Electronic Circuits & Applications (4321103) - Summer 2024 Solution

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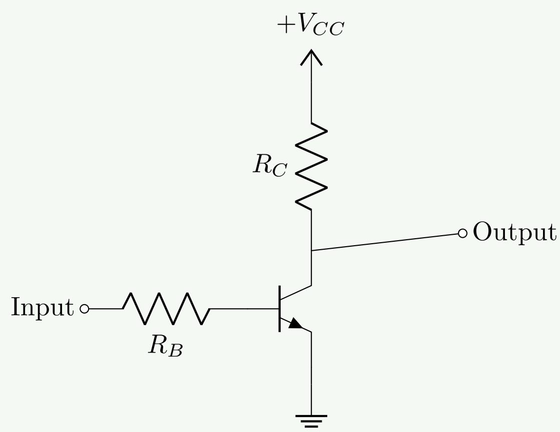
Question 1 [a marks]

3 Explain amplifier parameters Ai, Ri and Ro for CE configuration.

Solution

In **Common Emitter (CE)** configuration, the key parameters are:



- **Current Gain (A_i)**: Ratio of output current to input current (I_c/I_b). Typically 50-200 in CE configuration.
- **Input Resistance (R_i)**: Opposition to input current at base terminal. Ranges from 1-2 kΩ in CE.
- **Output Resistance (R_o)**: Opposition at collector terminal. Typically 50 kΩ in CE.

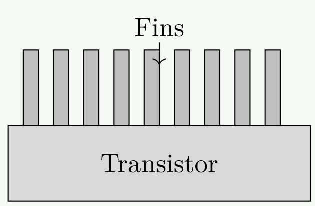
Mnemonic

CIR parameters - **C**urrent gain, **I**nput resistance, and output **R**esistance determine amplifier performance

Question 1 [b marks]

4 Write short-note on heat sink.

Solution



- **Purpose**: Dissipates excess heat from electronic components (like power transistors) to prevent thermal damage.
- **Types**:
  - **Passive**: Aluminum or copper fins that rely on natural convection.
  - **Active**: Uses fans or liquid cooling for forced convection.
- **Thermal Resistance**: Lower thermal resistance (θ, measured in °C/W) indicates better heat dissipation capability.
- **Materials**: Copper (best conductivity) or Aluminum (lightweight, cost-effective).

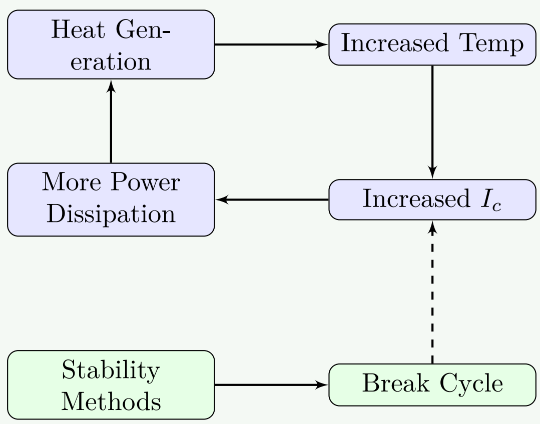
Mnemonic

HARD sinks - **H**eat **A**way using **R**adiation and **D**issipation through metal sinks

Question 1 [c marks]

7 Describe Thermal Runaway and Thermal Stability. How can overcome thermal run away in transistor?

Solution



Thermal Runaway:

- **Definition**: A self-accelerating destructive process where the transistor heats up, causing more current to flow, which generates even more heat.
- **chain Reaction**: Increase in temperature → Increases leakage current (I_{CO}) → Increases collector current ($I_C = \beta I_B + (1+\beta)I_{CO}$) → Increases Power Dissipation ($P_D = V_{CE}I_C$) → Further Temperature Rise.
- **Result**: If unchecked, it leads to the physical destruction of the transistor.

Thermal Stability:

- **Definition**: The ability of a circuit to maintain a stable operating point (Q-point) despite variations in temperature.
- **Measure**: Quantified by the **Stability Factor (S)**. Lower values of S indicate better thermal stability.

Overcoming Thermal Runaway:

1. **Heat Sinks**: Increasing surface area to dissipate heat into the air.
2. **Emitter Resistor**: Using an unbypassed emitter resistor (R_E) provides negative feedback. If I_C rises, voltage drop across R_E increases, reducing V_{BE}, which reduces I_B and thus opposes the rise in I_C.
3. **Biasing Methods**: Using circuits like **Voltage Divider Bias** which offer better stability than fixed bias.
4. **Compensation**: Using temperature-sensitive components (thermistors, diodes) in the bias circuit to counteract parameter changes.

Mnemonic

SHEER protection - **S**inks for **H**eat, **E**mitter resistors, **E**xternal cooling, and **R**obust biasing prevent thermal runaway

Question 1 [c marks]

7 Write down types of biasing methods. Explain the voltage divider biasing method in details.

Solution

Types of Biasing Methods:

Method	Stability	Complexity
Fixed Bias	Poor	Simple
Collector Feedback	Medium	Medium
Emitter Bias	Good	Medium
Voltage Divider	Excellent	Complex

Voltage Divider Biasing:

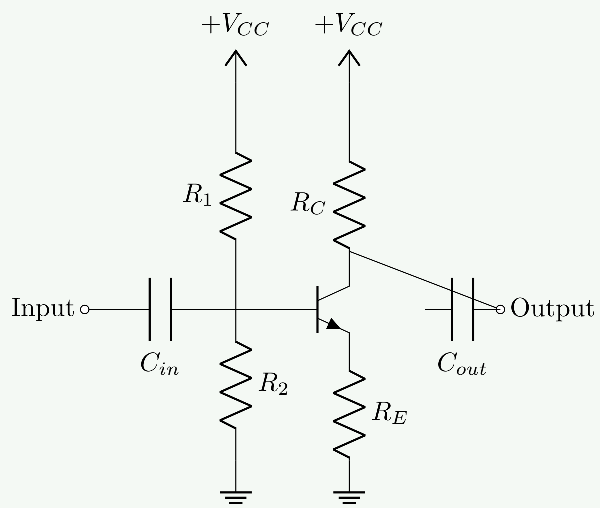


Figure 1. Voltage Divider Bias Circuit

- **Circuit Structure**: Uses two resistors R_1 and R_2 connected in series across the supply V_{CC} to provide a fixed potential at the base.
- **Operating Principle**: The voltage across R_2 (base voltage V_B) forward biases the emitter junction.
- **Base Voltage**: $V_B = V_{CC} \times \frac{R_2}{R_1+R_2}$
- **Stability**: This is the most widely used method because the operating point is almost independent of the transistor's β.
  - If I_C increases due to temperature, I_E increases ($I_E \approx I_C$).
  - Voltage drop across R_E ($V_E = I_E R_E$) increases.
  - Since V_B is constant, $V_{BE} = V_B - V_E$ decreases.
  - Decreased V_{BE} reduces I_B, which in turn reduces I_C, stabilizing the circuit.
- **Advantage**: High stability factor ($S \approx 1$).

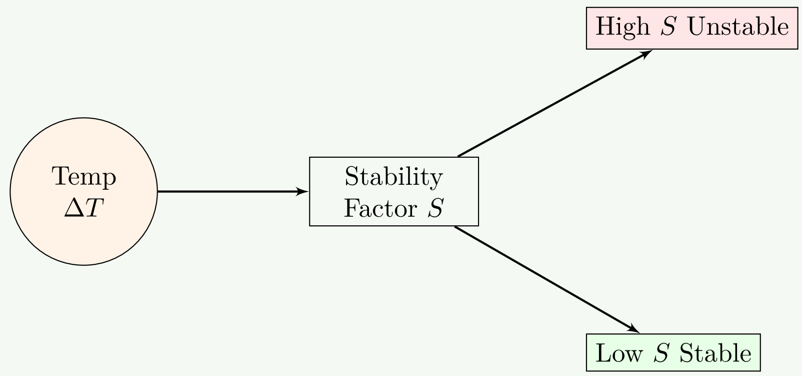
Mnemonic

DIVE for stability - **D**ivider **I**s **V**ery **E**ffective for temperature and β variations

Question 2 [a marks]

3 Explain Stability Factor with features.

Solution



- **Definition**: Stability factor (S) indicates the degree of change in collector current (I_C) with respect to the reverse saturation current (I_{CO}), keeping β and V_{BE} constant.
- **Formula**: $S = \frac{dI_C}{dI_{CO}}$
- **Ideal Value**: Ideally $S = 1$. The lower the value of S, the better the thermal stability.
- **Significance**: It quantifies how sensitive the Q-point is to temperature variations. A circuit with $S = 10$ is less stable than one with $S = 2$.

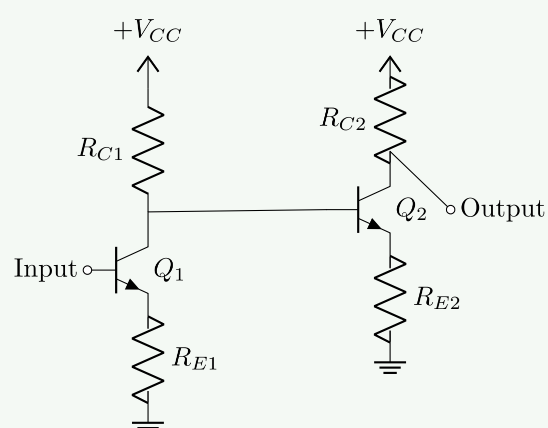
Mnemonic

LESS is better - **L**ower values **E**nsure **S**table **S**ystem for temperature changes

Question 2 [b marks]

4 Describe direct coupling technique of cascading.

Solution



- **Definition**: In direct coupling, the output of the first stage is directly connected to the input of the next stage without any coupling capacitor or transformer.
- **Working**: The DC collector voltage of the first stage provides the DC base bias for the second stage.
- **Advantages**:
  - Can amplify extremely low frequencies (including DC).
  - Simple circuit, fewer components (no capacitors/transformers).
  - Easy to fabricate in Integrated Circuits (ICs).
- **Disadvantages**:
  - Thermal drift (shift in Q-point) is amplified stage by stage.
  - Requires careful design to match DC levels.

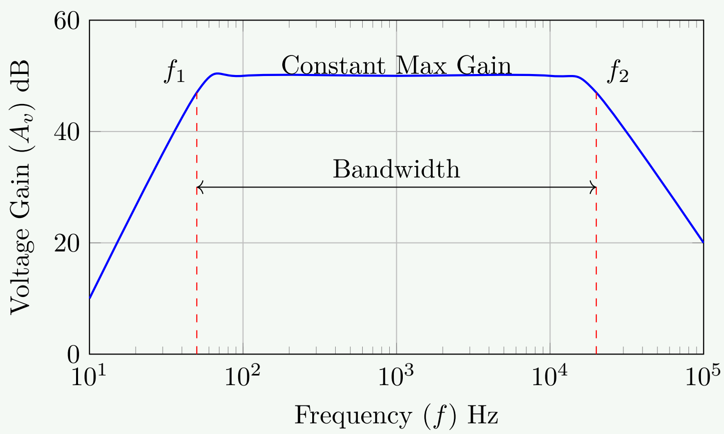
Mnemonic

DIAL for DC - **D**irect **I**nterconnection **A**mplifies **L**ow frequencies without capacitors

Question 2 [c marks]

7 Explain frequency response of two stages RC coupled amplifier.

Solution



Frequency Response Analysis:

1. **Low Frequency Region** ($f < f_1$):
   - The reactance of coupling capacitors ($C_C = 1/2\pi fC$) is high.
   - A significant voltage drop occurs across C_C, reducing the signal reaching the next stage.
   - The emitter bypass capacitor (C_E) also has high reactance, reducing the gain due to negative feedback.
2. **Mid Frequency Region** ($f_1 < f < f_2$):
   - Capacitors act as short circuits.
   - Gain remains constant and maximum.
3. **High Frequency Region** ($f > f_2$):
   - Reactance of internal transistor capacitances (inter-electrode capacitance) becomes low.
   - These shunt the signal to ground, reducing the gain.
   - Wiring capacitance also contributes to gain reduction.
4. **Bandwidth**: The range of frequencies between the lower cut-off (f_1) and upper cut-off (f_2) where gain is at least 70.7% (-3dB) of the maximum is the bandwidth.

Mnemonic

LMH frequency regions - **L**ow has rising gain, **M**iddle has flat gain, **H**igh has falling gain

Question 2 [a marks]

3 Briefly explain bandwidth and gain-bandwidth product of an amplifier.

Solution

Bandwidth (BW):

- It is the range of frequencies over which the amplifier provides satisfactory gain (usually defined as gain being $\geq$ 70.7% of maximum).

- Formula: $BW = f_2 - f_1$, where f_2 is upper cut-off and f_1 is lower cut-off frequency.

Gain-Bandwidth Product (GBW):

- For a given amplifier, the product of voltage gain (A_v) and bandwidth (BW) is a constant.
- $GBW = A_v \times BW =$ Constant.
- **Significance**: If we increase gain (e.g., by cascading), the bandwidth decreases, and vice versa. It represents the figure of merit for an amplifier.

Mnemonic

BIG value - **B**andwidth and gain **I**nverse relationship is a **G**iven constant

Question 2 [b marks]

4 Explain effects of emitter bypass capacitor and coupling capacitor on frequency response of an amplifier.

Solution

Capacitor	**Low Freq**	**Mid Freq**	**High Freq**
Emitter Bypass (C_E)	High reactance, reduces gain (feedback active)	Short circuit, max gain (feedback bypassed)	Short circuit, no effect
Coupling (C_C)	High reactance, blocks/attenuates signal	Short circuit, allows full signal	Short circuit, no effect

- **Coupling Capacitor** (C_C):
  - Blocks DC to prevent bias interaction between stages.
  - At low frequencies, its high reactance (X_C) causes signal loss, defining the lower cut-off frequency f_1.
- **Emitter Bypass Capacitor** (C_E):
  - Connected in parallel with R_E to bypass AC signals to ground.
  - Prevents degeneration (negative feedback) at signal frequencies, thus increasing voltage gain.
  - At low frequencies, if X_C is high, feedback occurs, reducing gain.

Mnemonic

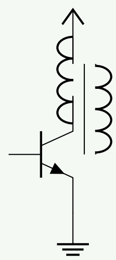
CABLE effect - **C**apacitors **A**ct as **B**arriers at **L**ow frequencies, improving at higher frequencies

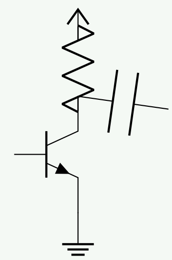
Question 2 [c marks]

7 Compare transformer coupled amplifier and RC coupled amplifier.

Solution

Parameter	Transformer Coupled	RC Coupled
Coupling Device	Transformer	Capacitor & Resistor
Impedance Matching	Excellent (adjustable via turns ratio)	Poor
Frequency Response	Poor (limited due to transformer inductance)	Excellent (wide and flat over audio range)
Efficiency	High (no power loss in collector resistor)	Low (power wasted in collector resistor)
Size & Weight	Bulky and Heavy	Compact and Light
Cost	Expensive	Inexpensive
Application	Power Amplifiers (Impedance matching)	Voltage Amplifiers (Audio/Pre-amps)





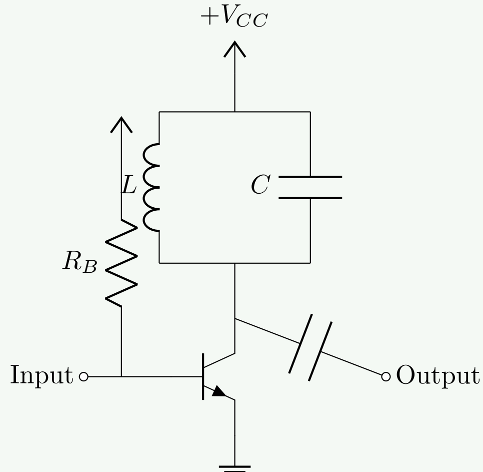
Mnemonic

TREE factors - **TR**ansformers provide **E**fficiency and **E**xcellent impedance matching, RC provides Cost savings

Question 3 [a marks]

3 Describe the transistorized tuned amplifier.

Solution



- **Definition**: An amplifier that uses a parallel LC circuit (tank circuit) as the collector load to amplify a specific narrow band of frequencies.
- **Resonance**: The LC circuit resonates at frequency $f_r = \frac{1}{2\pi\sqrt{LC}}$.
- **Gain**: At resonance, the impedance of the tank circuit is maximum (resistive), resulting in maximum voltage

gain.
- **Applications**: Used in the Radio Frequency (RF) and Intermediate Frequency (IF) stages of receivers.

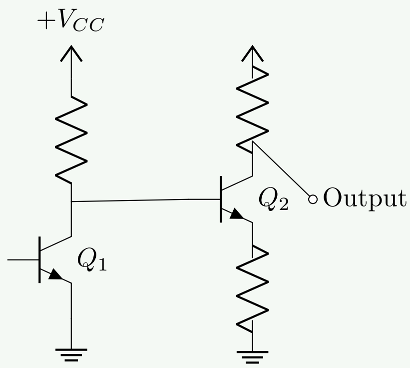
Mnemonic

TRIP to resonance - **T**uned **R**esonant circuits **I**mprove **P**erformance at specific frequencies

Question 3 [b marks]

4 Explain in brief Direct coupled amplifier.

Solution



- **Definition**: A multi-stage amplifier where the output of one stage is connected directly to the input of the next stage without any reactive components.
- **Characteristics**:
  - **Low Frequency Response**: Excellent, can amplify down to DC (0 Hz).
  - **Simplicity**: Requires fewer components (no bulky capacitors).
  - **Issues**: Suffers from **DC drift** (thermal instability shifting the operating point).
- **Application**: Linear ICs, Operational Amplifiers, low-frequency instrumentation.

Mnemonic

COLD advantages - **C**ompact design, **O**utstanding low-frequency response, **L**ess components, **D**irect connection

Question 3 [c marks]

7 Describe the importance of h parameters in two port network. Draw h-parameters circuit for CE amplifier.

Solution

Transistor h-parameter Model (CE Configuration):

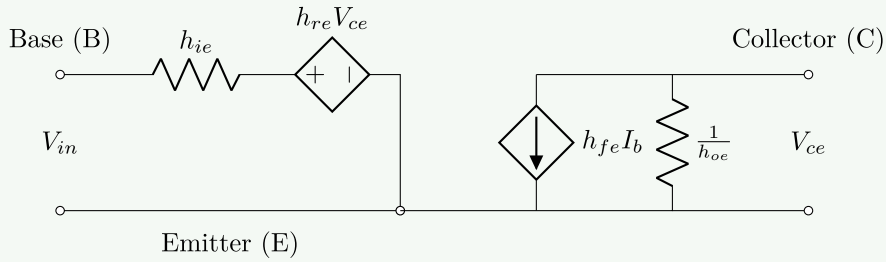


Figure 2. h-parameter Equivalent Circuit for CE

Importance of h-parameters:

- **Hybrid Nature**: They use a mix of units (Ω, Siemens, dimensionless), hence "hybrid".
- **Ease of Measurement**: They are defined based on open-circuit and short-circuit conditions which are easy to implement practically.
- **Accuracy**: They provide accurate results for small-signal analysis at low frequencies.
- **Standardization**: Manufacturers specify transistor characteristics using these parameters (h_{fe}, h_{ie}, etc.).

CE Parameters:

- h_{ie} (h_{11}): Input Impedance.
- h_{re} (h_{12}): Reverse Voltage Ratio.
- h_{fe} (h_{21}): Forward Current Gain.
- h_{oe} (h_{22}): Output Admittance.

Mnemonic

FINE parameters - **F**our **I**nterconnected **N**etwork **E**lements define transistor completely

Question 3 [a marks]

3 Compare transformer coupled amplifier and direct coupled amplifier.

Solution

Parameter	**Transformer Coupled**	**Direct Coupled**
DC Isolation	Complete	None
Freq Response	Poor (limited band)	Excellent (down to DC)
Size/Weight	Bulky/Heavy	Compact/Light
Impedance Matching	Excellent	Poor
Cost	High	Low
Drift	No drift problem	Severe drift problem

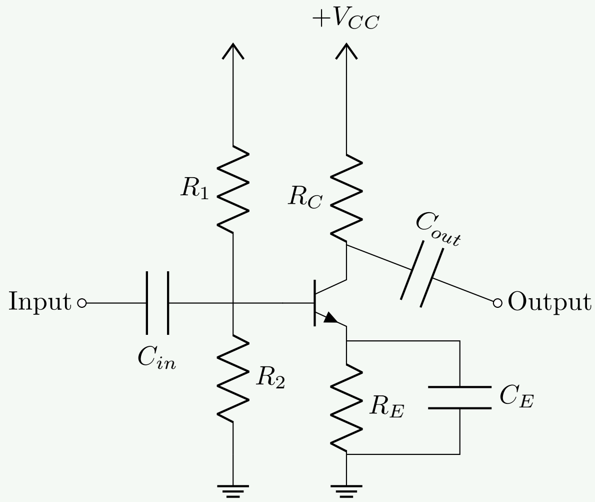
Mnemonic

TIP for selection - **T**ransformer for **I**mpedance matching and **P**ower transfer, Direct for low frequencies

Question 3 [b marks]

4 Draw and Explain circuit diagram of common emitter amplifier.

Solution



- **Circuit**: Uses Voltage Divider Bias (R_1, R_2) for stability. Capacitors C_{in} and C_{out} block DC. C_E bypasses R_E to prevent AC gain application.
- **Operation**: Small AC input at base varies base current, which is amplified by β at the collector.
- **Phase Shift**: Output is **180° out of phase** with input.
- **Characteristics**: Moderate input/output impedance, high voltage and current gain.

Mnemonic

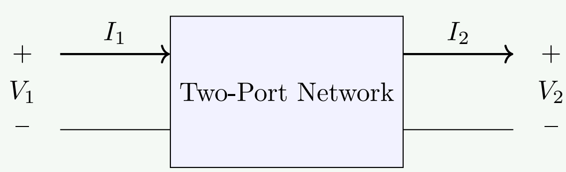
GAIN characteristics - **G**ood **A**mplification with **I**nverted output and **N**otable efficiency

Question 3 [c marks]

7 Draw Transistor Two Port Network and describe h-parameters for it. Write down advantages of hybrid parameters.

Solution

Two-Port Network:



h-Parameter Equations:

$$V_1 = h_{11}I_1 + h_{12}V_2$$
$$I_2 = h_{21}I_1 + h_{22}V_2$$

Advantages:

- **Realizable**: Parameters correspond to easy-to-measure physical quantities (impedance, gain, etc.).
- **Low Frequency Suitability**: Highly accurate for analyzing audio frequency circuits.
- **Universal**: Apply to any active device (BJT, FET) treated as a black box.
- **Dimensional Variety**: Since they mix ohms, siemens, and dimensionless ratios, they flexibly describe complex interactions.

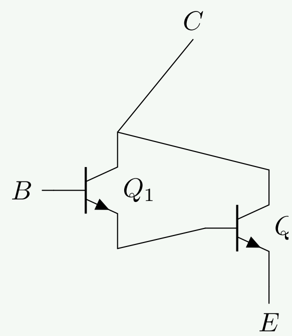
Mnemonic

SMART parameters - **S**imple **M**easurement, **A**ccurate modeling, **R**eliable, **T**emperature-stable

Question 4 [a marks]

3 Explain Darlington pair and its applications.

Solution



- **Definition**: Two transistors connected such that the emitter current of the first becomes the base current of the second, often packaged as a single device.
- **Current Gain**: The total current gain is the product of individual gains ($\beta_{total} \approx \beta_1 \times \beta_2$). Extremely high.
- **Input Impedance**: Very high.
- **Applications**: High current drivers (relays, motors), input stages of high-impedance amplifiers.

Mnemonic

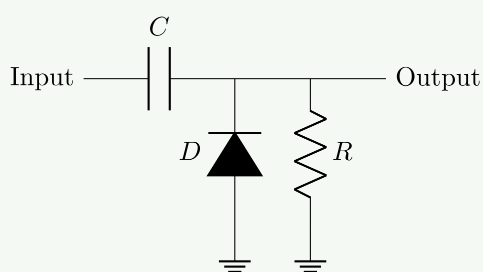
HIGH gain - **H**ugely **I**ncreased **G**ain from **H**arnessing two transistors

Question 4 [b marks]

4 Describe the diode clamper circuit with necessary diagram.

Solution

Positive Clamper:



- **Function**: Adds a DC shift to the input signal without changing its shape (DC Restorer).
- **Positive Clamper**: Shifts the signal UP so negative peaks sit on zero (or reference) level.
- **Operation**:
  - During the negative half-cycle, Diode conducts, charging Capacitor to V_p (polarity: + on right).
  - During the positive half-cycle, Diode is reverse biased.
  - Output voltage $V_o = V_{in} + V_C = V_{in} + V_p$.

Mnemonic

CAPS effect - **C**apacitor **A**nd diode **P**air **S**hifts signal by exact DC level

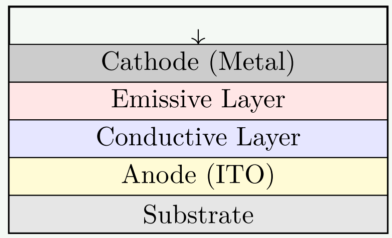
Question 4 [c marks]

7 Explain the construction, working and applications of OLED.

Solution

OLED Construction:

Structure of OLED



- **Construction**: Consists of organic semiconductor layers sandwiched between two electrodes (Anode and Cathode) deposited on a substrate.
- **Layers**:
  - **Emissive Layer**: Organic molecules that emit light.
  - **Conductive Layer**: Transports holes from anode.
- **Working**:
  - When voltage is applied, current flows from cathode to anode.
  - Cathode gives electrons to emissive layer; Anode removes electrons (adds holes) to conductive layer.
  - Electrons and holes recombine in the emissive layer, releasing energy as photons (Light).
- **Applications**: Premium smartphones, TVs, flexible displays, digital signage.

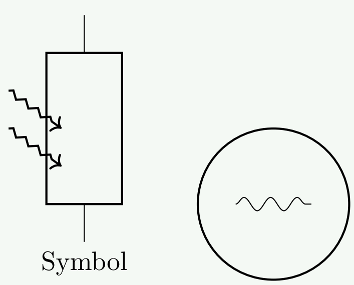
Mnemonic

OLED benefits - **O**rganic materials, **L**ightweight design, **E**fficient operation, **D**irect emission

Question 4 [a marks]

3 Explain Short note on LDR.

Solution



Symbol

Structure (Top View)

- **Full Form**: Light Dependent Resistor.
- **Principle**: Photoconductivity. Resistance decreases when light intensity increases.
- **Material**: Made of Cadmium Sulfide (CdS).
- **Operation**: In dark, resistance is very high (MΩ). In light, electron-hole pairs are generated, resistance drops (to few 100 Ω).
- **Use**: Automatic street lights, camera exposure meters.

Mnemonic

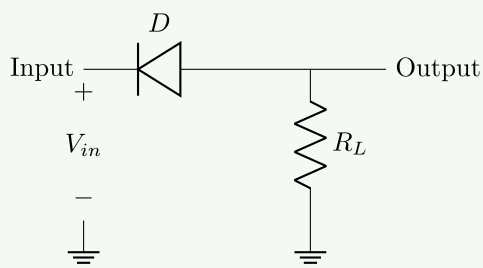
DARK increases resistance - **D**ecreasing light **A**nd **R**ising darkness **K**eep resistance high

Question 4 [b marks]

4 Describe the diode clipper circuit with necessary diagram.

Solution

Positive Clipper (Series):



- **Definition**: A circuit that removes (clips) a portion of the input signal waveform.
- **Positive Clipper**: Removes the positive half cycle.
- **Working**:
  - During positive half cycle, Diode is reverse biased (Open). No current flows to load. Output = 0.
  - During negative half cycle, Diode is forward biased (Short). Current flows. Output = Input (approx).
- **Applications**: Waveform shaping, protection against voltage spikes.

Mnemonic

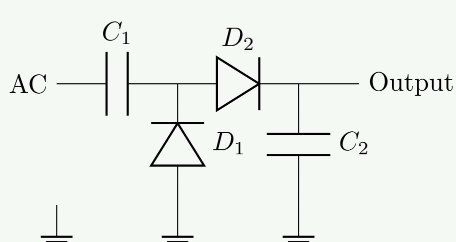
CLIP waves - **C**ircuit **L**imits **I**nput **P**eaks by using diode conduction

Question 4 [c marks]

7 Explain Half Wave and Full wave Voltage Doubler.

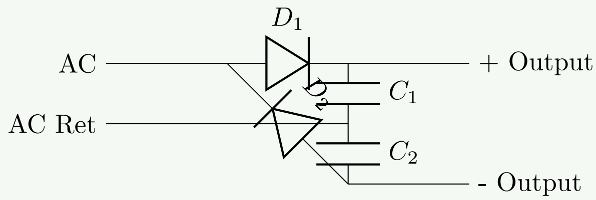
Solution

Half-Wave Voltage Doubler:



- **Operation**:
  - Negative Cycle: D_1 conducts, C_1 charges to V_m (peak).
  - Positive Cycle: D_2 conducts. Input voltage (V_m) + C_1 voltage (V_m) charges C_2 to $2V_m$.
- **Output**: DC voltage $\approx 2V_m$.

Full-Wave Voltage Doubler:



- **Operation**: Charges one capacitor during the positive cycle and the other during the negative cycle. The output is the sum across both.
- **Advantage**: Higher ripple frequency (easier to filter).

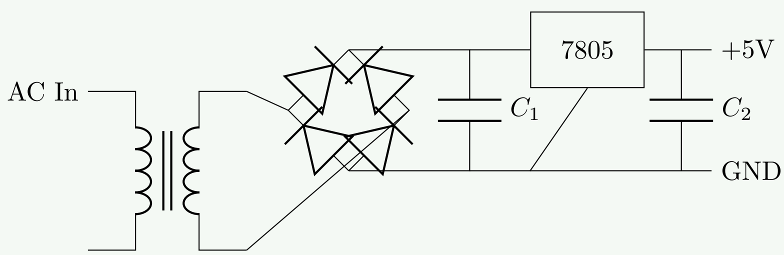
Mnemonic

CHASE 2V - **C**apacitors **H**old **A**lternating **S**upply **E**nergy to produce 2× Voltage

Question 5 [a marks]

3 Draw circuit diagram for +5v Power Supply using its IC and explain in brief.

Solution



- **Components**:
  - **Transformer**: Steps down AC mains (230V to 9V).
  - **Rectifier**: Converts AC to pulsating DC.
  - **Filter** (C_1): Smooths pulsations to produce unregulated DC.
  - **IC 7805**: Voltage regulator that provides constant +5V output.
  - **Capacitor** (C_2): Removes high-frequency noise/transients.
- **Working**: The AC is rectified, filtered, and then regulated by the 7805 IC which dissipates excess voltage as heat to maintain 5V.

Mnemonic

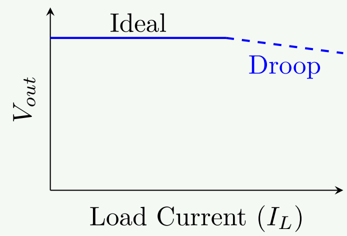
FIRM voltage - **F**iltered **I**nput, **R**egulated by 7805 **M**akes stable voltage

Question 5 [b marks]

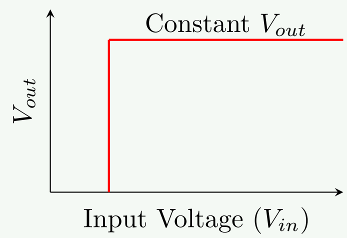
4 Discuss load regulation and line regulation in reference to power supply.

Solution

Load Regulation



Line Regulation



- **Load Regulation**:
  - **Definition**: The ability of a power supply to maintain constant output voltage despite changes in load current.
  - **Formula**: $\%LR = \frac{V_{NoLow} - V_{FullLoad}}{V_{FullLoad}} \times 100$
  - **Ideal**: 0% (Perfectly stiff voltage source).
- **Line Regulation**:
  - **Definition**: The ability to maintain constant output voltage despite changes in AC input (mains) voltage.
  - **Formula**: $\%SR = \frac{\Delta V_{out}}{\Delta V_{in}} \times 100$
  - **Significance**: Ensures voltage stability during brownouts or surges.

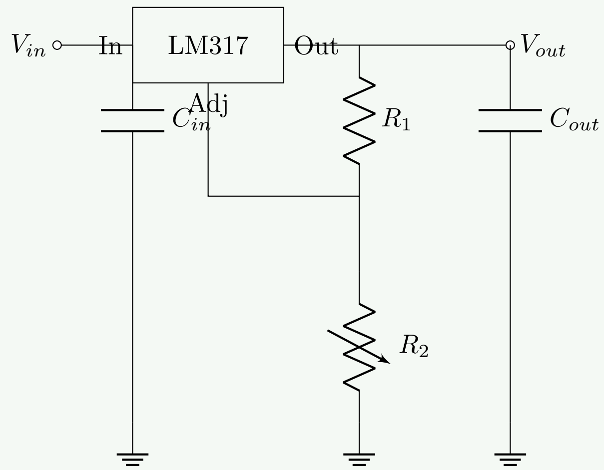
Mnemonic

LIVER health - **LI**ne regulation for **V**ariations in Input, load regulation for **E**xternal **R**esistance changes

Question 5 [c marks]

7 Explain adjustable voltage regulator using LM317 with circuit diagram.

Solution



- **Description**: LM317 is a popular adjustable positive voltage regulator capable of supplying more than 1.5A over a 1.25V to 37V output range.
- **Working**:
  - It develops a nominal 1.25V reference voltage (V_{ref}) between the Output and Adjustment terminal.
  - This reference voltage is impressed across resistor R_1, causing a constant current I_1 to flow.
  - This current also flows through R_2 (ignoring small I_{Adj}).
- **formula**: $V_{out} = 1.25V\left(1 + \frac{R_2}{R_1}\right) + I_{Adj}R_2$
- **Applications**: Variable bench power supplies, battery chargers.

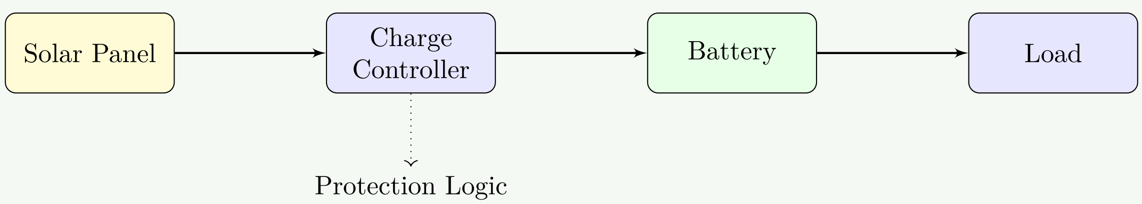
Mnemonic

VAIR control - **V**ariable **A**djustable **I**ntegrated **R**egulator controls voltage precisely

Question 5 [a marks]

3 Explain working of solar battery charger circuits.

Solution



- **Function**: Converts solar energy into electrical energy to charge a rechargeable battery.
- **Charge Controller**:
  - Regulates voltage and current from solar panels.
  - Prevents **Overcharging** (which damages battery) and **Reverse Current** (battery discharging into panel at night).
- **Operation**: Panel generates DC → Controller adjusts levels → Battery stores energy → Load uses it.

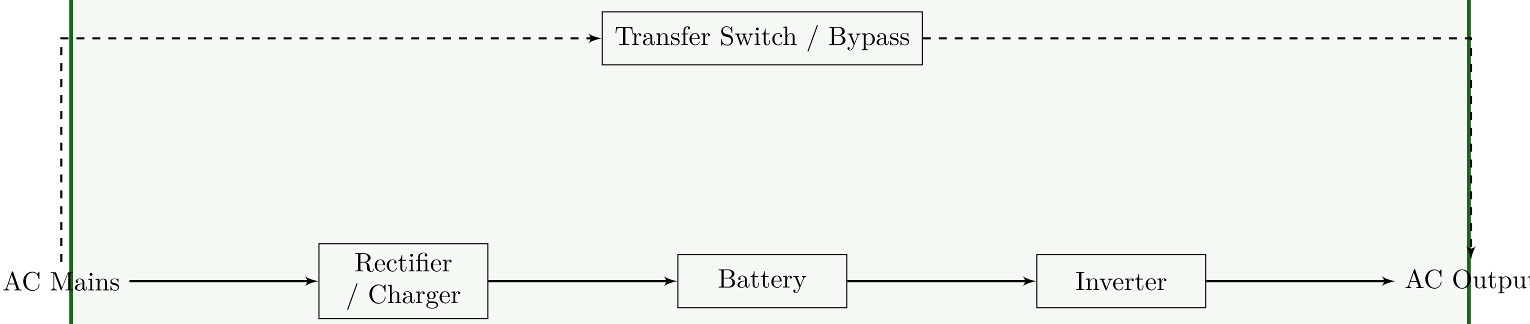
Mnemonic

SCBL system - **S**olar panel **C**onverts sunlight, **B**attery stores, **L**oad consumes

Question 5 [b marks]

4 Explain working of UPS.

Solution



- **Full Form**: Uninterruptible Power Supply.
- **Normal Mode**: AC mains powers the load (directly or via rectification) and charges the battery.
- **Backup Mode**: When mains fail, the Inverter converts DC from the Battery back to AC to power the load.
- **Transfer Switch**: Seamlessly switches between Mains and Inverter output to assume zero downtime.

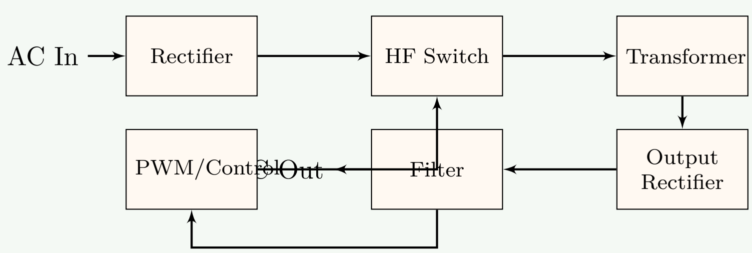
Mnemonic

PRIME power - **P**ower **R**emains **I**ntact during **M**ains **E**lectricity problems

Question 5 [c marks]

7 Draw and explain SMPS block diagram with its advantages and disadvantages.

Solution



Working of SMPS (Switch Mode Power Supply):

1. **Input Rectification**: AC mains is converted to high-voltage DC.
2. **Switching**: A high-speed transistor switches this DC on and off at high frequency (kHz to MHz).
3. **Transformation**: The high-frequency pulses are stepped down by a small, lightweight ferrite-core transformer.
4. **Output Rectification**: The secondary output is rectified and filtered to smooth DC.
5. **Regulation**: A feedback circuit adjusts the duty cycle (PWM) of the switch to maintain constant output voltage.

Advantages:

- **High Efficiency**: 70-90% (transistor operates as switch, low power loss).
- **Compact**: High frequency allows smaller transformers and capacitors.
- **Flexible**: Can step-up, step-down, or invert voltage.

Disadvantages:

- **Noise**: Switching generates EMI (Interference) and output ripple.
- **Complexity**: Complex circuit design compared to linear supplies.

Mnemonic

FISH factors - **F**requency switching, **I**solation, **S**mall size, **H**igh efficiency are SMPS benefits