ITE Exam-01 Spring 2024

Operational amplifiers and diodes

Problem 1 - Diode circuit

(a) Calculation of total current

$\boxed{V_{In} = 1.0V}$

Current through $R_1 = I_{R1} = \frac{1V}{1k\Omega} = 1\,mA$

Current through $R_2 = I_{R2} = \frac{1V - 0.7V}{1k\Omega} = 0.3\,mA$

$\Rightarrow$ Total current $= I_{In} = I_{R1} + I_{R2} =$

$= 1\,mA + 0.3\,mA = \underline{1.3\,mA}$

$\boxed{V_{In} = 5.0V}$

$I_{R1} = 5mA$

$I_{R2} = \frac{5V - 0.7V}{1k\Omega} = 4.3\,mA$

$I_{R3} = \frac{5V - 0.7V - 3V}{1k\Omega} = \frac{1.3V}{1k\Omega} = 1.3\,mA$

$I_{In} = \sum I_{Ri} = 5mA + 4.3mA + 1.3mA$

$= \underline{10.6\,mA}$

$\boxed{V_{In} = 10V}$

$I_{R1} = 10\,mA$

$I_{R2} = 9.3\,mA$

$I_{R3} = 6.3\,mA$

$$I_{R4} = \frac{10V - 2\times 0.7V - 2\times 3V}{1\,k\Omega} = \frac{2.6V}{1k\Omega} = 2.6mA$$

$$I_{In} = \sum I_{Ri} = 10mA + 9.3mA + 6.3mA + 2.6mA =$$
$$= \underline{\underline{28.2\,mA}}$$

(b) $I_{R4} = 1\,mA \Rightarrow V_{R4} = 1V$

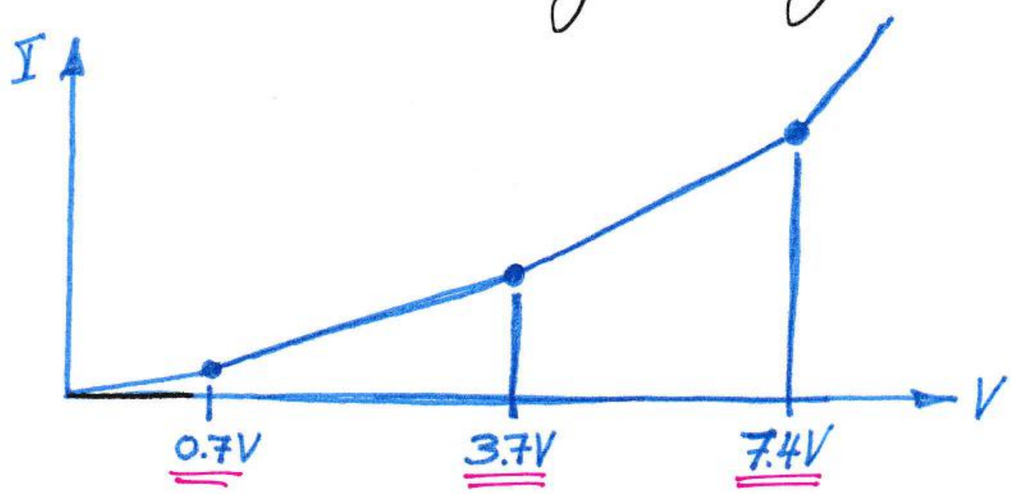
$$\Rightarrow I_{R3} = \frac{1V + 0.7V + 3V}{1k\Omega} = \frac{4.7V}{1k\Omega} = 4.7mA$$

$$\Rightarrow I_{R2} = \frac{4.7V + 3V}{1k\Omega} = \frac{7.7V}{1k\Omega} = 7.7mA$$

$$\Rightarrow I_{R1} = \frac{7.7V + 0.7V}{1k\Omega} = \frac{8.4V}{1k\Omega} = 8.4mA$$

Total current $= \sum I_{Ri} = 1mA + 4.7mA +$
$+ 7.7mA + 8.4mA = \underline{\underline{21.8\,mA}}$

(c) Current - voltage diagram



$0.7V \Rightarrow I = I_{R1} = \underline{\underline{0.7\,mA}}$

$3.7V \Rightarrow I = I_{R1} + I_{R2} = 3.7mA + 3mA = \underline{\underline{6.7mA}}$

$7.4V \Rightarrow I = I_{R1} + I_{R2} + I_{R3} = 7.4mA + 6.7mA + 3.7mA$
$= \underline{\underline{17.8\,mA}}$

Problem 2 – Op amp circuit

(a) Yes, it is a linear circuit because V_{out} is a linear function of V_1 and V_2.

(b) Effect of V_1 on V_{out}

$V_+ = 0 \Rightarrow V_- = 0$

$V_1 = I_{R1} R_1$ (1) $\quad V_{out} = -R_F I_{R1}$ (2)

$\Rightarrow$ Two eqns. Eliminate I_{R1}

$$\Rightarrow \frac{V_1}{R_1} = -\frac{V_{out}}{R_F} \Rightarrow V_{out} = -\frac{R_F}{R_1} V_1$$

(c) Effect of V_2 on V_{out}

$$V_+ = \frac{R_3}{R_2+R_3} V_2 \quad (1) \qquad V_- = V_+ \quad (2)$$

$$\frac{V_{out} - V_-}{R_F} = I_{R1} \quad (3) \qquad \frac{V_-}{R_1} = I_{R1} \quad (4)$$

Eliminate I_{R1} from Eqns. (3) and (4):

$$\frac{V_{out} - V_-}{R_F} = \frac{V_-}{R_1} \quad (5)$$

Eliminate V_- by using Eqns. (1) and (2)

$$\frac{V_{out} - \frac{R_3}{R_2+R_3} V_2}{R_F} = \frac{\frac{R_3}{R_2+R_3} V_2}{R_1}$$

$$\frac{V_{out}}{R_F} - \frac{R_3}{R_2+R_3}\frac{1}{R_F}V_2 = \frac{R_3}{R_2+R_3}\frac{1}{R_1}V_2$$

$$\frac{V_{out}}{R_F} = \frac{R_3}{R_2+R_3}\left(\frac{1}{R_F}+\frac{1}{R_1}\right)V_2$$

$$\Rightarrow V_{out} = \frac{R_3}{R_2+R_3}\left(1+\frac{R_F}{R_1}\right)V_2$$

(d) Superposition (addition)

$$V_{out} = \frac{R_3}{R_2+R_3}\left(1+\frac{R_F}{R_1}\right)V_2 - \frac{R_F}{R_1}V_1$$

$\Rightarrow$ This is a subtraction circuit

(e) Assume $R_1 = R_2 = R_3 = R_F$

$$\Rightarrow V_{out} = \frac{1}{2}(1+1)V_2 - V_1 = V_2 - V_1$$

$$\text{Amplification} = A = \frac{V_{out}}{V_2 - V_1} = 1$$

(f) R_4 does not enter the calculation because the output impedance of the op amp is zero.

(g) If $R_{output} \ll R_4$, there is no effect.

Output impedance of op amp.

If $R_{output} \lessapprox R_4$, there will be a drop in the output voltage.

a drop in the absolute value of the output voltage.

Problem 3

(a) True. A lower charging current causes less battery heating ($I^2 R_{int}$), thereby prolonging battery lifetime.

(b) True. A Zener diode becomes conductive at 0.7V forward bias.

(c) True. Otherwise a positive feedback catastrophe results.