Video 1: **The Multimeter**

1. **Introduction to Electric Variables & Multimeter:**
   Understood the resistance, voltage, current & and their relationship which is denoted by Ohm's Law. Multimeter is an electrical component which is used to measure electric parameters.
2. **Measuring Resistance with Multimeter:**
   There are two probes, one is black which is connected to common socket and other is red which is connected to voltage or current socket. There is a continuity feature in multimeter which indicates zero resistance and beeps if there are any cable breaks.
3. **Measuring Voltage and Current:**
   Measured Voltage in parallel, red probe was connected to positive side and black one to the negative. Measured current in series, the red probe was connected to 10-amp socket because it always start with the high current socket because the other socket can only endure up to 500 Milliamps.
4. **Multimeter issue:**
   If the multimeter isn't working, then replace its fuse to work properly.

Video 2: **Dimming All Kind of LEDs**

1. **Controlling of LEDs Brightness:**
   LED brightness can be controlled by with or without the help of an Arduino microcontroller, which is called PWM (Pulse With Modulation).
2. **Techniques of Dimming:**
   lowering the voltage underneath the forward voltage level less current will be consumed and the LED gets darker, but usually fixed voltage sources are used. Another easiest solution would be

using potentiometer in series but there would generate some problems like wasting energy and being expensive.

3. **Methods Of PWM:**
   Switches very fast between high and low voltage (e.g. 5V & 0V). There is a duty cycle, if it is 100% means LED is fully bright, when it is lowered the LED gets darker, e.g. 50% duty cycle means 2.5V perceived. Then we can get the signals in 2 ways, one is with the help of Arduino microcontroller: duty cycle 0% leads to a value of 0(0V) and duty cycle 100% leads to a value of 255(5V), the other one with a 555 Timer Chip: described as an ‘easy to wire’ ic, duty cycle is controlled by a potentiometer. Uses a MOSFET which acts as a switch that can handle larger currents and voltages than the signal-generating device itself.
4. **Benefits of PWM:**
   Works with fixed voltage sources, avoids energy waste and cost associated with potentiometers for high power, Scalable for Higher Power Loads using a MOSFET.

Video 3: **Programming an ATtiny + Homemade Arduino Shield:**

1. **Introduction of ATtiny 85 microcontroller:**
   The ATtiny 85 is a cost-effective alternative to the ATmega 328 for simple projects. The main summary is the utilization of the ATtiny85 as a more affordable and appropriately sized microcontroller for projects with limited I/O needs.
2. **Programming Method:** To program the ATtiny85, an Arduino Uno must first be transformed into an “Arduino ISP” programmer. This includes downloading the board data files for the ATtiny and uploading the “Arduino ISP” sketch to the Uno.
3. **Pinout and I/O capabilities:** The document outlines the I/O pins, memory, and available functionalities (analog input, PWM), while also addressing limitations, particularly the lack of built-in SPI hardware.

4. **Programming Shield:** The custom shield's advantage is improvement over direct wiring. The shield constructs a programmer platform using male headers, an IC socket, and bridge wire, it is also added with female header pins so that it can eliminate wiring effort when programming.
5. **Limitations:** There is a lack of hardware SPI support for WS2801 which can be overcome by using a 'bit-banged' emulated version of the protocol, another disadvantage of the ATtiny is that one cannot use all the functions of an Arduino.

Video 4: **Arduino + Bluetooth + Android = Awesome**

1. **Components:** Used an Arduino Nano and a common Bluetooth module named HC-05.
2. **Voltage incompatibility and Solution:** There was a voltage level difference between the Arduino (5V logic) and the Bluetooth module (3.3V logic). For the solution, a voltage divider circuit is required.
3. **Wiring and Connection**: Detailed with the wiring process, specifically connected the connection of the Bluetooth module's transmit (TX) and receive (RX) pins to the Arduino and used the resistors for LED connections. There was also a connection of a module's RX pin to the middle of the voltage divider.
4. **Use of Android App**: Used a "S2 terminal" android app for communication with the Bluetooth module.
5. **Code and Customization**: Provided with a framework for the Arduino code, allowing users to easily customize "code word[s]" (like "red," "green," "blue") and the corresponding actions and response text.

6. **Caution**: Always cut the TX and RX connections to the module when one uploads the code and it interferes with one another and it will not work.

Video 5: **How to Multiplex**

1. **Concept:** Controlling many LEDs individually requires a significant number of I/O pins, often exceeding the capacity of typical microcontrollers like the Arduino Nano.
2. **Matrix Wiring for Multiplexing**: The trick is to wire LEDs in a matrix format. This is done by connecting all the cathodes (negative pins) of LEDs in a column together and all the anodes (positive pins) of LEDs in a row together.
3. **Limitation with Matrix Wiring:** While matrix wiring reduces connections, simply applying voltage directly to rows and ground to columns to light multiple LEDs simultaneously leads to unwanted LEDs illuminating due to the shared connections.
4. **Solution:** lighting up each row (or column) individually, one after the other, in rapid succession.
5. **Power Considerations:** Driving an entire row of LEDs simultaneously can draw significant current (up to 200 milliamps with 10 LEDs in a row).
6. **P-Channel MOSFETs as Switches for Rows:** P-channel MOSFETs are used as switches to control the power supplied to each row. The microcontroller's I/O pins control the gate of the MOSFETs, effectively turning the rows on or off.
7. **TLC5940 LED Driver IC for Columns:** TLC5940 is used to control the current flowing through the columns. This IC simplifies controlling multiple LEDs and can handle the necessary current.

8. **Visual Demonstration of Multiplexing:** Increasing the "on time" of a row makes the multiplexing visible as individual rows lighting up sequentially rather than a single complete picture.

Video 6: **Standalone Arduino Circuit**

1. **Embedding the ATmega328p:** breaking the ATmega328p Microcontroller free from its Arduino prison and embedding it into a circuit. This allows for projects where the physical size or form factor of a standard Arduino board is prohibitive.
2. **Constructing Circuit:** Outlining the necessary external components and connections to get the ATmega328p running without a full Arduino board.
3. **Generating External Clock:** provided an external clock signal, typically provided by a 16 MHz crystal and two 22 pF capacitors. An alternative is to use the internal 8 MHz oscillator, but this requires uploading a different bootloader.
4. **Connection and Mapping:** Connected specific pins (7, 20, 21) to 5 volts, while others (8, 22) are connected to ground. A crucial point is that the digital and analog pin numbers used in Arduino sketches do not directly correspond to the physical pins on the ATmega328p.
5. **Reprogramming:** Once it's in a standalone circuit, there are several ways to upload new code (sketches) to the ATmega328p.

Video 7: **7 Segment Display**

1. **Concept:** 7-segment displays are a little bit older technology, particularly suited for projects displaying limited numerical or alphabetical output.

2. **Configuration:** The display consists of eight individual LEDs, seven forty bars and one for the decimal point. There are datasheets for pinout information and common anode and common cathode configurations.
3. **Functioning Display Without a Microcontroller:** Controlling 7-segment displays using discrete logic ICs—specifically the BCD to seven-segment display driver (SN74LS247) and the 4-bit binary counter (SN74HC290), enables simple counting or number display without relying on an Arduino.
4. **Functioning Display with an Arduino Microcontroller:** The use of 7-segment displays with an Arduino, especially for multi-digit setups, introduces multiplexing as a method to minimize the number of required Arduino pins.
5. **Using a Dedicated IC for Multi-Digit Displays:** A specialized IC like the SAA1064 is recommended for controlling multi-digit displays with an Arduino, as it manages multiplexing and communicates via the I^2C protocol, greatly reducing both the number of required Arduino pins and the processing power needed for display control.
6. **Extra Components (Resistors, Capacitors, Transistors):** The schematics require specific components such as 220-ohm resistors for current limiting, a 2.2-nanofarad capacitor to set multiplexing speed, and BC337 NPN transistors for handling multiplexing.

Video 8: **Everything about LEDs and current limiting resistors:**

1. **LED Parameters and the Need for Current Limiting**: LEDs have two crucial parameters: Forward Voltage (the voltage required across the LED for it to light up) and the Ideal Current (the amount of current needed for optimal brightness and

longevity). A typical LED might have a forward voltage of around 3.2 volts (though 3 volts is suggested as a more precise general value) and an ideal current of 20 milliamps. The resistor is necessary to limit the current flowing through the LED, ensuring it operates within its specified current range.

2. **Calculating the Resistor Value using Kirchhoff's and Ohm's Laws:** Kirchhoff's Voltage Law is fundamental to determining the voltage drop across the resistor. In a simple series circuit with a power source, resistor, and LED, the sum of the voltage drops across the resistor and the LED must equal the power source voltage. Ohm's Law (Resistance = Voltage / Current) is used to calculate the required resistor value.
3. **Resistor Power Rating:** Resistors have a power rating; this indicates the maximum amount of power the resistor can safely dissipate as heat. The power dissipated by the resistor is calculated using the formula: Power = Voltage x Current.
4. **Driving Multiple LEDs Efficiently:** Connecting LEDs in series is generally more efficient for driving multiple LEDs from a single power source, provided the total forward voltage of the series LEDs does not exceed the power source voltage. When connecting LEDs in series, the total forward voltage is the sum of the individual LED forward voltages. The current flowing through all LEDs in the series is the same.
5. **Advanced Considerations:** The actual forward voltage and current draw of individual LEDs can vary, even within the same batch. The current consumption of an LED is exponential with respect to voltage. A small change in voltage can lead to a significant change in current, potentially damaging the LED. Even if the power source voltage is equal to the LED's forward voltage, using a small resistor is recommended to linearize the current

consumption. This makes the LED less susceptible to voltage fluctuations. Using a single resistor to drive multiple LEDs in parallel is problematic because the forward voltage of individual LEDs can vary. The most effective way to drive LEDs is in a constant current mode rather than a constant voltage mode. Dedicated constant current sources (e.g., using an LM317 or TLZ 5940) are superior for precise LED control, although they can have efficiency drawbacks.

Video 9: **Diodes & Bridge Rectifiers**

1. **Diodes:** Diodes are widely used across electronic devices, from older linear power supplies to modern switching power supplies and a range of consumer electronics. The fundamental principle of a diode is that it allows current to flow in only one direction
2. **Preventing Reverse Polarity**: Diodes can be used to protect circuits from damage caused by incorrectly connecting the power supply with reversed polarity. By placing a diode in series, if the polarity is reversed, no current will flow, safeguarding the circuit.
3. **Voltage Drop Across a Diode**: Diodes exhibit a voltage drop when conducting current, which depends on the current draw and reduces the effective voltage delivered to the rest of the circuit, indicating they are not perfect switches.
4. **RMS vs. Peak Voltage in AC:** AC voltage from a transformer is typically specified as RMS (Root Mean Square) voltage, which relates to the maximum or peak voltage by the formula: RMS voltage = Max Voltage / $\sqrt{2}$ for sine waves.
5. **Smoothing DC with a Capacitor:** Adding a capacitor after a single-diode rectifier helps to smooth out the bumpy DC by storing charge during the peaks of the waveform and discharging during

the gaps. However, the output can still become bumpy when current is drawn.

6. **Bridge Rectifier for Full-Wave Rectification:** A bridge rectifier, consisting of four diodes, provides a more effective way to convert AC to DC. By using a specific arrangement of diodes, the negative half of the AC waveform is "flipped" and added to the positive half, resulting in a more continuous, albeit still bumpy, DC output.

Video 10: **Digital to Analog Converter (DAC)**

1. **The Need for DACs**: Digital devices operate on discrete digital logic levels (high/low, 0/1). To produce analog signals like sound waves, which are continuous in nature, a conversion process is required. DACs bridge this gap.
2. **Resolution of DACs:** The "bit" value of a DAC determines its resolution, or the number of distinct voltage levels it can produce. A higher bit count allows for a greater range of possible output voltages and thus a more precise representation of the analog signal.
3. **Building DAC & Generating Analog Waveforms**: A basic resistor ladder DAC is constructed using resistors to show how varying digital inputs produce corresponding analog output voltages. With a DAC, it is possible to generate various analog waveforms like ramp, triangle, and sine waves by systematically changing the digital input value.
4. **Output Buffering:** Connecting a load, such as a speaker, directly to a simple DAC can cause the output voltage to collapse or change form. An operational amplifier (op-amp) configured as a voltage follower is essential to keep the output voltage stable when a load is connected.

5. **Arduino's analogWrite () Function:** The analogWrite() function in Arduino generates a Pulse-Width Modulation (PWM) signal rather than a true analog output. Although it can be filtered to approximate an analog signal, it differs fundamentally from the output of a dedicated DAC.
6. **External DAC Modules:** Pre-built external DAC modules, often communicating via protocols like I2C, provide a convenient way to add high-quality analog output capabilities to microcontrollers like Arduino.

Video 11: **Sending SMS with Arduino || TC 35 GSM Module**

1. **Module Origin and Quality & Affordability:** The TC35 module originates from a reputable manufacturer, likely Siemens, known for reliable and functional products, while the surrounding board appears to be of Chinese origin, suggested by features like "beautiful solar joints" and the presence of a CDC Jack. The TC35 GSM module board is described as relatively inexpensive, with one unit acquired for $23 and an even lower-priced option available at $18.
2. **Sim Card Preparation:** A prepaid SIM card should first be inserted into a smartphone to remove the SIM lock before placing it into the module's holder.
3. **Powering the Board:** The board can be powered via the DC jack or VCC and ground pins. The presenter strongly recommends 5V due to the MAX232 IC, which is directly connected to VCC/ground and has a maximum endurance of 6V. Using 12V is possible but requires removing the MAX232. Using 5V also saves power.

4. **Network Login Process:** The module requires a button press to initiate the network login. This can be automated by connecting the "right side" of the switch (which connects to ground to start the login) to an Arduino pin (specifically pin 10 in the example). Pulling this pin low initiates the login.
5. **Communication Protocol (AT Commands)**: The module communicates using "simple AT commands." These commands are listed in “at command reference." A basic test typing "a" and receiving "okay" confirms communication is working. Other basic information like network operator and signal strength can also be retrieved.
6. **Arduino Wiring and Compatibility:** The wiring between the Arduino and the TC35 board is "super easy." Although the TC35 uses 3.3V logic levels, it is "compatible with the 5vt signals of the ftdi and Arduino." The TX and RX pins on the board are described as having "messed up the labeling," requiring a reverse connection (TX to rxd0 and RX to txd0).
7. **Sending SMS Program Logic**: The provided Arduino sketch demonstrates the process of sending an SMS. This involves opening the serial monitor, pulling the startup switch low, entering the SMS text, and finishing it with a "DOT at the end." The program then handles the transmission.
8. **Future Applications:** The board is intended for use in building an alarm system that sends SMS notifications.

Video 12: **Coils / Inductors (Part 1)**

1. **Importance of Coils:** Coils are highlighted as fundamental components, commonly found across a wide range of electronic devices and systems, alongside resistors and capacitors.

2. **Magnetic Field Creation:** A fundamental principle is that current flowing through a wire generates a magnetic field around it, with the field's strength directly proportional to the current.
3. **Induction:** Induction occurs when a voltage is generated in a conductor either by its movement through a magnetic field or by changes in the magnetic field’s intensity.
4. **Enhancing Magnetic Fields:** To create a stronger magnetic field, the wire is wound into a coil. Furthermore, adding a ferromagnetic core (like iron) significantly enhances the magnetic field strength, creating an electromagnet.
5. **Coil Behavior in DC Circuits:** In DC circuits with switching voltages, such as square wave signals, coils introduce a delay in the current reaching its final state—unlike resistors, which respond immediately.
6. **Energy Storage in Coils**: Coils can store energy in their magnetic field. The energy stored is calculated as (L * I^2) / 2, where L is inductance and I is current.
7. **Output Voltage:** Coils can also be used at the output of switching power supplies (like step-down converters) as energy storage to keep the output voltage at a constant level.

Video 13: **Coils / Inductors (Part 2) || Reactance**

1. **Inductive Reactance (X_L) as Frequency-Dependent Resistance:** The central concept is that inductors oppose changes in current by building and collapsing a magnetic field. This opposition is termed reactance (X_L) and is distinct from standard resistance (R) because power is stored magnetically rather than dissipated as heat.

2. **Reactive Power and Power Grid Strain:** The build-up and collapse of the magnetic field in inductors lead to power oscillating between the voltage source and the load. This is referred to as reactive power and can strain power grids.
3. **Phase Shift (Voltage-Current Relationship):** In AC circuits with inductors, the voltage and current waveforms are not perfectly aligned as they are with purely resistive loads. This misalignment is called a phase shift.
4. **Cheap Inductance Measurement Tool:** A readily available and inexpensive "transistor tester" is recommended as an alternative to RLC meters for measuring inductance.

Video 14: **Capacitors**

1. **Introduction:** Capacitors are prevalent in almost all consumer electronics circuits, and their failure can be a common cause of device malfunction. The core function of a capacitor is to store electrical energy in an electrostatic field. This is achieved by separating two conductive plates with non-conductive (dielectric) material. A simple capacitor can be constructed with two parallel conductive plates separated by a small distance.
2. **Factors Affecting Capacitance:** More space for electrons leads to a bigger electrostatic field, the force on electrons increases, allowing more electrons to accumulate. Dielectric materials, like distilled water, align with the electrostatic field and increase the force on electrons, creating more space for others.
3. **Polarity (for Electrolytic Capacitors):** Electrolytic capacitors are polarized and must relate to the correct polarity. Reversing polarity can damage them.

4. **Comparison to Inductors:** Capacitors and inductor coils both introduce reactance in AC circuits; however, capacitors are often preferred for filters because they are typically cheaper and more compact than coils.

Video 15: **Temperature Measurement (Part 1) || NTC, PT100, Wheatstone Bridge**

1. **Resistor-based temperature sensors:** Temperature sensors with resistance that change with temperature include NTC thermistors and RTDs such as the PT100.
2. **Measuring Resistance:** Requires supplying a low constant current (around 1 milliamp) to avoid heating the resistor. Voltage across the resistor is measured, and resistance is calculated using Ohm's Law.
3. **Circuits to Improve Measurement:** Voltage divider can create offset voltage to cancel the PT100's offset at 0^0. Wheatstone Bridge measures the voltage between two identical voltage dividers with one changing resistor value. Differential Op-amp subtracts the offset voltage from the changing PT 100 one.
4. **Limitations of resistance-based methods**: The concept of thermal inertia is introduced as a common drawback of the discussed resistance-based sensors.

Video 16: **Resistors**

1. **Functions:** Resistors are primarily used to limit current flow in a circuit. Multiple resistors in series can be used to divide a supply voltage, creating specific voltage levels for different components. Resistors can facilitate the conversion of data signal voltage levels

between different systems (e.g., Arduino 5V to ESP32/ESP8266 3.3V).

2. **Types:** Potentiometers are variable resistors, allow for on-the-fly adjustment of output voltage or as input for microcontrollers. Pull-up/Pull-down Resistors are used to define a clear initial state (high or low logic level) for input pins, preventing "floating" inputs and ensuring stable readings.
3. **Ohm's Law and Current Limiting:** A fundamental application is using Ohm's Law (V=IR) to calculate the appropriate resistor value for limiting current to a desired level (e.g., protecting an LED from "immediate DEP").
4. **Current Sense Resistor Principle:** The current sense resistor principle involves using very small-value resistors to measure current flow. By amplifying the voltage drop across these resistors with a differential circuit and knowing the resistance value, the current can be accurately calculated. This is a key method for current measurement and control.
5. **Parasitic Effects in AC Circuits:** At higher frequencies, the parasitic inductance and capacitance inherent in a resistor's structure become significant. As capacitive reactance decreases, current flow increases, illustrating the non-ideal behavior of real-world components.

Video 17: **Oscillators || RC, LC, Crystal**

1. **Function of Oscillators:** An oscillator's core purpose is to generate periodic alternating voltage signals—such as square, triangle, or sine waves—that function as clock signals for devices or as carrier waves for radio communication and other wireless data exchange. These signals are essential for timing in electronic

systems, including microcontroller processing speeds and multimeter refresh rates.

2. **Relaxation Oscillators (RC Circuits):** This type of oscillator utilizes the charging and discharging of capacitors through resistors to generate periodic signals. Astable Multivibrator uses "two capacitors C1 and C2 which get charged alternating through a resistor to a certain threshold voltage of the transistor." When a capacitor reaches a threshold, it triggers a transistor to become conductive, discharging that capacitor while the other charges. This alternating charge/discharge cycle creates a "rectangle waveform." 555 Timer IC implements the core idea of charging and discharging a capacitor periodically to create a "stable and variable rectangle wave."
3. **LC Resonators (LC Tank Circuits**): These circuits, comprising an inductor (L) and a capacitor (C), are used to generate "very high frequencies" and typically produce a sine wave. Oscillation occurs due to the exchange of energy between the capacitor and the inductor. The capacitor stores electrostatic energy when charged, which is then discharged through the inductor, building up stored magnetic energy.
4. **Crystal Oscillators:** These oscillators offer even greater stability compared to RC and LC types. functions "just like an LC resonator but also uses the mechanical vibrations of a piezoelectric crystal." The piezoelectric crystal vibrates at a very precise frequency when an electric field is applied, and these mechanical vibrations in turn generate an electrical signal.

Video 18: **DC & Brushless DC Motor + ESC**

1. **Operation**: DC motors utilize direct current to generate rotational movement. They consist of a stationary component called the stator (containing permanent magnets with opposing polarity) and a rotating component called the rotor (containing coils). Commutator and carbon brushes are crucial mechanical components in DC motors. Applying voltage to the coils through the brushes and commutator creates an opposing magnetic field. The interaction between the magnetic fields of the stator magnets and the rotor coils generates a force that pushes and attracts the rotor, causing it to rotate.
2. **Brushless DC (BLDC) Motor Operation:** The ESC is the electronic component responsible for controlling the speed of BLDC motors. It acts as the electrical equivalent of the mechanical commutator in DC motors. ESCs energize the stator coil pairs in a controlled sequence. By adjusting the frequency of this energizing sequence (which is controlled by an input voltage or signal), the ESC determines the speed of the rotating magnetic field and thus the motor's RPM (Revolutions Per Minute).A higher frequency of energizing steps results in a higher RPM.ESCs utilize arrays of P-channel and N-channel MOSFETs to achieve the required high, low, and floating output states for controlling the coil energizing. The number of parallel MOSFETs in an ESC directly influences its current handling capability, and thus the potential power of the motor it can drive.
3. **Electronic Speed Controller (ESC):**The ESC is the electronic component responsible for controlling the speed of BLDC motors. It acts as the electrical equivalent of the mechanical commutator in DC motors. ESCs energize the stator coil pairs in a controlled sequence. By adjusting the frequency of this energizing sequence (which is controlled by an input voltage or signal), the ESC

determines the speed of the rotating magnetic field and thus the motor's RPM (Revolutions Per Minute).A higher frequency of energizing steps results in a higher RPM.ESCs utilize arrays of P-channel and N-channel MOSFETs to achieve the required high, low, and floating output states for controlling the coil energizing. The number of parallel MOSFETs in an ESC directly influences its current handling capability, and thus the potential power of the motor it can drive.

4. **KV Rating:** The KV rating of a BLDC motor represents the theoretical RPM per volt applied. A higher KV rating indicates that the motor will achieve a higher RPM for a given voltage. While voltage is a factor, the ultimate RPM is also limited by the maximum frequency the ESC can achieve, which in turn depends on the characteristics of the motor and the applied voltage. Calculating RPM based on the KV rating and applied voltage provides values that are generally close to reality.

Video 19: **I2C and how to use it**

1. **Introduction:** I^2C utilizes only two wires for communication: SDA (Serial Data) and SCL (Serial Clock). These connect to specific pins on the master device. I^2C operates with at least one master device that initiates and controls the communication, and one or more slave devices that respond to the master's commands. Each slave device on the I^2C bus has a unique 7-bit address, which the master uses to identify and communicate with a specific slave. This address is typically found in the slave device's data sheet.
2. **Communication Sequence (Reading Data):** A typical I^2C read sequence follows a similar pattern but with the R/W bit set to 1 and the acknowledge generated by the master after receiving data.

3. **Data Representation:** While binary representation is the fundamental level, hexadecimal is more commonly used for representing data bytes sent over I²C.
4. **Practical Application**: An example is provided to demonstrate how to calculate the required data bytes—specifically the PLL value—to tune a TDA5767 FM radio IC to a desired frequency. Using the formula from the datasheet, the calculation is illustrated for tuning to 95.6 MHz.

Video 20: **Thyristor, Triac || Phase Angle Control**

1. **Structure & Functionality:** A thyristor has four layers and includes an additional gate terminal. A triac is essentially two thyristors connected in an inverse parallel configuration within a single component. This allows for the control of both the positive and negative half-waves of the AC signal.
2. **Phase Angle Control Circuit:** The core application demonstrated is a phase angle control circuit, enabling control of power consumption in AC appliances by allowing only a portion of each half-wave to pass through the triac. The circuit works by introducing a controllable delay between the AC signal's zero crossing and the activation of the triac. By varying this delay, the point at which the triac begins to conduct within each half-wave is controlled, thus regulating the amount of power delivered to the load.
3. **Applications and Disadvantages of Phase Angle Control:** Controls the temperature by regulating the power supplied and adjusts the speed. A significant drawback of phase angle control is the constantly decreasing power factor due to the non-sinusoidal

current waveform created by switching the triac on and off within the AC cycle. This is highlighted as a topic for future discussion.

4. **Safety Precautions:** Safety is strongly emphasized when working with AC voltages, with a recommendation to avoid direct interaction with high-voltage mains power without proper precautions. An autotransformer is suggested for safely stepping down mains voltage during experimentation.

Video 21: **OpAmp (Operational Amplifier)**

1. **Fundamental:** Op amps are depicted as ubiquitous components in electronic circuits, often appearing as triangle-shaped symbols in simplified schematics. They are available as integrated circuits (ICs) in various packages, commonly with multiple op amps per chip.
2. **Basic Structure:** The core pins of an op amp: the positive input (non-inverting), the negative input (inverting), the output, and power supply pins (V+ and ground).
3. **Golden Rules:** The output attempts to keep the voltage difference between the inputs at zero volts. The input draws no current. This implies infinite input impedance in an ideal op amp. When no feedback is connected, the output will go to either the maximum or minimum output voltage depending on the differential voltage between the inputs. This configuration functions as a comparator.
4. **Non-Ideal Op Amp Characteristics:** The source acknowledges that real-world op amps are not perfect and have limitations. Key non-ideal characteristics mentioned include: Limited output voltage swing (bounded by supply voltage), Non-infinite input impedance (meaning some input current flows), Non-zero output

impedance (limiting the amount of current that can be drawn), Limited output current.

5. **Versatility:** Beyond the specific examples, the source lists numerous other circuits that can be built using op amps, emphasizing their wide range of applications.

Video 22: **Transistor (BJT) as a Switch**

1. **Structure and Terminals:** BJTs have three terminals: emitter, collector, and base. The specific function of each terminal in a switching circuit is demonstrated. It is crucial to always check the datasheet for pin configuration as it varies between packages.
2. **Base Current Controls Collector Current:** The core principle of using a BJT as a switch is that a small current flowing into the base (base current) controls a larger current flowing between the collector and emitter (collector current). This relationship is defined by the current gain (beta or β), a characteristic found in the BJT's datasheet.
3. **Calculating the Base Resistor:** To ensure the transistor operates reliably as a switch (specifically in the saturated state), the necessary base current needs to be calculated based on the required collector current and the BJT's current gain (using the worst-case value of beta for conservative design). The base resistor value is then determined using Ohm's law, considering the control voltage and the base-emitter forward voltage.
4. **Disadvantages of BJTs as High-Current Switches:** The biggest disadvantage of BJT’s High current switches is the power loss and thus the lower efficiency of the circuits." Power loss occurs due to both the base current and the voltage drop across the collector-

emitter path. This can lead to significant heat generation, requiring thermal management for higher current applications.

5. **Darlington Transistors for Higher Current Gain**: For switching larger loads or when control signals have limited current capability (like those from a microcontroller), Darlington transistors are beneficial. They consist of two cascaded BJTs, resulting in a much higher overall current gain. This allows a smaller base current to control a significantly larger load current. While providing high current gain, Darlington transistors typically have a bigger collector-emitter and base-emitter voltage drop compared to single BJTs. This can lead to more power loss in certain applications.

Video 23: **Transistor (MOSFET) as a Switch**

1. **Efficiency:** The MOSFET only has an energy loss of 0.6 watts across as equivalent collector emitter path and thus increases the overall efficiency of the circuits up to 97%. This means the significant efficiency advantage of MOSFETs over BJTs for switching higher power loads.
2. **Voltage Control:** Unlike BJTs, which rely on base current to switch loads, MOSFETs require only sufficiently high voltage at the gate with virtually no current. This fundamental difference is key to understanding how the two types of transistors operate.
3. **Linear Region Operation:** When used as a switch, MOSFETs operate in the "linear region in which the resistance of the drain to source path is almost constant," leading to low voltage drop and power dissipation.
4. **Voltage Oscillations with Inductive Loads:** Switching inductive loads can cause a damped oscillation that reaches peaks around 64

volts when the MOSFET switches off. This is a critical issue to address for MOSFET longevity.

5. **Switching Losses at High Frequencies:** Switching Losses at High Frequencies: "With a frequency of 1MHz we have switching losses of 80mW." While gate losses are negligible at low frequencies, they become significant at higher frequencies.

Video 24: **Stepper Motors and how to use them:**

1. **Introduction:** Stepper motors are preferred for positioning applications like 3D printers due to their ability to precisely control rotational movement in discrete steps and their inherent holding torque.
2. **Structure:** Contains four permanent magnets with alternating polarity (North and South). Each pole shoe has 50 teeth, with an offset between the teeth of different pole shoes. This creates alternating North/South magnetized teeth when viewed from the front. Also possess teeth that are not initially magnetized. It contains eight physically separated coils, wired as two pairs of coils.
3. **Mechanism**: Powering specific coil pairs generates magnetic poles in the stator teeth, attracting the rotor's permanent magnet teeth. Sequentially activating the coil pairs in a defined each step shifts the magnetic field by 45 degrees, causing the rotor to move one tooth position. Four-step order causes the rotor to move in precise increments.
4. **Step Angle and Steps Per Rotation:** The motor described has 50 teeth and requires four steps to move one tooth to the location of the next. This results in 200 steps per rotation (50 teeth * 4 steps). The step angle is calculated as 360° / 200 steps = 1.8°. Stepper

motors require drivers to easily control their current direction through the coils. An H-bridge circuit allows current flow in either direction. The source builds a basic driver using MOSFETs and an Arduino. A significant advantage of stepper motors is their ability to maintain their position when current flows through the coils, even without rotation.

5. **Microstepping Drivers (ICs):** Implementing microstepping effectively requires a constant current driver that can vary the current strength. Specialized Integrated Circuits (ICs) like the A4988 are designed for this purpose and are basically more advanced H-bridges.

Video 25: **Servos and how to use them**

1. **Characteristics:** Common servos have a sawtooth shaft, three wires (Brown: Ground, Red: VCC (4.8-7.2V), Orange: Control Signal), and are typically controlled by a PWM signal.
2. **Position Mapping to PWM:** A 1ms on time corresponds to -90°, 1.5ms to 0°, and 2ms to +90°, allowing for a 180° rotation range.
3. **Internal Components**: Servos contain reduction gears (decreasing RPM and increasing torque), a DC motor, a potentiometer for position feedback, and a control IC (like the KC 5188) with an H-bridge to drive the motor.
4. **Control Mechanism:** The control IC compares the potentiometer's voltage (current position) to the target position indicated by the PWM signal and adjusts the motor's rotation until the difference is zero. An Arduino with the servo library can easily generate the required PWM signal, although the full 180° range may require a signal varying between 0.5ms and 2.5ms, which the library supports. A 555 timer IC with external components can also

generate a suitable PWM signal for servo control, even if the periodic time isn't perfectly constant.
5. **Pre-made Continuous Rotation Servos:** Servos with these modifications pre-installed are available, sometimes offering additional control over the simulated 0° position.

Video 26: **555 Timer IC**

1. **Utility:** The 555 timer IC is highlighted as an incredibly popular and useful component in building electrical circuits, making our life easier.
2. **Internal Structure and Pinout**: Three 5 Kiloohm resistors in series, which gives the IC its name and creates a voltage divider, two comparators, an integrated flip-flop, an output driver, a bipolar junction transistor at the discharge pin. Pin 1 is connected to the ground. Pin 2 (Trigger)is directly connected to the negative input of the first comparator. Pin 3 (Output) is connected to an output driver and the flip-flop's output. Pin 4 (Reset) is directly connected to the reset pin of the flip-flop and can be used to instantly reset the flip-flop by connecting it to ground. Pin 5 (Control Voltage) connects to the negative input of the second comparator and the voltage divider. Pin 6 (Threshold) connects to the positive input of the second comparator. This pin monitors the voltage of an external capacitor in timing circuits. Pin 7 (Discharge) directly connected to the collector of a bipolar junction transistor, which is used to discharge an external capacitor. Pin 8 (VCC/Supply Voltage) is connected to the supply voltage.
3. **Basic Circuit Configurations:** Generates a single, temporary output pulse of a defined duration when triggered. The high output state is unstable, while the low state is stable. The pulse duration is

set by external resistor and capacitor values. It is commonly used to create delays for notification lights. Creates two stable output states (high and low) and acts as a simple latch or flip-flop. It does not require RC components and uses the Trigger (Pin 2) as the set pin and Reset (Pin 4) as the reset pin. Applying a ground potential to either pin 2 or pin 4 toggles the output state. Perfect for turning LEDs on and off manually with push buttons.

4. **Advantages of CMOS 555 Timers:** By using diodes and a potentiometer, the charging and discharging currents can be separated and adjusted, allowing for the creation of a beautiful PWM signal with constant frequency.

Video 27: **ADC (Analog to Digital Converter)**

1. **Sampling Rate:** This refers to how frequently the ADC takes a measurement of the analog signal. A higher sampling rate captures more data points and allows for a more accurate representation of a rapidly changing signal. The source uses the example of a 10 kHz sine wave and demonstrates that a low sampling rate results in "complete bullshit" when trying to recreate the function.
2. **Resolution:** This refers to the number of bits the ADC uses to represent the analog voltage. A higher resolution means the ADC can distinguish between smaller voltage differences, resulting in a more precise digital value.
3. **Successive Approximation ADCs (SAR ADCs) Work:** This circuit captures the analog voltage at a specific point in time and holds it steady for the duration of the conversion. This is achieved using a capacitor and a voltage follower. This component compares the sampled analog voltage with a voltage generated by DAC.

4. **Alternative ADC Type: Flash ADCs:** particularly suitable for DIY projects as they do not require a DAC. A Flash ADC "basically consists of four comparators and five resistors" (for a 2-bit version) and uses a resistance network to create different voltage references for each comparator. The input voltage is compared to these references, and the comparator outputs are fed into an encoder with a truth table to produce the digital value. While "ridiculously fast", Flash ADCs "usually have a low resolution" due to the exponential increase in the number of comparators needed for higher resolutions.

Video 28: **IGBT and when to use them**

1. **Comparison of IGBTs and MOSFETs as power switches:** The core focus is to differentiate between BJTs and MOSFETs and identify their appropriate use cases based on their distinct operating principles and characteristics.
2. **Internal Structure of IGBTs:** Understanding how IGBTs are constructed from elements of both MOSFETs and BJTs.
3. **Switching Characteristics:** Analyzing the differences in switching speed and behavior between IGBTs and MOSFETs.
4. **Power Loss Characteristics:** Comparing the power dissipation of IGBTs and MOSFETs under load.
5. **Suitable Applications:** Identifying the conditions under which an IGBT is a better choice than a MOSFET.
6. **Driving IGBTs**: Discussing the methods and requirements for controlling the gate of an IGBT.

Video 29: **Solar Panel & Charge Controller:**

1. **Regenerative Energy Sources:** Solar panels are identified as an easy-to-use, regenerative energy source that converts light into electricity, suitable for powering loads or charging batteries. Solar panels are composed of individual "solar cells." These cells are the fundamental unit that generates voltage when exposed to light.
2. **Voltage Generation and Series Connection**: A single solar cell generates a low voltage (around 0.5 volts). To achieve higher output voltages suitable for practical applications, many solar cells are connected in series within a solar panel. For example, a 100-watt panel discussed connects "36 cells in series to create an open circuit voltage of around 14 point 3 volts."
3. **Challenges of Series Connections**: Partial Shading: A significant drawback of series connections is the impact of partial shading. If even a small portion of the panel is shaded, the affected cells act as a higher resistance, drastically reducing the overall power output.
4. **Bypass Diodes:** Bypass diodes are added in parallel to solar cells (or groups of cells) to address the issue of partial shading. These diodes allow current to flow around a shaded cell.
5. **Power Output Under Varying Loads:** The actual power output of a solar panel varies depending on the connected load.
6. **Maximum Power Point Tracking (MPPT) Controllers:** MPPT controllers are the best ones of this kind. They utilize switching converters to act as the ideal MPP loads and thus a charge of the battery. MPPT controllers constantly track and adjust the load presented to the solar panel to ensure it operates at its MPP, maximizing the energy harvested.
7. **Pulse Width Modulation (PWM) Controllers:** Other, less efficient charge controllers, such as PWM controllers, simply use PWM to charge the battery but they do not try to find the MPP and thus can decrease the efficiency of up to 40%.

Video 30: **Microcontroller (Arduino) Timers**

1. **Precise Timing:** Examples such as alarm clocks, LED matrix animations, and audio generation are highlighted to demonstrate the importance of accurate timing in electronic applications.
2. **Limitations of delay ():** While simple, the delay () function in Arduino sketches is inefficient and can block the main program loop, preventing the microcontroller from responding to other inputs or tasks. It also suffers from potential timing inaccuracies over longer durations.
3. **Timers as Dedicated Peripherals:** Microcontrollers, including the ATmega328P on the Arduino Uno, feature dedicated hardware timers that can handle precise timing independently of the main program execution. These times are set up once and then run continuously in the background.
4. **Timer Modes and Functionality: Timers offer various modes of operation to achieve different timing goals:**
5. **Normal Mode:** The timer counts to a maximum value (overflow) and then resets. Overflow flags and associated interruptions can be used to trigger events.
6. **CTC Mode (Clear Timer on Compare Match):** The timer counts to a specific value defined in a "compare register." When the counter matches this value, a match flag and interruption are triggered. This allows for more precise timing intervals than relying solely on overflows and enables multiple independent timing events.
7. **PWM Modes (Pulse Width Modulation):** Timers can be configured to generate PWM signals, which are essential for controlling motor speed, LED brightness, and generating the duty cycle and frequency of the PWM signal can be adjusted.

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