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IoT Based Smart Irrigation System Using ESP32

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CHAPTER 1

INTRODUCTION

In this project, we develop an **IoT-Based Smart Irrigation System using ESP32 WiFi Module**. The ESP32 connects to a WiFi network and uploads real-time soil moisture level, rain detection status, and pump operation status to the **Adafruit IO cloud platform**. The system uses a soil moisture sensor to determine the water content in the soil and a rain drop sensor to detect rainfall, enabling intelligent control of irrigation. A relay module controlled by the ESP32 is used to switch the water pump automatically based on sensor data, while a 16×2 I2C LCD provides real-time local display of system parameters.

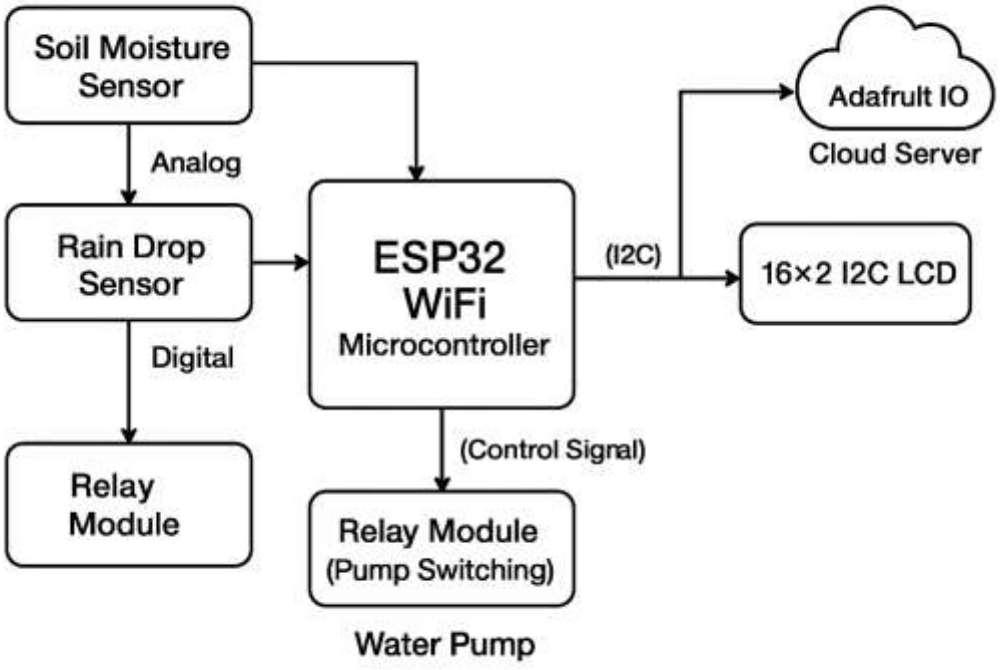
Efficient irrigation management is essential for agriculture and gardening, as traditional irrigation methods often lead to excessive water usage and manual dependency. Water scarcity is a major concern in many regions, making smart water management systems increasingly important. Over-irrigation can damage crops, increase electricity consumption, and waste water resources, while under-irrigation affects plant growth and yield. This project addresses these issues by using sensor-based automation and IoT technology to optimize water usage and improve irrigation efficiency.

The project enables continuous monitoring of soil moisture conditions and environmental factors such as rainfall using the ESP32 microcontroller. The soil moisture sensor measures the real-time moisture level of the soil, while the rain sensor ensures that irrigation is stopped during rainfall. The ESP32 processes the sensor data and controls the water pump accordingly through a relay module. Using the Adafruit IO cloud dashboard, users can remotely monitor soil moisture percentage, pump status, and rain detection status from anywhere in the world using an internet-connected device.

This smart irrigation system has a wide range of applications, including **smart agriculture, home gardening, greenhouses, nurseries, parks, and water-efficient farming practices**. By integrating automation, real-time monitoring, and IoT-based control, the system promotes sustainable agriculture, reduces water wastage, minimizes human intervention, and supports efficient utilization of natural resources.

CHAPTER 1

1.1. BLOCK DIAGRAM



1.2 DESCRIPTION

The block diagram represents the working structure of the IoT-based Smart Irrigation System designed using an ESP32 WiFi microcontroller. The system mainly consists of a soil moisture sensor, rain drop sensor, ESP32 controller, relay module, water pump, LCD display, and Adafruit IO cloud platform.

The **soil moisture sensor** is used to measure the water content present in the soil. It provides an analog output signal proportional to the soil moisture level, which is fed to the ESP32 through an analog input pin. The **rain drop sensor** detects the presence of rainfall and sends a digital signal to the ESP32, enabling the system to stop irrigation during rain conditions.

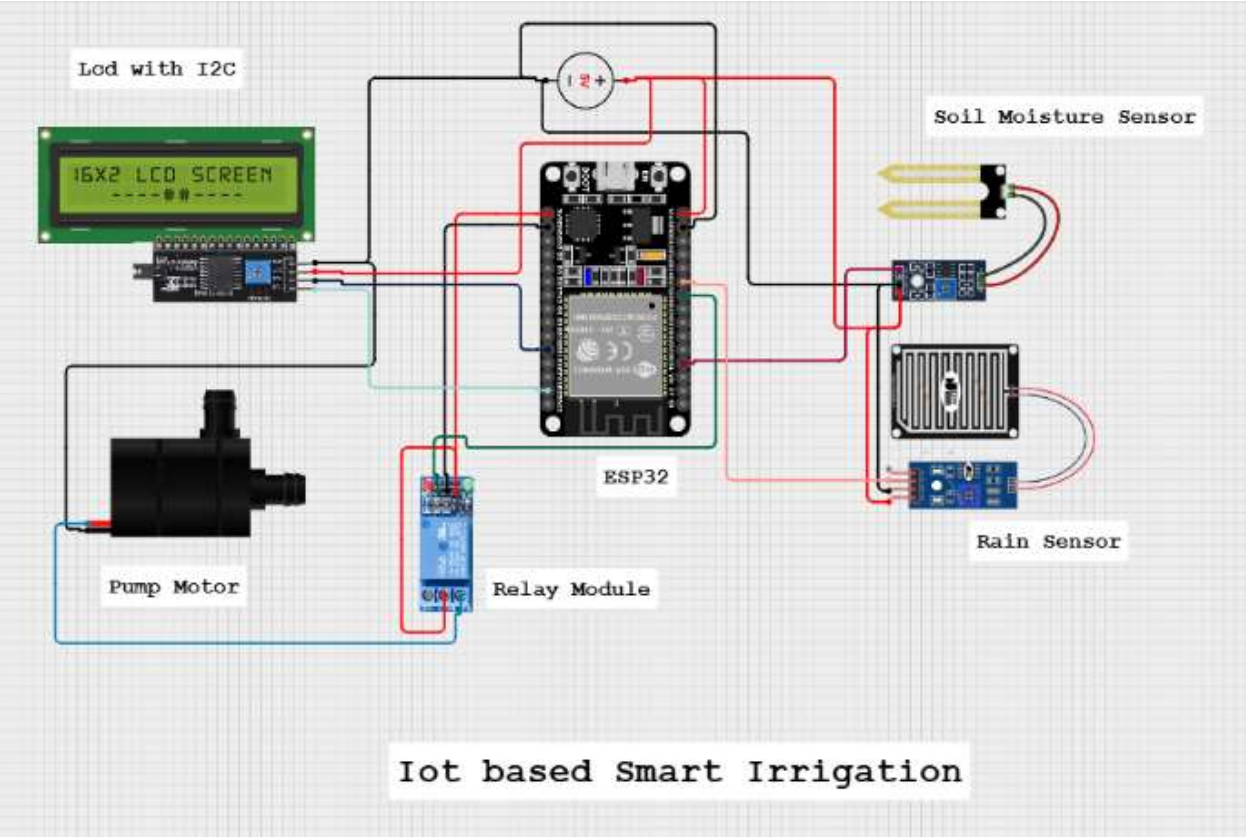
The **ESP32 WiFi microcontroller** acts as the central processing unit of the system. It continuously reads the sensor values, processes the data, and makes decisions based on predefined conditions. If the soil is dry and no rain is detected, the ESP32 activates the **relay module** through a control signal. The relay module then switches the **water pump** ON to irrigate the soil. When the soil becomes wet or rain is detected, the ESP32 turns the relay OFF, stopping the pump.

A **16×2 I2C LCD display** is connected to the ESP32 to provide real-time local information such as soil moisture percentage and pump status. Additionally, the ESP32 uses its built-in WiFi capability to upload sensor data and system status to the **Adafruit IO cloud server**. This allows users to remotely monitor soil moisture, rain detection, and pump operation from anywhere using an internet-enabled device.

Overall, the block diagram demonstrates an efficient and automated irrigation system that integrates sensors, control logic, and IoT technology to optimize water usage, reduce manual intervention, and support smart agriculture applications.

CHAPTER 2

2.1. CIRCUIT DIAGRAM



2.2. WORKING

The **ESP32-based IoT Smart Irrigation System** is designed to automatically water plants based on soil moisture levels, while also responding to rainfall, and provides real-time monitoring via an LCD display and Adafruit IO dashboard. The system uses a **soil moisture sensor**, which outputs an analog value ranging approximately from 1600 when wet to 4095 when dry. This value is inverted and mapped to a percentage scale from 0% to 100% for intuitive understanding, where 100% represents wet soil and 0% represents dry soil. This moisture percentage is displayed on a 16×2 I2C LCD on the first line and also sent to the Adafruit IO cloud, where a gauge shows the current soil condition.

To prevent unnecessary watering during rainfall, a **digital rain drop sensor** is connected to the ESP32. When the sensor detects rain (digital LOW), the system immediately stops the pump regardless of the soil moisture level. The rain status is also sent to Adafruit IO to update a dedicated indicator labeled “RAIN” or “NO RAIN.”

The water pump is controlled via a **3.3V-compatible active-low relay module** connected to the ESP32 GPIO 26. When the soil is dry and no rain is detected, the relay is energized (LOW), turning the pump ON. When the soil is wet or rain is detected, the relay is de-energized (HIGH), turning the pump OFF. The pump status is displayed on the second line of the LCD and sent to Adafruit IO, where an indicator shows “PUMP ON” or

"PUMP OFF." To ensure clarity on the LCD, every message line is padded to 16 characters, which eliminates leftover or garbage characters such as "FF" that can appear when overwriting shorter text.

The system's sensors, relay, and LCD all share a common ground with the ESP32 to ensure stable operation. The soil moisture sensor is connected to GPIO 34 (analog input), the rain sensor to GPIO 27 (digital input), and the LCD uses I2C pins GPIO 21 (SDA) and GPIO 22 (SCL). The relay VCC is powered from the ESP32 3.3V output, while its COM and NO terminals control the pump mains. To avoid throttling issues on Adafruit IO, the system publishes updates every 10 seconds or only when there is a significant change in moisture percentage or pump/rain status.

In operation, the system ensures the soil is maintained at the desired moisture level while conserving water during rainfall. The LCD provides immediate local feedback, showing both soil moisture percentage and pump status, while Adafruit IO allows remote monitoring from anywhere in the world. The active-low relay, rain sensor integration, and inverted moisture logic make the system both safe and intuitive, providing a reliable solution for smart irrigation in gardens or farms.

CHAPTER 3

LIST OF COMPONENT

SR. NO	COMPONENT NAME	QUANTITY	PRISE
1	RAIN SENSOR	1	500=00
2	LM7805	1	25=00
3	SOIL MOISTURE SENSOR	1	360=00
4	I2C IC	1	400=00
5	Diode 1N4007 (rectifier diode)	8	16=00
6	LED (RED,GREEN)	2	25=00
7	ESP32	1	800=00
8	LCD16*2	1	350=00
9	transformer	1	560=00
10	RELAY MODULE WITH PUMP	2	500=00
11	Capacitor 220uf/25V	6	30=00
12	Capacitor 100pf	2	10=00
13	Capacitor 1000uf	1	15=00
14	Resistor 1KE	3	03=00
15	Resistor 1.5K	1	04=00
16	Resistor 1.8K	1	04=00
17	Resistor 4.7K	4	04=00
18	10K	2	08=00
19	22K	1	08=00
20	Voltmeter	1	450=00

21	Solar panel 10Watt	1	3200=00
22	Buzzer	1	35=00
23	Transformer 12V-0-12V	1	150=00
24	Mains scrod	1	25=00
25	Other accessories	-	800=00

CHAPTER 4

COMPONENT

The basic component used in this project its description and function is given bellow.

1. **Resistor**
2. **Diode**
3. **Capacitor**
4. **Transformer**
5. **Data-sheet**

4.1RESISTOR

A package of material which exhibits a certain resistance made up into a single unit is called a resistor. Different res. having the same resistance value may be different in physical size and construction depending on its power and applications.

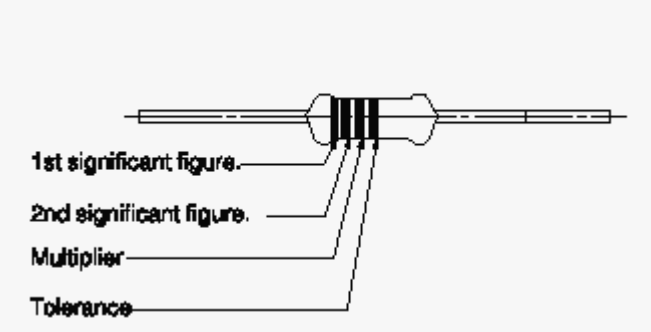
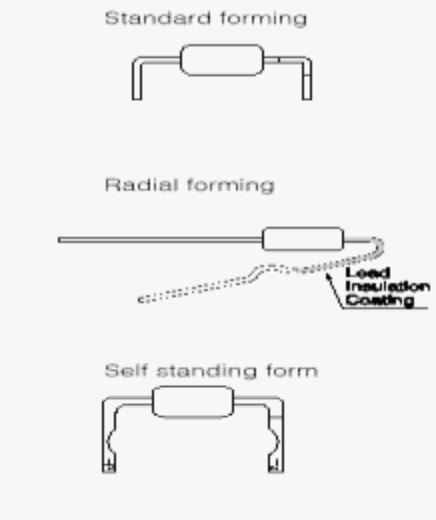


Figure above shows a typical carbon film res. which is commonly used in the market. Chip resistor is becoming more common nowadays replacing carbon film resistor.

Figure below shows the typical form of the carbon form of resistors.

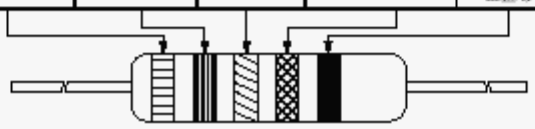


VALUE AND TOLERANCE OF RESISTANCE

Unit of resistance is ohms; the symbol for ohm is an omega. Res. values are normally shown using colored bands. Each color represents a number as shown in the table below.

Color code

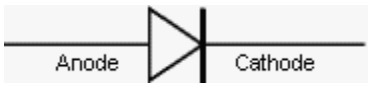
Color	First digit	Second digit	Third digit	Multiplier	tolerance	
					%	Code
Black	0	0	0	1		
Brown	1	1	1	10	±1	F
Red	2	2	2	10^2	±2	G
Orange	3	3	3	10^3	±0.05	W
Yellow	4	4	4	10^4		
Green	5	5	5	10^5	±0.5	D
Blue	6	6	6	10^6	±0.25	C
Violet	7	7	7	10^7	±0.1	B
Grey	8	8	8			
White	9	9	9			
Gold				10^{-1}	±5	J
Silver				10^{-2}	±10	K
None					±20	M



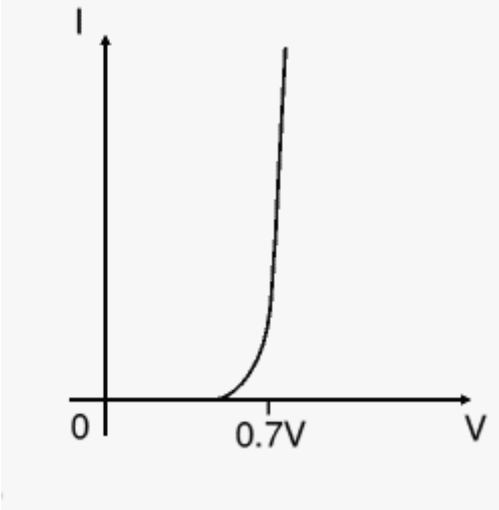
Resistor Colour Code	
Colour	Number
Black	0
Brown	1
Red	2
Orange	3
Yellow	4
Green	5
Blue	6
Violet	7
Grey	8
White	9

4.2 DIODE

There are many types of semiconductor diodes namely Selenium, Germanium and Silicon types. Selenium type is commonly used in the early days in ac power suppliers but in recent years it has been replaced by silicon type as it sometimes emit toxic fumes when it burnt out. The characteristic is that it allows current to flow in one direction as shown in the symbol below. It has a cathode and an anode which determine the flow of the current. Current can only flow from anode to cathode.



Silicon V-I characteristics are shown in the figure below. The junction barrier for silicon is about 0.7V and for Germanium is about 0.3V. It is also called forward voltage drop. Most of the diode used today is of silicon type as they are robust and reliable from DC to RF small signal applications.



The Peak Reverse Voltage (PIV) of silicon types is available up to 1000 volts or more. They can also carry up to 100A DC current. In typical applications, it is advisable to ensure that it operates within the maximum ratings specified by the manufacturer and apply the Failure Mode and Effects Analysis to the device. The temperature of the device is one of the more important parameter to consider. Heat sinks may be used where they have to handle large amount of power.

When reverse voltage is applied, there will be a small leakage current usually in the region of uA. Beyond this voltage, it will breakdown and will be damaged permanently.

TYPES OF COMMERCIAL AVAILABLE DIODE

Diode	Maximum Current	Maximum Reverse Voltage
1N4001	1A	50V
1N4007	1A	1000V
1N5401	3A	100V
1N5408	3A	1000V

4.3 ALUMINUM ELECTROLYTIC CAPACITOR

Compact but glossy, these are available in the range of <1 µF to 1 F with working voltages up to several hundred volts DC. The dielectric is a thin layer of aluminum oxide. They contain corrosive liquid and can burst if the device is connected backwards. The oxide insulating layer will tend to deteriorate in the absence of a sufficient rejuvenating voltage, and eventually the capacitor will lose its ability to withstand voltage if voltage is not applied. A capacitor to which this has happened can often be "reformed" by connecting it to a voltage source through a resistor and allowing the resulting current to slowly restore the oxide layer. Bipolar

electrolytic (also called Non-Polarized or NP capacitors) contain two capacitors connected in series opposition and are used when the DC bias voltage must occasionally reverse. Bad frequency and temperature characteristics make them unsuited for high-frequency applications. Typical values are a few nf to fared.

A **capacitor** or **condenser** is a passive electronic component consisting of a pair of condenser separated by a dielectric. When a voltage potential difference exists between the conductors, an electric field is present in the dielectric. This field stores energy and produces a mechanical force between the plates. The effect is greatest between wide, flat, parallel, narrowly separated conductors.

The applications of capacitor are energy storage, power factor correction, signal coupling, noise filters, and motor starters.

4.4 TRANSFORMER

A transformer is a device that moves electrical energy from one circuit to another through electromagnetism and without change in frequency. They are an important part of electrical systems. Transformers can come in many different sizes, from a very small coupling transformer inside a stage microphone to big units that carry hundreds of MVA used in power grids.

The main reason to use a transformer is to make power of one voltage level into power of another voltage level. High voltage is easier to send a long distance, but less voltage is easier and safer to use in the office or home. Transformers are used to increase or decrease alternating current (AC) voltage in circuits. The transformer is usually built with two coils around the same core. The primary coil is connected to supply side while secondary coil supplies power to load. The second one is called the output coil.

THERE ARE SEVERAL BASIC TYPES OF TRANSFORMERS:

- Step-up transformer: the voltage output is greater than the voltage input.
- Step-down transformer: the voltage input is greater than the voltage output.
- Some transformers have the same output voltage as input voltage and are used to electrically isolate two electrical circuits.

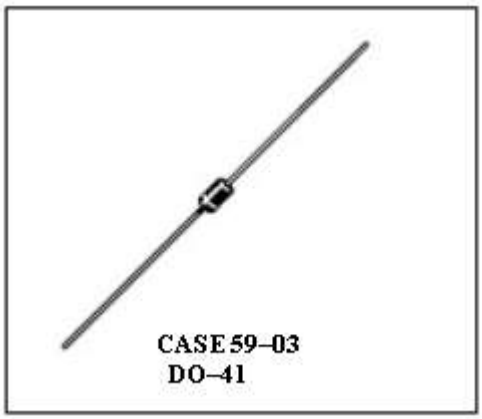
VOLTAGE AND CURRENT MEASURMENT ON DMM

A millimeter or a multicenter, also known as a VOM (Volt-Ohm meter), is an electronic measuring instrument that combines several measurement functions in one unit. A typical millimeter would include basic features such as the ability to measure voltage, current, and resistance. Analog millimeters use a micro ammeter whose pointer moves over a scale calibrated for all the different measurements that can be made. Digital millimeters (DMM, DVOM) display the measured value in numerals, and may also display a bar of a length proportional to the quantity being measured. Digital millimeters are now far more common than analog ones, but analog millimeters are still preferable in some cases, for example when monitoring a rapidly-varying value.

A millimeter can be a hand-held device useful for basic fault finding and field service work, or a bench instrument which can measure to a very high degree of accuracy. They can be used to troubleshoot electrical problems in a wide array of industrial and household devices such as electronic equipment, motor controls, domestic appliances, power supplies, and wiring systems.

MOTOROLA

1N4001 thru 1N4007



CHARACTORISTICS OF DIODE

- Weight: 0.4 gram (approximately)
- Finish: All External Surfaces Corrosion Resistant and Terminal Leads are readily Solder-able
- Lead and Mounting Surface Temperature for Soldering Purposes: 220°C Max. For 10 Seconds, 1/16″ from case.
- Shipped in plastic bags, 1000 per bag.
- Available Tape and Reeled, 5000 per reel, by adding a “RL” suffix to the Part number
- Polarity: Cathode Indicated by Polarity Band
- Marking: 1N4001, 1N4002, 1N4003, 1N4004, 1N4005, 1N4006, 1N4007

MAXIMUM RATING

Rating	Symbol	1N4001	1N4002	1N4003	1N4004	1N4005	1N4006	1N4007
Peak Repetitive Reverse Voltage Working Peak Reverse Voltage DC Blocking Voltage	VRRM VRWM VR	50	100	200	400	600	800	1000
Non–Repetitive Peak Reverse Voltage (half wave, single phase, 60 Hz)	VRSM	60	120	240	480	720	1000	1200
RMS Reverse Voltage	VR(RMS)	35	70	140	280	420	560	700

FAIRCHILD SEMICONDUCTOR®

LM78XX 3-TERMINAL 1A POSITIVE VOLTAGE REGULATOR

FEATURES

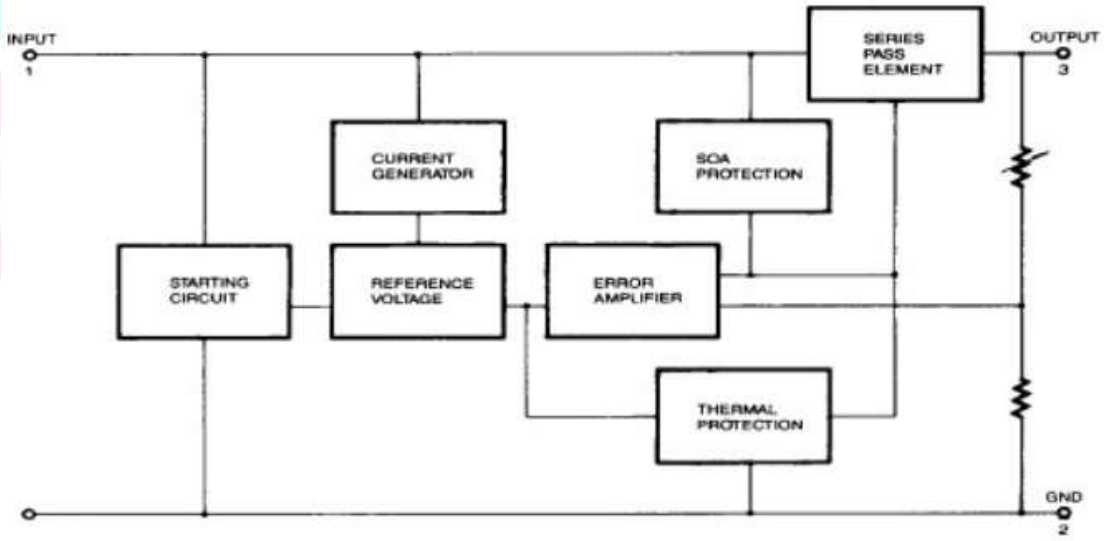
- Output Current up to 1A
- Output Voltages of 5, 6, 8, 9, 10, 12, 15, 18, 24V
- Thermal Overload Protection
- Short Circuit Protection
- Output Transistor Safe Operating Area Protection

DESCRIPTION

The MC78XX/LM78XX/MC78XXA series of three terminal positive regulators are available in the TO-220/D-PAK package and with several fixed output voltages, making them useful in a wide range of applications. Each type employs internal current limiting, thermal shut down and safe operating area protection, making it essentially indestructible. If adequate heat sinking is provided, they can deliver over 1A output current. Although designed primarily as fixed voltage regulators, these devices can be used with external components to obtain adjustable voltages and currents.

TO-220

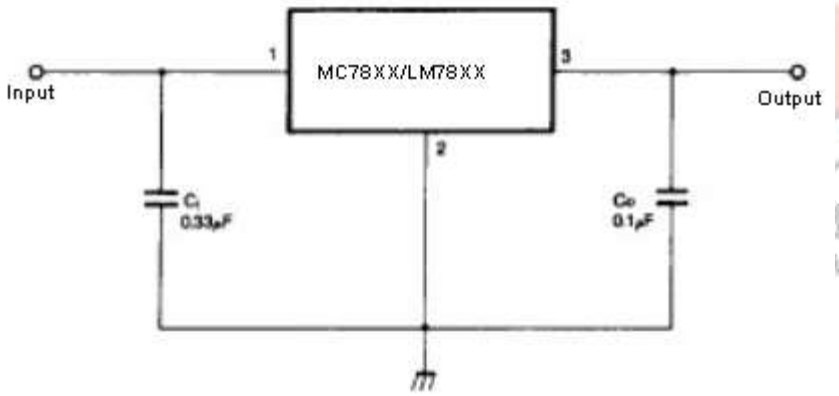
Internal Block Diagram



ABSOLUTE MAXIMUM RATINGS

Parameter	Symbol	Value	Unit
Input Voltage (for VO = 5V to 18V) (for VO = 24V)	VI VI	35 40	V V
Thermal Resistance Junction-Cases (TO-220)	RþX	5	o C/W
Thermal Resistance Junction-Air (TO-220)	RþA	65	o C/W
Operating Temperature Range	TOPR	0 ~ +125	o C
Storage Temperature Range	TSTG	-65 ~ +150	o C

TYPICAL APPLICATIONS



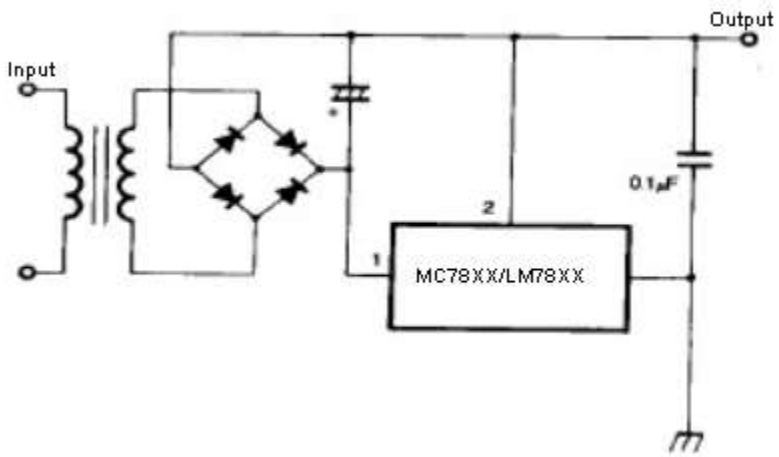
Notes:

1) To specify an output voltage. Substitute voltage value for "XX." A common ground is required between the input and the Output voltage. The input voltage must remain typically 2.0V above the output voltage even during the low point on the input ripple voltage.

2) CI is required if regulator is located an appreciable distance from power Supply filter.

3) CO improves stability and transient response.

NEGATIVE OUT PUT VOLTAGE CIRCUIT



FAIRCHILD
SEMICONDUCTOR®

BC546/547/548/549/550

Switching and Applications

- High Voltage: BC546, VCEO=65V
- Low Noise: BC549, BC550
- Complement to BC556 ... BC560

Pin-out diagram

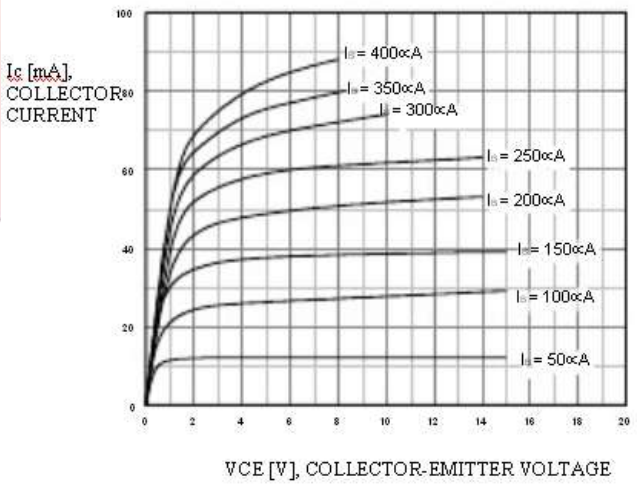
TO-92

1. Collector 2. Base 3. Emitter

Absolute Maximum Ratings

Symbol	Parameter	Value	Units
VCBO	Collector-Base Voltage : BC546 : BC547/550 : BC548/549	 80 50 30	 V V V
VCEO	Collector-Emitter voltage : BC546 : BC547/550 : BC548/549	 65 45 30	 V V V
VEBO	Emitter-Base Voltage : BC546/547 : BC548/549/550	6 5	V V
IC	Collector Current (DC)	100	mA
PC	Collector Power Dissipation	500	mW
TJ	Junction Temperature	150	ºX

Typical Characteristics



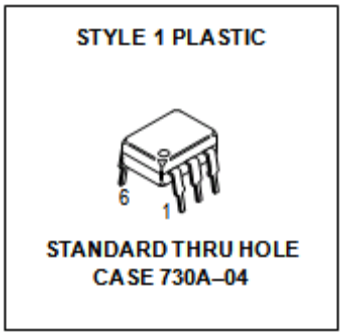
MCT2E

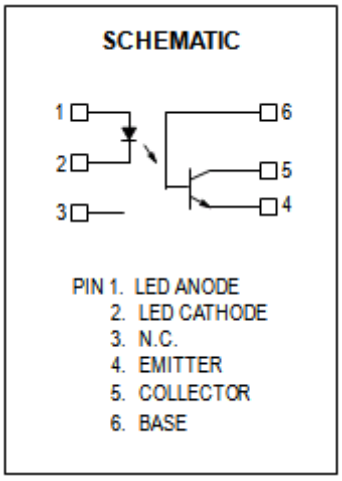
The MCT and MCT2E devices consist of a gallium arsenide infrared emitting diode optically coupled to a monolithic silicon phototransistor detector.

APPLICATIONS

- General Purpose Switching Circuits
- Interfacing and coupling systems of different potentials and impedances
- I/O Interfacing
- Solid State Relays
- Monitor and Detection Circuits

PINOUT DIAGRAM





MAXIMUM RATINGS (T_A = 25C unless otherwise noted)

INPUT LED

Rating	Symbol	Value	Unit
Reverse Voltage	V_R	3	Volts
Forward Current — Continuous	I_F	60	mA
LED Power Dissipation @ T_A = 25□C with Negligible Power in Output Detector Derate above 25□C	P_D	120	mW

OUTPUT TRNASISTOR

Rating	Symbol	Value	Unit
Collector–Emitter Voltage	V_{CEO}	30	Volts
Emitter–Collector Voltage	V_{ECO}	7	Volts
Collector–Base Voltage	V_{CBO}	70	Volts
Collector Current — Continuous	I_C	150	mA

ESP 32 CONTROLLER

1. **Introduction to ESP32 WROOM**:
- The ESP32 WROOM is a powerful and versatile microcontroller module developed by Espressif Systems.
- It is part of the ESP32 series of chips, which integrate Wi-Fi and Bluetooth capabilities, making it ideal for IoT (Internet of Things) applications.

2. **Key Features**:
- Dual-core Tensilica LX6 microprocessors, which can be individually controlled.
- Integrated Wi-Fi (802.11 b/g/n) and Bluetooth (BLE) connectivity.
- Low power consumption, supporting various power modes for energy-efficient operation.
- Rich set of peripheral interfaces including UART, SPI, I2C, GPIO, etc.
- Support for multiple development frameworks and programming languages including Arduino, MicroPython, and ESP-IDF (Espressif IoT Development Framework).
- Integrated security features such as secure boot, flash encryption, and cryptographic accelerators.
- Extensive documentation and community support.

3. **Technical Specifications**:

- Processor: Dual-core 32-bit LX6 microprocessors
- Clock Frequency: Up to 240 MHz
- Flash Memory: Up to 16 MB
- RAM: Up to 520 KB SRAM
- Wireless Connectivity: Wi-Fi 802.11 b/g/n, Bluetooth BLE
- Operating Voltage: 2.2V to 3.6V
- Operating Temperature: -40°C to +125°C
- Dimensions: Typically 18 mm x 25.5 mm

4. **Development Environment**:

- The ESP32 WROOM can be programmed using various development environments such as the Arduino IDE, MicroPython, and the Espressif IoT Development Framework (ESP-IDF).
- Arduino IDE provides an easy-to-use interface for beginners and a vast library ecosystem for rapid development.
- MicroPython offers a Python interpreter optimized for microcontrollers, allowing for quick prototyping and development.
- ESP-IDF provides low-level access to the hardware, allowing for maximum customization and optimization.

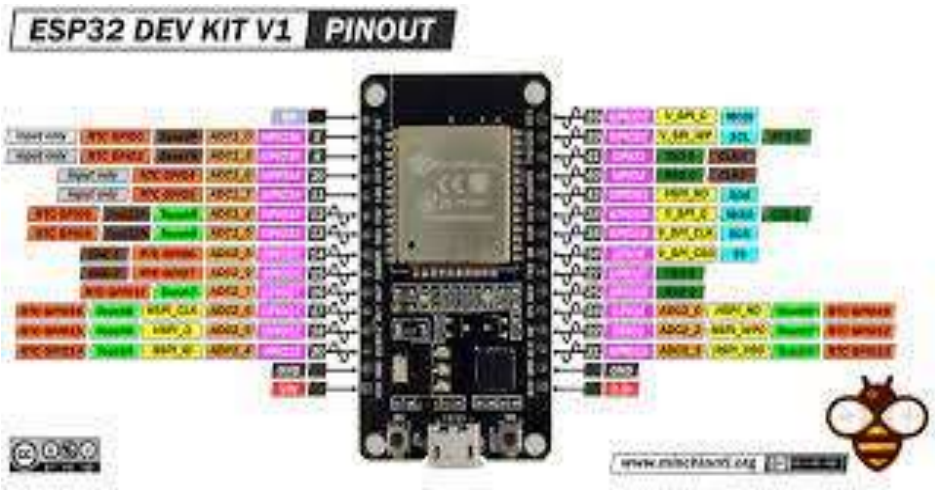
5. **Applications**:

- IoT devices such as smart home appliances, environmental monitoring systems, and wearable devices.
- Industrial automation and control systems.
- Wireless sensor networks.
- Prototyping and proof-of-concept development for various projects.

6. **Conclusion**:

- The ESP32 WROOM board offers a powerful and flexible platform for developing IoT and embedded projects.
- Its combination of processing power, wireless connectivity, and low power consumption make it suitable for a wide range of applications.
- With its extensive documentation and support, developers can quickly prototype and deploy their projects using the ESP32 WROOM.

By including these points in your project report, you can provide a comprehensive overview of the ESP32 WROOM board and its capabilities.



Pin Information:

1. **Power Pins**:
- **VIN**: Input voltage (typically 3.3V).
- **3V3**: 3.3V output pin.
- **GND**: Ground pin.

2. **Digital Pins**:
- **GPIO0 - GPIO34**: General-purpose input/output pins.
- **TX0, RX0**: Serial UART communication pins (UART0).
- **TX1, RX1**: Serial UART communication pins (UART1).
- **SCL, SDA**: I2C communication pins.
- **MOSI, MISO, SCK**: SPI communication pins.

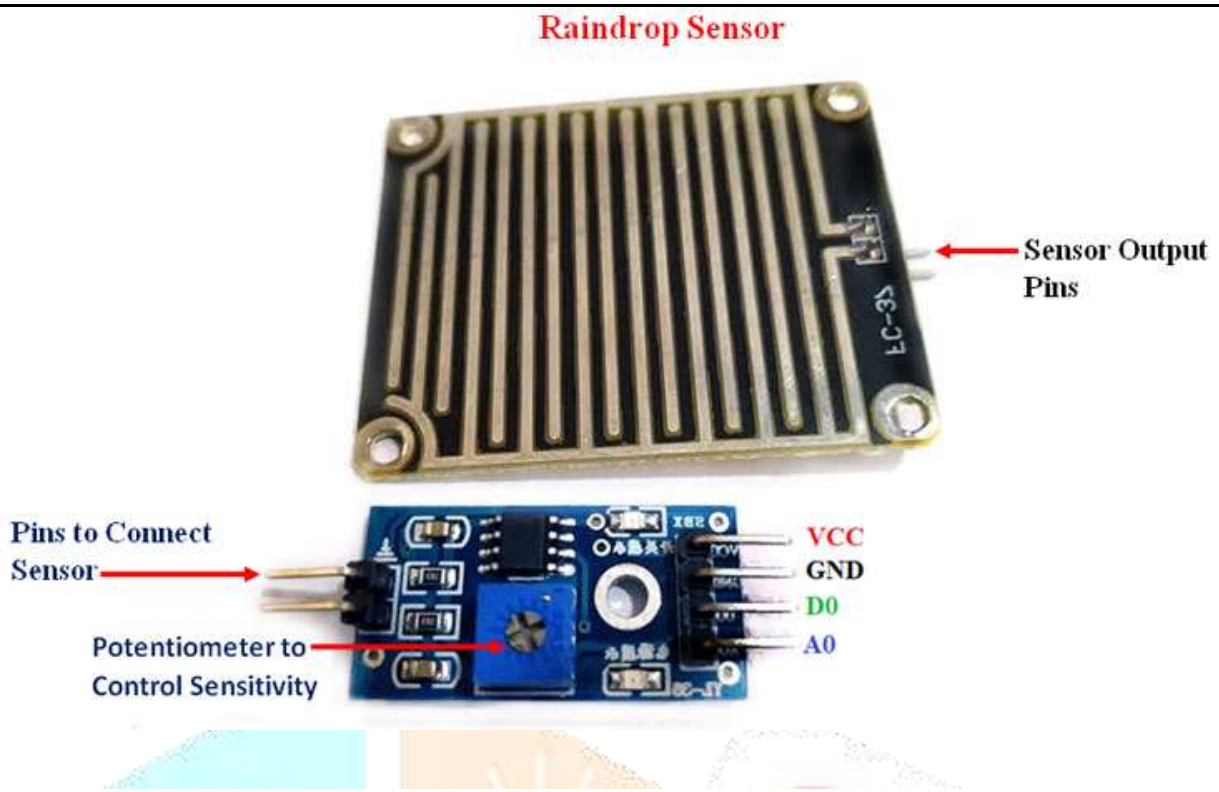
3. **Analog Pins**:
- **ADC1_0 - ADC1_8**: Analog-to-digital converter pins.

4. **Special Function Pins**:
- **EN**: Chip enable pin.
- **BOOT**: Boot mode selection pin.
- **IO0**: Bootstrapping pin for programming the chip.
- **IO13**: Built-in LED pin (may vary depending on the development board).
- **IO16**: Wake-up pin from deep sleep mode.

5. **Additional Pins**:
- **VBAT**: Battery input pin.
- **RTC GPIOs**: Pins dedicated for real-time clock (RTC) functions.
- **HSPI/VSPI**: Pins for high-speed and versatile serial peripheral interface.
- **U0RXD, U0TXD**: Serial UART communication pins (UART0, alternative).
- **U1RXD, U1TXD**: Serial UART communication pins (UART1, alternative).
- **DAC1, DAC2**: Digital-to-analog converter pins.
- **SD2, SD3**: Secondary SPI data pins.

Rain drop Sensor Module

Raindrop Sensor is a tool used for sensing rain. It consists of two modules, a **rain board** that detects the rain and a **control module**, which compares the analog value, and converts it to a digital value. The raindrop sensors can be used in the automobile sector to control the windshield wipers automatically, in the agriculture sector to sense rain and it is also used in home automation systems.



Pin Configuration of Rain Sensor:

S.No:	Name	Function
1	VCC	Connects supply voltage- 5V
2	GND	Connected to ground
3	D0	Digital pin to get digital output
4	A0	Analog pin to get analog output

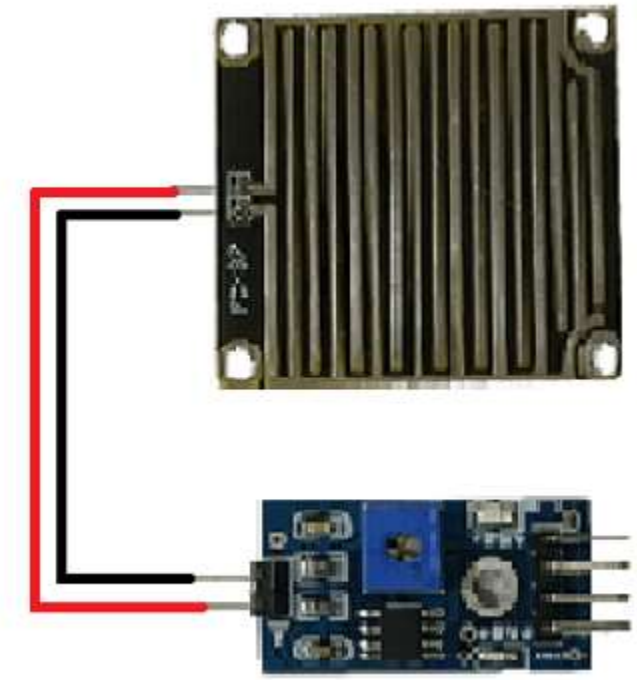
Raindrop Sensor Features:

- Working voltage 5V
- Output format: Digital switching output (0 and 1), and analog voltage output AO
- Potentiometer adjust the sensitivity
- Uses a wide voltage LM393 comparator
- Comparator output signal clean waveform is good, driving ability, over 15mA
- Anti-oxidation, anti-conductivity, with long use time
- With bolt holes for easy installation
- Small board PCB size: 3.2cm x 1.4cm

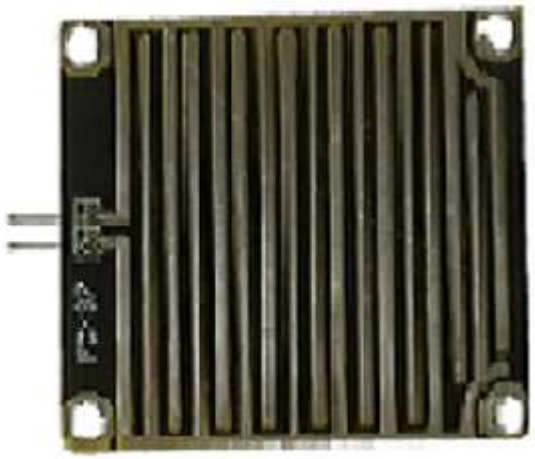
Note: The complete technical details can be found in the **Rain Sensor datasheet** given at the bottom of this page.

How to use Raindrop sensor:

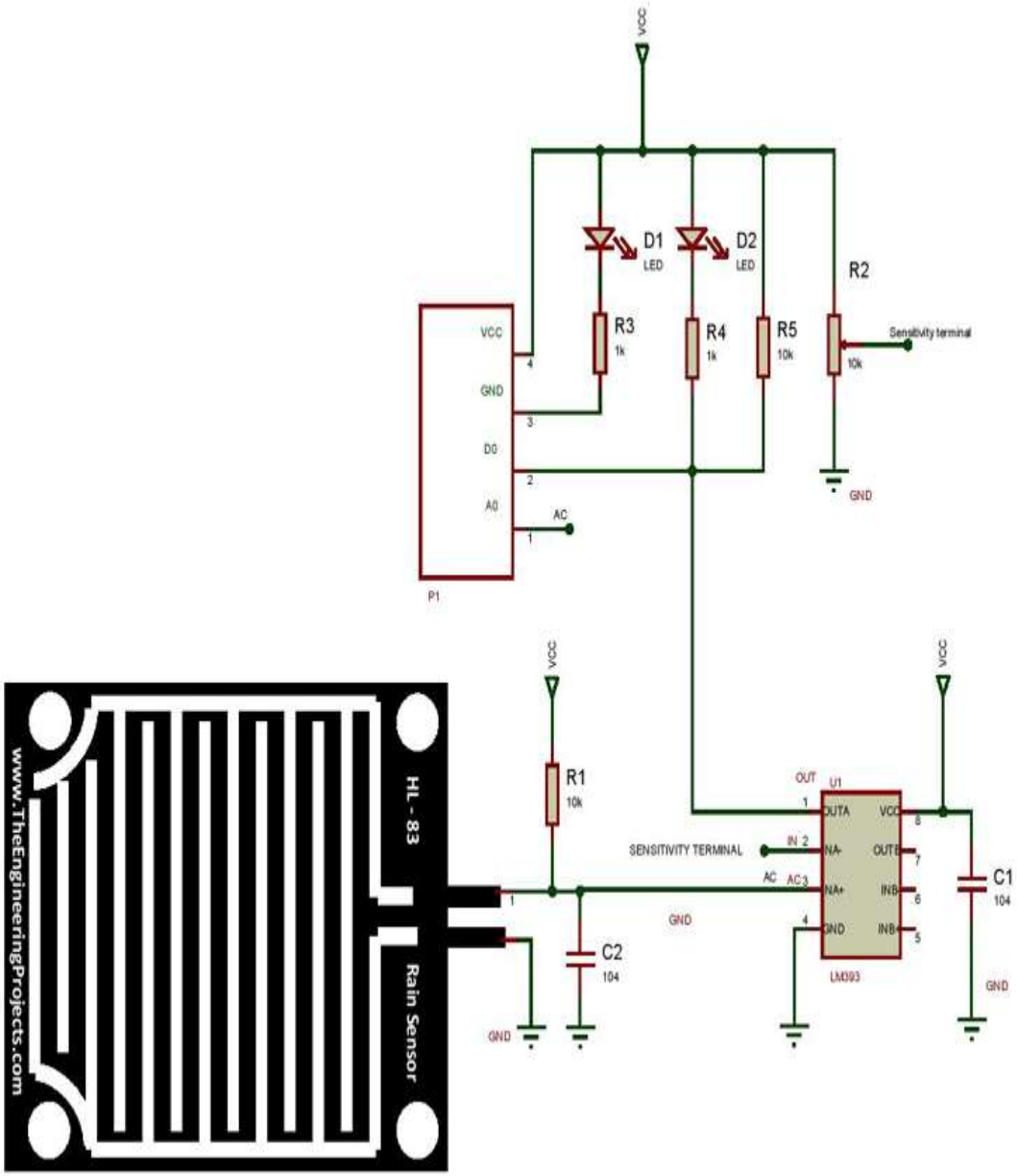
Interfacing the raindrop sensor with a microcontroller like 8051, Arduino, or PIC is simple. The rain board module is connected with the control module of the raindrop sensor as shown in the below diagram.



The control module of the raindrop sensor has 4 outputs. VCC is connected to a 5V supply. The GND pin of the module is connected to the ground. The D0 pin is connected to the digital pin of the microcontroller for digital output or the analog pin can be used. To use the analog output, the A0 pin can be connected to the ADC pin of a microcontroller. In the case of Arduino, it has 6 ADC pins, so we can use any of the 6 pins directly without using an ADC converter. The sensor module consists of a potentiometer, LN393 comparator, LEDs, capacitors and resistors. The pinout image above shows the components of the control module. The rainboard module consists of copper tracks, which act as a **variable resistor**. Its resistance varies with respect to the wetness on the rainboard. The below fig shows the rain board module.



The circuit diagram of a raindrop sensor module is given below.



As shown in the above figure, the R1 resistor and the rain board module will act as a **voltage divider**. Capacitors C1 and C2 are used as a biasing element. The input for the Non-inverting terminal is taken from the connection point of the R1, and rain board module. Another point is taken from this connection and connected to the A0 terminal of the control module.

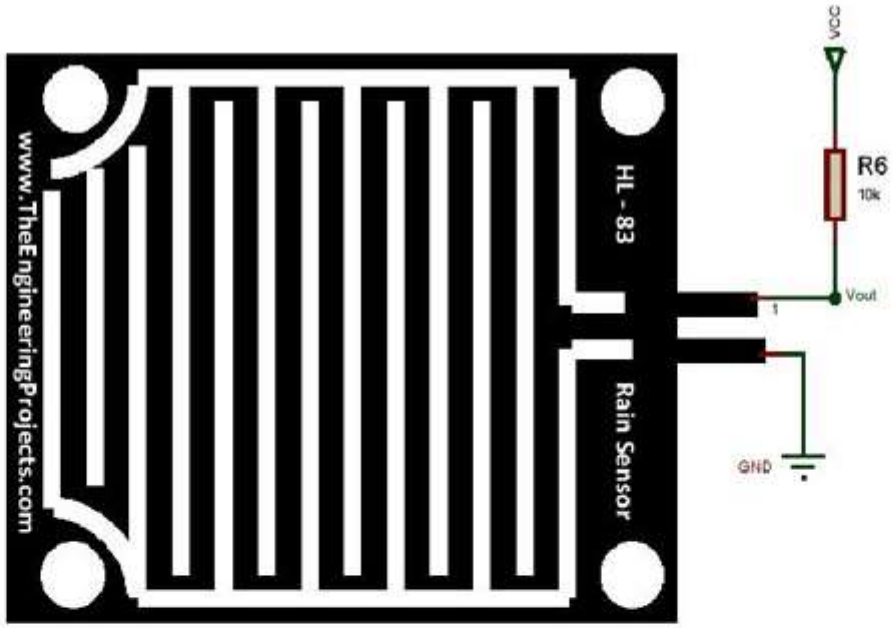
The input to the inverting terminal of the LM393 is taken from the potentiometer (R2). The R2 resistor acts as a voltage divider, and by varying R2 we can vary the input voltage to the inverting terminal, which in turn affects the sensitivity of the control module. The connections are shown in the above fig. The resistors R3 and R4 will act as current limiting resistors, while resistor R5 will act as a pull-up resistor to keep the bus in a high state when not in use.

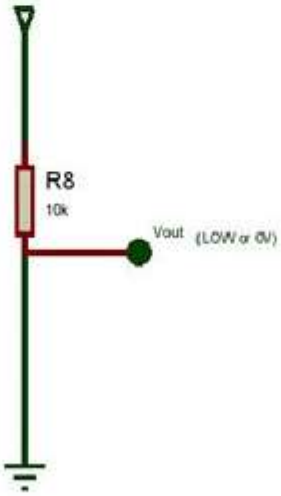
Working of Rain Sensor:

Case1: When the input of the inverting terminal is higher than the input of the non-inverting terminal.

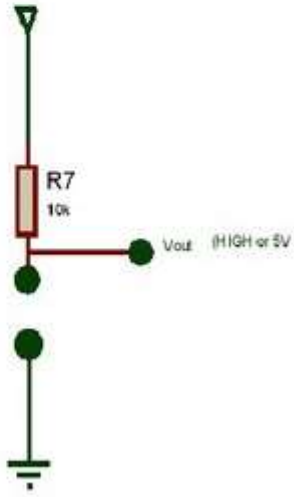
Case2: If the input of the inverting terminal is lower than the input of the non-inverting terminal.

The input to the inverting terminal is set to a certain value by varying the potentiometer and the sensitivity is set. When the rain board module's surface is exposed to rainwater, the surface of the rainboard module will be wet, and it offers minimum resistance to the supply voltage. Due to this, the minimum voltage will be appearing at the non-inverting terminal of LM393 Op-Amp. The comparator compares both inverting and non-inverting terminal voltages. If the condition falls under case(1), the output of the Op-Amp will be digital LOW. If the condition falls under case(2), the output of the Op-Amp will be digital HIGH. The below diagram shows the equivalent circuit of both the conditions.





Case(1):- During wet condition



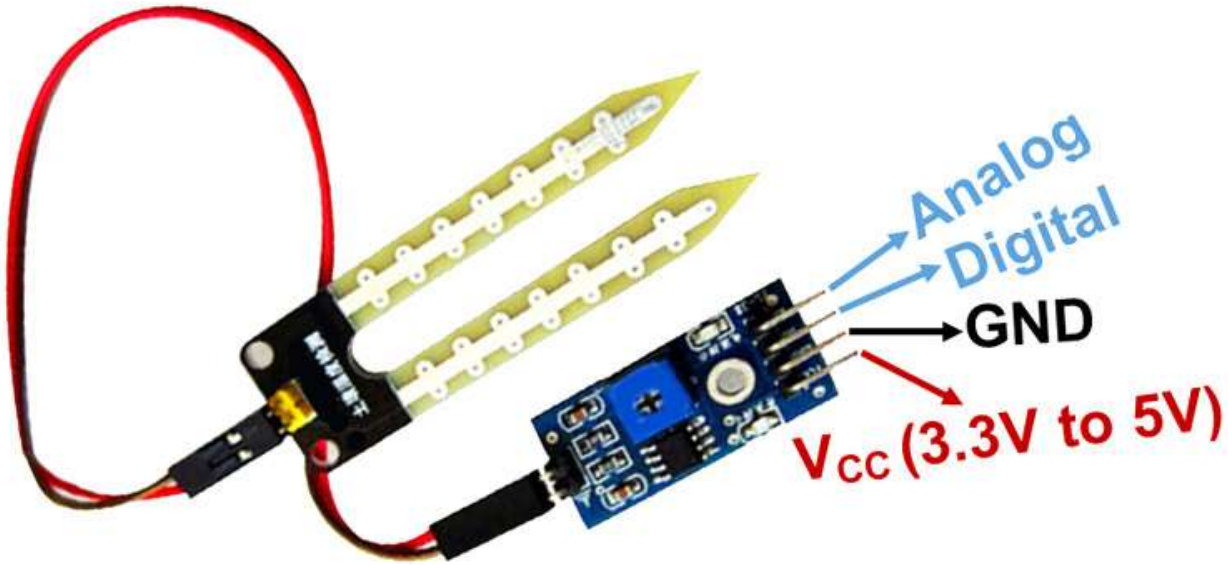
Case(2):- During dry condition

When the A0 pin is connected to the microcontroller, an additional analog to digital converter (ADC) circuit is used. In the case of Arduino, it consists of 6 ADC pins, which can be directly used for calculation purposes.

Applications of Rain sensor:

- Automatic windshield wipers
- Smart Agriculture
- Home-Automation

Soil Moisture Sensor Module



This **soil moisture sensor module** is used to detect the moisture of the soil. It measures the volumetric content of water inside the soil and gives us the moisture level as output. The module has both digital and analog outputs and a potentiometer to adjust the threshold level.

Soil Moisture Sensor Module Pinout Configuration

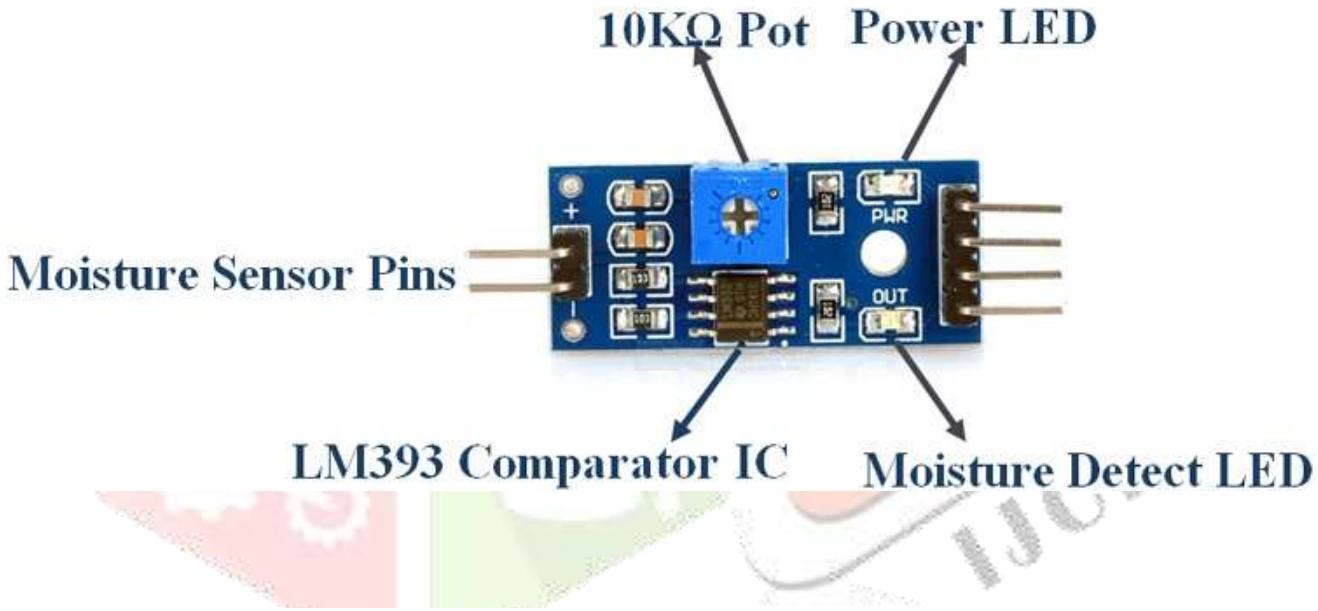
Pin Name	**Description**
VCC	The Vcc pin powers the module, typically with +5V
GND	Power Supply Ground
DO	Digital Out Pin for Digital Output.
AO	Analog Out Pin for Analog Output

Soil Moisture Sensor Module Features & Specifications

- Operating Voltage: 3.3V to 5V DC
- Operating Current: 15mA
- Output Digital - 0V to 5V, Adjustable trigger level from preset
- Output Analog - 0V to 5V based on infrared radiation from fire flame falling on the sensor
- LEDs indicating output and power
- PCB Size: 3.2cm x 1.4cm
- LM393 based design
- Easy to use with Microcontrollers or even with normal Digital/Analog IC
- Small, cheap and easily available

Brief about Soil Moisture Sensor Module

This Moisture sensor module consists of a Moisture sensor, Resistors, Capacitor, Potentiometer, Comparator LM393 IC, Power and Status LED in an integrated circuit.



LM393 IC

LM393 Comparator IC is used as a voltage comparator in this Moisture sensor module. Pin 2 of LM393 is connected to Preset (10KΩ Pot) while pin 3 is connected to Moisture sensor pin. The comparator IC will compare the threshold voltage set using the preset (pin2) and the sensor pin (pin3).

Moisture Sensor

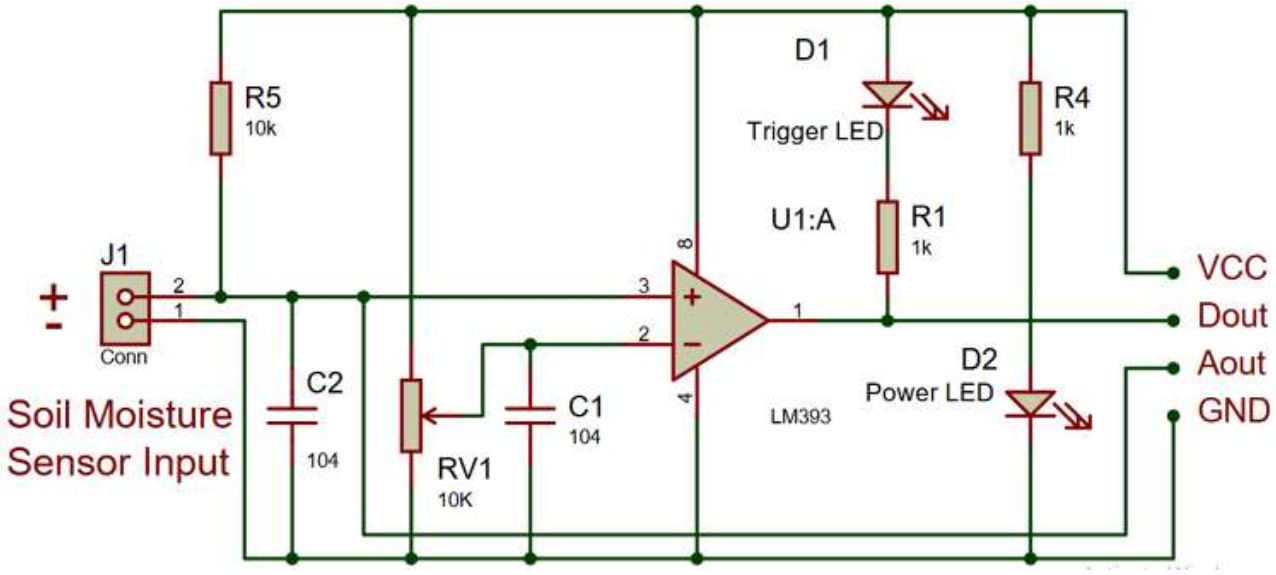
The moisture sensor consists of two probes that are used to detect the moisture of the soil**.** The moisture sensor probes are coated with immersion gold that protects Nickel from oxidation. These two probes are used to pass the current through the soil and then the sensor reads the resistance to get the moisture values.

Preset (Trimmer pot)

Using the onboard preset you can adjust the threshold (sensitivity) of the digital output.

How to Use Soil Moisture Sensor Module

Moisture sensor module consists of four pins i.e. VCC, GND, DO, AO. Digital out pin is connected to the output pin of LM393 comparator IC while the analog pin is connected to Moisture sensor. The internal Circuit diagram of the Moisture sensor module is given below.



Using a Moisture sensor module with a microcontroller is very easy. Connect the Analog/Digital Output pin of the module to the Analog/Digital pin of Microcontroller. Connect VCC and GND pins to 5V and GND pins of Microcontroller. After that insert the probe inside the soil. When there is more water presented in the soil, it will conduct more electricity that means resistance will be low and the moisture level will be high.

Applications of Soil Moisture Sensor

- Gardening
- Irrigation Systems
- Used in Controlled Environments

DS18B20

The DS18B20 is one type of temperature sensor and it supplies 9-bit to 12-bit readings of temperature. These values show the temperature of a particular device. The communication of this sensor can be done through a one-wire bus protocol which uses one data line to communicate with an inner microprocessor. Additionally, this sensor gets the power supply directly from the data line so that the need for an external power supply can be eliminated. The applications of the DS18B20 temperature sensor include industrial systems, consumer products, systems which are sensitive thermally, thermostatic controls, and thermometers.

DS18B20 Pin Configuration

- Pin1 (Ground): This pin is used to connect to the GND terminal of the circuit
- Pin2 (Vcc): This pin is used to give the power to the sensor which ranges from 3.3V or 5V
- Pin3 (Data): The data pin supplies the temperature value, which can communicate with the help of 1-wire method.

Specifications

The specifications of this sensor include the following.

- This sensor is a programmable and digital temperature sensor
- The communication of this sensor can be done with the help of a 1-Wire method
- The range of power supply is 3.0V – 5.5V
- Fahrenheit equal s to -67°F to +257°F
- The accuracy of this sensor is ±0.5°C
- The o/p resolution will range from 9-bit to 12-bit
- It changes the 12-bit temperature to digital word within 750 ms time
- This sensor can be power-driven from the data line
- Alarm options are programmable
- The multiplexing can be enabled by Unique 64-bit address
- The temperature can be calculated from -55°C to +125°C.
- These are obtainable like SOP, To-92, and also as a waterproof sensor

Working Principle

The working principle of this DS18B20 temperature sensor is like a temperature sensor. The resolution of this sensor ranges from 9-bits to 12-bits. But the default resolution which is used to power-up is 12-bit. This sensor gets power within a low-power inactive condition. The temperature measurement, as well as the conversion of A-to-D, can be done with a convert-T command. The resulting temperature information can be stored within the 2-byte register in the sensor, and after that, this sensor returns to its inactive state.

If the sensor is power-driven by an exterior power supply, then the master can provide read time slots next to the Convert T command. The sensor will react by supplying 0 though the temperature change is in the improvement and reacts by supplying 1 though the temperature change is done.

DS18B20 Temperature Sensor Applications

The applications of DS18B20 include the following.

- This sensor is extensively used to calculate temperature within rigid environments which includes mines, chemical solutions, otherwise soil, etc.
- This sensor is used to measure the liquid temperature.
- We can use it in the thermostat controls system.
- It can be used in industries as a temperature measuring device.
- This sensor is used as a thermometer.
- It can be used in devices like which are sensitive to thermal.
- These are used in HVAC systems.
- Applications where the temperature has to be measured at multiple points.

Thus, this is all about a DS18B20 temperature sensor. This sensor can be accessible in two packages like simple DS18B20 sensor and waterproof DS18B20 sensor which are used in hydro-projects to determine the temperature of the water.

LCD 16×2

Nowadays, we always use the devices which are made up of LCDs such as CD players, DVD players, digital watches, computers, etc. These are commonly used in the screen industries to replace the utilization of CRTs. Cathode Ray Tubes use huge power when compared with LCDs, and CRTs heavier as well as bigger. These devices are thinner as well power consumption is extremely less. The LCD 16×2 working principle is, it blocks the light rather than dissipate. This article discusses an overview of LCD 16X2, pin configuration and its working.

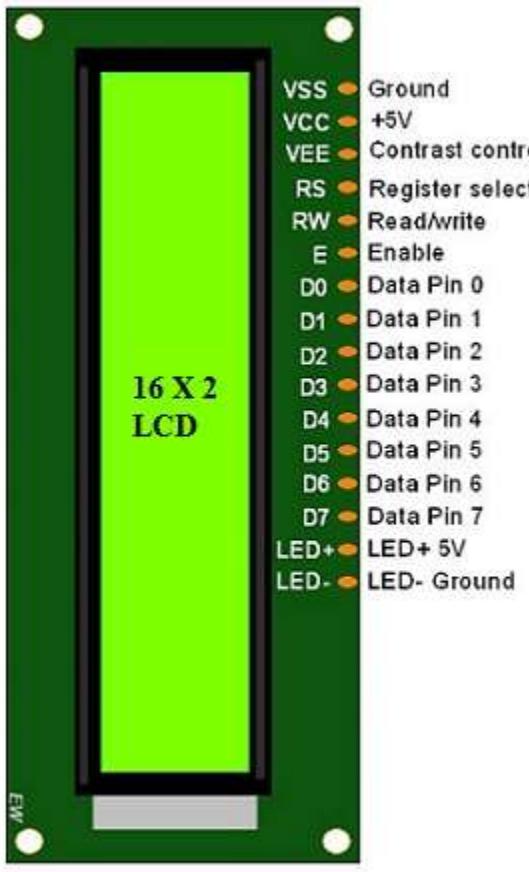
What is the LCD 16×2?

The term LCD stands for liquid crystal display. It is one kind of electronic display module used in an extensive range of applications like various circuits & devices like mobile phones, calculators, computers, TV sets, etc. These displays are mainly preferred for multi-segment light-emitting diodes and seven segments. The main benefits of using this module are inexpensive; simply programmable, animations, and there are no limitations for displaying custom characters, special and even animations, etc.

LCD 16×2 Pin Diagram

The 16×2 LCD pinout is shown below.

- Pin1 (Ground/Source Pin): This is a GND pin of display, used to connect the GND terminal of the microcontroller unit or power source.
- Pin2 (VCC/Source Pin): This is the voltage supply pin of the display, used to connect the supply pin of the power source.
- Pin3 (V0/VEE/Control Pin): This pin regulates the difference of the display, used to connect a changeable POT that can supply 0 to 5V.
- Pin4 (Register Select/Control Pin): This pin toggles among command or data register, used to connect a microcontroller unit pin and obtains either 0 or 1(0 = data mode, and 1 = command mode).
- Pin5 (Read/Write/Control Pin): This pin toggles the display among the read or writes operation, and it is connected to a microcontroller unit pin to get either 0 or 1 (0 = Write Operation, and 1 = Read Operation).
- Pin 6 (Enable/Control Pin): This pin should be held high to execute Read/Write process, and it is connected to the microcontroller unit & constantly held high.
- Pins 7-14 (Data Pins): These pins are used to send data to the display. These pins are connected in two-wire modes like 4-wire mode and 8-wire mode. In 4-wire mode, only four pins are connected to the microcontroller unit like 0 to 3, whereas in 8-wire mode, 8-pins are connected to microcontroller unit like 0 to 7.
- Pin15 (+ve pin of the LED): This pin is connected to +5V
- Pin 16 (-ve pin of the LED): This pin is connected to GND.



LCD-16×2-pin-diagram

Features of LCD16x2

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

Registers of LCD

A 16×2 LCD has two registers like data register and command register. The RS (register select) is mainly used to change from one register to another. When the register set is '0', then it is known as command register. Similarly, when the register set is '1', then it is known as data register.

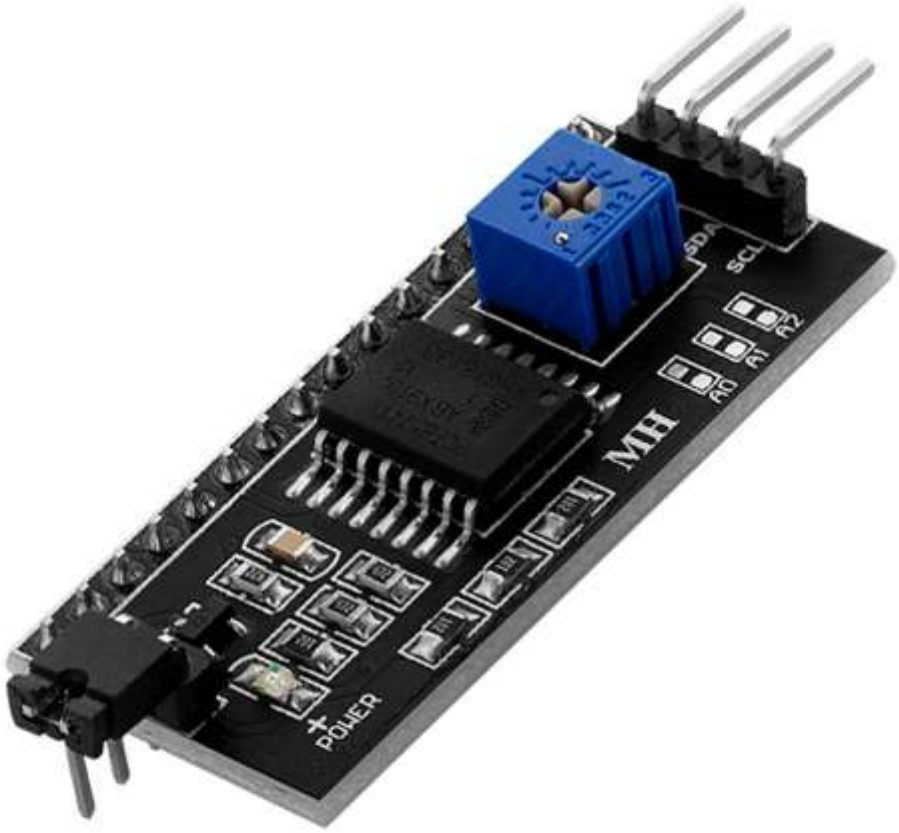
Command Register

The main function of the command register is to store the instructions of command which are given to the display. So that predefined tasks can be performed such as clearing the display, initializing, set the cursor place, and display control. Here commands processing can occur within the register.

Data Register

The main function of the data register is to store the information which is to be exhibited on the LCD screen. Here, the ASCII value of the character is the information which is to be exhibited on the screen of LCD. Whenever we send the information to LCD, it transmits to the data register, and then the process will be starting there. When register set =1, then the data register will be selected.

I2C Module



General Description

The I2C LCD module is an interface board designed to control standard character LCDs (16×2 or 20×4) using the **I2C communication protocol**. It is built around the **PCF8574 I/O expander IC**, which converts serial I2C data into parallel signals required by the LCD. This module reduces the number of microcontroller pins required from 8–12 pins to only **two data lines (SDA and SCL)**, making it ideal for compact embedded and IoT applications.

Electrical Specifications

Parameter	**Specification**
Operating Voltage	3.3V – 5V DC
Communication Protocol	I2C
I2C Address	0x27 (common), 0x3F
Controller IC	PCF8574
Compatible LCDs	16×2, 20×4
Power Consumption	Low
Backlight Control	Supported

Pin Configuration

Pin	Name	Description
1	VCC	Power supply (3.3V or 5V)
2	GND	Ground
3	SDA	I2C data line
4	SCL	I2C clock line

Onboard Components

- **PCF8574 IC** – I2C to parallel data converter
- **Contrast Potentiometer** – Adjusts LCD contrast
- **Backlight Circuit** – Controls LCD backlight
- **Pull-up Resistors** – For stable I2C communication

Features

- Reduces LCD wiring complexity
- Saves microcontroller GPIO pins
- Simple and reliable I2C communication
- Adjustable display contrast
- Compatible with ESP32 and Arduino
- Ideal for IoT and embedded systems

Adafruit IO Server

Adafruit IO is a cloud-based **Internet of Things (IoT) platform** designed to help makers, students, and engineers monitor and control electronic projects over the internet. It enables microcontrollers such as the **ESP32** to securely send sensor data to the cloud using common IoT protocols like **MQTT** and **REST APIs**. Adafruit IO then stores this data in structures called **feeds** and displays them in customizable **dashboards** that update in real time without any backend development required. This makes it easy to visualize sensor readings, control actuators, and analyze data from anywhere in the world using a web browser or mobile device.

Core Components of Adafruit IO

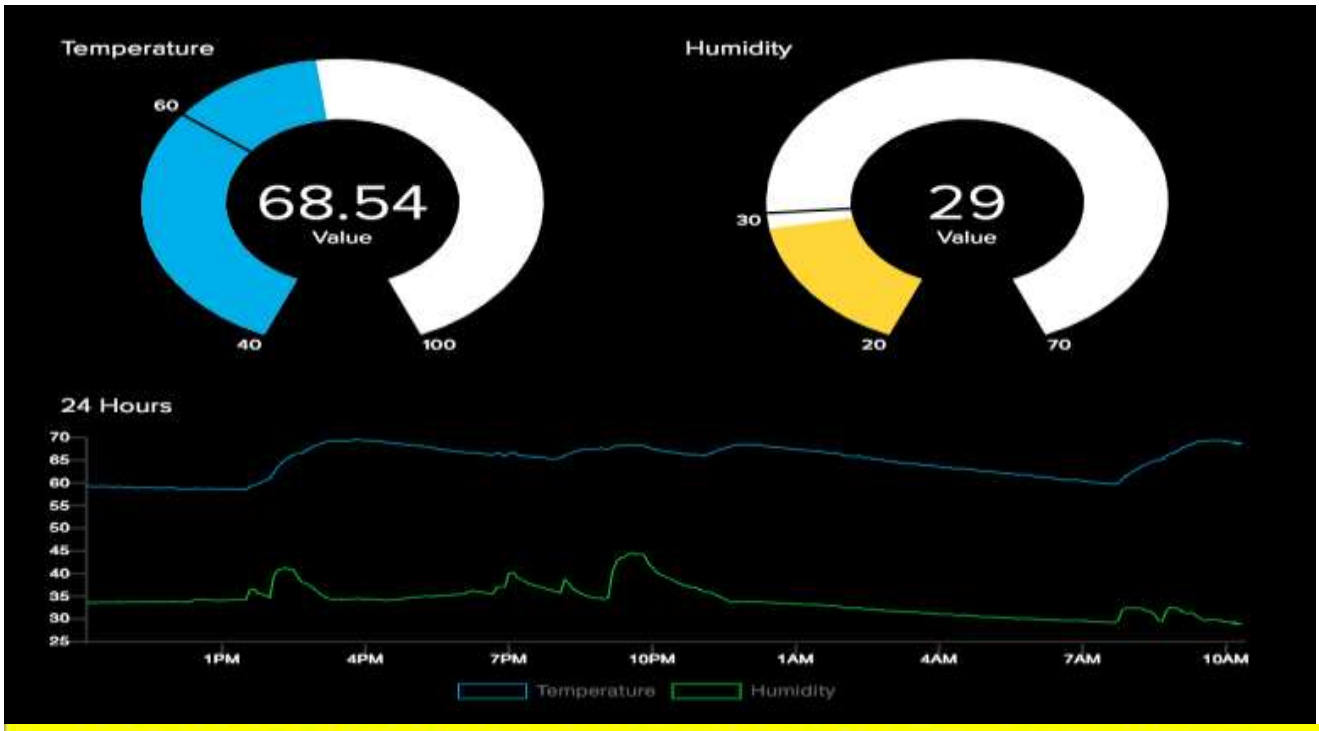
Feeds

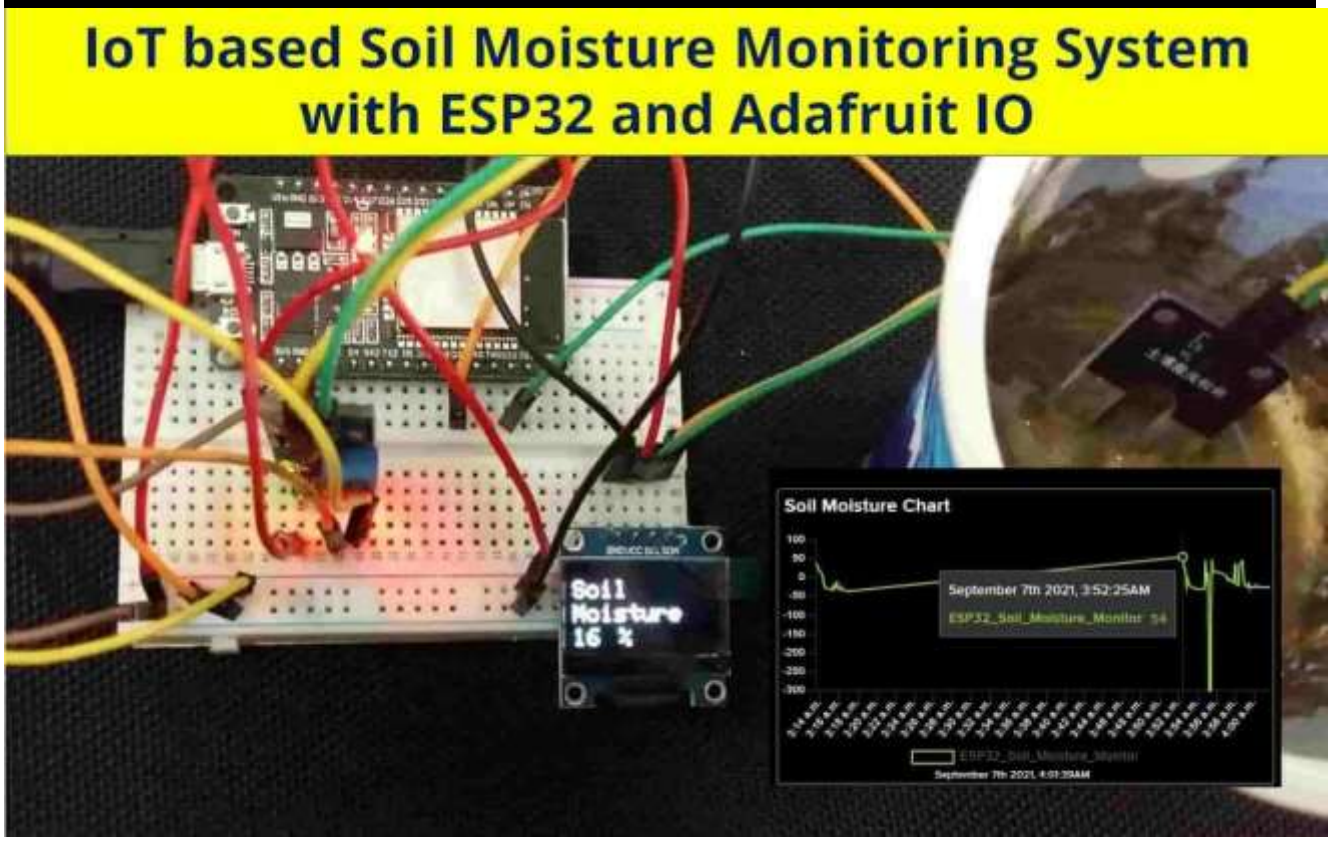
A **feed** is a data storage unit in Adafruit IO that holds sensor values or status messages from your device. Each unique data point (like soil moisture, pump status, or rain status) should have its own feed. Feeds store both **the latest value** and optionally **historical values** over time, allowing you to graph and analyze trends. You can create, read, update, and delete feeds using the built-in platform tools or programmatically via the REST API. Adafruit IO

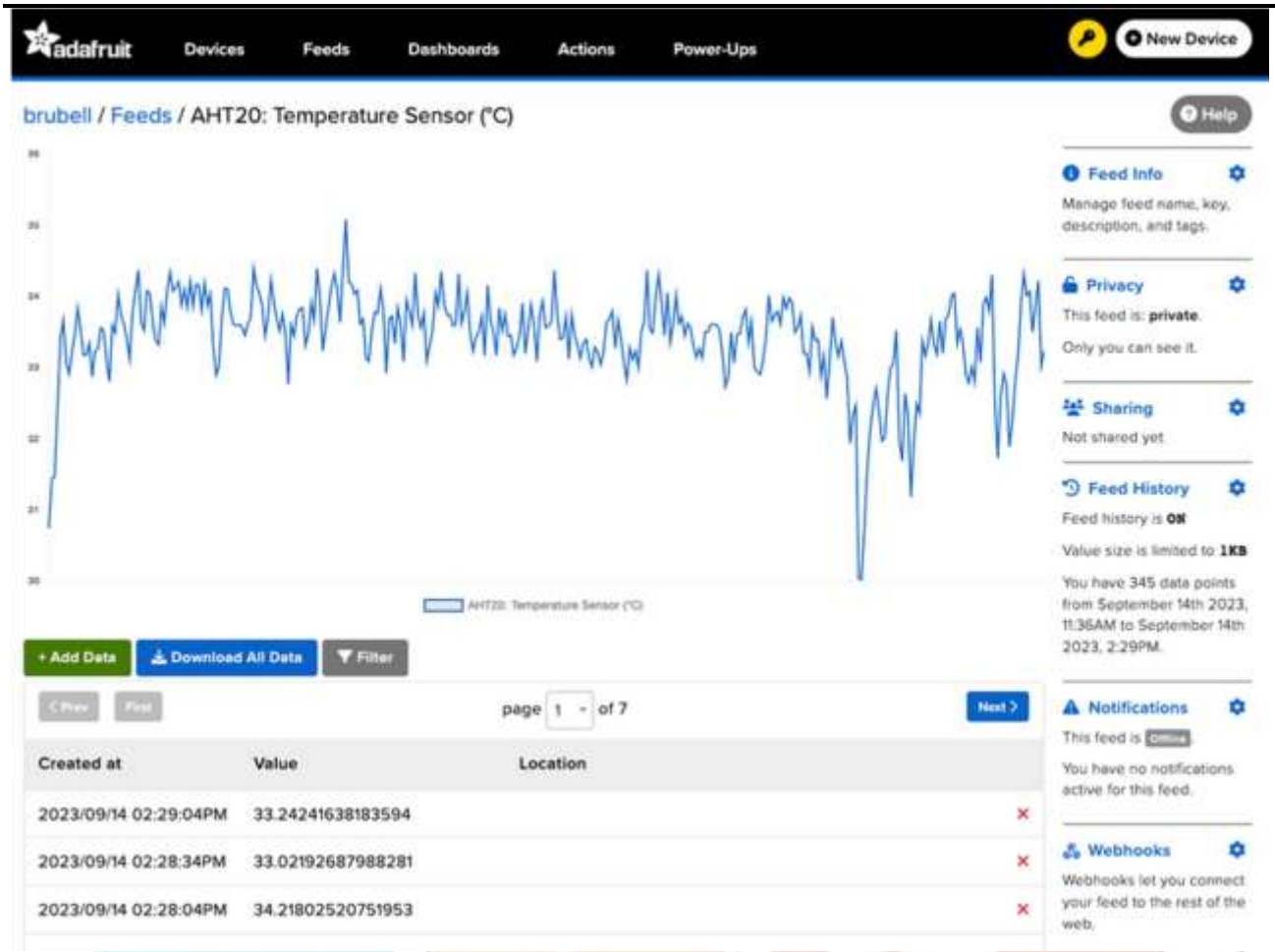
Dashboards

A **dashboard** is a visual web page that displays live data from one or more feeds. Users add **blocks** (widgets) to visualize data — for example, gauges, line charts, indicators, toggles, and text blocks. Dashboards update **in real time** as new data arrives from the device, making them ideal for monitoring sensor systems like smart irrigation.

Here's how an Adafruit IO dashboard can look:







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- **Gauges** show current values like soil moisture percentage. Adafruit Learning System
- **Line charts** plot historical data over time. Adafruit Learning System
- **Indicator blocks** clearly show statuses like "PUMP ON" or "RAIN". Adafruit IO

These blocks help visualize data without extra coding and make dashboards meaningful and interactive.

🔄 How Data Flows in Adafruit IO

1. **Device Connection:** Your ESP32 connects to WiFi and then to the Adafruit IO server (io.adafruit.com) using your Adafruit username and API key.
2. **Publishing Data:** Sensors send values, such as moisture level or rain detection, which the ESP32 publishes to respective feeds.
3. **Dashboard Update:** Adafruit IO pushes this data to the dashboard blocks in real time, so the visuals update automatically.
4. **Remote Access:** You can open your dashboard on any device (computer, phone, tablet) with an internet connection — no special app needed. Adafruit Learning System

Communication Methods

MQTT (Message Queuing Telemetry Transport)

MQTT is a lightweight messaging protocol designed for IoT. Devices publish data to Adafruit IO using MQTT topics associated with feeds. Subscribing to a topic enables real-time updates without polling. It's efficient and ideal for intermittent connections like WiFi modules. Adafruit IO

REST API

Adafruit IO also supports a RESTful API that lets you interact with your feeds through standard HTTP requests. You can fetch data, update values, or retrieve historical records using simple URLs and your API key in HTTP headers. Adafruit IO

Adafruit IO Features in Brief

Here are some major strengths of the platform:

Real-Time Visualization: Dashboards update instantly with new data. Adafruit Learning System
Custom Dashboards: Drag and drop blocks to build UI without coding. Adafruit IO
Device Control: Some blocks like **toggles** can send values back to devices. Adafruit Learning System
Historical Data: Feeds can store past values for trend analysis. Adafruit Learning System
Easy Integration: Works with many microcontrollers (ESP32, Arduino, Raspberry Pi). Adafruit Learning System

RESULTS AND CONCLUSION

ADVANTAGES

1. **Water Conservation:**
   - Automatically turns the pump ON/OFF based on soil moisture and rain, preventing water wastage.
2. **Remote Monitoring:**
   - IoT integration via Adafruit IO allows users to monitor soil moisture, pump status, and rain conditions from anywhere using a smartphone or computer.
3. **Automation:**
   - Reduces manual effort in irrigation by automating the watering process.
4. **Real-Time Feedback:**
   - Provides immediate feedback through LCD display and cloud dashboard for better farm management.
5. **Scalability:**
   - System can be expanded to multiple zones, sensors, or pumps for larger farms or gardens.
6. **Data Logging and Analysis:**
   - Historical soil moisture data on Adafruit IO allows farmers to analyze watering patterns and optimize irrigation schedules.

DISADVANTAGES

1. **Initial Cost:**
   - Higher initial cost compared to traditional manual irrigation due to ESP32, sensors, and relay modules.
2. **Internet Dependence:**
   - Requires a stable WiFi connection for real-time monitoring and cloud updates.
3. **Maintenance:**
   - Sensors and relay modules may require periodic calibration and maintenance to ensure accuracy.
4. **Technical Knowledge:**
   - Users need basic knowledge of electronics and IoT systems for installation and troubleshooting.
5. **Power Dependence:**
   - System depends on electricity for ESP32 and pump operation; outages can affect irrigation.

APPLICATIONS

1. **Agriculture and Farming:**
   - Automated watering of crops based on soil moisture and rain detection.
2. **Smart Gardens and Lawns:**
   - Efficient irrigation of home gardens or lawns without manual watering.
3. **Greenhouses:**
   - Maintaining optimal soil moisture in controlled environments.
4. **Urban Farming / Vertical Farming:**
   - IoT integration helps monitor multiple small-scale farms efficiently.
5. **Environmental Monitoring Projects:**
   - Can be combined with weather and soil sensors for research and educational purposes.
6. **Water Conservation Projects:**
   - Reduces water wastage by automating irrigation based on environmental conditions.

RESULTS

In this project, an **IoT-based smart irrigation system** was successfully implemented using an **ESP32 microcontroller**, **soil moisture sensor**, **rain sensor**, **16×2 I2C LCD**, and **relay module**. The following results were observed:

1. **Soil Moisture Monitoring:**
   - The soil moisture sensor accurately detects dry and wet conditions.
   - Dry soil shows higher analog values, while wet soil shows lower values.
   - Real-time soil status is displayed on the LCD and reflected on **Adafruit IO dashboards**.
2. **Automatic Irrigation Control:**
   - The relay successfully controls the water pump based on soil moisture and rain detection.
   - The pump turns ON automatically when soil is dry and there is no rain.
   - The pump turns OFF when soil is wet or rain is detected, preventing overwatering.
3. **Rain Detection:**
   - The rain sensor effectively stops irrigation during rainfall, conserving water.
   - Rain status is displayed on both LCD and Adafruit IO dashboard.
4. **IoT Dashboard Monitoring:**
   - All sensors and the pump status are transmitted in real time to **Adafruit IO**.
   - Dashboard blocks like **gauges** and **indicators** show live soil moisture levels, rain detection, and pump status.
   - Remote monitoring allows viewing system performance from any device with internet access.
5. **System Reliability:**

- The system works continuously without manual intervention.
- Alerts for pump status and sensor readings can be viewed remotely.

CONCLUSION

The IoT-based smart irrigation system proved to be **efficient, reliable, and water-saving**. Key conclusions include:

- Automated irrigation reduces water wastage by turning the pump ON/OFF based on soil moisture and rain.
- The ESP32 microcontroller, combined with sensors and Adafruit IO, allows **remote real-time monitoring and control**, making the system user-friendly.
- The 16×2 I2C LCD provides a **local status display**, while Adafruit IO provides a **cloud-based monitoring interface**.
- The system can be scaled for large farms or gardens by adding multiple sensors and pumps.
- Overall, the project demonstrates the integration of **IoT technology in agriculture**, improving efficiency, conserving water, and reducing manual labor.

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