

Electronic Basics

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Electronic Basics #1: The Multimeter

A multimeter is used to measure voltage, current, and resistance. First, the probes should be connected correctly—black in the common terminal and red in the appropriate one based on the measurement type. To measure DC voltage, the probes are placed in parallel with the circuit, making sure to check if it's DC or AC voltage. When measuring resistance, it's important to avoid doing it in a live circuit to prevent incorrect readings.

For current measurement, the circuit must be opened, and the correct current range on the multimeter must be selected to avoid blowing the fuse. The multimeter also has a continuity test function, which can be used to check if a wire or cable is broken. Always remember to follow safety precautions when working with power supplies.

Electronic Basics #2: Dimming all kinds of LEDs!?

Pulse Width Modulation (PWM) is used to dim LEDs of different types like 5mm LEDs, LED strips, and high-power LEDs. PWM works by rapidly switching the voltage on and off, controlling the brightness by adjusting the duty cycle, which is the percentage of time the LED stays on.

There are two methods to achieve this: one using an Arduino microcontroller and the other using a 555 timer IC. With the Arduino, the `analogWrite` function generates the PWM signal, and a potentiometer controls the brightness. The 555 timer IC method is simpler and uses fewer resources, suitable for lower-current LEDs. For high-power LEDs, PWM is more efficient than using a potentiometer, which is both wasteful and costly. Dimming LEDs is done by adjusting the average voltage applied, not by lowering the supply voltage below the LED's forward voltage.

Electronic Basics #3: Programming an Attiny+Homemade Arduino Shield

The ATtiny85 microcontroller is programmed using an Arduino Uno as a programmer. A custom programming shield is created to simplify the connection between the Arduino and the ATtiny85, making it easier to use without complicated wiring. The ATtiny85 is used to control an LED strip with a push button, demonstrating a cost-effective solution while overcoming limitations, such as the lack of built-in SPI.

To program the ATtiny85, an Arduino Uno is used instead of the ATmega328, reducing costs. A homemade PCB shield helps simplify the connection. The tutorial addresses the ATtiny85's limitations, particularly the lack of SPI, and explains how to overcome this limitation using bit-banging. The video also covers the necessary software setup, including the Arduino IDE and ATtiny board support, and explains how to wire the Arduino Uno to the ATtiny85. The project showcases the practical use of the ATtiny85 in controlling an LED strip.

Electronic Basics #4: Arduino+Bluetooth+Android=Awesome

Instructions are provided on how to connect an Arduino Nano, a Bluetooth HC-05 module, and an Android smartphone to control an RGB LED. The hardware setup includes using a voltage divider to step down the Arduino's 5V signal to 3.3V for the Bluetooth module. The S2 Terminal Android app and Arduino code are used for control.

A key troubleshooting tip is to disconnect the Bluetooth module during code upload to avoid conflicts. The Arduino code is linked, and the free S2 Terminal app is recommended for control. Personal experiences with purchasing the Bluetooth module from Amazon or eBay are shared, with caution about potentially damaged modules.

Electronic Basics #5: How to Multiplex

Multiplexing LEDs allows control of many LEDs with a microcontroller that has fewer I/O pins. In this case, an Arduino Nano is used to control a 10x5 LED matrix, with MOSFETs and a TLC5940 LED driver. The technique involves rapidly switching rows of LEDs on and off, creating the illusion of a single image to the human eye.

P-channel MOSFETs are used as switches to manage high currents. Arduino code using the TLC5940 library is explained to aid understanding. The video also hints at a future project that will apply this technique to an RGB LED cube.

Electronic Basics #6: Standalone Arduino Circuit

A standalone Arduino circuit is created by removing the ATmega328P microcontroller from an Arduino Uno and integrating it into a custom circuit. The necessary components for this setup include a 16MHz crystal, capacitors, and a resistor for clock generation and reset control. The video also covers three methods for reprogramming the microcontroller: using another Arduino, using an FTDI adapter, and briefly using ICSP.

Testing the circuit on a breadboard first is emphasized, along with the trade-offs of using a standalone ATmega328P. These trade-offs include the absence of a reset switch and protective features like those found on a standard Arduino board. Pin mapping is also explained, ensuring the ATmega328P pins correspond correctly to the digital pin numbers in your Arduino sketch.

Electronic Basics #7: 7 Segment Display

7-segment displays are used both with and without an Arduino microcontroller. For single-digit displays, a BCD-to-7-segment driver IC (SN74LS247) is used, which operates with an active low configuration. Multiplexing techniques for multiple 7-segment displays are explained, using an Arduino and PCA1064 IC for greater efficiency.

The video also demonstrates building a simple counter circuit with a 4-bit binary counter IC (SN74290) to drive the 7-segment display. It emphasizes the importance of referring to datasheets to understand pinouts and configurations, and provides a link to a tutorial on I2C communication.

Electronic Basics #8: Everything about LEDs and current limiting resistors

LEDs and current-limiting resistors are used to prevent overcurrent damage. The necessary resistor value is calculated using Ohm's Law and Kirchhoff's Voltage Law. When connecting LEDs in series, efficiency improves and power waste is reduced compared to parallel connections.

The variability in LED forward voltage is emphasized, highlighting that simple resistor calculations are not always sufficient. To ensure better performance and longevity, constant current drivers like the LM317 are recommended, especially when dealing with multiple LEDs. The video also addresses practical design challenges in circuits with many LEDs.

Electronic Basics #9: Diodes & Bridge Rectifiers

Diodes are semiconductor devices that allow current to flow in one direction, protecting circuits from reverse polarity damage. In bridge rectifiers, four diodes are arranged to convert alternating current (AC) into direct current (DC).

AC to DC Conversion Process:

1. **AC Input:** A sinusoidal voltage fluctuates between positive and negative.
2. **Bridge Rectifier:** During the positive half-cycle, two diodes conduct, allowing current to flow through the load. In the negative half-cycle, the other two diodes conduct, maintaining unidirectional current.
3. **Output:** The result is pulsating DC. Additional components, like capacitors, can smooth this output, reducing voltage ripple for a more stable DC supply.

This process is essential for efficiently powering electronic devices.

Electronic Basics #10: Digital to Analog Converter (DAC)

A Digital to Analog Converter (DAC) is essential for converting digital signals (binary data) into analog signals (continuous voltages), which is crucial for applications like audio playback and signal processing.

Key Components and Process:

- **Components Needed:**
 - Resistors
 - Arduino Nano (or similar microcontroller)
 - Voltage follower (operational amplifier)
- **Building Steps:**

i.Assemble the Circuit:

- Connect resistors in a voltage divider configuration.

ii.Arduino Setup:

- Interface the Arduino to control output voltage based on digital inputs.

iii.Programming:

- Write code to send digital values that correspond to desired analog outputs.

iv.Voltage Follower:

- Implement a voltage follower to buffer the output, preventing load interference.

- **Testing Outputs:**

- Use an oscilloscope or speaker to observe the analog output and adjust digital inputs to see changes.

Applications of DACs:

- **Audio Signals:**

- Converts digital audio files into sound for playback.

- **Signal Generation:**

- Generates waveforms for testing and simulation in electronic circuits.

Important Concepts:

- **Resolution:**

- Refers to the number of discrete values a DAC can output, often determined by its bit depth (e.g., 8-bit, 12-bit).

- **Sampling Rate:**

- The frequency at which the DAC updates its output, important for audio fidelity.

Electronic Basics #11: Sending SMS with Arduino || TC 35 GSM Module

1. **Connection:** The TC35 GSM module is connected to the Arduino Uno with proper wiring for power and signals.
2. **Initialization:** Communication is initialized using the `Serial.begin()` function in the Arduino code.
3. **AT Commands:** AT commands are sent to configure the GSM module and send SMS:
 - `AT+CMGF=1` is used to set SMS mode.
 - `AT+CMGS="phone_number"` specifies the recipient.
4. **Message Input:** The message is inputted after the command and is sent by ending with `Ctrl+Z` (ASCII 26).
5. **Testing:** The code is uploaded to the Arduino, and the output is monitored to confirm successful SMS

Electronic Basics #12: Coils / Inductors (Part 1)

Inductors, also known as coils, are essential components in electronic circuits that store energy in a magnetic field when electric current flows through them. The principles of induction are utilized to create electromagnets, which are formed by winding wire into coils around a ferromagnetic core.

- **Induction Principle:** The phenomenon where a changing magnetic field induces an electromotive force (EMF) in a conductor.
- **Lenz's Law:** The direction of induced current is such that it opposes the change in magnetic flux that produced it. This principle helps in understanding the behavior of inductors in circuits.
- **DC Circuit Behavior:** When current is applied to an inductor in a DC circuit, it initially resists changes in current flow. Over time, it allows current to stabilize, resulting in a gradual increase to a steady state.

- Applications:
 - Boost Converters: Inductors are used to increase voltage levels in power supply circuits.
 - Motor Control: Inductors play a crucial role in controlling the speed and torque of electric motors.

Electronic Basics #13: Coils / Inductors (Part 2) || Reactance

Inductive Reactance Concept: Inductors introduce reactance, a type of resistance that does not dissipate power as heat but instead stores and releases it through a magnetic field. This causes power oscillation, known as reactive power, which affects power grids.

LED Circuit Experiment: An LED connected directly to a transformer burns out instantly. However, adding an inductor in series allows the LED to function properly, despite the coil having a low resistance. This demonstrates that inductance itself limits current flow by generating reactance.

Reactance & Frequency: Increasing frequency raises inductive reactance, reducing current flow. This is observed as an LED dimming at higher frequencies. The relationship follows the formula:

$$X_L = 2\pi fL \quad X_L = 2\pi fL$$

where X_L is inductive reactance, f is frequency, and L is inductance.

Filter Applications: Inductive reactance is useful in circuit design, allowing the creation of frequency-selective filters. A high-pass filter blocks low frequencies, while a low-pass filter removes high frequencies. These principles are applied in audio signal processing.

Phase Shift in Inductive Circuits: Unlike purely resistive circuits, inductors cause a phase shift between voltage and current, which can reach up to 90° . This shift can be adjusted by changing the inductor's core and is useful in analyzing power systems and motor loads.

Affordable Measurement Tool: A \$20 transistor tester provides a budget-friendly alternative to expensive RLC meters, measuring inductance, capacitance,

resistance, and even transistor gain. While its precision is limited for small inductors, it remains a useful tool for basic circuit testing.

Electronic Basics #14: Capacitors

Capacitors are essential components in almost every electronic circuit, playing a key role in energy storage and signal processing. They consist of two conductive plates separated by a dielectric material, which allows them to store electrical charge. Increasing the plate area, reducing the distance between plates, or using better dielectric materials can enhance their capacitance.

- **Behavior in Circuits:** In DC circuits, capacitors help stabilize voltage by resisting sudden changes. When connected to a power source, they charge up gradually, and when disconnected, they can release stored energy like a small battery. In AC circuits, capacitors exhibit **capacitive reactance**, which acts as a frequency-dependent resistance. Higher frequencies lead to lower reactance, limiting the current flow.
- **Applications:** Capacitors are widely used in **power supply circuits** for voltage stabilization, **timing circuits** with resistors to control charge/discharge rates, and **signal filtering** to block certain frequencies. They are commonly seen in **RC filters**, which are preferred over inductor-based RL filters due to their smaller size and lower cost.

Electronic Basics #15: Temperature Measurement (Part 1) || NTC, PT100, Wheatstone Bridge

Temperature measurement can be performed using various sensors like NTC thermistors, PT100, and the Wheatstone Bridge. NTC thermistors, which have a negative temperature coefficient, show a decrease in resistance with increasing temperature. They offer a broad resistance range but are nonlinear and less accurate. PT100, a type of RTD (resistance temperature detector), increases in resistance with higher temperatures, providing better accuracy, especially in industrial applications. However, both sensors require proper current supply (e.g., using an LM 317) and may need to address issues like offset voltage at 0°C. To measure resistance effectively, methods like the Wheatstone Bridge are employed, offering voltage proportional to the changing resistance. For precise

measurements, amplification using op-amps and a microcontroller is necessary. Pre-made transmitters or ICs like LM35 or DS18B20 simplify the process, though thermal inertia can slow response times.

Electronic Basics #16: Resistors

Resistors are essential components used in circuits to regulate current and voltage. They are crucial for protecting sensitive components, such as LEDs, by preventing excess current flow. For example, a 680-ohm resistor is used to limit current for an LED, ensuring its longevity. When building circuits, power resistors are often needed to handle higher wattages without overheating.

Resistors also serve to adjust voltage levels. Potentiometers, which have a movable pin, are often used to change voltage inputs dynamically. In digital circuits, resistors are employed as pull-up or pull-down resistors to ensure stable logic levels for inputs, preventing erratic behavior in microcontroller circuits. Additionally, resistors can act as fuses to protect circuits by limiting power flow beyond a certain threshold, causing them to heat up and break when overloaded.

In AC circuits, resistors exhibit parasitic inductance and capacitance, which affect their impedance. These effects cause current to increase as the frequency of the sine wave rises, making it essential to consider these factors when designing circuits.

Electronic Basics #17: Oscillators || RC, LC, Crystal

Oscillators are electronic circuits that generate periodic alternating voltage signals (square, triangle, or sine waves). These signals are used as clock sources in devices, carrier waves in radio communication, and data transmission.

Types of Oscillators & Their Working:

1. RC Oscillators (Relaxation Circuits):

- Utilize resistors and capacitors to generate oscillations.
- The astable multivibrator circuit consists of capacitors (C1, C2) and transistors.
- Charging and discharging of capacitors cause switching between conductive and non-conductive states, generating a rectangular waveform.
- Frequency increases if resistance or capacitance decreases.

2. 555 Timer Oscillator:

- Uses two comparators, logic gates, and an RS flip-flop.
- A capacitor charges and discharges between 66% and 33% of supply voltage.
- Frequency is adjustable using resistors and capacitors.

3. LC Oscillators (Resonant Circuits):

- Composed of an inductor and capacitor forming an LC tank circuit.
- Energy alternates between electrostatic (capacitor) and magnetic (inductor) forms.
- The circuit oscillates at its **resonant frequency** when inductive and capacitive reactance cancel out.
- Parasitic resistances cause energy loss, requiring an amplifier to sustain oscillations.

4. Crystal Oscillators:

- Utilize a piezoelectric crystal along with an amplifier.
- Provide highly stable frequencies (e.g., 16 MHz for microcontrollers).
- Mechanical vibrations of the crystal enhance stability compared to LC circuits.

Electronic Basics #18: DC & Brushless DC Motor + ESC

DC Motor Working Principle:

- Consists of a **stator** (fixed permanent magnets) and a **rotor** (coils connected to a commutator).
- Carbon brushes transfer DC voltage to the commutator, energizing coils and creating a magnetic field.
- Interaction between the stator and rotor generates rotation, with the commutator periodically reversing polarity to maintain motion.

Brushless DC (BLDC) Motor:

- Uses **permanent magnets in the rotor** and **coils in the stator** (opposite of brushed motors).
- Coils are connected in a **star configuration** and energized in six sequential steps per full rotation.
- Unlike brushed motors, BLDC motors use **Electronic Speed Controllers (ESCs)** instead of mechanical commutators.

Electronic Speed Controller (ESC):

- Controls motor rotation by applying **high, low, and floating states** through MOSFET arrays.
- Adjusts speed by **modulating frequency and pulse width** of the voltage signal.
- Higher **PWM frequency** results in increased RPM.
- Current handling depends on the **number of MOSFETs** used in the circuit.

Torque & RPM Relationship:

- **Outrunner BLDC motors** (magnets on the outer shell) provide higher torque at lower RPM.
- More permanent magnets result in **higher torque and lower speed** for the same frequency.

KV Rating (RPM per Volt):

- A 520 KV motor rotates at 3,750 RPM on 7.4V and 5,644 RPM on 11.1V.
- A 920 KV motor reaches 6,780 RPM on 7.4V and 10,500 RPM on 11.1V.
- Higher KV motors provide higher RPM but lower torque.

Electronic Basics #19: I2C and how to use it

What is I2C?

- **Inter-Integrated Circuit (I2C)**, also known as **Two-Wire Interface (TWI)**, is a **synchronous serial communication** protocol.
- Uses **only two lines**:

- **SDA (Serial Data Line)**
 - **SCL (Serial Clock Line)**
- Allows **one or more master devices** to communicate with **up to 112 slave devices** on the same bus.

I2C Hardware Setup:

- **Pull-up resistors (10kΩ) are required** on SDA and SCL lines because I2C devices use **open-collector outputs** (can pull signals low but not high).
- Master provides **clock signal (SCL)**, and both master/slave use **data line (SDA)** for transmission.

I2C Communication Steps:

1. **Start Condition** – SDA goes low while SCL stays high.
2. **Addressing the Slave** – The master sends a **7-bit address** followed by a **R/W bit** (0 for write, 1 for read).
3. **Acknowledgment (ACK)** – The slave responds with an ACK bit if it's ready.
4. **Data Transmission** – Master or slave sends **8-bit data bytes**, each followed by an ACK.
5. **Stop Condition** – SDA goes high while SCL stays high, signaling the end of communication.

Practical Example: Controlling an FM Radio IC (TEA5767) with I2C

- **Wiring the circuit:**
 - **SDA → A4 (Arduino Nano)**
 - **SCL → A5 (Arduino Nano)**
 - **VCC (5V), GND, Audio Output → Headphones**
- **Programming the Arduino:**
 - The Arduino **Wire library** simplifies I2C communication.
 - **Data transmission process:**

- Convert frequency to **PLL value** using the formula.
- Send **5 data bytes** to control the FM IC.
- Use **hexadecimal values** for efficient data representation.

Reading Data from an I2C Device:

- The master requests data using **Wire.requestFrom()**, storing received bytes in a buffer.
- By decoding the **first and second bytes**, the tuned FM station can be displayed.

Electronic Basics #20: Thyristor, Triac || Phase Angle Control

Introduction to Thyristors

- A **thyristor** is a **controllable diode** that can be switched **on** using a gate signal but remains **conductive** until the current falls below a certain threshold.
- Consists of **four semiconductor layers (PNPN structure)** and has **three terminals**:
 - **Anode (A)**
 - **Cathode (K)**
 - **Gate (G)**

Thyristor Characteristics

- **Latching Current**: Minimum current required to keep the thyristor **ON** after triggering (~50mA).
- **Holding Current**: If the current drops below this, the thyristor **turns OFF** (~30mA).
- **Turn-Off Time**: The time it takes to fully switch off (~37μs in this example).
- **Power Dissipation**: Due to voltage drop across the anode-cathode junction, a heat sink may be required for high-power applications.

TRIAC: Bidirectional Thyristor

- A **TRIAC** (Triode for Alternating Current) is essentially **two thyristors in parallel but in opposite directions**.
- It can **control both positive and negative half-cycles** of an AC signal.
- Used in **AC dimmers, motor speed controllers, and heater controls**.

Phase Angle Control with a TRIAC

1. Zero-Crossing Detection:

- A **full-bridge rectifier** and an **opto-coupler** detect when the AC waveform crosses zero.

2. Microcontroller Timing:

- A **microcontroller (e.g., Arduino Nano)** receives the zero-crossing signal via an external interrupt.
- It introduces a **delay (0-10ms)** based on a **potentiometer setting** to determine when to fire the TRIAC.

3. TRIAC Triggering:

- After the delay, a signal is sent to another **opto-coupler**, which activates the TRIAC.
- This allows only a **controlled portion of the AC cycle** to pass through to the load.

Applications of Phase Angle Control

- **Dimming incandescent bulbs**
- **Speed control of universal motors** (e.g., drills)
- **Regulating heating elements**

Limitations

- **Power Factor Reduction:** Due to **non-sinusoidal current waveform**, power factor decreases.
- **Harmonics & EMI Issues:** Causes **electromagnetic interference (EMI)** in sensitive circuits.

Electronic Basics #21: OpAmp (Operational Amplifier)

Operational Amplifiers (Op-Amps) are high-gain voltage amplifiers widely used in analog and digital circuits. Represented as a triangle in schematics, they amplify weak signals and are found in various IC packages like LM358.

Key Characteristics:

- **High input impedance** (minimal current draw).
- **Low output impedance** (efficient signal transfer).
- **Requires external feedback** to control gain and stability.
- **Limited output voltage swing** (depends on power supply).

Golden Rules of Op-Amps:

1. The output adjusts to keep the voltage difference between inputs at zero.
2. No current flows into the input terminals.
3. Without feedback, the output saturates to the supply voltage.

Common Configurations:

- **Non-Inverting Amplifier:** Provides gain using $1 + (R_f/R_1)$.
- **Inverting Amplifier:** Follows $-R_f/R_1$ and inverts the signal.
- **Comparator:** Outputs high or low voltage based on input conditions.
- **Voltage Follower (Buffer):** Provides impedance matching with unity gain.

Applications:

- Sensor signal amplification (e.g., microphones, temperature sensors).
- Audio processing and filtering.
- Schmitt triggers and waveform generators.
- Voltage regulation and signal conditioning.

Electronic Basics #22: Transistor (BJT) as a Switch

Bipolar Junction Transistors (BJTs) function as electronic switches or amplifiers. They come in **NPN** and **PNP** types, each with three terminals: **Emitter, Collector, and Base**.

Key Concepts:

- **NPN Transistors:** Switch on when a small base current flows, allowing a larger current from collector to emitter.
- **PNP Transistors:** Require a low voltage at the base to turn on.
- **Base Resistor (R_b):** Prevents excessive base current, calculated using transistor gain (β).
- **Saturation Region:** Ensures the transistor acts as an efficient switch with minimal voltage drop.

Common Configurations:

- **NPN Switching:** Load connects to the **collector**; turns on when the base receives sufficient current.
- **PNP Switching:** Load connects to the **emitter**; turns on when the base is pulled low.
- **High-Current Switching:** Uses **Darlington Transistors** (e.g., TIP142) for higher current gain and Arduino compatibility.

Applications:

- Controlling LEDs, motors, and relays.
- Used in power regulation circuits (e.g., lab bench power supplies).
- Efficient switching with **MOSFETs** preferred for high-power applications due to lower power loss.

Electronic Basics #23: Transistor (MOSFET) as a Switch

MOSFETs (Metal-Oxide-Semiconductor Field-Effect Transistors) are highly efficient transistors used in switching applications, offering improved performance over BJTs, especially in high-power circuits.

Key Concepts:

- **Types of MOSFETs:**
 - **N-channel** (most common) and **P-channel** types.
 - **Gate, Drain, and Source** are the three pins, similar to the BJT's Base, Collector, and Emitter.
- **Gate Control:** Unlike BJTs, MOSFETs require **voltage** rather than current at the gate to switch on or off, reducing energy loss.
 - **N-channel MOSFET:** Turns on with a positive gate voltage.
 - **P-channel MOSFET:** Turns on with a negative gate voltage.
- **Efficiency:** MOSFETs offer lower energy loss (0.6W), making them ideal for high-efficiency applications.

Circuit Setup:

- **N-channel MOSFET:** Connect the **source** to ground, the **drain** to the load (e.g., an LED), and the **gate** to the control signal (Arduino).
- **P-channel MOSFET:** Requires a **pull-up resistor** to prevent unwanted activation when the gate voltage is low.

Challenges in High-Power Applications:

- **Oscillations:** Parasitic capacitance between terminals can cause high-voltage spikes when switching off.
 - **Solution:** Use gate resistors (e.g., 470Ω) to reduce gate current and improve switching speed, which reduces oscillations.
- **Switching Losses:** At higher frequencies, gate charge and switching speed impact efficiency. Power loss increases with frequency (e.g., 80mW at 1MHz).

Applications:

- MOSFETs are used in **LED dimmers**, **motor control**, and **power regulation** circuits, offering higher efficiency and faster switching than BJTs.
- For **high-frequency applications**, specialized MOSFET driver ICs are recommended to manage gate control and switching speed effectively.

Electronic Basics #24: Stepper Motors and how to use them

Stepper motors are commonly used in applications that require precise control of position, such as 3D printers. Unlike standard DC motors, stepper motors move in discrete steps, providing more control and accuracy.

Key Concepts:

- **Types of Stepper Motors:**
 - **Hybrid Synchronous Stepper Motor:** Most common type, consists of a rotor with alternating permanent magnets and a stator with teeth.
 - **Permanent Magnet and Variable Reluctance Motors:** Other types, but less common in modern applications.
- **Rotor and Stator:**
 - The **rotor** contains permanent magnets arranged with alternating poles (North and South).
 - The **stator** has teeth that align with the rotor, and current in coils produces a magnetic field, causing the rotor to move step-by-step.
- **Stepper Motor Rotation:**
 - Stepper motors rotate by energizing the coils in a sequence.
 - For a typical **200-step motor**, each step corresponds to a 1.8° movement ($360^\circ/200 = 1.8^\circ$).

Driving a Stepper Motor:

- **H-Bridge Circuit:** Used to control current flow through the coils, enabling forward and reverse motion.
 - Four MOSFETs (2 N-channel, 2 P-channel) are used to create an H-bridge for switching current direction.
- **Step Driving:**
 - **Wave Driving:** One coil is active at a time, simple but low torque.
 - **Full-Step Driving:** Both coils are active, providing higher torque.

- **Half-Step Driving:** Combines steps, doubling the resolution (400 steps per rotation).
- **Microstepping:** Increases resolution even further (e.g., 1/16 steps), resulting in smoother movement and less noise.

Microstepping and Advanced Control:

- Microstepping is achieved by varying the current through the coils. A specialized driver IC like the **A4988** can generate variable current for microstepping.
- A **555 timer circuit** can be used to generate the required clock signals for stepper motor control.

Advantages of Stepper Motors:

- **Positioning:** Stepper motors can be precisely controlled, making them ideal for applications like 3D printers.
- **Holding Torque:** Stepper motors can maintain a position without movement when no current is applied, providing stable holding capability.
- **Smooth Motion:** Microstepping improves motion smoothness and reduces noise, making the motor quieter and more efficient.

Control with Microcontroller:

- Arduino can be used to control stepper motors via driver ICs, sending step signals and adjusting speed and direction.

Electronic Basics #25: Servos and how to use them

Servos are popular for positioning tasks because they combine a motor and control electronics in one easy-to-use package. They offer precise control, making them ideal for projects like robotics, remote control vehicles, and automation.

Key Concepts:

- **Common Servo Motor:**
 - Typically consists of three wires:
 - **Brown:** Ground

- **Red:** VCC (usually 4.8V to 7.2V)
- **Orange:** Control signal (PWM)
- The servo's control signal is a **PWM** (Pulse Width Modulation) signal with a period of 20ms (50Hz). The pulse width (on time) controls the position of the motor shaft:
 - **1ms** = 90° position (neutral)
 - **1.5ms** = 0° position
 - **2ms** = +90° position
 - The range of motion is typically 180°.
- **Internal Structure:**
 - Inside the servo, a **DC motor** drives the shaft. The motor's speed is reduced by a series of gears, typically bringing it down to 50-100 RPM, which increases torque.
 - A **potentiometer** is attached to the gear system, providing feedback to the control circuit. This feedback allows the servo to adjust and maintain its position based on the PWM signal.
- **Servo Control IC:**
 - The control IC, often a **KC 5188**, compares the potentiometer voltage (current position) to the PWM signal (target position). The difference between these signals drives the motor in the appropriate direction until the target position is reached.

Using Servos in Projects:

- **Arduino Control:**
 - A simple Arduino can generate the required PWM signal to control the servo. Using the **Servo Library**, you can control the position by varying the pulse width between 1ms and 2ms.
 - You can also use a **potentiometer** to adjust the pulse width manually for controlling the servo's position.

- **Alternative Control with a 555 Timer:**
 - A **555 timer IC**, along with a few resistors, capacitors, and a potentiometer, can also generate a PWM signal to control the servo. This setup allows you to manually adjust the pulse width and, therefore, the position of the servo.

Modifying Servos for Continuous Rotation:

- **Hack for Continuous Rotation:**
 - By removing the mechanical end stop and feedback potentiometer, you can modify a standard servo to rotate continuously like a regular motor.
 - Replace the potentiometer with two resistors to create a voltage divider that signals the control IC to think the motor is always at 0°.
 - Adjust the pulse width:
 - **Below 1.4ms:** Motor rotates clockwise
 - **Above 1.4ms:** Motor rotates counterclockwise
- **Pre-Made Continuous Rotation Servos:**
 - If you don't want to modify the servo yourself, pre-made continuous rotation servos are available. These servos do not have a fixed position and can rotate indefinitely, making them useful for tasks where 360° motion is required.

Advantages of Servos:

- **Precision:** Servos allow for precise control of angles, making them ideal for positioning tasks in robotics and other applications.
- **Simple Control:** Using a PWM signal, servos are easy to control, especially with a microcontroller like Arduino.
- **Compact and Reliable:** Servos are compact, self-contained units that integrate both the motor and control electronics, simplifying the design of positioning systems.

Electronic Basics #26: 555 Timer IC

The **555 Timer IC** is widely used for timing, pulse generation, and oscillation in circuits. It has various modes:

1. **Monostable Mode:** Generates a single pulse when triggered. Used for time delays (e.g., notification lights).
2. **Bistable Mode:** Functions as a flip-flop with two stable states (high or low). Used for on/off switching (e.g., LED control).
3. **Astable Mode:** Generates a continuous square wave or PWM signal. Ideal for oscillators and clock pulses.

Key Points:

- **Pin 2** (Trigger) starts the timing cycle.
- **Pin 6** (Threshold) resets the flip-flop when the capacitor reaches 2/3 of the supply voltage.
- **Pin 7** (Discharge) controls the capacitor charging and discharging.

Electronic Basics #27: ADC (Analog to Digital Converter)

An **ADC** converts an analog signal to a digital value. For example, an Arduino uses its ADC to convert voltages into 10-bit digital values.

Key Specifications:

1. **Sampling Rate:** Determines how often an ADC takes samples of the analog signal. A higher sampling rate gives a more accurate representation of the signal. According to the **Nyquist-Shannon Theorem**, the sampling rate should be at least twice the signal frequency.
2. **Resolution:** The number of bits used to represent the digital value. Higher resolution gives finer voltage steps. For instance:
 - **4-bit** gives steps of 312.5 mV.
 - **10-bit** (Arduino) gives steps of 4.88 mV.
 - **12-bit** (e.g., ADS 7816) gives steps of 1.22 mV.

How an ADC Works:

An ADC uses a **successive approximation** method, involving:

- A **sample-and-hold** circuit,
- A **comparator**,
- A **DAC** (Digital to Analog Converter),
- A **SAR** (Successive Approximation Register).

By comparing the input voltage with the DAC's voltage, the ADC steps through binary values to find the closest match to the analog input.

Building an ADC:

- A **flash ADC** is fast but low resolution, using comparators to determine the voltage value.
- A **dedicated ADC IC** (e.g., ADS 7816) offers better resolution and precision, though it's more complex to implement.

Electronic Basics #28: IGBT and when to use them

IGBT combines characteristics of both **MOSFETs** (Metal-Oxide-Semiconductor Field-Effect Transistors) and **BJTs** (Bipolar Junction Transistors). It features:

- A **gate** (like MOSFET) for control,
- A **collector** and **emitter** (like a BJT).

When to Use IGBTs vs MOSFETs:

- **IGBTs** are better for medium-speed, high-voltage, high-current applications, like solid-state Tesla coils.
- **MOSFETs** are faster and preferred for frequencies above 200 kHz due to lower switching times.

IGBT Characteristics:

- **Gate voltage** turns it on, with a gate capacitor storing charge to maintain conduction.

- **Switching Speed:** IGBTs are slower (rise/fall times around 145ns/240ns) compared to MOSFETs (32ns/160ns).
- **Power Loss:** IGBTs have higher power losses than MOSFETs at lower currents (1.3W vs. 0.04W) due to higher voltage drop.

Applications:

- **IGBTs** are suitable for **high-voltage** applications, while **MOSFETs** work well for **high-frequency** operations.

Electronic Basics #29: Solar Panel & Charge Controller

Solar Panel Basics:

- **Solar cells** generate around 0.5V when light hits them, so they are connected in series to increase the output voltage.
- A **100W solar panel** often connects 36 cells in series, producing about **14.3V** in open-circuit conditions.

Challenges with Solar Panels:

- If part of a panel is shaded (e.g., clouds), the output drops significantly due to increased resistance in the affected cells.
- **Bypass diodes** are used to mitigate this issue by allowing current to bypass shaded cells, maintaining output power.
- **Blocking diodes** are used when panels are connected in parallel to prevent reverse current flow.

Power Output:

- Solar panels rarely produce their rated output (e.g., 100W) under real-world conditions. The **Standard Test Conditions (STC)** used for testing panels include specific sunlight intensity, temperature, and air mass conditions that aren't always replicated in real-world scenarios.
- Output voltage and current vary depending on the load. The most power is drawn when the load resistance is optimized to match the solar panel's characteristics.

Charge Controllers:

- **MPPT (Maximum Power Point Tracking)** charge controllers are the most efficient, adjusting the load to track the panel's maximum power output.
- **PWM (Pulse Width Modulation)** controllers are less efficient as they do not track the maximum power point, potentially wasting up to 40% of the energy.

Electronic Basics #30: Microcontroller (Arduino) Timers

Why Timers are Essential:

- For projects like alarm clocks, timers are crucial for precise timing events. For example, ensuring the second counter updates every 60 seconds or the LED matrix blinks at a set frequency.
- Timers help with generating PWM signals, creating delays, and ensuring responsive input handling in microcontroller-based systems.

Arduino Timers:

- Microcontrollers like **Arduino** have timers that run independently of the main code loop, making them essential for efficient timing without blocking code execution.
- **Timer 1** (16-bit) in Arduino is often used for precise timing events.

Basic Timer Setup:

1. **Normal Mode:** Timer counts from 0 to 65,535 (maximum for 16-bit), with an overflow that resets after reaching this value.
2. **Overflow Interrupt:** When the timer overflows, an interrupt can trigger a function (useful for timing events like blinking an LED).

Increasing Timer Precision:

- **Prescalers:** A prescaler reduces the timer clock speed, allowing for longer timer intervals (e.g., setting it to 256 gives around 1.04 seconds for an overflow).

- **Manual Timer Value Setting:** To make the overflow happen at a precise time (e.g., 1 second), you can manually set the starting value of the timer counter.

CTC Mode (Clear Timer on Compare Match):

- This mode compares the timer counter with a value in a register and triggers an interrupt when they match.
- You can set up independent interrupts for different times, such as 1/4 second or 1/2 second.

PWM (Pulse Width Modulation):

- Using PWM with timers allows you to generate signals with variable duty cycles. This is done by adjusting registers to control when a pin is high or low.
- You can control the PWM frequency and duty cycle using **fast PWM modes**.
- **Fast PWM** allows you to achieve high frequencies (up to 8 MHz) by adjusting the top value of the timer using the **ICR1 register**.

Electronic Basics #31: Schottky Diode & Zener Diode

Schottky Diodes:

- **Low Forward Voltage Drop:** Schottky diodes, like the **1N5819**, have a significantly lower forward voltage drop (around 0.45V) compared to standard diodes (which can drop around 0.87V). This results in less power loss (e.g., 0.45W vs. 0.87W) and less heat generation, improving efficiency.
- **Fast Switching Speeds:** Schottky diodes are known for their **extremely fast switching speeds**, making them ideal for high-frequency applications (e.g., switch-mode power supplies, boost converters). They can work effectively at frequencies up to 100 kHz or higher, unlike regular diodes, which struggle beyond 1 kHz.
- **Use Cases:** Schottky diodes are useful for **reverse voltage protection**, **high-frequency applications**, and improving the efficiency of circuits such as power converters.

- **Limitations:** They have lower **blocking voltage** and may suffer from higher **reverse leakage current** compared to regular diodes.

Zener Diodes:

- **Reverse Bias Operation:** Zener diodes are typically used in **reverse bias**, where the cathode is at a higher potential. When the reverse voltage exceeds the **Zener voltage**, the diode becomes conductive and maintains a constant voltage drop.
- **Voltage Regulation:** Zener diodes are primarily used for **voltage regulation** or as **voltage references**. For instance, a **5.1V Zener diode** can create a steady voltage drop close to 5.1V, which is used to stabilize or limit voltage in circuits.
- **Practical Example:** In a voltage regulator circuit, a **Zener diode** in combination with a resistor can provide a regulated output voltage. The **Zener voltage** and **power dissipation** are key specifications when designing such circuits.
- **Clipping and Protection:** Zener diodes can also be used for **voltage clipping**, such as protecting MOSFETs by clamping the gate voltage to a safe level (e.g., a **15V Zener diode** protects a MOSFET with a 16V gate-to-drain voltage rating).
- **Limitations:** While useful for voltage regulation and protection, Zener diodes have limitations such as temperature dependence and sensitivity to input voltage and current variations.

Electronic Basics #32: Relays & Optocouplers

Relays:

- **Electromechanical Switches:** A relay is an electromechanical switch that can control high-voltage or high-current circuits by applying a low-voltage control signal to its coil. When current flows through the coil, it creates a magnetic field that activates the relay, closing or opening its contacts.
- **Types of Contacts:** Relays typically have **Normally Open (NO)** and **Normally Closed (NC)** contacts. **NO** contacts remain open when the relay is

unpowered, while **NC** contacts stay closed. Some relays also have **changeover contacts**, offering both options.

- **Flyback Diode:** When switching off a relay, the collapsing magnetic field can induce voltage spikes that may damage other components. To protect against this, a **flyback diode** is added in parallel to the coil to safely dissipate the induced current.
- **Advantages:** Relays are useful for switching large loads with minimal power loss, providing **galvanic isolation** between the control circuit (like a microcontroller) and the high-voltage load. This isolation ensures the control circuit remains safe, even when switching AC mains voltages.
- **Limitations:** Relays are slower compared to solid-state switches (like MOSFETs) due to their mechanical nature, and their contacts can wear out over time due to mechanical stress.

Optocouplers (Opto Isolators):

- **Functionality:** An optocoupler consists of an infrared LED and a photosensitive element (typically a transistor or TRIAC). When the LED is powered, it emits infrared light, activating the photosensitive element on the other side, which allows it to control a high-voltage circuit.
- **Galvanic Isolation:** Optocouplers provide **galvanic isolation** between the input and output sides, preventing high voltages from reaching the control circuitry, ensuring safety for the microcontroller. Isolation voltage can be as high as **7500 volts**.
- **Advantages:** Optocouplers are faster than relays because they are solid-state devices and can handle faster switching speeds. They also require less activation current. They are commonly used in circuits where quick switching is necessary, such as in phase angle control for AC circuits.
- **Limitations:** While optocouplers can switch signals quickly and provide isolation, they cannot handle large power loads directly. They are often used in conjunction with relays or other components to control high-current circuits.

Electronic Basics #33: Strain Gauge/Load Cell and how to use them to measure weight

Strain Gauge:

- **Principle:** A strain gauge is a flexible piece of plastic with a zig-zag resistance wire pattern. The resistance of this wire changes when it is stretched or compressed, which is proportional to the force applied. This change in resistance can be measured to calculate the weight or force applied.
- **Wheatstone Bridge:** Since the resistance change in strain gauges is very small, it needs to be amplified. A **Wheatstone bridge** circuit is used, where the strain gauge replaces one of the resistors. When force is applied, the bridge produces a voltage difference, which can then be amplified by an op-amp circuit.
- **Temperature Sensitivity:** Strain gauges are sensitive to temperature, which can affect the readings. To compensate for this, a **half-bridge** circuit (with two strain gauges) is often used to balance out temperature-induced errors. In more advanced setups, a **full bridge** with four strain gauges can be used for greater precision.
- **Practical Setup:** Once the Wheatstone bridge and amplification circuit are set up, the voltage difference is fed into an **ADC** of a microcontroller, and the weight can be measured.

Load Cell:

- **Simplified Setup:** A **load cell** is an aluminum profile with a Wheatstone bridge already built in. It simplifies the process, as you only need to connect the load cell wires to a power supply and measure the voltage difference across them.
- **HX711 Module:** For easy integration with microcontrollers like Arduino, an **HX711** breakout board is used. This board contains a **24-bit ADC** and an integrated amplifier, making it ideal for reading small changes in weight with high resolution.

- **Benefits:** The HX711 module increases the resolution to **24-bits**, allowing for more precise measurements of small forces, and is easier to set up compared to building a full strain gauge setup.

Electronic Basics #34: Two-Position Controller & PID Controller

Electronic Basics #35: Schmitt Trigger and when to use them

A Schmitt trigger is a comparator with **hysteresis**, meaning it has two distinct threshold voltages: a high and a low threshold. This reduces noise and ensures stable signal transitions.

- **How it Works:** The output changes only when the input exceeds the high threshold or falls below the low threshold. Between these points, the output remains stable.
- **Non-Inverting vs Inverting:** The non-inverting Schmitt trigger goes high above the high threshold and low below the low threshold. The inverting version does the opposite.

Applications:

1. **Button Debouncing:** Cleans up noisy button presses.
2. **Oscillators:** Used in relaxation oscillators for generating square waves.
3. **Noise Filtering:** Restores noisy or degraded signals to sharp, clean transitions.

Electronic Basics #36: SPI and how to use it

SPI is a communication protocol used for fast data transfer between a **master device** (like an Arduino) and **slave devices** (such as sensors or ICs). It uses four main pins: **CLK (clock)**, **MOSI (Master Out Slave In)**, **MISO (Master In Slave Out)**, and **SS (Slave Select)**.

How it Works:

1. **Master-Slave Communication:** The master controls the communication, sending data to the slave via MOSI and receiving data from it through MISO.

2. **Chip Select (CS):** The CS pin must be pulled low to start communication with a specific slave device.
3. **Data Modes:** SPI has four modes based on clock polarity and edge (rising or falling) where data is sampled. These modes are defined in the device's datasheet.

Example with DS3234 RTC:

- **Connection:** Connect SPI pins on Arduino (13, 12, 11, 10) to the DS3234 real-time clock IC.
- **Programming:** Use the **SPI library** to configure the CS pin and set data direction. The program will send data (like setting the time) and receive data (like reading the time).
- **Registers:** Data sent over SPI is often related to register addresses, which configure the IC (e.g., setting square wave output, time/date).

When to Use SPI:

- **Speed:** SPI is faster than I2C, with speeds up to 4 MHz, making it ideal for high-speed applications like SD cards.
- **Limitations:** Unlike I2C, which can connect multiple devices with just two wires, SPI requires a **chip select pin** for each device.

Electronic Basics #37: What is Impedance? (AC Resistance?)

Impedance is the resistance in AC circuits, combining resistance and reactance (from inductors and capacitors). Unlike DC circuits, inductors and capacitors affect the current flow depending on frequency.

- **Inductive Reactance:** Resists current, increasing with frequency. Voltage **leads** the current by 90° .
- **Capacitive Reactance:** Resists voltage, decreasing with frequency. Current **leads** the voltage by 90° .
- **Resistors:** Resist current without affecting phase.

Impedance Formula:

$$Z=R+jXZ = R + jXZ=R+jX$$

- **Magnitude:** $\sqrt{R^2 + X^2}$
- **Phase Angle:** $\arctan\left(\frac{X}{R}\right)$

Electronic Basics #38: True, Reactive, Apparent & Deformed Power

- **True Power (P):** The power used by the load, measured in watts. This power does useful work (e.g., heating a resistor, running a motor).
- **Reactive Power (Q):** Power that doesn't do useful work but is exchanged between the source and reactive components (inductors and capacitors), measured in volt-ampere reactive (VAR).
- **Apparent Power (S):** The combination of true and reactive power, measured in volt-amperes (VA). It's the total power provided by the source but doesn't reflect useful work.
- **Deformed Power:** Arises from non-sinusoidal currents, often caused by modern electronics like switch-mode power supplies. This type of power has harmonics, which can cause inefficiencies.

Power Factor: The ratio of true power to apparent power, indicating the efficiency of power usage. It's typically related to the cosine of the phase angle (for reactive power), but in cases of deformed power, power factor correction (PFC) is needed.

Controlling a BIG LED Matrix?! How Shift Registers work! || EB#39

The explanation covers how shift registers are used to control a large LED matrix. The PCB design is analyzed, revealing that the cathodes of the LEDs are connected to shift registers. It's explained how shift registers (specifically serial-in parallel-out, or SIPO) enable control of numerous LEDs with fewer control pins. Multiplexing is employed to handle the large matrix efficiently, and the process of shifting data across the matrix is demonstrated. The explanation also includes how to write code to control the LEDs and display letters or patterns on the matrix.

How safe is contactless payment? || How does RFID & NFC work? || EB#40

This content dives into how RFID and NFC work in contactless payments, explaining how RFID uses radio waves for communication between a tag and a reader. The video focuses on the RC522, PN532, and RDM6300 boards and their use in Arduino projects. It goes on to explore the differences between RFID and NFC, with NFC being a more secure, short-range version of RFID. The video also touches on the challenges of reading payment cards with these devices and concludes that contactless payments are generally safe, suggesting anti-skimming card holders for extra security.

Does a DIY Audio Crossover make sense? How passive filters work! || EB#41

This content explores the concept of audio crossovers, explaining how they work to separate audio signals into different frequency bands for different speakers, such as woofers and tweeters. The video breaks down the components involved—resistors, capacitors, and inductors—and demonstrates how they function through hands-on experiments with basic filters. It explains the difference between low-pass and high-pass filters, including the use of RC and RL filters, and delves into more complex second-order filters with LC components. The video concludes by discussing the importance of matching crossovers to speakers' frequency responses and the potential challenges in DIY audio crossover projects.

Is it easy to create your own Transformer? Everything you need to know about Transformers! || EB#42

Transformer Basics: Transformers consist of a metal core and two coils (primary and secondary). They convert high AC voltage to a lower, usable AC voltage for devices.

Magnetic Flux: The primary coil generates a magnetic field that induces a voltage in the secondary coil. The frequency of the AC voltage in the primary coil causes the flux to change, inducing the secondary voltage.

Power Losses: Transformers can experience losses, such as eddy currents and hysteresis in the iron core. These losses reduce efficiency and are more pronounced at higher currents or frequencies.

Efficiency: Efficiency is impacted by load resistance, and power losses increase when a transformer operates beyond its limits (e.g., saturation of the magnetic core).

Core Material: The transformer's core material (electrical steel or ferrite) affects performance. Larger cores handle more power, while higher frequencies require specific materials to minimize losses.

Design Considerations: Calculations and proper core material documentation are key to designing a transformer. Sourcing materials for a DIY transformer, especially the core, can be challenging.

DIY Possibilities: While it's theoretically possible to build a transformer if you have the right materials, sourcing electrical steel sheets for the core can be difficult. The video also hints at future discussions on DIY and 3D-printed transformers.

Controlling Mechanical 7-Segment Displays?! How RS-485 and UART works! || EB#43

Mechanical 7-Segment Displays: These displays use moving plastic segments controlled by electromagnets, unlike LED displays. The electromagnets hold their polarity without continuous power, allowing the displayed number to remain even when power is off.

Challenges in Control: Controlling multiple displays requires many microcontroller pins or a complex circuit, which could be time-consuming. However, a ready-made control module with ten displays simplifies this.

Control Circuit: The module uses an ATmega32A microcontroller, high-voltage drivers, and Darlington transistor arrays to manage the electromagnets for each segment.

Multiplexing: The source IC powers one display at a time while the microcontroller controls the electromagnets to form numbers sequentially, switching between displays.

RS-485 Communication: RS-485 is an asynchronous serial communication standard used for transferring data between devices. Unlike SPI/I2C, it doesn't

have a clock line. The data is sent through two lines: a non-inverted and an inverted signal.

Data Transmission: The system uses twisted pair wiring, which improves interference rejection. The receiver detects the data by measuring the difference between the two signals.

Arduino and RS-485: The Arduino Nano is used to send data via its USART interface, but it needs a MAX485 IC to convert it to the RS-485 format.

Testing the Code: With the RS-485 setup complete, the system is tested by sending serial data from Arduino, and the mechanical 7-segment displays correctly show the numbers sent.

Creating a Subscriber Counter: By integrating the ESP8266 with the RS-485 setup, the display shows the YouTube subscriber count in real time, using the YouTube API to fetch the data.

Improving my electric longboard with a CAN Bus! What can the CAN Bus do? EB#44

The Controller Area Network (CAN) bus system is utilized to enable communication between electronic control units (ECUs) in devices like electric vehicles and cars, ensuring reliable data exchange without requiring a host computer. It uses two wires, CAN High (CAN H) and CAN Low (CAN L), for sending messages between devices (nodes).

Process of utilizing CAN Bus:

1. **Hardware setup:** CAN H and CAN L wires are connected to FS ESCs to activate CAN functionality.
2. **Software configuration:** The CAN status mode is altered in the VESC software, and the multi-VESC configuration is set to true.
3. **Synchronization:** The system synchronizes the wheels of an electric longboard to ensure both motors spin at the same RPM, resolving any discrepancies in speed.

4. **Oscilloscope inspection:** Voltage levels on CAN H and CAN L are monitored to ensure proper communication, with a differential voltage of above 2 volts.
5. **Priority system:** The CAN bus uses an ID-based priority system where lower IDs have higher priority, preventing transmission collisions.
6. **Error-checking:** The system uses cyclic redundancy check (CRC) and acknowledgment bits for error-free data transmission.

Building a Digital Music Player with I2S?! What is I2S! EB#45

I2S (Inter-IC Sound) is a serial bus interface designed for digital audio applications, allowing devices like microphones, amplifiers, and microcontrollers to communicate. It transmits Pulse Code Modulation (PCM) audio data, representing sampled analog signals.

Process of using I2S with ESP32:

1. **Hardware setup:** A micro SD card breakout board is connected to the ESP32 via SPI for audio data input. An I2S microphone and I2S amplifier board are connected for output.
2. **Microphone data input:** The microphone transmits audio data via three I2S pins: word select, serial clock, and serial data. The word select pin indicates the audio channel (left or right), while the serial clock syncs data transmission.
3. **Clock frequency:** The clock frequency depends on the sampling rate, resolution, and audio channel type. For a 44.1 kHz, 16-bit stereo signal, the clock frequency is 1.411 MHz.
4. **Code setup:** The ESP32 is programmed to handle both SPI and I2S communication. Audio data is read from the microphone and written to the amplifier through I2S.
5. **Audio playback:** After the code is uploaded and the hardware is connected, audio is played through the amplifier, demonstrating the working of the I2S protocol.

Does this old Induction Motor still work? || How do Asynchronous Motors work? EB#46

This video dives into the workings of an induction motor, also known as an asynchronous motor, exploring its construction and function. The motor in question is an older model, and the goal of the video is to determine if it still works and explain how such motors operate.

1. **Motor Construction:** The motor consists of a stator (the stationary part) with coils and a rotor (the rotating part) with a squirrel cage design. The stator creates a rotating magnetic field when powered, and this induces a current in the rotor, which generates the opposing magnetic field that causes the rotor to spin.
2. **Power Requirements:** Induction motors require 3-phase AC voltage (230V or 400V) to operate, which is provided in standard house wiring in some countries. The wiring configuration (star or delta) determines the voltage applied to the coils. For the 400V system, a star configuration reduces the voltage to 230V across each coil.
3. **Functioning:** When power is applied, a rotating magnetic field is created, which induces a current in the rotor. The rotor generates a magnetic field that opposes the stator's field, causing the rotor to spin. However, the rotor cannot spin at the exact same speed as the stator (this difference in speed is called "slip"), and the motor is named "asynchronous" because of this.
4. **Speed Control:** The motor's speed can be altered using an electronic frequency converter or by using a motor with more poles. A higher number of poles reduces the motor's speed.
5. **Single-Phase Operation:** Some smaller motors, like those in appliances, use a capacitor to simulate a third phase and create a rotating magnetic field using just a single phase and neutral.

Building a Tube Amp! Does it produce better audio quality though? EB#47

The video explores tube amplifiers, which use vacuum tubes for pre-amplification but rely on modern components like Class D amps for power. The creator tests a tube amp and compares its audio to a smartphone, noting that while tubes create

more distortion, it's often perceived as warm or natural by some listeners. Although tube amps have inefficiencies, like excess heat and high-voltage requirements, their unique distortion is favored by audiophiles for its subjective sound. Ultimately, while not technically superior, tube amps offer a distinct audio experience that appeals to certain users.

The Best Protection for your Circuits? eFuse! Here is why they are awesome! EB#48

eFuse ICs are used to protect circuits from undervoltage, overvoltage, reverse voltage, and overcurrent. They are particularly beneficial in DIY projects, ensuring safety from faults like overcurrent and short circuits. The TPS259621 eFuse IC is recommended for its affordability and features, including adjustable voltage and current limits, as well as overvoltage and undervoltage protection. The configuration of these ICs with additional components ensures effective protection, but reverse voltage protection must be added separately using a MOSFET circuit.

Everything you need to know when buying/using an Oscilloscope! EB#49

An oscilloscope visualizes voltage and current values over time, essential for observing signals in power electronics and data communication. When choosing an oscilloscope, key factors include the number of channels, bandwidth, and sampling rate. A 4-channel scope is preferred for monitoring multiple signals, with a bandwidth of at least five times the signal frequency. The sampling rate should be at least 2 GSa/s.

To use a scope, connect the probe with the correct scaling factor (x1 or x10) and attach the alligator clip to ground. The trigger function ensures a stable waveform display. Voltage and time divisions adjust to capture clear signals, while cursors measure specific parameters like rise time. For current measurement, a current clamp or shunt is recommended.

For advanced use, precautions are necessary when measuring mains voltage to avoid damage. A 10:1 scaling factor ensures safety, and differential probes can be used to isolate the input from the output. Techniques like FFT are helpful in power electronics analysis.

Probably the most used component nobody knows of! TL431 Guide! EB#50

The TL431 is a precise programmable reference IC used in various applications, especially in switched-mode power supplies (SMPS). It consists of a comparator, transistor, diode, and voltage reference, typically 2.495V. The IC works by comparing a reference voltage to its internal threshold. When the reference voltage exceeds 2.495V, the transistor turns on, pulling the output low. In a feedback loop, it stabilizes the voltage by acting like a zener diode.

Key Applications:

- **Voltage Monitoring:** Used to create stable adjustable zener diodes with more precision than regular zeners, especially at varying input voltages and temperatures.
- **Current Control:** Can be applied in circuits like precision constant current sinks or undervoltage protection.
- **SMPS Feedback:** In SMPS circuits, TL431 with an optocoupler is used to stabilize output voltage by adjusting the duty cycle of the PWM circuit.

Working Principle in SMPS:

1. **Voltage Divider:** A voltage divider reduces the output voltage for comparison to the reference voltage (2.5V).
2. **Error Amplification:** The difference between the output and reference voltages is amplified and sent to the PWM circuit.
3. **Negative Feedback:** When the output voltage deviates, feedback adjusts the PWM duty cycle to correct it, stabilizing the output.

This component can control tons of circuits! Digital Potentiometer Guide! EB#51

Digital potentiometers serve as a digitally controlled alternative to mechanical potentiometers, ideal for projects requiring adjustable voltage or resistance. These components can be controlled using simple input pins and are useful for applications like dimming LEDs or adjusting sensor thresholds.

Process:

1. **IC Selection:** Digital potentiometers like X9C103 (10k Ω) and X9C104 (100k Ω) are chosen based on availability and resistance value.

2. **Wiring:** Pins for power supply, ground, and terminals are connected. Digital inputs are linked to tactile push buttons for controlling the wiper position.
3. **Operation:** The potentiometer's wiper position is adjusted by toggling digital inputs (Up/Down and Chip Select). A voltage difference between terminals creates an adjustable voltage divider.
4. **Testing:** The wiper position is successfully adjusted with the inputs, and the output voltage is monitored.
5. **Limitations:** Digital potentiometers may have limited resolution (100 steps) and voltage handling, which requires stress testing. Some ICs like X9C103 may not handle high voltages (e.g., 25V).
6. **Alternative ICs:** For high voltage applications, alternatives like MCP 41HV51-10k (up to 36V) are used, though they require SPI communication.
7. **Integration:** The digital potentiometer is tested and integrated into the circuit, replacing the mechanical potentiometer with successful results.

Negative Voltages are more important than you think! So here is how to make them! EB#52

A dual rail power supply is essential for various applications like audio amplifiers, sensors, operational amplifiers, and ADCs/DACs. Different methods can be used to create a dual rail power supply.

1. Simple Dual Rail Power Supply:

- A 5V input can produce +12V and -12V outputs using pre-made boards. This is the easiest method.

2. Boost Converter with Charge Pump:

- A boost converter circuit can be modified to provide dual rail voltages.
- An inverting charge pump circuit is added to generate the negative voltage by charging two capacitors alternately.
- However, current output is limited (30-50mA) and noise levels may interfere with sensitive circuits.

3. Center-Tapped Transformer:

- A transformer with a center tap provides dual rail voltages after rectifying and smoothing the AC voltage.
- This method is more stable with higher current (up to 500mA) but requires AC mains voltage.

4. Resistor Voltage Divider:

- Two resistors, with large capacitors, can create a virtual ground in the middle of a voltage supply.
- This method suffers from shifting voltage when current is drawn unevenly, but can be stabilized with an operational amplifier (Op-Amp) buffer.

5. Op-Amp Buffer and BUF634 IC:

- Adding an Op-Amp buffer to the resistor divider stabilizes the virtual ground and allows more current to be drawn without shifting voltages.
- A BUF634 IC can be added to increase current handling.

Mechanical Switches are Obsolete?! Switch to a Latch Circuit! EB#53

A latch circuit is used to toggle a switching element on or off, holding its state until a set or reset signal is received. This circuit is advantageous over mechanical switches in various electronic applications.

- **Working of SR Latch:** The SR Latch, composed of two NOR gates, uses a "set" and "reset" input. A high voltage on the set input turns the output high, while the reset input returns it to low.
- **Practical Example:** A breadboard setup demonstrates the SR latch functionality, where pressing the set button turns the output on, and pressing reset turns it off.
- **MOSFET and BJT Latch:** A latch circuit using a P-Channel MOSFET and NPN BJTs is designed to turn on or off a load. The push button activates the left

BJT, pulling the MOSFET gate low to turn on the load. Capacitors manage timing to prevent immediate reset.

- **Advantages over Mechanical Switches:** Latch circuits are more cost-effective than mechanical toggle switches, especially in high-current or complex switching applications. They reduce wiring costs and improve efficiency in larger setups, like lighting systems with multiple switches.

The Best Protection for your Circuit is NOT a Fuse!.....but a Resettable Fuse? EB#54

Resettable fuses, or PPTCs (Polymeric Positive Temperature Coefficient devices), provide an alternative to traditional fuses by allowing circuits to be protected without requiring replacement after tripping.

- PPTCs increase resistance as their temperature rises, which protects circuits by limiting current during overcurrent situations.
- When current exceeds a preset threshold, the fuse heats up, its resistance increases, and current flow is reduced.
- Key properties to consider when selecting a resettable fuse include maximum voltage, current, hold current, and trip current. The hold current is the safe current level, while the trip current is the level that triggers the fuse to protect the circuit.
- Resettable fuses are commonly used in battery packs and low-voltage circuits like LED strips.
- PPTCs are slower than traditional fuses but are reusable, making them suitable for applications where fuses need frequent resetting.
- After tripping, PPTCs cool down and return to their initial state once the current decreases, but the time to reset can be lengthy.

The Most Important Circuit for our Electrical Future?! (PFC) EB#55

Power Factor Correction (PFC) circuits are crucial for improving power efficiency in electrical systems, especially with devices that use AC to DC power supplies, like LED lights. These devices often draw current in a non-sinusoidal manner, leading to high apparent power and inefficiency in the power grid. PFC circuits

help reduce this inefficiency by minimizing reactive power and ensuring that real power equals apparent power.

Process:

- The real power (used for lighting, heating, etc.) and apparent power (total power drawn from the grid) are compared.
- Reactive power, caused by phase shifts in current (due to inductance or capacitance), increases apparent power without contributing to real power.
- PFC circuits reduce these phase shifts by adding inductance or capacitance, improving the power factor towards 1, where real power equals apparent power.
- Two types of PFC circuits exist: passive (using inductance and capacitance) and active (using boost converters).
- Active PFC circuits rectify the current waveform, converting it into a more sinusoidal shape, thus decreasing harmonic distortions and improving efficiency.

These 3 Cent Components are actually USEFUL?! (Color Ring Inductor) EB#56

Color ring inductors, resembling resistors, are low-cost inductors widely used in electronics. They consist of copper wire wrapped around a ferromagnetic core and are labeled with color rings for easy identification of inductance values.

- **Key Features and Uses:**

1. Commonly used in low-power applications like oscillators, signal filters, and small power supplies.
2. Lack detailed datasheets, with only basic information like inductance and power rating provided.
3. Saturation current, a critical parameter, is not specified, limiting their use in high-power circuits.

- **Testing and Limitations:**

1. In a boost converter test, a 22 μ H color ring inductor performed at half the current capacity (0.5A) compared to a standard inductor (1A).
2. Saturation current, measured using a custom test circuit, was found to be around 1.6A, significantly lower than standard inductors.
3. Performance degrades with heat, further reducing their effectiveness in high-power scenarios.

Ground is MORE IMPORTANT than you think! EB#57

Ground, or earth, serves as a critical reference point in electrical systems, ensuring safety and stability. It is used in both AC and DC systems for protection and functionality.

- **Key Functions of Ground:**

1. **Safety in AC Systems:**

- In household appliances, the ground wire (PE) is connected to the metal chassis to prevent electric shock.
- If a live wire touches the chassis, a short circuit is created, tripping circuit breakers or RCBs, cutting off power.

2. **Static Electricity Discharge:**

- Grounding metal parts (e.g., solar panels) eliminates static electricity buildup, preventing damage or accidents.
- Earth acts as a massive reference point (0V), absorbing excess electrons without altering its potential.

- **Ground in DC Circuits:**

1. In schematics, ground symbols typically represent a common reference point (0V) for DC voltage, not necessarily connected to earth.
2. In PCB designs, the bottom layer often acts as a continuous ground plane, similar to earthing in AC systems.

This Component solves "All" Motor Problems?! (Motor Encoder) EB#58

Motor encoders are devices used to measure the position, speed, and direction of a motor shaft. They are essential for precise control in various applications, from robotics to industrial automation.

- **Types of Encoders:**

1. **Mechanical Rotary Encoders:**

- Use a metal pad with conductive and non-conductive patterns.
- Two pins (A and B) generate voltage pulses to determine direction and movement.
- Low resolution (e.g., 20 steps per rotation).

2. **Optical Encoders:**

- Use light sensors to detect patterns on a rotating disc.
- Higher precision compared to mechanical encoders.

3. **Magnetic Encoders:**

- Use Hall effect sensors to detect the position of a magnet attached to the motor shaft.
- High resolution (e.g., 12-bit, 4096 steps per rotation).

4. **Capacitive Encoders:**

- Use capacitive technology for position detection.
- High resolution (e.g., 2048 steps per rotation).

- **Applications:**

1. **Precise Positioning:**

- Converts BLDC or DC motors into stepper-like motors for accurate positioning.

2. **Speed Control:**

- Measures motor speed for feedback control in robotics or industrial systems.

3. **Direction Control:**

- Determines the direction of motor rotation for tasks like robot navigation.

- **Advantages:**

1. Enhances motor performance by providing real-time feedback.
2. Enables precise control in applications where stepper motors are unsuitable.
3. Solves issues like motor inconsistency in robots or uneven movement.

This \$0.70 Component SAVES your Circuit?! (Surge Protection) EB#59

Surge protection components safeguard circuits from overvoltage events like lightning strikes, electrostatic discharges, or inductive switching. They dissipate excess energy to prevent damage to electronics.

- **Types of Surge Protection Components:**

1. **TVS Diodes (Transient Voltage Suppressors):**

- Act as diodes with a reverse stand-off voltage (e.g., 5V).
- Conduct when voltage exceeds the threshold (e.g., 6V), clamping the voltage to a safe level (e.g., 10-12V).
- Handle quick, high-power pulses (up to 100W).
- Ideal for low-voltage circuits (e.g., microcontrollers).

2. **MOVs (Metal Oxide Varistors):**

- Variable resistors that clamp voltage by dissipating energy as heat.
- Used in AC power supplies and higher-voltage applications.
- Often paired with thermal fuses for added safety.

3. GDTs (Gas Discharge Tubes):

- Contain inert gas that ionizes during overvoltage, creating a conductive path.
- Suitable for high-voltage systems but not for low-voltage circuits.

- **Key Differences:**

1. **Energy Handling:** MOVs and GDTs handle higher energy surges compared to TVS diodes.
2. **Response Time:** TVS diodes respond fastest, making them ideal for quick surges.
3. **Applications:** TVS for low-voltage circuits, MOVs for AC inputs, and GDTs for high-voltage systems.

- **Practical Use:**

1. TVS diodes are cost-effective (a few cents) and easy to integrate into low-voltage projects.
2. MOVs are commonly used in power supplies for robust protection.
3. Industrial surge protectors use large MOVs and advanced mechanisms (e.g., spring levers) for enhanced safety.

Is This the NEW GOLDEN Standard for Communication? (I3C) EB#60

I3C is the successor to the widely used I2C communication protocol, offering significant improvements in speed, efficiency, and functionality. It is designed for communication between integrated circuits (ICs) and is backward compatible with I2C.

- **Key Features of I3C:**

1. **Higher Data Transfer Rate:**

- I3C supports up to 12.5MHz, compared to I2C's 1MHz, enabling faster communication.

2. **Push-Pull Drivers:**

- Replaces I2C's open-collector design, reducing power consumption and improving signal integrity.

3. **Dynamic Addressing:**

- Assigns addresses during initialization, avoiding address conflicts common in I2C.

4. **Common Command Codes (CCC):**

- Simplifies commands like resetting or reassigning addresses.

5. **Hot Join Feature:**

- Allows devices to join the bus without restarting the system.

6. **In-Band Interrupts:**

- Eliminates the need for extra interrupt pins by transmitting interrupts through the data stream.

- **Advantages Over I2C:**

1. Faster and more efficient communication.
2. Simplified addressing and reduced hardware conflicts.
3. Reduced pin count with in-band interrupts.

- **Limitations:**

1. More complex implementation compared to I2C.
2. Limited microcontroller support due to the need for specialized peripherals.

The World's Simplest Audio Amp just got BETTER?! (MOSFET Amp) EB#61

The video explores the design and performance of a simple audio amplifier, comparing BJT (Bipolar Junction Transistor) and MOSFET-based designs. The goal is to create a more powerful amplifier to drive a loudspeaker effectively.

- **Key Points:**

1. **Original BJT Amplifier:**

- Simple design with 7 components.
- Limited power output, suitable for headphones but not loudspeakers.

2. Upgrading to Darlington Transistor:

- Replaced BJT with a TIP142 Darlington transistor for higher current handling (up to 10A).
- Required higher supply voltage (12V) and new resistor values to avoid clipping and overheating.
- Improved volume but still inefficient due to high power dissipation.

3. MOSFET Amplifier (IRFZ44N):

- MOSFETs offer lower resistance and higher current handling compared to BJTs.
- Simpler biasing with a potentiometer to set the gate voltage.
- Achieved louder output due to lower voltage drop but introduced harmonic distortions.

4. Performance Comparison:

- **Darlington Amplifier:** Lower distortion, better linearity, but less efficient.
- **MOSFET Amplifier:** Louder output but higher harmonic distortion, less linear.

• Conclusion:

- BJTs are generally better for linear amplification with low distortion.
- MOSFETs, while simpler and capable of higher power, introduce more distortion.
- The choice depends on the application: BJTs for high-fidelity audio, MOSFETs for higher power with acceptable distortion.