

# Fundamentals of Electronics (DI01000051) - Summer-2025 Solution

Milav Dabgar

June 12, 2025

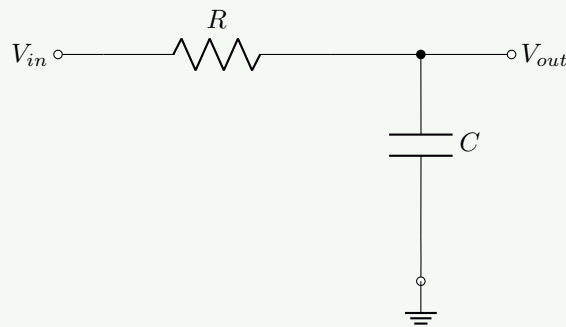
## Question 1(a) [3 marks]

Draw a simple RC (Resistor-Capacitor) low-pass filter circuit.

### Solution

An **RC low-pass filter** is a passive electronic circuit that allows “low-frequency signals” to pass while attenuating ‘high-frequency signals’. It consists of a **resistor** (R) and **capacitor** (C) connected in series.

**Circuit Diagram:**



**Figure 1.** RC Low-Pass Filter Circuit

**Key Characteristics:**

- **Cutoff Frequency:**  $f_c = \frac{1}{2\pi RC}$  (frequency at which output is 70.7% of input)
- **Low Frequencies:** Pass through with minimal attenuation
- **High Frequencies:** Blocked by capacitor acting as low impedance to ground

### Mnemonic

“RC-LP: Resistor-Capacitor blocks High, passes Low”

## Question 1(b) [4 marks]

Calculate the cutoff frequency of an RC low-pass filter with  $R = 1.5\text{ k}\Omega$  and  $C = 100\text{ nF}$ . Also find the output voltage if input is 10V at cutoff frequency.

### Solution

**Given Data:**

- Resistance:  $R = 1.5\text{ k}\Omega = 1500\text{ }\Omega$
- Capacitance:  $C = 100\text{ nF} = 100 \times 10^{-9}\text{ F}$
- Input Voltage:  $V_{in} = 10\text{ V}$

**Step 1: Calculate Cutoff Frequency** The cutoff frequency formula for RC low-pass filter is:

$$f_c = \frac{1}{2\pi RC}$$

Substituting values:

$$f_c = \frac{1}{2\pi \times 1500 \times 100 \times 10^{-9}}$$

$$f_c = \frac{1}{2\pi \times 1.5 \times 10^{-4}}$$

$$f_c = \frac{1}{9.42 \times 10^{-4}} = 1061.57 \text{ Hz} \approx 1.06 \text{ kHz}$$

**Step 2: Calculate Output Voltage at Cutoff** At cutoff frequency, output voltage is **0.707 times** (or  $\frac{1}{\sqrt{2}}$ ) the input voltage:

$$V_{out} = 0.707 \times V_{in} = 0.707 \times 10 = 7.07 \text{ V}$$

**Results:**

- **Cutoff Frequency:**  $f_c = 1.06 \text{ kHz}$
- **Output Voltage:**  $V_{out} = 7.07 \text{ V}$  at cutoff
- **Attenuation:**  $-3 \text{ dB}$  at cutoff frequency
- **Phase Shift:**  $-45^\circ$  at cutoff frequency

**Mnemonic**

“RC-Formula:  $f_c = 1/(2\pi RC)$ ,  $V_{out} = 0.707 V_{in}$  at  $f_c$ ”

## Question 1(c) [7 marks]

Compare active and passive electronic components with suitable examples.

### Solution

Electronic components are classified into **active** and **passive** categories based on their ability to control or amplify electrical energy.

**Table 1.** Active vs Passive Components Comparison

Characteristic	Active Components	Passive Components
Energy Source	Require external power source	Do not require external power
Control Ability	Can control/amplify current flow	Cannot amplify, only regulate
Directionality	Usually unidirectional	Bidirectional
Power Gain	Provide power gain ( $> 1$ )	Power gain is always $\leq 1$
Examples	Transistors (BJT, FET), Diodes (LED, Zener), ICs (Op-Amp, 555 Timer), SCR	Resistors, Capacitors, Inductors, Transformers
Function	Amplification, switching, oscillation, rectification	Resistance, capacitance, inductance, filtering
Linearity	Can be linear or non-linear	Generally linear

**Active Components in Detail:**

- **Transistors:** Used for amplification and switching. BJT uses current control, FET uses voltage control.

- **Diodes:** Allow current in one direction. LED emits light, Zener regulates voltage.
- **ICs:** Integrated circuits like 555 timer (oscillator), op-amps (amplifier).
- **Power Requirement:** All active components need DC bias/supply to operate.

#### Passive Components in Detail:

- **Resistors:** Oppose current flow, dissipate power as heat. Value in  $\Omega$ .
- **Capacitors:** Store energy in electric field. Value in Farads (F), blocks DC, passes AC.
- **Inductors:** Store energy in magnetic field. Value in Henry (H), opposes AC changes.
- **Transformers:** Transfer energy between circuits via magnetic coupling.

**Key Distinction:** The fundamental difference is that active components can “inject power” into a circuit (amplification), while passive components can only “absorb or store” energy, never increase it.

#### Mnemonic

“ACTIVE = Amplify, Control, Transform; PASSIVE = Resist, Store, Filter”

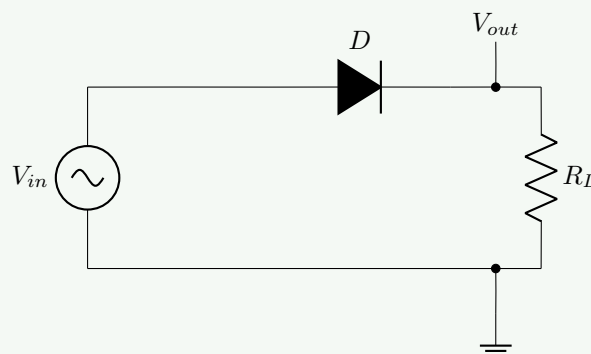
## Question 1(c OR) [7 marks]

Draw and explain the working of a half-wave rectifier circuit with input and output waveforms.

#### Solution

A **half-wave rectifier** converts AC voltage to pulsating DC by allowing only one half-cycle (positive or negative) of the input AC waveform to pass through.

#### Circuit Diagram:

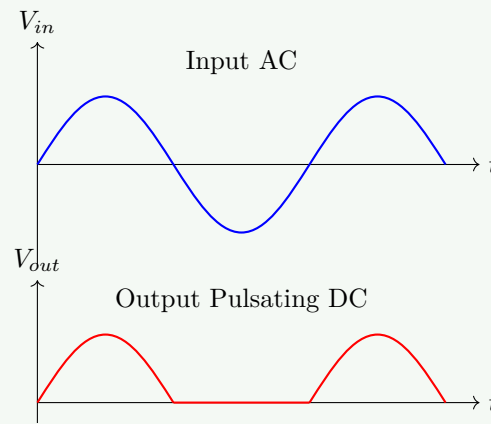


**Figure 2.** Half-Wave Rectifier Circuit

#### Working Principle:

1. **Positive Half-Cycle:** When input AC is positive, diode is forward-biased (conducts). Current flows through load resistor  $R_L$ , producing output voltage.
2. **Negative Half-Cycle:** When input AC is negative, diode is reverse-biased (blocks). No current flows, output voltage is zero.
3. **Result:** Only positive half-cycles appear at output, creating pulsating DC.

#### Waveform Representation:



**Figure 3.** Input and Output Waveforms

**Key Parameters:**

- **Efficiency:**  $\eta = 40.6\%$  (theoretical maximum)
- **Ripple Factor:**  $r = 1.21$  (high ripple content)
- **Peak Inverse Voltage (PIV):**  $PIV = V_m$  (maximum reverse voltage across diode)
- **DC Output:**  $V_{DC} = \frac{V_m}{\pi} = 0.318V_m$  where  $V_m$  is peak AC voltage

**Applications:** Half-wave rectifiers are used in low-power applications like battery charging, signal demodulation, and voltage multipliers. They are *not suitable* for high-power applications due to poor efficiency.

**Mnemonic**

“HWR: Half-Wave = Half output, 40.6% efficiency,  $PIV = V_m$ ”