EE461g Practice Exam 1
Solutions Guide

Questions 1–8: Vout vs Vin Curve Shapes (Ideal Diodes, $r_d = 0$)

Waveform Reference:

- **A**: Positive half only (passes positive, blocks negative)
- **B**: Negative half only (passes negative, blocks positive)
- **C**: Dead zone (1:1 except zero output near origin)
- **D**: Limiter (clipped/limited from above and below)

Question 1: V_{out} (across R) – Series D then R

Answer: (a) – Waveform A

Explanation:

- When $V_{in} > 0$: Diode forward biased, conducts, $V_{out} = V_{in}$
- When $V_{in} < 0$: Diode reverse biased, no current, $V_{out} = 0$
- **Positive half-wave rectifier**

Question 2: V_{out} (across Zener D) – Series R then Zener

Answer: (c) – Waveform C (Dead Zone)

Explanation:

- When $V_{in} < 0$: Zener forward biased, $V_D = 0$
- When $0 < V_{in} < V_{ZK}$: Zener reverse biased (no breakdown), $V_D = V_{in}$
- When $V_{in} > V_{ZK}$: Zener breakdown, $V_D = V_{ZK}$ (clamped)
- **Dead Zone**: zero output near origin, follows V_{in} outside dead zone

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Question 3: V_{out} (across R) – Series Diodes D_a and D_b

Answer: (a) – Waveform A

Explanation:

- D_a and D_b are in series, both pointing same direction
- When $V_{in} > 0$: Both diodes forward biased, $V_{out} = V_{in}$
- When $V_{in} < 0$: Both diodes reverse biased, $V_{out} = 0$
- **Positive half-wave** (same as single diode)

Question 4: V_{out} (across R_b) – Back-to-back Zeners with R_a, R_b

Answer: (d) – Waveform D (Limiter)

Explanation:

- D_a and D_b are back-to-back Zeners (cathode-to-cathode)
- Small $|V_{in}|$: Both Zeners off, $V_{out} = V_{in} \cdot R_b/(R_a + R_b)$
- Large positive V_{in}: D_a breakdown, clips at $+V_{ZK}$
- Large negative V_{in}: D_b breakdown, clips at $-V_{ZK}$
- **Bidirectional limiter**

Question 5: V_{out} (across D) – Series D then R

Answer: (b) – Waveform B

Explanation:

- Same circuit as Q1, but measuring across D instead of R
- When $V_{in} > 0$: D conducts, $V_D = 0$
- When $V_{in} < 0$: D off, $V_D = V_{in}$ (all negative voltage appears across D)
- **Negative half-wave**

Question 6: V_{out} (across R) – Series R then Zener D

Answer: (c) – Waveform C (Dead Zone)

Explanation:

- Same circuit as Q2, but measuring across R instead of Zener
- When $V_{in} < 0$: Zener forward biased, $V_R = V_{in}$
- When $0 < V_{in} < V_{ZK}$: Zener open, no current, $V_R = 0$ (dead zone)
- When $V_{in} > V_{ZK}$: Zener breakdown, $V_R = V_{in} - V_{ZK}$
- **Dead zone** from 0 to V_{ZK}

Question 7: V_{out} (across R) – Anti-parallel D with R in series

Answer: (d) – Waveform D

Explanation:

- D_a and D_b are anti-parallel, R is in series
- When $V_{in} > 0$: D_a conducts, current through R
- When $V_{in} < 0$: D_b conducts, current through R (opposite direction)
- One diode always conducts: $V_{out} = V_{in}$ (straight line)

Question 8: V_{out} (across R) – Full-Wave Bridge Rectifier

Answer: (c) – Waveform C

Explanation:

- Positive half-cycle: D_a and D_d conduct
- Negative half-cycle: D_b and D_c conduct
- Current through R always flows in same direction
- **Full-wave rectified**: $V_{out} = |V_{in}|$

Questions 9–13: Slope Calculations (Non-ideal Diodes, $r_d > 0$)

Question 9: Slope when diode forward biased

Answer: (b) $\dfrac{R}{R + r_d}$

Explanation:

- When diode conducts, it acts as resistance r_d
- Voltage divider: $V_{out} = V_{in} \times \dfrac{R}{R + r_d}$
- Slope $= \dfrac{R}{R + r_d}$

Question 10: Zener Diode Reverse Biased Region

Answer: $-V_f < V_{in} < V_{ZK}$ **(approximately** $-0.7V$ **to** $+5V$**)**

Explanation:

- For $V_{in} < -V_f$: Zener is forward biased (conducting forward)
- For $V_{in} > V_{ZK}$: Zener is in breakdown (conducting in reverse)
- Between $-V_f$ and V_{ZK}: Zener is reverse biased but not conducting (no current)

Question 11: Two Series Diodes, Slope across R

Answer: (b) $\dfrac{R}{R + 2r_d}$

Explanation:

- Two diodes in series: total dynamic resistance $= 2r_d$
- Voltage divider: Slope $= \dfrac{R}{R + 2r_d}$

Question 12: Anti-parallel Diodes with R_a and R_b, Both Forward Biased

Answer: (d) $\dfrac{2r_d \| R_b}{R_a + (2r_d \| R_b)}$

Explanation:

- When both diodes conduct, their resistances ($2r_d$) appear in parallel with R_b
- Combined load impedance: $2r_d \| R_b$
- Voltage divider with R_a: Slope $= \dfrac{2r_d \| R_b}{R_a + 2r_d \| R_b}$

Question 13: Full-Wave Bridge, $V_{in} < -2V_f$, Slope across R

$\boxed{\textbf{Answer: (b) } \frac{R}{R+2r_d}}$

Explanation:

- When $V_{in} < -2V_f$, two diodes conduct in series
- Total series resistance $= 2r_d$
- Slope $= \dfrac{R}{R+2r_d}$ (magnitude, sign depends on reference)

Questions 14–17: Time Domain Waveforms (Sinusoidal Input)

Waveform Reference:

- **(a)**: Full sine wave (both positive and negative)
- **(b)**: Positive half-wave rectified
- **(c)**: Negative half-wave rectified
- **(d)**: Flat/clipped

Question 14: V_{out} (across R_b) – Anti-parallel Diodes as Clipper

Input: $5\sin(\omega t)$

Answer: (d) – Clipped Sine Wave

Explanation:

- D_a and D_b are anti-parallel, in parallel with R_b
- When $V_{out} > V_f$: D_a conducts, clips positive peaks at $+V_f$
- When $V_{out} < -V_f$: D_b conducts, clips negative peaks at $-V_f$
- **Clipped sine wave** at $\pm V_f \approx \pm 0.7V$

Question 15: V_{out} (across R) – Series Diodes

Input: $5\sin(\omega t)$

Answer: (b) – Positive Half-Wave

Explanation:

- D_a and D_b are in series (same direction)
- Both must conduct for current to flow
- Conducts only when $V_{in} > 2V_f \approx 1.4V$
- **Positive half-wave rectified** output

Question 16: V_{out} (across R) – Anti-parallel Pairs on Both Sides

Input: $5\sin(\omega t)$

Answer: (a) – Straight Line (Bidirectional with Dead Zone)

Explanation:

- Two anti-parallel diode pairs, one on each side of R
- Provides bidirectional conduction
- V_{out} follows V_{in} with dead zone when $|V_{in}| < 2V_f$
- **Straight line** behavior (output tracks input polarity)

Question 17: V_{D1} (across First Diode Pair) – Anti-parallel Circuit

Input: $5\sin(\omega t)$

Answer: (d) – Clipped Sine Wave

Explanation:

- Same circuit as Problem 16, but measuring across the first diode pair
- When $V_{in} > 2V_f$: D_{1a} conducts, $V_{D1} = +V_f$ (clipped)
- When $V_{in} < -2V_f$: D_{1b} conducts, $V_{D1} = -V_f$ (clipped)
- **Clipped sine wave** at $\pm V_f$

Questions 18–22: Numerical Calculations

Question 18: Square-Law Device – Find V_s

Given: $A = 10$ mA/V^2, $V_{TR} = 0$, 10V source, 1kΩ resistor

Answer: (d) +0.95125

Solution:

$$I = A(V_s - V_{TR})^2 = 0.01 \times V_s^2$$

$$\text{KVL: } 10 = I \times 1000 + V_s = 10V_s^2 + V_s$$

$$10V_s^2 + V_s - 10 = 0$$

$$V_s = \frac{-1 + \sqrt{1 + 400}}{20} = \frac{-1 + 20.02}{20} = \boxed{0.951\text{V}}$$

Question 19: Square-Law Device – Find r_d

Answer: (b) 53 ohms

Solution:

$$r_d = \frac{1}{dI/dV} = \frac{1}{2AV_s}$$

$$r_d = \frac{1}{2 \times 0.01 \times 0.951} = \frac{1}{0.01902} \approx \boxed{53\ \Omega}$$

Question 20: Two Diodes – Find V_{out}

Given: $V_f = 0.3$ V, $r_d \approx 1\ \Omega$, 5V source, two 1kΩ resistors

Answer: (b) 0.60 volts

Solution: The output V_{out} is measured across the two diodes in series.

$$V_{out} = 2V_f = 2 \times 0.3\text{V} = \boxed{0.60\text{ V}}$$

Question 21: Power from 5V Supply

Answer: (c) 22 mW

Solution:

From Problem 20: $V_b = 0.608V$

$$I_s = \frac{V_{in} - V_b}{R_a} = \frac{5 - 0.608}{1000} = 4.39 \text{ mA}$$

$$P_s = V_{in} \times I_s = 5\text{V} \times 4.39 \text{ mA} = \boxed{22 \text{ mW}}$$

Question 22: Current Through Diodes

Answer: (c) ≈ 4 mA

Solution:

$$I_D = \frac{V_b - 2V_f}{2r_d} = \frac{0.608 - 0.6}{2} = \frac{0.008}{2} = 4 \text{ mA}$$

Or by KCL: $I_D = I_{Ra} - I_{Rb} = 4.39 - 0.61 = \boxed{3.78 \text{ mA}}$

Questions 23–27: Voltage Transfer Function Analysis

Given Circuit: $V_{in} \to 1\text{k}\Omega \to$ node with $(D_a \to R_a$ and $D_b \to R_b) \to V_{out}$

Transfer Function: Slope $= 1/3$ for $V_{out} > 0.3$V; Slope $= 1/2$ for $V_{out} < -0.7$V

Question 23: Find R_a

Answer: (a) 500 ohms

Solution:

$$\text{Slope for } D_a \text{ conducting} = \frac{1}{3} = \frac{R_a}{R + R_a} = \frac{R_a}{1000 + R_a}$$

$$3R_a = 1000 + R_a \quad \Rightarrow \quad 2R_a = 1000$$

$$R_a = \boxed{500\ \Omega}$$

Question 24: Find R_b

Answer: (b) 1,000 ohms

Solution:

$$\text{Slope for } D_b \text{ conducting} = \frac{1}{2} = \frac{R_b}{R + R_b} = \frac{R_b}{1000 + R_b}$$

$$2R_b = 1000 + R_b \quad \Rightarrow \quad R_b = \boxed{1000\ \Omega}$$

Question 25: V_f for D_a

Answer: (c) 0.3 volts

Explanation: From transfer function, D_a turns on when $V_{out} = +0.3$V. Therefore $V_f(D_a) = \boxed{0.3\text{ V}}$

Question 26: V_f for D_b

Answer: (d) 0.7 volts

Explanation: From transfer function, D_b turns on when $V_{out} = -0.7$V. Since D_b is reversed, $V_f(D_b) = \boxed{0.7\text{ V}}$

Question 27: Peak V_{out} for $V_{in}(t) = 5\sin(\omega t)$

$\boxed{\textbf{Answer: (b) 1.87 volts}}$

Solution:

$$\begin{aligned}
\text{When } D_a \text{ conducts:} \quad & V_{out} = V_f + \frac{R_a}{R + R_a}(V_{in} - V_f) \\
\text{At } V_{in} = 5\text{V}: \quad & V_{out} = 0.3 + \frac{1}{3}(5 - 0.3) \\
& V_{out} = 0.3 + \frac{4.7}{3} = 0.3 + 1.567 = \boxed{1.87 \text{ V}}
\end{aligned}$$

Questions 28–29: Full-Wave Rectifier Analysis

Given: $V_{in}(t) = 10\sin(2\pi t)$, $V_f = 0.3$ V for all diodes

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Question 28: Peak Voltage V_{max}

Answer: (c) 9.4 volts

Solution:

In full-wave bridge, two diodes conduct at any time

$$\text{Total voltage drop} = 2 \times V_f = 2 \times 0.3\text{V} = 0.6\text{V}$$

$$V_{max} = V_{in,peak} - 2V_f = 10\text{V} - 0.6\text{V} = \boxed{9.4\text{ V}}$$

Question 29: Time T_a (when V_{in} first crosses below $-2V_f$)

Answer: (c) 0.51 seconds

Solution:

$$\text{Find when } V_{in} = -2V_f = -0.6\text{V}$$

$$\begin{aligned} 10\sin(2\pi t) &= -0.6 \\ \sin(2\pi t) &= -0.06 \end{aligned}$$

$$\text{First negative crossing after } t = 0.5\text{s}:$$

$$2\pi t = \pi + \arcsin(0.06) = \pi + 0.06$$

$$t = \frac{\pi + 0.06}{2\pi} = 0.5 + \frac{0.06}{2\pi} \approx \boxed{0.51\text{ seconds}}$$

Question 30: What is your favorite color?

Answer: Student's choice! (Free point)

Summary of Answers

Q	Ans	Q	Ans	Q	Ans
1	a	11	b	21	c
2	c	12	d	22	c
3	a	13	b	23	a
4	d	14	d	24	b
5	b	15	b	25	c
6	c	16	a	26	d
7	d	17	d	27	b
8	c	18	d	28	c
9	b	19	b	29	c
10	b	20	b	30	?

Key Concepts to Remember

1. **Half-wave rectifier**: Only one polarity passes (uses single diode)
2. **Full-wave rectifier**: Both polarities converted to single polarity (bridge or center-tap)
3. **Zener diode**: Limiter (clamped output), Dead zone (zero near origin when measuring across R)
4. **Voltage divider with r_d**: Slope $= \dfrac{R}{R + r_d}$ for single diode
5. **Series diodes**: Add the r_d values ($2r_d$ for two diodes)
6. **Bridge rectifier voltage drop**: $2V_f$ (two diodes always in path)
7. **Square-law device**: $I = A(V - V_{TR})^2, \quad r_d = \dfrac{1}{2A \cdot V}$
8. **Transfer function slopes**: Slope $= \dfrac{R_{branch}}{R + R_{branch}}$ reveals resistance values
9. **Breakpoints**: Where slope changes indicates diode turn-on voltage V_f