Note

>>>video 1:Electronic Basics #1: The Multimeter

Introduction to Electrical Fundamentals and Multimeters

The instructor introduces the fundamental electrical concepts of voltage, current, and resistance, explaining their relationship through Ohm's law. They present the multimeter as an affordable and essential tool for measuring these parameters.

Measuring Resistance and Continuity

The instructor demonstrates resistance measurement using multimeter probes, showing how to measure a 68 kiloohm resistor. They explain the limitations of measuring resistance in built circuits and introduce the continuity testing feature for checking cable breaks.

Voltage Measurement and Safety Considerations

The video covers the distinction between AC and DC voltage measurements, focusing on DC applications like batteries and power supplies. The instructor emphasizes safety precautions, particularly warning against touching the insides of power supplies where AC converts to DC.

Current Measurement and Maintenance
The instructor explains DC current measurement, emphasizing the importance of using the 10-amp socket initially. They demonstrate the process of measuring current, including how to open the circuit and troubleshoot common issues like blown fuses. The segment includes practical maintenance advice on replacing multimeter fuses.

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

Introduction to LED Brightness Control

The presenter introduces the fundamental question of LED brightness control, mentioning that the solution works both with and without Arduino microcontrollers. He introduces PWM (Pulse Width Modulation) as the key concept and explains its applicability to various LED types including 5mm LEDs, LED strips, and high-power LEDs.

Basic LED Dimming Principles

Using a green LED with 3.2V forward voltage, the presenter demonstrates basic dimming principles using a bench power supply. He explains how increasing voltage above forward voltage can damage the LED, while reducing voltage below forward voltage decreases brightness. He discusses why using a potentiometer isn't ideal, particularly for high-power LEDs, due to energy waste and cost implications.

PWM Technology Explanation

Using an oscilloscope, the presenter explains PWM operation, showing how it rapidly switches between 5V and 0V. He explains the duty cycle concept, where 100% represents full brightness, 50% represents approximately 2.5V, and 20% represents about 1V.

Arduino Implementation

The presenter demonstrates PWM implementation using Arduino's analogWrite function, which accepts values from 0 to 255. He shows how to use a potentiometer as an analog input to control LED brightness on PWM pin 3, with 0 representing 0V and 255 representing 5V.

555 Timer and MOSFET Implementation

For non-microcontroller applications, the presenter introduces the 555 timer chip solution. He explains how to wire it with a potentiometer for duty cycle control. For high-power applications, he demonstrates using a MOSFET configuration, connecting the PWM signal to gate, LED negative to drain, and ground to source.

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

Project Introduction and Microcontroller Selection

The creator introduces their LED bar project requiring a WS2801 LED strip with push button control. They explain choosing the ATtiny85 over Atmega328 for cost efficiency ($1 vs $4). The ATtiny85's specifications (5 IOs, 8KB flash memory) are deemed sufficient for the project's needs.

Software Setup and Requirements

Instructions for software installation are provided, specifically requiring Arduino IDE version 1.0.5, as version 1.5.5 beta is incompatible. The process includes downloading ATtiny board data from highlowtech.org and proper installation in the Arduino hardware folder.

ATtiny85 Pin Configuration and Wiring

Detailed explanation of ATtiny85 pinout: pin 4 (ground), pin 8 (VCC), and IOs on pins 2, 3, 5, 6, and 7. The wiring process to Arduino Uno is described, including connections for programming pins and the requirement of a 10µF capacitor between Arduino's reset pin and ground.

Programming Shield Construction

The creator demonstrates building a custom ATtiny programming shield, including PCB modification, soldering male headers, adding an IC socket, and creating bridge wire connections. The shield simplifies future programming by eliminating the need for repeated manual wiring.

Project Implementation and Limitations

Discussion of ATtiny limitations, particularly regarding SPI protocol support needed for WS2801 LED strip. The creator mentions SparkFun's bit-banging solution as a workaround and previews future developments of the LED project.

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

Introduction to Bluetooth Module and Project Overview

The presenter introduces a small four-pin Bluetooth device compatible with Arduino projects. They showcase a practical application where they built a controller for LED lighting in their living room, capable of controlling brightness and animations.

Hardware Acquisition and Challenges

The presenter discusses purchasing options from Amazon and eBay, noting the fragility of these modules. They share personal experiences with a broken Chinese module and another that was damaged during Arduino connection. They introduce the Arduino Nano as their chosen microcontroller for this project.

Technical Specifications and Voltage Considerations

Detailed explanation of voltage compatibility between the 5V Arduino and 3.3V Bluetooth module. The presenter explains why receiving 3.3V signals on Arduino works fine but sending 5V signals to the module can cause damage.

Implementation of Voltage Divider Solution

The presenter explains the voltage divider solution using a 2kΩ and 4.7kΩ resistor combination to achieve approximately 3.4V output. Detailed wiring instructions are provided for connecting the TX/RX pins through the voltage divider.

LED Wiring and Android App Setup

Instructions for wiring a common anode RGB LED using 460-ohm resistors and connecting to digital pins 8, 9, and 10 of the Arduino Nano. The presenter recommends the S2 Terminal Android app for Bluetooth control.

Programming and Final Setup

The presenter shares their custom code for controlling the LED colors, explaining how to modify code words for different functions. Important instructions are given about disconnecting TX/RX connections during code upload, and details about Bluetooth pairing (using codes 1234 or 0000).

>>>video 5:Electronic Basics #5: How to Multiplex

Introduction to the LED Control Problem

The presenter introduces the common problem faced when building LED projects like 4x4x4 RGB LED cube (192 LEDs) or 10x5 LED matrix (50 LEDs), where traditional microcontrollers lack sufficient IO pins. Even the Arduino Mega's 54 IOs aren't enough for these projects.

Required Components and Matrix Construction

The solution requires an Arduino Nano, TLC 5940 LED driver, five F9540N P channel MOSFETs, one 2K resistor, and five 1K resistors. The presenter demonstrates the construction of an LED matrix by connecting cathodes in columns and anodes in rows, with clear labeling from A-J for columns and A-E for rows.

Multiplexing Technique and Circuit Design

The presenter explains the multiplexing technique to avoid unwanted LED activation. Each row is lit individually in rapid succession, creating the illusion of a complete image. MOSFETs are used as switches to handle the 200mA current draw per row, with detailed connections to the Arduino Nano and TLC 5940.

Code Implementation and Demonstration

The implementation uses a TLC library from Arduino playground to simplify the coding process. The presenter demonstrates the working system with a moving sine wave pattern and static text, showing how increasing row on-time reveals the multiplexing effect. The code is available for download with detailed comments for better understanding.

>>>video 6:Electronic Basics #6: Standalone Arduino Circuit

Introduction and Project Context

The presenter introduces a LED color organ circuit built on a breadboard and discusses the limitations of using an Arduino Uno board when trying to fit the circuit into a compact gadget box. They suggest that while creating a shield is one solution, a more space-efficient approach is needed.

Essential Components for Standalone Atmega 328p

The presenter details the four crucial external components needed: a 16MHz clock crystal, two 22pF capacitors for the external clock signal, and one 10kΩ resistor connecting between the reset pin and 5V. They explain the crystal connects to pins 9 and 10, with capacitors between each pin and ground. An alternative 8MHz internal oscillator option is mentioned but requires a different bootloader.

Power Connections and Arduino Comparison

The tutorial covers the power connections (pins 7, 20, 21 to 5V, pins 8 and 22 to ground) and discusses the tradeoffs compared to an Arduino board, including the lack of reset switch, USB-serial conversion, and various protection features.

Programming Methods

Three programming methods are explained: 1) Physically moving the Atmega to an Arduino board, 2) Using an Arduino as a programmer by connecting TX/RX/reset pins, and 3) Using an FTDI chip for USB-serial conversion. The presenter also mentions ICSP programming as an advanced option but notes its complexity.

Final Implementation

The presenter demonstrates the successful implementation in the gadget box, emphasizing the importance of breadboard testing first. They show the addition of female headers for RX and TX lines to enable future reprogramming capabilities.

>>>video 7:Electronic Basics #7: 7 Segment Display

Introduction to Seven-Segment Displays

The presenter introduces the concept of seven-segment displays as old-school but useful components for projects requiring numerical output. They explain their applications in clocks, temperature sensors, and power supply displays.

Understanding Display Types and Datasheets

The video explains different display types, from single-digit to two-digit configurations. Using the LTS 546AG as an example, it details how to read datasheets, understand the eight LED configuration (seven segments plus decimal point), and common anode setup with pins 3 or 8 as the common plus terminal.

Non-Arduino Control Methods

The presenter demonstrates controlling displays without a microcontroller using the SN74LS247 BCD to seven-segment display driver and SN74LS290 four-bit binary counter. They explain the connection process, including the use of 220 ohm resistors and proper pin configurations for BCD counting sequence.

Multiple Digit Display Control

The discussion moves to controlling multiple digits, introducing multiplexing concepts and the

SAA1064 IC solution. The IC can control four digits through multiplexing and supports I2C communication with Arduino. The presenter provides detailed wiring instructions, including the use of 2.2 nF capacitors and 4.7k ohm pull-up resistors.

Implementation and Conclusion

The final segment covers the implementation of I2C code using the SAA1064 library, demonstrating the complete functionality of the display system. The presenter encourages experimentation with the library and IC while emphasizing the efficiency of this approach for Arduino projects.

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

Introduction to LED Basics

GreatScott introduces the topic, acknowledging his frequent use of LEDs in videos and the need to address proper LED handling techniques. He admits that even he sometimes doesn't handle them correctly and promises to explain both simple and complex aspects of LED usage.

Basic LED Tutorial and Calculations

GreatScott explains the two crucial LED parameters: forward voltage (3.2V) and current requirement (20mA). Using a 9V battery example, he demonstrates how to calculate the proper resistor value using Kirchhoff's voltage law and Ohm's law, arriving at 290 ohms. He also covers resistor power ratings, showing that a quarter-watt resistor is sufficient for the calculated 0.116W power dissipation.

Multiple LED Configurations

GreatScott demonstrates the efficiency of series LED connections versus parallel configurations. With two LEDs in series, he calculates a reduced resistor value of 130 ohms and shows how this arrangement cuts power waste in half while doubling light output. He notes the voltage limitations when attempting to connect three LEDs in series.

Advanced LED Considerations

GreatScott warns about manufacturer specifications' reliability and explains the exponential nature of LED current consumption. He discusses his Moped mod project, acknowledging criticism about using a single power resistor for parallel LEDs. He explains how forward voltage variations (2.9V to 3.1V) among LEDs can cause uneven current distribution and premature failure in parallel configurations.

Professional LED Driving Solutions

GreatScott recommends constant current mode over constant voltage mode for driving LEDs. He introduces the LM317 with a resistor as a simple constant current source, though noting its poor efficiency. He mentions the TLC 5940 as a more advanced constant current driver option, promising future coverage of this topic

>>>video 9:Electronic Basics #9: Diodes & Bridge Rectifiers

Introduction to Diodes and Their Presence

The presenter introduces diodes as ubiquitous components in power supplies, noting that both older linear power supplies (containing four diodes) and modern switching power supplies utilize them. A demonstration using a Banana Pi shows how even small SMD diodes are used in consumer electronics.

DC Circuits and Reverse Polarity Protection

Using an LED blink circuit demonstration, the presenter explains how diodes protect circuits from reverse polarity damage. The 1N4007 diode is examined, showing its voltage drop characteristics and efficiency implications, with calculations revealing a 13% power loss (4.55 milliwatts) in the demonstrated circuit.

AC to DC Conversion Basics

The presenter demonstrates AC to DC conversion using a 220V to 15V transformer. The explanation covers RMS values versus peak voltage (25.6V peak shown on oscilloscope), and how dividing by the square root of two gives the RMS value for sine waves. A single diode demonstration shows basic AC to DC conversion with resulting rough DC output.

Bridge Rectifier and Advanced DC Power Supply

The final segment explains bridge rectifier operation, showing how four diodes can convert both positive and negative portions of AC waves to DC. The presenter illustrates the current flow paths and demonstrates how this configuration improves power supply efficiency compared to single-diode rectification.

Chapter 11

Introduction to Dual Rail Power Supplies

- The video introduces the concept of dual rail power supplies, which provide both positive and negative DC voltages, unlike typical power supplies that only offer a positive voltage.
- It highlights the necessity of dual rail power supplies in applications such as audio amplifiers, sensors, operational amplifiers, ADCs, DACs, and LCDs.

Simple Dual Rail Power Supply Boards

- The video demonstrates using commercially available dual voltage boards that can be easily ordered online.
- These boards, when connected to a 5V input, output +12V and -12V.

Reverse Engineering a Boost Converter with Charge Pump

- The video explains how a standard boost converter circuit can be modified into a dual rail voltage circuit by adding an inverting charge pump.
- The charge pump uses a high-frequency square wave voltage to charge capacitors, creating a negative voltage.
- Common Schottky diodes and capacitors can be used to add this charge pump to an existing boost converter.

Limitations of Charge Pump Circuits

- The video points out that charge pump circuits have limitations, including a low maximum output current (30-50 milliamps in the commercial version) and significant switching noise (1 volt peak-to-peak).
- DIY attempts may perform worse due to the boost converter's limitations.

Dual Rail Power Supply with Center Tapped Transformer

- The video introduces a more robust solution using a center-tapped transformer, capable of outputting 500 milliamps of current on both rails with minimal noise.

- The transformer outputs 30 volts RMS, which is then rectified using a full bridge rectifier.
- The center tap serves as the ground potential, creating positive and negative waves that are smoothed out with capacitors and linear voltage regulators to produce stable 12V rails.
- An alternative is using a transformer with two identical output windings connected to form a center tap.

Virtual Ground with Resistors and Op-Amp

- The video explores creating a virtual ground using two identical resistors, which splits the supply voltage into two equal parts.
- However, this method is highly susceptible to voltage shifts due to resistive differences and current draw.
- Adding an operational amplifier as a buffer stabilizes the virtual ground by maintaining a constant voltage potential.
- For higher current needs, a buffer IC like the 634 can be added after the op-amp.

Alternative Voltage Rail Splitter Approaches

- The video mentions other voltage rail splitter approaches, such as using a TL2426 IC or a discrete transistor solution, and provides links for further information.

Conclusion and Sponsor

- The video concludes by summarizing the various methods for creating dual rail power supplies.

Chapter 12

Introduction to Digital Potentiometers

- GreatScott! introduces digital potentiometers as alternatives to mechanical potentiometers for controlling circuits.
- He highlights their utility in projects requiring adjustments over time, such as dimming an LED based on the time of day.
- The problem addressed is how to adjust potentiometer values with a microcontroller to control voltage and dimming.

Initial Digital Potentiometer Selection and Challenges

- GreatScott! initially used X9C103 and X9C104 digital potentiometers due to their availability.
- He mentions discovering a significant problem with these initial choices, leading him to seek alternatives.
- He notes that most digital potentiometers use I2C or SPI for communication, which are more complex than the three digital input pins of his first potentiometers.

Understanding Digital Potentiometer Pinouts and Basics

- GreatScott! explains how to identify the supply voltage, ground pins, and pins corresponding to a traditional mechanical potentiometer.
- He uses the 103 version, a 10 kiloohm digital potentiometer, and mentions the 104 IC is a 100 kiloohm version.
- He connects the digital inputs to tactile push buttons with pull-up resistors and debouncing capacitors on a breadboard.

Digital Potentiometer Functionality and Limitations

- GreatScott! describes the internal structure of the IC, consisting of 99 resistors connected between terminals.
- He explains how the IC activates switches to create adjustable resistances, functioning as a voltage divider.
- He points out that the digital potentiometer's wiper has only 100 different positions, limiting the voltage division resolution.

Testing and Practical Application Issues

- GreatScott! mentions the three-terminal potentiometer setup is suitable for audio amplifiers or

adjusting operational amplifier trigger voltages.
- He notes that in voltage converters, potentiometers are often used as two-terminal variable resistors.
- He identifies three potential problems: needing the exact resistance value, high voltage drop across the potentiometer, and exceeding the datasheet's maximum voltage.

Stress Testing and IC Failure
- GreatScott! reports that the initial IC failed under a voltage of 25 volts during stress testing.
- He also tested the maximum current flow, finding it to be around 100 milliamps before destruction.
- He concludes that this particular digital potentiometer is unsuitable for the boost converter application.

Transition to MCP41HVX1 and Implementation
- GreatScott! introduces the MCP41HVX1, which can handle up to 36 volts.
- He mentions that this IC requires SPI codes for control, adding complexity.
- He uses an Instructables article for guidance and successfully integrates the MCP41HVX1, testing it with an Arduino by sending 'U' for up and 'D' for down to control the wiper position.

Final Testing and Conclusion
- GreatScott! desolders the old components and replaces them with the new digital potentiometer.
- He conducts a final test, which works perfectly, demonstrating the successful integration of the MCP41HVX1.

Chapter 13

Introduction to Switch Mode Power Supplies and TL431
- The video introduces switch mode power supplies and their ability to convert mains voltage to lower DC voltages efficiently (around 84%).
- The video expresses admiration for switch mode power supplies and references a previous video about their function and a DIY version created.
- The video introduces the TL431, a precise programmable reference, and states the video will cover its workings and applications, including its use in switch mode power supplies.

TL431 Basics: Schematic and Functionality
- The video presents a simplified schematic of the TL431, resembling a Zener diode with a reference voltage pin.
- The video shows a functional block diagram revealing the IC consists of a comparator, transistor, diode, and a 2.495 volts voltage reference.
- The video specifies the IC operates with a cathode voltage between Vref and 36 volts, requiring a maximum current of 1 milliamp.
- The video details the pinout: ref, anode, and cathode, with the cathode typically connected to a resistor and the anode to ground.

TL431 as a Comparator
- The video explains that in an open loop setup, the TL431 functions as a comparator.
- The video describes how a rising voltage affects the comparator's output, activating a transistor to pull the output voltage low when the ref voltage exceeds the voltage reference.
- The video shows a breadboard demonstration of the TL431 functioning as a comparator.

TL431 as a Zener Diode Substitute
- The video explains that connecting the ref pin to the cathode creates a closed loop circuit, making the TL431 a substitute for a 2.5 volt Zener diode.
- The video mentions that the circuit maintains a 2.5 volts voltage at the cathode, regardless of input voltage increases.
- The video highlights the TL431's stability compared to ordinary Zener diodes, which have voltage drift issues, while advising not to exceed 100 milliamp current flow.

Adjustable Zener Diode and Applications

- The video details how adding a voltage divider allows creating an adjustable Zener diode, using a simplified formula based on the 2.5 volts threshold.
- The video suggests using two 10 kiloohm resistors to create a 5 volt Zener diode.
- The video emphasizes the TL431's ability to monitor voltage and switch at a threshold, making it suitable for monitoring and feedback circuits.
- The video presents schematics for a 12 volt battery over discharge protection circuit and a precision constant current sink.

TL431 in Switch Mode Power Supply Feedback Systems

- The video transitions to discussing switch mode power supplies and the use of TL431 with an optocoupler in feedback systems.
- The video simplifies feedback loop design, avoiding complex concepts like Laplace transformation.
- The video explains how a feedback loop system maintains a 5 volts output voltage using a voltage divider, error amplifier, and PWM circuit.
- The video notes that TL431 is commonly used in power supplies for error amplification, often with added passive components.

Component Value Calculations and Test Setup

- The video details the calculation of resistor values for the feedback system: two 500 ohm resistors for the voltage divider and a 650 ohm resistor for the optocoupler LED.
- The video recommends a 100 nanofarad capacitor for the feedback system.
- The video describes building a test power supply partly on a perfboard and partly in the air.
- The video mentions using Teensy programming to generate a 54 kilohertz sawtooth signal.
- The video concludes that the feedback system is acceptably stable and functions as expected.

Chapter 14

Introduction to Oscilloscopes and a Prototype Demonstration

- The video starts with the creator showcasing a functional prototype of a switch mode power supply that converts 230 volts AC mains voltage into 5 volts DC.
- The creator hooks up the power supply, noting that it doesn't blow up and outputs around 5 volts.
- The creator then plans to demonstrate interesting waveforms on the oscilloscope but stops to highlight a common and potentially damaging mistake when using oscilloscopes.
- The video promises to cover everything one needs to know about using an oscilloscope, from basic voltage and current measurements to advanced topics like safe mains voltage measurements and FFT.

Why Use an Oscilloscope and Choosing the Right One

- The creator explains that an oscilloscope visualizes voltage and current values over time, essential for building or repairing electronics due to the prevalence of switching and data communication protocols.
- The video shifts focus to a more budget-friendly oscilloscope option.
- When choosing an oscilloscope, one should consider the number of channels, available bandwidth, and sampling rate.
- A four-channel scope is preferable for observing multiple signals simultaneously.

Understanding Bandwidth and Sampling Rate

- Bandwidth is described as the frequency at which the input signal gets damped by -3dB, reducing its amplitude to 70.7% of its original value.
- The creator demonstrates how higher frequencies can lower the amplitude on the oscilloscope, as it acts like a low pass filter.
- A rule of thumb is that a 200 MHz scope can handle signals with frequencies up to one-fifth of its

bandwidth (40 MHz), which is sufficient for many applications.

- The sampling rate is a digital value that describes how many measurements the scope can take per second; two gigasamples per second is considered plenty.
- The sampling rate splits up when using more channels.

Using Passive Probes and Scaling Factors

- The video discusses using passive probes, which are easy to work with.
- To use a probe, connect the BNC connector, select a scaling factor (X1 or X10), attach the alligator clip to ground, and touch the circuit point of interest with the probe tip.
- The scaling factor either decreases the voltage signal by a factor of 10 (X10) or doesn't change it (X1), with X1 having lower resistance and higher capacitance, thus a lower bandwidth.
- The creator recommends using X10 for the highest bandwidth.

Triggering and Adjusting the Oscilloscope Display

- The trigger is used to create a stationary image of a periodic signal by capturing the waveform at the same point, such as a rising or falling edge.
- The trigger type can be adjusted to a certain pulse width, a pattern, or specific rise or fall time, but the edge option usually works fine.
- The video demonstrates adjusting the trigger threshold value to get a clear PWM signal.
- The vertical voltage division can be changed using the vertical knob.
- The video corrects a beginner's mistake by choosing the correct scaling factor to display the proper voltage.
- The horizontal time division can be adjusted to present the waveform in the best way.
- The frequency of the signal can be calculated with the known time division, but digital scopes have measuring features that include frequency measurement.

Measuring Rise Time and Voltage Ripple

- To measure the rise time of a MOSFET gate, stop the scope, zoom in, and activate the cursor function to determine the time difference between 10% and 90% of the voltage value.
- To measure voltage ripple, the input coupling can be changed to AC, which adds a capacitor in series to the input, removing the offset voltage.
- The video demonstrates measuring the ripple of a boost converter, finding it to be 4.2 volts peak to peak, making it unsuitable for the job.

Capturing Charging Curves and Measuring Current

- To capture a charging curve, select single mode capturing, which triggers the scope when the capacitor reaches the trigger threshold voltage.
- The scope can only directly measure voltage signals; to measure current, a current shunt or current clamp is needed.
- The creator recommends using a current clamp for its simplicity and ease of use.

Advanced Section: Measuring Mains Voltage Safely

- The video warns about the dangers of measuring mains voltage, which can cause major injuries if not handled correctly.
- The RMS voltage value of mains voltage is around 230 volts, which is above the maximum rated input voltage of the oscilloscope.
- Using a scaling factor of 10 to 1 decreases the voltage to 23 volts, and because the probe can handle 300 volts RMS, it should be safe.
- The video warns against connecting the alligator ground reference to the reference points, as it is connected to the PE wire and can cause a short circuit.
- To solve this problem, differential probes, whose input and output are isolated, can be used to safely hook up mains voltage.

Math and FFT Functions in Power Electronics and Conclusion

- The video mentions that math and FFT functions are important in power electronics.
- The creator recommends watching a previous video about different kinds of power forms to learn more about these functions.

Chapter 16

Introduction to Tube Amplifiers and Viewer Requests

- He explains that tube amplifiers use vacuum tubes, which resemble Nixie tubes but light up less.
- GreatScott! notes that triode vacuum tubes were invented in 1906 and largely replaced by transistors in 1947, making them seem like relics.
- Despite their age, tube amps are still available, prompting the question of their continued relevance.

Objectives and Overview of the Tube Amplifier Analysis

- GreatScott! bought a tube amplifier to examine how vacuum tubes work and how to create a simple audio preamplifier with them.
- The video aims to determine if using vacuum tubes still makes sense after 100 years.

Sponsorship by Altium Designer00:01:57

- GreatScott! announces that the video is sponsored by Altium.
- He switched to Altium Designer for creating schematics, citing its comprehensive features and ability to search for components from online sellers.
- He encourages viewers to test Altium Designer using the links in the video description.

Tube Amplifier Examination and Initial Sound Quality Assessment

- GreatScott! bought a tube amplifier for around 80 euros to examine it.
- He appreciates the replaceable tubes and the high-quality metal enclosure.
- The amp supports stereo input via wires or Bluetooth and output via speakers or headphones.
- GreatScott! compares the amp's audio output to his phone, noting the tube amp offers a more pleasant sound spectrum.
- He mentions that terms like "warm" or "natural" are often used to promote tube amplifiers.

Internal Components and Functionality of the Tube Amplifier

- GreatScott! finds many ICs on the PCB, including operational amplifiers, a headphone amplifier, and a Class-D amplifier.
- The Class-D amplifier is used for the speaker output, and the headphone amplifier is for headphones.
- The vacuum tubes only preamplify the original audio signal.
- The 6J4 tubes are triodes that can handle a maximum current of 20 milliamps, insufficient to directly drive speakers.

Triode Vacuum Tube Functionality and Class A Amplifier Design

- GreatScott! explains the function of the triode's pins: plates (anode), cathode, grid, and heater.
- Current flows from the cathode to the anode when the heater pins are powered with 6.3 volts.
- The heat generated, around 1.8 watts, is an excess power loss compared to transistors.
- Applying a control signal to the grid repels electrons, reducing current flow and enabling amplification.
- He builds a simple class A amplifier design to test the tube's functionality, noting it requires 100 to 150 volts DC.

High Voltage DC Converter and Circuit Testing

- GreatScott! uses a high voltage DC converter, originally for a Nixie clock project, to supply the required voltage.
- He adjusts the output voltage to around 100 volts using the onboard trimmer.

- After soldering wires to the tube's pins and connecting them to the components, he tests the circuit with a function generator.
- The output shows amplification but with a waveform issue at around 24.4 kilohertz, the same frequency as the boost converter.

Comparison with Transistor Amplifier and Distortion Analysis

- GreatScott! builds the same class A amplifier circuit with a BC637 NPN BJT for comparison.
- The transistor amplifier yields similar waveform results to the tube amplifier.
- He analyzes the transistor's datasheet, noting its linear relation between collector current and collector-emitter voltage, indicating low distortion.
- The vacuum tube's lines are less linear, indicating more distortion.
- GreatScott! explains that some people prefer the distortions created by tube amps, describing them as warm or natural.

Advantages and Subjective Preferences of Tube Amplifiers

- GreatScott! mentions that tube amps may not create high-frequency harmonics, which some listeners find favorable.
- A real advantage of tube amps is that they do not clip like transistors when overdriven.
- He concludes that the tube preamplifier in his bought product might add distortions, but he doesn't notice or care much.

Chapter 17

Introduction to Asynchronous Motors

- The video introduces asynchronous or induction motors, positioning them as potentially more complex than stepper, DC, or BLDC motors.
- The presenter aims to demonstrate how to make such a motor function and discuss its advantages over other motors used by hobbyists.
- The presenter notes that asynchronous motors are the most widely used type globally.

Disassembling and Understanding Motor Components

- The presenter initially disassembles an old asynchronous motor to understand its construction, encountering difficulty with the gear system.
- To avoid damaging the old motor, a new one is ordered for further testing.
- The presenter successfully removes the rotor from the new motor, describing it as a squirrel cage design with conductive metal sticks shorted at each end.
- The stator, which remains stationary, is examined, revealing numerous copper wires connected to the coils in the terminal box.

Voltage Requirements and Configuration

- The presenter explains that a DC voltage is insufficient for operating the motor, which requires three-phase AC voltage.
- The motors are rated for 230V/400V, aligning with German house wiring standards.
- The presenter cautions that working with 230V or 400V can be lethal and should be handled by professionals.
- The presenter clarifies that the 230V rating indicates the maximum voltage the coils can handle, suitable for delta configurations, while the 400V rating necessitates a star configuration to reduce voltage across each coil to 230V.

Motor Operation and Rotating Magnetic Fields

- The presenter explains that the motor operates without permanent magnets by using a rotating magnetic field.
- Three sine wave voltages, 120 degrees out of phase, are applied to coil pairs, creating sine currents and a changing magnetic field.

- This rotating magnetic field induces a voltage into the rotor's metal sticks, creating a current and opposing magnetic field that causes the rotor to spin.

RPM, Slip, and Motor Types

- The presenter explains that with a 50 Hertz voltage, the rotor should ideally spin at 3000 RPM, but it measures slightly lower due to 'slip'.
- Slip is the difference in RPM between the stator and rotor, necessary for voltage induction in the rotor.
- Asynchronous motors are contrasted with synchronous BLDC motors, which use permanent magnets and have rotors spinning at the exact frequency of the applied voltage.

Altering RPM and Single-Phase Motors

- The presenter notes that RPM can be altered using expensive frequency converters or by using motors with more poles.
- Motors with more poles, such as four-pole motors, have their RPM cut in half.
- Single-phase asynchronous motors, like those in water pumps, use a capacitor to create a third phase with a 90-degree phase shift, enabling the creation of a rotating magnetic field.

Conclusion: Advantages and Recommendations

- The presenter successfully connects the old motor in a star configuration, demonstrating its functionality.
- Asynchronous motors are highlighted for being simple to make, robust, cheap, and easy to use, requiring only a connection to the power grid.

Chapter 18

Introduction to Audio Playback with ESP32

- The video introduces playing back sound clips using an ESP32 microcontroller board.
- It mentions using a microSD card breakout board connected via SPI for fast data transfer, preserving original audio quality with 16 bits resolution and 44.1 kHz sampling rate.
- The video explains that a higher bit resolution gets closer to the original analog signal.
- It also explains that a higher sampling rate gets closer to the real analog signal.

Output Options and I2S Explanation

- The video discusses using the internal DAC of the ESP32 but notes its limitation of 8 bits resolution, which would bottleneck audio quality.
- It introduces the MAX98357 amplifier breakout board, which uses I2S for communication.
- I2S stands for Inter IC Sound and is designed for audio applications, communicating PCM audio data (Pulse Code Modulation).
- PCM is a method to digitally represent sampled analog signals, used by .wav files.

Practical Example with I2S Microphone

- The video uses the INMP441 microphone breakout board to explain I2S, focusing on reading data with the microphone.
- The microphone board features six pins: two for power, three for the I2S interface (Word Select, Serial Clock, and Serial Data), and one for channel selection (left or right).
- The ESP32 has two I2S peripherals with configurable pins; pins 15, 2, and 4 were selected.
- Code was copied from the I2S programming guide to set the resolution to 16 bits and the sampling rate to 44.1 kHz, initializing I2S communication.

Oscilloscope Analysis and Clock Frequency

- The video analyzes the three I2S pins on an oscilloscope, showing the word select line alternating between high and low for stereo audio (left and right channels).
- The serial clock, generated by the ESP32, samples data from the serial data line at its rising edge.
- The clock signal frequency depends on the sampling rate, bit resolution, and whether mono or stereo is used.

- For the microphone example, 44.1 kHz sampling rate, 16-bit resolution, and stereo result in a measured frequency of 1.411 MHz.

Integrating Amplifier and MicroSD Card with ESP32

- Wires were soldered to the I2S amplifier and microSD card boards and connected to the ESP32.
- The ESP8266 audio library and code bits from SparkFun were used to simplify the coding process, which involves both I2S and SPI.
- After uploading the code, connecting a speaker, and inserting the microSD card, audio playback is demonstrated.

Conclusion on I2S

- The video concludes that I2S is an easy-to-implement and handy communication interface for receiving and sending digital audio.
- It recommends Bitluni's video for a more advanced topic on creating a sound driver for the ULP of the ESP32.

Chapter 19

Identifying and Addressing Motor Misalignment

- The creator noticed that the hub motors of their electric longboard did not start spinning at the same time, even with identical PPM signals to the electronic speed controllers.
- This misalignment occurred during small throttle inputs.
- The creator decided to use the CAN bus of the FSECs to fix this issue, despite not feeling a significant power difference during previous test rides.

Introduction to CAN Bus and its Applications

- The video introduces the CAN bus (Controller Area Network) and its location on the original VESC, next to the mini USB port, with four pins labeled as 5 volts, ground, CANH, and CANL.
- CAN bus is a serial bus system that allows microcontrollers and devices to communicate without a host computer, primarily used in cars.
- The creator was inspired by upgrading their car's music system to understand how various components communicate via the CAN bus.
- The CAN bus requires only two wires (CANH and CANL) to connect electronic control units (nodes) in a car, saving copper and reducing implementation costs.

Activating CAN Functionality and Voltage Inspection

- The creator activated the CAN functionality of the FSECs by altering the CAN status message mode in the VESC software and setting the multiple VESCs over CAN option to true.
- After this setup, both wheels turned perfectly fine without any noticeable RPM difference, even after removing the RC input wire from one of the FSECs.
- Inspection of the CANH and CANL voltages on the oscilloscope revealed that the CANH line swings up to a high voltage, while the CANL line swings down to a low voltage.
- The common bus voltage is around 2.3 volts, with a high level of 2.9 volts and a low level of around 1 volt, which is deemed sufficient.

CAN Bus Communication and Priority System

- When both CAN lines are actively driven, the data represents a zero (dominant), and when idle, the voltage returns to the common voltage, representing a one (recessive).
- The CAN bus features an ID-based priority system to prevent collision errors between devices.
- If two devices send a frame simultaneously, the device with the lower ID (higher priority) overrides the other, ensuring only one transmits at a time.

Advantages and Technical Details of CAN Bus

- The CAN bus includes a CAN ID, data, 16 bits for cyclic redundancy check, and two bits for acknowledge, allowing for error checking during data transmission.

- The twisted pair data wires and differential voltage make the system robust.
- The CAN bus is half-duplex (devices can send or receive data but not simultaneously) and asynchronous (no clock line, devices synchronize based on baud rate and voltage changes).
- There is no standardized connector, and termination resistors are required, with location and value varying based on the type of CAN bus.
- Different CAN bus speeds exist: high speed CAN (up to 1 megabit per second), low speed CAN (125 kilobit per second), and CAN FD (5 megabit per second).

Longboard Reassembly and Traction Control

- The creator reassembled their electric longboard, now with wheels that react identically and feature traction control.
- Traction control matches the power consumption and RPM of the wheels, improving traction in curves or muddy terrain.
- The creator mentions the existence of CAN controller/transceiver boards for reading/writing to a CAN bus, allowing for added functionality to existing systems, but this is a topic for another video.

Chapter 20

Introduction to Mechanical Seven Segment Displays

- The video introduces mechanical seven segment displays received by the creator, which use moving white plastic segments instead of LEDs.
- The creator explains that each segment is connected to a magnet, controlled by electromagnets that reverse polarity when hooked up to 12V DC.
- The display retains its state without continuous power, as the electromagnets maintain polarity even without current.

Reverse Engineering the Control Circuit

- The creator received a module with ten displays from AlfaZeta, along with a control circuit.
- The video details the process of examining the control circuits by removing them from the display PCB.
- The creator identified the Atmega32A microcontroller as the central component, controlling electromagnets via high voltage source driver ICs and Darlington transistor array ICs.
- The creator theorizes that the circuit uses multiplexing to control the displays, powering one display at a time.

Communication via RS485

- The video discusses how to communicate with the microcontroller to display specific numbers using RS485.
- RS485 is described as an industry standard for asynchronous serial data transfer, differing from synchronous communication methods like SPI and I2C.
- The creator notes that RS485 only defines electrical properties, requiring a specific communication protocol and hardware pinout from the manufacturer.
- The system uses a twisted pair of wires for non-inverted and inverted data signals to minimize interference.

Interfacing with Arduino and MAX485

- The creator uses an Arduino Nano with its UART interface to control the display.
- A MAX485 breakout board is used to convert the Arduino's serial data into RS485 standardized serial data.
- The setup involves creating a twisted wire pair and connecting it to the control PCB and MAX485 board.
- The creator confirms that the code works, displaying data on the seven-segment displays.

YouTube Subscriber Counter with ESP8266

- The creator uses the mechanical displays as a subscriber counter for his YouTube channel.
- An ESP8266 is connected to the MAX485 breakout board.

- The Arduino YouTube API library is merged with the seven segment control board codes.
- The display successfully shows the subscriber number, demonstrating the integration of the hardware and software.

#21 Introduction to Operational Amplifiers

The introduction of operational amplifiers as common electronic components identified by their triangle shape in circuit schematics.

Physical Characteristics and Setup

Detailed explanation of op amp packaging options and demonstration of LM358 dual op amp configuration with proper voltage connections.

Basic Operating Principles

Discussion of the fundamental rule of op amps and demonstration of voltage amplification using specific resistor values to achieve a 6.1 gain factor.

Practical Applications and Limitations

Exploration of real-world applications including sensor amplification and microphone signal processing, highlighting the limitations with AC signal amplification.

Real-World Considerations

Analysis of non-ideal op amp characteristics including input/output impedance limitations and practical voltage constraints.

#22 Introduction to BJTs in Op-amps

Here introduced BJTs as fundamental components found within operational amplifiers, alongside other basic electronic components like resistors, capacitors, and diodes.

Types and Applications of BJTs

Here explained the two types of BJTs (NPN and PNP) and their dual functionality as electronic switches and signal amplifiers, particularly in Arduino-controlled circuits and audio applications.

Practical Implementation with BJT

Here demonstrated a practical example using a PC6V7 NPN BJT with a 1-watt high-power LED, explaining the three terminal connections (emitter, collector, and base) and the importance of package configuration verification.

#23 Introduction to MOSFETs vs BJTs

Here introduces MOSFETs as an improvement over BJTs, highlighting their superior efficiency with only 0.6 watts loss and up to 97% circuit efficiency compared to BJTs' higher heat generation.

MOSFET Types and Basic Operation

Discussion of N-channel and P-channel MOSFETs, focusing on the IRLZ44N model and its voltage-based operation principle versus BJT's current-based operation.

Basic Circuit Implementation

Practical demonstration of MOSFET circuit construction with Arduino, emphasizing the importance of 10kΩ pull-down resistors for preventing static electricity issues.

Advanced Challenges and Solutions

Analysis of oscillation problems with larger loads, showing peaks of 64 volts and solutions using gate resistors to control current flow and switching times.

High-Frequency Considerations

Discussion of high-frequency applications, gate losses, and switching efficiency, noting 80 milliwatts of switching losses at 1 MHz frequency.

#24 Introduction to Stepper Motors

It introduces the topic by comparing stepper motors to brush DC motors, questioning their use despite being noisier.

Internal Structure Analysis

Examine a hybrid synchronous stepper motor's internal components, detailing the arrangement of magnets, pole shoes, and teeth structure.

Coil Configuration and Operation

Here demonstrates the motor's operation by connecting different coil combinations to create specific magnetic poles and movement patterns.

Driver Circuit Implementation

Here explains the creation and functionality of a driver circuit using MOSFETs and Arduino control.

Advanced Driving Methods

Discussion on various driving methods including wave, full-step, and half-step driving, explaining their impact on torque and resolution.

#25 Introduction to Servo Motors and Basic Specifications

Here introduces servo motors as a reliable positioning system, explaining their basic structure with three wires (ground, VCC, and control signal) and operating voltage requirements of 4.8-7.2 volts.

PWM Signal Requirements and Internal Mechanics

Detailed explanation of PWM signal specifications: 20ms period (50 Hz), with pulse widths of 1-2ms controlling positions from -90 to +90 degrees.

Internal Components and Feedback System

Here demonstrates the internal gear system that reduces motor speed and explains the potentiometer's role in position feedback.

Control System Operation

Explanation of how the KC5188 IC compares potentiometer feedback with the target position to control motor rotation through an H-bridge circuit.

Arduino Control Implementation

Demonstration of servo control using Arduino with pin 9 and a potentiometer for input, discussing signal timing requirements for full rotation range.

Alternative Control Methods

Presentation of a 555 timer-based control circuit as an alternative to microcontroller-based control.

360-Degree Rotation Modification

Instructions for modifying a standard servo for continuous rotation by removing mechanical stops and adjusting the feedback system.

#26 Introduction to 555 Timer IC

Here introduces the 555 timer IC as one of the most widely used integrated circuits in electrical circuit design, emphasizing its importance in simplifying circuit construction.

Internal Structure and Pin Configuration

Details on the internal architecture of the 555 timer IC, including the three 5 kΩ resistors, comparators, and integrated flip-flop, explaining the function of each of the eight pins.

Monostable Multivibrator Configuration

Here explains the monostable multivibrator configuration, describing how it operates with a temporary high output state and its application in creating delay circuits for notification lights.

Bistable and Astable Configurations

Here discusses the bistable multivibrator's ability to maintain two stable states and the astable multivibrator's function as an oscillator, including the variations in charging and discharging paths.

#27 Introduction to ADC Sampling Rate Requirements

Here introduced ADC functionality through a practical example of sampling a 10Hz sine wave, explaining the limitations of Arduino's default 9kHz sampling rate and the importance of the Nyquist-Shannon theorem.

Successive Approximation ADC Operation

Detailed explanation of how successive approximation ADCs work, using the ADS 7816 as an example, demonstrating the process with a 4-bit resolution system and 3V input voltage.

ADC Resolution Specifications

Discussion of different ADC resolutions, comparing 4-bit (312.5mV steps), Arduino's 10-bit (4.88mV steps), and ADS 7816's 12-bit (1.22mV steps) capabilities.

Practical Implementation of ADC

Instructions for implementing a 12-bit ADC IC with Arduino, including datasheet consultation and connection setup.

Flash ADC for DIY Projects

Introduction to flash ADC as a DIY-friendly alternative, explaining its simple design using four comparators and five resistors.