Electronics Devices & Circuits (1323202) - Winter 2024 Solution

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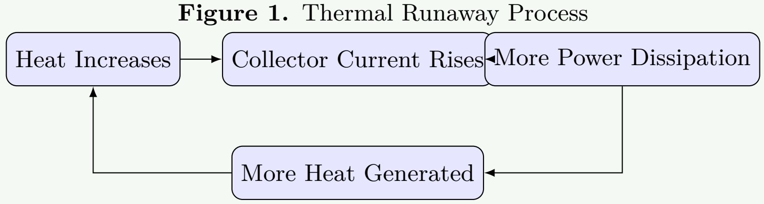
Question 1(a) [3 marks]

Explain thermal runaway in detail.

Solution

Thermal runaway is a destructive process where a transistor gets increasingly hotter until it fails.

Figure 1. Thermal Runaway Process



- **Cause**: Increased temperature decreases base-emitter voltage
- **Effect**: Collector current increases with temperature
- **Result**: Self-reinforcing cycle of heating leads to destruction

Mnemonic

"Heat Rises, Current Climbs, Transistor Dies"

Question 1(b) [4 marks]

Draw and explain fixed bias method.

Solution

Fixed bias uses a single resistor from base to voltage supply for biasing.

Figure 2. Fixed Bias Circuit

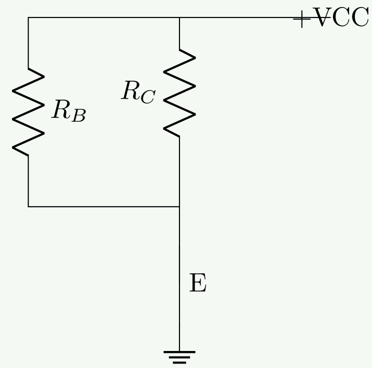
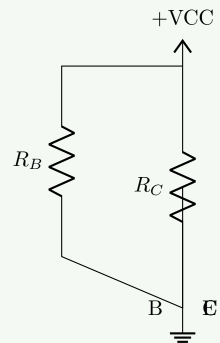


Figure 3. Fixed Bias Circuit



- **Working**: Base current $(I_B) = (V_{CC} - V_{BE})/R_B$
- **Characteristics**: Simple circuit but poor stability
- **Disadvantage**: Highly sensitive to temperature variations
- **Application**: Used in small signal circuits where stability isn't critical

Mnemonic

"Fixed Bias: One Resistor, Poor Stability"

Question 1(c) [7 marks]

List the biasing methods. Draw the circuit of voltage divider type bias method and explain it.

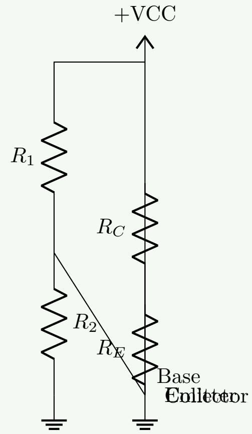
Solution

The biasing methods for transistors include several techniques for establishing proper operating points.

Table 1. Transistor Biasing Methods

Method	**Stability**	**Complexity**	**Temperature Sensitivity**
Fixed Bias	Poor	Simple	High
Collector-to-Base Bias	Medium	Medium	Medium
Voltage Divider Bias	Excellent	Complex	Low
Emitter Bias	Good	Medium	Low

Figure 4. Voltage Divider Bias Circuit



- **Working**: R_1-R_2 divider creates stable base voltage
- **Advantage**: Less affected by β variations and temperature
- **Key feature**: R_E provides negative feedback stabilization
- **Application**: Most widely used in amplifier circuits

Mnemonic

"Divide and Rule for Stable Bias"

OR

Question 1(c) [7 marks]

Draw and explain DC load line for common emitter amplifier.

Solution

DC load line represents all possible operating points of a transistor.

Figure 5. DC Load Line

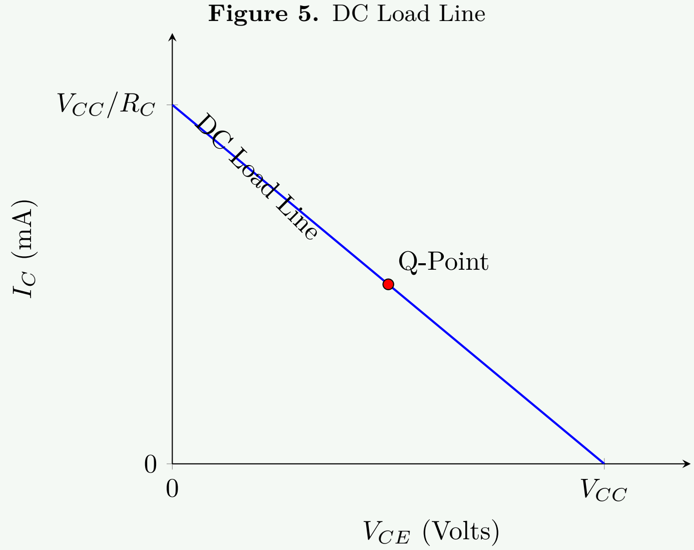


Table 2. Load Line Equations

Parameter	Equation	Description
Maximum V_{CE}	V_{CC}	When $I_C = 0$
Maximum I_C	V_{CC}/R_C	When $V_{CE} = 0$
Load Line Equation	$I_C = (V_{CC} - V_{CE})/R_C$	All possible operating points
Q-point	Set by biasing	Stable operation point

- **Purpose**: Graphically shows relationship between I_C and V_{CE}
- **Significance**: Helps determine operating point (Q-point)
- **Application**: Essential for amplifier design and analysis

Mnemonic

"Maximum Current or Maximum Voltage, Never Both"

Question 2(a) [3 marks]

Explain term (i) Gain (ii) Bandwidth.

Solution

These are key parameters that describe amplifier performance.

Table 3. Amplifier Parameters

Parameter	Definition	Unit	Significance
Gain	Ratio of output to input signal	dB	Amplification power
Bandwidth	Range of frequencies with gain not less than 70.7% of maximum	Hz	Useful frequency range

- **Gain Types**: Voltage gain (A_v), Current gain (A_i), Power gain (A_p)
- **Bandwidth Formula**: $BW = f_H - f_L$ (Higher cutoff - Lower cutoff)
- **Related Parameter**: Gain-Bandwidth Product (constant for a specific amplifier)

Mnemonic

"Gain Makes Bigger, Bandwidth Makes Broader"

Question 2(b) [4 marks]

List advantages and disadvantages of negative feedback in amplifier.

Solution

Negative feedback significantly improves amplifier performance but with tradeoffs.

Table 4. Negative Feedback Characteristics

Advantages	**Disadvantages**
Increased bandwidth	Reduced gain
Reduced distortion	More input signal required
Improved stability	More complex circuit
Better noise immunity	Potential oscillation if improperly designed
Controlled input/output impedances	Higher power consumption

Mnemonic

"Stabilize Wide And Clean, Just Give Up Gain"

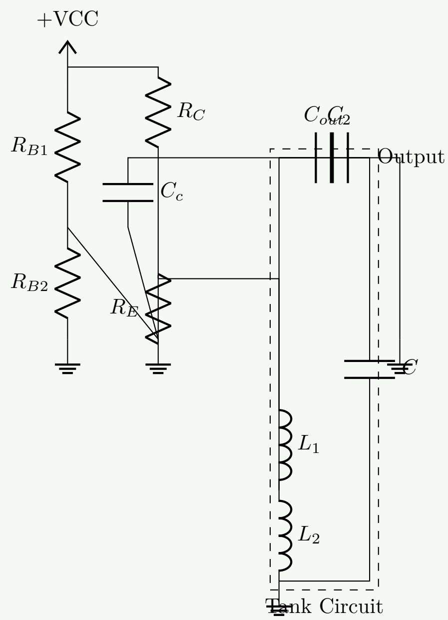
Question 2(c) [7 marks]

Draw and explain Hartley oscillator.

Solution

Hartley oscillator generates sine decorate, decoration=snake, amplitude=.4mm, segment length=2mm, post length=1mms using inductive feedback.

Figure 6. Hartley Oscillator Circuit



- **Frequency Determination**: By L_1, L_2 and C_1 values ($f = 1/2\pi\sqrt{L_{eq}C}$) where $L_{eq} = L_1 + L_2$
- **Feedback Mechanism**: Inductive voltage divider (L_1 and L_2)
- **Identifying Feature**: Tapped inductor or two inductors in series
- **Applications**: RF signal generation, radio transmitters, communication systems

Mnemonic

"Hartley Has Helpful Inductors"

OR

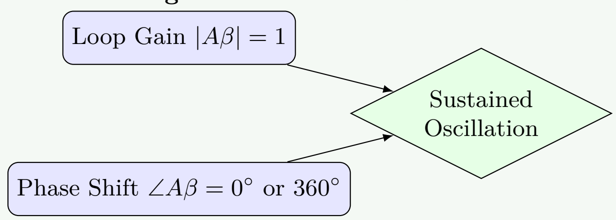
Question 2(a) [3 marks]

State and explain Barkhausen criterion of oscillation.

Solution

Barkhausen criteria define conditions for sustained oscillations.

Figure 7. Barkhausen Criteria



- **Loop Gain Condition**: $|A\beta| = 1$ (exactly 1 for sustained oscillation)
- **Phase Shift Condition**: $\angle A\beta = 0°$ or $360°$ (signal reinforcement)
- **Practical Design**: Initial $|A\beta| > 1$, eventually stabilizes at $|A\beta| = 1$

Mnemonic

"For Oscillation: Unit Gain, Zero Phase"

OR

Question 2(b) [4 marks]

Compare negative and positive feedback amplifier.

Solution

Feedback type dramatically changes amplifier behavior.

Table 5. Comparison of Feedback Types

Parameter	Negative Feedback	Positive Feedback
Gain	Decreases	Increases
Bandwidth	Increases	Decreases
Distortion	Reduces	Increases
Stability	Improves	Reduced (may oscillate)
Noise	Reduces	Amplifies
Applications	Stable amplifiers	Oscillators, triggers
In/Out impedance	Controllable	Less predictable

Mnemonic

"Negative Stabilizes, Positive Oscillates"

OR

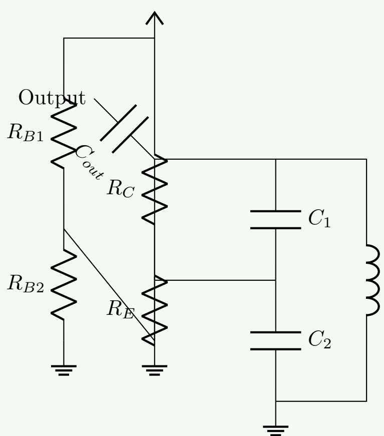
Question 2(c) [7 marks]

Draw and explain colpitt's oscillator.

Solution

Colpitt's oscillator uses capacitive voltage divider for feedback.

Figure 8. Colpitt's Oscillator Circuit



- **Frequency Determination**: By L, C_1 and C_2 values ($f = 1/2\pi\sqrt{LC_{eq}}$)
- **Feedback Mechanism**: Capacitive voltage divider (C_1 and C_2)
- **Identifying Feature**: Two capacitors in series across inductor
- **Advantage**: More stable frequency than Hartley

Mnemonic

"Colpitts Catches Capacitive Current"

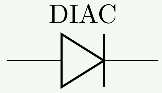
Question 3(a) [3 marks]

Explain about DIAC.

Solution

DIAC (Diode for Alternating Current) is a bidirectional trigger diode.

Figure 9. DIAC Symbol



- **Operation**: Conducts in both directions after breakdown voltage
- **Characteristic**: Symmetrical V-I curve in both directions
- **Key Parameter**: Breakover voltage (typically 30-40V)
- **Main Application**: Triggering TRIACs in AC power control

Mnemonic

"DIAC: Double Direction Breakdown Device"

Question 3(b) [4 marks]

Explain triggering methods of SCR.

Solution

SCR can be triggered to conduct by several methods.

Table 6. SCR Triggering Methods

Method	Description	Advantages	Limitations
Gate Triggering	Current pulse at gate	Most common, controllable	Requires control circuit
Temperature	High temperature	No external circuit	Uncontrolled, unreliable
Voltage	Exceeding breakover voltage	No external circuit	Stresses device, uncontrolled
dv/dt	Rapid voltage rise	Simple	Can cause unwanted triggering
Light	Photons hitting junction	Electrical isolation	Requires special packaging

Mnemonic

”Gate Voltage Temperature Rate Light”

Question 3(c) [7 marks]

Draw symbol and construction of SCR. Also draw and explain V-I characteristic of SCR.

Solution

SCR (Silicon Controlled Rectifier) is a four-layer PNPN semiconductor device with three terminals.

Figure 10. SCR Symbol and Construction

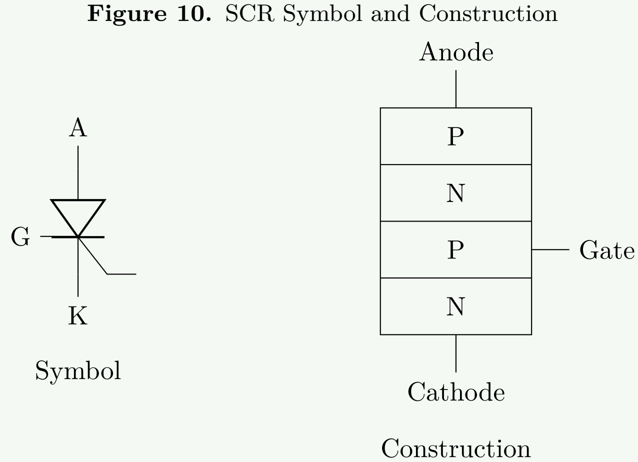
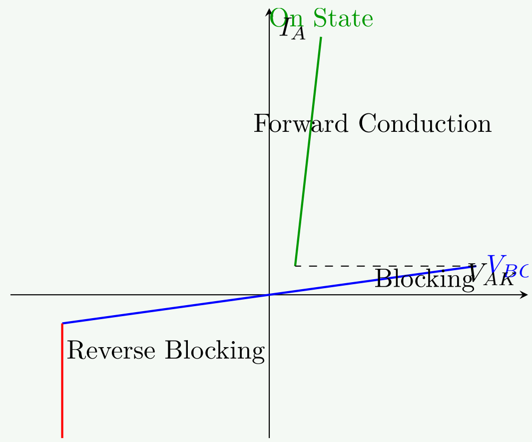


Figure 11. SCR V-I Characteristic



- **Forward Blocking**: Low current until triggering
- **Forward Conduction**: High current after triggering (latched)
- **Holding Current**: Minimum current to maintain conduction
- **Latching Current**: Minimum current to start latching
- **Reverse Blocking**: Blocks current in reverse direction

Mnemonic

"Trigger Once, Conducts Forever, Until Current Falls"

OR

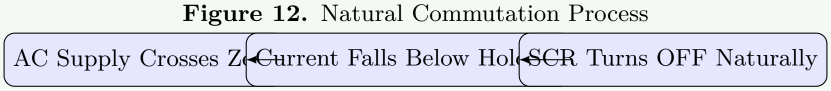
Question 3(a) [3 marks]

Explain about natural commutation technique of SCR.

Solution

Natural commutation turns off SCR without external circuit when AC current naturally reaches zero.

Figure 12. Natural Commutation Process



- **Principle**: Uses natural zero-crossing of AC supply
- **Advantage**: No additional commutation circuit required
- **Application**: AC power control circuits, light dimmers
- **Limitation**: Only works with AC supplies, not DC

Mnemonic

"Natural Commutation: Zero Current, Zero Effort"

OR

Question 3(b) [4 marks]

Explain about Opto-couplers.

Solution

Opto-couplers provide electrical isolation using light transmission.

Figure 13. Opto-coupler Structure

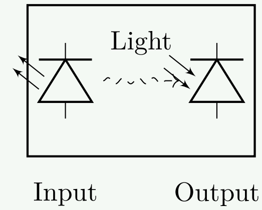


Table 7. Opto-coupler Types

Type	Photodetector	Speed	Applications
Standard	Phototransistor	Medium	General isolation
High-speed	Photodiode	Fast	Digital communication
TRIAC	Photo-TRIAC	Slow	AC power control
Linear	Photodarlington	Slow	Analog signals

- **CTR**: Current Transfer Ratio (output/input current)
- **Key Feature**: Complete electrical isolation between circuits
- **Benefits**: Noise immunity, voltage level shifting, safety

Mnemonic

"Light Leaps gaps Electrons Can't"

OR

Question 3(c) [7 marks]

Draw symbol and construction of TRIAC. Also draw and explain V-I characteristic of TRIAC.

Solution

TRIAC (Triode for Alternating Current) is a bidirectional three-terminal semiconductor device.

Figure 14. TRIAC Symbol and Structure

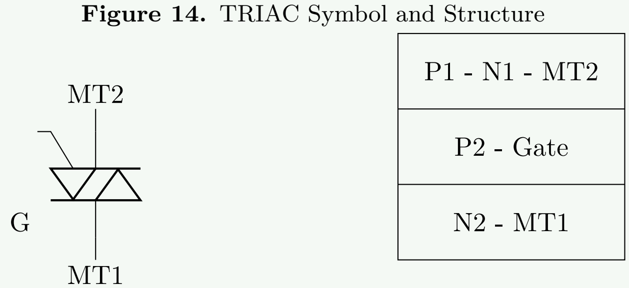
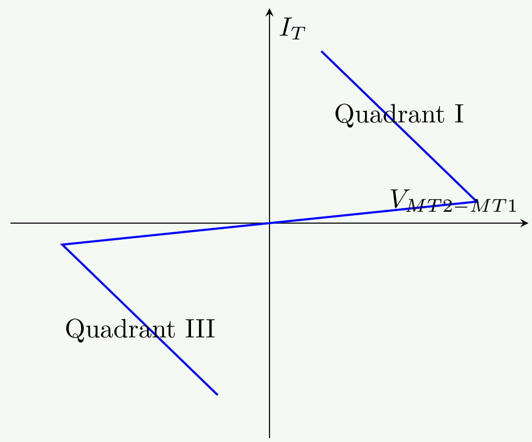


Figure 15. TRIAC V-I Characteristic



- **Bidirectional**: Conducts in both directions after triggering
- **Quadrant Operation**: Four triggering modes based on polarities
- **Applications**: AC power control, light dimmers, motor control
- **Advantage over SCR**: Controls both halves of AC cycle

Mnemonic

"TRIAC: Two-way Road In AC Circuits"

Question 4(a) [3 marks]

State characteristics of ideal Op-Amp.

Solution

An ideal Op-Amp has perfect characteristics that real Op-Amps approximate.

Table 8. Ideal Op-Amp Characteristics

Parameter	Ideal Value	Meaning
Open-loop gain	Infinite	Amplifies smallest input difference
Input impedance	Infinite	Draws no current from source
Output impedance	Zero	Can drive any load
Bandwidth	Infinite	Works at all frequencies
CMRR	Infinite	Rejects common-mode signals
Slew rate	Infinite	Instantaneous output change
Offset voltage	Zero	No output with zero input

Mnemonic

"Infinite Gain, Impedance, Bandwidth; Zero Offset, Output Z"

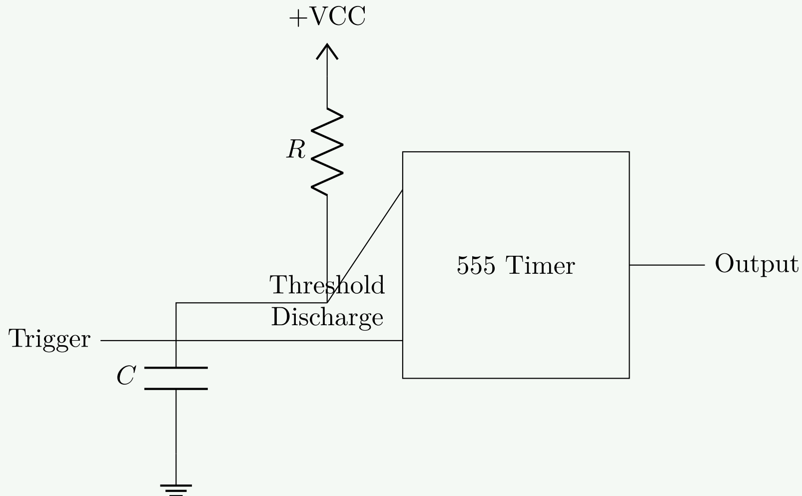
Question 4(b) [4 marks]

Draw and explain monostable multivibrator using 555 timer IC.

Solution

Monostable multivibrator produces single pulse of fixed duration when triggered.

Figure 16. Monostable 555 Circuit



Question 4(c) [7 marks]

Draw and explain Inverting amplifier using IC 741. Also draw input and output decorate, decoration=snake, amplitude=.4mm, segment length=2mm, post length=1mmforms.

Solution

Inverting amplifier reverses polarity while amplifying input signal.

Figure 17. Inverting Amplifier Circuit

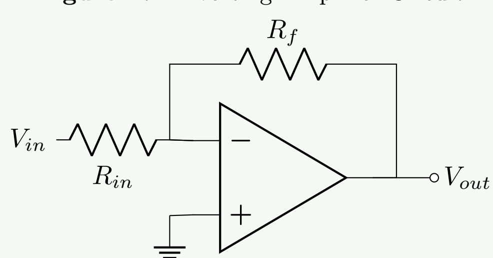
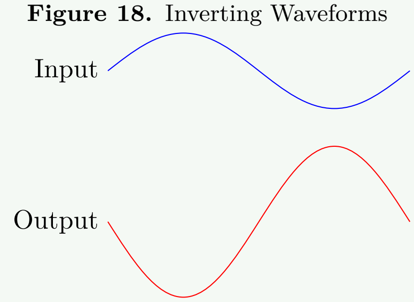


Figure 18. Inverting Waveforms



- **Gain Equation**: $A_v = -R_f/R_{in}$
- **Input Impedance**: Equal to R_{in}
- **Virtual Ground**: Inverting input maintained near 0V

Mnemonic

"Flips and Multiplies by Rf/Rin"

OR

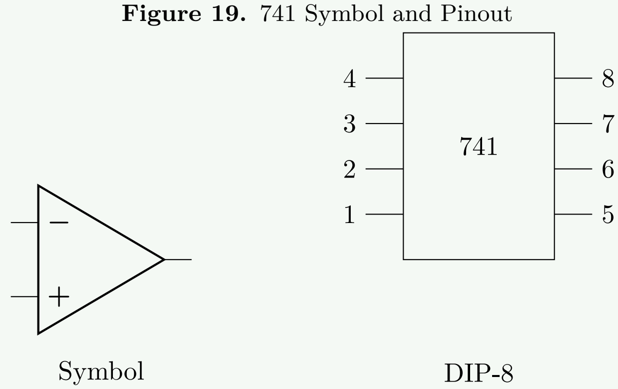
Question 4(a) [3 marks]

Draw symbol and pin diagram of IC 741.

Solution

The 741 is a popular general-purpose operational amplifier.

Figure 19. 741 Symbol and Pinout



- **Pin Functions**: 2:Inverting, 3:Non-inv, 6:Output, 7:V+, 4:V-
- **Optional Pins**: 1,5:Offset Null, 8:NC

Mnemonic

"Never Invert Plus, Very Output Not Connected"

OR

Question 4(b) [4 marks]

Explain term (i) CMRR (II) Slew Rate.

Solution

These parameters define operational amplifier performance limits.

Table 9. Key Op-Amp Parameters

Parameter	Typical Value	Significance
CMRR	90-120 dB	Higher is better
Slew Rate	0.5-50 V/μs	Higher for faster signals

- **CMRR**: Ratio of differential gain to common-mode gain
- **Slew Rate**: Maximum rate of output voltage change

OR

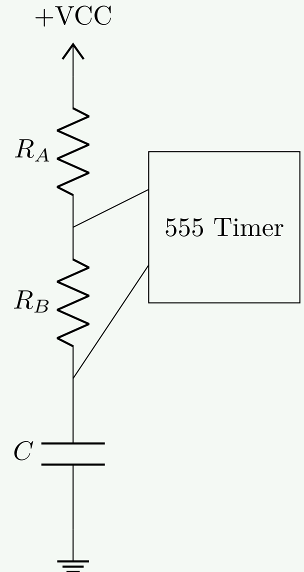
Question 4(c) [7 marks]

Draw and explain Astable multivibrator using 555 timer IC.

Solution

Astable multivibrator generates continuous square decorate, decoration=snake, amplitude=.4mm, segment length=2mm, post length=1mms.

Figure 20. Astable 555 Circuit



- **Timing**: $T_{high} = 0.693(R_A + R_B)C$, $T_{low} = 0.693(R_B)C$
- **Frequency**: $f = 1.44/((R_A + 2R_B)C)$

Question 5(a) [3 marks]

Draw basic block diagram of regulated power supply and explain it.

Solution

A regulated power supply converts AC to stable DC voltage.

Figure 21. Power Supply Block Diagram

Mnemonic

"Transformer Rectifies Filters Regulates"

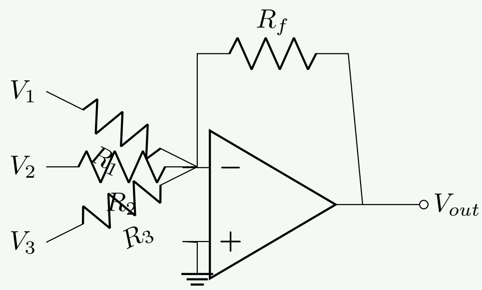
Question 5(b) [4 marks]

Draw and explain summing amplifier using Op-amp.

Solution

Summing amplifier adds multiple input signals with weighted proportions.

Figure 22. Summing Amplifier



- **Output Equation**: $V_{out} = -R_f(V_1/R_1 + V_2/R_2 + V_3/R_3)$

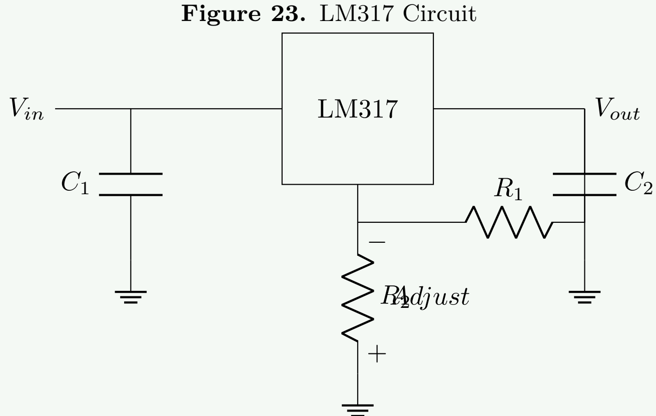
Question 5(c) [7 marks]

Draw and explain the circuit diagram of 3 terminal voltage regulator using IC LM317 with adjustable output voltage.

Solution

LM317 is a versatile adjustable voltage regulator.

Figure 23. LM317 Circuit



- **Output Voltage**: $V_{out} = 1.25(1 + R_2/R_1)$

Mnemonic

"Adjust with R2, Reference Stays at 1.25"

OR

Question 5(a) [3 marks]

State full form of SMPS. Also state applications of SMPS.

Solution

SMPS stands for Switch Mode Power Supply.

Table 10. SMPS Applications

Application	SMPS Type
Computer Power Supply	ATX
Mobile Phone Chargers	Flyback
LED Drivers	Buck

Mnemonic

"Switch Mode Powers Small devices"

OR

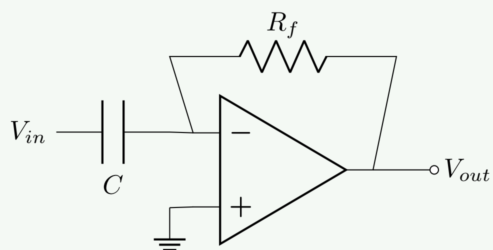
Question 5(b) [4 marks]

Draw and explain differentiator using Op-amp.

Solution

Differentiator produces output proportional to rate of change of input.

Figure 24. Differentiator Circuit



- **Equation**: $V_{out} = -RC(dV_{in}/dt)$
- **Applications**: Waveshaping, rate-of-change detection

Mnemonic

"Rate of Change Goes In, Amplitude Comes Out"

OR

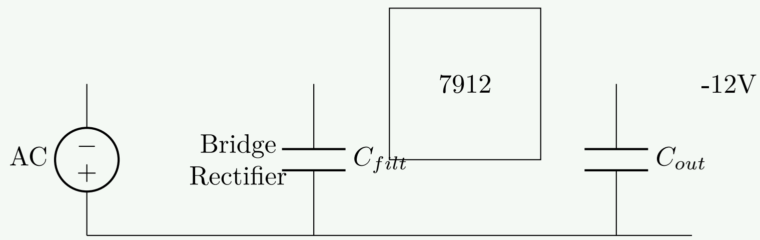
Question 5(c) [7 marks]

Draw and explain the circuit diagram of -12 V regulated dc power supply.

Solution

A -12V regulated supply provides stable negative voltage.

Figure 25. -12V Power Supply



- **Key Component**: 7912 Regulator for negative voltage

Mnemonic

"Full Bridge, Big Capacitor, 7912 Regulates Negative"