

# Solutions for Chapter 2

## Exercise 2.1

We assume a forward voltage for the LED of 1.5V. Then for  $I_{LED}$  we have

$$I_{LED} = \frac{V_R}{R} = \frac{3.3V - 1.5V}{330\Omega} \approx \boxed{5.5mA}$$

To estimate the  $\beta_{min}$  we need the current entering the base

$$I_B = \frac{3.3V - 0.6V}{10k\Omega} = 0.27mA$$

Thus

$$\beta_{min} \geq \frac{I_{LED}}{I_B} = \boxed{20}$$

## Exercise 2.2

**NOTE: According to the errata 0.63 should be replaced by 0.76 and  $63\mu\text{sec}$  by  $76\mu\text{sec}$ .**

Starting from the hint that the capacitor charges from  $-4.4V$  towards  $+5V$ , we would result to a total  $9.4V$  for a full charge. However, the  $V_{BE}$  of  $Q_2$  is clipping the charging process at only  $5V$  of the total (from  $-4.4V$  to  $0.6V$ ). Thus, the capacitor will be 53% charged at the end.

Solving the voltage equation for a charging capacitor gives us

$$V_C(t) = V_f * (1 - e^{-\frac{t}{RC}})$$

set  $V_C(t_1) = 0.53 * V_f$

$$0.53 = 1 - e^{-\frac{t_1}{R_3 C_1}}$$

$\Rightarrow$

$$t_1 = -RC * \ln(0.47) \approx \boxed{0.76 * R_3 C_1}$$

## Exercise 2.3

The output voltage is reduced due to the  $R_4 - R_5$  voltage divider

$$V_{out} = \frac{R_5}{R_4 + R_5} * (V_{CC} - 0.6V) \approx \boxed{4.18V}$$

To estimate the minimum  $\beta_3$ , we need first to find the maximum (worst-case) collector current for which  $Q_3$  should still be in saturation. For this we can assume a  $0V$  drop across C and  $Q_3$  while the current travels through the parallel connected resistors  $R_2 || R_3$ .

$$I_{C3,max} = \frac{V_{CC}}{R_2 || R_3} = 5.5mA$$

$$\Rightarrow \beta_{3,min} = \frac{I_{C3,max}}{I_{B3}} = \frac{5.5mA}{\frac{(4.18V - 0.6V)}{20k\Omega}} \approx \boxed{31}$$