

## EE210: HW-4

Date: 29.01.2019

Unless stated otherwise, the BJT in the problems given below has the following characteristics

$$I_S = 2.03 \times 10^{-15} \text{ A}; \beta_F = 100; \beta_R = 1; V_A = 100; r_{bb} = 200 \Omega; V_T = 26 \text{ mV}; C_{je0} = 1 \text{ pF}; \\ C_{jc0} = 0.5 \text{ pF}; C_{js0} = 3 \text{ pF}; m = 0.5; V_{bi} = 0.85; \tau_F = 1 \text{ ns}$$

**Q.1:** For the circuit shown below in Fig. 1, determine the dc collector current. Using small signal analysis, determine the change in collector current if collector supply voltage changes by 10%. Determine next the change in collector current if temperature increases by  $1^\circ \text{C}$ . Neglect change in  $\beta$  due to temperature.

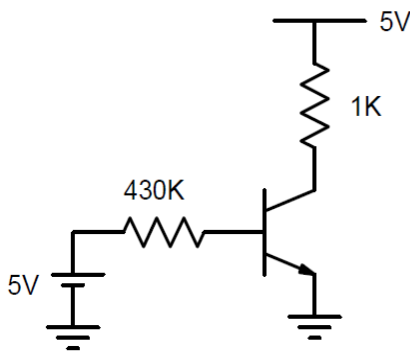


Fig. 1

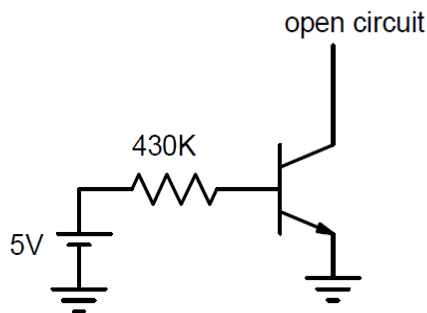


Fig. 2

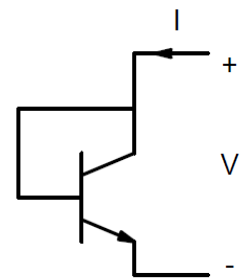


Fig. 3

**Q.2:** Determine the mode of operation of the transistor shown in Fig. 2.

**Q.3:** Sketch the qualitative I-V characteristics of the circuit shown in Fig. 3. What does the transistor behave as in this circuit? Determine the low frequency small signal model of the circuit assuming that dc current  $I = 1 \text{ mA}$ . At what frequency, will this circuit ceases to behave as a resistor under small signal condition?

**Q.4:** The two-transistors connected in the manner shown in Fig. 4 can be considered as a single transistor with an effective current gain  $\beta_{eff}$ . Determine this gain in terms of gains of transistors  $Q_1$  and  $Q_2$ .

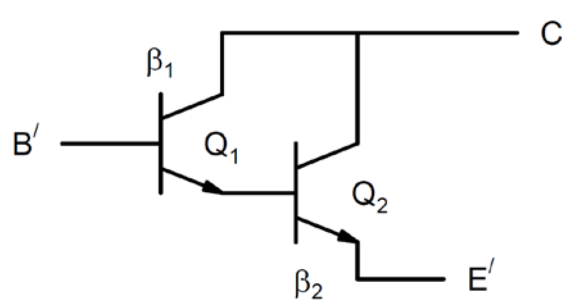


Fig. 4

**Q.5:** Assuming that one has the freedom to choose  $V_{B2}$  in the circuit shown in Fig.5, determine the minimum supply voltage  $V_{CC}$  required to ensure that transistors  $Q_1$  and  $Q_2$  operate in forward active mode. Determine appropriate value for bias voltage  $V_{B2}$  under this condition.

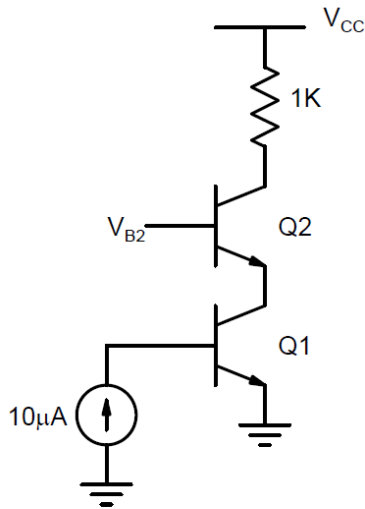


Fig. 5

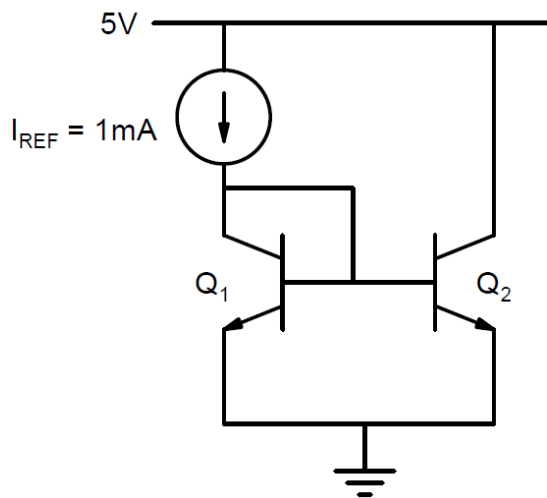


Fig.6

**Q.6:** The circuit shown in Fig. 6 is called a current mirror, where it is desired that current through  $Q_2$  be equal to  $I_{REF}$ . Taking base currents into account but neglecting Early effect, determine the collector currents of the two transistors assuming that they have identical characteristics (in other words are 'matched'). Use Early effect next to determine the % difference in the two collector currents.

**Q.7:** There is a circuit shown in Fig. 7, where current sources of 2mA and 3mA are required. Using the idea of current mirror shown in Fig.6 and assuming that a reference current of 1mA is available, design appropriate circuit to generate these current sources. For simplicity, neglect base current and Early effect in your calculations. You have any number of matched NPN and PNP transistors to carry out the design. (This example illustrates that from one reference current, biasing currents for different parts of the circuit can be easily generated.)

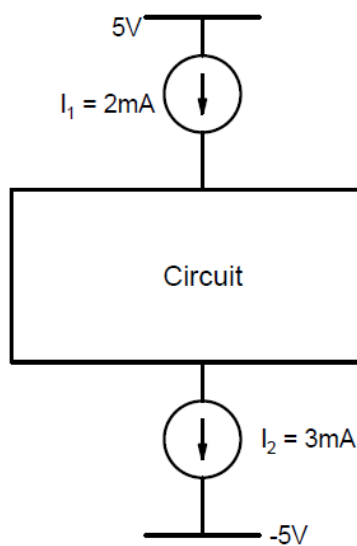


Fig. 7