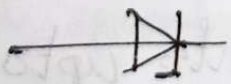
Schottky Diode & Zener Diode (Vid-31):-

* Schottky Diode →  1N5819
* very small conduction loss, low forward voltage drop
* Extremely fast switching
* High frequency operation
* Boost converter - boost a low DC voltage to higher DC voltage - coil, MOSFET, Diode, Capacitor.
* ~~Now~~ Low blocking voltage → cons

* Zener Diode : 
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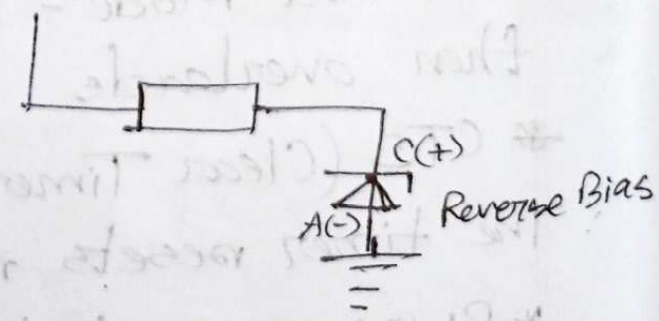

Relays and Optocouplers (Vid - 32)

Relay - electromechanical switch
* sits next to 4 pin ICs
* A coil, two contacts
* NC - Normally Closed, NO - Normally open
* contacts open-close via magnetic field
* add flyback diode parallel to coil
* MOSFET and triac causes power loss
* Galvanically isolated

Optocoupler:-
* Inside → led, photosensitive sensor → triac/transistor
* Input - output galvanically isolated
* switch faster than relays
* need less activation current

Strain Gauge / Load Cell and how to use them to measure weight:- (Vid - 33)

* Resistance - 120 Ω / 370 Ω / 1000 Ω /
* Resistance changes as the shape changes
* $F \sim \varepsilon \sim R$
* Wheatstone Bridge
* Temperature Sensitive
* Half Bridge

Load Cell :- * aluminium profile
* Wheatstone Bridge is attached
* Connect with HX711 breakboard - amplifier ADC circuit

Two-position Controller and PID Controller (Vid - 34) :-
* PID - Proportional Integral Derivative
* Fmg = Fa, gets closer to magnet + turns off
gets far - turns on
* P controller ⇒ Outp = (Set p - Act v). Kp
* I controller ⇒ Diminishes gap with set point
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Schmitt Trigger and When to use (Vid - 35)
* comparator —resistor→ Schmitt Trigger
* two threshold values
* avoid noise caused oscillation
* Mechanical switch creates noise oscillation, Schmitt trigger helps in smooth transition

SPI and How to Use it (Vid-36)

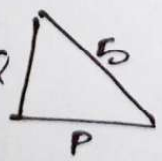
* SPI ⇒ Serial Peripheral Interface
* 4 main lines:- MOSI, MISO, SCLK, SS/CS
* full duplex communication
* can communicate with multiple slaves
* high speed communication, simple hardware interface no need of device addressing.
* More pins required, short distance communication and no built-in error checking

What is Impendance (AC Resistance) [Vid-37]

* Impendance - resistor in AC circuits
* Two concepts - resistance (real part) and reactance (imaginary)
* $Z = R + jX$
* Inductive Reactance ↑ frequency ↑
* Capacitive Reactance ↓ frequency ↑
* Impedence Triangle (Resistance, Reactance, Impedence Magnitude)
* Capacitors cause current to lead voltage, Inductors cause current to lag voltage

True, Active, Apparent & Deformed Power (Vid-32)

* Energy Multimeter - 8 probes, can measure electric power. and also energy overtime in AC appliances
* True Power / Active Power (P):- This is the actual power consumed by resistive components in a circuit to perform work. (watts)
* Reactive Power (Q):- Power that oscillates between the source and reactive components (inductors and capacitors), doesn't perform any real work, but essential for maintaining voltage level.
* Apparent Power:-(S):- $S = \sqrt{P^2 + Q^2}$ (volt-amp) Represents the total power supplied to the circuit
* Deformed / Distortion Power:-(D) Arises due to non-linear loads that distort the waveform of the current, e.g. electronic devices with rectifiers
* Power Triangle:-



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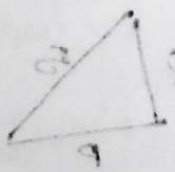
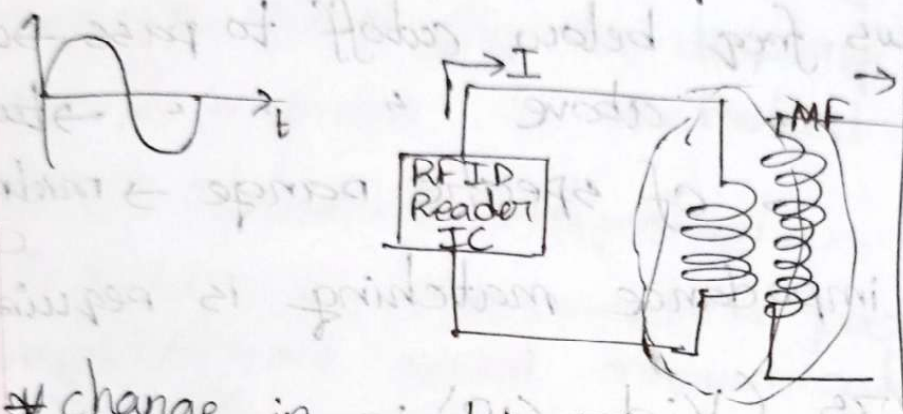
* controlling large number of ~~leds~~ LEDs using shift register.
* A shift register is a digital memory circuit that takes in data serially (one bit at a time) and outputs in parallel.
* 74HC595 → 8 output pin, serial input, clock input, latch input, output enable
* Multiplexing:- only one row is active at a time, shift register outputs define the lit LEDs.
* Program rapidly traverses through all rows
* NPN transistor also used
* flip-flop:- 6 NOT → 1, NAND → 4



RFID and NFC :- (Vid-40) :-

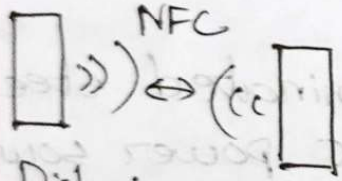
RFID → Radio Frequency Identification



* the tag also contains a ~~tunch~~ coil or antenna and a chip
* wireless energy transfer

* change in amplitude due to short-circuit

NFC → Near Field Communication



Dist is mandatory

* encrypted via keys
* close proximity
* Transaction limit

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* Audio crossover - electronic circuit that divides an audio signal into separate frequency bands directing each band to appropriate speaker drivers
Tweeters - high freq, Midrange Driver - mid freq
Woofers - Low freq
* clearer and more accurate sound production

* Passive crossover utilize resistor, capacitor and inductors to filter audio signal.

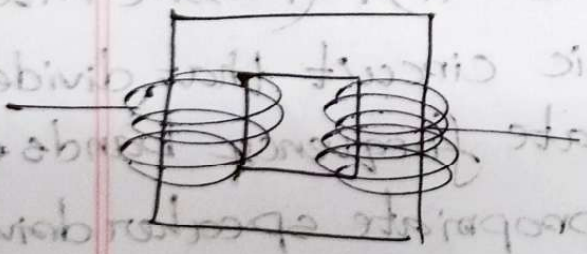
LPF :- Allows freq below cutoff to pass → woofer
HPF :- " above " " → tweeters
BPF :- " of specific range → midrange driver

* Accurate impedance matching is required

Transformers (Vid - 42) :-

* Transformer - steps voltage up or down through electromagnetic induction

* Parts :- core - made from laminated steel plates
Primary Coil - Connected to AC power source
Secondary Coil - Delivers transformed voltage to output load



AC flows through coil - MF in core - changing field induces voltage in the second coil - Faraday's Second Law - Ratio of coil decides

$$\frac{V_s}{V_p} = \frac{n_s}{n_p}$$

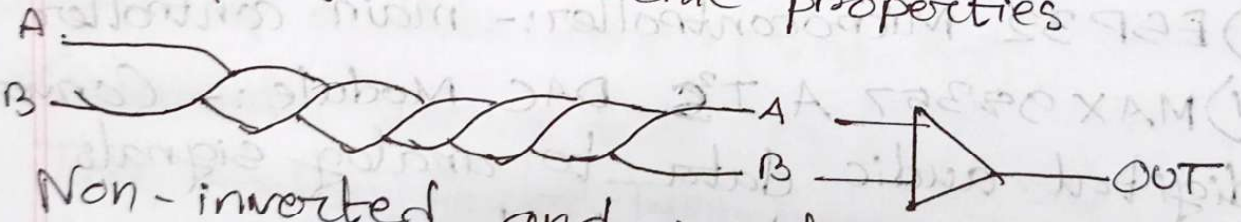
Power loss - Copper Wire
Core - Hysteresis Loss, Eddy Current Loss
Leakage Loss, Dielectric Loss

Controlling Mechanical 7segment displays:- (Vid-43)

* Mechanical 7- segment display - use physical segments that flip to display digits.
* each segment is controlled by electromagnet

UART (Universal Asynchronous Receiver/Transmitter)
A hardware communication protocol that enables asynchronous serial communication

RS-485 :- An electrical standard that supports serial communication over longer distance
* only defines electronic properties



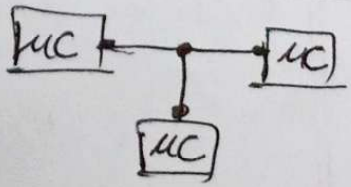
Non-inverted and inverted data signal

Improving Electric Longboard with CAN bus:-

* CAN - Controller Area Network (Vid-44)

Features:- i) Multi-master capability - allows multiple micro controller communicate without host
ii) Error-detection.
iii) Efficient Communication

Bus System

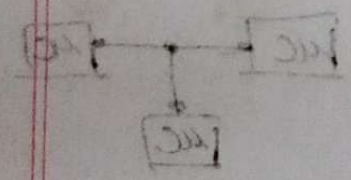


* CANH and CANL

* hardware cheap
* No collision error, ID based system
* Half-duplex, asynchronous

Building a Digital Music Player with I^2S (Vid-45)

* I^2S (Inter IC sound) – communication protocol ~~designed~~ designed for digital audio data transmission between ICs.
* Digital Music Player:-
  i) ESP32 Microcontroller:- main controller
  ii) MAX98357A I^2S DAC Module:- Converts digital audio data to analog signals
  iii) Speaker – audio output
* ESP-32 – Audio I2S Library
* 3 primary lines:-
  i) SCK (Serial Clock):- Sync data transmission
  ii) WS (Word Serial):- Channel for stereo audio
  iii) SD (serial data):- Carries audio data

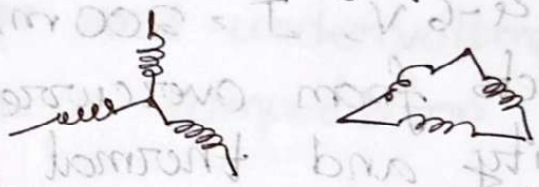


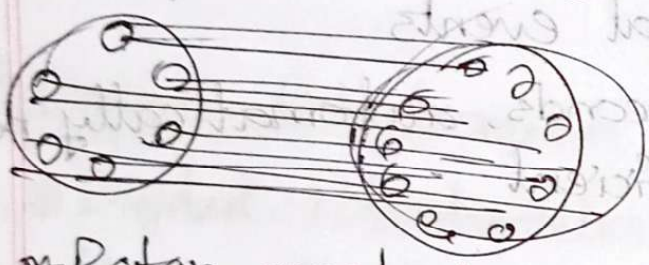
Asynchronous Motor / Induction Motors:- (Vid-46)

* most widely used in the world

U_1 —— U_2
V_1 —— V_2
W_1 —— W_2

Y-delta configuration:-





* magnetic field
* induces voltage in the rotors
* Rotor must turn slower than the stator freq.

Building a Tube Amp:- (Vid-47)

Components:- Vaccum tube (EL84/6V6)
Tube Socket, Power Transformer, Output Transformer, Capacitor, Resistor, Potentiometer, Audio Input Jack, Speaker output Terminal, Chasis

* warm and rich sound
* produces more even-order harmonic distortion, which is pleasing to hear
* a softer clipping behaviour while overdriven

eFuse :- (Vid-1.43)

* Using power bank to power circuit
* eFuse IC :- used for protection
* V = 4-6 V, I = 200 mA
* protects from overcurrent, overvoltage, reverse polarity and thermal events
* responds in microseconds, automatically reset
* space and cost efficient

Oscilloscope (Vid-40) :-

* Vizualizes voltage and current,
* Amount of channels - 04, bandwidth - 50MHz
* low-pass filter; * sampling rate - Higher rate
* 10V → 10x → 1V * scaling factor
* cursor function - Rise Time * safety

TL-431 (Vid-50) :-

A three terminal adjustable precision shunt regulator...

* Acts like a programmable Zener diode
* Voltage reference + Error Amplifier + Shunt Regulator

* Maintains consistent output voltage at changing input voltage / load.

Application:- voltage regulator, feedback control in SMPS, overvoltage and undervoltage protection

* Can be used as a comparator

Digital Potentiometer Guide:- (Vid - 51)

* Digital Potentiometer - allowing resistance adjustment through digital signals
* Used for volume control, LCD brightness adjust, turning circuits programmatically
* I^2C or SPI protocol
* 8 pin IC, Resistor ladder network, MOSFET, Digital Interface
* Replaces ~~manual~~ manual knob to digital commands

Negative Voltages:- (Vid - 52)

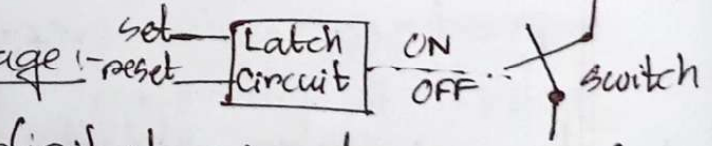
* Required for Op-Amps, RS-232s, audio circuit and sensors to ensure proper biasing and signal range
* enable symmetrical power supplies
* Ways to generate:- Charge pump, Inverting Buck boost, Flyback Converter, Virtual Ground (Op-Amps)
* Dual-Rail Power Supply - (+)ve and (-)ve PSU

Mechanical Switch VS Latch Circuit:-

Cons of Mechanical Switch:- (Vid - 53)

limited lifespan, false trigger in digital circuit, bulkier and less reliable on harsh environment

Latch Circuit Advantage:-



Longer lifespan, Clean digital signal, compact, suitable with MC.

* Used as toggle switch, memory storage and control systems

Resettable fuse:- (Vid - 54)

* Multifuse / Polyfuse / Polyswitch
* Automatically limit current flow ~~Once~~ when overcurrent situation occurs, and resets once normal conditions resume.
* PPTC Device :- Polymeric Positive Temperature Coefficient
* ~~Increase~~ Temp ↑ Resistance ↑
* Excess current → heat up → polymer expands → disrupts conductive pathway → increase in resistance
* Automatic reset, cost efficient, compact, versatile

PFC :- (Vid - 55)

* PFC - Power Factor Correction
* Power Factor = $\frac{\text{Real Power}}{\text{Apparent Power}}$
* To address poor power factors.
  i) Passive PFC :- using inductors and capacitors to counteract the phase diff between I and V
  ii) Active PFC :- Electronic Circuit, centered around a boost converter topology. Higher PF

Color Ring Inductor (Vid-56):-

* Axial Lead Inductors
* resistor like appearance, colored bands → inductance value
* measured in μH or mH
* Application :- ~~LC filter, Oscillator~~
  i) LC filter - filter out unwanted signals
  ii) Oscillator - Generate oscillating signal
  iii) Boost Converter - Store and transfer energy
  iv) Chokes - block high freq AC signal

Ground IS MORE IMPORTANT :- (Vid-57)

* Inadequate grounding - signal noise, voltage instability, component failure.
* Proper Grounding should be ensured

Motor Encoders (Vid-58):-

* A sensor that provides position and/or speed feedback from the motor shaft.
* Rotary Encoder - converts angular position to electric signals. Each cycle completes circuit and sends electric signal.

Disadvantage:- no back shaft in every motor, resolution of encoder - 18° per step.

* Magnetic Encoder - 12 bit resolution, 0.088° per step. Cons - good position matters.
* Use in 3d Printers.
* Alternative - stepper motors
* precise speed regulation, accurate position control, better performance in robotics

Surge Protection - (Vid-59):-

OL ⇒ overload

TVS ⇒ Transient Voltage Supressor

* acts as open circuit under normal voltage & when a transient voltage exceeds diode's breakdown voltage, acts like Zener diode, passes small current
* small, easy to add, cheap

* MOV (Metal Oxide Varistor) :- variable resistance. Works similarly like TVS.
* Can handle more energy than TVS.
* GDT (Gas Discharge Tubes) :- Excess energy dissipated as heat. Slower.

I3C Protocol (Vid - 60) :-

* I2C vs I3C :-
  i) Timing - ($I^2C \rightarrow 1$ MHz, I3C $\rightarrow$ 12.5 MHz)
  ii) push-pull drivers, used by I3C
  iii) I3C uses dynamic addressing targeting, reduces data collision.
  iv) Smooth transition from I^2C

MOSFET Amplifier (Vid - 61) :-

* BJT can't handle too much current
* Darlington Transistor - 2 BJT put together, higher current gain and improved drive capability., but increased voltage drop.
* MOSFET :- amplify signal, tiny voltage drop ; less waste of power

(6)

MOSFET ⇒ Metal Oxide Semiconductor field Effect Transistor

PLC (Vid-62):-

PLC ⇒ Programmable Logic Controller

* big operating temperature, 4 output - 250V 10A
* used for industrial input and output
* bit more expensive than microcontroller
* function blocks, easy to debug
* easier wiring, simpler wiring
* but reaction time is slower than M.C,

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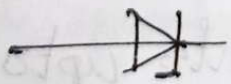
* Zener Diode : 
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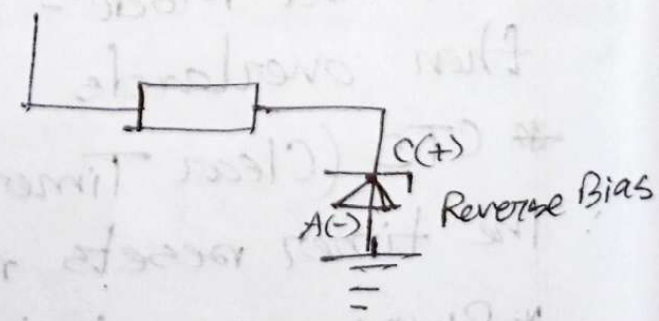

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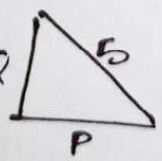

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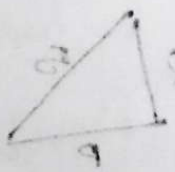

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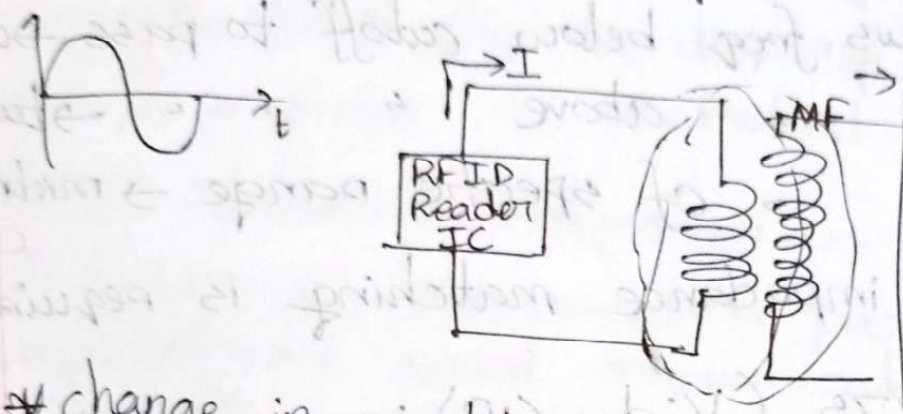

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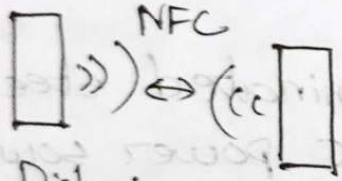

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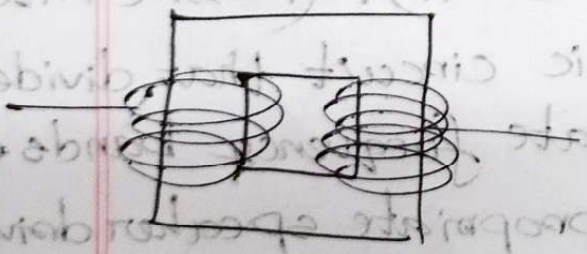

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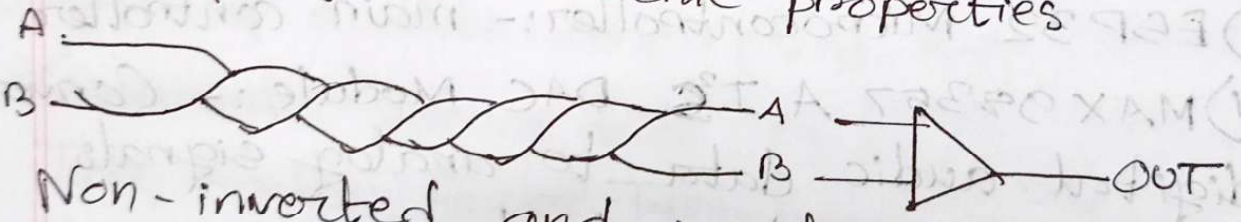

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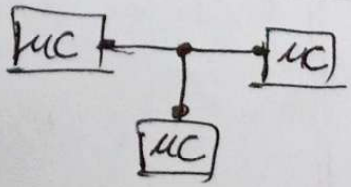

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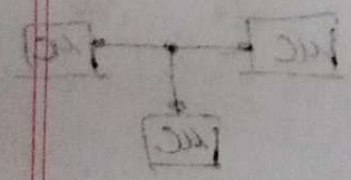
  ii) WS (Word Serial):- Channel for stereo audio
  iii) SD (serial data):- Carries audio data

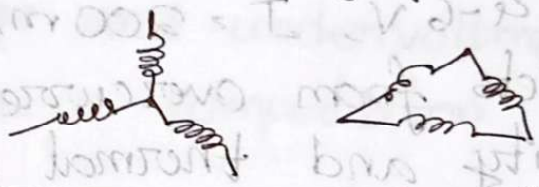


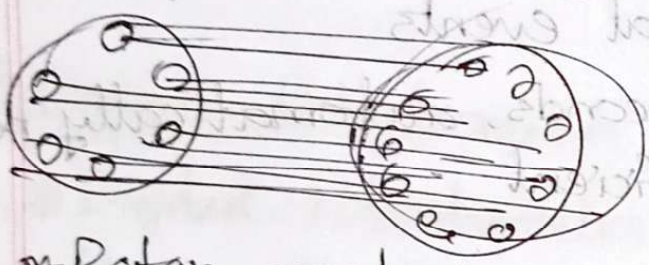
Asynchronous Motor / Induction Motors:- (Vid-46)

* most widely used in the world

U_1 —— U_2
V_1 —— V_2
W_1 —— W_2

Y-delta configuration:-





* magnetic field
* induces voltage in the rotors
* Rotor must turn slower than the stator freq.

Building a Tube Amp:- (Vid-47)

Components:- Vaccum tube (EL84/6V6)
Tube Socket, Power Transformer, Output Transformer, Capacitor, Resistor, Potentiometer, Audio Input Jack, Speaker output Terminal, Chasis

* warm and rich sound
* produces more even-order harmonic distortion, which is pleasing to hear
* a softer clipping behaviour while overdriven

eFuse :- (Vid-1.43)

* Using power bank to power circuit
* eFuse IC :- used for protection
* V = 4-6 V, I = 200 mA
* protects from overcurrent, overvoltage, reverse polarity and thermal events
* responds in microseconds, automatically reset
* space and cost efficient

Oscilloscope (Vid-40) :-

* Vizualizes voltage and current,
* Amount of channels - 04, bandwidth - 50MHz
* low-pass filter; * sampling rate - Higher rate
* 10V → 10x → 1V * scaling factor
* cursor function - Rise Time * safety

TL-431 (Vid-50) :-

A three terminal adjustable precision shunt regulator...

* Acts like a programmable Zener diode
* Voltage reference + Error Amplifier + Shunt Regulator

* Maintains consistent output voltage at changing input voltage / load.

Application:- voltage regulator, feedback control in SMPS, overvoltage and undervoltage protection

* Can be used as a comparator

Digital Potentiometer Guide:- (Vid - 51)

* Digital Potentiometer - allowing resistance adjustment through digital signals
* Used for volume control, LCD brightness adjust, turning circuits programmatically
* I^2C or SPI protocol
* 8 pin IC, Resistor ladder network, MOSFET, Digital Interface
* Replaces ~~manual~~ manual knob to digital commands

Negative Voltages:- (Vid - 52)

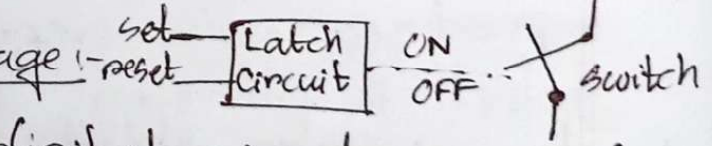
* Required for Op-Amps, RS-232s, audio circuit and sensors to ensure proper biasing and signal range
* enable symmetrical power supplies
* Ways to generate:- Charge pump, Inverting Buck boost, Flyback Converter, Virtual Ground (Op-Amps)
* Dual-Rail Power Supply - (+)ve and (-)ve PSU

Mechanical Switch VS Latch Circuit:-

Cons of Mechanical Switch:- (Vid - 53)

limited lifespan, false trigger in digital circuit, bulkier and less reliable on harsh environment

Latch Circuit Advantage:-



Longer lifespan, Clean digital signal, compact, suitable with MC.

* Used as toggle switch, memory storage and control systems

Resettable fuse:- (Vid - 54)

* Multifuse / Polyfuse / Polyswitch
* Automatically limit current flow ~~Once~~ when overcurrent situation occurs, and resets once normal conditions resume.
* PPTC Device :- Polymeric Positive Temperature Coefficient
* ~~Increase~~ Temp ↑ Resistance ↑
* Excess current → heat up → polymer expands → disrupts conductive pathway → increase in resistance
* Automatic reset, cost efficient, compact, versatile

PFC :- (Vid - 55)

* PFC - Power Factor Correction
* Power Factor = $\frac{\text{Real Power}}{\text{Apparent Power}}$
* To address poor power factors.
  i) Passive PFC :- using inductors and capacitors to counteract the phase diff between I and V
  ii) Active PFC :- Electronic Circuit, centered around a boost converter topology. Higher PF

Color Ring Inductor (Vid-56):-

* Axial Lead Inductors
* resistor like appearance, colored bands → inductance value
* measured in μH or mH
* Application :- ~~LC filter, Oscillator~~
  i) LC filter - filter out unwanted signals
  ii) Oscillator - Generate oscillating signal
  iii) Boost Converter - Store and transfer energy
  iv) Chokes - block high freq AC signal

Ground IS MORE IMPORTANT :- (Vid-57)

* Inadequate grounding - signal noise, voltage instability, component failure.
* Proper Grounding should be ensured

Motor Encoders (Vid-58):-

* A sensor that provides position and/or speed feedback from the motor shaft.
* Rotary Encoder - converts angular position to electric signals. Each cycle completes circuit and sends electric signal.

Disadvantage:- no back shaft in every motor, resolution of encoder - 18° per step.

* Magnetic Encoder - 12 bit resolution, 0.088° per step. Cons - good position matters.
* Use in 3d Printers.
* Alternative - stepper motors
* precise speed regulation, accurate position control, better performance in robotics

Surge Protection - (Vid-59):-

OL ⇒ overload

TVS ⇒ Transient Voltage Supressor

* acts as open circuit under normal voltage & when a transient voltage exceeds diode's breakdown voltage, acts like Zener diode, passes small current
* small, easy to add, cheap

* MOV (Metal Oxide Varistor) :- variable resistance. Works similarly like TVS.
* Can handle more energy than TVS.
* GDT (Gas Discharge Tubes) :- Excess energy dissipated as heat. Slower.

I3C Protocol (Vid - 60) :-

* I2C vs I3C :-
  i) Timing - ($I^2C \rightarrow 1$ MHz, I3C $\rightarrow$ 12.5 MHz)
  ii) push-pull drivers, used by I3C
  iii) I3C uses dynamic addressing targeting, reduces data collision.
  iv) Smooth transition from I^2C

MOSFET Amplifier (Vid - 61) :-

* BJT can't handle too much current
* Darlington Transistor - 2 BJT put together, higher current gain and improved drive capability., but increased voltage drop.
* MOSFET :- amplify signal, tiny voltage drop ; less waste of power

(6)

MOSFET ⇒ Metal Oxide Semiconductor field Effect Transistor

PLC (Vid-62):-

PLC ⇒ Programmable Logic Controller

* big operating temperature, 4 output - 250V 10A
* used for industrial input and output
* bit more expensive than microcontroller
* function blocks, easy to debug
* easier wiring, simpler wiring
* but reaction time is slower than M.C,