15.50

a. Switching voltage

$$v_X = \left(\frac{R_1 + R_3}{R_1 + R_3 + R_2}\right) \cdot V_P = \left(\frac{10 + 10}{10 + 10 + 10}\right)(\pm 10)$$

So $v_X = \pm 6.667$ V

Using Equation (15.83(b))

$$v_X = V_P + \left(-\frac{2}{3}V_P - V_P\right)e^{-t_1/\tau_X} = \frac{2}{3}V_P$$

Then $1 - \frac{5}{3} \cdot e^{-t_1/\tau_X} = \frac{2}{3}$

$\frac{1}{3} = \frac{5}{3} \cdot e^{-t_1/\tau_X}$ or $t_1 = \tau_X \ln(5)$

$t_1 = \frac{T}{2} = \frac{1}{2f} = \frac{1}{2(500)} \Rightarrow t_1 = 0.001$ s

$10^{-3} = \tau_X \ln(5) \Rightarrow \tau_X = 6.21 \times 10^{-4}$

$= R_X(0.01 \times 10^{-6})$

So $\underline{R_X = 62.1\text{ k}\Omega}$

b. Switching voltage

$$v_X = \left(\frac{R_1}{R_1 + R_3 + R_2}\right)(\pm V_P)$$

$$= \left(\frac{10}{10 + 10 + 10}\right)(\pm V_P) = \frac{1}{3} \cdot (\pm V_P)$$

Using Equation (15.83(b))

$$v_X = V_P + \left(-\frac{1}{3}V_P - V_P\right)e^{-t_1/\tau_X} = \frac{1}{3}V_P$$

Then $1 - \frac{4}{3} \cdot e^{-t_1/\tau_X} = \frac{1}{3}$

$\frac{2}{3} = \frac{4}{3} \cdot e^{-t_1/\tau_X}$

$t_1 = \tau_X \ln(2) = (6.21 \times 10^{-4}) \ln(2) = 4.30 \times 10^{-4}$ s

$T = 2t_1 = 8.6 \times 10^{-4}$ s

$f = \frac{1}{T} \Rightarrow \underline{f = 1.16\text{ kHz}}$

15.53

a. From Equation (15.95)

$T = 1.1RC$

For $T = 60$ s $= 1.1$RC

then $RC = 54.55$ s

For example, let

$\underline{C = 50\ \mu F}$ and $\underline{R = 1.09\ M\Omega}$

b. Recovery time: capacitor is discharged by current through the discharge transistor.

If $V^+ = 5$ V, then $I_B \cong \frac{5 - 0.7}{100} = 0.043$ mA

If $\beta = 100$, $I_C = 4.3$ mA

$V_C = \frac{1}{C}\int I_C\, dt = \frac{I_C}{C} \cdot t$

Capacitor has charged to $\frac{2}{3} \cdot V^+ = 3.33$ V

So that $t = \frac{V_C \cdot C}{I_C} = \frac{(3.33)(50 \times 10^{-6})}{4.3 \times 10^{-3}}$

So recovery time $\underline{t \approx 38.7\ ms}$

15.54

$T = 1.1RC$

$5 \times 10^{-6} = 1.1RC$

so $RC = 4.545 \times 10^{-6}$ s

For example, let

$\underline{C = 100\ pF}$ and $\underline{R = 45.5\ k\Omega}$

From Problem (15.53), recovery time

$t \cong \frac{V_C \cdot C}{I_C} = \frac{(3.33)(100 \times 10^{-12})}{4.3 \times 10^{-3}}$

or

$\underline{t = 77.4\ ns}$

15.55

From Equation (15.102),

$$f = \frac{1}{(0.693)(20 + 2(20)) \times 10^3 \times (0.1 \times 10^{-6})}$$

or $\underline{f = 240.5 \text{ Hz}}$

$$\text{Duty cycle} = \frac{20 + 20}{20 + 2(20)} \times 100\% = \underline{66.7\%}$$

15.56

$$f = \frac{1}{(0.693)(R_A + 2R_B)C}$$

$R_A = R_1 = 10 \text{ k}\Omega$, $R_B = R_2 + xR_3$

So $10 \text{ k}\Omega \leq R_B \leq 110 \text{ k}\Omega$

$$f_{min} = \frac{1}{(0.693)(10 + 2(110)) \times 10^3 \times (0.01 \times 10^{-6})}$$

$$= 627 \text{ Hz}$$

$$f_{max} = \frac{1}{(0.693)(10 + 2(10)) \times 10^3 \times (0.01 \times 10^{-6})}$$

$$= 4.81 \text{ kHz}$$

So $627 \text{ Hz} \leq f \leq 4.81 \text{ kHz}$

$$\text{Duty cycle} = \frac{R_A + R_B}{R_A + 2R_B} \times 100\%$$

Now

$$\frac{10 + 10}{10 + 2(10)} \times 100\% = \underline{66.7\%}$$

and

$$\frac{10 + 110}{10 + 2(110)} \times 100\% = \underline{52.2\%}$$

So $52.2 \leq \text{Duty cycle} \leq 66.7\%$

15.57

$1\ \text{k}\Omega \le R_A \le 51\ \text{k}\Omega$

$1\ \text{k}\Omega \le R_B \le 51\ \text{k}\Omega$

$$f_{min} = \frac{1}{(0.693)(1+2(51)) \times 10^3 \times (0.01 \times 10^{-6})}$$

$$= 1.40\ \text{kHz}$$

$$f_{max} = \frac{1}{(0.693)(51+2(1)) \times 10^3 \times (0.01 \times 10^{-6})}$$

$$= 2.72\ \text{kHz}$$

or $1.40\ \text{kHz} \le f \le 2.72\ \text{kHz}$

$$\text{Duty cycle} = \frac{R_A + R_B}{R_A + 2R_B} \times 100\%$$

$$\frac{1+51}{1+2(51)} \times 100\% = \underline{50.5\%}$$

or

$$\frac{51+1}{51+2(1)} \times 100\% = \underline{98.1\%}$$

or $\underline{50.5\% \le \text{Duty cycle} \le 98.1\%}$