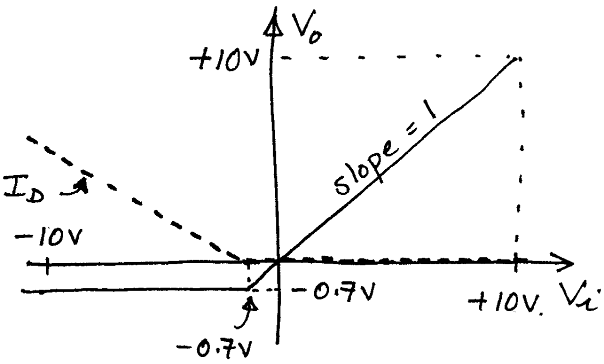
EEE123 Problem Sheet Solutions

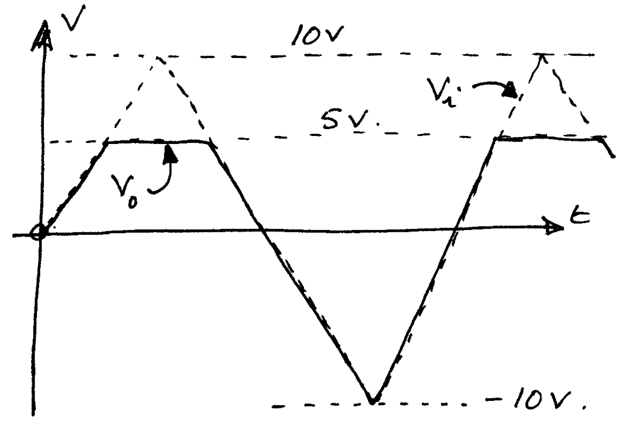
Diode, Resistor and Capacitor Circuits

Q1 The diode is on the point of conduction when $V_o = -0.7V$. For $V_i < -0.7V$, the diode conducts and $V_o = -0.7$. For $V_i > -0.7V$ the diode does not conduct, no current flows through R so $V_o = V_i$.



$$I_D = \frac{-0.7V - V_i}{R} \quad \text{for } V_i < -0.7V.$$

Q2 The diode will be on the point of conduction when $V_o = 4.3V + 0.7V = 5V$. For $V_i > 5V$, D will conduct and V_o will be held (by D) at 5V. For $V_i < 5V$, no current flows through R and so $V_o = V_i$.



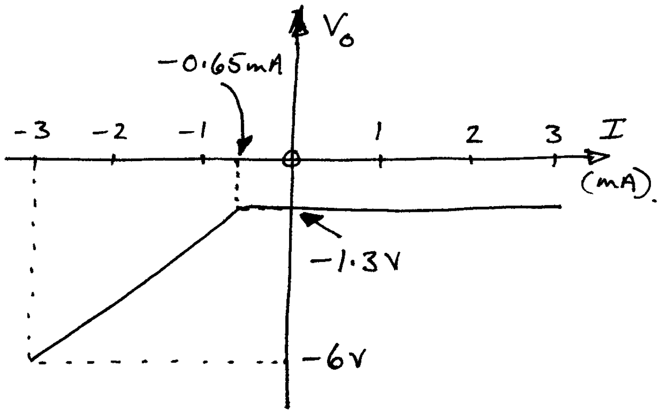
I_f max occurs when the biggest V exists across R — ie, at the positive peak of V_i. $I_{f max} = \frac{10V - 5V}{R} = \underline{\underline{5mA}}$.

Q3 It will be D_1 that clips voltages that are too high and D_2 that clips voltages that are too low.

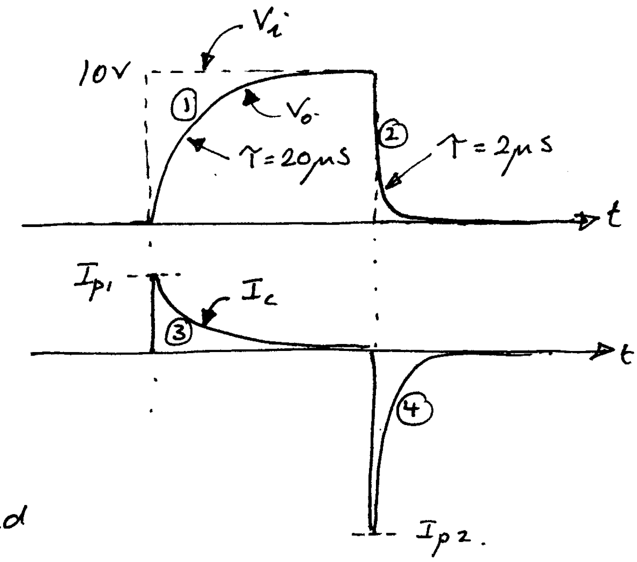
For D_1 to clip V_i at 3.3V, $V_1 = 3.3V - 0.7V = \underline{\underline{2.6V}}$.

For D_2 to clip V_i at 0V, $V_2 = 0 + 0.7V = \underline{\underline{0.7V}}$.

Q4 The diode will be on the point of conduction if $V_o = -2V + 0.7V = -1.3V$. The value of I_i that will give a V_o of $-1.3V$ with a diode current of zero is $I_i = \frac{-1.3V}{2k\Omega} = -0.65mA$.



For $I_i < -0.65mA$, there is no conduction through the diode so all I_i goes through R and $V_o = I_i R$. For $I_i > -0.65mA$, the diode conducts and V_o is held at $-1.3V$.



Q5 (a) τ is much shorter than the pulse width so V_o has reached V_i by the end of the pulse.

On rising edge, D is reverse biased so current flows through R_2 to charge C.

On falling edge, D is forward biased so C discharges through R_1 and R_2 in parallel.

I_{p1} occurs on leading edge transient....

$$I_{p1} = \frac{V_i}{R_2} = \frac{10V}{2k\Omega} = \underline{\underline{5mA}}.$$

I_{p2} occurs on trailing edge transient....

$$I_{p2} = -\frac{V_i}{R_1 /\!/ R_2} = -\frac{10V}{200\Omega} = \underline{\underline{-50mA}}.$$

The four exponential relationships are.

① $V(t) = 10\left(1 - e^{-t/20\mu s}\right)$.

② $V(t) = 10\, e^{-t/2\mu s}$

③ $I(t) = 5mA\, e^{-t/20\mu s}$

④ $I(t) = -50mA\, e^{-t/2\mu s}$.

Output pulse width at half height....

→ time for ① to reach half height is given by

$$5 = 10\left(1 - e^{-t_1/20\mu s}\right)$$

which leads to $t_1 = 13.86\mu s$.

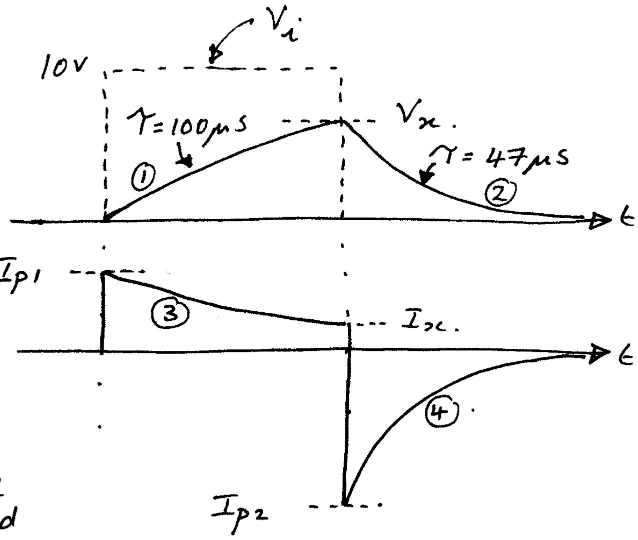
→ time for ② to fall to half height is given by

$$5 = 10\, e^{-t_2/2\mu s}$$

which leads to $t_2 = 1.37\mu s$.

$$\therefore \text{ output pulse width } = 100\mu s - t_1 + t_2$$
$$= (100 - 13.86 + 1.37)\mu s$$
$$= \underline{\underline{87.53\mu s}}$$

Q5 (b) In this circuit D_2 is forward biassed by the leading edge and D_1 by the trailing edge. In other words, C charges via R_2 and discharges via R_1. The charging time constant, CR_2 is of the same order as the pulse width so the value of V_o at the end of the pulse, V_x, will have to be calculated.



The four exponentials are ....

① $V(t) = 10(1 - e^{-t/100\mu s})$.

② $V(t) = V_x e^{-t/47\mu s}$

③ $I(t) = I_{p1} e^{-t/100\mu s}$

④ $I(t) = I_{p2} e^{-t/47\mu s}$.

We need V_x in order to find I_{p1} and I_{p2}, so using ① $V_x = 10\left(1 - e^{-\frac{100\mu s}{100\mu s}}\right) = 6.32V$

$$I_{p1} = V_i/R_2 = \frac{10V}{10k\Omega} = 1mA.$$

$$I_x = \frac{V_i - V_x}{R_2} = \frac{10 - 6.32}{R_2} = 0.368\ mA.$$

$$I_{p2} = -\frac{V_x}{R_1} = -\frac{6.32}{4.7k\Omega} = -1.34\ mA.$$

time for ① to reach 5V given by

$5 = 10(1 - e^{-t_1/100\mu s})$ or $t_1 = 69.3\mu s$.

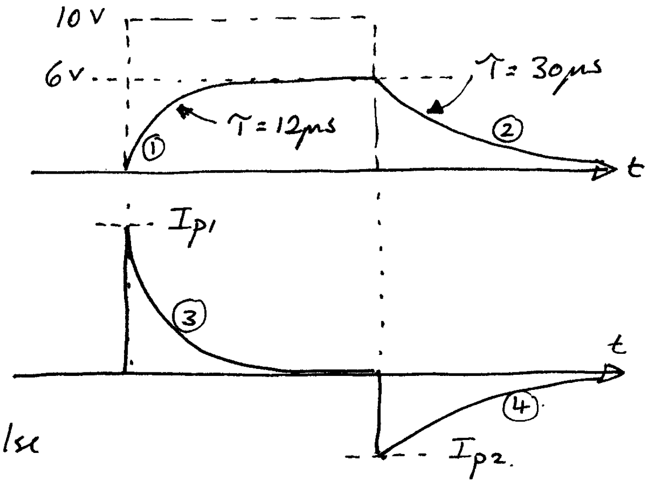
time for ② to fall to 5V given by

$5 = 6.32\, e^{-t_2/47\mu s}$ or $t_2 = 11\mu s$.

output pulse width $= 100\mu s - 69.3\mu s + 11\mu s$

$= \underline{\underline{41.7\mu s}}$.

Q5 (c) In this circuit the diode conducts when $V_i = 10\,V$ but does not conduct for $V_i = 0V$. During the pulse, C charges via R_1 but R_1 also supplies current through R_2 leading to an aiming voltage that is a potentially divided version of the input pulse amplitude.



The four exponentials are

① $V(t) = 6(1 - e^{-t/\tau_1})$ where $\tau_1 = CR_1 \| R_2 = 12\mu s$.

② $V(t) = 6e^{-t/\tau_2}$ where $\tau_2 = CR_2 = 30\mu s$.

③ $I(t) = I_{p1} e^{-t/\tau_1}$

④ $I(t) = I_{p2} e^{-t/\tau_2}$.

$I_{p1} = \frac{V_i}{R_1} = 5mA$. [On the leading edge, V_o is initially zero so all V_i appears across R_1.].

$I_{p2} = -\frac{6V}{R_2} = -2mA$. [On the trailing edge, D is reverse biassed so C discharges through R_2]

Half height of V_o is 3V. The time it takes ① to reach 3V is given by

$$3 = 6(1 - e^{-t_1/12\mu s}) \quad \text{or} \quad t_1 = 8.3\mu s.$$

Time taken for V_o to fall to 3V after trailing edge is given by

$$3 = 6e^{-t_2/30\mu s} \quad \text{or} \quad t_2 = 20.8\mu s.$$

pulse width $= 100\mu s - 8.3\mu s + 20.8\mu s$

$= \underline{\underline{112.5\mu s}}$.