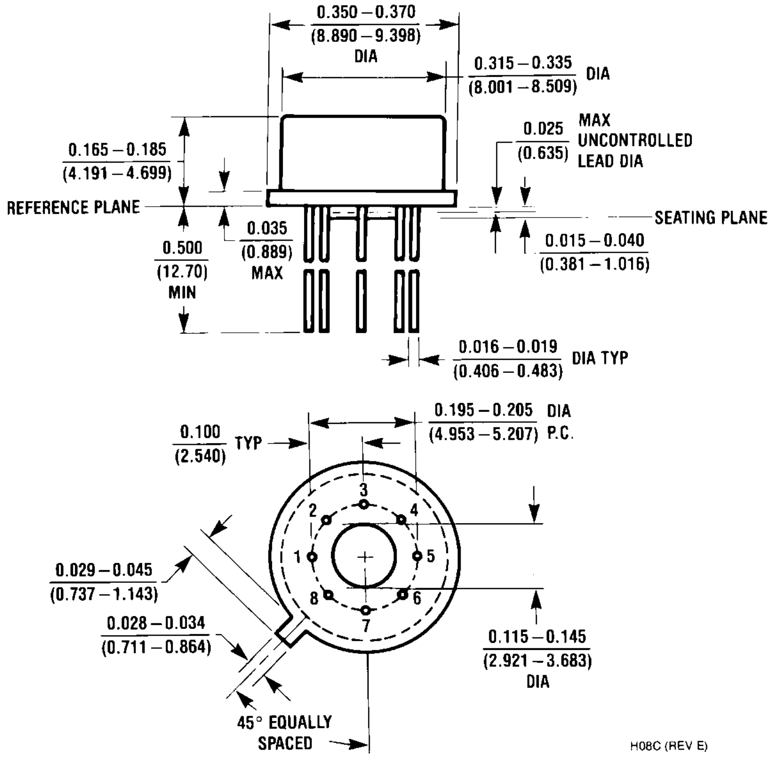
Note 8: Human body model, 1.5 kΩ in series with 100 pF.

Schematic Diagram



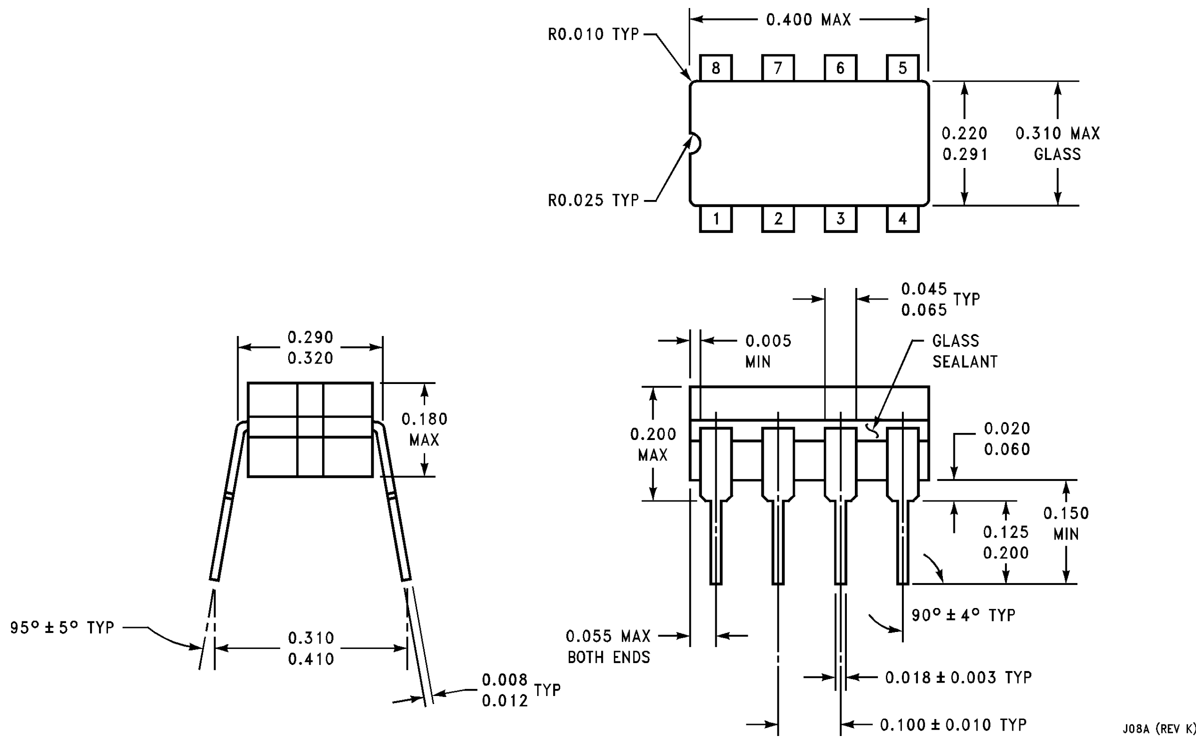
00934101

Physical Dimensions inches (millimeters) unless otherwise noted

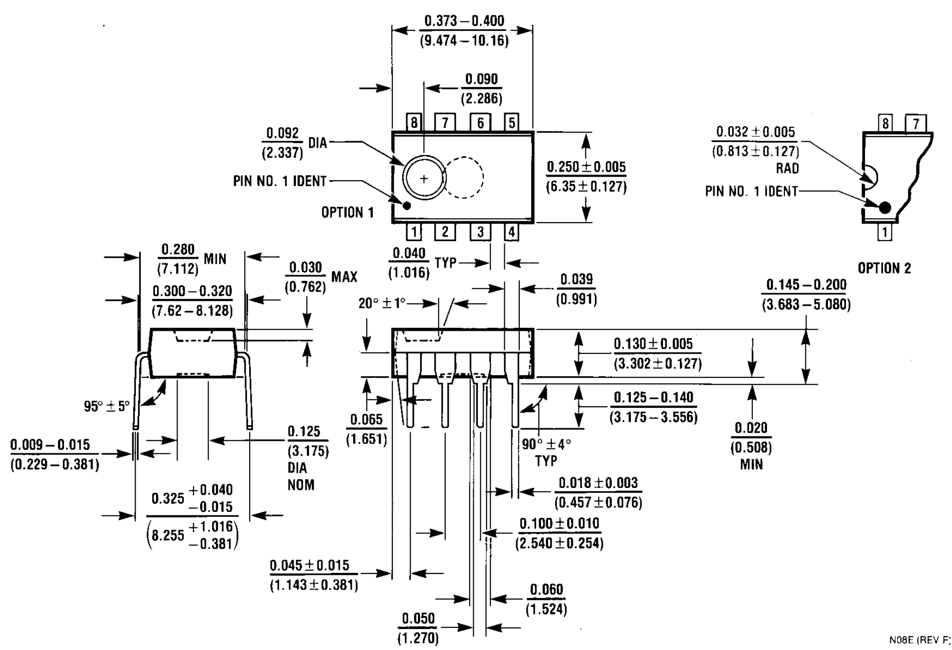


Metal Can Package (H)
Order Number LM741H, LM741H/883, LM741AH/883, LM741AH-MIL or LM741CH
NS Package Number H08C

Physical Dimensions inches (millimeters) unless otherwise noted (Continued)

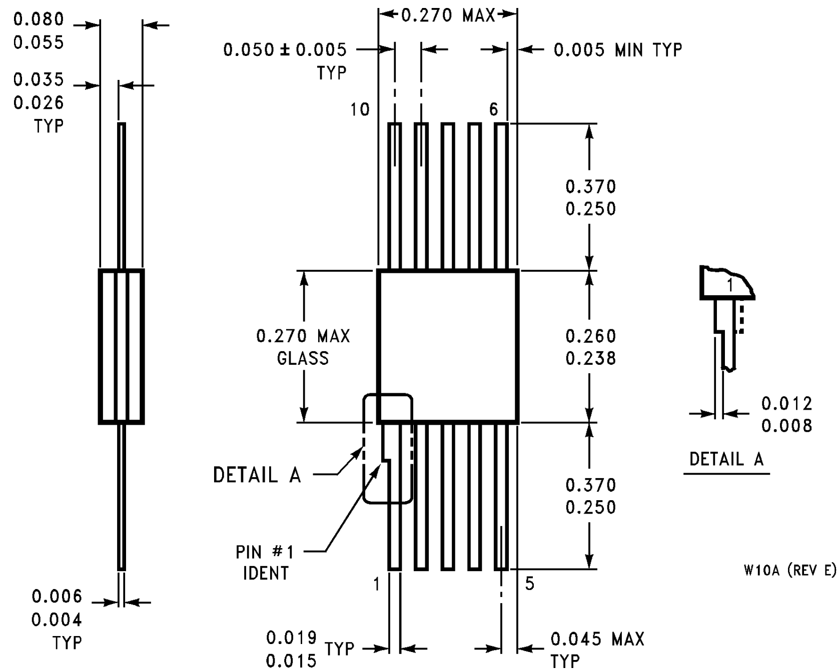


Ceramic Dual-In-Line Package (J)
Order Number LM741J/883
NS Package Number J08A



Dual-In-Line Package (N)
Order Number LM741CN
NS Package Number N08E

Physical Dimensions inches (millimeters) unless otherwise noted (Continued)



10-Lead Ceramic Flatpak (W)
Order Number LM741W/883, LM741WG-MPR or LM741WG/883
NS Package Number W10A

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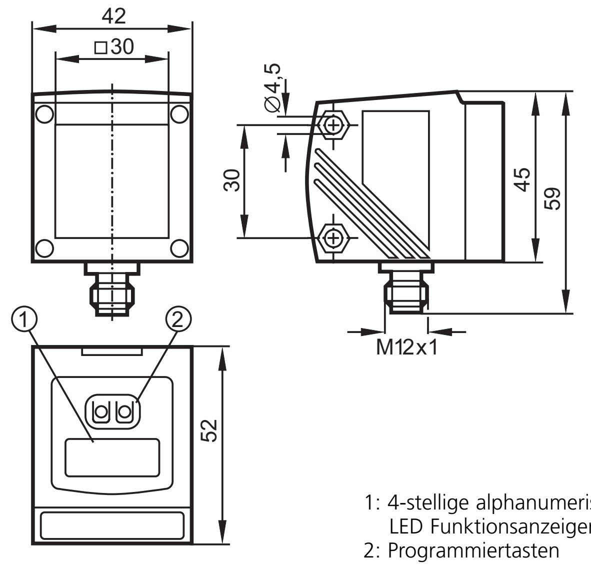
O1D100

Optischer Abstandssensor
O1DLF3KG
Sichtbares Laserlicht,
Laserschutzklasse 2
4-stellige alphanumerische Anzeige
Messbereich 0,2...10 m
(bezogen auf weißes Papier, 90 % Remission)
Hintergrundausblendung:
> 10...19 m

CE
c UL us LISTED



1: 4-stellige alphanumerische Anzeige
LED Funktionsanzeigen
2: Programmiertasten

Elektrische Ausführung Ausgangsfunktion	DC PNP OUT1: Schließer / Öffner programmierbar OUT2: Schließer / Öffner programmierbar oder analog (4...20 mA / 0...10V, skalierbar)
Lichtfleckdurchmesser [mm]	6 (TW max. = 10 m)
Betriebsspannung [V]	18...30 DC*
Strombelastbarkeit [mA]	2 x 200
Kurzschlussschutz, getaktet	•
Verpolungssicher / Überlastfest	• / •
Stromaufnahme [mA]	< 150
Messrate [Hz]	max. 50, einstellbar
Bürde für Analogausgang [Ohm]	I: max. 250; U: min. 5000
Umgebungstemperatur [°C]	-10...60
Schutzart, Schutzklasse	IP 65, III
Lebensdauer Laserdiode [h]	50000
EMV	EN 60947-5-2
Werkstoff	Gehäuse: Zinkdruckguss Frontscheibe: Glas LED-Fenster: Polycarbonat
Programmiermöglichkeiten	Schließer; Öffner; analog
Funktionsanzeige Schaltzustand [LED] Betrieb [LED] Abstandswert, Programmierung	 2 x gelb grün 4-stellige alphanumerische Anzeige
	* Betriebsspannung "supply class 2" gemäß cULus

\DATEN200\DB-FORM\O1D\01/04

Genauigkeit / Reproduzierbarkeit
für Messfrequenz 50 Hz

	Reproduzierbarkeit		Genauigkeit	
	weiß (90 % Remission)	grau (18 % Remission)	weiß (90 % Remission)	grau (18 % Remission)
200...1000 mm	± 5,0 mm	± 7,5 mm	± 15,0 mm	± 18,0 mm
1000...2000 mm	± 5,5 mm	± 10,0 mm	± 15,0 mm	± 20,0 mm
2000...4000 mm	± 17,5 mm	± 22,5 mm	± 25,0 mm	± 32,0 mm
4000...6000 mm	± 27,5 mm	± 40,0 mm	± 35,0 mm	± 50,0 mm
6000...10000 mm	± 60,0 mm		± 70,0 mm	

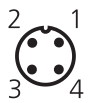
für Messfrequenz 1 Hz

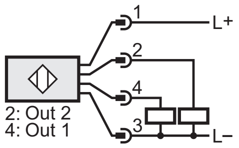
	Reproduzierbarkeit		Genauigkeit	
	weiß (90 % Remission)	grau (18 % Remission)	weiß (90 % Remission)	grau (18 % Remission)
200...1000 mm	± 4,0 mm	± 4,5 mm	± 14,0 mm	± 15,0 mm
1000...2000 mm	± 4,5 mm	± 6,0 mm	± 14,5 mm	± 16,0 mm
2000...4000 mm	± 13,5 mm	± 14,5 mm	± 23,5 mm	± 24,0 mm
4000...6000 mm	± 19,0 mm	± 21,0 mm	± 29,0 mm	± 31,0 mm
6000...10000 mm	± 37,0 mm		± 47,0 mm	

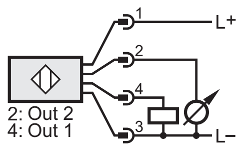
Tastweite auf Schwarz (6 % Remission) ≤ 4000 mm
Die Werte gelten für
- konstante Umweltbedingungen (23 °C / 960 hPa)
- max. 8 klx Fremdlicht
- min. Einschaltdauer von 10 Minuten.

Anschluss: M12 Steckverbindung

Anschlussschema







Bemerkungen

Achtung: Laserlicht
Leistung <= 4,1 mW Wellenlänge = 650 nm
Puls 1,3 ns
Nicht in den Strahl blicken
Kontakt mit Laserlicht vermeiden
Laserklasse 2
EN 60825-1:2003-10

\DATEN200\DB-FORM\O1D\01/04

efector200

Photoelectric sensors and systems

ifm electronic

O1D100

Optical distance sensor

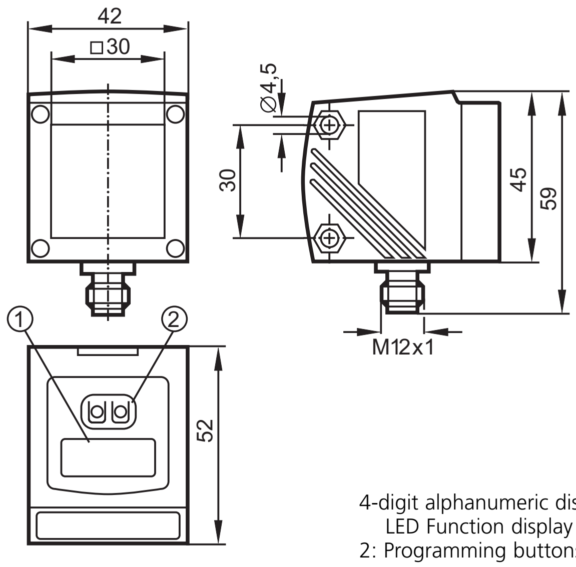
O1DLF3KG

Visible laser light,
Class 2 laser

4-digit alphanumeric display

Measuring range 0.2...10 m
(Range referred to white paper, 90 % remission)

Background suppression:
> 10...19 m



4-digit alphanumeric display
LED Function display
2: Programming buttons

Electrical design **Output**	**DC PNP** **OUT1: normally open / closed programmable** **OUT2: normally open / closed programmable** **or analogue (4...20 mA / 0...10 V, scaleable)**
Light spot diameter [mm]	6 (range max. = 10 m)
Operating voltage [V]	18...30 DC*
Current rating [mA}	2 x 200
Short-circuit protection	yes
Reverse polarity / overload protection	yes / yes
Current consumption [mA]	< 150
Sampling rate [Hz]	max. 50, adjustable
Load for analogue output [ohms]	I: max. 250; U: min. 5000
Operating temperature [°C]	-10...60
Protection	IP 65, III
Life of the laser diode [h]	50000
EMC	EN 60947-5-2
Material	Housing: diecast zinc Front pane: glass LED window: polycarbonate
Programming options	N.O.; N.C.; analogue
Function display Switching status [LED] Power [LED] Distance, programming	 2 x yellow green 4-digit alphanumeric display
	* cULus - Class 2 source required

\DATEN200\DB-FORM\O1D/01/04

Repeatability accuracy
for sampling rate 50 Hz:

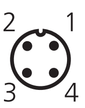
	Repeatability		Accuracy	
	white (90 % remission)	grey (18 % remission)	white (90 % remission)	grey (18 % remission)
200...1000 mm	± 5.0 mm	± 7.5 mm	± 15.0 mm	± 18.0 mm
1000...2000 mm	± 5.5 mm	± 10.0 mm	± 15.0 mm	± 20.0 mm
2000...4000 mm	± 17.5 mm	± 22.5 mm	± 25.0 mm	± 32.0 mm
4000...6000 mm	± 27.5 mm	± 40,0 mm	± 35.0 mm	± 50.0 mm
6000...10000 mm	± 60.0 mm		± 70.0 mm	

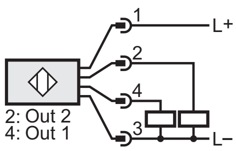
for sampling rate 1 Hz:

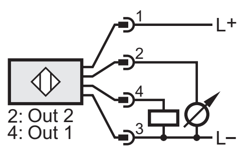
	Repeatability		Accuracy	
	white (90 % remission)	grey (18 % remission)	white (90 % remission)	grey (18 % remission)
200...1000 mm	± 4.0 mm	± 4.5 mm	± 14.0 mm	± 15.0 mm
1000...2000 mm	± 4.5 mm	± 6.0 mm	± 14.5 mm	± 16.0 mm
2000...4000 mm	± 13.5 mm	± 14.5 mm	± 23.5 mm	± 24.0 mm
4000...6000 mm	± 19.0 mm	± 21.0 mm	± 29.0 mm	± 31.0 mm
6000...10000 mm	± 37.0 mm		± 47.0 mm	

Range on black (6 % remission) ≤ 4000 mm
The values apply at
- constant ambient conditions (23 °C / 960 hPa)
- extraneous light of max. 8 klx
- only after unit powered up for 10 minutes.

Connection	M12 connector
Wiring	







Remarks

Caution: Laser Light
Power <= 4.1 mW wavelength = 650 nm
pulse 1.3 ns
Do not stare into beam
Avoid exposure
Class 2 laser product
EN 60825-1:2003-10

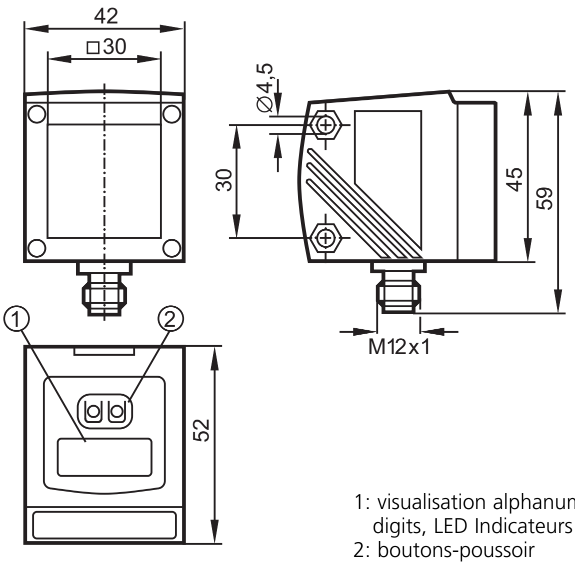
efector200

ifm electronic

Cellules et systèmes optoélectroniques

O1D100

Capteur de distance
O1DLF3KG
Lumière laser visible, protection classe 2
Visualisation alphanumérique à 4 digits
Etendue de mesure 0,2...10 m (Portée sur papier blanc, 90 % rémission)
Supression de l´arrière-plan: > 10...19 m



1: visualisation alphanumérique à 4 digits, LED Indicateurs d'état
2: boutons-poussoir

Technologie **Sortie**	**DC PNP** **OUT1: normalement ouvert / fermé programmable** **OUT2: normalement ouvert / fermé programmable ou analogique (4...20 mA / 0...10 V, réglable)**
Diamètre du spot lumineux [mm]	6 (TW max. = 10 m)
Tension d'alimentation [V]	18...30 DC*
Courant de sortie [mA]	2 x 200
Protection courts-circuits	•
Protégé: inv. de pol. et surcharges	•
Consommation [mA]	< 150
Taux d'échantillonnage [Hz]	maxi 50, réglable
Charge pour sortie analogique [ohm]	I: max. 250; U: min. 5000
Température ambiante [°C]	-10...60
Protection	IP 65, III
Vie de la diode laser [h]	50000
CEM	EN 60947-5-2
Matière	boîtier: zinc moulé sous pression / panneau avant: verre flotté fenêtre LED: polycarbonate
Options à programmer	normalement ouvert; fermé programmable; analogique
Indicateurs d'état Indication de commutation [LED] Disponibilité [LED] Distance, programmation	 2 x jaune verte visualisation alphanumérique à 4 digits
	* Tension d'alimentation "supply class 2" selon cULus

Cellules et systèmes optoélectroniques

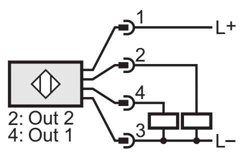
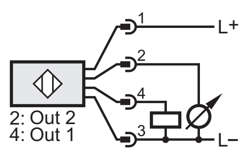
Précision / Répétabilité
pour taux d'échantillonnage 50 Hz

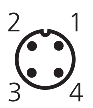
	Répétabilité		Précision	
	blanc (90 % rémission)	gris (18 % rémission)	blanc (90 % rémission)	gris (18 % rémission)
200...1000 mm	± 5,0 mm	± 7,5 mm	± 15,0 mm	± 18,0 mm
1000...2000 mm	± 5,5 mm	± 10,0 mm	± 15,0 mm	± 20,0 mm
2000...4000 mm	± 17,5 mm	± 22,5 mm	± 25,0 mm	± 32,0 mm
4000...6000 mm	± 27,5 mm	± 40,0 mm	± 35,0 mm	± 50,0 mm
6000...10000 mm	± 60,0 mm		± 70,0 mm	

pour taux d'échantillonnage 1 Hz

	Répétabilité		Précision	
	blanc (90 % rémission)	gris (18 % rémission)	blanc (90 % rémission)	gris (18 % rémission)
200...1000 mm	± 4,0 mm	± 4,5 mm	± 14,0 mm	± 15,0 mm
1000...2000 mm	± 4,5 mm	± 6,0 mm	± 14,5 mm	± 16,0 mm
2000...4000 mm	± 13,5 mm	± 14,5 mm	± 23,5 mm	± 24,0 mm
4000...6000 mm	± 19,0 mm	± 21,0 mm	± 29,0 mm	± 31,0 mm
6000...10000 mm	± 37,0 mm		± 47,0 mm	

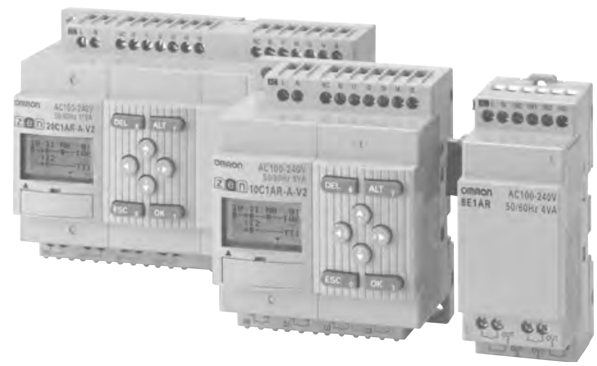
Portée sur noir (6 % rémission) ≤ 4000 mm
Les valeurs sont valables pour les conditions suivantes :
- conditions ambiantes constantes (23 °C / 960 hPa)
- lumière extérieure de max. 8 klx
- seulement après 10 minutes de mise sous tension.

Raccordement	embase M12
Schéma de branchement	 
Remarque	lumière laser Puissance <= 4,1 mW longueur d'onde = 650 nm pulse 1,3 ns Ne pas regarder dans le faisceau viter l'exposition au faisceau Produit laser classe 2 EN 60825-1:2003-10



Programmable Relay
ZEN V2 Units

Please read and understand this catalog before purchasing the products. Please consult your OMRON representative if you have any questions or comments. Refer to "*Warranty and Application Considerations*" on page 36, and "*Precautions for Safe Use*" on page 34.



c UL us CE NEW

Even Broader Applications with Increased Functionality and Higher Precision

- Increased functionality in a compact body (70 mm wide × 90 mm high).
- Easy programming is available using the LCD and operation buttons. (See note 1.)
- This single Unit easily provides relay, timer, counter, and time switch functions.
- Expansion is easy with Expansion I/O Units, allowing up to 44 I/O points. (See note 2.)
- Economy-type and Communications-type CPU Units have been added to series.
- Improved Weekly Timers (See note 1.)
  Increased timing accuracy with a monthly deviation of ±15 s max. Multiple-day operation and pulse output operation have been added.
- Select from two power supply options:
  100 to 240 VAC or 12 to 24 VDC.

Note: 1. Not supported for ZEN-☐C2☐☐-☐-V2 models.
2. When using CPU Units with 20 I/O points.

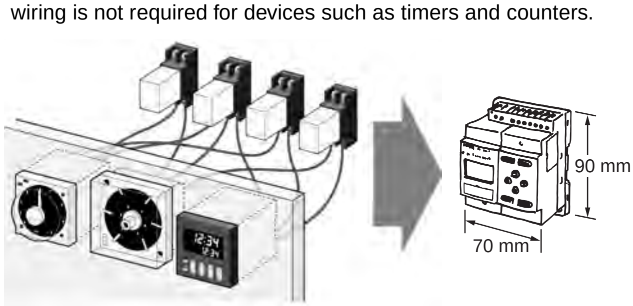
The information in this document applies to V2 Units. Refer to page 28 for details on differences with previous products.

Features

■ Easy and Simple Programming for Automatic Small-scale Control

Saves Space, Wiring, and Installation Steps

- Versatile functionality in a compact body (70 mm wide × 90 mm high).
- This single Unit easily provides relay, timer, counter, and time switch functions. Wiring work is greatly reduced because separate wiring is not required for devices such as timers and counters.



Easy Programming

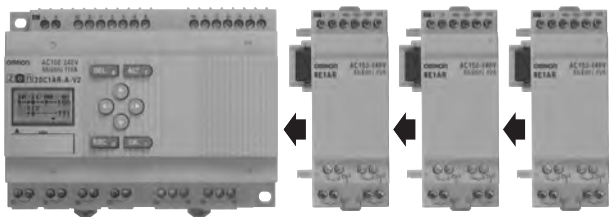
The LCD screen comes with 8 operation buttons on the front panel to enable programming in ladder view format. The LCD screen also has a backlight, making it easier to see when the ZEN is used in dark locations.

Note: Not supported for ZEN-☐C2☐☐-☐-V2 models.

Flexible Expansion Enables Up to 44 I/O Points

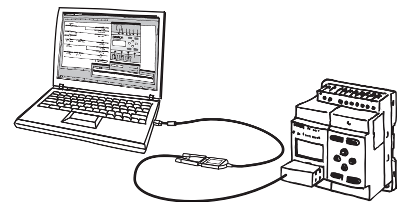
Up to three Expansion I/O Units can be connected if there are not enough I/O points. Expansion I/O Units are only 35 mm wide.

Note: CPU Units with 10 I/O points can be expanded to 34 I/O points. Expansion I/O Units cannot be connected to Economy-type CPU Units.



Support Software with Simulation Function

- Programs can be easily written, saved, and monitored by personal computer.
- Programs can be simulated on the personal computer without connecting to the ZEN.



Note: For notebook computers that do not have an RS-232C serial port, connect the computer to the ZEN by connecting an OMRON CS1W-CIF31 USB-Serial Conversion Cable to the ZEN-CIF01 Connecting Cable.

Other Versatile Functions

- Use of a Memory Cassette makes it easy to copy and save programs.
- Equipped with two analog input channels (CPU Units with DC power supply only).
- Password function ensures security. (See note.)
- Multi-language display in six languages (English, Japanese, German, French, Spanish, Italian). (See note.)
- Display user-set messages or analog-converted values. (See note.)

Note: Not supported for ZEN-☐C2☐☐-☐-V2 models.

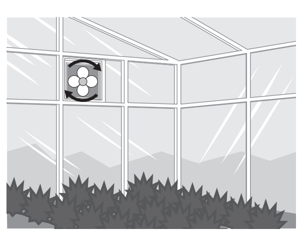
■ Enhanced Features of V2 CPU Units

Improved Weekly Timer and Calendar Timer Functions

Note: Not supported for ZEN-☐C2☐☐-☐-V2 models.

- The time precision has been increased.
  Conventional model: 2-min difference/month
  ↓
  -V2 models: ±15-s difference/month (at 25°C)
- Multiple-day operation and pulse-output operation are now possible.
- These improved functions are convenient for time-controlled applications such as lighting and air conditioning control.

Lighting control



Air conditioning control

Economy-type Added to the Series

- Economy-type CPU Units with a more affordable price have been added to the series, although Expansion I/O Units cannot be added.

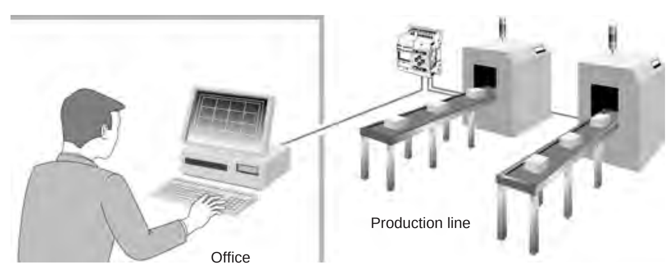
12 to 24 VDC Line Voltage Operation

Operation is now possible with 12 VDC.

Expansion I/O Units have been reduced to half-size (35 mm wide).

RS-485 Communications Model Added to Series

Production line conditions can be remotely monitored by monitoring the ZEN control status.



More Precise Analog Input

Conventional model: ± 10% FS → -V2 models: ± 1.5% FS
DC power supply models are equipped with two analog inputs (0 to 10 V). There are four analog comparators. The increased precision makes it even easier to use the Unit in simple control applications with voltage, current, temperature, and other analog values.

8-digit Counter, 150-Hz Counter

- An 8-digit counter and 8-digit comparator have been added.
- The maximum count for DC power supply models is 150 Hz.

Twin-timer Operation Added

Twin-timer operation allows you to set ON and OFF times separately, greatly simplifying intermittent operation.

■ Series Configuration

CPU Units

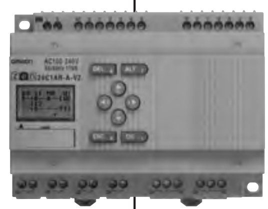
Power supply voltage: 100 to 240 VAC, 12 to 24 VDC, Output: Relay, transistor output

With LCD display, operation buttons, and calendar/clock function

10 I/O points

- Standard LCD type: ZEN-10C1□
- Economy type: ZEN-10C3□
  Expansion I/O Units cannot be connected.
- Communications type: ZEN-10C4□
  RS-485 communications type.

20 I/O points



- Standard LCD type: ZEN-20C1□
- Economy type: ZEN-20C3□
  Expansion I/O Units cannot be connected.

LED type

- 10 I/O points: ZEN-10C2□
- 20 I/O points: ZEN-20C2□

This CPU Unit has no LCD, operation buttons, or calendar/clock function.

(10 I/O points)

Expansion I/O Units

Only 35-mm wide.
4 input, 4 output points

Power Supply Unit

Same shape and design as ZEN.
24 VDC, 30 W

Support Software

Allows easy programming and operation simulation.

Model Number Structure

■ Model Number Legend

Note: This model number legend includes combinations that are not available.
Please check *"List of Models"* for availability.

CPU Units

ZEN-□C□□□-□-V2
1 2 3 4 5

1. **Number of I/O points**
   10: 6 inputs and 4 outputs (See note.)
   20: 12 inputs and 8 outputs
2. **Type classifier**
   1: Standard LCD type with display
   2: LED type without display
   3: Economy type with display
   (Expansion I/O Units cannot be connected.)
   4: Communications type with display
3. **Input type**
   A: AC input
   D: DC input
4. **Output type**
   R: Relay
   T: Transistor
5. **Supply voltage**
   A: AC power supply
   D: DC power supply

Note: The Communications-type CPU Unit has 6 inputs and 3 outputs.

Expansion I/O Units

ZEN-8E1□□
1 2 3 4

1. **Number of I/O points**
   8: 4 inputs and 4 outputs
2. **Unit version classifier**
   E1: Can connect to V2 CPU Units (See note.)
3. **Input type**
   A: AC input
   D: DC input
4. **Output type**
   R: Relay
   T: Transistor

Note: Use a ZEN-8E□□/-4E□ to connect to pre-V1 and V1 CPU Units.

This data sheet is provided as a guideline for selecting products. Be sure to refer to the following user manuals for application precautions and other information required for operation before attempting to use the product.

ZEN Operation Manual (Cat. No. Z211)

ZEN Communications Manual (Cat. No. Z212)

ZEN Support Software Operation Manual (Cat. No. Z184-E1-03)

The PDF versions of these manuals can be downloaded from the following website.

ZEN Website http://www.zen.omron.co.jp/eng/index.html

Ordering Information

■ List of Models

CPU Units and Expansion I/O Units

Unit	Name	No. of I/O points	LCD display	Power supply voltage	Inputs		Outputs		Buttons, calendar, and clock	Analog input	Model
CPU Units	Standard LCD type	10	Yes	100 to 240 VAC	6	100 to 240 VAC	4	Relays	Yes	No	ZEN-10C1AR-A-V2
				12 to 24 VDC		12 to 24 VDC				Yes	ZEN-10C1DR-D-V2
								Transistors			ZEN-10C1DT-D-V2
		20		100 to 240 VAC	12	100 to 240 VAC	8	Relays		No	ZEN-20C1AR-A-V2
				12 to 24 VDC		12 to 24 VDC				Yes	ZEN-20C1DR-D-V2
								Transistors			ZEN-20C1DT-D-V2
	LED type without display (See note 1.)	10	No	100 to 240 VAC	6	100 to 240 VAC	4	Relays	No	No	ZEN-10C2AR-A-V2
				12 to 24 VDC		12 to 24 VDC				Yes	ZEN-10C2DR-D-V2
								Transistors			ZEN-10C2DT-D-V2
		20		100 to 240 VAC	12	100 to 240V AC	8	Relays		No	ZEN-20C2AR-A-V2
				12 to 24 VDC		12 to 24 VDC				Yes	ZEN-20C2DR-D-V2
								Transistors			ZEN-20C2DT-D-V2
	Economy type (Expansion I/O Units cannot be connected)	10	Yes	100 to 240 VAC	6	100 to 240 VAC	4	Relays	Yes	No	ZEN-10C3AR-A-V2
				12 to 24 VDC		12 to 24 VDC				Yes	ZEN-10C3DR-D-V2
		20		100 to 240 VAC	12	100 to 240 VAC	8	Relays		No	ZEN-20C3AR-A-V2
				12 to 24 VDC		12 to 24 VDC				Yes	ZEN-20C3DR-D-V2
	Communica-tions type	10		100 to 240 VAC	6	100 to 240 VAC	3	Relays		No	ZEN-10C4AR-A-V2
				12 to 24 VDC		12 to 24 VDC				Yes	ZEN-10C4DR-D-V2
ZEN Kit		Set containing CPU Unit (ZEN-10C1AR-A-V2), Connecting Cable, ZEN Support Software, and manual.									ZEN-KIT01-EV4
		Set containing CPU Unit (ZEN-10C1DR-D-V2), Connecting Cable, ZEN Support Software, and manual.									ZEN-KIT02-EV4
Expansion I/O Units		8	---	100 to 240 VAC	4	100 to 240 VAC	4	Relays	---		ZEN-8E1AR (See notes 2, 3.)
				12 to 24 VDC		12 to 24 VDC					ZEN-8E1DR (See note 2.)
				---				Transistors			ZEN-8E1DT (See note 2.)

Note: 1. Programming is not possible using only the CPU in the LED-type CPU Unit. ZEN Support Software or a Memory Cassette is required.

2. Cannot be connected to pre-V1 and V1 CPU Units.

3. The ZEN-8E1AR cannot be connected to a CPU Unit with DC power supply.

Power Supply Unit

Power ratings	Input voltage	Output voltage	Output current	Model
30 W	100 to 240 VAC	24 VDC	1.3 A	ZEN-PA03024

Note: Refer to the *ZEN-PA03024 Datasheet* (Cat. No. L103) for detailed specifications.

Accessories (Order Separately)

Name	Specifications	Remarks			Model
Memory Cassette	EEPROM (for data security and copying)	Enables programs and parameter settings to be saved or copied to another ZEN. (See note 1.)			ZEN-ME01
			LCD-type CPU Unit with display (See note 2.)	LED-type CPU Unit without display (See note 3.)	
		Transfer from ZEN to Memory	Supported	Not supported	
		Transfer from Memory Cassette to ZEN	Supported	Automatic transfer when power turned ON	
		Memory Cassette initialization	Supported	Not supported	
Connecting Cable	2 m RS-232C (9-pin D-sub connector)	---			ZEN-CIF01
Battery Unit	10 years min. Battery life (at 25°C)	Ladder programs and parameter settings are saved to the CPU Unit EEP-ROM but calendar, clock, and holding timer bits and holding timer/counter present values are held by the capacitor. Therefore, if the power supply is interrupted for 2 days or more (at 25°C), this data will be reset. Use a Battery Unit for systems where the power supply may be interrupted for long periods.			ZEN-BAT01
ZEN Support Software	Runs on Windows 95, 98, 2000, ME, XP, or NT 4.0.	Specifically designed for the ZEN (CD-ROM).			ZEN-SOFT01-V4

Note: 1. Memory Cassettes created using a CPU Unit can be read to other CPU Units, regardless of which model is used. Restrictions, apply, however, to the functions that can be used, depending on the CPU Unit version combination. For details, refer to *"Memory Cassette and CPU Unit Combinations"* on page 33.

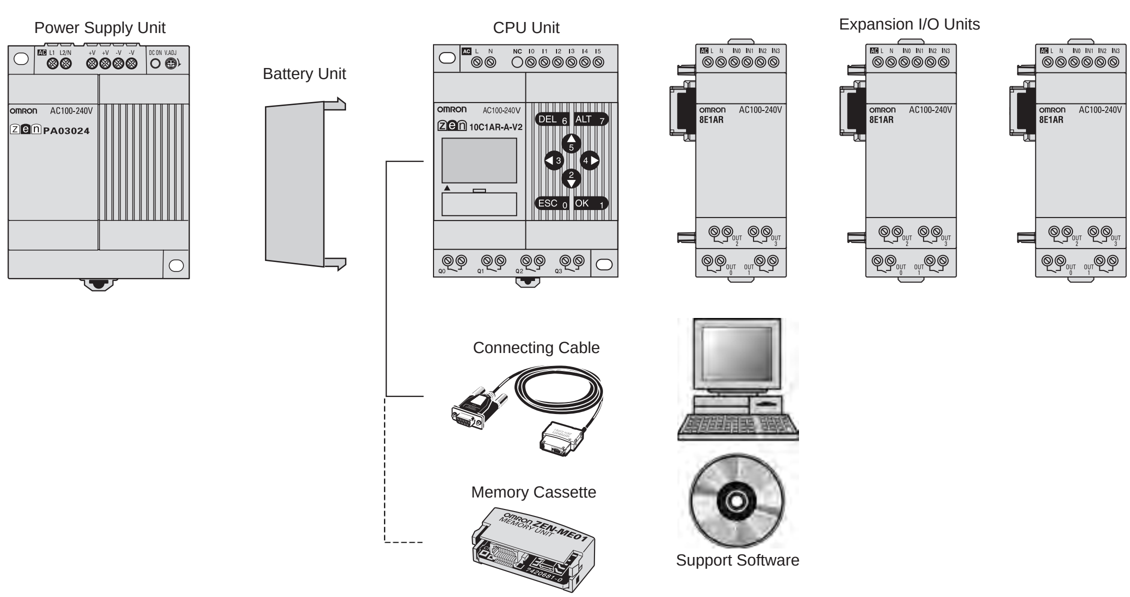
2. Standard LCD-type, Economy-type, and Communications-type CPU Units (i.e., excluding ZEN-□C2□□-□-V2 models).

3. LED-type CPU Unit without display (i.e., ZEN-□C2□□-□-V2 models).

Mounting Accessories (Order Separately)

Name	Specifications	Model
Mounting Track	50 cm (l) × 7.3 mm (t)	PFP-50N
	1 m (l) × 7.3 mm (t)	PFP-100N
	1 m (l) × 16 mm (t)	PFP-100N2
End Plate		PFP-M
Spacer		PFP-S

System Configuration



Note: 1. Up to 3 Expansion I/O Units can be connected to any type of CPU Unit except for Economy-type CPU Units. Expansion I/O Units with AC Inputs, however, cannot be connected to CPU Units with DC Power Supplies.

2. The Connecting Cable and Memory Cassette cannot be connected to the ZEN at the same time.

3. Programs cannot be written to LED-type CPU Units (i.e., ZEN-□C2□□-□-V2 models) without the ZEN Support Software or a Memory Cassette.

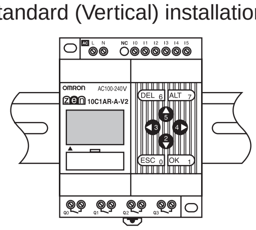
Specifications

■ Ratings

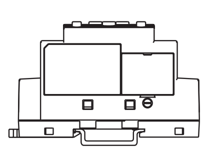
Item	Specification	
	ZEN-□C□AR-A-V2/ZEN-8E1AR	**ZEN-□C□D□-D-V2/ZEN-8E1D□**
Rated supply voltage	100 to 240 VAC, 50/60 Hz	12 to 24 VDC (DC ripple rate: 5% max.)
Operating voltage range	85 to 264 VAC	10.8 to 28.8 VDC
Power consumption	CPU Units without Expansion I/O Units • ZEN-10C1AR-A-V2/ZEN-10C2AR-A-V2/ ZEN-10C3AR-A-V2 100 V AC: 5 VA max. 240 V AC: 7 VA max. • ZEN-10C4AR-A-V2 100 V AC: 6 VA max. 240 V AC: 8 VA max. • ZEN-20C□AR-A-V2 100 V AC: 7 VA max. 240 V AC: 10 VA max. CPU Units with three Expansion I/O Units • ZEN-10C1AR-A-V2/ZEN-10C2AR-A-V2 100 V AC: 6 VA max. 240 V AC: 8 VA max. • ZEN-10C4AR-A-V2 100 V AC: 7 VA max. 240 V AC: 9 VA max. • ZEN-20C□AR-A-V2 100 V AC: 8 VA max. 240 V AC: 11 VA max. Expansion I/O Units • ZEN-8E1AR 100 V AC: 3 VA max. 240 V AC: 4 VA max.	CPU Units without Expansion I/O Units • ZEN-10C□DR-D-V2 12/24 V DC: 3 W max. (ZEN-10C3DR-D-V2: 2.8 W max.) • ZEN-10C□DT-D-V2 12/24 V DC: 2 W max. • ZEN-20C□DR-D-V2 12/24 V DC: 4 W max. • ZEN-20C□DT-D-V2 12/24 V DC: 2 W max. CPU Units with three Expansion I/O Units • ZEN-10C□DR-D-V2 12/24 V DC: 4 W max. • ZEN-10C□DT-D-V2 12/24 V DC: 3 W max. • ZEN-20C□DR-D-V2 12/24 V DC: 5 W max. • ZEN-20C□DT-D-V2 12/24 V DC: 3 W max. Expansion I/O Units • ZEN-8E1DR 12/24 V DC: 2 W max.
Inrush current	ZEN-10C□AR-A-V2: 4.5 A max. ZEN-20C□AR-A-V2: 4.5 A max. ZEN-8E1AR: 4 A max.	ZEN-10C□D□-D-V2: 30 A max. ZEN-20C□D□-D-V2: 30 A max. ZEN-8E1DR: 15 A max.
Ambient temperature	0 to 55°C (–25 to 55°C for ZEN-□C2□□-□-V2 models)	
Ambient storage temperature	–20 to 75°C (–40 to 75°C for ZEN-□C2□□-□-V2 models)	
Ambient humidity	10% to 90% (with no condensation)	
Ambient conditions	No corrosive gases	
Mounting method	Surface mounting, DIN track mounting (standard (vertical) installation and horizontal installation) (See notes 1 and 2.)	
Terminal block	Solid-line terminal block (use solid wire or fine-stranded wire)	
Terminal screw tightening torque	0.565 to 0.6 N·m (5 to 5.3 in-lb)	
Degree of protection	IP20 (Mounted inside a control panel)	

Note: 1. Can be mounted to 35-mm DIN Track.

2. Standard (Vertical) installation



Horizontal installation



■ Characteristics

Item	Specification
Control method	Stored program control
I/O control method	Cyclic scan
Programming language	Ladder diagram
Program capacity	96 lines (3 input conditions and 1 output per line)
Max. No. of control I/O points	44 points (See note 1.) CPU Units with 20 I/O points: 12 inputs and 8 outputs Expansion I/O Units: 4 inputs and 4 outputs each, up to 3 Units.
LCD display (See note 2.)	12 characters × 4 lines, with backlight
Operation buttons (See note 2.)	8 (4 cursor buttons and 4 operation buttons)
User program backup	Internal EEPROM, Memory Cassette (optional)
Power interruption hold	Internal holding bit status, holding timer/counter present values, calendar and clock (year, month, day of month, day of week, time) • Super capacitor backup time: 2 days min. (25°C) • Life of optional battery: 10 years min. (25°C)
Calendar and clock function (See note 2.)	Accuracy: ±15 s/month (at 25°C)
Timer accuracy	0.01 s unit: –0.05% –10 ms max. (rate for set value) min/s unit: –0.05% –1 s max. (rate for set value) h/min unit: –0.05% –1 min max. (rate for set value)
Maximum counting speed	150 Hz: 8-Digit counter (F) set to high-speed operations (CPU Units with DC power supplies only) (The counting speed may be less than 150 Hz depending on the cycle time of the program. See page 21.)
Insulation resistance	20 MΩ (at 500 VDC) min.: Between power supply terminals and all output terminals. Between terminals of different output circuits. Between all terminals of CPU Unit and all terminals of Expansion I/O Unit.
Insulation	• Reinforced insulation Between power supply or input terminals and output terminals. Between terminals of different output circuits. Between all terminals of CPU Unit and all terminals of Expansion I/O Unit. • No separation Between power supply and input terminals of the same unit. Between power supply terminals of CPU Unit and computer connector, Battery Unit connector, or all Expansion Unit connectors (all interfaces are live parts).
Dielectric strength	2,300 VAC, 50/60 Hz for 1 min (leakage current 1 mA max.): Between power supply terminals and all output terminals. Between terminals of different output circuit. Between all terminals of CPU Unit and all terminals of Expansion I/O Unit.
Vibration resistance	Conforms to IEC60068-2-6, 5 to 9 Hz with 3.5-mm single amplitude, 9 to 150 Hz acceleration 9.8 m/s^2, 10 sweeps each in X, Y, and Z directions (1 octave/min)
Shock resistance	Conforms to IEC60068-2-27, 147 m/s^2, 3 times each in X, Y, and Z directions.
Weight	CPU Unit with 10 I/O points: Approx. 300 g max. CPU Unit with 20 I/O points: Approx. 350 g max. Expansion I/O Unit: Approx. 120 g max.

Note: 1. Up to 34 points for CPU Units with 10 I/O points. With Communications-type CPU Units, however, the CPU Unit has 6 inputs and 3 outputs, for a maximum of 33 I/O points.
2. Not provided for LED-type CPU Unit without display (i.e., ZEN-□C2□□-□-V2 models).

■ Communications Specifications (Communications-type CPU Units)

Item	ZEN-10C4□R-□-V2
Communications	RS-485 (two-wire, half duplex)
Synchronization method	Start-stop synchronization
Baud rate	4800, 9600, or 19200 bps
Transmission code	ASCII
Data bit length	7 or 8 bits
Stop bit length	1 or 2 bits
Error detection	Vertical parity (none, even, odd), Block check character (BCC)
Flow control	None
Interface	RS-485
Retry function	None
Node number	0 to 99 (default: 1), XX (broadcasting)

■ Approved Standards

Item	Specification
Safety standards	cULus: UL508/CSA C22.2 No.142 Class I Div2 Conforms to EN/IEC 61131-2 clause 11, excluding 11.7.2.2 (Overvoltage category 2 and Pollution degree II conforms to IEC 60664-1)
EMC **(See note.)**	Radiation Field Emission CISPR11 Class A, Group 1 Noise Terminal Voltage Emission CISPR11 Class A, Group 1
	Electrostatic Discharge Immunity IEC61000-4-2 In air: 8 kV, In contact: 6 kV Electromagnetic Field Immunity IEC61000-4-3 10 V/m Electrical Fast Transient/Burst Immunity IEC61000-4-4 Power line AC I/O: 2 kV DC I/O: 1 kV Surge Immunity IEC61000-4-5 Normal Noise AC power supply, AC I/O: 1 kV DC power supply, DC I/O: 0.5 kV Common Noise AC power supply, AC I/O: 2 kV DC power supply: 1 kV DC I/O: 0.5 kV Immunity to Conducted Disturbances Induced by Radio-frequency Fields IEC61000-4-6 3 V Momentary Power Interruption Immunity IEC61131-2 CPU Units with AC Power Supplies: 10 ms max. CPU Units with DC Power Supplies: 2 ms max. (level: PS1)

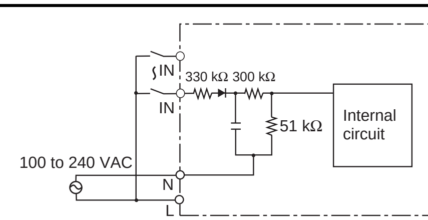
Note: EMC conforms to EN 61131-2 clause 8 except in the following cases.

- When Expansion I/O Units with DC inputs are connected to a CPU Unit with an AC power supply, the burst immunity between power supplies will be 1 kv.
- When the signal wire for transistor outputs exceeds 10 m, the surge immunity of DC output signal lines will not conform.

■ Input Specifications

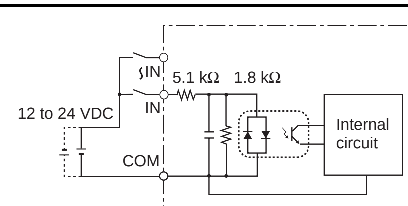
CPU Units

AC Inputs (Not Isolated)

Item	Specifications	Circuit drawing
Input voltage	100 to 240 VAC +10%, –15%, 50/60 Hz	
Input impedance	680 kΩ	
Input current	0.15 mA/100 VAC, 0.35 mA/240 VAC	
ON voltage	80 VAC min.	
OFF voltage	25 VAC max.	
ON response time	50 ms or 70 ms at 100 VAC (See note.) 100 ms or 120 ms at 240 VAC (See note.)	
OFF response time		

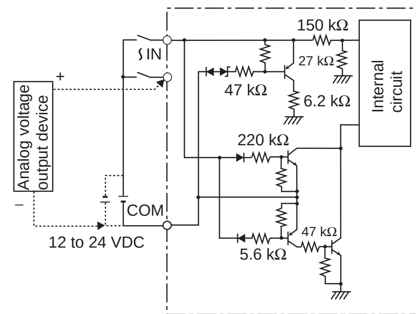
Note: Can be selected using the filter settings.

DC Inputs: I0 to I3 for Units with 10 I/O points, I0 to I9 for Units with 20 I/O Points (Not Isolated)

Item	Specifications	Circuit drawing
Input voltage	12 to 24 VDC +20%, –10%	
Input impedance	5.3 kΩ	
Input current	4.5 mA (typ.)/24 VDC	
ON voltage	8 VDC min.	
OFF voltage	5 VDC max.	
ON response time	15 ms or 50 ms (See note.)	
OFF response time		

Note: Can be selected using the input filter settings, except when I0 is being used for an 8-digit counter with a high-speed input.

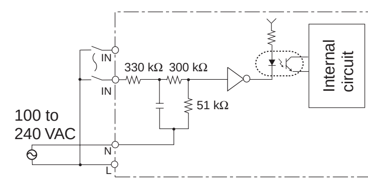
DC Inputs: I4 and I5 for Units with 10 I/O points, Ia and Ib for Units with 20 I/O Points (Not Isolated)

Item		Specifications	Circuit drawing
DC Inputs	Input voltage	12 to 24 VDC +20%, –10%	
	Input impedance	PNP: 5.5 kΩ/14 VDC min. 100 kΩ/14 VDC max. NPN: 5.2 kΩ	
	Input current	PNP: 4.3 mA (typ.)/24 VDC NPN: 4.6 mA (typ.)/24 VDC	
	ON voltage	8 VDC min.	
	OFF voltage	3 VDC max.	
	ON response time	15 ms or 50 ms (See note.)	
	OFF response time		
Analog Inputs	Input range	0 to 10 V	
	External input impedance	100 kΩ min.	
	Resolution	0.1 V (1/100 FS)	
	Accuracy	±1.5% FS (at ambient operating temperature within rated range)	
	AD conversion data	0 to 10.5 V (in increments of 0.1 V)	

Note: Can be selected using the input filter settings.

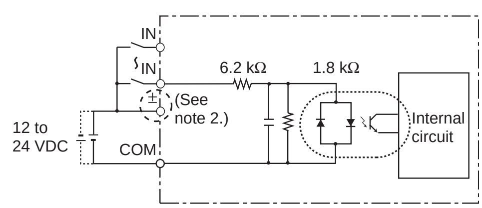
Expansion I/O Units

AC Inputs (Not Isolated)

Item	Specifications	Circuit drawing
Input voltage	100 to 240 VAC +10%, –15%, 50/60 Hz	
Input impedance	680 kΩ	
Input current	0.15 mA/100 VAC, 0.35 mA/240 VAC	
ON voltage	80 VAC min.	
OFF voltage	25 VAC max.	
ON response time	50 ms or 70 ms at 100 VAC (See note.) 100 ms or 120 ms at 240 VAC (See note.)	
Off response time		

Note: Can be selected using the input filter settings.

DC Inputs (ZEN-8E1DR: Not Isolated, ZEN-8E1DT: Photocoupler Isolated)

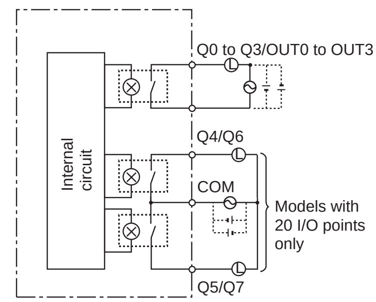
Item	Specifications	Circuit drawing
Input voltage	12 to 24 VDC +20%, –10%	
Input impedance	6.5 kΩ	
Input current	3.7 mA (typ.)/24 VDC	
ON voltage	8 VDC min.	
OFF voltage	5 VDC max.	
ON response time	15 ms or 50 ms (See note 1.)	
OFF response time		

Note: 1. Can be selected using the input filter settings.

2. The ZEN-8E1DT has no +/- terminals. There is no need to supply power.

■ Output Specifications (CPU Units and Expansion I/O Units)

Units with Relay Outputs

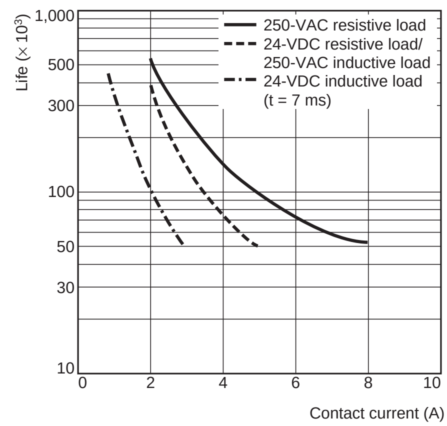
Item		Specifications	Circuit drawing
Maximum switching capacity		250 VAC/8 A (resistive load: cosϕ = 1) 24 VDC/5 A (resistive load) Use the following values for the total of all outputs. CPU Units with 10 I/O points: 20 A max. (15 A max. for Communications-type CPU Units) CPU Units with 20 I/O points: 40 A max. Expansion I/O Units: 20 A max.	
Minimum switching capacity		5 VDC/10 mA (resistive load)	
Relay life	**Electrical**	Resistive load: 50,000 times (cosϕ = 1) Inductive load: 50,000 times (cosϕ = 0.4)	
	Mechanical	10 million times	
ON response time		15 ms max.	
OFF response time		5 ms max.	

The life under the worst conditions, of the output contacts used in ZEN relay outputs is given in the above table. Guidelines for the normal life of the relays are shown in the diagram on the right.

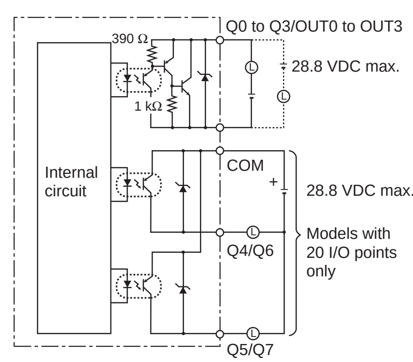
Note: The switching capacity, switching durability, and applicable load area when actually using the relay depend on the type of load, environmental conditions, and switching conditions. Therefore, be sure to confirm these conditions for the actual machine before use.

Life-test Curve (Reference Value)

Usage: 360 times/hour



Units with Transistor Outputs

Item	Specifications	Circuit drawing
Maximum switching capacity	24 VDC +20%, 500 mA	Each circuit is configured with an independent common circuit 
Leakage current	0.1 mA max.	
Residual voltage	1.5 V max.	
ON response time	1 ms max.	
OFF response time	1 ms max.	

Connections

■ Input Connections

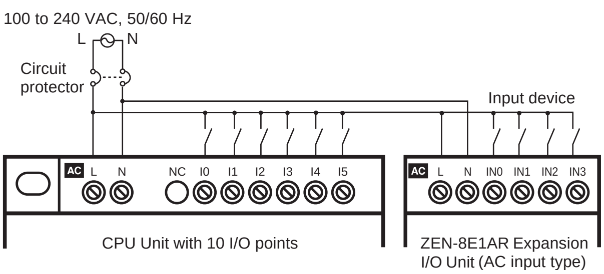
Units with AC Power Supply

Note: 1. Supply power to both the CPU Unit and Expansion I/O Units from the same power supply and turn them ON and OFF at the same time.

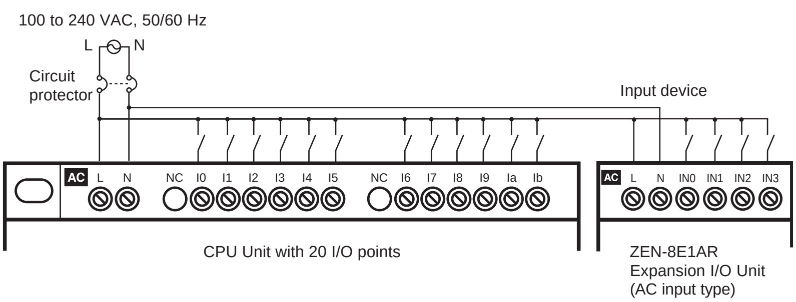
2. The input circuit commons for CPU Units with AC power supply are internally connected to the N terminal of the power supply circuit. Wire the L terminal to the power supply of the input device.

3. The input circuit commons for Expansion I/O Units with AC power supply are internally connected to the N terminal of the power supply circuit. Wire the L terminal to the power supply of the input device.

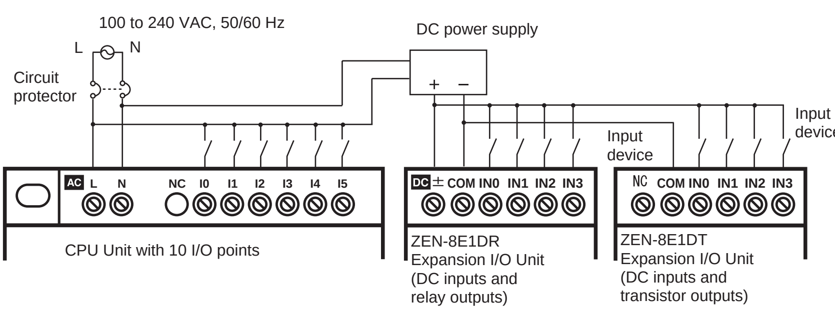
CPU Units with 10 I/O Points and Expansion I/O Units



CPU Units with 20 I/O Points and Expansion I/O Units



Connecting Expansion I/O Units with DC Inputs



Note: When connecting Expansion I/O Units with DC inputs to a CPU Unit with an AC power supply, the burst noise immunity will be 1 kV (IEC 61000-4-4).

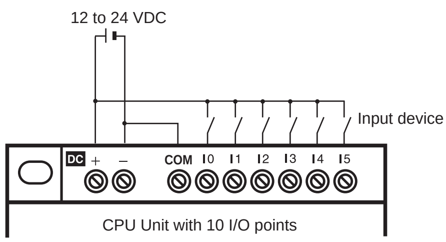
Units with DC Power Supply

Note: 1. Be sure to connect the COM terminal before turning ON the power supply. If the COM terminal is disconnected, or if the wiring is changed after turning ON the power supply, a malfunction may occur.

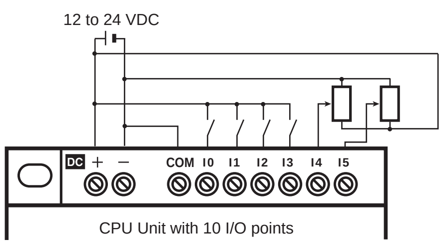
2. Apply the power supply voltage through a relay or switch in such a way that the voltage reaches the rated value within 4 s. If the voltage is applied gradually, the power may not be reset or unstable output operations may result.

CPU Units with 10 I/O Points

For Connections to Negative (–) Common (PNP Connection)

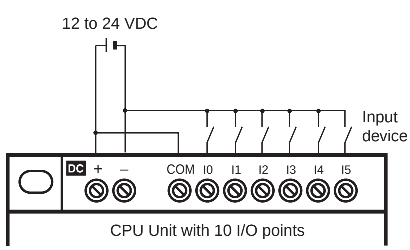


For Connecting Analog Input Devices to Input Terminals I4 and I5



Note: When connecting an analog input device, always connect the negative side to the COM terminal.

For Connections to Positive (+) Common (NPN Connection)



Note: When connected to the positive (+) common, I4 and I5 cannot be used as analog inputs.