VISVESVARAYA TECHNOLOGICAL UNIVERSITY

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Project Report

On

A MOBILE WASTE SEGREGATING SYSTEM USING A ROBOTIC ARM FOR DOMESTIC USE

Submitted in partial fulfillment of the requirements for the award of the degree of

BACHELOR OF ENGINEERING

in

ELECTRONICS AND COMMUNICATION ENGINEERING

Submitted by

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CERTIFICATE

Certified that the project work entitled **"A Mobile waste segregating system using a robotic arm for domestic use",** by **SHEETAL U (1BI18EC134), TANUSHREE HEGDE (1BI18EC150), TEJAS HIREMUTT (1BI18EC151), TEJASHREE A (1BI18EC152)** bonafide students of **Bangalore Institute of Technology** in partial fulfillment for the award of **Bachelor of Engineering** in **Electronics and Communication Engineering** of the Visvesvaraya Technological University, Belgaum during the year 2021-2022. It is certified that all corrections/suggestions indicated for Internal Assessment have been incorporated in the Report deposited in the departmental library. The project report has been approved as it satisfies the academic requirements in respect of Project Work prescribed for the said Degree.

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ABSTRACT

In policy circles, waste management is becoming a major problem. Municipal governments, who are generally responsible for the construction and maintenance of garbage disposal networks, are eager to find ways to reduce the cost of waste disposal as well as the amount of waste society produces. Urban society rejects and generates solid material on a regular basis because of rapid increases in production and consumption, resulting in a significant increase in the volume of waste generated from various sources such as domestic waste, commercial waste, institutional wastes, and industrial wastes. Human health can be harmed by exposure to numerous hazardous wastes, with children being particularly vulnerable to the contaminants. Direct dumping of untreated trash into rivers, seas, and lakes causes hazardous compounds to accumulate in the food chain via plants and animals.

The project's main goal is to create a system that uses an Arm cortex LPC2148 microcontroller to automatically separate garbage at the source and clean it. This project intends to build an automatic segregator bin that can segregate garbage at the source, reducing the time it takes to process waste and the amount of segregation effort required in later stages. It has several partitions for collecting various wastes utilizing sensors, as well as an LCD display that shows the status of the bin.

The device employs an infrared sensor for obstacle detection. Wet wastes containing moisture elements are detected using a moisture sensor. The metal sensor is used to detect metal based on a relay, which means that if any metal waste is placed near the metal detector, the relay is activated. Electromagnetic induction is the basis behind it. The state of the bin is shown on an LCD monitor. Ultrasonic sensors calculate the distance between the front obstructions and transmit a message to the bin's owner via GSM, indicating whether the bin is full or not. Offices, apartments, and shopping malls can all benefit from this bin.

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CHAPTER 1

INTRODUCTION

Solid waste management is a major concern in urban areas, not only in India but in most countries throughout the world. According to estimates, the world's cities produced 1.3 billion tonnes of rubbish every year, with Asia accounting for one million tonnes per day. Global trash generation is expected to reach 2.2 billion tonnes by 2025, owing to current urbanization and population growth rates. More than half of the world's population lacks access to regular trash collection, causing problems that have reached crisis proportions. In recent years, technology has advanced dramatically, resulting in massive manufacturing.

As a result, vast amounts of waste are generated every day. The accumulation of garbage, which is expanding at a faster rate than the growth of urbanization, has had a significant influence on the environment. Garbage should be checked regularly. The current situation necessitates intelligent waste management, with most of the waste requiring processing and recycling using cutting-edge technologies. Therefore, a system must be developed to eliminate or at the very least lessen this problem. Our project provides one of the most efficient ways to keep our environment clean and green. Only if the dustbins are correctly positioned and collected will a society's waste be properly dispatched. The biggest issue with today's waste management system in most Indian cities is the state of the dustbins. This can be made more efficient by sorting garbage at the source, minimizing the need for human intervention. In this project, we have tried to upgrade the trivial but vital component of the urban waste management system which is the dustbin.

1.1 AIM

The main purpose of this project is to contribute to society by reducing human intervention. The overall aim is to categorize waste materials into different partitions for disposal considerations, to take proper measures for waste handling, and to promote prevention,

preparation for reuse, recycling, other recovery, and disposal. It focuses on various options available for the disposal of waste for a sustainable future.

1.2 OBJECTIVES

- As the world evolves, there is one frustrating issue that must be addressed: garbage.
- We've all seen photos of garbage cans that are overflowing. As a result, many insects nest there, and a variety of diseases develop.
- The initiative's main purpose is to help society by reducing the amount of human interaction. The overall purpose is to segregate waste materials for disposal consideration, execute proper waste handling methods, and promote waste avoidance, reuse, recycling, and other types of recovery and disposal.
- It focuses on the various rubbish disposal options available to create a brighter, more sustainable future.

1.3 LITERATURE SURVEY

[1] Murdan, A. P., & Ramkissoon, P. K. (2020). A smart autonomous floor cleaner with an Android-based controller. 2020 3rd International Conference on Emerging Trends in Electrical, Electronic and Communications Engineering (ELECOM):

In the present world, all are automated without the help of human efforts. Nowadays robotic cleaners have taken major attention in robotics research due to their effectiveness in assisting humans in i-floor cleaning applications at homes, hotels, restaurants, offices, hospitals, workshops, warehouses and universities, etc. Robotic cleaners are distinguished in their cleaning expertise like floor mopping, dry vacuum cleaning, etc.

The objective of this project is to make a vacuum robot that is fully automated and manual and featured a user-friendly interface. The vacuum cleaner can clean, brush and dispose-off. This type of cleaner can be used in autonomous and manual modes as per the user's will.

During its autonomous mode, this robot can be scheduled with the proper date and time. When that time comes this product automatically starts and cleans the whole room and counters check pattern. When this robot completes the whole path it automatically cleans itself in the station from where it started cleaning. Moreover, the manual mode is to save the energy of the robot and cleans the particular place.

The vacuum cleaner has reliable circuitry and it has a safety circuit that rectifies different poles and restricts high voltage to affect the circuitry. In our project, we are including a vacuum cleaner to suck the waste which is of small sizes, and lightweight products like papers, leaves, pebbles, dust particles, and small objects.

[2] Behzad Esmaeiliana, Ben Wangb, Kemper Lewisc (2017) "Innovative Waste Management For Smart City" International Journal of Engineering Science Invention Research & Development; Vol. III, Issue IX, March 2017 www.ijesird.com:

This paper presents solid waste management which uses a Robotic arm and ATMEGA328 microcontroller, the robotic arm is used to pick and place the objects with the help of IR sensors, and the movement of the robotic arm can be taken place by the DC motors and stepper motors.

The ATMEGA328 microcontroller is of low-power CMOS RICS architecture. Since the collection is done by a robot it can reduce the health issues of the person and work can be done very quickly and efficiently. While performing the pick and place operation if it got stuck by any obstacle then with the help of an IR sensor which is in front of the Robotic arm will detect them and then the robot will give the warning to remove or to move away from its path and return to its work.

The function of the robotic path is done by using an IR sensor (black and white). Based on the intensity of the color it performs operations like turn left/right, go straight, stop, etc. This paper only talked about the collection of waste at the source level but it did not talk about the segregation part, and since they are using a robotic arm for the collection purpose

it is very costly to install the bins in homes, hotels, etc. And this model is efficient in big cities and small townships.

[3] S.Vinoth Kumar, A. Krishna Kumar (2017) "Smart Garbage Monitoring and Clearance System using Internet Of Things" 2017 IEEE International Conference on Smart Technologies and Management for Computing, Communication Controls Energy and Management (ICSTM):

This paper introduces a system for the management of a collection of waste. It precisely focuses on the issue of an overflow of waste in the dustbins due to inefficient collection. An android application is presented to display the status of the bin i.e if the bin is full or normal. The user needs to open the app to know the status and it is automatically updated according to the sensors in the bin. They make use of Google maps to establish the location of the bin so that the assigned worker could go and collect the waste from the dustbin when it is full.

When the bin is full, the status is updated and is shown to the user. There is a map option to directly see which bin is full. The status of the bin is also displayed on the LCD on the bin such as 'bin normal', 'bin full', and 'high weight'. Implementation of this project is done by a user who needs to log in to his account to access the information on dustbins. GSM module is used here to send a message when the bin is full and heavy. RFID is used to provide different identities to each bin. This system does not consider the later process for waste management which is waste segregation. It does not take into account what should happen to the huge amounts of waste that are being collected. This can only be implemented on dustbins which are huge and where lots of waste will be placed.

[4] Amrutha Chandramohan, Joyal Mendonca, Nikhil Ravi Shankar, Nikhil U Baheti (2014) "Automated Waste Segregator", 2014 Texas Instruments India Educators Conference (TIIEC):

This paper presents a waste segregation system that uses LDC1000 and a microcontroller for the operation of sensing modules. It detects if the waste entering is metal, wet, or dry based

on LDC1000, Inductive coil, and Conductive coil. The LDC1000 is also used to keep a count in sensing the proximity level of the object. The system starts working once the flap is moved and sensing is done at the entrance. The wet and dry waste is detected using the capacitive sensing module. The inductive coil and capacitive plates are kept in a sliding position and sensing is done as the waste travels on the slide surface. They made use of a de motor for the rotation of base where three buckets for wet, metal, and dry are placed. Once the detection is waste is done, the waste is stopped at the end of the slide using a flap until the respective bucket is rotated to a position right under the flap. The waste is dropped into a suitable bucket and the segregation is done. The bigger size waste is stopped before the segregation process and must be separated by human labor. This system is effective only for the smaller particle segregation. It cannot be set up everywhere since it needs a lot of space. It does not affect the collection and deposition of waste management and also does not provide a solution when the bucket or bin is overloaded. There is no status update if there is a hurdle incurred during the segregation process.

[5] Bhoomika P, Sonika, Suma B, Vismitha S, Mrs. Sangeetha (2018) "Automatic Waste Segregator Bin using Robotic Arm", 2018 3rd IEEE International Conference on Recent Trends in Electronics, Information & Communication Technology (RTEICT-2018):

This paper introduces a dustbin that segregates the waste inside into dry, wet, and metal. It makes use of IR sensors, Moisture sensors, and Metal sensors. The waste dropped inside the bin is placed on a flipper and the detection of waste takes place. The bin is rotatable and is divided into three different partitions. The bin rotates according to the detected waste based on delay in the clockwise direction. The ultrasonic sensor is used at the top of the partitions to detect if the bin is full and the message is sent to the concerned person mobile through the GSM module. The robotic arm is used to pick and place the waste surrounding the dustbin. The detection of waste around this bin is done using an IR sensor. This bin is also a collector and a segregator. It is the most efficient waste management system the existing. The cost of the bin is slightly higher level due to the incorporation of a robotic arm. This can be avoided by making use of a vacuum cleaner mechanism on a moving dustbin which is comparatively

more efficient. The pressure is created at the top of the bin so that the absorbed waste is directly transferred to the top of the bin. The modified bin can move on its own and tackle the obstacles it faces.

1.4 METHODOLOGY

1.4.1 BLOCK DIAGRAM

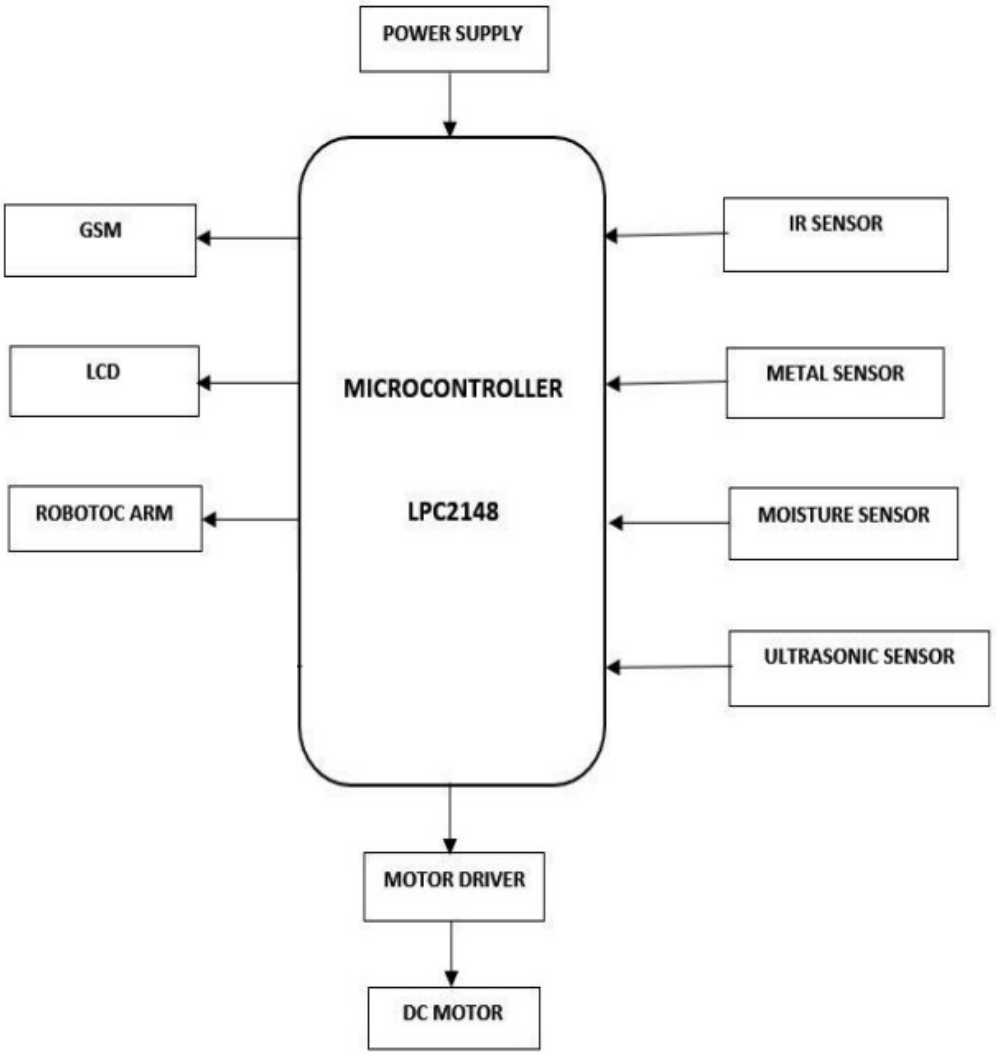

Figure 1.1: Block Diagram of the Model

1.4.2 SEGREGATION METHODOLOGY

The system is partitioned into three subdivisions as Wet waste, Dry waste, and Metallic waste. A flipper (small container) will be placed just above the dustbin which is used to collect the waste and where sensing is carried out. When the waste is dumped in the container, the waste is first sensed as an obstacle by the IR sensor and then checks whether it is a wet waste by the moisture sensor. If it is not the wet waste it will further check for metal waste by metal or proximity sensor. When the waste is neither of these it will be considered dry waste. Based on the type of waste detected the bin is rotated and it will be dumped accordingly to the respective partitions.

1.4.3 MOVEMENT METHODOLOGY

Bin moves across the floor, it cleans and backs up right when it bumps into something in its way. It uses collision and infrared sensors for direction control. When the collision sensor is trigged, the bumper backs up, which means the system has hit an object, thus sensor sends a signal to PCB. We use two collision sensors. When both the sensors are triggered, it means the obstacle is directly in front of it. If one of the sensors is triggered, which means there is an obstacle on the side. If the collision sensors are triggered one after the other, which means the system has hit a comer. It immediately turns and changes its direction. At what distance the obstacle is present is detected by the IR sensor.

The side (collision) sensors are made up of a receiver and a mirror containing a diode that emits infrared beams of invisible light which bounce off the wall. The mirror is positioned in such a way that infrared radiation always hits the wall at a specific angle. When the system is at the idle distance from the wall 2 inches each, IR radiation bounces back to the receiver. If IR radiations don't reach the receiver it means the system is either too close or too far from the obstacle. Thus, the PCB analyses the information, and the system adjusts the path.

CHAPTER 2

HARDWARE AND SOFTWARE COMPONENTS

The Hardware Components used are LPC2148 Microcontroller, DC Motor, Robotic Arm, and various sensors for waste detection. The Software used is the Proteus8 Professional.

2.1 LPC2148 MICROCONTROLLER

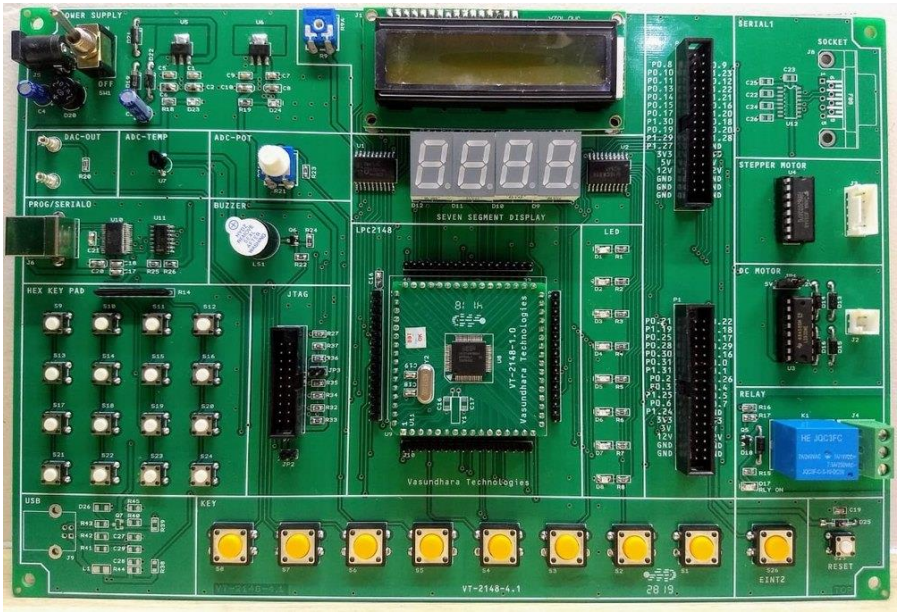

Figure 2.1: LPC2148 Microcontroller

LPC2148 microcontroller is shown in Figure 2.1. It is a 32-bit microcontroller based on RISC architecture. LPC2148 microcontroller belongs to the ARM7 family manufactured by Philips. It consists of many inbuilt peripherals, which makes it more efficient. Due to its tiny size and low power consumption, it is widely used in many applications. The arm has the advantage of low power consumption and fast response. LPC2148 is a 32-bit and has more memory than it can process more amount of information.

Features of LPC2148:

The main features of LPC2148 include the following-

- The LPC2148 is a 16-bit or 32-bit ARM7 family-based microcontroller and is available in a small LQFP64 package.
- ISP (in-system programming) or IAP (in application programming) using on-chip boot loader software.
- On-chip static RAM is 8 kB-40 kB, on-chip flash memory is 32 kB-512 kB, the wide interface is 128 bit, or the accelerator allows 60 MHz high-speed operation.
- It takes 400 milliseconds to erase the data in full chip and I millisecond time for 256 bytes of programming.
- Embedded Trace interfaces and Embedded ICE RT offers real-time debugging with high-speed tracing of instruction execution and on-chip Real Monitor software.
- It has 2 kB of endpoint RAM and a USB 2 full-speed device controller. Furthermore, this microcontroller offers 8kB on-chip RAM nearby to USB with DMA.
- One or two 10-bit ADCs offer 6 or 14 analogsi/ps with a low conversion time of 2.44 μs/channel.
- Only 10-bit DAC offers changeable analog o/p.
- External event counter/32-bit timers-2, PWM unit, & watchdog.
- Low power RTC (real-time clock) & 32 kHz clock input.
- Several serial interfaces like two 16C550 UARTs, and two 12C-buses with 400 kbit/s speed.
- 5 volts tolerant quick general purpose Input/output pins in a small LQFP64 package.
- Outside interrupt pins-21.
- 60 MHz of utmost CPU CLK-clock obtainable from the programmable-on-chip phase-locked loop by resolving time is 100 μs.
- The incorporated oscillator on the chip will work by an exterior crystal that ranges from MHz-25 MHz
- The modes for power-conserving mainly comprise idle & power down.

LPC2148 Architecture:

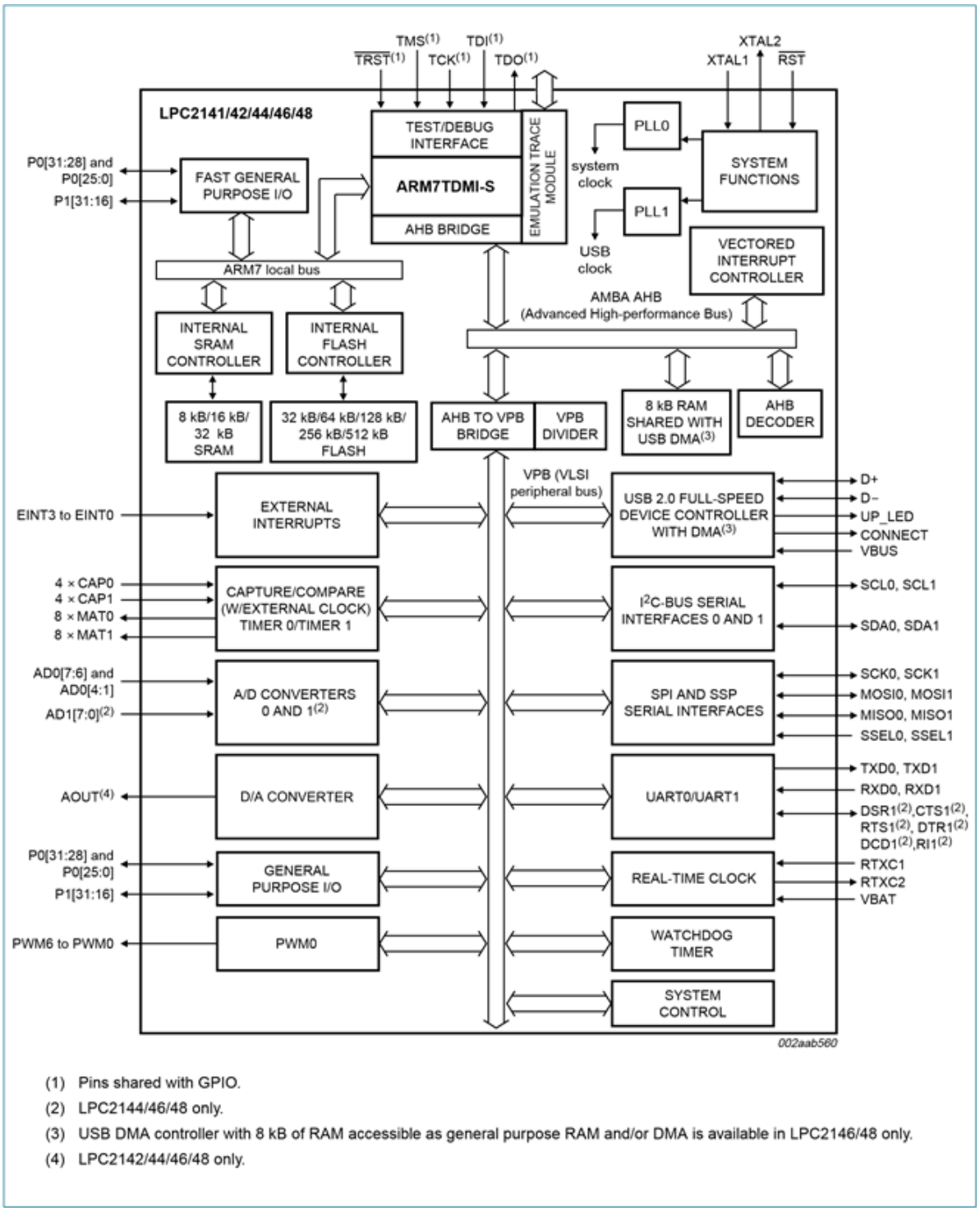

Figure 2.2: ARM7 Based Microcontroller (LPC2148) Architecture

Memory

The LPC2148 microcontroller has 512-kB on-chip FLASH memory as well as 32-kB on-chip SRAM. Also, this microcontroller includes inherent support for up to 2kB finish point USB RAM. This memory is well matched for all the microcontroller applications.

On-chip SRAM

This microcontroller offers static RAM with 32 kB and is very useful for data storage or code. It is accessible for 8-bits, 16-bits, & 32-bits.

On-chip FLASH Memory System

This microcontroller includes a 512-kB Flash memory system and this memory may be useful for both the data storage as well as code. The programming of this memory can be done by the following.

- By incorporating the JTAG interface in serial
- Using UART or ISP (in-system programming)
- Capabilities of IAP (in-application Programming)

The IAP function Based application program may also remove while the program is running. Whenever the microcontroller LPC2148 on-chip boot-loader is utilized, then 500 kB of Flash memory is obtainable for consumer code. The Flash memory of this microcontroller offers the smallest amount of 100,000 writes/erase cycles as well as 20 years of data preservation.

Input/Output Ports

The LPC2148 microcontroller has two input/output ports and these are termed P0 &P1. Every port pin is branded with PX.Y. Here, 'X' denotes a port number like 0 or 1, whereas 'Y' denotes PIN 0-31. All the pins can execute alternate tasks also. For instance, P0.8 provides GPIO and Tx pin of the UART1, AD1.1, and PWM4. On RST (RESET), every pin is arranged as GPIO.

LPC2148 Pin Configuration:

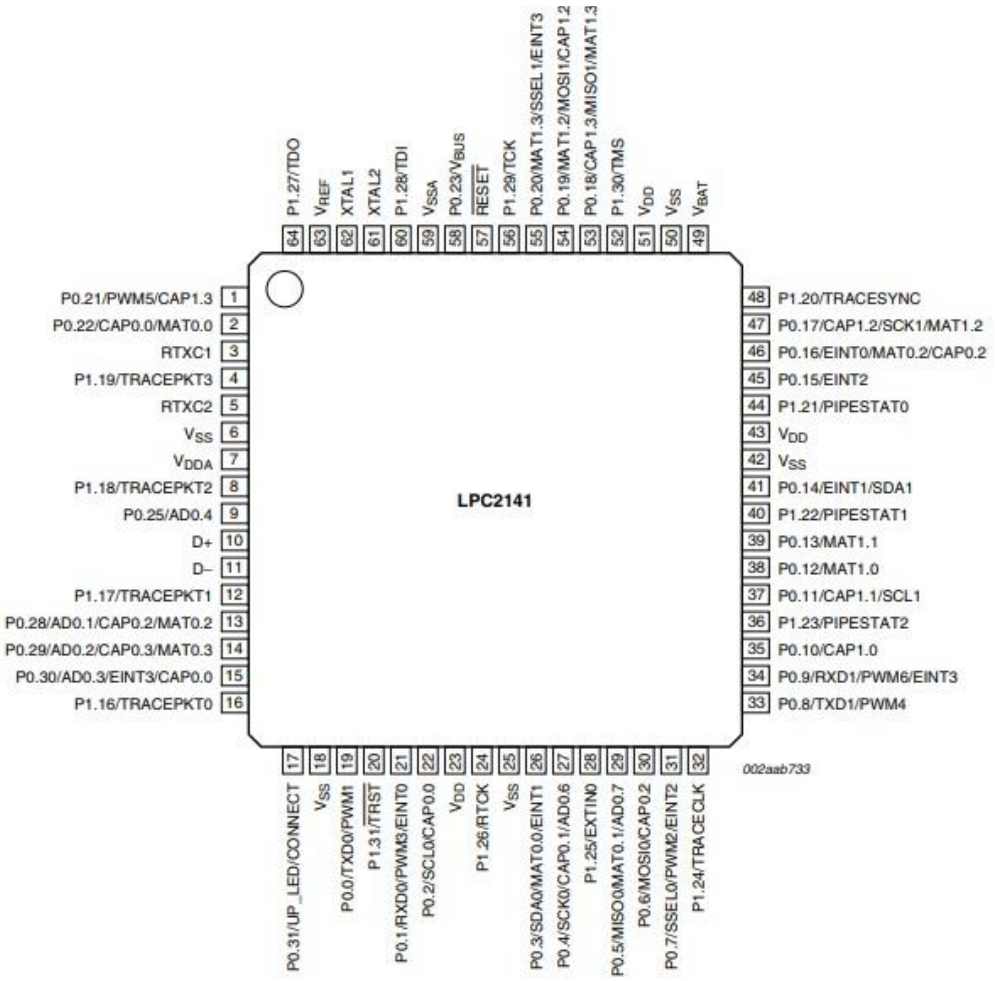

Figure 2.3: ARM7 Based Microcontroller (LPC2148) Pin Configuration

ARM7 Based Microcontroller (LPC2148) Pin Configuration is shown in Figure 2.3. It can be either an input pin or an output pin, whose behavior can be controlled at the run time. A group of these pins is called a port (for example, Port 0 of LPC2148 has 32 pins). LPC2148 has two 32-bit General Purpose I/O ports. Out of these 32 pins, 28 pins can be configured as either general-purpose input or output.

LPC2148 has two 32-bit General Purpose I/O ports.

1. **PORT 0**
2. **PORT 1**

PORT 0 is a 32-bit port-

- Out of these 32 pins, 28 pins can be configured as either general-purpose input or output.
- One of these 32 pins (P0.31) can be configured as general-purpose output only.
- Three of these 32 pins (P0.24, P0.26, and P0.27) are reserved. Hence, they are not available for use. Also, these pins are not mentioned in the pin diagram.

PORT 1 is also a 32-bit port. Only 16 of these 32 pins (P1.16-P1.31) are available for use as general-purpose input or output.

Pin Function Select Registers

Pin Function Select Registers are 32-bit registers. These registers are used to select or configure specific pin functionality.

There are 3 Pin Function Select Registers in LPC2148:

1. **PINSEL 0:-** PINSEL0 is used to configure PORT 0 pins P0.0 to P0.15.

2. **PINSEL1**:- PINSEL1 is used to configure PORT 0 pins P0.16 to P0.31.

3**. PINSEL2**:-PINSEL2 is used to configure PORTI pins Pl.16 to P1.31.

It makes it perfectly suitable for different applications by memory limitations where the density of code is a matter.

Interrupt sources

Every peripheral device consists of a single interrupt line allied to the VIC (vector interrupt controller), although can have various interrupt flags inside. Individual interrupt flags can also signify one or more interrupt resources.

Code Security

The code security feature of the microcontrollers LPC2148 permits a function to control whether it can be protected or debugged from inspection.

2.2 LCD DISPLAY

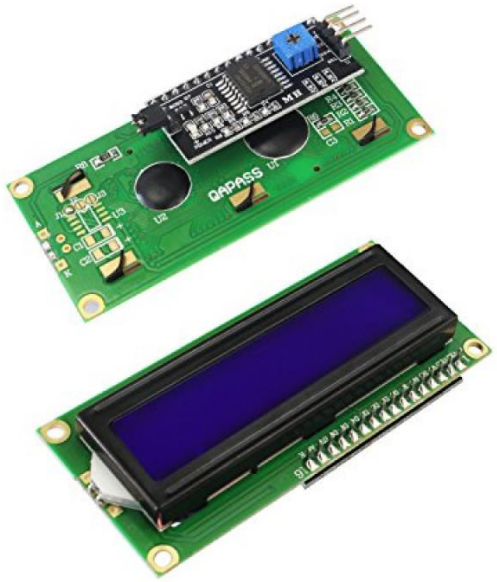

Figure 2.4: 16x2 LCD (Liquid Crystal Display)

LCD (Liquid Crystal Display) screen is an electronic display module and find a wide range of applications. A 16x2 LCD is a very basic module and is very commonly used in various devices and circuits as shown in Figure 2.4. These modules are preferred over seven segments and other multi-segment LEDs. A liquid crystal display or LCD draws its definition from its name itself. It is a combination of two states of matter, the solid and the liquid. LCD uses a liquid crystal to produce a visible image. Liquid crystal displays are super-thin technology display screens that are generally used in laptop, computer screen, TVs, cell phones, and portable video games. LCD's technologies allow displays to be much thinner when compared to cathode-ray tube (CRT) technology. An LCD is either made up of an active matrix display grid or a passive display grid. Most of the Smartphone with LCD

technology uses active matrix display, but some of the older displays still make use of the passive display grid designs. Most of the electronic devices mainly depend on liquid crystal display technology for their display LCD technology is used for displaying the image in a notebook or some other electronic devices like mini-computers Light is projected from a lens on a layer of liquid crystal This combination of colored light with the grayscale image of the crystal (formed as electric current flows through the crystal) forms the colored image.

The features of this LCD mainly include the following:

- The operating voltage of this LCD is 4.7V-5.3V
- It includes two rows where each row can produce 16-characters.
- The utilization of current is 1mA with no backlight
- Every character can be built with a 5×8 pixel box
- The alphanumeric LCDs alphabets & numbers
- Is display can work on two modes like 4-bit & 8-bit
- These are obtainable in Blue & Green Backlight
- It displays a few custom-generated characters

The main advantages of this LCD device include power consumption is less and low cost. The main disadvantages of this LCD device include it occupies a large area, slow devices, and also lifespan of these devices will be reduced due to direct current.

Block diagram of LCD Display:

The liquid has a unique advantage of having low power consumption than the LED or cathode ray tube. Block diagram and pin configuration of LCD are shown in Figure 2.5 and Table 2.1 respectively.

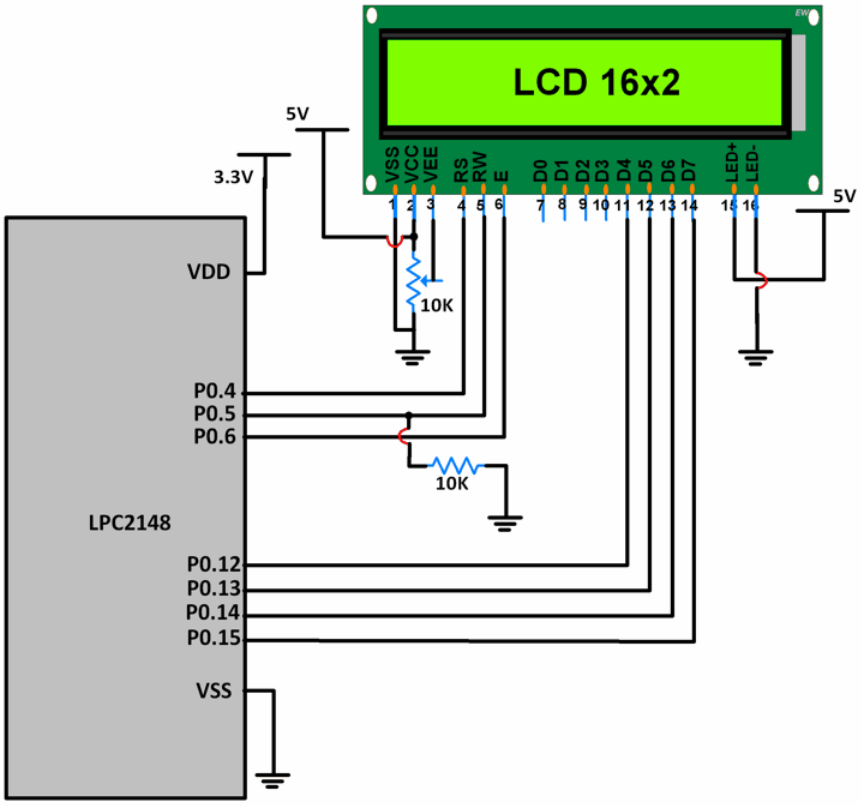

Figure 2.5: Interfacing Connections of 16x2 LCD With LPC2148

Pin Configuration table for a 16x2 LCD Character display:

Table 2.1: Pin Configuration of 16x2 LCD

Pin number	Pin Name	Pin Description/Function
1	Vss = Ground	Connect this to your system ground or reference
2	Vdd (Logic power)	Logic voltage to drive LCD, this could be 5V or 3.3V. 5V is best for colder temperatures.
3	V_E	Contrast adjust to lighten or darken the character with respect to the background. This is a variable between max logic power and ground.
4	RS = Register Select	Connect this to your microprocessor to shift between Command and the data register
5	RW = Read/Write	Used to read or write data between the LCD and the microprocessor. This can be tied to ground if you only plan to write data.
6	Enable	0 or 1 to communicate with the microprocessor
7	DB0	DB is Data Bit from 0 to 7
8	DB1	These are connected to the microcontroller to send/receive up to 8 bits of data at a time. It is possible to only use four data bits if you have limited I/Os. (In/Outs)
9	DB2	
10	DB3	
11	DB4	
12	DB5	
13	DB6	
14	DB7	
15	LED +	This is the power for the LED and is independent of the LCD voltage. About 50% of the LCDs have pin 15 as positive and 16 negative, the other 50% are reversed. LEDs are DC(Direct Current) and have polarity.
16	LED -	

LCD Construction

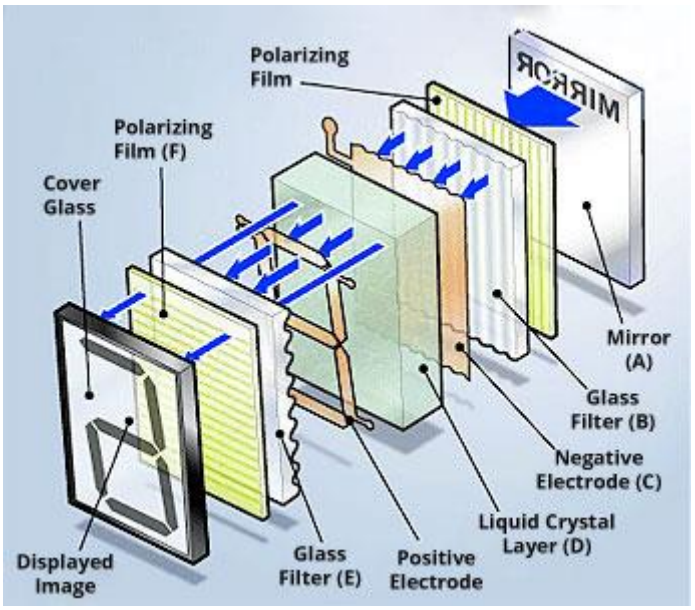

Figure 2.6: 16x2 LCD Layered Construction

Simple facts that should be considered while making an LCD:

1. The basic structure of LCD should be controlled by changing the applied current.
2. We must use polarized light.
3. Liquid crystal should able be to control both of the operations to transmit or can also able to change the polarized light.

Working of LCDs

The principle behind the LCDs is that when an electrical current is applied to the liquid crystal molecule, the molecule tends to untwist. This causes the angle of light which is passing through the molecule of the polarized glass and also causes a change in the angle of the top polarizing filter. As a result, a little light is allowed to pass the polarized glass through a particular area of the LCD. Thus that particular area will become dark compared to others. The LCD works on the principle of blocking light rather than emitting light. LCDs require a backlight as they do not emit light by them. We always use devices that are made up of LCDs

which are replacing the use of cathode-ray tubes. Cathode ray tube draws more power compared to LCDs and is also heavier and bigger.

Advantages of an LCDs:

- LCDs consume less amount of power compared to CRT and LED
- LCDs consist of some microwatts for display in comparison to some mill watts for LEDs
- LCDs are of low cost
- Provides excellent contrast
- LCDs are thinner and lighter when compared to cathode-ray tubes and LED

Disadvantages of an LCDs:

- Require additional light sources
- Range of temperature is limited for operation
- Low reliability
- Speed is very low
- LCDs need an AC drive

Applications of Liquid Crystal Display:

- Liquid crystal technology has major applications in the field of science and engineering as well as on electronic devices.
- Liquid crystal thermometer Optical imaging
- The liquid crystal display technology is also applicable in the visualization of the radio frequency waves in the waveguide
- Used in the medical application.

Most of the LCD Displays available in the market are 16X2 (That means, the LCDs are capable of displaying 2 lines each having 16 Characters a).

2.3 AC ADAPTER

It is an external power supply that changes household electric current from mains voltage (either 120 or 230 volts AC) to a low voltage suitable for consumer electronics. AC adapters are used with electrical devices that require power. Here, in our project power is supplied to ARM7 micro-controller with the help of this adapter.

2.4 INFRARED SENSOR

Figure 2.7: LM 393 Infrared Sensor

IR sensor is shown in Figure 2.7. Infrared technology addresses a wide variety of wireless applications. It is an obstacle detector that consists of an infrared transmitter and a receiver. It is an electronic sensor that measures infrared light radiating from the obstacle. An infrared sensor can measure the heat of an object as well as detects motion. An infrared sensor emits and/or detects infrared radiation to sense its surroundings. The working of any Infrared sensor is governed by three laws: Planck's Radiation Law, Stephen-Boltzmann Law, and Wien's Displacement Law.

Planck's law states that "every object emits radiation at a temperature not equal to 0°K". Stephen-Boltzmann law states that "at all wavelengths, the total energy emitted by a black body is proportional to the fourth power of the absolute temperature". According to Wien's

Displacement law, "the radiation curve of a black body for different temperatures will reach its peak at a wavelength inversely proportional to the temperature".

Types of IR Sensors

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

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

Infrared sources include an LED or infrared laser diode. Infrared detectors include photodiodes or phototransistors. The energy emitted by the infrared source is reflected by an object and falls on the infrared detect.

IR Transmitter

An infrared Transmitter is a Light-Emitting Diode (LED) that emits infrared radiations. Hence, they are called IR LED. Even though an IR LED looks like a normal LED, the radiation emitted by it is invisible to the human eye. The picture of a typical Infrared LED is shown below in Figure 2.8.

There are different types of infrared transmitters depending on their wavelengths, output power, and response time. A simple infrared transmitter can be constructed using an infrared LED, a current limiting resistor, and a power supply.

The frequencies of IR are higher than those of microwaves, but lower than those of visible light, ranging from about 300 Ghz to 400 THz.

Figure 2.8: IR Transmitter in LM 393

The schematic of a typical IR transmitter is shown below.

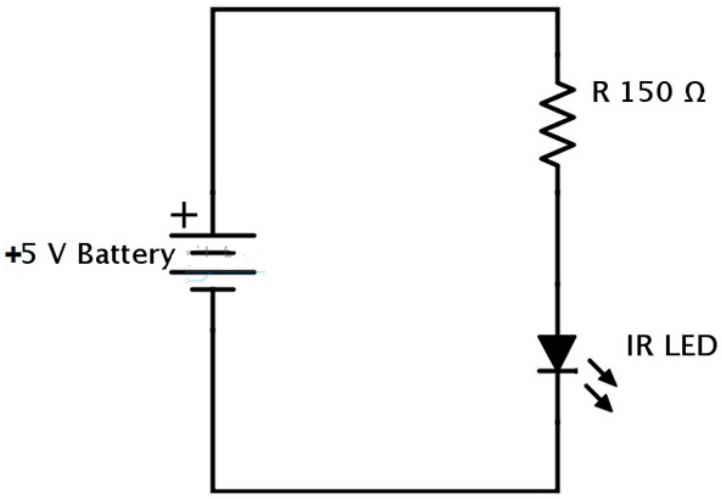

Figure 2.9 Schematic Circuit of LM 393 IR Transmitter

The internal circuit of the IR sensor is shown in Figure 2.9. When operated at a supply of SV, the IR transmitter consumes about 3 to 5 mA of current. Infrared transmitters can be modulated to produce a particular frequency of infrared light. The most commonly used

modulation is OOK (ON-OFF-KEYING) modulation. A transmitter can be found in several applications. Some applications require infrared heat and the best-infrared source is an infrared transmitter. When infrared emitters are used with Quartz, solar cells can be made.

IR Receiver

The Infrared receiver is also called an infrared sensor as they detect the radiation from an IR transmitter. IR receivers come in the form of photodiodes and phototransistors. Infrared Photodiodes are different from normal photodiodes as they detect only infrared radiation. The picture of a typical IR receiver or a photodiode is shown in Fig 2.10.

Figure 2.10: IR Receiver in LM 393

Different types of IR receivers exist based on the wavelength, voltage, package, etc. When used in an infrared transmitter-receiver combination, the wavelength of the receiver should match that of the transmitter. A typical infrared receiver circuit using a phototransistor is shown in Fig 2.11.

The IR receiver circuit is shown in Figure 4:11. It consists of an IR phototransistor, a diode, a MOSFET, a potentiometer, and an LED When the phototransistor receives any infrared radiation, current flows through it and MOSFET turns on. This in turn lights up the LED which acts as a load. The potentiometer is used to control the sensitivity of the phototransistor.

Principle of Working

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

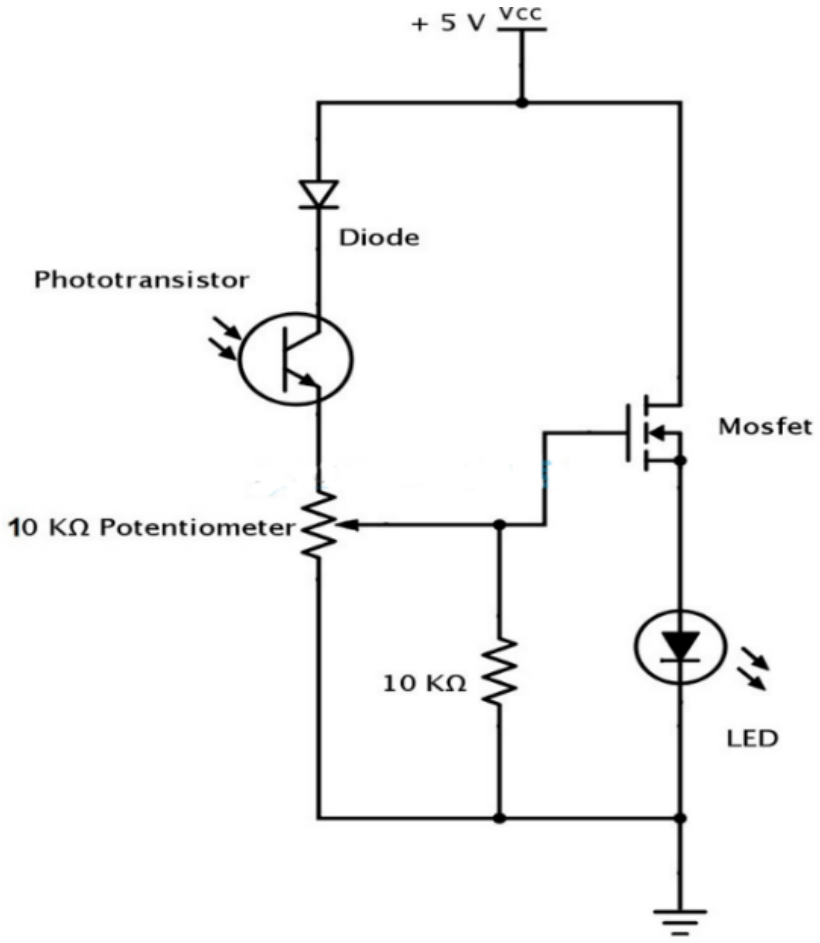

Figure 2.11: Schematic Circuit of LM 393 IR Receiver

The IR receiver circuit is shown in Figure 2.12. When the IR transmitter emits radiation, it reaches the object and some of the radiation reflects the IR receiver. Based on the intensity of the reception by the IR receiver, the output of the sensor is defined.

Obstacle Sensing Circuit or IR Sensor Circuit

A typical IR sensing circuit is shown in Fig 2.13.

The IR sensor circuit is shown in Figure 2.13. It consists of an IR LED, a photodiode, a potentiometer, an IC Operational amplifier, and an IR LED that emits infrared light. The Photodiode detects infrared light. An IC Op-Amp is used as a voltage comparator. The potentiometer is used to calibrate the output of the sensor according to the requirement.

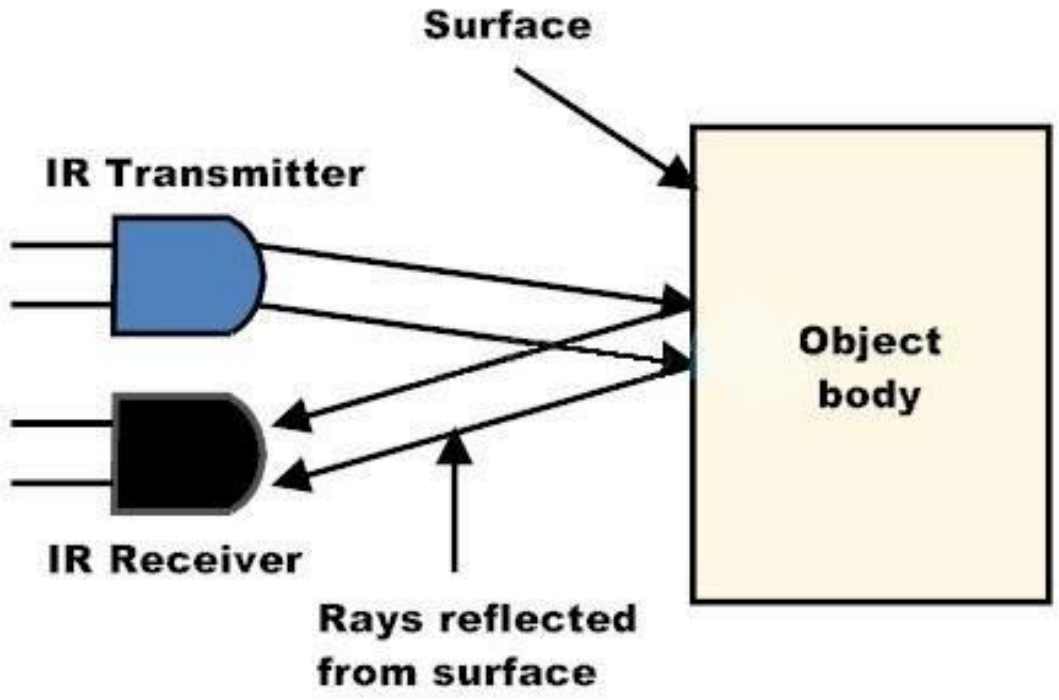

Figure 2.12: Working Block Diagram of IR Sensor

When the light emitted by the IR LED is incident on the photodiode after hitting an object, the resistance of the photodiode falls from a huge value. One of the inputs of the op-amp is a threshold value set by the potentiometer. The other input to the op-amp is from the photodiode's series resistor. When the incident radiation is more on the photodiode, the voltage drop across the series resistor will be high. In the IC, both the threshold voltage and the voltage across the series resistor is compared. If the voltage across the resistor series to photodiode is greater than that of the threshold voltage, the output of the IC Op-Amp is high.

As the output of the IC is connected to an LED, it lightens up the threshold voltage can be adjusted by adjusting the potentiometer depending on the environmental conditions.

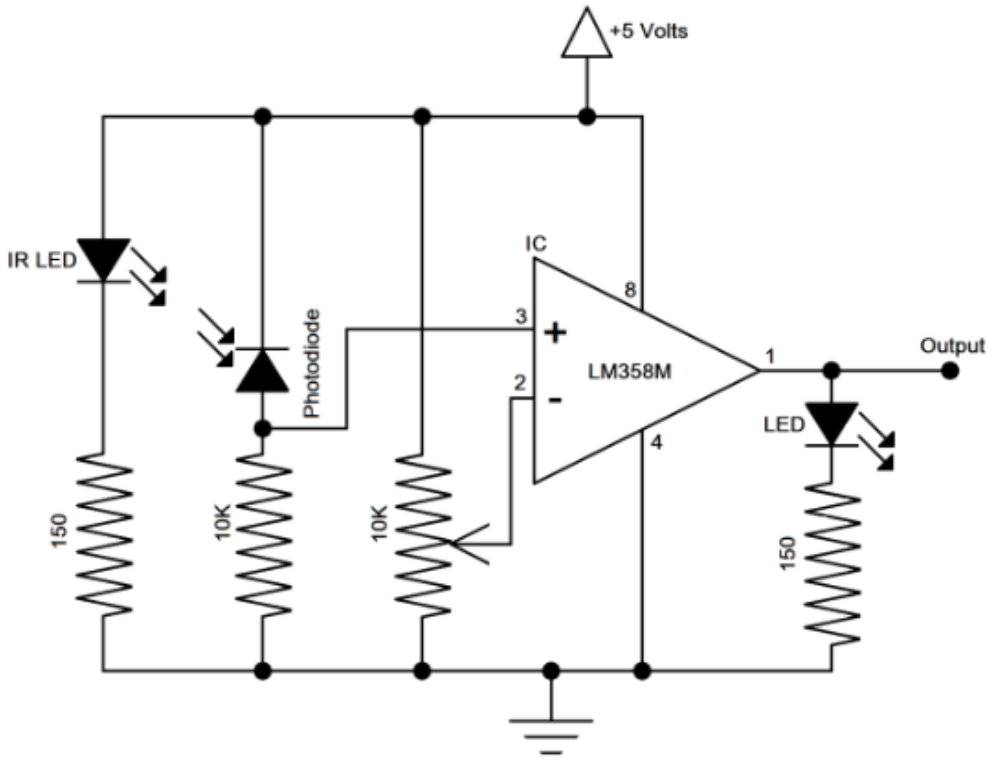

Figure 2.13: IR Sensor Circuit

The positioning of the IR LED and the IR Receiver is an important factor. When the IR LED is held directly in front of the IR receiver, this setup is called Direct Incidence. In this case, almost the entire radiation from the IR LED will fall on the IR receiver. Hence there is a line of sight communication between the infrared transmitter and the receiver. If an object falls in this line, it obstructs the radiation from reaching the receiver either by reflecting the radiation or absorbing the radiation. They allow a robot to see an obstacle. without actually having to come into contact with it. This can prevent possible entanglement, allow for better obstacle avoidance (over touch-feedback methods), and possibly allow the software to distinguish between obstacles of different shapes and sizes, there are several methods used to allow a sensor to detect obstacles from a distance.

2.5 ULTRASONIC SENSORS

Figure 2.14: HC-SR04 Ultrasonic Sensor

An ultrasonic sensor is shown in Figure 2.14. Ultrasonic sensors (also known as transceivers when they both send and receive, but more generally called transducers) work on a principle similar to radar or sonar, which evaluate attributes of a target by interpreting the echoes from radio or sound waves respectively. Active ultrasonic sensors generate high-frequency sound waves and evaluate the echo which is received back by the sensor, measuring the time interval between sending the signal and receiving the echo to determine the distance to an object. Passive ultrasonic sensors are microphones that detect ultrasonic noise that is present under certain conditions.

An ultrasonic transducer is a device that converts energy into ultrasound or sound waves above the normal range of human hearing. While technically a dog whistle is an ultrasonic transducer that converts mechanical energy in the form of air pressure into ultrasonic sound waves, the term is more apt to be used to refer to piezoelectric transducers or capacitive transducers that convert electrical energy into sound.

Piezoelectric crystals have the property of changing size when a voltage is applied; applying an alternating current (AC) across them causes them to oscillate at very high

frequencies, thus producing very high-frequency sound waves. The location at which a transducer focuses the sound can be determined by the active transducer area and outline, the ultrasound rate, and the sound velocity of the propagation medium. Since piezoelectric crystals generate a voltage when force is functional to them, a similar mineral can be used as an ultrasonic sensor. Various structures use separate transmitter and receiver components while others combine both into a single piezoelectric transceiver. The level of waste is determined using an ultrasonic sensor. If the dustbin is full, the message is sent to the concerned authority through GSM.

2.6 METAL DETECTOR

A metal detector is an electronic instrument that detects the presence of metal nearby as shown in Figure 2.15. Metal detectors are useful for finding metal inclusions hidden. Within

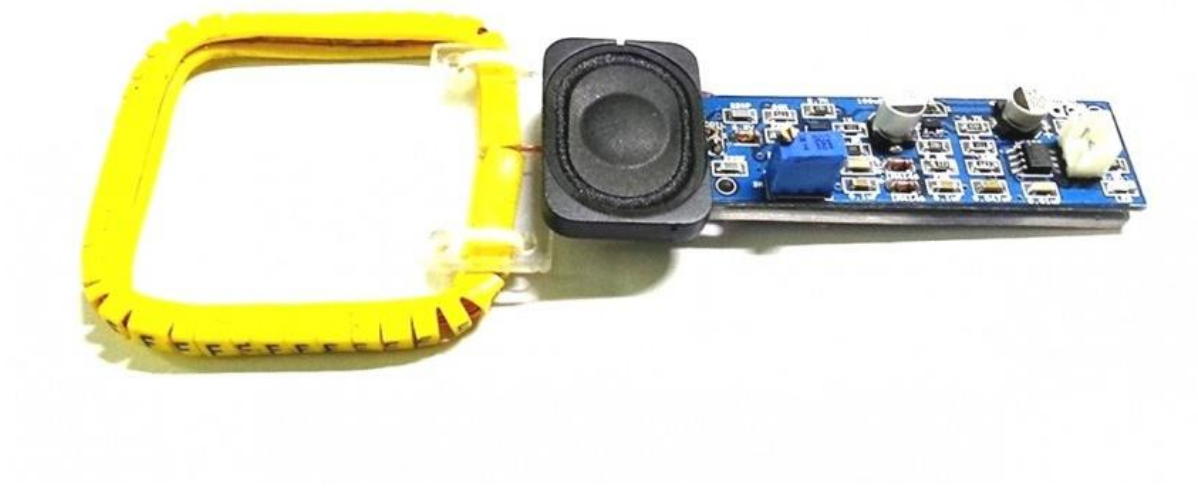

Figure 2.15: Metal Detector

objects, or metal objects buried underground. The basic working principles of metal detectors: e based on electromagnetic induction

Metal detectors work by interacting with metallic elements on the ground through one or more inductor coils that are attached to them. They work by electromagnetic field transmission from the search coil attached to the ground. As a result of this electromagnetic transmission, any metal objects (targets) within the electromagnetic field range will then become energized and transmit an electromagnetic field of their own in return. The detector's search coil then receives the re-transmitted field and alerts the user by producing a target response

The simplest form of a metal detector consists of an oscillator producing an alternating current that passes through a coil producing an alternating magnetic field. If a piece of electrically conductive metal is close to the coil, eddy currents will be induced in the metal, and this produces a magnetic field of its own. If another coil is used to measure the magnetic field (acting as a magnetometer), the change in the magnetic field due to the metallic object can be detected. It is used to detect the metal based on the relay, ie if any metal waste is placed near the metal detector, the relay is turned on. It uses a 12V power supply. We use this sensor to separate metal waste inside the bin.

2.7 MOISTURE SENSOR

The moisture sensor is shown in Figure 2.16. To calculate the moisture content of the waste material we have made use of a soil moisture sensor. The soil moisture sensor is used to measure the volumetric water content of the soil. It uses the principle of capacitance to measure the dielectric permittivity of the surrounding medium. The dielectric permittivity: in this case is a function of water content. The sensor creates a voltage proportional to the dielectric permittivity, and therefore the water content in the soil. The water content of waste material will be more as compared to dry waste. Hence the dielectric constant of wet waste material will be more as compared to dry waste material.

A current is passed across the electrodes through the waste material and the resistance of the current in the material determines the water content. If the material has more water, resistance will be low, and thus more current will pass through it. On the other hand, when

the water content is low the sensor module outputs a high level of resistance. This sensor has both digital and analog outputs. The digital output is simple to use but is not as accurate as of the analog output. This concept is used to separate wet waste from dry waste.

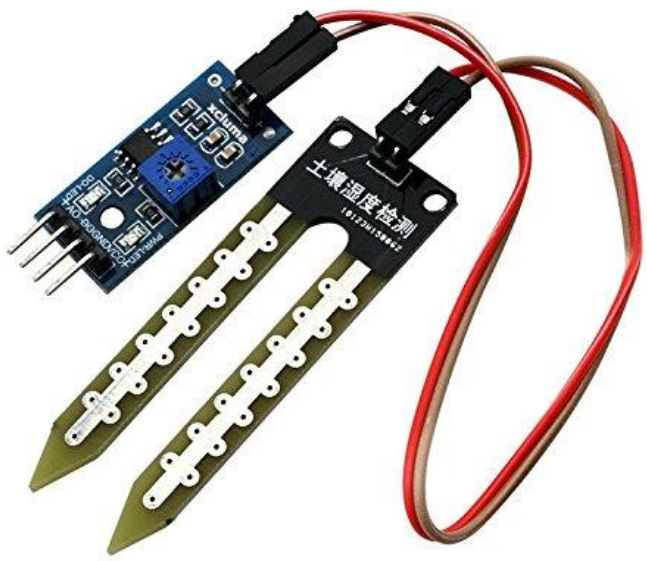

Figure 2.16: SKU: 130230 Moisture Sensor

Features of moisture sensor are as follows

- Sensitivity can be adjusted
- Has a bolt hole, so it is convenient to install
- Threshold level can be configured

Applications of the sensor are as follows

- Agriculture
- Landscape irrigation
- Plant-soil-water interaction studies
- Water sensor

Table 2.2: Specifications of the SKU: 130230 Moisture Sensor

Item	Condition	Min	Typical	Max	Unit
Voltage	-	3.3	/	5	V
Current	-	0	/	35	mA
Output Voltage	Supply Voltage 5 V	0	~	4.2	V
Output Value	Sensor in dry soil	0	~	300	/
	Sensor in humid soil	300	~	700	/
	Sensor in water	700	~	950	/

Capacitive sensing in the field of moisture determination features the advantage that the permittivity of the media being examined typically differs significantly from the permittivity of water (er,water=80).

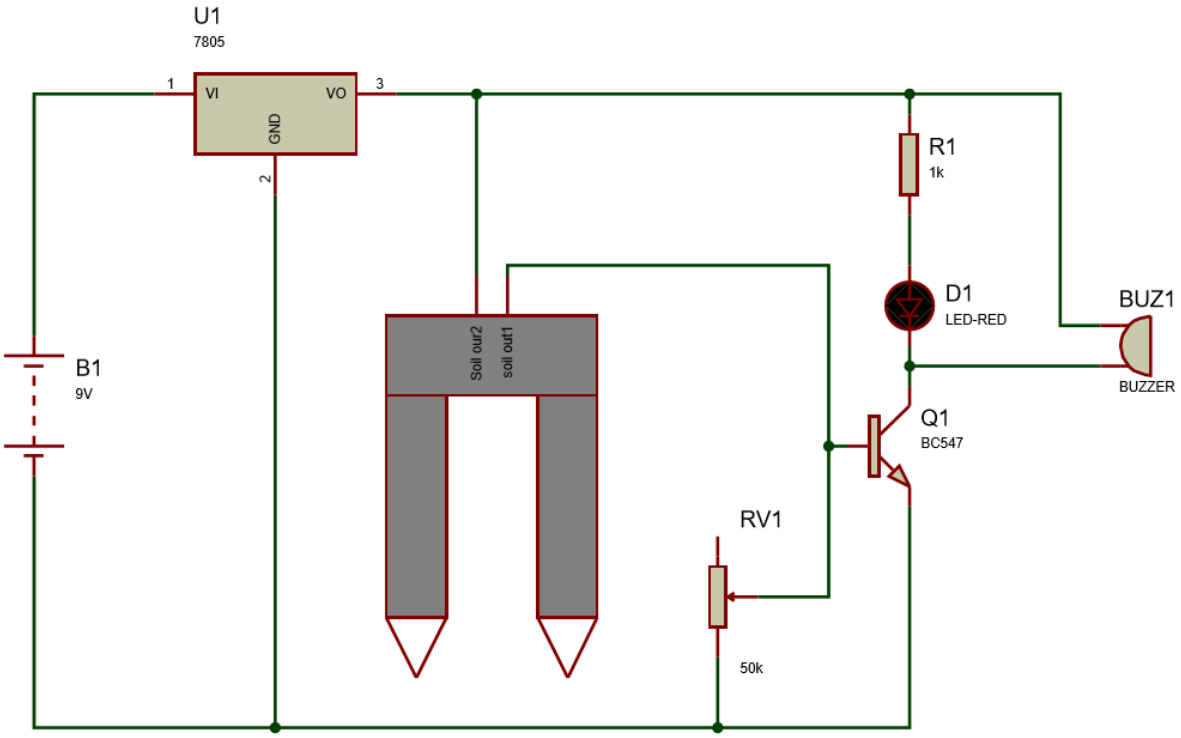

Figure 2.17: Internal Circuit Of SKU: 130230 Moisture Sensor

Waste material and water represent a heterogeneous dielectric mixture for a capacitance-based measurement system Composition of the waste used in the experiments. Waste component Weight (%) Paper and card 30 Kitchen and garden 28 Plastics 21 Wood and textile 18 Metal 3 components have been developed One of the most commonly used models

for dielectric mixtures is the Maxwell Garnett mixing formula and the Polder-van Santen model: when the moisture is randomly distributed in the material, both formulae allow for a calculation of the effective permittivity by knowing the parameters material permittivity (nearly constant), water permittivity and volume fraction of water.

The internal circuit of the moisture sensor is shown in Figure 2.17 This soil moisture detector probe is homemade and built using general-purpose PCB (Perf board) Buzzer and LED are used as an indication of soil moisture detection

2.8 DC MOTOR

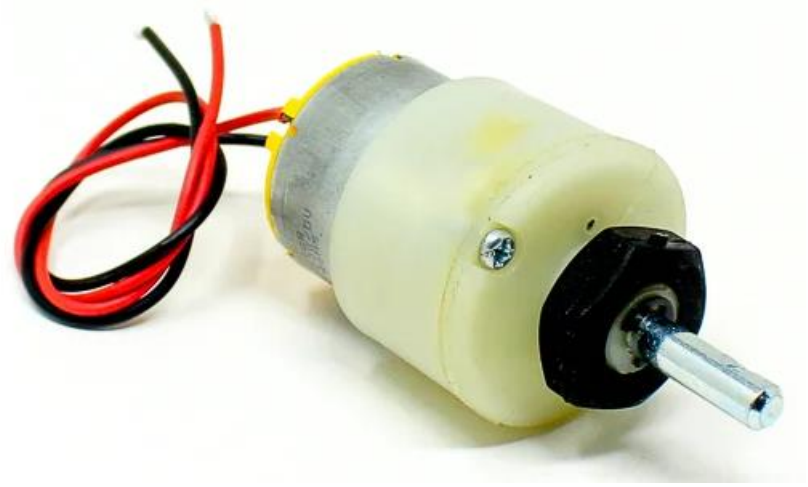

Figure 2.18: DC Motor

DC Motor is shown in Figure 2.18. A DC motor is any of a class of rotary electrical machines that converts direct current electrical energy into mechanical energy. The most common types rely on the forces produced by magnetic fields. Nearly all types of DC motors have some internal mechanism, either electromechanical or electronic, to periodically change the direction of current flow in part of the motor.

DC motors were the first type widely used since they could be powered from existing direct-current lighting power distribution systems. A DC motor's speed can be controlled

over a wide range, using either a variable supply voltage or by changing the strength of the current in its field windings. Small DC motors are used in tools, toys, and appliances.

The universal motor can operate on direct current but is a lightweight brushed motor used for portable power tools and appliances. Larger DC motors are used in the propulsion of electric vehicles, elevators, and hoists, or drives for steel rolling mills. The advent of power electronics has made the replacement of DC motors with AC motors possible in many applications.

Working Principle of A DC Motor

An electric motor is an electrical machine that converts electrical energy into mechanical energy. The basic working principle of a DC motor is: "whenever a current. carrying conductor is placed in a magnetic field, it experiences a mechanical force". The direction of this force is given by Fleming's left-hand rule and its magnitude is given by F - BIL. Where, B = magnetic flux density, I = current and L= length of the conductor.

Fleming's left-hand rule: If we stretch the first finger, second finger, and thumb of our left hand to be perpendicular to each other, and the direction of the magnetic field is represented by the first finger, the direction of the current is represented by the second finger, then the thumb represents the direction of the force experienced by the current-carrying conductor. When the armature windings are connected to a DC supply, an electric current sets up in the winding. The magnetic field may be provided by field winding (electromagnetism) or by using permanent magnets. In this case, current-carrying armature conductors experience a force due to the magnetic field, according to the principle stated above.

The commutator is made segmented to achieve unidirectional torque. Otherwise, the direction of force would have reversed whenever the direction of movement of the conductor is reversed in the magnetic field.

Back EMF

According to fundamental laws of nature, no energy conversion is possible until there is something to oppose the conversion. In the case of generators, this opposition is provided by

magnetic drag, but in the case of the motors, there is a back emf. When the armature of a motor is rotating, the conductors are also cutting the magnetic flux lines, and hence according to Faraday's law of electromagnetic induction, an emf induces in the armature conductors. The direction of this induced emf is such that it opposes the armature current.

Significance of Back Emf:

The magnitude of back emf is directly proportional to the speed of the motor. Consider the load on a motor is suddenly reduced. In this case, the required torque will be small as compared to the current torque. The speed of the motor will start increasing due to the excess torque. Hence, being proportional to the speed, the magnitude of the back emf will also increase. With increasing back emf armature current will start decreasing. Torque is proportional to the armature current, it will also decrease until it becomes sufficient for the load. Thus, the speed of the motor will regulate. On the other hand, if a de motor is suddenly loaded, the load will cause a decrease in the speed. Due to a decrease in speed, back emf will also decrease allowing more armature current. Increased armature current will increase the torque to satisfy the load requirement. Hence, the presence of the back emf makes a de motor "self-regulating".

2.9 MOTOR DRIVER

Figure 2.19: L293D Motor Driver

L293D Motor driver is shown in Figure 2.19. L293D contains two inbuilt H-bridge driver circuits. In its common mode of operation, two DC motors can be driven simultaneously, both in the forward and reverse direction. The motor operations of two motors can be controlled by input logic at pins 2 & 7 and 10 & 15. Input logic 00 or 11 will stop the corresponding motor. Logic 01 and 10 will rotate it clockwise and anticlockwise. directions, respectively.

Enable pins 1 and 9 (corresponding to the two motors) must be high for motors to start operating When an enable input is high, the associated driver gets enabled. As a result, the outputs become active and work in phase with their inputs. Similarly, when the enable input is low, that driver is disabled, and their outputs are off and in the high-impedance state

Pin configuration

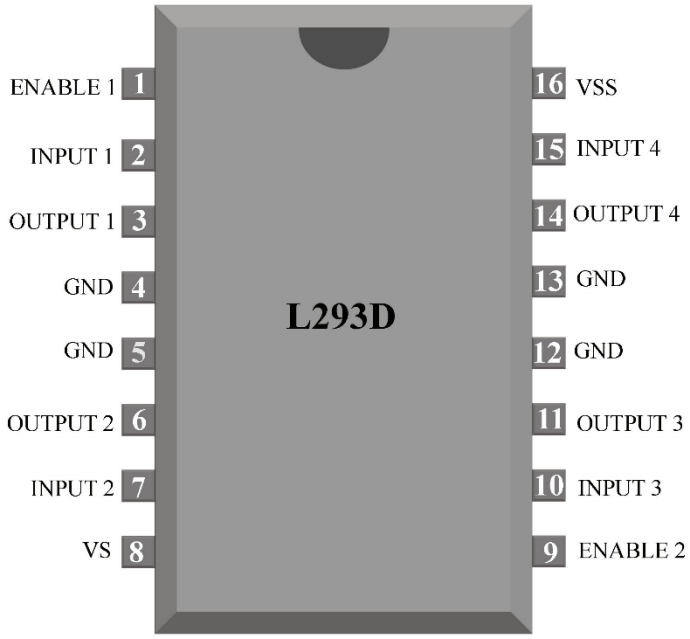

Figure 2.20: Pin Configuration of Motor Driver

Motor Driver Operation

Pin configuration of the Motor driver is shown in Figure 2.20. The L293D IC receives signals from the microprocessor and transmits the relative signal to the motors. It has two voltage

pins, one of which is used to draw current for the working of the L293D and the other is used to apply voltage to the motors.

L293D and Its Working

The L293D is a 16-pin IC, with eight pins, on each side, dedicated to controlling a motor. There are 2 INPUT pins, 2 OUTPUT pins, and 1 ENABLE pin for each motor. 1293D consists of two H-bridge. H-bridge is the simplest circuit for controlling a low current-rated motor.

2.10 ROBOTIC ARM

The pick and place robot is the one that is used to pick up an object and place it in the desired location. It can be a cylindrical robot providing movement in horizontal, vertical, and rotational axes, a spherical robot providing two rotational and one linear movement, an articulated robot, or a scary robot (fixed robots with 3 vertical axes and rotary arms).

Fig 2.21: Robotic Arm SG90 Servo Motors

This robotic arm is preferred due to the following advantages:

- They are faster and can get the work done in seconds compared to their human counterparts.
- They are flexible and have the appropriate design.
- They are accurate.
- They increase the safety of the working environment and never get tired.

This robotic arm is placed in front of the segregating bin which is useful to pick up the waste from a place and place it inside the bin for further segregation. We make use of DC motors to move the robotic arm. The basic function of a pick and place robot is done by its joints. Joints are analogous to human joints and are used to join the two consecutive rigid bodies in the robot.

They can be rotary joints or linear joints. To add a joint to any link of a robot, we need to know about the degrees of freedom and degrees of movement for that body part. Degrees of freedom implement the linear and rotational movement of the body and Degrees of movement imply the number of axes the body can move. The robotic arm is shown in Figure 2.21

2.11 GSM

GSM (Global System for Mobile communications) is a standard developed by the European Telecommunications Standards Institute (ETSI) to describe the protocols for second-generation (2G) digital cellular networks used by mobile devices such as mobile phones and tablets as shown in Figure 2.23. It was first deployed in Finland in December 1991 As of 2014, it has become the global standard for mobile communications - with over 90% market share, operating in over 193 countries and territories. This expanded over time to include data communications, first by circuit-switched transport, then by packet data transport via GPRS (General Packet Radio Services) and EDGE (Enhanced Data rates for GSM Evolution, or EGPRS)

GSM Network Architecture

The GSM network architecture elements:

- Network and Switching Subsystem (NSS)
- Base-Station Subsystem (BSS)
- Mobile station (MS)
- Operation and Support Subsystem (OSS)

Network Switching Subsystem (NSS)

The GSM system architecture contains a variety of different elements and is often termed the core network as shown in Figure 2.24. It provides the main control interfacing for the whole mobile network. The major elements within the core include

i. **Mobile Services Switching Centre (MSC):** The main element within the core and network area of the overall GSM network architecture is the Mobile switching Services Centre (MSC). The MSC acts like a normal switching node within a PSTN or ISDN, but also provides additional functionality to enable the requirements of a mobile user to be supported. These include registration, authentication, call location, inter-MSC handovers, and call routing to a mobile subscriber. It also provides an interface to the PSTN so that calls can be routed from the mobile network to a phone connected to a landline. Interfaces to other MSCs are provided to enable calls to be made to mobiles on different networks.
ii. **Home Location Register (HLR):** This database contains all the administrative information about each subscriber along with their last known location. In this way. the GSM network can route calls to the relevant base station for the MS. When a user switches on their phone, the phone registers with the network, and from this, it is possible to determine which BTS it communicates with so that incoming calls can be routed appropriately. Even when the phone is not active (but switched on) it re-registers periodically to ensure that the network (HLR) is aware of its latest position. There is one HLR per network, although it may be distributed across various sub-centers for operational reasons.
iii. **Visitor Location Register (VLR):** This contains selected information from the HLR that enables the selected services for the individual subscriber to be provided. The VLR can be implemented as a separate entity, but it is commonly realized as an integral part of the MSC, rather than a separate entity. In this way, access is made faster and more convenient.

iv. **Equipment Identity Register (EIR):** The EIR is the entity that decides whether a piece of given mobile equipment may be allowed onto the network. Each mobile equipment has a number known as the International Mobile Equipment Identity. This number, as mentioned above, is installed in the equipment and is checked by the network during registration. Dependent upon the information held in the EIR, the mobile may be allocated one of three states - allowed onto the network, barred access, or monitored in case of its problems.

v. **Authentication Centre (AuC):** The AuC is a protected database that contains the secret key also contained in the user's SIM card. It is used for authentication and for ciphering on the radio channel.

vi. **Gateway Mobile Switching Centre (GMSC):** The GMSC is the point to which a ME terminating call is initially routed, without any knowledge of the MS's location. The GMSC is thus in charge of obtaining the MSRN (Mobile Station Roaming Number) from the HLR based on the MSISDN (Mobile Station ISDN number, the "directory number" of an MS) and routing the call to the correct visited MSC. The "MSC" part of the term GMSC is misleading since the gateway operation does not require any linking to an MSC.

vii. **SMS Gateway (SMS-G):** The SMS-G or SMS gateway is the term that is used to collectively describe the two Short Message Services Gateways defined in the GSM standards. The two gateways handle messages directed in different directions. The SMS-GMSC (Short Message Service Gateway Mobile Switching Centre) is for short messages being sent to an ME. The SMS-IWMSC (Short Message Service Inter Working Mobile Switching Centre) is used for short messages originating with a mobile on that network. The SMS-GMSC role is similar to that of the GMSC. whereas the SMS-IWMSC provides a fixed access point to the Short Message Service Centre.

Base Station Subsystem (BSS)

The Base Station Subsystem (BSS) section of the 2G GSM network architecture is fundamentally associated with communicating with the mobiles on the network. It consists of two elements:

i. **Base Transceiver Station (BTS):** The BTS used in a GSM network comprises the radio transmitter-receivers and their associated antennas that transmit and receive to directly

communicate with the mobiles. The BTS is the defining element for each cell. The BTS communicates with the mobiles and the interface between the two is known as the Um interface with its associated protocols.

ii. **Base Station Controller (BSC):** The BSC forms the next stage back into the GSM network. It controls a group of BTSs and is often co-located with one of the BTSs in its group. It manages the radio resources and controls items such as handover within the group of BTSS allocates channels and the like. It communicates with the BTSs over what is termed the Abis interface.

Mobile station

Mobile stations (MS), mobile equipment (ME), or as they are most widely known, cell or mobile phones are the section of a GSM cellular network that the user sees and operates. In recent years their size has fallen dramatically while the level of functionality has greatly increased. A further advantage is that the time between charges has significantly increased.

There are several elements to the cell phone, although the two main elements are the main hardware and the SIM.

The hardware itself contains the main elements of the mobile phone including the display. case, battery, and the electronics used to generate the signal process the data receiver and to be transmitted. It also contains a number known as the International Mobile Equipment Identity (IMEI).

This is installed in the phone at manufacture and "cannot be changed. It is accessed by the network during registration to check whether the equipment has been reported as stolen. The SIM or Subscriber Identity Module contains the information that provides the identity of the user to the network. It contains a variety of information including a number known as the International Mobile Subscriber Identity (IMSI).

Operation and Support Subsystem (OSS)

The OSS or operation support subsystem is an element within the overall GSM network architecture that is connected to components of the NSS and the BSC. It is used to control

and monitor the overall GSM network and it is also used to control the traffic load of the BSS. It must be noted that as the number of BS increases with the scaling of the subscriber population some of the maintenance tasks are transferred to the BTS, allowing savings in the cost of ownership of the system.

The 2G GSM network architecture follows a logical method of operation. It is far simpler than current mobile phone network architectures which use software-defined entities to enable very flexible operation. However, the 2G GSM architecture does show the voice and operational basic functions that are needed and how they fit together. In our project, we are using GSM Module for communication purposes. That is to send an SMS or message to the respective authority saying that the Dustbin is full.

2.12 Proteus 8 Professional

- Proteus is used to simulate, design, and drawing of electronic circuits. It was invented by the Labcenter electronic.
- By using proteus you can make two-dimensional circuit designs as well.
- With the use of this engineering software, you can construct and simulate different electrical and electronic circuits on your personal computers or laptops.
- There are numerous benefits to simulating circuits on proteus before making them practically.
- Designing circuits on the proteus takes less time than practical construction of the circuit.
- The possibility of error is less in software simulation such as loose connection that takes a lot of time to find out connection's problems in a practical circuit.
- Circuit simulations provide the main feature that some components of circuits are not practical then you can construct your circuit on proteus.
- There is zero possibility of burning and damaging any electronic component in proteus.
- The electronic tools that are very expensive can easily get in proteus such as an oscilloscope.

- Using proteus you can find different parents of circuits such as current, a voltage value of any component, and resistance at any instant which is very difficult in a practical circuit.

Features of Proteus:

- There are 2 main parts of proteus first is used to design and draw different circuits and the second is for designing PCB layout.
- First is ISIS which is used to design and simulate circuits. And second is ARES used for designing a printed circuit board.
- It also provides features related to the three-dimensional view of design in PCB.

CHAPTER 3

SIMULATION AND WORKING

The Proteus 8 Professional software is used to simulate, design, and drawing of two-dimensional electronic circuits of the waste detection and segregation mechanism.

3.1 SIMULATION STEPS:

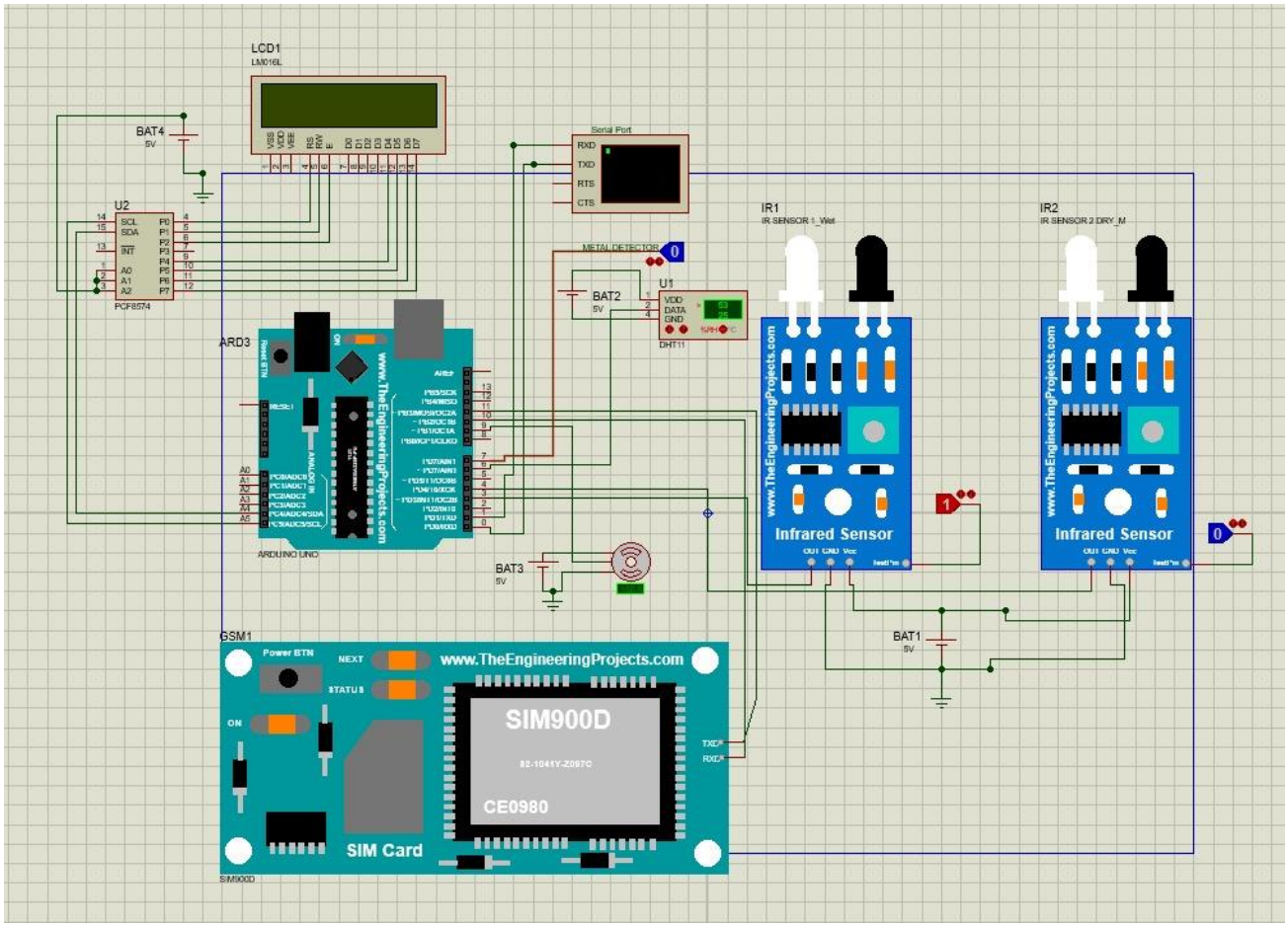

Fig 3.1: Simulation Setup

- Open the circuit sent in proteus.
- Unzip the library files sent to the proteus library location.
- Open proteus, double click on IR sensor, click add file icon, select the library file you just pasted into the library folder. Repeat the same for SIM800 or GSM module.

- Open the Arduino IDE, click on file – preferences – tick the compilation option.
- Open the Arduino file sent, compile for Arduino uno board.
- Open proteus, double click on Arduino uno, click add file icon, go to temp folder of your PC, open Arduino build folder and select the .hex file.
- Click on start button on left button corner, change the IR sensor inputs to show different states.
- To close, click stop at left corner, do not close the terminal window by any means before stopping the simulation, it will not open the next time you start simulation.

3.2 RESULT OF SIMULATION:

Refer Fig. 3.2 for detection of Dry Waste in the Simulation, the virtual terminal reads the following.

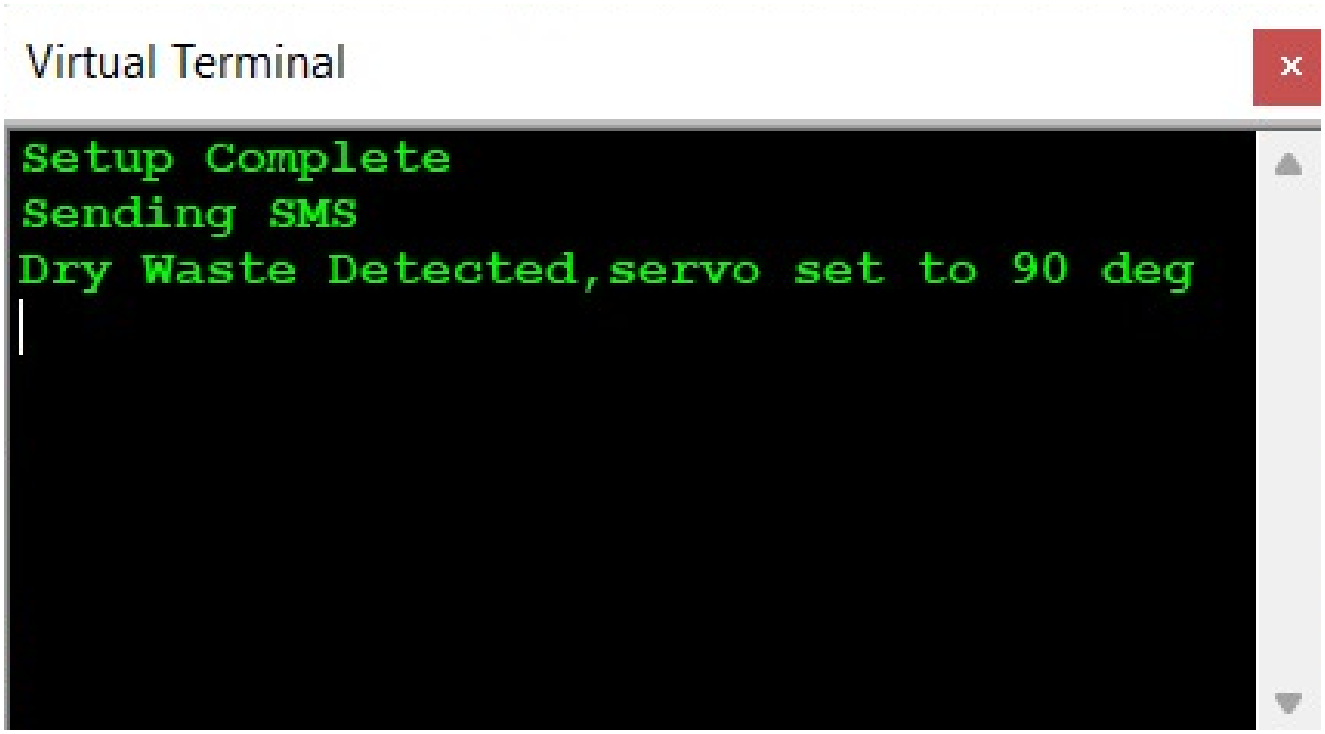

Fig 3.2: Virtual Terminal for Dry Waste Detection

Refer Fig. 3.3 for detection of Metal Waste in the Simulation, the virtual terminal reads the following.

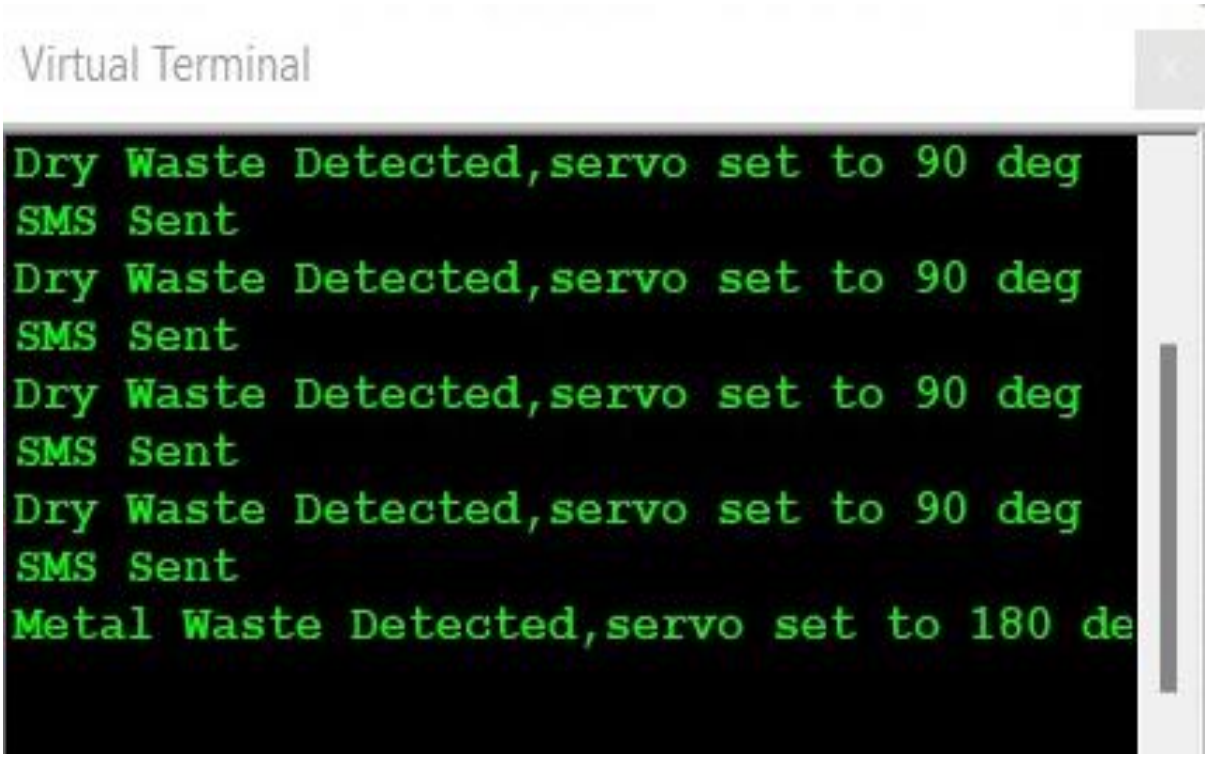

Fig 3.4: Virtual Terminal for Metal Waste Detection

3.3 WORKING OF THE MODEL:

A robotic arm, as the name suggests, acts exactly like an arm that mainly concentrates on picking and placing of the different types of waste. When the model is turned on, the bin shows a message on the LCD stating that it is ready to segregate waste. If garbage is present, the robotic arm picks it up and rotates it into the collecting aperture. The arm returns to its previous position once the garbage is placed in the collector. With the help of different types of sensors, the waste is identified and is classified as dry, wet, or metal waste based on IR

sensors, moisture sensor, and metal sensor respectively. The GSM module is utilised to send a message to the concerned authorities' phone number once the bin is discovered to be full.

Fig 3.5: Waste Detection System

Fig 3.6: LED Displaying the State of the Bins

As soon as a waste item is detected in front of the arm, the arm, which has a clamp, picks up the waste, gets identified as a particular waste and gets dropped into the respective pile. When the waste is detected and when the pile of gets full, a message is sent to the users' mobile phone through a GSM module.

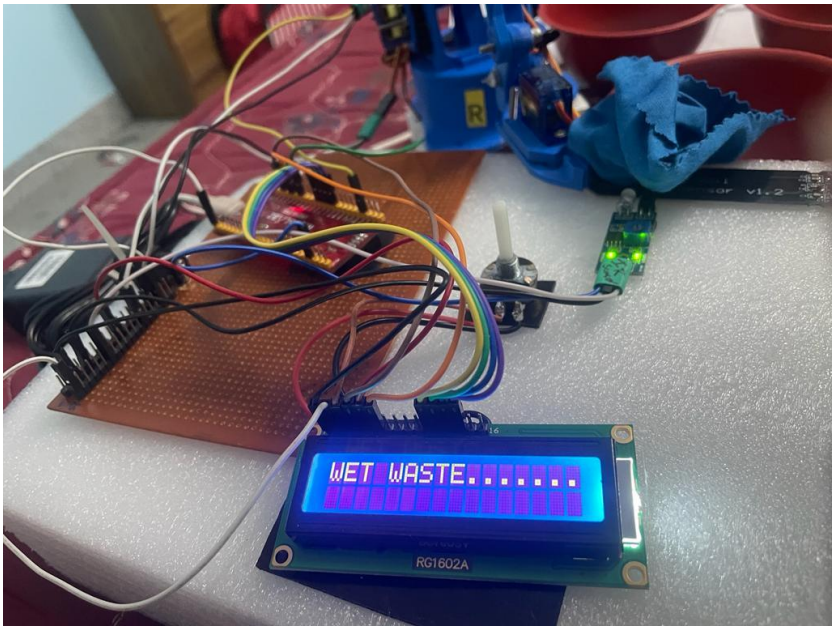

Fig 3.7: LCD Displaying Wet Waste Detection

CHAPTER 4

RESULT AND DISCUSSIONS

The prototype assisted by various sensors and a microprocessor aims at segregating wet and dry waste and further separating the dry waste into metallic, plastic, and others. The waste around the system is detected and the robotic arm performs the task of "Pick and Place" as programmed into the bin situated behind it resulting in minimizing the human interaction in waste segregation. This system is innovative, effective, efficient, and aids in the conservation of time when implemented on a larger scale. The advantage of this work is its contribution to making a smart city. Among the many challenges that a city faces, waste management is of utmost importance. The discarded waste can be then processed to recover materials effectively and convert them to energy as usable fuels.

This project not only takes a step towards implementing cleanliness in our society but also supports the "Swachh Bharat Abhiyan" proposed by our humble Prime Minister Narendra Modi.

This system can be advanced in the future by incorporating artificial intelligence for image recognition and an automatic dumping mechanism instead of manual disposal of waste when the bins are full. Further developments include the integration of machine learning and artificial intelligence to make it a humanoid waste segregation robot.

APPLICATIONS

- Management of huge volumes of waste produced by increasing urban population.
- Reduces the human interaction in waste segregation.
- It reduces the adverse effects of waste on health, the environment, and aesthetics.
- Since waste segregation is done at the source level, it helps in smoothening the process. Large-scale segregation becomes relatively easier.
- Sustainable, clean, and habitable cities.
- Low-cost procedure.
- Efficient and adaptable to various environments.

CONCLUSION AND FUTURE WORK

Conclusion

- Innovativeness and usefulness Inclusion of a vacuum cleaning mechanism with its movement is a key feature of innovativeness.
- It is a cost-effective and efficient waste management system because it improves the performance of our current waste system by making it easier for disposal and processing as segregated waste arrives directly from the bin.
- It reduces the time required for processing waste in the current waste management system as the current system does not segregate waste before the collection of waste at all places. All this collected waste is finally dumped at dump yards.
- The waste can be collected separately and used for producing energy.
- Directing the bin by defining the path for the bin to pick and place the waste into the bin is another point that adds to the innovativeness.

Industrial relevance

- It can withstand the market for a longer time because of its better features.
- Performance is good.
- Components are durable.
- It takes minimum place for installation.

Market Potential & Competitive advantage

- It is cost-effective

Innovativeness and usefulness

- Inclusion of vacuum cleaning mechanism with its movement is a key feature of innovativeness.
- It is a cost-effective and efficient waste management system because it improves the performance of our current waste system by making it easier for disposal and processing as segregated waste arrives directly from the bin.
- It reduces the time required for processing waste in the current waste management system as the current system does not segregate waste before the collection of waste at all places. All this collected waste is finally dumped at dump yards.
- The waste can be collected separately and used for producing energy.
- Directing the bin by defining the path for the bin to pick and place the waste into the bin is another point that adds to the innovativeness.

Industrial relevance

- It can withstand the market for a longer time because of its better features.
- Performance is good.
- Components are durable It takes minimum place for installation.

Market Potential & Competitive advantage

- It is cost-effective.
- It is easy to install.
- Components are available easily in the market so that we can build the circuit.
- Efficiency is more.
- The system is user-friendly.
- It is portable.
- It is flexible

Future work

- It can be made compact and more efficient by adding a crusher/compressor to increase the volume of waste that can be accumulated inside the bin.
- This system can be made more advanced and efficient by using artificial intelligence in the future.
- The model can also have a vacuum cleaner attached to it and that vacuum cleaner can suck all the dust particles on its way.

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3) S. Vinod Kumar, T. Senthil Kumaran, A. Krishna Kumar, "Smart Garbage Monitoring and Clearance System using Internet of Things",2017 IEEE International Conference on Smart Technologies and Management for Computing, Communication, Controls, Energy and Materials (lCSTM), Veltech Dr. RR & Dr.SR University, Chennai, T.N., lndia.2

4) August 2017 4) Amrutha Chandramohan, Joyal Mendonca, Nikhil Ravi Shankar, "Automated Waste Segregator", India Educators' Conference (TIIEC), 2014 Texas Instruments

5) Deeksha More E.K, Divya.S, G. Kalyani, Gowthami. R, "Automatic Waste Segregator Bin using Robotic Arm",2018 3111 IEEE International Conference on Recent Trends in Electronics, Information & Communication Technology (RTEICT-2018)

6)https://www.elprocus.com/ann7-based-lpc2148-microcontroller-pinconfiguration/

7) https://www.elprocus.com/ever-wondered-lcd-works

APPENDIX A

Pin Configuration of LPC2148:

Pin Number	Pin Configuration	Interface	Comments	Pin Number
P0.0	TXD0	GSM RX		P1.0
P0.1	RXD0	GSM TX		P1.1
P0.2				P1.2
P0.3				P1.3
P0.4	ADC	RS of LCD		P1.4
P0.5	ADC	Unused		P1.5
P0.6	ADC	E of LCD		P1.6
P0.7	PWM	SERVO 1 Claw		P1.7
P0.8	ADC/PWM	SERVO 2 Right		P1.8
P0.9	PWM	SERVO 3 Optional Left		P1.9
P0.10	ADC			P1.10
P0.11				P1.11
P0.12	ADC	D4 of LCD		P1.12
P0.13	ADC	D5 of LCD		P1.13
P0.14		D6 of LCD		P1.14
P0.15	ADC	D7 of LCD		P1.15
P0.16				P1.16
P0.17				P1.17
P0.18				P1.18
P0.19				P1.19
P0.20				P1.20
P0.21	PWM	SERVO 4 Sweep		P1.21
P0.22	ADC			P1.22
P0.23				P1.23
P0.24				P1.24
P0.25				P1.25
P0.26	ADC			P1.26
P0.27	ADC			P1.27
P0.28	ADC	Moisture/Humidity Sensor Output		P1.28
P0.29	ADC	IR Sensor Output		P1.29

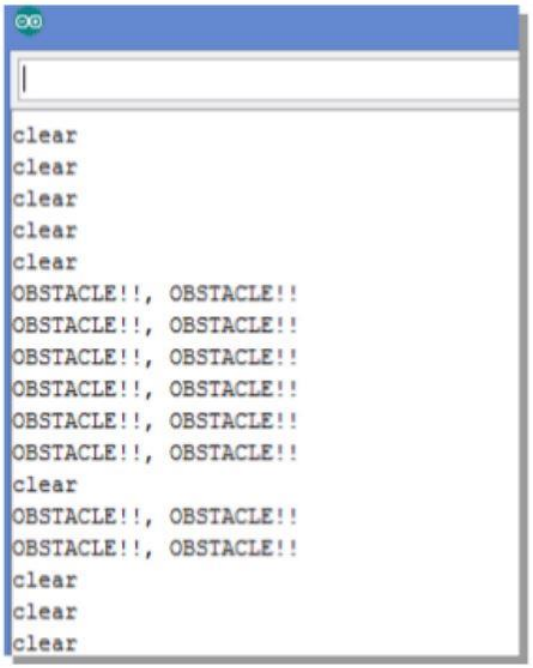
IR Sensor Specifications:

Main Chip	LM393
Operating Voltage (VDC)	3.6 ~ 5
Average Current Consumption (mA)	0.06
Detection Angle	35 Â°
Distance Measuring Range (CM)	2 ~ 30
Dimensions (mm) LxWxH	48 × 14 × 8
Weight (gm)	5
Shipment Weight	0.01 kg
Shipment Dimensions	5 × 4 × 1 cm

Pin, Control Indicator	Description
Vcc	3.3 to 5 Vdc Supply Input
Gnd	Ground Input
Out	Output that goes low when obstacle is in range
Power LED	Illuminates when power is applied
Obstacle LED	Illuminates when obstacle is detected
Distance Adjust	Adjust detection distance. CCW decreases distance. CW increases distance.
IR Emitter	Infrared emitter LED
IR Receiver	Infrared receiver that receives signal transmitted by Infrared emitter.

Test the Tutorial Sketch

Move your hand towards the IR LEDs. As you near them, the Output LED on the module and the LED for pin 13 on your Arduino will illuminate. Open your serial monitor and vary the distance of your hand while viewing the serial monitor. The output should look like the picture below:



Moisture Sensor Specification:

Operating Voltage	3.3 ~ 5.5 VDC
Output Voltage	0 ~ 3.0VDC
Operating Current	5mA
Interface	PH2.54-3P
Dimensions mm(LxWxH)	98 × 23 × 4
Weight (gm)	15
Shipment Weight	0.018 kg
Shipment Dimensions	12 × 4 × 1 cm

SIM900A GSM Module:

SIM900A Pin Configuration

The Module SIM900A looks like a single chip but it has a bunch of features that can help to build almost many commercial applications. Although, there are a total of 68 pins on SIM900A and using these pins helps to build the applications. But we will need few pins if you we use a module for interfacing with Arduino. We list details of pinout diagram in next section.

SIM900A GSM Module Pin Configuration Descripton

GPIO Pins:

The GPIO pins help to perform the simple and advance I/O function. All pins give the maximum output equal to the power supply which is useable to control most of the devices like sensors and other modules. All GPIO pins in SIM900A are:

- GPIO1 – Pin40
- GPIO2 – Pin41
- GPIO3 – Pin42
- GPIO4 – Pin43
- GPIO5 – Pin44
- GPIO6 – Pin47
- GPIO7 – Pin48
- GPIO8 – Pin49
- GPIO9 – Pin50
- GPIO10 – Pin51
- GPIO11 – Pin67
- GPIO12 – Pin68

Status Pins:

The module has two status pins which help to indicate two different kinds of status. The first one is the working status of the module and the second for communication status. Net status means

either the module is connecting to the network or other network functions, etc. Both these pins can't operate LED directly. They always act with a combination of a transistor.

- STATUS – Pin52
- NIGHTLIGHT – Pin66

SIM900A Display Interface Pins:

The device offers a 4 pin display interface with itself. The display isn't necessary, it is only in case of requirement. The use of interface helps to get the visualization with the module and make it an application. All display pins are:

- DISP_DATA – Pin12 – For Display Data
- DISP_CLK – Pin11 – For Clock Input
- DISP_CS – Pin14 – To enable the display
- DISP_D/C – Pin13 – To select between data and command

I2C Pins:

SIM900A has multiple kinds of communication and I2C is one of them due to is popularity. The module has a single I2C protocol pin, which helps to build the application with any module with that communication.

- SCL – Pin38
- SDA – Pin37

SDA for data and SCL for clock pulse.

SIM900A GSM Module Keypad interface Pins

The two-pin keypad is interfaceable with the module. The module will take the keypad data as a 2D matrix value from the KCB pins for each value. The keypad interface pins in the module are:

- KBR0~KBR4 (ROWS) – Pin40~Pin44
- KBC0~KBC4 (COLUMN) – Pin47~Pin51

Serial Port:

The UART_serial interface uses the two pins for proper data communication, which are RX and TX. Both pins have no independence on any other pins or modules. In SIM900A these pins are available, but it also has some other pins for status/indication of data. By combining these pins, the serial port helps to generate the RS-232 connector too. All the serial pins are:

- RXD – Pin10 – To receive the data
- TXD – Pin 9- To send the data
- RTS – Pin8 – To send the request of data transmission
- CTS – Pin7 – To clear the send request
- RI – Pin4 – Ring indicator
- DSR – Pin6 – To indicate that data set ready
- DCD – Pin5 – To indicate data carry detect
- DTR – Pin3 – To indicate data terminal ready

Debug Interface

Debugging helps the developers to debug the module and update its firmware. In this module, there are sperate serial interface pins for debugging. Both pins are:

- DBG_TXD – Pin27 – For Data Transmission
- DBG_RXD – Pin28 – For Data receiving

SIM Interface:

As we know that module SIM900A is a GPRS/GSM module. The module is dependent on some devices for some of its features. The most important one is the SIM. The SIM needs to connect with the module for GPRS/GSM functions to fully operate. All the sim interface of the module is:

- SIM_ SIM_VDD – Pin30 – Power Supply of the SIM
- SIM_DATA – Pin31 – For data output
- SIM_CLK – Pin32 – For clock pulse
- SIM_RST – Pin33 – For reset
- PRESENCE – Pin34 – To detect the SIM

SIM900A Analog to Digital converter Pins:

The module has only a single pin to detect and convert the analog signal to digital for SIM900A. The voltage range on the ADC pin is from 0 to 3 only.

- ADC – Pin25

PWM Pins

The PWM is mostly in microcontrollers for industrial applications but due to IoT, the module offers two PWM pins which helps to make the IoT and PWM based device without using any third interface.

- PWM1 – Pin35
- PWM2 – Pin36

Audio Interface:

The audio interface will help to connect the mic and speaker with SIM900A. The connection of Line, Audio and Speaker will help to make the calls through the modules.

- MIC_P – Pin19
- MIC_N – Pin20
- SPK_P – Pin21
- SPK_N – Pin22
- LINEIN_R – Pin23
- LINE_L – Pin24

Control Pin:

There is power on pins on the device, which helps to turn it on using external signals. There is two power on pins. The first one is PWRKEY which requires a LOW signal to power on/off the system. To do that, the pins require an input signal for a little bit long time. The second pin is PWRKEY_OUT, which gets short with the PWRKEY pin and turn on/off the device.

- PWRKEY – Pin1
- PWRKEY_OUT – Pin2

Reset pins:

The device has an external LOW input signal reset pin to reset the device with the use of an external signal.

- NRESET – Pin16

SIM900A GSM Module RF Antenna:

To extend the range of the SIM900A the antenna pin needs to connect with an external wire. The official antenna is also available for the module.

- RF_ANT – Pin60

Power Pins:

The module SIM900A has multiple types of power pin. Some works as input and some as output. The most important one to understand is VRTC, which acts as a backup for the internal RTC of the device. All power and ground pins of the module are:

- VBAT(Input) – Pin55, Pin56, Pin57
- VRTC (Input/Output) – Pin26
- VDD_EXT(OUTPUT) – Pin15
- GND – Pin17, Pin18, Pin29, Pin39, Pin45, Pin46, Pin53, Pin54, Pin58, Pin59, Pin61, Pin62, Pin63, Pin64, Pin65

LCD Display Specifications:

Model	JHD 16×2
Characters	16
Character Color	White
Backlight	Blue
Input Voltage (V)	5
Length (mm)	80
Width (mm)	36
Height (mm)	14.5
Weight (gm)	30
Shipment Weight	0.033 kg
Shipment Dimensions	9 × 5 × 1 cm

APPENDIX B

Pin Description of LPC2148:

Symbol	Pin	Type	Description
P0.0 to P0.31		I/O	**Port 0:** Port 0 is a 32-bit I/O port with individual direction controls for each bit. Total of 31 pins of the Port 0 can be used as a general purpose bidirectional digital I/Os while P0.31 is output only pin. The operation of port 0 pins depends upon the pin function selected via the pin connect block. Pins P0.24, P0.26 and P0.27 are not available.
P0.0/TXD0/ PWM1	19 [1]	I/O	**P0.0** — General purpose input/output digital pin (GPIO).
		O	**TXD0** — Transmitter output for UART0.
		O	**PWM1** — Pulse Width Modulator output 1.
P0.1/RXD0/ PWM3/EINT0	21 [2]	I/O	**P0.1** — General purpose input/output digital pin (GPIO).
		I	**RXD0** — Receiver input for UART0.
		O	**PWM3** — Pulse Width Modulator output 3.
		I	**EINT0** — External interrupt 0 input
P0.2/SCL0/ CAP0.0	22 [3]	I/O	**P0.2** — General purpose input/output digital pin (GPIO).
		I/O	**SCL0** — I^2C0 clock input/output. Open-drain output (for I^2C-bus compliance).
		I	**CAP0.0** — Capture input for Timer 0, channel 0.
P0.3/SDA0/ MAT0.0/EINT1	26 [3]	I/O	**P0.3** — General purpose input/output digital pin (GPIO).
		I/O	**SDA0** — I^2C0 data input/output. Open-drain output (for I^2C-bus compliance).
		O	**MAT0.0** — Match output for Timer 0, channel 0.
		I	**EINT1** — External interrupt 1 input.
P0.4/SCK0/ CAP0.1/AD0.6	27 [4]	I/O	**P0.4** — General purpose input/output digital pin (GPIO).
		I/O	**SCK0** — Serial clock for SPI0. SPI clock output from master or input to slave.
		I	**CAP0.1** — Capture input for Timer 0, channel 0.
		I	**AD0.6** — ADC 0, input 6.
P0.5/MISO0/ MAT0.1/AD0.7	29 [4]	I/O	**P0.5** — General purpose input/output digital pin (GPIO).
		I/O	**MISO0** — Master In Slave OUT for SPI0. Data input to SPI master or data output from SPI slave.
		O	**MAT0.1** — Match output for Timer 0, channel 1.
		I	**AD0.7** — ADC 0, input 7.
P0.6/MOSI0/ CAP0.2/AD1.0	30 [4]	I/O	**P0.6** — General purpose input/output digital pin (GPIO).
		I/O	**MOSI0** — Master Out Slave In for SPI0. Data output from SPI master or data input to SPI slave.
		I	**CAP0.2** — Capture input for Timer 0, channel 2.
		I	**AD1.0** — ADC 1, input 0. Available in LPC2148 only.
P0.7/SSEL0/ PWM2/EINT2	31 [2]	I/O	**P0.7** — General purpose input/output digital pin (GPIO).
		I	**SSEL0** — Slave Select for SPI0. Selects the SPI interface as a slave.
		O	**PWM2** — Pulse Width Modulator output 2.
		I	**EINT2** — External interrupt 2 input.
P0.8/TXD1/ PWM4/AD1.1	33 [4]	I/O	**P0.8** — General purpose input/output digital pin (GPIO).
		O	**TXD1** — Transmitter output for UART1.
		O	**PWM4** — Pulse Width Modulator output 4.
		I	**AD1.1** — ADC 1, input 1. Available in LPC2148 only.

Symbol	Pin	Type	Description
P0.9/RXD1/ PWM6/EINT3	34 [2]	I/O	**P0.9** — General purpose input/output digital pin (GPIO).
		I	**RXD1** — Receiver input for UART1.
		O	**PWM6** — Pulse Width Modulator output 6.
		I	**EINT3** — External interrupt 3 input.
P0.10/RTS1/ CAP1.0/AD1.2	35 [4]	I/O	**P0.10** — General purpose input/output digital pin (GPIO).
		O	**RTS1** — Request to Send output for UART1. Available in LPC2148 only.
		I	**CAP1.0** — Capture input for Timer 1, channel 0.
		I	**AD1.2** — ADC 1, input 2. Available in LPC2148 only.
P0.11/CTS1/ CAP1.1/SCL1	37 [3]	I/O	**P0.11** — General purpose input/output digital pin (GPIO).
		I	**CTS1** — Clear to Send input for UART1. Available in LPC2148 only.
		I	**CAP1.1** — Capture input for Timer 1, channel 1.
		I/O	**SCL1** — I^2C1 clock input/output. Open-drain output (for I^2C-bus compliance)
P0.12/DSR1/ MAT1.0/AD1.3	38 [4]	I/O	**P0.12** — General purpose input/output digital pin (GPIO).
		I	**DSR1** — Data Set Ready input for UART1. Available in LPC2148 only.
		O	**MAT1.0** — Match output for Timer 1, channel 0.
		I	**AD1.3** — ADC input 3. Available in LPC2148 only.
P0.13/DTR1/ MAT1.1/AD1.4	39 [4]	I/O	**P0.13** — General purpose input/output digital pin (GPIO).
		O	**DTR1** — Data Terminal Ready output for UART1. Available in LPC2148 only.
		O	**MAT1.1** — Match output for Timer 1, channel 1.
		I	**AD1.4** — ADC input 4. Available in LPC2148 only.
P0.14/DCD1/ EINT1/SDA1	41 [3]	I/O	**P0.14** — General purpose input/output digital pin (GPIO).
		I	**DCD1** — Data Carrier Detect input for UART1. Available in LPC2148 only.
		I	**EINT1** — External interrupt 1 input.
		I/O	**SDA1** — I^2C1 data input/output. Open-drain output (for I^2C-bus compliance)
P0.15/RI1/ EINT2/AD1.5	45 [4]	I/O	**P0.15** — General purpose input/output digital pin (GPIO).
		I	**RI1** — Ring Indicator input for UART1. Available in LPC2148 only.
		I	**EINT2** — External interrupt 2 input.
		I	**AD1.5** — ADC 1, input 5. Available in LPC2148 only.
P0.16/EINT0/ MAT0.2/CAP0.2	46 [2]	I/O	**P0.16** — General purpose input/output digital pin (GPIO).
		I	**EINT0** — External interrupt 0 input.
		O	**MAT0.2** — Match output for Timer 0, channel 2.
		I	**CAP0.2** — Capture input for Timer 0, channel 2.
P0.17/CAP1.2/ SCK1/MAT1.2	47 [1]	I/O	**P0.17** — General purpose input/output digital pin (GPIO).
		I	**CAP1.2** — Capture input for Timer 1, channel 2.
		I/O	**SCK1** — Serial Clock for SSP. Clock output from master or input to slave.
		O	**MAT1.2** — Match output for Timer 1, channel 2.
P0.18/CAP1.3/ MISO1/MAT1.3	53 [1]	I/O	**P0.18** — General purpose input/output digital pin (GPIO).
		I	**CAP1.3** — Capture input for Timer 1, channel 3.
		I/O	**MISO1** — Master In Slave Out for SSP. Data input to SPI master or data output from SSP slave.
		O	**MAT1.3** — Match output for Timer 1, channel 3.

Symbol	Pin	Type	Description
P0.19/MAT1.2/ MOSI1/CAP1.2	54 [1]	I/O	**P0.19** — General purpose input/output digital pin (GPIO).
		O	**MAT1.2** — Match output for Timer 1, channel 2.
		I/O	**MOSI1** — Master Out Slave In for SSP. Data output from SSP master or data input to SSP slave.
		I	**CAP1.2** — Capture input for Timer 1, channel 2.
P0.20/MAT1.3/ SSEL1/EINT3	55 [2]	I/O	**P0.20** — General purpose input/output digital pin (GPIO).
		O	**MAT1.3** — Match output for Timer 1, channel 3.
		I	**SSEL1** — Slave Select for SSP. Selects the SSP interface as a slave.
		I	**EINT3** — External interrupt 3 input.
P0.21/PWM5/ AD1.6/CAP1.3	1 [4]	I/O	**P0.21** — General purpose input/output digital pin (GPIO).
		O	**PWM5** — Pulse Width Modulator output 5.
		I	**AD1.6** — ADC 1, input 6. Available in LPC2148 only.
		I	**CAP1.3** — Capture input for Timer 1, channel 3.
P0.22/AD1.7/ CAP0.0/MAT0.0	2 [4]	I/O	**P0.22** — General purpose input/output digital pin (GPIO).
		I	**AD1.7** — ADC 1, input 7. Available in LPC2148 only.
		I	**CAP0.0** — Capture input for Timer 0, channel 0.
		O	**MAT0.0** — Match output for Timer 0, channel 0.
P0.23	58 [1]	I/O	**P0.23** — General purpose input/output digital pin (GPIO).
		I/O	$\mathbf{V_{BUS}}$ — Indicates the presence of USB bus power.
P0.25/AD0.4/ AOUT	9 [5]	I/O	**P0.25** — General purpose input/output digital pin (GPIO).
		I	**AD0.4** — ADC 0, input 4.
		O	**AOUT** — DAC output.
P0.28/AD0.1/ CAP0.2/MAT0.2	13 [4]	I/O	**P0.28** — General purpose input/output digital pin (GPIO).
		I	**AD0.1** — ADC 0, input 1.
		I	**CAP0.2** — Capture input for Timer 0, channel 2.
		O	**MAT0.2** — Match output for Timer 0, channel 2.
P0.29/AD0.2/ CAP0.3/MAT0.3	14 [4]	I/O	**P0.29** — General purpose input/output digital pin (GPIO).
		I	**AD0.2** — ADC 0, input 2.
		I	**CAP0.3** — Capture input for Timer 0, Channel 3.
		O	**MAT0.3** — Match output for Timer 0, channel 3.
P0.30/AD0.3/ EINT3/CAP0.0	15 [4]	I/O	**P0.30** — General purpose input/output digital pin (GPIO).
		I	**AD0.3** — ADC 0, input 3.
		I	**EINT3** — External interrupt 3 input.
		I	**CAP0.0** — Capture input for Timer 0, channel 0.

Symbol	Pin	Type	Description
P0.31/UP_LED/ CONNECT	17 [6]	O	**P0.31** — General purpose output only digital pin (GPO).
		O	**UP_LED** — USB Good Link LED indicator. It is LOW when device is configured (non-control endpoints enabled). It is HIGH when the device is not configured or during global suspend.
		O	**CONNECT** — Signal used to switch an external 1.5 kΩ resistor under the software control. Used with the Soft Connect USB feature. **Important:** This is an digital output only pin. This pin MUST NOT be externally pulled LOW when RESET pin is LOW or the JTAG port will be disabled.
P1.0 to P1.31		I/O	**Port 1:** Port 1 is a 32-bit bidirectional I/O port with individual direction controls for each bit. The operation of port 1 pins depends upon the pin function selected via the pin connect block. Pins 0 through 15 of port 1 are not available.
P1.16/ TRACEPKT0	16 [6]	I/O	**P1.16** — General purpose input/output digital pin (GPIO).
		O	**TRACEPKT0** — Trace Packet, bit 0. Standard I/O port with internal pull-up.
P1.17/ TRACEPKT1	12 [6]	I/O	**P1.17** — General purpose input/output digital pin (GPIO).
		O	**TRACEPKT1** — Trace Packet, bit 1. Standard I/O port with internal pull-up.
P1.18/ TRACEPKT2	8 [6]	I/O	**P1.18** — General purpose input/output digital pin (GPIO).
		O	**TRACEPKT2** — Trace Packet, bit 2. Standard I/O port with internal pull-up.
P1.19/ TRACEPKT3	4 [6]	I/O	**P1.19** — General purpose input/output digital pin (GPIO).
		O	**TRACEPKT3** — Trace Packet, bit 3. Standard I/O port with internal pull-up.
P1.20/ TRACESYNC	48 [6]	I/O	**P1.20** — General purpose input/output digital pin (GPIO).
		O	**TRACESYNC** — Trace Synchronization. Standard I/O port with internal pull-up. LOW on TRACESYNC while $\overline{\text{RESET}}$ is LOW enables pins P1[25:16] to operate as Trace port after reset.
P1.21/ PIPESTAT0	44 [6]	I/O	**P1.21** — General purpose input/output digital pin (GPIO).
		O	**PIPESTAT0** — Pipeline Status, bit 0. Standard I/O port with internal pull-up.
P1.22/ PIPESTAT1	40 [6]	I/O	**P1.22** — General purpose input/output digital pin (GPIO).
		O	**PIPESTAT1** — Pipeline Status, bit 1. Standard I/O port with internal pull-up.
P1.23/ PIPESTAT2	36 [6]	I/O	**P1.23** — General purpose input/output digital pin (GPIO).
		O	**PIPESTAT2** — Pipeline Status, bit 2. Standard I/O port with internal pull-up.
P1.24/ TRACECLK	32 [6]	I/O	**P1.24** — General purpose input/output digital pin (GPIO).
		O	**TRACECLK** — Trace Clock. Standard I/O port with internal pull-up.
P1.25/EXTIN0	28 [6]	I/O	**P1.25** — General purpose input/output digital pin (GPIO).
		I	**EXTIN0** — External Trigger Input. Standard I/O with internal pull-up.
P1.26/RTCK	24 [6]	I/O	**P1.26** — General purpose input/output digital pin (GPIO).
		I/O	**RTCK** — Returned Test Clock output. Extra signal added to the JTAG port. Assists debugger synchronization when processor frequency varies. Bidirectional pin with internal pull-up. LOW on RTCK while $\overline{\text{RESET}}$ is LOW enables pins P1.31:26 to operate as Debug port after reset.
P1.27/TDO	64 [6]	I/O	**P1.27** — General purpose input/output digital pin (GPIO).
		O	**TDO** — Test Data out for JTAG interface.
P1.28/TDI	60 [6]	I/O	**P1.28** — General purpose input/output digital pin (GPIO).
		I	**TDI** — Test Data in for JTAG interface.

Symbol	Pin	Type	Description
P1.29/TCK	56 [6]	I/O	**P1.29** — General purpose input/output digital pin (GPIO).
		I	**TCK** — Test Clock for JTAG interface.
P1.30/TMS	52 [6]	I/O	**P1.30** — General purpose input/output digital pin (GPIO).
		I	**TMS** — Test Mode Select for JTAG interface.
P1.31/$\overline{\text{TRST}}$	20 [6]	I/O	**P1.31** — General purpose input/output digital pin (GPIO).
		I	**$\overline{\text{TRST}}$** — Test Reset for JTAG interface.
D+	10 [7]	I/O	USB bidirectional D+ line.
D−	11 [7]	I/O	USB bidirectional D− line.
$\overline{\text{RESET}}$	57 [8]	I	**External reset input:** A LOW on this pin resets the device, causing I/O ports and peripherals to take on their default states, and processor execution to begin at address 0. TTL with hysteresis, 5 V tolerant.
XTAL1	62 [9]	I	Input to the oscillator circuit and internal clock generator circuits.
XTAL2	61 [9]	O	Output from the oscillator amplifier.
RTXC1	3 [9]	I	Input to the RTC oscillator circuit.
RTXC2	5 [9]	O	Output from the RTC oscillator circuit.
V_{SS}	6, 18, 25, 42, 50	I	**Ground:** 0 V reference.
V_{SSA}	59	I	**Analog ground:** 0 V reference. This should nominally be the same voltage as V_{SS}, but should be isolated to minimize noise and error.
V_{DD}	23, 43, 51	I	**3.3 V power supply:** This is the power supply voltage for the core and I/O ports.
V_{DDA}	7	I	**Analog 3.3 V power supply:** This should be nominally the same voltage as V_{DD} but should be isolated to minimize noise and error. This voltage is used to power the on-chip PLL.
V_{REF}	63	I	**ADC reference:** This should be nominally the same voltage as V_{DD} but should be isolated to minimize noise and error. Level on this pin is used as a reference for ADC(s) and DAC(s).
V_{BAT}	49	I	**RTC power supply:** 3.3 V on this pin supplies the power to the RTC.

Interrupt Sources:

The table given below lists the interrupt sources for each peripheral function. Each peripheral device has one interrupt line connected to the VIC, but may have several internal interrupt flags. Individual interrupt flags may also represent more than one interrupt source.

Block	Flag(s)	VIC channel #
WDT	Watchdog Interrupt (WDINT)	0
-	Reserved for software interrupts only	1
ARM Core	Embedded ICE, DbgCommRX	2
ARM Core	Embedded ICE, DbgCommTX	3
TIMER0	Match 0 to 3 (MR0, MR1, MR2, MR3) Capture 0 to 3 (CR0, CR1, CR2, CR3)	4
TIMER1	Match 0 to 3 (MR0, MR1, MR2, MR3) Capture 0 to 3 (CR0, CR1, CR2, CR3)	5
UART0	RX Line Status (RLS) Transmit Holding Register empty (THRE) RX Data Available (RDA) Character Time-out Indicator (CTI)	6
UART1	RX Line Status (RLS) Transmit Holding Register empty (THRE) RX Data Available (RDA) Character Time-out Indicator (CTI) Modem Status Interrupt (MSI) (LPC2148 only)	7
PWM0	Match 0 to 6 (MR0, MR1, MR2, MR3, MR4, MR5, MR6) Capture 0 to 3 (CR0, CR1, CR2, CR3)	8
I^2C0	SI (state change)	9
SPI0	SPIF, MODF	10
SSP	TX FIFO at least half empty (TXRIS) RX FIFO at least half full (RXRIS) Receive Timeout (RTRIS) Receive Overrun (RORRIS)	11
PLL	PLL Lock (PLOCK)	12
RTC	RTCCIF (Counter Increment), RTCALF (Alarm)	13
System Control	External Interrupt 0 (EINT0)	14
	External Interrupt 1 (EINT1)	15
	External Interrupt 2 (EINT2)	16
	External Interrupt 3 (EINT3)	17
AD0	ADC 0	18
I2C1	SI (state change)	19
BOD	Brownout Detect	20
AD1	ADC 1	21
USB	DMA interrupt, USB high priority interrupts, USB low priority interrupts	22

Pin Connect Block:

The pin connect block allows selected pins of the microcontroller to have more than one function. Configuration registers control the multiplexers to allow connection between the pin and the on-chip peripherals. Peripherals should be connected to the appropriate pins prior to being activated, and prior to any related interrupt(s) being enabled. Activity of any enabled peripheral function that is not mapped to a related pin should be considered undefined**.**

The Pin Control Module contains three registers as shown below:

Address	Name	Description	Access
0xE002 C000	PINSEL0	Pin function select register 0	Read/Write
0xE002 C004	PINSEL1	Pin function select register 1	Read/Write
0xE002 C014	PINSEL2	Pin function select register 2	Read/Write