ELECTRONIC BASICS

- **Lecture-1:** This lecture is about Multimeter . This lecture describes how to measure current, voltage, resistance by multimeter . In measuring current we have to connect the multimeter in series and in measuring voltage we have to connect the multimeter in parallel with the circuit.

- **Lecture-2:** This lecture is about PWM (Pulse With Modulation). Pulse Width Modulation (PWM) is a common technique used to control LED brightness by adjusting the **duty cycle** of a digital signal. Instead of changing the voltage, PWM rapidly switches the LED **ON and OFF** at a high frequency. The human eye perceives this as a change in brightness.

•If the duty cycle is **0%**, the LED remains OFF.
•If the duty cycle is **50%**, the LED is ON for half the time, appearing dim.
•If the duty cycle is **100%**, the LED is always ON at full brightness.

➢ **Lecture-3:** In this lecture there made a Arduino by using Attiny instead of an Atmega328. **ATtiny** is a family of small, low-power **microcontrollers (MCUs)** developed by **Microchip Technology (formerly Atmel)**. These microcontrollers are part of the **AVR architecture**, just like ATmega series (used in Arduino), but they are smaller, cheaper, and have fewer pins.

ATmega328 is an 8-bit microcontroller from **Microchip Technology (formerly Atmel)**, widely used in embedded systems and DIY electronics. It is the **heart of the Arduino Uno**, making it one of the most popular microcontrollers.

➢ **Lecture-4:** This video explains how to use a **Bluetooth module (HC-05/HC-06)** with an **Arduino Nano** to control devices such as **RGB LEDs** using an **Android app**.

❑ **Introduction to Bluetooth Control**

•Bluetooth is an easy way to control gadgets wirelessly using a smartphone.
•The HC-05 Bluetooth module is small, has **only four pins**, and is easy to connect to an Arduino.
•The creator demonstrates using it to control **LED brightness, color changes, and animations**.

❑ **Using an Arduino Nano**

•The **Arduino Nano** is used instead of an Arduino Uno because of its **compact size**.
•Both use the **ATmega328** microcontroller and have **similar features**.

❑ **Voltage Compatibility Issue**

•The **Bluetooth module operates at 3.3V logic**, but the Arduino uses **5V logic**.
•While receiving data (RX), the Arduino can handle 3.3V signals.
•But when **sending data (TX), the 5V signal can damage the Bluetooth module**.
•A **voltage divider** is needed to safely reduce **5V to 3.3V** using **two resistors (2KΩ and 4.7KΩ)**.

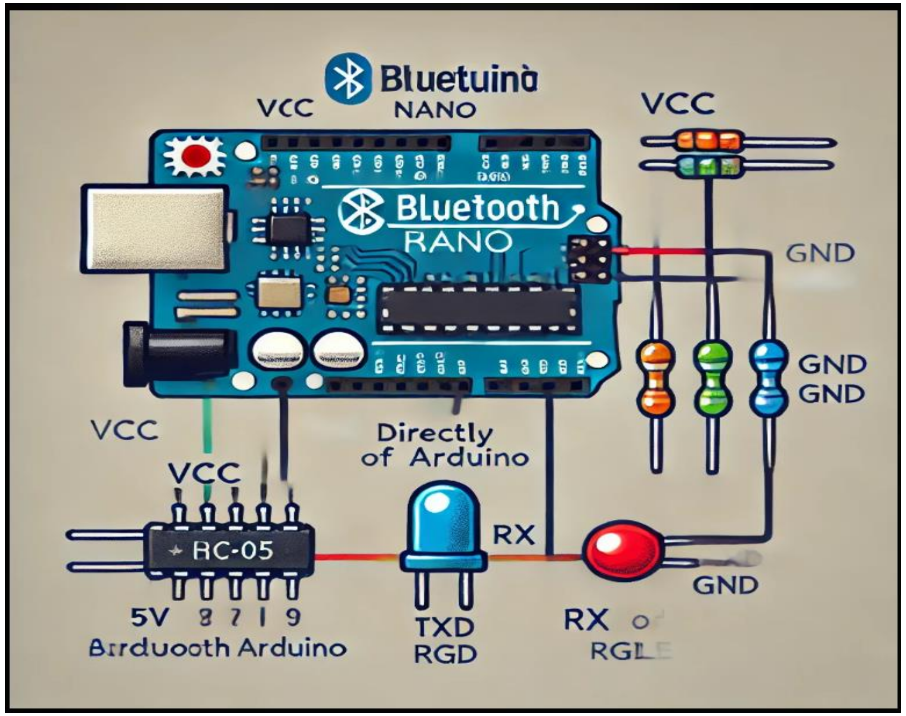
❑ Wiring the Circuit

•**RGB LED Wiring:**

- Uses a **common anode RGB LED**.
- Each **cathode (R, G, B)** is connected to Arduino **pins 8, 9, and 10** with **460Ω resistors**.

•**Bluetooth Module Wiring:**

- TX of the **Bluetooth module → RX of Arduino** (direct connection).
- RX of the **Bluetooth module ← TX of Arduino (via voltage divider)**.
- **VCC → 5V, GND → GND**.



➢ **Lecture-5:** This video explains how to control **a large number of LEDs** (such as a **4×4×4 RGB LED cube** or a **10×5 LED matrix**) using only a **few I/O pins** on an **Arduino Nano**. The main challenge is that microcontrollers, including the **Arduino Mega (54 I/O pins)**, do not have enough pins to control hundreds of LEDs directly. The solution involves **multiplexing** and using **LED driver ICs and MOSFETs**.

1. LED Matrix Setup:

•The LEDs are arranged in a **matrix format**:

- **Anodes (positive) are connected row-wise.**
- **Cathodes (negative) are connected column-wise.**

•This structure allows **controlling individual LEDs** by selecting specific rows and columns.

2. The Multiplexing Technique:

•Instead of controlling all LEDs at once, the system **lights up one row at a time** in rapid succession.

•**Persistence of Vision (PoV)** makes it appear as if all LEDs are on simultaneously.

3. Using P-Channel MOSFETs (F9540N) for Row Control:

•**Rows draw up to 200mA**, which is too much for a single Arduino pin.

•**P-Channel MOSFETs** act as electronic switches to control **each row individually**.

•The **MOSFET's gate** is connected to the Arduino, the **source** to **5V**, and the **drain** to the LED anode rows.

•**Pull-up resistors (1KΩ)** are used to keep the MOSFETs stable.

4.Using the TLC5940 LED Driver for Column Control:

•The **TLC5940 LED driver** controls **10 LED columns** with **constant current sinking**.

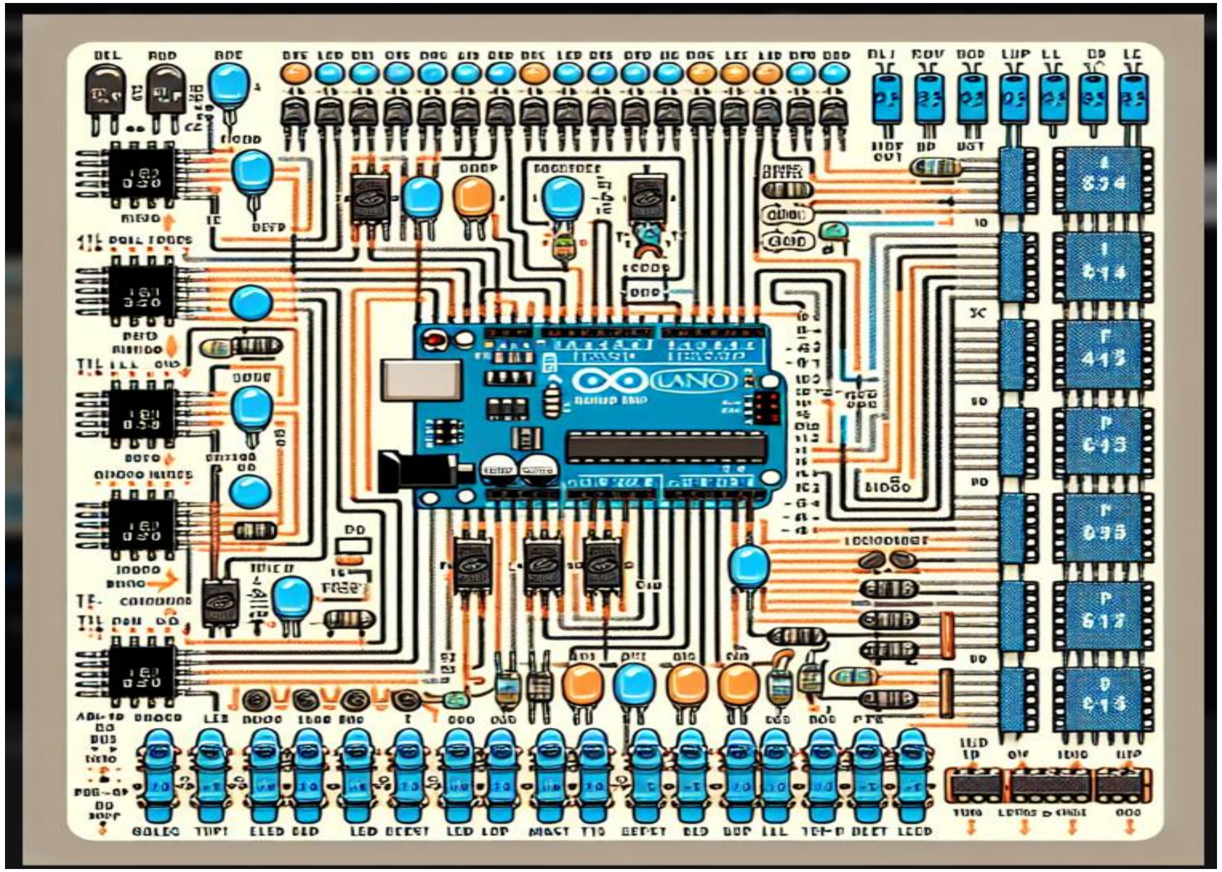
•The LED driver receives **serial data from the Arduino** to determine which LEDs should be turned on.

5. Wiring Details:

•**MOSFET gates** are connected to Arduino pins **(Pins 4-8)** to control the rows.

•**TLC5940 output pins** control the LED matrix columns.

•A **2KΩ resistor** is used to set the TLC5940's **constant current** to **20mA per LED**.



➢ **Lecture-6:** This guide explains how to use an **ATmega328p microcontroller** independently of an **Arduino Uno** by embedding it into a circuit.

•A **16MHz crystal** and **two 22pF capacitors** for the clock signal
•A **10kΩ pull-up resistor** on the **reset pin**

The **power connections** are:
•**5V to pins 7, 20, and 21**
•**Ground to pins 8 and 22**

This setup essentially creates an **Arduino on a breadboard**, but it lacks built-in features like **USB-to-serial conversion**, **reset switch**, and **overvoltage protection**.

➢ **Lecture-7:** The aim of this experiment is to demonstrate how to control a 7-segment display using both discrete logic circuits and an Arduino microcontroller. The experiment explores direct wiring, BCD to 7-segment drivers, binary counters, and multiplexing techniques for efficient digit control.

Components Used:

1. **7-Segment Display (LTS546AG)** – A common anode display with labeled segments (A-G, DP).
2. **BCD to 7-Segment Driver (SN74LS247)** – Converts binary-coded decimal (BCD) inputs to appropriate 7-segment outputs.
3. **4-bit Binary Counter (SN74LS290)** – Generates binary count sequence to feed into the display driver.
4. **Arduino Microcontroller** – Used in the later part to demonstrate microcontroller-based control.
5. **Shift Register (SAA1064 IC)** – Specialized IC for multiplexing and controlling multiple digits efficiently.
6. **NPN Transistors (BC337)** – Used for multiplexing common anodes in multi-digit displays.

7.Resistors (220Ω, 4.7kΩ, etc.) – Used for current limiting and pull-up configurations.
8.Capacitor (2.2nF) – Used to set the multiplexing speed for the SAA1064.
9.Push-button Switch – Used for manually incrementing the counter in one of the configurations.
10.Infrared/Tilt Sensors (Optional) – Demonstrated as alternative ways to trigger counting.

- **Lecture-8:** This lecture shows us how to control LED in wright way . We should Use **resistors** to ensure the proper amount of current flows through the LEDs. Wiring LEDs in **series** is generally more efficient than in parallel. A **constant current source** is the best way to power LEDs reliably. Small variations in LED forward voltage can cause uneven current distribution, so careful planning is necessary when wiring multiple LEDs together.
- why we should connect LED in series instead of parallel ?

1. Current Consistency:

•**Series connection:** When you connect LEDs in series, the **same current** flows through each LED. This ensures that each LED receives the same current, which is crucial because LEDs are current-sensitive devices. With a series circuit, the current is consistent across all LEDs, which prevents uneven brightness or potential damage to the LEDs.

•**Parallel connection:** In a parallel setup, the current splits among each LED. If the LEDs have slightly different forward voltages, one LED might draw more current than the others, causing it to burn out faster. This uneven current distribution can lead to reduced efficiency and lifespan of your LEDs.

2. Voltage Requirements:
•**Series connection:** The voltage across each LED adds up, but each individual LED only requires its specific forward voltage. For example, if each LED requires 3V and you connect 3 LEDs in series, your power supply needs to provide 9V (3V x 3). This allows you to use fewer components and manage the voltage more easily.
•**Parallel connection:** In a parallel setup, all LEDs will need the same voltage (e.g., 3V for each LED). This can be harder to manage if you're using a higher-voltage power supply, as you'll need to add resistors for each LED to limit the current, which can lead to inefficiency and wasted power.

3. Power Consumption:
•**Series connection:** Power consumption in a series circuit is generally more efficient because you're using a single resistor (or none at all in certain cases) to limit the current, which minimizes power loss. The current remains constant, and the LEDs work together efficiently.
•**Parallel connection:** In parallel, if you use resistors for each LED to limit current, there's power loss across those resistors. The total power required increases, and there's more energy wasted, making the system less efficient.

- **Lecture-9:** This video provides an introduction to the importance and functionality of **diodes** in electronic circuits, particularly in **DC (direct current)** applications.

Diodes in DC Circuits:
The video starts by explaining a simple **LED blink circuit**, where current flows only in one direction (DC). It shows how a diode can be used to protect circuits by preventing damage when power is connected the wrong way (reverse polarity). If the polarity is reversed, the diode blocks the current, preventing damage to the circuit.

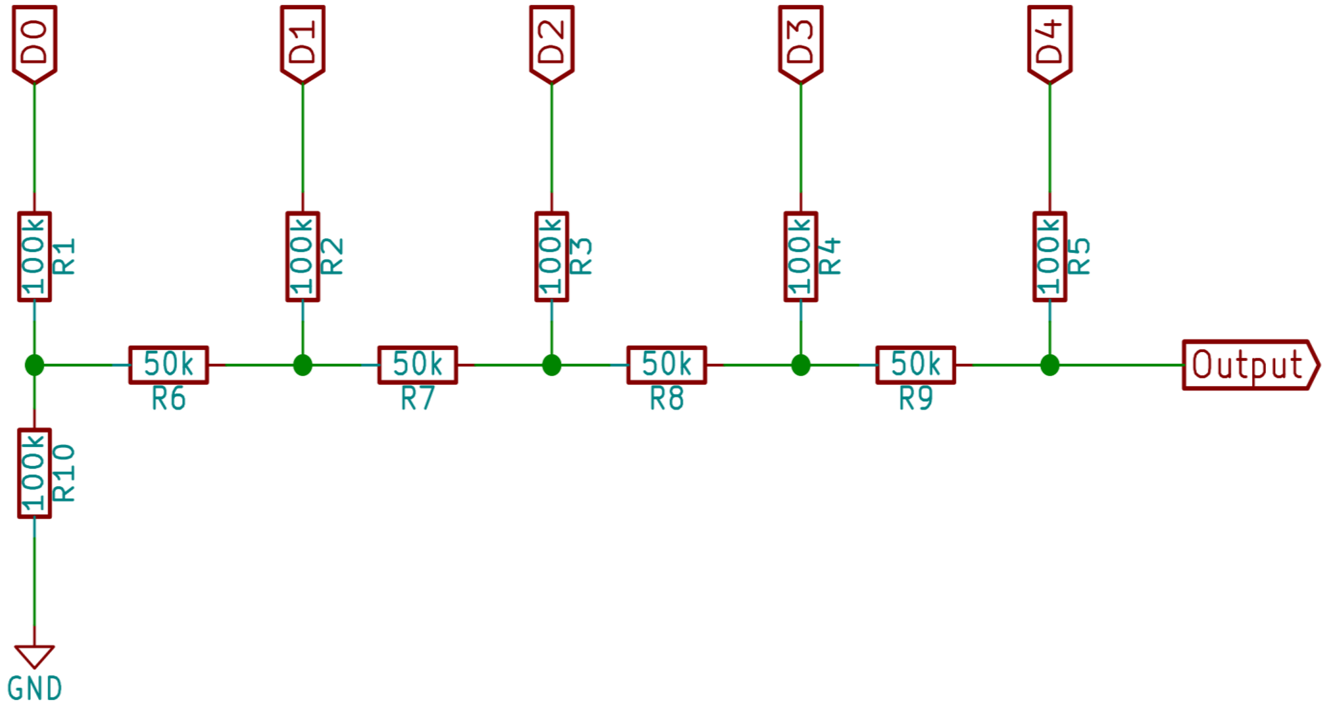
•**Voltage Drop Across Diodes:**
It highlights a limitation of diodes, specifically the **voltage drop** across them. The example shows how a common diode (1N4007) causes a voltage drop (around 0.65V), which reduces the voltage supplied to the circuit. For instance, with 5V at the input, the useful circuit only receives 4.35V. The video also notes that this leads to some power loss and heat generation, especially when the circuit draws a high current.
•**AC to DC Conversion:**
The video shifts to explain how diodes are used to convert **AC (alternating current)** to **DC (direct current)**. It demonstrates the use of a **transformer** to step down the voltage from 220V AC to 15V AC and then uses a diode in a **rectifier circuit** to convert the AC to DC. However, this results in a **bumpy DC** (ripples), as the capacitor can only charge during the positive half of the AC waveform.
•**Bridge Rectifier:**
The video introduces the **bridge rectifier**, a more efficient circuit that uses four diodes to rectify both halves of the AC waveform. This results in a smoother DC output where the current only flows in one direction, regardless of the input polarity. This makes the DC power supply more usable for various applications.
•**Practical Use of Diodes:**
The video concludes by emphasizing that diodes are essential for converting AC to usable DC power and protecting circuits. It also mentions that there are many different types of diodes, each with specific uses and characteristics, and that this is just an introduction to their functionality.

➢ **Lecture-10:** This video is an introduction to **Digital-to-Analog Converters (DACs)** and how they work. The creator explains different DAC techniques and demonstrates a basic **resistor ladder DAC** using an **Arduino Nano**. The video covers concepts related to digital signals, analog signals, and how DACs convert digital values into continuous voltage levels that can be used for sound generation and other applications.

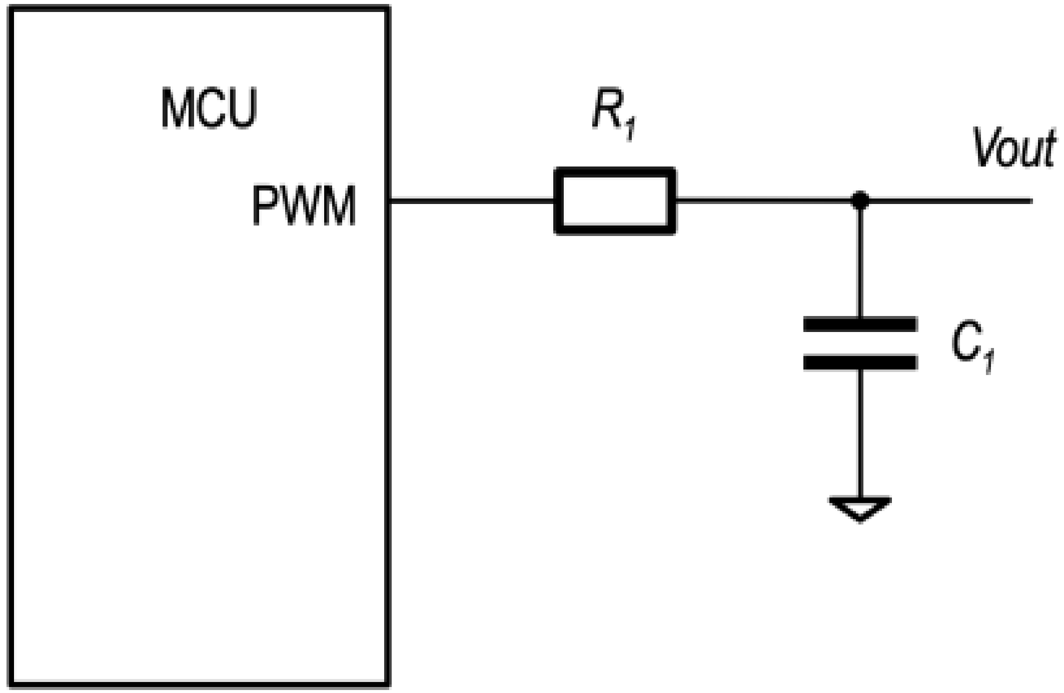
The video mentions multiple methods for converting digital signals to analog:

1. **Resistor Ladder (R-2R DAC)**
2. **RC DAC**

R-2R Ladder DAC Circuit:

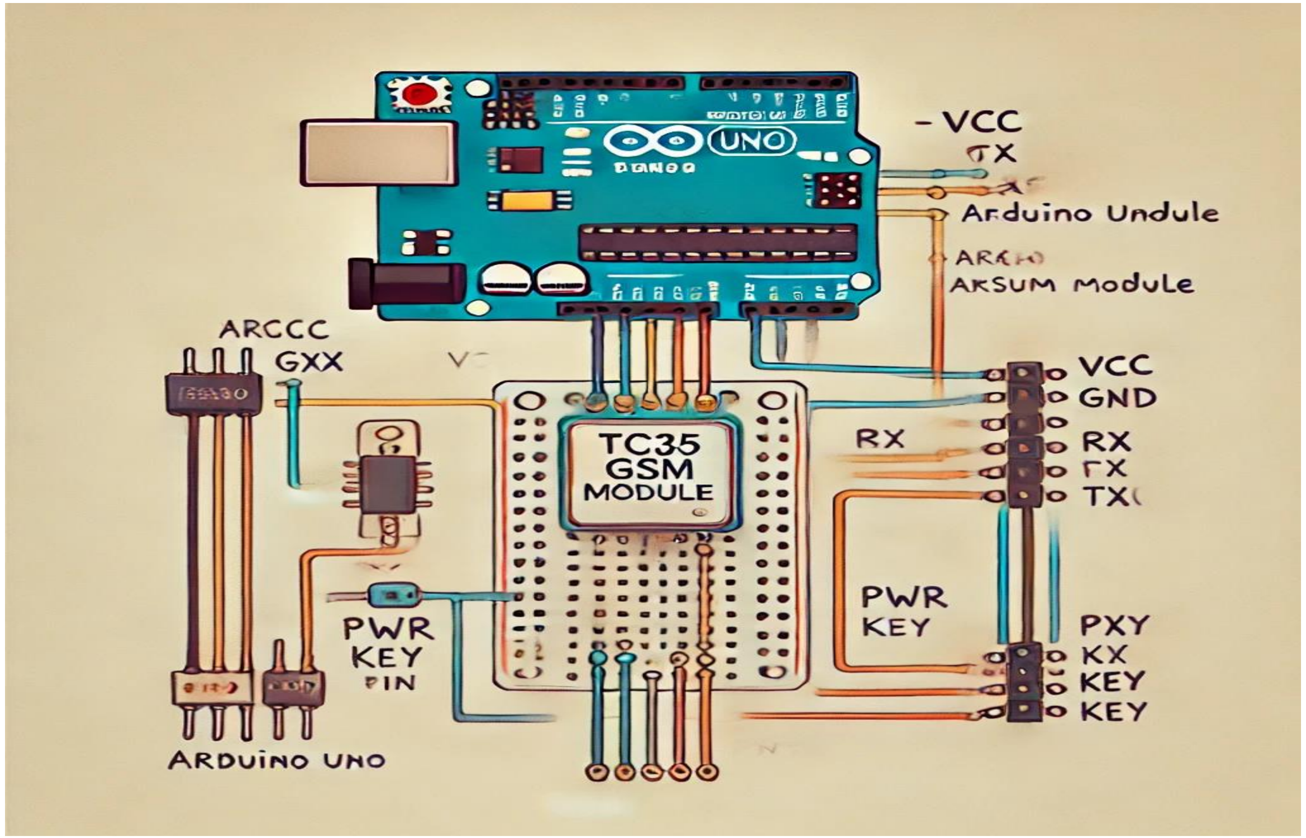


RC DAC circuit:



➢ **Lecture-11:** This video demonstrates **how to use the TC35 GSM module properly** and **send an SMS using an Arduino UNO.**

The **TC35 GSM Module** is a widely used **GSM (Global System for Mobile Communication) module** that allows microcontrollers and embedded systems to send/receive SMS, make/receive calls, and connect to mobile networks. It is based on **Siemens TC35** and operates on **2G networks**.



Here is a simple circuit diagram showing the connection between an **Arduino UNO** and a **TC35 GSM Module**.

- **Lecture-12:** This experiment demonstrates the basic behavior of inductors in electrical circuits, including their response to DC signals, their ability to store energy in a magnetic field, and their role in voltage conversion and circuit protection.

•Inductors store energy in magnetic fields and resist changes in current.
•They are used in voltage conversion (boost converters) and circuit protection (flyback diodes).
•Inductive properties must be considered in designing circuits with motors, transformers, and power supplies.

- **Lecture-13:** This experiment explores how inductors behave in AC circuits, demonstrating the concept of **inductive reactance**, its dependence on frequency, and its effect on voltage and current phase shifts.

  •Inductive reactance limits AC current flow and depends on frequency.
  •Inductors cause phase shifts in AC circuits, affecting power factor.
  •Inductors can be used for filtering, voltage transformation, and energy storage.
  •Practical applications include power grids, audio processing, and motor control.

- **Lecture-14:** This video explains **capacitors**, their working principle, different properties, and how they function in electronic circuits. Let's go step by step through the key concepts discussed. **It store and release electrical energy**, filter signals, stabilize power supplies, and correct power factor

Capacitance can be **increased** by:

1. **Increasing the plate area** – More space for electrons to accumulate.
2. **Reducing the distance between plates** – Stronger electrostatic field.
3. **Using a dielectric material** – A material like **distilled water** increases capacitance significantly.

- **Lecture-15:** This experiment is a hands-on demonstration of how to measure temperature accurately using different types of temperature sensors, including **NTC thermistors** and **PT100 RTDs**, and how to build a simple thermometer circuit.

NTC (Negative Temperature Coefficient) thermistors are resistors whose resistance decreases as the temperature increases.

The **PT100** is a type of **Resistance Temperature Detector (RTD)**, which is a temperature sensor that operates based on the principle that the electrical resistance of certain metals increases with temperature.

- **Lecture-16:** This experiment is a practical demonstration of the various applications of **resistors** in electronic circuits. The video explains the fundamental principles of resistors, their different types, and how they are used in **DC (Direct Current) and AC (Alternating Current) circuits**.

Resistors are used with LED in series to limit the voltage drop of the LED. Resistors are used in voltage divider law. A **potentiometer** is a **variable resistor** with a **movable pin** that changes the resistance. These resistors are used to **stabilize digital signals** in microcontrollers. Shunt resistors are used to measure current. Unlike **capacitors** and **inductors**, resistors **do not** cause a **phase shift** in AC circuits.

- **Lecture-17:** This experiment explores **oscillators**, which are circuits that generate periodic signals such as **square waves, triangle waves, and sine waves**. Oscillators are crucial for **timing circuits, microcontroller clocks, and radio communication**.

•**Oscillators** generate repetitive waveforms and are used in electronics for timing and signal generation.
•**RC oscillators** (e.g., **multivibrators and 555 timer circuits**) are simple but limited in frequency range.
•**LC oscillators** use **inductors and capacitors** to generate high-frequency sine waves.
•**Crystal oscillators** use **mechanical resonance** to create **highly stable frequencies**, such as microcontroller clock signals.

- **Lecture-18:** The video discusses how **Brushless DC Motors (BLDC)** work and how an **Electronic Speed Controller (ESC)** drives them. Here's the step-by-step breakdown:

1. Understanding a Brushed DC Motor

- **Inside a DC Motor**: It has two **permanent magnets (stator)** and a **rotor** made of copper coils.
- **Commutator & Brushes**: These components ensure the coil polarity reverses, creating continuous rotation.
- **Magnetic Forces**: The current in the coils generates a magnetic field that interacts with the permanent magnets to push/pull the rotor.

2. How a Brushless DC Motor (BLDC) Works

- **Main Difference**: The **stator** (stationary part) has coils, and the **rotor** (moving part) has permanent magnets.
- **Three-Phase Winding**: The coils are connected in a **star (Y) connection**, allowing controlled energization.
- **Rotating Magnetic Field**: Unlike brushed motors, BLDC motors use an **Electronic Speed Controller (ESC)** to switch coil activation electronically.

3. How an ESC Controls the Motor

- **MOSFET Switching**: ESCs use **MOSFET transistors** to switch voltage on and off, controlling motor speed.
- **Pulse-Width Modulation (PWM)**: The ESC sends PWM signals to regulate speed and torque.
- **6-Step Commutation**: The ESC switches current between coils in a **six-step sequence** to create rotation.

➢ **Lecture-19:** This experiment demonstrates **I^2C (Inter-Integrated Circuit) communication** between an **Arduino** (master) and a **TEA5767 FM radio IC** (slave). The goal is to program the Arduino to control the FM radio module and receive signals from it.

1. Understanding I^2C Communication

•**I^2C (Inter-Integrated Circuit)** is a serial communication protocol that uses only **two wires**:

- **SDA (Serial Data Line)** → Used for sending and receiving data.
- **SCL (Serial Clock Line)** → Provides clock signals to synchronize communication.

•A **master device (Arduino)** can communicate with up to **112 slave devices (like sensors, displays, radio modules, etc.)** using I^2C.

•Each slave has a **unique 7-bit address** used for communication.

2.Setting Up the TEA5767 FM Radio Module with Arduino

(A) Creating a Breakout Board for the FM Module

•The TEA5767 IC was mounted onto a small **stripboard** for easy connections.

•A **5-pin male header** was soldered to the board.

•The **ground, 5V, antenna, and audio output** were connected as per the **circuit schematic**.

(B) Wiring the Components

•**GND** and **5V** were connected to the Arduino's power lines.

•The **audio output** was connected to headphones or an amplifier for sound output.

•**SDA (A4 on Arduino)** was connected to the **SDA pin of TEA5767**.

•**SCL (A5 on Arduino)** was connected to the **SCL pin of TEA5767**.

•Two **10kΩ pull-up resistors** were used on SDA and SCL lines to stabilize the I^2C signals.

- **Lecture-20:** This experiment demonstrates the working principle of **Thyristors (SCRs) and Triacs** and how they can be used to control **AC power** by adjusting the phase angle of the AC waveform. A practical **phase angle control circuit** is built using an **Arduino, an optocoupler, and a Triac** to regulate the power supplied to an AC load.

Understanding the Thyristor (SCR)

A **thyristor (Silicon Controlled Rectifier - SCR)** is a semiconductor switch that behaves like a **controllable diode**. It has **three terminals**:

- **Anode (A)**
- **Cathode (K)**
- **Gate (G)** (used to trigger the thyristor ON)

Key Characteristics of a Thyristor:

1. **Conducts current in only one direction** (like a diode).
2. **Turns ON when a small current is applied to the Gate (G).**
3. **Remains ON even after the Gate signal is removed** (requires the current to drop below a certain level to turn OFF).

Introduction to the Triac

A **Triac (Triode for AC)** is similar to a thyristor but can:

- **Conduct current in both directions** (positive and negative AC cycles).
- **Be turned ON using a Gate pulse**, just like a thyristor.
- **Be used for AC power control (e.g., dimming lights, motor speed control, heaters, etc.).**

Phase Angle Control Using a Triac

- By delaying the **Gate trigger signal**, the **amount of power delivered to the load** can be controlled.
- This technique is called **Phase Angle Control**.

•**Thyristors (SCRs) and Triacs** are powerful components for **AC power control**.
•**Phase angle control** is an effective way to regulate power in **resistive and inductive loads**.
•The **Arduino-controlled system successfully adjusted power levels**, demonstrating **basic dimming and speed control techniques**.
•Further improvements could include **PWM control, closed-loop feedback, and improved heat management**.

- **Lecture-21:** This experiment demonstrates the working principles of **operational amplifiers (Op-Amps)** and their applications in signal amplification, signal processing, and voltage comparison. The experiment explores **non-inverting amplifiers, inverting amplifiers, and comparators**.

- **Introduction to Operational Amplifiers (Op-Amps)**

•**Op-Amps** are fundamental components in analog electronics.
•They are represented as **triangular symbols** in circuit schematics.
•They are widely used in **signal amplification, voltage comparison, and mathematical operations**.
Common Op-Amp IC Packages:
•**14-pin ICs** (e.g., LM358, LM324) → Contain multiple op-amps.
•**8-pin ICs** (e.g., LM741, LM358) → Contain one or two op-amps.

Experiment 1: Non-Inverting Amplifier
A **non-inverting amplifier** increases the voltage of an input signal while maintaining its original polarity.
Circuit Setup:
1. **Input Voltage:** +1V applied to the **non-inverting input (V_{in}^{+}).**
2. **Feedback Network:**
    1. A **5.1kΩ resistor (R1)** from **output to inverting input (V_{in}^{-}).**
    2. A **1kΩ pull-down resistor (R2)** to ground.
3. **Output Voltage Observed: 6.1V.**

Experiment 2: Amplifying an AC Signal from a Microphone
Problem:
- The **electret microphone** generates **small AC voltage peaks (~100mV AC).**
- The signal needs to be **amplified** before being processed or output to a speaker.

Solution:
- Using the **non-inverting amplifier configuration** with a gain of **48**:
    - **R1 = 47kΩ, R2 = 1kΩ**
    - **Gain = 1 + (47kΩ / 1kΩ) = 48**

Observations:
- The positive half of the **AC signal was amplified**, but the **negative half was clipped**.
- **Cause:** The op-amp output **cannot go below 0V** (since it is powered by a **single 12V supply**).
- **Solution:** A **dual power supply (±12V)** allows full AC signal amplification

Experiment 3: Inverting Amplifier for Full AC Signal Amplification
Circuit Setup:
1. The **non-inverting input (Vin^+) is connected to 0V (ground).**
2. The **input signal is fed into the inverting input (Vin^-) through R1.**
3. **R2 is connected between Vin^- and the output.**
4. **A DC offset is applied to Vin^+ instead of ground.**

Results:
- The full **AC signal is successfully amplified**, without DC bias interference.
- However, the op-amp **cannot drive a speaker directly** due to **low output current capability**.

Experiment 4: Comparator Mode (Zero Feedback Configuration)
When an op-amp is used **without feedback**, it functions as a **comparator**.
Circuit Behavior:
- If **$Vin^+ > Vin^-$**, then **Vout jumps to the max voltage (12V).**
- If **$Vin^- > Vin^+$**, then **Vout jumps to the min voltage (0V).**
- This happens because the **op-amp has a high open-loop gain** (several thousand).

- **Lecture-22:** This experiment demonstrates how **Bipolar Junction Transistors (BJTs)** can be used as electronic switches to control loads such as **LEDs, bulbs, and high-power devices**. It also explores the key principles of transistor operation, including base current control, saturation, and power dissipation.

1. **BJTs can be used as electronic switches**, but require careful calculation of **base current**.
2. **Base resistors** are essential to **prevent damage** to the transistor.
3. **For high-current loads, power dissipation must be considered**, and heat sinks may be necessary.
4. **NPN transistors are used for low-side switching**, while **PNP transistors are used for high-side switching**.
5. **Darlington transistors** allow **low-power control of high-current loads**, making them **Arduino-friendly** but less efficient.

- **Lecture-23:** In this experiment, the goal is to **demonstrate the use of MOSFETs as switches** and **compare their efficiency with BJTs (Bipolar Junction Transistors)**. The experiment covers the **basic working principle of MOSFETs**, their behavior in **low and high-power applications**, and methods to **mitigate switching issues like oscillations and energy loss**.

✅ **MOSFETs are more efficient than BJTs**, reducing energy loss significantly.
✅ **Gate drive considerations are important** – pull-down/pull-up resistors prevent unwanted switching.
✅ **For high loads, oscillation issues arise due to parasitic capacitance**.
✅ **Gate resistors help control switching speed and reduce oscillations**.
✅ **MOSFETs are great for low-frequency applications but need proper gate drivers for high-frequency applications**.

➢ **Lecture-24:** This experiment aims to **explain how a stepper motor works**, why it is used in **precise positioning applications like 3D printers**, and how to **control it with and without a microcontroller**. It covers the **internal structure of a stepper motor, different driving techniques, and microstepping using a stepper motor driver IC**.

- **Stepper motors move in precise steps, unlike DC motors.**
- **Different drive modes (wave, full-step, half-step, microstepping) affect torque and smoothness.**
- **Microstepping makes motion smoother and quieter.**
- **Using driver ICs like A4988 simplifies control and improves efficiency.**

➢ **Lecture-25:** This experiment aims to **understand the working principle of a servo motor**, how it is controlled, and how it can be modified for continuous rotation. The experiment includes **disassembling a servo motor**, analyzing its internal components, and controlling it using **an Arduino and a 555 timer IC**.

✅ **Servo motors use PWM signals for precise position control.**
✅ **Internal gears reduce speed and increase torque.**
✅ **Feedback potentiometer helps maintain the desired position.**
✅ **Arduino or a simple 555 timer circuit can control a servo.**
✅ **Servos can be modified for continuous rotation by removing the feedback system.**

➢ **Lecture-26:** This experiment explores the **555 Timer IC** and its various configurations, including **monostable, bistable, and astable** modes. Each mode is analyzed through practical circuit implementations to understand how external components (resistors, capacitors, and diodes) influence the IC's behavior.

The **555 Timer IC** is one of the most popular **integrated circuits (ICs)** used in **timing, pulse generation, and oscillator applications**. It is widely used in electronics projects, including **servo motor control, frequency generation, delay circuits, and PWM signal generation**.

❖ Internal Structure of the 555 Timer IC

Inside the **555 Timer IC**, several key components work together:

✅ **Voltage Divider:** Three **5kΩ resistors** form a voltage divider between **VCC (Pin 8) and GND (Pin 1)**. This provides **reference voltages** at **1/3 VCC and 2/3 VCC**.

✅ **Comparators:** Two comparators compare input voltages to the reference voltages.

- **Comparator 1:** Connected to **Trigger (Pin 2)**, sets the flip-flop when the voltage falls below **1/3 VCC**.
- **Comparator 2:** Connected to **Threshold (Pin 6)**, resets the flip-flop when the voltage rises above **2/3 VCC**.

✅ **Flip-Flop:** Stores the state of the timer, controlling the output **(Pin 3)**.

✅ **Discharge Transistor:** Connected to **Pin 7**, it allows a capacitor to discharge under specific conditions.

The **555 Timer IC** can be used in **monostable, bistable, and astable** configurations.

Monostable mode generates a **single pulse**.

Bistable mode creates a **toggle switch**.

Astable mode generates a **continuous waveform**.

PWM signals can be created for motor control and power electronics.

➢ **Lecture-27:** This experiment explores the **Analog-to-Digital Converter (ADC)**, its **sampling rate**, **resolution**, and **working principles**, and demonstrates a **DIY ADC implementation** using Arduino and external ADC ICs.

A **microcontroller** like Arduino can convert an **analog signal** (continuous voltage) into a **digital value** using an ADC.

✅ **Example:**

•Suppose we have an **analog voltage** of **3V**.

•If the Arduino's **reference voltage** is **4.62V**, the **ADC value** would be **666** (out of 1023 in a 10-bit system).

Key Takeaways from the Experiment

✅ **Sampling rate** must be at least **twice the signal frequency** (Nyquist Theorem).

✅ **Higher resolution ADCs** provide **better accuracy**.

✅ **External ADCs** can improve precision when **Arduino's 10-bit ADC** is insufficient.

✅ **DIY Flash ADCs** are possible but become impractical for high resolutions.

➢ **Lecture-28:** This experiment explores the differences between **MOSFETs (Metal-Oxide-Semiconductor Field-Effect Transistors)** and **IGBTs (Insulated-Gate Bipolar Transistors)**, focusing on their **switching characteristics, efficiency, and power losses** in a power-switching circuit. The goal is to determine which component is better suited for specific applications, such as **Tesla coils, inverters, and high-power electronics**.

Key Takeaways from the Experiment

✓ **MOSFETs are faster and more efficient for high-frequency applications (>200 kHz).**

✓ **IGBTs handle higher voltages and currents better but switch slower (<200 kHz).**

✓ **Power dissipation is lower in MOSFETs at low currents but can be lower in IGBTs at high currents.**

✓ **Proper gate driving (TC4420, IR2113) is essential for both MOSFETs and IGBTs.**

✓ **For Tesla coils, IGBTs can work, but MOSFETs might be better depending on the frequency range.**

- **Lecture-29:** The Objective of the experiment is to understand how to maximize power output from a **solar panel, to** investigate how **series and parallel connections** of solar cells affect performance, to explore **how solar panels charge batteries efficiently** using **MPPT.**

Basics of Solar Panels

A **solar panel** consists of multiple **solar cells** connected in series to increase voltage. Each solar cell generates a voltage of around **0.5V** when exposed to light.

•Example: A **100W solar panel** typically has **36 cells** connected in series, producing an **open-circuit voltage of around 14.3V**.

•**Issue with Series Connection:**

- If **one cell is shaded**, the overall current decreases drastically, reducing power output.
- **Bypass diodes** are used to allow current to flow around shaded cells, preventing major power loss.

•**Parallel Connections and Blocking Diodes:**

- **Blocking diodes** are used when panels are connected in parallel to prevent reverse current flow at night or when some panels receive less sunlight.

•**Solar panel efficiency depends on proper load matching.**
•**Shading significantly reduces power output**, but **bypass diodes** help mitigate losses.
•**MPPT controllers are the best choice for charging batteries efficiently.**

- **Lecture-30:** The experiment demonstrates how to use timers in an **ATmega328P** microcontroller (commonly found in the **Arduino Uno**) to generate **precisely timed events** and **PWM signals**.

1. Basic Time Events Using Delay() (Not Recommended)

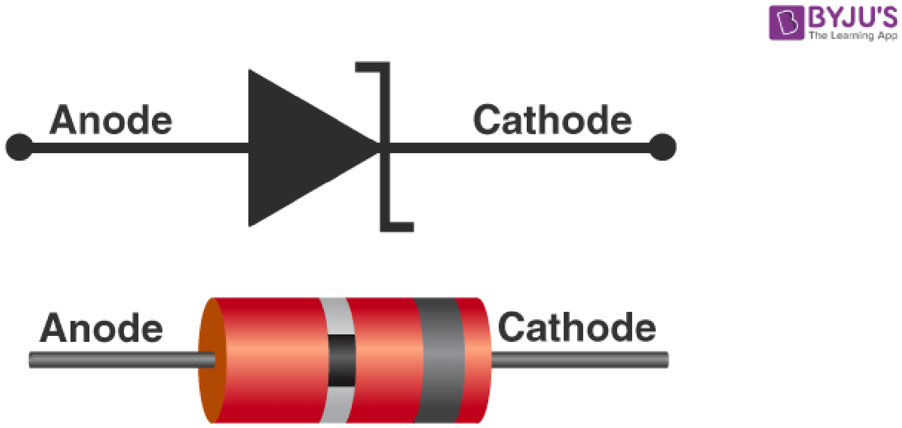
•A simple **LED blinking** program is written using delay(1000), which makes the LED turn on and off every second.
•A button input is added, but the microcontroller **ignores** the button most of the time because it is stuck in the delay() function.
•Another issue is that **delay() is not highly precise**, leading to timing drift over long periods.

Conclusion

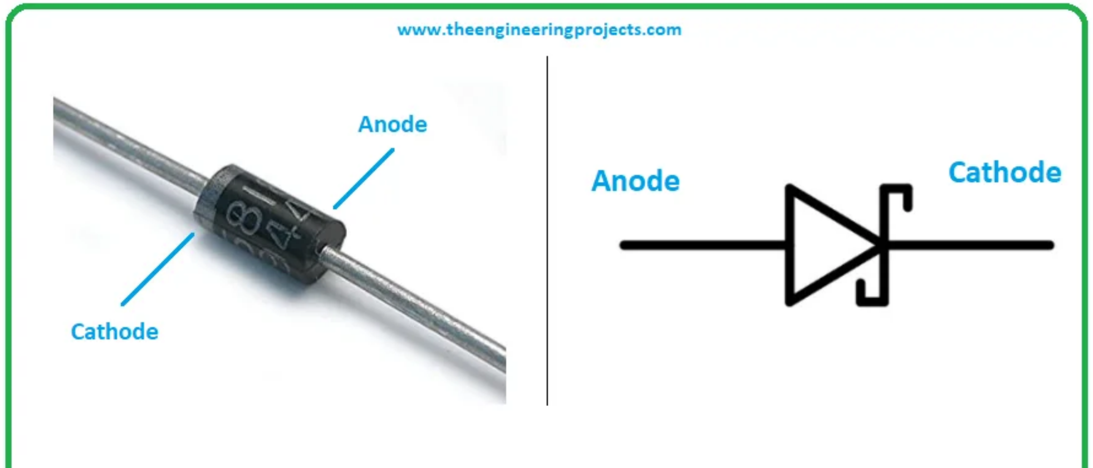
•**Timers allow precise timing without using delay(), keeping the microcontroller responsive.**
•**Multiple interrupts can be set up for different events.**
•**PWM signals with adjustable duty cycle and frequency can be generated efficiently.**
•**Timers are crucial for real-time applications like LED matrices, motor control, and alarm clocks.**

- **Lecture-31:** The experiment in the video demonstrates the characteristics and practical applications of **Schottky diodes** and **Zener diodes** through a series of tests.

•**Schottky diodes** are ideal for **low voltage drop** and **fast switching** applications like **switch-mode power supplies**.
•**Zener diodes** are used for **voltage regulation**, **overvoltage protection**, and **clipping signals**.
•**Regular diodes** are useful but may not always be the best choice depending on the circuit requirements.



(Zener diode)



Schottky Diode

➢ **Lecture-32:** The experiment in the video demonstrates how **relays** and **optocouplers** work, their applications, and why they are useful in circuits involving **high voltages and isolation**.

❖ **Exploring Relays**

Objective:

To understand how a **relay** functions and how it can be used to control high-voltage appliances with a low-voltage control signal.

Procedure:

1.Opening a Remote-Controlled Socket:

1. The socket is disassembled, revealing components such as:
   1. **A fuse**
   2. **A radio frequency (RF) PCB**
   3. **HX2272 IC** (remote control encoder)
   4. **A relay** (the main switching component)
2. The relay **clicks** when switching, indicating mechanical movement.

2.Relay Structure Analysis:

A relay is **opened** to inspect its internal components:

1. **A coil**
2. **A set of switch contacts**

The relay casing specifies a **coil voltage of 5V**, meaning that when 5V is applied, the coil energizes and closes the switch.

3.Testing the Relay with a Light Bulb Circuit:
•A **simple circuit** is built where a relay switches a **small light bulb** on/off.
•When **5V** is applied to the coil, the relay **activates**, closing the contacts and powering the bulb.

4.Observing Voltage Spikes:
•A **voltage spike of 200V** is observed across the switch when turning off the relay.
•This is caused by the **collapsing magnetic field** in the coil, inducing a back EMF (electromotive force).

5.Adding a Flyback Diode for Protection:
•A **flyback diode** is placed **parallel to the coil** to allow the excess current to discharge safely.
•The circuit is tested again, and the **voltage spikes disappear**, ensuring **safe transistor operation**.

❖ **Understanding Optocouplers**

Objective:

To demonstrate how **optocouplers** work and their role in **safe signal isolation**.

Procedure:

1.Examining the Internal Structure of an Optocoupler:

1. The **817 optocoupler** is analyzed, which contains:
    1. An **Infrared LED (input side)**
    2. A **photosensitive transistor (output side)**

2.Building an Optocoupler Test Circuit:

1. The IR LED is powered by a **low-voltage signal (e.g., 5V from a microcontroller)**.
2. When the LED lights up, the **transistor turns on**, completing the circuit.

3.Controlling a TRIAC with an Optocoupler:

- The optocoupler is connected to a **TRIAC**, which switches **AC mains voltage**.
- This setup allows safe **high-voltage switching** using **low-voltage control**.
- The **galvanic isolation rating** of **7500V** ensures **protection against electric shocks**.

4.Double Isolation with Relay & Optocoupler:

- The optocoupler is used to **switch a transistor**, which in turn **activates the relay**.
- This provides **double isolation**, ensuring **maximum safety** for the control circuit.

➢ **Lecture-33:** This experiment explores how strain gauges and load cells function to measure weight or force electronically. The goal is to integrate them into a circuit to obtain accurate weight measurements using a microcontroller.

- **Strain gauges** detect force by resistance change.
- **Wheatstone Bridge** converts resistance changes into voltage.
- **Amplifiers or HX711 ADC** boost small signals for better readings.
- **Load Cells** simplify strain gauge usage.
- **HX711 offers higher precision** than standard microcontroller ADCs.

- **Lecture-34:**

Two-Position (On-Off) Controller

Concept:

A **Two-Position Controller** (also known as a **Bang-Bang Controller**) operates using only two states: **ON** or **OFF**. It switches between these states based on a **threshold** or **setpoint**.

How It Works:

•If the system parameter (e.g., temperature, speed, position) is **below the setpoint**, the controller **turns ON** the actuator.

•If the system parameter is **above the setpoint**, the controller **turns OFF** the actuator.

Example:

•A **thermostat** controlling a heater:

- If room temperature is below 25°C → Heater **ON**.
- If room temperature exceeds 25°C → Heater **OFF**.

Advantages:

✅ **Simple & Cost-Effective** – Easy to implement.

✅ **Fast Response** – Reacts quickly to changes.

✅ **Works Well for Binary Systems** – Like turning lights ON/OFF or simple heating elements.

PID (Proportional-Integral-Derivative) Controller
Concept:
A **PID Controller** continuously adjusts the system output to **minimize error** (difference between the desired and actual value) using three components:

1. **Proportional (P):** Adjusts output based on the current error.
2. **Integral (I):** Eliminates steady-state error by considering past errors.
3. **Derivative (D):** Predicts future errors and smoothens system response.

Advantages:
✅ **Precise & Smooth Control** – Reduces oscillations and stabilizes output.
✅ **Works for Complex Systems** – Used in robotics, motor control, and process automation.
✅ **Adjustable Performance** – Tunable parameters allow customization.

- **Lecture-35:**A **Schmitt Trigger** is a special type of comparator circuit with **hysteresis** that helps eliminate unwanted signal noise and erratic switching. It is widely used in digital electronics, signal processing, and control systems.

Instead of one threshold, a Schmitt Trigger has **two threshold voltages**:

1. **Upper Threshold (Vh)** – The output switches **HIGH** when the input exceeds this value.
2. **Lower Threshold (Vl)** – The output switches **LOW** when the input drops below this value

❖ **How to Build a Schmitt Trigger**

a) Using an Op-Amp

- An **op-amp with positive feedback** creates a Schmitt Trigger.
- Resistors set the **hysteresis width** (difference between Vh and Vl).

b) Using a Dedicated Schmitt Trigger IC

- **74HC14** (Hex Inverting Schmitt Trigger) is a common IC with six built-in Schmitt Triggers.
- **Advantages**: Simple, fast response, and reliable operation.

➢ **Lecture-36: SPI (Serial Peripheral Interface)** is a high-speed communication protocol used to transfer data between a **master** (e.g., Arduino) and one or more **slave** devices (e.g., sensors, memory chips, or RTC modules). It is faster than I2C but requires more connections.

- **SPI is a high-speed communication protocol** that allows **fast data transfer** between devices.
- The **DS3234 RTC uses SPI**, not I2C.
- The **Arduino communicates with DS3234** using **SPI Mode 1 (clock low, data read on falling edge)**.
- SPI allows **precise real-time clock control and data retrieval**.

➢ **Lecture-37:** This video explains the **concept of impedance**, which extends the idea of resistance from **DC circuits** to **AC circuits**. The key difference is that in AC circuits, **inductors** and **capacitors** also resist current flow, but in a frequency-dependent manner. The video explores **inductive reactance, capacitive reactance, and impedance** using practical experiments.

- **Lecture-38:**

- **True power (P)** does useful work.
- **Reactive power (Q)** oscillates between source and load, adding unnecessary current flow.
- **Apparent power (S)** is the total power supplied to the circuit.
- **Power factor (PF) = P/S**, indicating efficiency.
- **Poor power factor** increases energy losses and costs.
- **Power factor correction** helps improve efficiency and reduce power system stress.

- **Lecture-39:** This video describes the process of reverse engineering and controlling a custom **LED matrix** using **shift registers** and an **Arduino**.

- The project **demonstrates shift registers and multiplexing**.
- The LED matrix can display text using an **Arduino Nano**.
- Improvements are needed for **better text scrolling and display performance**.

- **Lecture-40:** This video dives into **RFID** (Radio Frequency Identification) and **NFC** (Near Field Communication), explaining how they are used in **contactless payments** and their safety concerns, particularly when used in systems like Google Pay, Girocard, and other contactless payment methods.

•NFC is a safe and efficient technology for **contactless payments**, and RFID is widely used in **Arduino-based projects**.
•**Contactless payments** are **not as dangerous** as some people think due to the **security protocols** in place.
•To protect against unauthorized RFID access, **anti-skimming wallets** can be used, which block the communication signals.

- **Lecture-41:** This video explores how audio crossovers work, their importance in audio systems, and how they are used to improve the sound quality of loudspeakers. An **audio crossover** is a circuit that separates an audio signal into different frequency bands. It directs the appropriate frequencies to the correct speakers, such as sending low frequencies to the woofer (larger speaker) and high frequencies to the tweeter (smaller speaker). This ensures each speaker works in its optimal frequency range.

Experimenting with Filters:
•**Resistor**: A resistor alone dampens the audio signal across all frequencies equally.
•**Inductor**: When connected to the circuit, an **inductor** dampens high frequencies. This makes it useful for low-pass filters that allow low frequencies to pass while blocking higher ones.
•**Capacitor**: A **capacitor** behaves the opposite, dampening low frequencies and allowing high frequencies to pass, making it ideal for high-pass filters.

Understanding Filter Types:
•**RC Filters**: Combinations of resistors and capacitors create either high-pass or low-pass filters. The cutoff frequency, where the filter begins to attenuate the signal, can be calculated using formulas involving resistance and capacitance.
•**LC Filters**: Combining inductors and capacitors forms an **LC filter** that can filter frequencies more sharply than RC filters, giving a faster roll-off (a steeper decrease in signal strength beyond the cutoff frequency).

Order of Filters:
•A **first-order filter** has a **20 dB per decade** attenuation, which means the signal strength decreases slowly beyond the cutoff frequency.
•A **second-order filter**, formed by combining inductors and capacitors, offers a **40 dB per decade** roll-off, meaning it attenuates unwanted frequencies much faster.

Conclusion:
•The speaker learned that their previous decision to replace an audio crossover was misguided, as the new crossover didn’t match the frequency response of the speakers, which led to poor audio quality.
•While building DIY crossovers is possible (using software like **WitWix Cat 2**), it's important to consider the specific requirements of the loudspeakers in use.

- **Lecture-42:** This video provides a detailed explanation of how transformers work, their construction, and the factors that influence their efficiency and performance. **Transformers** are devices used to convert high-voltage AC (Alternating Current) into a lower voltage AC, which is safe to use with common electronic devices. For example, a transformer can take 230V AC from the mains and step it down to 13.5V AC for use by lower voltage devices.

•**Basic Structure**: A transformer consists of two coils of wire wrapped around a metal core (usually made of laminated electrical steel sheets). These coils are known as the **primary** coil (connected to the input voltage) and the **secondary** coil (providing the output voltage).
•**Magnetic Induction**: When AC voltage is applied to the primary coil, it creates a changing magnetic field, which induces a voltage in the secondary coil through **magnetic induction**. This induced voltage depends on the number of turns (windings) in each coil.
•**Induced Voltage Calculation**: The induced voltage in the secondary coil can be calculated based on the number of turns in the primary and secondary coils.

- **Lecture-43:**

The video demonstrates how to control mechanical seven-segment displays using a microcontroller (Arduino) and RS-485, converting serial data for display purposes. The final project is a subscriber counter that automatically updates the number of subscribers in real-time using the YouTube API and displays the count on the mechanical display. The creator emphasizes the charm and appeal of the mechanical movement of the display, especially in a creative project like this one.

- **Lecture-44:** In this video, the creator is addressing a synchronization issue between the two hub motors of his electric longboard. Despite both motors receiving the same signal from the remote control's electronic speed controller (ESC), the motors don't start spinning at the exact same time. This small misalignment of the unloaded RPMs doesn't cause noticeable performance issues, but the creator wants to fix it for better synchronization and safety.

To solve this, the creator uses the **CAN Bus** (Controller Area Network) to synchronize the two ESCs and ensure both motors spin in sync.

CAN Bus is a serial communication system that allows multiple devices (called "nodes") to communicate with each other without a host computer. It was originally designed for automotive use but is now widely used in various industries. n a car, the CAN Bus allows different electronic control units (ECUs) like buttons, knobs, motors, and sensors to communicate with each other. For example, the system can control the power windows, parking sensors, etc. The CAN Bus requires only two wires, **CAN-H (high)** and **CAN-L (low)**, for communication, which makes it cheap and efficient in terms of wiring.

- **Lecture-45:** In this video, the creator explains how to use the **I2S (Inter-IC Sound)** communication protocol with an **ESP32 microcontroller** to play back an audio file, "Stay Creative!". The process involves using an I2S microphone for recording and an I2S amplifier for outputting the sound.

I2S is used for transmitting digital audio data, enabling high-quality sound playback without the limitations of the internal DAC’s lower resolution. **SPI** is used for reading data from the micro SD card, which holds the audio file. The **MAX98357A** is a high-quality I2S amplifier that plays back the audio with better sound quality than the ESP32’s internal DAC.

- **Lecture-46:** The video aims to explain **how an induction motor works**, how to **connect it properly**, and why it's the **most widely used motor type in the world**. The speaker successfully tests their old motor, which works fine. **Induction motors dominate industrial and commercial applications** because of their **efficiency, durability, and ease of use**.

How the Induction Motor Works

•**No Permanent Magnets**: Unlike **BLDC or stepper motors**, induction motors work using **electromagnetic induction**.

•**Rotating Magnetic Field (RMF)**:
- Three-phase AC power creates **three sine waves**, each **120° out of phase**.
- The currents in the stator coils generate a **rotating magnetic field**.

•**Induction in the Rotor**:
- The **rotating magnetic field** induces **current** in the **squirrel cage rotor**.
- This current generates **another magnetic field**, which interacts with the stator's field, causing the rotor to **follow** the rotation.

•**Slip**:
- The rotor **never spins exactly at the same speed** as the stator field.
- This difference (slip) is essential, as **no induction would occur if both rotated at the same speed**.

Why is the RPM Less Than 3000?

•The stator field rotates at **3000 RPM** (assuming a **50Hz** power supply and a **2-pole motor**).

•The rotor speed is **slightly less than 3000 RPM** due to **slip**.

- **Lecture-47:** This video is about **vacuum tube amplifiers (tube amps)** and explores their functionality and relevance in modern audio systems.

3. What's Inside the Tube Amp?

- Upon **disassembling the amp**, the creator found:
  - **Operational amplifiers (op-amps)**
  - **A class D amplifier for the speakers**
  - **A headphone amplifier**
  - **Vacuum tubes only handling the pre-amplification stage**
- The **actual power amplification** is done by transistors, not the vacuum tubes.
- This suggests that **the tubes are mainly for adding a particular sound character, not for power amplification**.

4. How Do Vacuum Tubes Work?

- **Triode vacuum tubes** consist of:
  - **Plate (anode)**
  - **Cathode**
  - **Grid (control signal)**
  - **Heater (filament)**
- When the heater is powered, it excites electrons to flow from the **cathode to the anode**.
- The **grid** controls this flow, allowing for **amplification**.
- However, tubes **consume more power and produce more heat** compared to transistors.
- **Modern transistor amplifiers** are **cheaper, more efficient, and technically superior** in most ways.
- However, **audiophiles and musicians** still appreciate tube amps for their **"warm" sound** and unique distortion characteristics.

- **Lecture-48:** This experiment explores how an **eFuse IC (TPS259621)** can be used to protect an electronics project from **overvoltage, undervoltage, overcurrent, and short circuits**. The project involves powering an **Arduino Nano-based LED blinker** and ensuring it remains operational under various power conditions.

✅ **Undervoltage Protection:** Circuit does not start below 4V.
✅ **Overvoltage Protection:** Voltage is clamped at 5.35V when exceeded.
✅ **Overcurrent Protection:** Limits current at 200mA.
✅ **Reverse Voltage Protection:** Prevents damage when power polarity is reversed.

- **Lecture-49:** This experiment revolves around demonstrating the correct and incorrect ways to use an **oscilloscope**, particularly when working with **mains voltage** and **switching power electronics**. The main objective is to measure and analyze the electrical waveforms in a **Switched Mode Power Supply (SMPS)** while highlighting a common but dangerous mistake that beginners often make.

- **Lecture-50:** The experiment aimed to explore the TL431 programmable shunt voltage reference and its application in switched-mode power supplies (SMPS).

TL431 was examined in multiple configurations:

•**As a Comparator**: The TL431 was connected in an open-loop setup, where it switched states based on the reference voltage.

•**As a Fixed 2.5V Zener Diode**: Connecting the reference pin to the cathode created a stable 2.5V reference, making it act as a precision Zener diode.

•**As an Adjustable Zener Diode**: A resistor divider was used to set different voltage references, making it an adjustable precision voltage regulator.

Exploring TL431 Applications
The TL431's ability to monitor and regulate voltages was tested in:
•A **12V battery undervoltage protection circuit**, which disconnected the load if the voltage dropped too low.
•A **precision constant current sink**, where the TL431 controlled the current flow through a load.

Implementing TL431 in an SMPS Feedback Circuit
The key experiment involved using the TL431 in an SMPS feedback system. The goal was to maintain a stable 5V output by adjusting the duty cycle of the PWM signal.
•**Voltage Divider Calculation**: Two 500Ω resistors were used to scale the output voltage down to 2.5V for the TL431 reference pin.
•**Optocoupler Integration**: The TL431 controlled an optocoupler, which fed the feedback signal to the PWM circuit.
•**Circuit Testing**: The SMPS was built using a combination of perfboard and air wiring. A microcontroller was programmed to generate a 54kHz sawtooth waveform for PWM control.

Observations & Results
•The feedback system successfully regulated the output voltage.
•The TL431 effectively stabilized the system without requiring a dedicated error amplifier.
•A 100nF capacitor was added to improve stability, preventing unwanted oscillations in the feedback loop.

- **Lecture-51:** This experiment explores how digital potentiometers can replace mechanical ones in various circuits, allowing microcontroller-based control. The key focus is on testing digital potentiometers, understanding their limitations, and successfully using them in a high-voltage application.

•Digital potentiometers can **electronically replace mechanical ones**, making circuits programmable.
•The **X9C103 failed** due to voltage and current limitations.
•The **MCP41HV51-10k worked perfectly** in a high-voltage environment.
•This method allows **microcontroller-based voltage control**, useful for applications like **dimming LEDs, setting amplifier gain, and sensor calibration**.

- **Lecture-52:** The experiment in the video demonstrates different methods to generate a **dual rail power supply**, which provides both **positive and negative DC voltages**.

•Different methods exist to create **dual rail voltages**, each with pros and cons.
•**Charge Pumps**: Simple, low current, noisy.
•**Transformer-Based**: High current, low noise, but requires AC power.
•**Virtual Ground Methods**: Easy but require stabilization.

- **Lecture-53:** The experiment demonstrates different types of **latch circuits**, their working principles, and their applications in real-world electronics.

A **latch circuit** is a type of bistable circuit that "latches" onto a state (ON or OFF) based on input signals. Once triggered, it maintains that state until a reset signal is applied.
Example applications:

- **Corridor lighting** using a latching relay
- **Power buttons** in electronic devices
- **Overcurrent protection circuits**
- **Microcontroller self-deactivation**

The experiment showcased **various latch circuit implementations**, from **basic logic gates** to **solid-state MOSFET switches** and **practical applications** like **power control and protection circuits**. The key takeaway is that **latch circuits are essential in electronics for controlling and maintaining states with minimal power consumption**.

- **Lecture-54:** The experiment aimed to demonstrate how **resettable fuses (PPTCs)** function, how they trip when excessive current flows, and how they compare to traditional glass fuses.

•Resettable fuses work by increasing resistance instead of completely disconnecting the circuit like traditional fuses.
•They are slower than electronic fuses (eFuses) but trip faster than traditional glass fuses.
•They are best suited for applications where circuit protection is needed, but immediate total disconnection is not required (e.g., battery protection, LED strips).
•Choosing the right resettable fuse depends on balancing trip time, power loss, and current ratings for specific applications.

➢ **Lecture-55:** In this video, the experiment is focused on demonstrating how Power Factor Correction (PFC) circuits improve the performance of power supplies by reducing reactive power and improving the power factor.

Key Concepts:

•**Apparent Power vs. Real Power**: Apparent power is the total power that the power grid must supply to deliver real power (the power used for lighting, heating, etc.). The real power is the actual power consumed by the device, while the apparent power includes both real and reactive power. Reactive power is unwanted power that doesn't do useful work and is a result of phase shifts between voltage and current waveforms.
•**Power Factor**: The power factor is the ratio of real power to apparent power. A power factor of 1 means that all the supplied power is used efficiently, and there is no reactive power.

•Without the PFC, the power supply generated significant current harmonics and had a low power factor, leading to inefficient power usage.
•After adding the active PFC, the power supply drew current in a way that closely matched the mains voltage, reducing the harmonic distortion and improving the power factor. This resulted in more efficient energy usage and less strain on the power grid.

- **Lecture-56:** In this experiment, the focus is on testing and understanding the limitations of color ring inductors, particularly in a boost converter circuit, and comparing them with more commonly used inductors in such applications.

•The experiment concludes that **color ring inductors** are useful for low-power applications, such as small power supplies, oscillators, or signal filters. However, they are not suitable for high-power applications, like power converters, where higher currents and inductive performance are required.
•These inductors are more appropriate for beginners who want to experiment and learn without the risk of costly damage if the inductor fails.
•The key takeaway is that while color ring inductors are inexpensive and easy to use, they have limitations in terms of current handling and inductance performance. They are best suited for low-power circuits but may not be reliable for more demanding applications.

- **Lecture-57:** In this experiment, the focus is on understanding **the concept of ground/earth in electrical systems** and how it functions for safety and static electricity discharge. The presenter also demonstrates various real-world examples and experiments to explain this.

1. Soil as an Electrical Conductor:
•The presenter starts by demonstrating how soil, often considered an insulator, can actually conduct electricity. They show that by using copper wires to connect soil, it can carry current, powering a light bulb.
•This is significant because soil or ground can conduct electricity under certain conditions, and this concept is used in many electrical systems, particularly for grounding purposes.

2. The Purpose of Grounding in AC Appliances:

•The next part of the experiment involves a **household AC appliance** (toaster in this case) to show the practical use of grounding.

•The appliance is connected to the **mains power**, and the typical AC power cable is examined. The cable includes **live (L)**, **neutral (N)**, and **ground (PE)** wires (Protective Earth in Germany).

•The presenter highlights that the **live** and **neutral** wires are enough to power the toaster, but the **ground wire** (PE) is important for safety.

3. Safety Function of Grounding:

•The grounding wire is connected to the **metal chassis** of the toaster to prevent electric shock in case of a fault (e.g., if the live wire comes loose or loses insulation).

•The experiment simulates a fault condition where the live wire touches the toaster's metal chassis, and the presenter uses a multimeter to show that the chassis is connected to ground.

•**Short Circuit and Protection:** If the live wire touches the chassis, a **short circuit** occurs, and the ground wire provides a path for the current to flow to the earth, triggering safety devices (circuit breakers and RCBs) to **disconnect the power** and protect the user from electric shock. This is demonstrated with sparks and a power cut.

4. Earth Grounding and Soil's Conductivity:

•The experiment shifts to explain how the **earth** (or ground) is used in electrical systems. In the presenter's panel, the ground wire connects to a **metal rod** buried deep in the earth.

•The soil or ground has a certain **resistance** that allows it to conduct electricity, though it is not as conductive as metals. The presenter uses the example of **soil resistance** and notes that the resistance can vary depending on moisture levels or soil composition.

5. Static Electricity and the Role of Earth Grounding:

- The presenter explains **static electricity** by showing an example of how rubbing feet on a carpet can build up a **voltage difference** in the body, leading to a discharge when touching a metal object (such as a door handle).
- Static electricity can cause shocks and even damage **sensitive electronics**. To prevent this, metal parts (like electronics enclosures) are **connected to earth** to discharge static electricity safely into the ground.
- The earth is a very large mass, so it can absorb and neutralize excess electrons without significantly changing its potential (i.e., the voltage).

6. Earth Grounding in Electrical Systems:

- The presenter further explains the concept of earth grounding by relating it to **large-scale electrical systems**, such as **solar panels** or **power distribution grids**, where grounding prevents damage from high voltages (such as those from lightning strikes).
- Grounding helps in establishing a common reference point (0V) for electrical systems, ensuring that different parts of the system maintain a consistent and safe potential.

7. Ground in Circuit Schematics and PCB Designs:

- The final part of the video discusses **grounding in electronics circuit design**. Most circuits use ground as a **common reference point** (0V) rather than directly connecting to earth. This is why many circuit schematics feature multiple grounds, which are actually just different points of the same reference potential.
- In **PCB (Printed Circuit Board) design**, the bottom layer of a 2-layer PCB is often used as a continuous **ground plane** to provide a stable reference potential for the components on the top layer. This is similar to the concept of grounding in household and industrial electrical systems.

- **Lecture-58:** The experiment in this video demonstrates the use of motor encoders, specifically focusing on how to use encoders with different types of motors for precise positioning and motor control. Motor encoders, like rotary and magnetic encoders, are used to measure the position or rotation of a motor shaft. The basic function of these encoders is to output signals based on the rotation of a disk or magnet. The signals can be interpreted to determine the direction of rotation and the precise position of the shaft.

•The experiment shows how motor encoders, specifically magnetic encoders, can be used to improve the precision of motor control. By adding encoders, even low-cost DC motors and powerful BLDC motors can be made capable of precise positioning, which is useful in robotics and other applications requiring high accuracy.
•The video emphasizes the potential of motor encoders to solve practical issues in projects, such as improving accuracy and turning powerful motors into more precise positioning systems.

- **Lecture-59:** In this experiment, the goal is to test and compare the effectiveness of various overvoltage protection components when subjected to high voltage pulses. Overvoltage situations can occur due to events like lightning strikes, inductive switching in power grids, or electrostatic discharge (ESD), which can damage sensitive electronic circuits. To prevent this damage, protective components like TVS diodes, MOVs (Metal Oxide Varistors), and GDTs (Gas Discharge Tubes) are commonly used.

This experiment demonstrates the effectiveness of different overvoltage protection components in preventing damage to electronic circuits. TVS diodes are great for protecting against fast surges, MOVs handle larger energy pulses, and GDTs are suited for high-voltage applications. The experiment emphasizes the importance of selecting the right protection for specific needs, and the difference in safety between cheap and expensive surge protection devices.

- **Lecture-60:** In this video, the creator explores the differences between I2C and I3C communication protocols while working on a breakout board for a haptic feedback driver IC (BOS1921), which can be used in a project to provide vibration feedback to the user.

Introduction to Haptic Feedback and I3C:

•The experiment begins with the use of a haptic feedback system that generates various vibration patterns.

•The creator wanted to use the BOS1921 IC for haptic feedback, but the development board was too expensive, priced at €240.

•However, the main IC itself (BOS1921) costs only around €4, so the creator aimed to create a cheaper breakout board for it.

•While researching the BOS1921 IC, the creator discovered that it uses I3C communication, the successor to the I2C protocol.

•The creator concludes that while I3C offers significant advantages (faster communication, dynamic addressing, etc.), it is more complex and may require peripherals in microcontrollers, making it harder to implement without specialized hardware.

•For this specific project, I2C was deemed sufficient, as even the original development board used I2C.

•The creator intends to continue experimenting with I3C to see if it becomes more widespread and easier to use in the future.

➢ **Lecture-61:** The experiment focuses on upgrading a simple **Class A audio amplifier** to drive a louder **loudspeaker**. The goal was to improve its power handling capability while maintaining good audio quality.

•**BJTs (Darlington Transistors) are better for amplification** due to their **linear response**.
•**MOSFETs are simpler** and can provide **higher output power**, but their **non-linearity introduces distortion**.
•While the MOSFET amp was **louder**, the **Darlington amp had better audio quality**.
•The experiment demonstrated **the trade-offs between loudness, efficiency, and distortion**.

Conclusion
•The **MOSFET amp** was chosen for its **loudness**.
•However, due to its **inefficiency**, neither design would be used in a **final audio project**.
•Future work would focus on a **better amplifier design** with improved **efficiency and linearity**.