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1. The Multimeter

Multimeter:

It is used to measure voltage, current and resistance.

- ***The measurement of Resistance***:
  The black probe always connects to the common socket (COM). The red socket connects to the same (VohmHz) socket for voltage and resistance.

  N.B.: Measuring the resistance in a built-in circuit mostly fails because current choose the way of least resistance. Meaning that the measuring current will not only flow through that one resistor. So, it will not give accurate measurement.

  OL sign on the screen – Over Limit (Resistance is beyond limits of the meter to register).

  When the probes touch each other, it beeps. It is a way to check if the cable is broken or not. The feature is called 'Continuity'.

- ***The measurement of Voltage***:
  There are two different signs for the alternating voltage and direct current voltage. (Precaution: Do not touch the inside of any DC power supply because that's where the AC becomes DC.)
  As we measure voltage in parallel, it needs the probes to be connected in parallel. Connect the red probe to the higher voltage point and the black probe to the lower voltage point.

- ***The measurement of Current***: We need to connect the red probe to the 10-amp (the higher one) socket. (N.B.: Always start with the high current socket because the other socket can only endure up to 500 Milliamps. The fuse is going to blow up when it's going to measure higher current.)

2. Dimming all kinds of LEDs

LED = Light Emitting Diode

PWM = Pulse Width Modulation

MOSFET = Metal-Oxide- Semiconductor Field-Effect Transistor

- ***How to control the brightness of LED using PWM***:
  Controlling the brightness of an LED using PWM (Pulse Width Modulation) is a common and effective technique. It works by rapidly turning the LED on and off and adjusting the ratio of "on" time to "off" time (called the duty cycle) to control how bright it appears.

- ***The problem with using potentiometer to control the brightness of the LED:***

  Using a variable resistor (potentiometer) directly connected to the LED, which is simple but inefficient for high-power LEDs due to heat generation and wasted electricity.

  - ***Efficient LED Brightness Control Methods:***
    - Voltage Control:
      1. Adjusting the voltage supplied to an LED changes its brightness.
      2. However, this method is inefficient and can risk damaging the LED if the voltage exceeds safe limits.

    - PWM (Pulse Width Modulation):
      1. PWM controls brightness by rapidly switching the power on and off.
      2. The perceived brightness depends on the duty cycle (percentage of time the signal is ON).
         100% duty cycle: Fully bright
         Lower duty cycle: Dimmer light
      3. This method maintains efficiency and avoids overheating.

    - Arduino Implementation:
      1. An Arduino can generate PWM signals using ‘analogWrite()’
      2. A potentiometer can be used to dynamically adjust brightness via analog input.

- NE555 Timer IC:
  1. The NE555 timer can be configured to generate PWM signals without a microcontroller.
  2. A variable resistor adjusts the duty cycle, allowing manual control over LED brightness.

- MOSFET Usage
  1. For high-power LEDs or LED bars, MOSFETs are used to switch large currents efficiently.
  2. They are ideal for handling the load when using PWM with high-power applications.

❖ Use of PWM: Speed controlling of motors, LED dimming, Power Supply Regulation, Audio and Signal Generation, Microcontroller Applications.

3. Programming an ATtiny+Homemade Arduino Shield

❖ ATtiny85 microcontroller is smaller, more cost efficient and more affordable than an ATmega328. It has 5 I/Os and eight kilobytes of flash memory giving enough space for some animations.
❖ We can just plug that IC in Arduino uno instead of ATmega328 and program it.

➢ *Way to program an ATtiny85 using the Arduino software and an Arduino uno:*

ATtiny85 has a ground (pin 4), a Vcc (pin 8) and 5 IOs or pin (2,3,5,6 & 7 of the IC). IO-2,3,4 can also be used as analog inputs and IO- 0,1 can produce a PWM signal. The pin 1 of the IC is 'Reset'.

The wiring of the Arduino:

- Arduino pin 13 to ATtiny IO 2,
- Arduino pin 12 to ATtiny IO 1,

- Arduino pin 11 to ATtiny IO 0,
- Arduino pin 10 to ATtiny reset pin 1,
- 5 Volts goes to ATtiny pin 8 aka Vcc,
- Ground of the Arduino (GND) to ground of ATtiny85 aka pin4

4. Arduino + Bluetooth + Android

- Arduino Nano – is used due to its compact size and compatibility
- Arduino responds to commands by turning on or off the corresponding LEDs.

5. How to multiplex

- **Arduino Uno:** Used for controlling circuit.
- TLC5940 LED Driver: A 16-channel PWM unit that helps manage the brightness and control multiple LEDs. It allows to control over multiple LEDs.
- P Channel MOSFETs (F95): Used as switches to handle the high current required by the LEDs.
- Resistors: Including pull-up resistors between the gate of each MOSFET and 5 volts, and one 2K resistor to set the constant current of the TLC5940 to 20 milliamps per LED.
- LED Matrix: A grid of LEDs arranges in rows and columns.
- Tlc5940.h library: The Tlc5940.h library from the Arduino Playground simplifies the process of controlling the TLC5940.

➢ *How to multiplex:*

- The number of I/O pins in an Arduino is not sufficient to control a lost of LEDs.
- An LED matrix can be built by connecting all the cathode (negative) pins in columns and the positive (anode) pins in rows.
- A normal LED matrix fails when someone wants to light up A1 and E5 simultaneously, it also lights up A5 and E1.
- To solve this, multiplexing is used. We light up each row one after another so fast that our eyes don't notice.

6. Standalone Arduino Circuit

- *Advantage of Using an External Microcontroller:*
  - Flexibility. (Allows for more compact and customized designs.)
  - Cost-Effectiveness.
  - Portability
- Modularity: The use of libraries and modular components makes the project scalable and easy to replicate.

7. Segment Display

- *Seven segment displays*: It is an electronic component commonly used in digital clocks, calculator, temperature sensor and other devices that display numerical information.

- *Types of Seven-Segment Displays:*

  1. Single-Digit vs Multi-Digit Displays: Single-Digit displays are simpler and easier to control, while multi-digit displays require more complex multiplexing techniques.

  2. Common anode vs Common Cathode: The display can have either a common anode or a common cathode configuration. This affects how the segments are powered and controlled.

- LTS-546AG (single-digit display) has 8 individual LEDs, 7 for the bars and one for the decimal point. These LEDs are connected in a common anode configuration. There is one common plus terminal for all LEDs which are the pins 3 or 8. The bars are labels from A to G and the dot is DP.
- To check individual LEDs, it is needed to use 2.1 volts instead of 5 volts.
- BCD to seven-segment display driver (SN74LS247): It can control all individual cathodes of the display. While using a common cathode display, it needs an active high level. 220 Volts resistor is used to connect bars to the IC to limit the current.
- A 4-bit binary counter (SN74LS29O): 4 inputs can be controlled.

8. LEDs and Current Limiting Resistors

- LEDs must be connected with a resistor to prevent any burn out.

- A particular valued resistor and LEDs in series combination will consume less power than in a parallel combination.

- In the characteristic line of the LED, the current consumption is exponential. This means a small change in power source can destroy all LEDs. So, a small resistor must be used to linearize the current consumption. In this way, the voltage changes do not affect the LEDs that much.

- *To run LEDs in a constant current mode*: It is crucial because LEDs are current-driven devices. Their brightness and lifespan depend heavily on the current flowing through them. LEDs can draw more current as they heat up, leading to further heating and eventual failure. Brightness remains stable even if the supply voltage fluctuates. Operating within safe current limits extends the longevity.

9. Diodes and Bridge Rectifiers

- *Diode*: When high voltage terminal is connected to the anode of the diode and the cathode to the low voltage terminal, the circuit is powered normally. But if the polarity is reversed, no current will flow. A diode is only conductive when positive voltage is applied to the anode and ground to the cathode.

- When a load draws a lot of current, imperfect valued diode will burn.

- If a diode is connected in series with a capacitor, the capacitor becomes a DC power supply. But when a little bit of current is drawn, the supply becomes AC again. The capacitor gets charged with positive voltage supply and then discharged until the next wave comes.

- *Bridge Rectifier:* Four diodes are arranged in such a way that no matter what the polarity is, the output current flows only one way. This way negative sine wave is turned into a positive sine wave.

10. Digital and Analog Converter

- A R-2R Resistor Ladder DAC (Digital-to-Analog Converter) is an effective architecture for converting digital signals into analog voltages.
- In R-2R DAC of 8-bit, 8 bit means the 256 values between 0V and maximum voltage value.
- DACs are used to produce analog audio and video, useful to build the frequency generator or to test audio filters.

11.Sending SMS with Arduino

- After removing the sim-lock, insert the sim in the holder of (TC35) SMS Module.
- To power the board, use the DC jack or the VCC and ground pins on the board. 5 volts AC/DC Adaptor is recommended. Because the max RS-232 IC is necessary to communicate with the module through a RS-232 port, is directly connected to VCC and ground. There is no voltage regulator for it. But the IC can only endure a maximum of 6 volts.

12.Coils/ Inductors-(part 1)

- When current flows through a wire, it creates a magnetic field around it. More current means bigger fields.
- Current probe is used to measure the magnetic fields.
- Human body is a source of voltage with sine wave because the magnetic field of our main wires all around us induce a small voltage on to the body making it a big antena.
- If a conductor moves inside the magnetic fields like AC motor or DC motor when a magnetic field is changing its intensity like it happens with all AC signals, it induces a voltage.
- The magnetic field of a plain wire is quite weak. So,to create an electromagnet, it is winded up to create a bigger length increasing magnetic force and a ferromagnetic material (i.e. iron) as a core to enhance the magnetic field.
- The intensity of the magnetic field depends upon the dimensions, winding and ferromagnetic core of the coil. This property is represented with the value 'Inductance' (which is measured in Henry). Inductance is measured with an RLC meter or through different measurements.

- Flyback diode: A flyback diode is a diode used to supress voltage spikes or kicks that are caused by the sudden reduction of current through an inductive load, such as a motor, relay, solenoid or transformer.

- Step-down converter: A step-down converter , also known as buck converter , is a type of DC-to-DC power converter that steps down voltage from its input (source) to its output (load) while increasing current.

13. Coils/Inductors (part 2)|| Reactance

- Frequency Filters: Frequency filters are electronic circuits designed to pass certain frequency ranges while attenuating(blocking or reducing) others. They are widely used in signal processing, communications, audio systems and control systems.

- Transistor tester: Transistor tester is a device or circuit used to determine the functionality and pinout (Emitter, Base, Collector for BJTs or Gate,Drain, Source for MOSFETs) of transistors. It can help identify:
    1. Whether the transistor is good or faulty.
    2. The type of transistor
    3. The correct pin configuration.

14. Capacitors

- In capacitor, electron flow charges up the plates by creating an electron [excess] on the negative side and thus an electrostatic field is created between the plates which stores electric energy. When the power source is

disconnected, the capacitor cannot hold any charge. They can supply the stored energy from the electrostatic field just like a battery can supply power just way less power.

- Putting the plates closer increases the capacitance.
- Putting dialectric material between the plates changes the capacitance.
- Electrolytic capacitors have a fixed polarity and maximum voltage limit. Connecting them in a reverse polarity or exceeding the voltage limit can ruin the capacitors.
- Capacitors are used to keep voltages at a stable level at the output of the power supply or to decouple an IC in the circuit.
- Capacitors just like the inductive coils create a kind of resistance called capacitive reactance. The capacitance and frequency are in direct proportional to the value of reactance.

15. Temperature Measurement (Part-1)

- An NTC resistor stands for a Negative Temperature Coefficient thermistor, which is a type of temperature-sensitive resistor. Its key characteristic is that its electrical resistance decreases as the temperature increases.

- PT 100 is a Platinum (Pt) Resistance Thermometer with a resistance of 100 Ω at 0°C. Type of sensor: Resistance Temperature Detector (RTD). Resistance increases with higher temperature.
  Resistance vs. Temperature Behavior is nearly linear over a wide range.
- PT100 can be used up to 850°C while the NTCs only go up to 150°C.
- To measure the current properly, we need to supply a low constant current of around 1 milliamp with the help of e.g. an LM-317.

16. Resistors

- Resistors are used in series with an LED to avoid excessive current flow which damages the LED.
- For high power components, normal resistors do not work; Power resistors are instead used in this case.
- Two resistors in series can be used as a voltage divider, though the voltage value will not exceed that of the power source.
- Pull up or pull-down resistors are used to maintain logic levels in Arduino.
- Resistors do not cause any phase shift in current and voltage in AC.

17. Oscillators // RC, LC, Crystal

- An oscillator is an electronic circuit that generates a periodic waveform (sine, square etc) without requiring an external input signal.
- RC oscillators utilize resistors and capacitors to create phase shifts, commonly in configurations like the RC phase shift oscillator.
- LC oscillators use inductors and capacitors to form a resonant circuit that determines the oscillation frequency.

18. DC and Brushless DC Motor + ESC

- In case of brushed DC motor, there are a metal casing, two permanent magnets (stators), rotor and carbon brushes.
- In the rotor, there are coils and commutators.
- On the other hand, BLDC motors have four permanent magnets with alternating polarities in the rotor.

- The coils are in stators which use the metal body as a heat sink to increase longevity.
- Lower RPM of a brushless motor can cause higher torque.

19. 12C and how to use it

- I2C is a two-wire protocol
- It helps a master device like an Arduino nano to talk up to 112 slave devices to either tell them to what to do or receive data from them which they acquired
- TEA5767 is an FM Radio IC

20. Thyristor, Triac || Phase Angle Control

- Thyristor is like controllable diode
- A thyristor has four layers and adds an additional gate terminal. Example: TYN604
- A thyristor usually stays in its conductive state even when the gate voltage disconnects
- Two thyristors in an inverse parallel configuration are called a Triac
- To operate triac properly, we need microcontroller support

21. OpAmp (Operational Amplifier)

- LM358 is a dual Op-Amp IC

- For a microphone amplifier, inverting OpAmp is used
- An Op-Amp (Operational Amplifier) has two input pins: Non-inverting Input (+), Inverting Input (-) and one output pin.

22. Transistor (BJT) as a Switch

- Bipolar Junction Transistor (BJT) comes in two types; NPN PNP type
- These can be used as switches and amplifiers
- A BJT's collector current is the product of its base current and Beta
- PNP transistor is more suitable for switching purposes than NPN transistor
- In case of a bigger load, there is a big energy loss in collector-emitter path

23. Transistor (MOSFET) as a Switch

- In case of switching purpose, MOSFETs are more efficient than BJTs
- There are two types of MOSFETS; N-channel type and P-channel type
- N-channel MOSFETs like IRLZ44N are more common
- IRLZ44N has three pins; Gate, drain and source

24. Stepper Motors and how to use them

- The removable rotor of a stepper motor has 4 permanent magnets with alternating polarity
- It has eight physically separated coils (basically two coils which are spread out
- These can be precisely controlled and suitable for 3D printers

Video 25: Servos and how to use them

- Servos have 3 pins; GND, VCC and control pin
- It needs a PWM signal in control pin with 20ms periodic time and a duty cycle of 1ms-2ms
- We can rotate the shaft of a servo motor to 180 degrees
- It has a KC5188 IC

26. 555 Timer IC

- Connecting the reset pin to ground resets the IC
- Pin 1 and Pin 8 of the IC is connected with 3 5kiloOhm resistors in series (Hance the name 555)
- These resistors work as voltage dividers
- Pin 2 is a trigger pin
- The IC can be used to generate PWM signals

27. ADC (Analog to Digital Converter)

- Analog pins of an Arduino can convert input analog signal in 10-bit digital signal
- Using a higher resolution will make the reconstruction of the sample function more precise
- Flash ADC is more appropriate for DIY

28. IGBT and when to use them

- Full form- Insulated Gate Bipolar Transistor
- Like MOSFETs, there are N-channel IGBT ad P-channel IGBT
- P-channel ones are inferior characteristics, they are rarely used
- Simplified equivalent circuit of a IGBT contains a N-channel MOSFET with PNP transistor
- It can also be used for switching purposes
- Switching speed of MOSFET is faster than IGBT
- IGBT comparatively has more loss at low current
- Better for high voltage, high current, and medium frequency (<200 kHz) applications despite higher voltage drop.
- IGBTs are viable for Tesla coils due to their high current and voltage handling, but not ideal for high frequency.

29. Solar Panel & Charge Controller

- Solar panels convert sunlight into electricity. They can power small or large loads depending on their size. To maximize output, proper wiring and configuration (e.g., for battery charging) are crucial.
- A solar panel consists of individual solar cells (~0.5V each). To achieve usable voltage, many cells (e.g., 36 for 14.3V in a 100W panel) are connected in series. DIY cell assembly is fragile and less reliable than pre-made panels.
- Series connections are sensitive to partial shading.
- Covering just a few cells drastically reduces power output due to increased resistance, even if only a small portion is shaded.

- Bypass diodes can mitigate power loss from partial shading by allowing current to bypass shaded cells. These are typically integrated into commercial panels.
- Blocking diodes are used when panels are wired in parallel to prevent reverse current. Ideal test conditions (STC) are rarely met in practice, so actual panel output is usually less than rated.
- Different loads draw different voltages and currents. Solar cell behavior can be modeled with an equivalent circuit (current source, diodes, and resistors), showing how load impacts output.
- Using a power logger, the presenter identifies the maximum power point (MPP)-the optimal
- To efficiently charge batteries, MPPT (Maximum Power Point Tracking) charge controllers are preferred. They adjust input resistance to stay at MPP. PWM controllers are cheaper but can be up to 40% less efficient.

30. Microcontroller (Arduino) Timers

- The ATMEGA328P IC of an Arduino features timers

31. Schottky Diode and Zener Diode

- A Schottky diode, also known as a Schottky barrier diode, is a type of semiconductor diode formed by bringing a metal into contact with a semiconductor material (typically n-type).
- A Schottky diode is a metal-semiconductor junction diode that offers:
  Faster Switching, High frequency operation, Lower forward voltage drops, Higher efficiency in power applications.
- Boost converter: Its job is to boost a DC voltage to a higher DC voltage using the simplified schematic consisting of coil, a MOSFET, a diode and a capacitor. The coil basically builds up energy when the MOSFET is closed and then releases it when the MOSFET is open to create a higher voltage at the outputs.

- A Zener diode is a special type of semiconductor diode designed to operate in the reverse breakdown region without getting damaged. It operates in reverse breakdown, is used for voltage regulation, has sharp breakdown voltage, requires current limiting, is available in various voltages.

- Zener voltage: The Zener voltage is the reverse bias voltage at which a Zener diode starts to conduct significantly in reverse and enters breakdown without being damaged.

- Power dissipation of Zener diode: Power dissipation in a Zener diode refers to the total electrical power (in watts) converted into heat when the diode is operating in the Zener (breakdown) region.

32. Relays & Optocouplers

- Relays: Relay is like a remote-control switch. Applying a specific voltage (stated in the relay casing as coil voltage) to the pins of the coil, current will flow through it creating a magnetic field which attracts the anchor on top of the coil and closes the previously open contacts. This way the switch is now closed and connects the appliance to main voltage.
- The symbol of a common relay has the coil on the right side and the NO (Normally open) switch on the right side.
- Relay often have three terminals i.e. COM, NO, NC.

- NO stands for normally open which describes the state of the contacts when the coil is not energized. The circuit is open (disconnected) by default. It closes (connects) when the relay is activated.
- NC (Normally Closed) switches: This circuit is closed (connected) by default. It opens (disconnects) when the relay is activated.
- COM (Common) is the middle point that connects to either NO or NC. It connects to either NC or NO depending on the relay state.
- It consists of three contact points and basically provides both switch options.
- There exists voltage and current limitations for the switches.
- If too low voltage is applied to the coil, the switch will not activate or behave unreliable due to the low magnetic force. On the contrary, if a too high voltage is applied, the over current may heat up the coil and thus cause a coil short circuit which renders the relay unusable.
- Flyback diode: A flyback diode is used to suppress voltage spikes that occur when the current through an inductive load (e.g. relay, solenoid, motor) is suddenly interrupted.
- TRIAK : TRIode for Alternating Current. A triac is a three-terminal semiconductor device used for controlling current in AC circuits.
- Optocoupler (aka Opto Isolator): An optocoupler (also known as an opt isolator) is a device that uses light to transfer an electrical signal between two isolated circuits. It provides electrical isolation while allowing a signal to pass, which is especially useful in protecting sensitive electronics from high voltages or noise.
- Photosensitive Sensor: A photosensitive sensor is a type of input transducer (Transducer: An electronic device or component that converts energy from one form to another) that detects light and changes its electrical behavior in response to the intensity of the light it receives.

33. Strain Gauge/Load Cell and How to use them to measure weight

- Strain Gauge: A strain gauge is a sensor whose resistance changes when it is subjected to mechanical deformation (stretching or compressing). It is usually used to measuring masses or forces electrically. It is flexible piece of plastic on which a

zig-zag pattern of resistance wire is secured by soldering two thin wires to its contacts.

- Load Cell: A load cell is an electromechanical transducer that converts force or weight (mechanical force) into an electrical signal.

- A load cell typically uses strain gauges bonded to a metallic element (called the "spring element" or "flexure"). A load cell typically uses strain gauges bonded to a metallic element (called the "spring element" or "flexure"). This resistance change is converted into a measurable electrical output using a Wheatstone bridge circuit.

34.Two-Position Controller & PID Controller

- PID Controller: A PID controller is a control loop feedback mechanism widely used in industrial control systems to regulate process variables like temperature, pressure, speed, flow, and more. It continuously calculates an error value as the difference between a desired setpoint (SP) and a measured process variable (PV), then applies a correction based on: Proportional (P), Integral (I), Derivative (D).

- A Two-Position Controller, also known as an On-Off Controller, is the simplest type of control system used to regulate a process variable (like temperature, pressure, or level) by switching a control element fully ON or OFF based on whether the measured value is above or below a setpoint.

35. Schmitt Trigger and when to use them

- An operational amplifier (op-amp) can act as a comparator by comparing two input voltages and producing an output that indicates which of the two inputs is at a higher potential.

- How Comparator works: If the non-inverting input (+) voltage is higher than the inverting input (-) voltage, the output goes HIGH (near the positive supply voltage). If the inverting input (-) voltage is higher, the output goes LOW (near 0 volts or negative supply).

- To convert our comparator into a Schmitt trigger, all we need is a couple of resistors. Depending on how we connect them to the comparator, we can create a non-inverting Schmitt trigger. With comparator, we got one threshold value which determines whether the output is high or low. A Schmitt trigger on the other hand offers wo threshold values, a high one and a low one. And only if the to-be-monitored voltage passes the high threshold value, the output gets pulled high, and only if the low threshold value gets undershot the output gets pulled low. This way we can avoid noise caused oscillation on the output because in this so-called Hysteresis voltage (between the two thresholds) no switching of the output is possible. This functional principal of a Schmitt trigger would equal that of a non-inverting one. While an inverting schmitt trigger would basically work the same but reverses the output state for its high and low threshold values. We can calculate the hysteresis and threshold voltages for both schmitt trigger types with a few different formulas.

- The 72HC14-Hex inverting Schmitt trigger IC: After connecting the IC to a supply voltage of 5 Volts, we can connect our to-be-monitored voltage to one of the six data input pins and observe the Schmitt trigger signal on its corresponding data output pin. If we put two of them in series, then we can get rid of this inversion. Now by utilizing a potentiometer on the input and slowly rising and lowering the voltage, the two threshold voltages can be found.

- When to use a Schmitt trigger: Let's say we got a push button to use as input. In the oscilloscope, the voltage will get pulled down to groud whenever the button is pushed. But the transition from low to high state reveals taht there is no fluid transition but lots of bounces, which is a problem. So, at first adding an RC network to the output of the switch to decrease the rise/full time of the bounces so that afterwards a Schmitt trigger can be added to recreate the sharp edges and thus a fluid switch transition.
- If we want to add the push button to an Arduino circuit, then we will only need the RC network for the bouncing since the digital inputs of the microcontroller already offers a high and low threshold voltage, which is just like a Schmitt trigger.

36. SPI and how to use it

- SPI communication: **SPI** is a **synchronous serial communication protocol** used to transfer data between a **microcontroller (master)** and one or more **peripheral devices (slaves)**.
- SPI is used in communicating with sensors, driving displays, reading from SD cards, controlling DACs/ADCs, memory chips, etc.

- Basic SPI BUS Lines (4 wires):

Pin	Name	Function
MOSI	Master Out Slave In	Data from Master to Slave
MISO	Master In Slave Out	Data from Slave to Master
SCLK	Serial Clock	Clock signal from Master
SS/CS	Slave Select/Chip Select	Enables communication with specific slave

37. Impedance (AC resistance)

- The resistance to current flow imposed by the inductor is called Inductive Reactance. The resistance to current flow imposed by the capacitor is called Capacitive Reactance.

- Inductive reactance increases with the frequency. In case of a capacitor, a 90° phase shift and the current leads the voltage wave and the reactance decreases with the rise of frequency.
- The cause of capacitive reactance is the constant charge reversal of the electrostatic fields of the capacitor.
- The resistance of the capacitor or inductor not only changes the value of current flow dependent of the frequency but also effects sthe phase angle between voltage and current.
- The Ohmic resistance only changes the magnitude of the current and not the phase difference.
- In case of AC, the ohmic resistance and the capacitive and inductive resistance are not summed up in normal ways but are transformed into a complex impedance where the ohmic resistance is the real part and the capacitive and inductive resistance are imaginary part.

38.True, Reactive, Apparent & Deformed Power

- Transformer: A transformer is a static electrical device that transfers alternating current (AC) electrical energy from one circuit to another, usually with a change in voltage or current level, without changing the frequency. When an AC voltage is applied to the primary coil, it creates a changing magnetic field in the iron core. This magnetic field induces an AC voltage in the secondary coil — according to Faraday's Law of electromagnetic induction.

Type	Function
Step-up Transformer	Increases voltage, decreases current
Step-down Transformer	Decreases voltage, increases current
Isolation Transformer	Keeps voltage same, provides electrical isolation

40. Contactless payment || RFID & NFC

- RFID – Radio Frequency Identification which means it has to do with wireless communication. The PCB of the RFID reader features an antenna which is simplified as a coil.
- The reader IC in combination with some passive components pushes a sinusoidal current through the antenna which therefore creates a magnetic field around the coil.
- The tags consist of antenna or coil and a small chip.
- When the tag coil enters the magnetic field of the reader, it uses a voltage into it and thus also currents which powers the IC. This is called "Wireless Energy Transfer"
- NFC – Near Field Communication.
- NFC is a type of RFID. As only high frequency is used, couple centimeters distance between reader and tag is mandatory.

42. Transformer

- A transformer is a device that transfers electrical energy between two or more circuits through electromagnetic induction.
- Used to step-up or step-down AC voltage levels.
- Basic Components of a transformer:
  - Primary Coil: Receives input voltage.
  - Secondary Coil: Delivers transformed output voltage.
  - Core: Made of laminated iron or steel, used to concentrate magnetic flux and improve efficiency.

- Based on Faraday's Law of Electromagnetic Induction, a changing magnetic field in the primary coil induces a voltage in the secondary coil.
- The core is made of laminated silicon steel to reduce eddy current losses. Primary and secondary windings are insulated from each other and the core.
- Winding resistance is measured using a multimeter. In AC circuits, impedance matters more than just resistance due to reactance.
- Power losses in Transformers:
  1. Copper losses: Due to resistance of windings (I^2R loss)
  2. Eddy current losses: Caused by circulating currents in the core.

3. Hysteresis losses: Due to repeated magnetization and de magnetization of the core material.
4. Lamination and special materials like electrical steel help reduce these losses.

- When the core reaches its maximum magnetic flux density, it becomes saturated. Magnetic saturation leads to distortion, overheating, reduced efficiency.
- Leakage flux: not all magnetic flux links both coils, some leaks into the air. Leakage flux causes voltage drops and reduces efficiency.

43.Mechanical 7-Segment Displays || RS-485 and UART

- RS-485 Communication Protocol
  - RS-485 is an industry-standard asynchronous serial communication protocol.
  - It uses differential signaling to transmit data, which makes it robust against noise and suitable for long-distance networking in noisy environments.
  - Features:
    - Differential Signaling: Uses two wires (A and B) to transmit signals. The receiver detects the difference between the voltages on these two lines.
    - Robustness: Provides a reliable data transmission even under severe signal degradation across cables and connectors.
    - Application: Ideal for industrial and long distance communication.
- MAX485 IC: An RS-485 transceiver IC that converts single-ended signals to differential signals and vice versa.
- UART (Universal Asynchronous Receiver/Transmitter):
  - UART is a type of serial communication interface.
  - It sends data one bit at a time over a single wire.
  - The Arduino nano's UART pins are connected to the MAX485 IC to convert single-ended UART signals to differential RS-485 signals.

44.CAN Bus

- CAN Bus:
  - CAN is a serial bus system that allows microcontrollers and devices to communicate with one another.
  - It is developed for use in cars as it simplifies the wiring of complex systems by reducing the number of wires needed.
  - It needs only two wires (CAN High and CAN Low). It is resistant to noise and interference. It uses a priority-based arbitration system to avoid data collisions.
  - CAN Bus Components:
    - Nodes: Devices connected to the CAN bus, such as microcontrollers or sensors.
    - Messages: Data packets transmitted between nodes, containing an identifier (ID), data, and error-checking bits.
    - CAN High (CANH) and CAN Low (CANL): Two differential signal lines used for communication.
  - CAN Bus Operation:
    - Differential Signaling: Transmits data as the difference between the voltages on CANH and CANL.
    - Voltage Levels: Dominant State (Voltage difference between CANH and CANL is around 2V), Recessive State (Both lines are at the same voltage).

45. Building a Digital Music Player with I^2S

- Creating a Digital Music Player using the I^2S (Inter-IC Sound) interface involves connecting a microcontroller or digital audio source to an I^2S-compatible audio DAC (Digital-to-Analog Converter) or directly to a digital amplifier. This setup allows for high-quality, low-noise transmission of digital audio data.

46. Induction Motor || Asynchronous Motor

- An induction motor is one of the most commonly used types of AC electric motors, especially in industrial applications. It works based on the principle of electromagnetic induction and does not require electrical connections to the rotor.

❖ Basic parts of an Induction Motor
  - Stator: The stationary part with windings that produce a rotating magnetic field.
  - Rotor: The rotating part placed inside the stator. It can be 'Squirrel Cage Rotor', 'Wound Rotor'.
  - Air gap: A small space between the rotor and stator.

❖ How an Induction Motor work:
  - Rotating Magnetic Field: When three-phase AC power is applied to the stator windings, it generates a rotating magnetic field. This RMF rotates at a constant speed called the synchronous speed.
  - Induction in the Rotor: As the RMF cuts across the conductive bars of the rotor, EMF is induced due to electromagnetic induction. Since the rotor forms a closed circuit, current flows in the rotor conductors.
  - Torque Production: The current-carrying rotor conductors are now placed in the magnetic field of the stator. According to Fleming's Left Hand Rule, this interaction produces a mechanical force (torque), causing the rotor to rotate.

- Slip: The rotor always rotates at a speed slightly less that the synchronous speed.

- Asynchronous Motor: The rotor runs slower than the stator's magnetic field hence not synchronized.

47. A Tube Amp

- Transistors replaced vacuum tubes in most applications due to their smaller size, lower power consumption, and higher reliability.
- Vacuum tubes produce "tube sound" with warm, natural distortions but require high voltages, generate excess heat, and are less effective.
- Transistors-based Amplifiers operate at lower voltages, are more efficient, produce cleaner signals but lack the characteristic "tube sound".

48. eFuse IC

- An eFuse (Electronic Fuse) is a power switch with built-in protection features. It can automatically disconnect the power supply when a fault condition is detected (like overheat or overvoltage), and it can reconnect once the fault is cleared without requiring manual replacement.

49. Oscilloscope Basics

- An oscilloscope is used to visualize voltage signals over time. Display shows waveforms that represent changes in voltage or current. It is helpful for analyzing electronic circuits, debugging, and testing.
- Choosing an Oscilloscope:
  - Bandwidth: Determines the higher frequency the scope can accurately measure.
  - Sampling Rate: Number of samples taken per second; higher rates provide better resolution.

- Channels: Number of inputs; 4-channel scopes are preferred for complex setups.
- Memory Depth: Amount of data stored for analysis.
- Triggering Options: Allows stable display of periodic signals.

- Proper probe usage:
  - Types of probes:
    - Passive probes: Commonly used for general-purpose measurements.
    - Active probes: For high-frequency signals with low attenuation.
  - Attenuation Factor: Typically, 10x to reduce input impedance and improve bandwidth.
  - Ground Connection: Proper grounding ensures acurate measurements.
- Advanced Features:
  - FFT (Fast Fourier Transform):
    - Analyze frequency components of a signal.
    - Useful for identifying harmonics or noise.
  - Math Functions:
    - Perform calculations like addition, subtraction, multiplication, and division of waveforms.
  - Triggering:
    - Edge triggering: Captures signals based on rising or falling edges.
    - Pulse width triggering: Triggers on pulse within a specific duration.
    - Pattern triggering: Matches predefined signal patterns.
  - Appropriate probes should always be used, and safety guidelines must be followed. Differential probes must be used for measuring mains voltages safely.

50. TL431 Guide

- TL431 is a component that functions as a precision adjustable voltage reference. It is commonly employed in applications such as power supplies, regulators, and comparators.
- The TL431 has three main pins:
  - REF (Reference Pin): Connects to external resistor divider network, Sets the desired output voltage.
  - Anode (Output Pin): Drives the load, Acts as the emitter of the internal transistor.
  - Cathode (Ground pin): Connects to the circuit ground.

- Basic Operations:
  - Open-Loop Operation:
    - When the voltage at the REF pin is below the internal reference voltage, the output transistor is off.
    - When the voltage at REF pin exceeds the internal reference voltage, the output transistor turns off, pulling the output voltage low.
  - Closed-Loop Operation:
    - In a closed-loop configuration, the REF pin is connected to a resistor divider network.
    - The output voltage is regulated by comparing the voltage at the REF pin with the internal reference voltage.
- Applications: Power supplies, Voltage References, Comparators, Battery Management Systems.

51. Digital Potentiometer

- A digital potentiometer, or digipot, is a semiconductor-based component that emulates the functionality of a traditional mechanical potentiometer, but its resistance is set electronically, typically via a digital interface (like SPI or I^2C).
- It consists of a resistor ladder network with a digitally controlled wiper that selects one of many discrete tap points, offering a programmable voltage divider or variable resistor function.

52. Negative Voltages and Dual Rail Supplies

- Negative voltages are crucial in many electronic applications, especially in precision circuits like audio amplifiers, operational amplifiers (Op-Amps), and data converters (ADCs and DACs)
- A charge pump is a simple circuit that can generate a negative voltage using capacitors and diodes.
- Rail Splitter Circuit uses an Op-Amp to create a virtual ground and split the supply voltage into positive and negative rails.

53. Latch Circuits

- Latch circuits are used to store binary information (1 or 0) and maintain that state until a reset signal is applied. It is a type of sequential logic circuit that can store one bit of information.
- Applications of Latch Circuits:
  - Memory Storage: Used in flip-flops and registers to store data in sequential logic circuits.
  - Control Systems: Implement toggle switches, counters, and state machines.
  - Power Management: Overcurrent protection circuits use latches to detect and respond to excessive current.

54.Resettable Fuses

- Resettable Fuses:
  - Automatically reset after the fault condition is removed.
  - No need for replacement, reducing maintenance costs.
  - Ideal for applications where frequent tripping is expected.
- PPTCs (Polymeric Positive Temperature Coefficient):
  - Made of a polymer material with a positive temperature coefficient.
  - Under normal conditions, they have low resistance.

- When current exceeds a certain threshold (trip current), their resistance increases dramatically to limit the current flow.
- Once the fault is removed, they cool down and return to their low-resistance state, resetting automatically.

❖ When selecting a resettable fuse, consider the following parameters:

- Maximum Voltage (*Vmax)*: Must be greater than or equal to the maximum voltage in your circuit.
- Maximum Current (Imax): Should exceed the maximum continuous current your circuit will draw.
- Hold Current (I hold): The maximum current that can flow continuously without triggering the fuse.
- Trip Current (I trip): The current level at which the fuse trips and limits the current flow.