

# Electronic Circuits Applications (4321103) - Summer 2024 Solution

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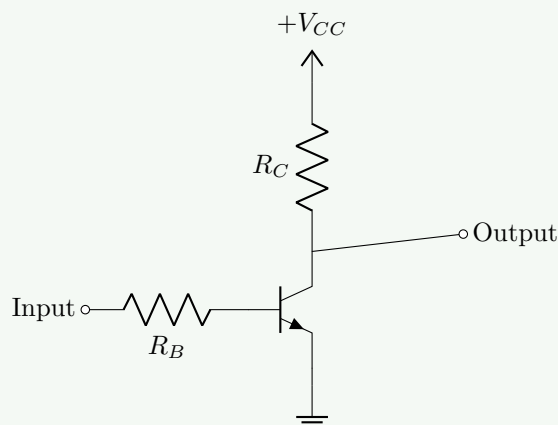
June 18, 2024

## Question 1 [a marks]

3 Explain amplifier parameters  $A_i$ ,  $R_i$  and  $R_o$  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 k $\Omega$  in CE.
- **Output Resistance ( $R_o$ ):** Opposition at collector terminal. Typically 50 k $\Omega$  in CE.

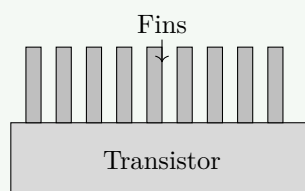
### Mnemonic

"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 ( $\theta$ , measured in  $^{\circ}\text{C}/\text{W}$ ) indicates better heat dissipation capability.
- **Materials:** Copper (best conductivity) or Aluminum (lightweight, cost-effective).

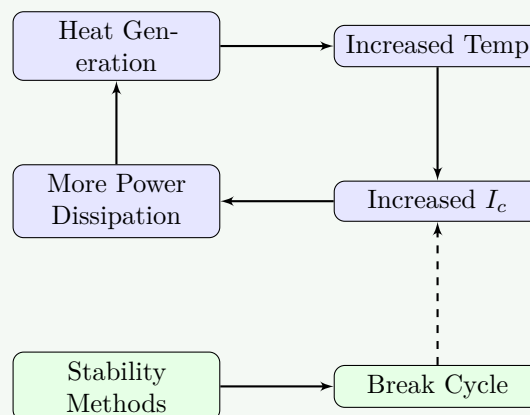
#### Mnemonic

"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  $\rightarrow$  Increases leakage current ( $I_{CO}$ )  $\rightarrow$  Increases collector current ( $I_C = \beta I_B + (1 + \beta)I_{CO}$ )  $\rightarrow$  Increases Power Dissipation ( $P_D = V_{CE}I_C$ )  $\rightarrow$  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:

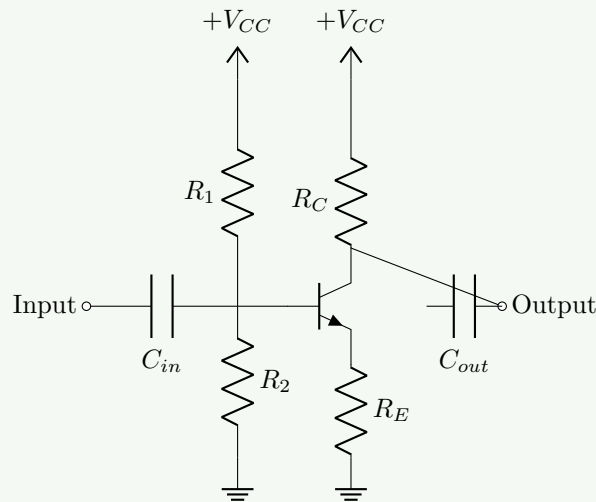


Figure 1. Voltage Divider Bias Circuit

- **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  $\beta$ .
  - 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 ( $S \approx 1$ ).

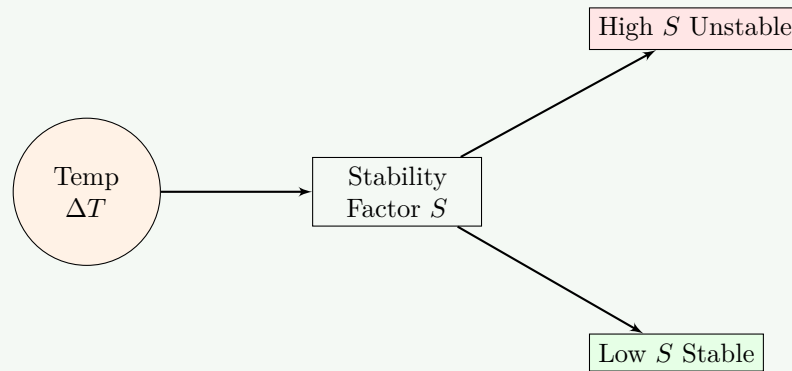
#### Mnemonic

"DIVE for stability - Divider Is Very Effective for temperature and  $\beta$  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  $\beta$  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  $S = 2$ .

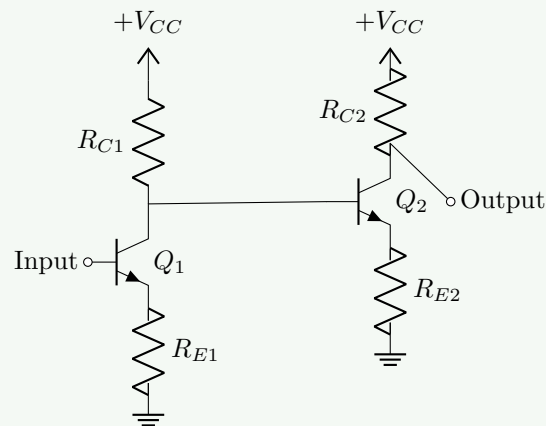
## Mnemonic

"LESS is better - Lower values Ensure Stable System for temperature changes"

## Question 2 [b marks]

4 Describe direct coupling technique of cascading.

## Solution



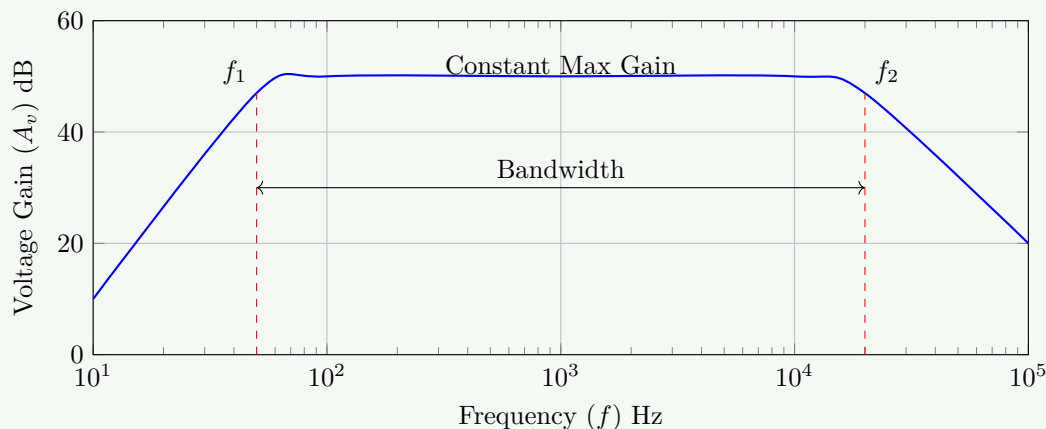
- **Definition:** In direct coupling, the output of the first stage is directly connected to the input of the next stage without any coupling capacitor or transformer.
- **Working:** The DC collector voltage of the first stage provides the DC base bias for the second stage.
- **Advantages:**
  - Can 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:**

- 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.
- Mid Frequency Region ( $f_1 < f < f_2$ ):**
  - Capacitors act as short circuits.
  - Gain remains constant and maximum.
- 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.
- 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.
- $GBW = A_v \times BW = \text{Constant}$ .
- **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**

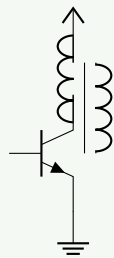
"CABLE effect - **C**apacitors **A**ct as **B**arriers at **L**ow frequencies, improving at higher frequencies"

## Question 2 [c marks]

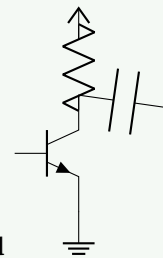
7 Compare transformer coupled amplifier and RC coupled amplifier.

## 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)



Transformer Coupled



RC Coupled

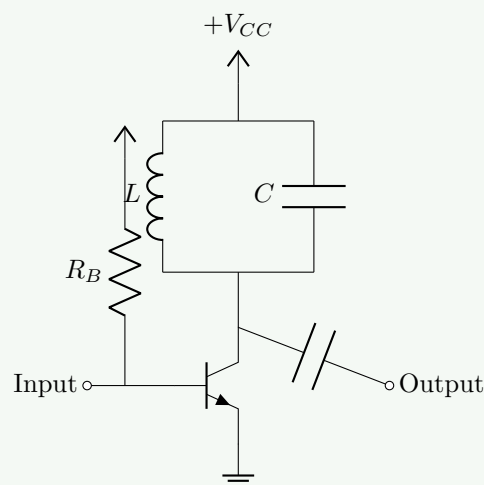
## Mnemonic

"TREE factors - **T**Ransformers provide **E**fficiency and **E**xcellent impedance matching, RC provides **C**ost 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.

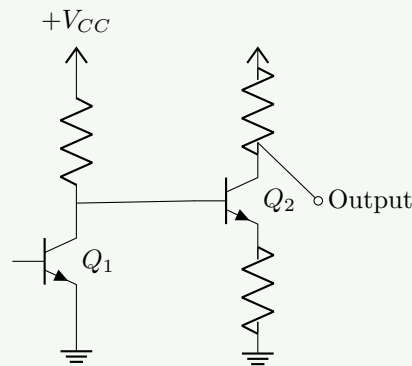
#### Mnemonic

"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

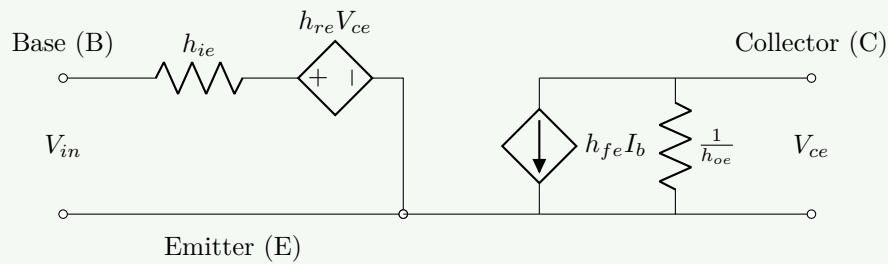
"COLD advantages - **C**ompact design, **O**utstanding low-frequency response, **L**ess components, **D**irect connection"

## 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 ( $\Omega$ , 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

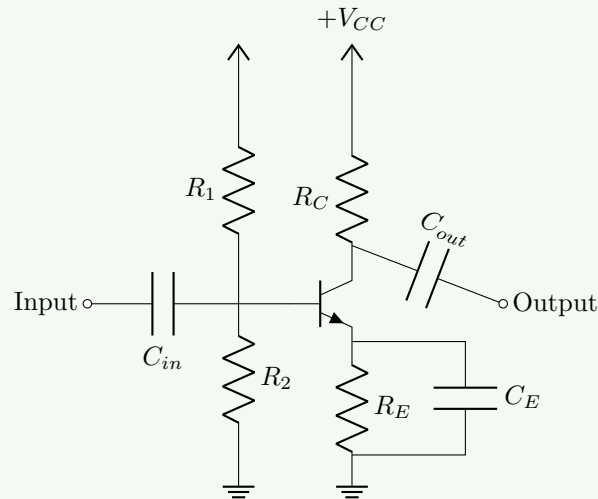
#### Mnemonic

"TIP for selection - **T**ransformer for **I**mpedance matching and **P**ower transfer, **D**irect 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  $\beta$  at the collector.
- **Phase Shift:** Output is **180° out of phase** with input.
- **Characteristics:** Moderate input/output impedance, high voltage and current gain.

## Mnemonic

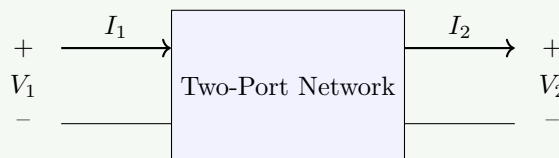
"GAIN characteristics - **G**ood **A**mplification with **I**nverted output and **N**otable efficiency"

## 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.

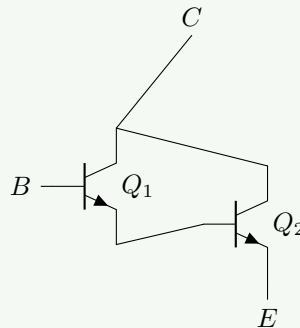
## Mnemonic

"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

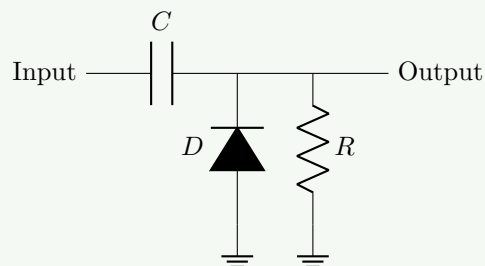
"HIGH gain - **H**ugely **I**ncreased **G**ain from **H**arnessing two transistors"

## 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

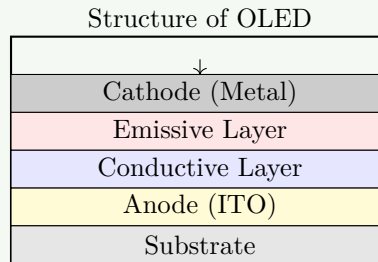
"CAPS effect - **C**apacitor **A**nd diode **P**air **S**hifts signal by exact DC level"

## Question 4 [c marks]

7 Explain the construction, working and applications of OLED.

### Solution

#### OLED Construction:



- **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.

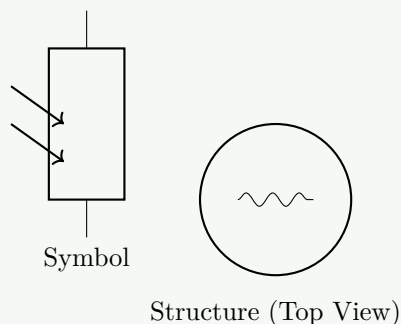
#### Mnemonic

"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



- **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 ( $M\Omega$ ). In light, electron-hole pairs are generated, resistance drops (to few  $100\ \Omega$ ).
- **Use:** Automatic street lights, camera exposure meters.

**Mnemonic**

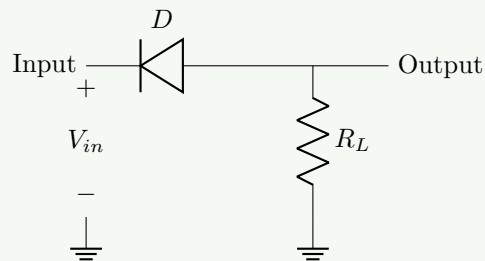
"DARK increases resistance - **D**ecreasing light **A**nd **R**ising darkness **K**eeP resistance high"

**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**

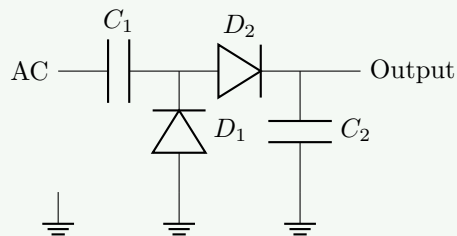
"CLIP waves - **C**ircuit **L**imits **I**nput **P**eaks by using diode conduction"

**Question 4 [c marks]**

7 Explain Half Wave and Full wave Voltage Doubler.

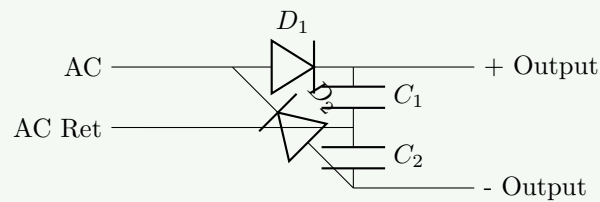
**Solution**

**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).

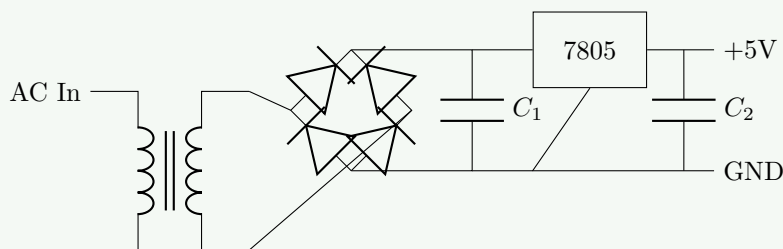
#### Mnemonic

"CHASE 2V - Capacitors **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.

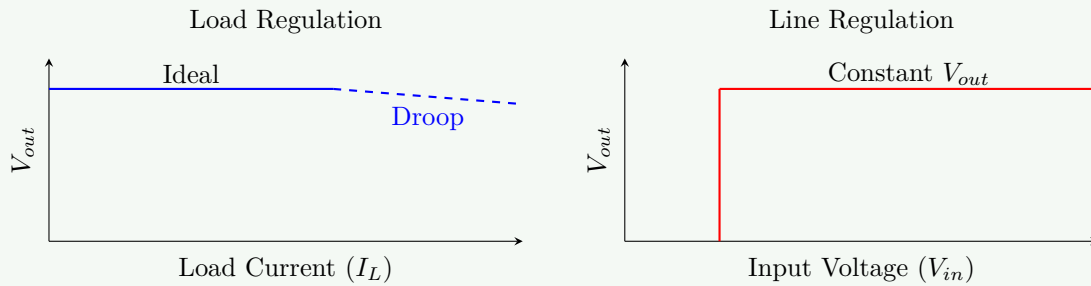
#### Mnemonic

"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:**
  - **Definition:** The ability of a power supply to maintain constant output voltage despite changes in load current.
  - **Formula:**  $\%LR = \frac{V_{NoLoad} - V_{FullLoad}}{V_{FullLoad}} \times 100$
  - **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.

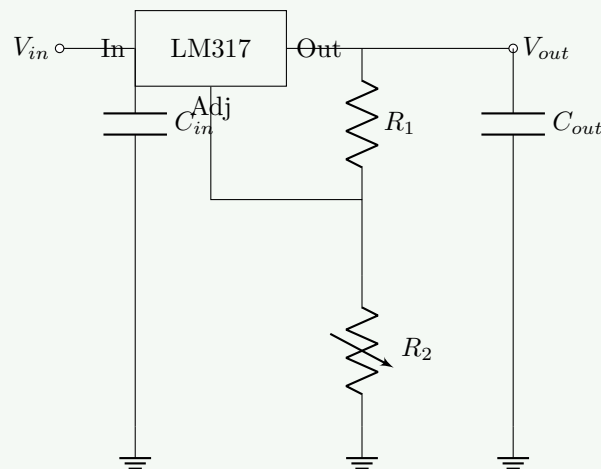
## Mnemonic

"LIVER health - **L**ine 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



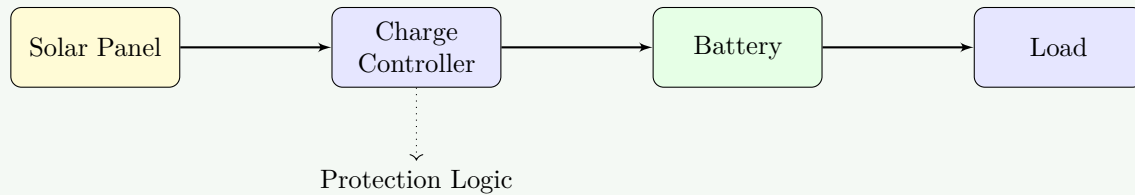
- **Description:** LM317 is a popular adjustable positive voltage regulator capable of supplying more than 1.5A over a 1.25V to 37V output range.
- **Working:**
  - It develops a nominal 1.25V reference voltage ( $V_{ref}$ ) between the Output and Adjustment terminal.
  - This reference voltage is impressed 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**ddjustable **I**ntegrated **R**egulator controls voltage precisely"

**Question 5 [a marks]**

3 Explain working of solar battery charger circuits.

**Solution**

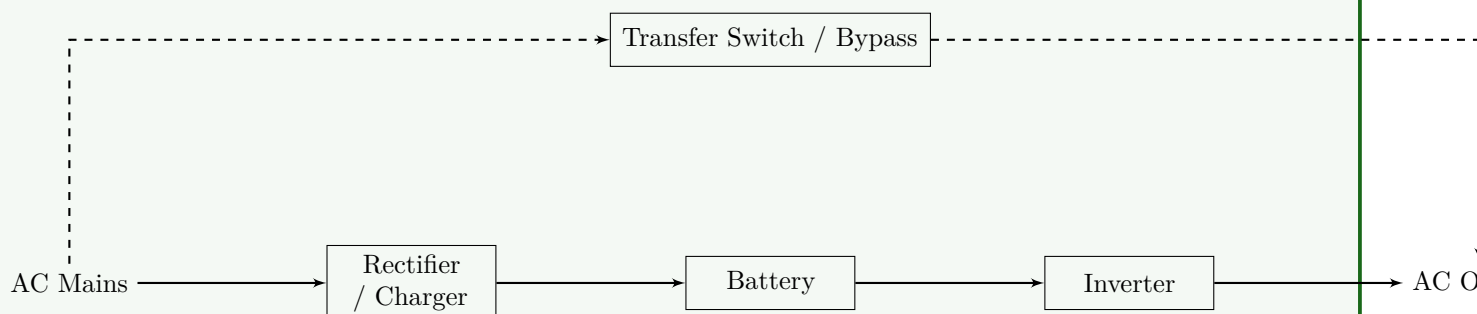
- **Function:** Converts solar energy into electrical energy to charge a rechargeable battery.
- **Charge Controller:**
  - Regulates voltage and current from solar panels.
  - Prevents **Overcharging** (which damages battery) and **Reverse Current** (battery discharging into panel at night).
- **Operation:** 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.

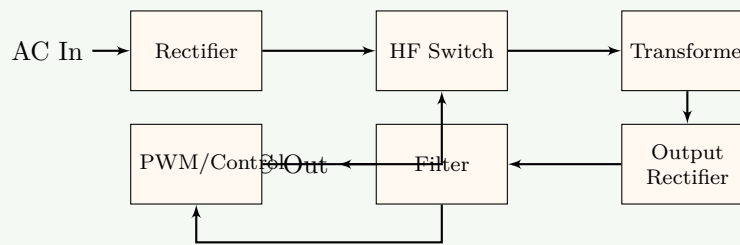
**Mnemonic**

"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"