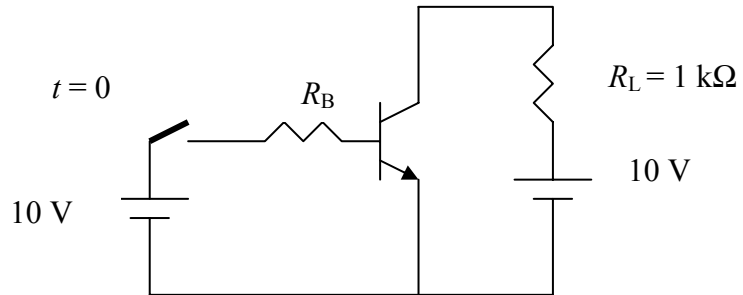


ECSE-2210 Microelectronics Technology
Class Activity 22 – Solution

The material for this class activity can be found in Chapter 12, pp 449-458.

The npn switching transistor used in the circuit below has the following parameters: Minority carrier lifetime in base, $\tau_B = 100$ ns; $\beta_{dc} = 50$. Assume $\gamma = 1$. Answer the following questions.



Assume R_B is 100 k Ω . At $t = 0$, the switch is turned on. (i.e., the base current increases from 0 to approximately to 0.1 mA at $t = 0$).

- a. Will the transistor be in saturation or forward active mode for $t \gg 0$, i.e. $t = \infty$? What will be the final value of the collector current?

The transistor will be in forward active mode. $I_c = \beta_{dc} I_B = 50 \times 0.1$ mA = 5 mA

This makes the $V_{CE} = 10$ V – 1 k $\Omega \times 5$ mA = 5 V. Hence, the transistor is in forward active mode because the emitter base junction is forward biased and the collector emitter junction is reversed biased.

If V_{CE} is zero, then transistor is in saturation.

- b. Calculate and plot the charge stored in the base, Q_B as a function of time, for $t > 0$.

$$Q_B = I_B \tau_B = 0.1 \text{ mA} \times 100 \text{ ns} = 10^{-11} \text{ C}$$

So, the base charge will exponentially increase towards the value 10^{-11} C with a time constant of 100 ns.

- c. Plot the collector current as a function of time for $t > 0$.

The collector current is 5 mA.

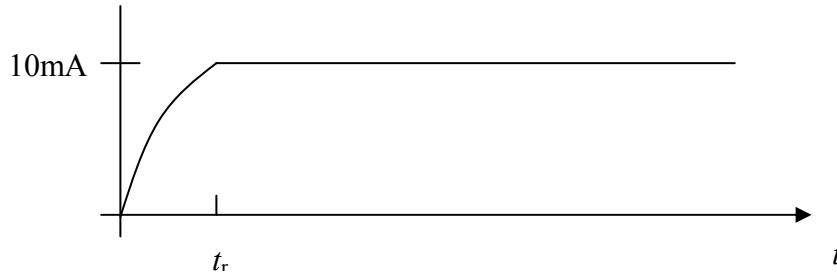
The collector current will exponentially reach 5 mA with a time constant of 100 ns

Suppose $R_B = 25$ k Ω . When the switch is turned on at $t = 0$, the base current switches from 0 to 0.4 mA.

- d. Is the transistor in saturation for $t \gg 0$?

Yes. The maximum collector current possible is 10 mA (because of the external circuit). But $\beta_{dc} I_B = 50 \times 0.4$ mA = 20 mA is now more than 10 mA. Therefore the transistor will go into saturation.

- e. Calculate and plot the collector current as a function of time and sketch it for $t > 0$.



- f. Find the rise time t_r required for the collector current to reach the steady state value.

$$t_r = \tau_B \ln \left(\frac{1}{1 - (I_C / \beta_{dc} I_B)} \right)$$
$$t_r = 100 \text{ ns} \ln \left(\frac{1}{1 - \frac{10}{20}} \right) = 69 \text{ ns}$$

The time required is about 69 ns.

Note: By making I_B large, we can reduce the turn-on time. However, this will put the transistor into “deep saturation” mode so that the turn-off time will be increased. Often, a “Schottky diode clamp” is used to bypass the base current when the transistor is in saturation. This greatly reduces the saturation-mode build up of stored charge, and hence the turn-off time.