5.2 Rectifiers and dc supplies

Name: _____ Class: _____ Date: _____ **Total: 22 marks**

KEY WORDS half-wave rectifier • bridge rectifier • filter capacitor • ripple • zener diode

Objective

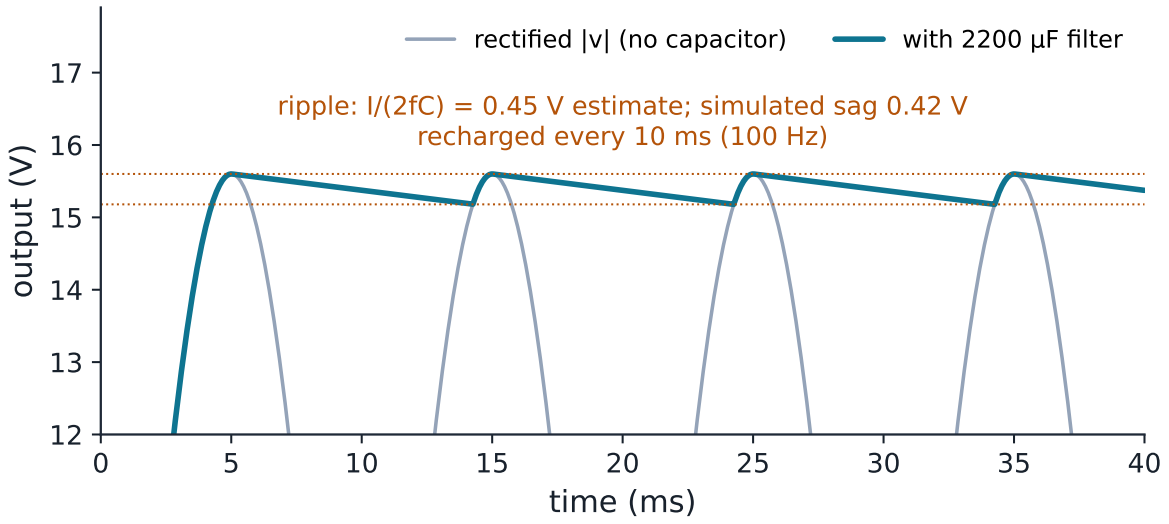
Analyse half- and full-wave rectifiers with capacitor filters, size a filter for a ripple specification, and check zener regulation against its current window and power limit.

1 Key knowledge and worked examples

■ The rectifier family

A **half-wave rectifier** conducts one half-cycle (one diode drop). A **full-wave bridge rectifier** conducts both half-cycles through two diodes at a time (1.4 V total). Peak output = $V_{peak} - diodedrops$.

Worked example. A 12 V RMS secondary at 50 Hz into a bridge: peak $12\sqrt{2} = 17.0V$, output peak `17.0 - 1.4 = 15.6 V`.



Full-wave bridge with 2200 µF at 100 mA: the capacitor bridges the gaps.

■ The filter capacitor and ripple

A **filter capacitor** holds the output between recharge peaks. The **ripple** $\Delta V \approx I/(f_r C)$ where f_r is the recharge rate (f for half-wave, 2f for full-wave).

Worked example. 100 mA load, 2200 µF, bridge (recharges every 10 ms): $\Delta V = 0.1/(100 \times 2200\mu) = 0.45V$. The output sits between 15.6 V (peak) and 15.1 V. Design rule: choose C from the spec – $C \geq I/(f_r \cdot \Delta V)$; e.g. requiring 0.2 V at 150 mA needs $C \geq 0.15/(100 \times 0.2) = 7500\mu F$.

■ Zener regulation, by the window

A **zener** regulator holds V_Z while I_Z stays within its window: above $I_Z(min)$ (regulation) and below $P_Z(max)/V_Z$ (survival). The check is two inequalities at the extreme loads – and the series resistor dissipates $(V_{in} - V_Z) \times I_R$, which is part of the design too.

2 Practice

2.1 A half-wave rectifier on a 6 V RMS, 50 Hz secondary (one diode): compute the peak output voltage. [2]

2.2 A bridge with 1000 µF supplying 50 mA from a 50 Hz supply: compute the ripple and the recharge interval. [3]

2.3 A 9 V zener regulator (R = 220 Ω from 12 V) feeds a variable load. Give I_R and the zener current at open circuit. [3]

3 Exam-style questions

3.1 Design a bridge supply: 15 V regulated output from a zener, load 0–120 mA, input 24 V DC, ripple at the filter $\leq$ 1 V.

Choose the series R for the zener path (zener needs $\geq$ 5 mA at full load), size the filter capacitor (from a 100 Hz recharge), and check the zener and resistor power at worst case. State which load case is worst for each component. [8]

3.2 A half-wave supply must deliver 20 mA DC with ripple $\leq$ 0.5 V from a 9 V RMS, 50 Hz secondary (one diode, constant-drop), capacitor filter.

Compute the peak output, the required capacitance, and the diode's average current. Then explain (with the numbers) why the same capacitor on a bridge halves the ripple, and give the peak diode current rationale (the capacitor recharges in a brief slug near the peak). [6]

Solutions

2.1

- Peak secondary: $6\sqrt{2} = 8.49V$; minus 0.7: `7.79 V`.

2.2

- $\Delta V = I/(2f \cdot C) = 0.05/(100 \times 1000\mu) = 0.5V$.
- Recharge interval: 10 ms (every half-cycle).

2.3

- $I_R = (12 - 9)/220 = 13.6mA$.
- Open circuit (no load current): $I_Z = 13.6mA$ – all of it.

3.1

- Filter R sees the zener input node; design the zener chain from the DC side first: full load needs $I_R(max) = 120 + 5 = 125mA$.
- $R = (24 - 15)/0.125 = 72\Omega$ (use 68 Ω standard → $I_R = 9/68 = 132mA$).
- Zener current at full load: `132 - 120 = 12 mA` ≥ 5 ✓.
- Capacitor from the ripple spec at recharge 100 Hz: `C ≥ I/(f_r ΔV) = 0.132/(100 × 1) = 1320 µF` (use 1500 µF).
- Worst zener case = OPEN load: $I_Z = 132mA$, $P_Z = 15 \times 0.132 = 1.98W$ – needs a $\geq$ 2 W zener.
- Worst resistor case = same open load (max current both paths): $P_R = 9 \times 0.132 = 1.19W$ – a 2 W resistor.

3.2

- Peak output: $9\sqrt{2} - 0.7 = 12.0V$.
- Capacitance: $C \geq I/(f\Delta V) = 0.02/(50 \times 0.5) = 800\mu F$ (half-wave: f = 50 Hz).
- Diode average current = load DC = 20 mA (charge in = charge out).
- On a bridge the recharge is 100 Hz: `ΔV = I/(2fC) = 0.02/(100 × 800µ) = 0.25 V` – exactly half, because the capacitor waits only 10 ms instead of 20 ms.
- Peak diode current: the capacitor recharges only near the AC peak, replacing in ~1 ms what the load took for a whole period – so the diode's peak current is several times its average (the reason diodes have a surge rating).