

Time allowed: 1 hour

Date: 15 March 2019

Name: _____

Student Number: _____

Attempt ALL questions. Total is 70 marks

1. Figure 1 shows a simplified pi model of a bipolar junction transistor (BJT) including junction capacitor C_π and strays capacitance C_μ . (8 marks)

Redraw this pi model when this transistor is used at

- Lower frequency range
- Mid frequency range
- High frequency range

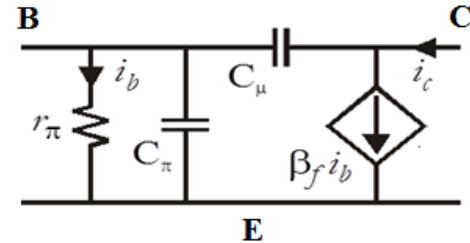
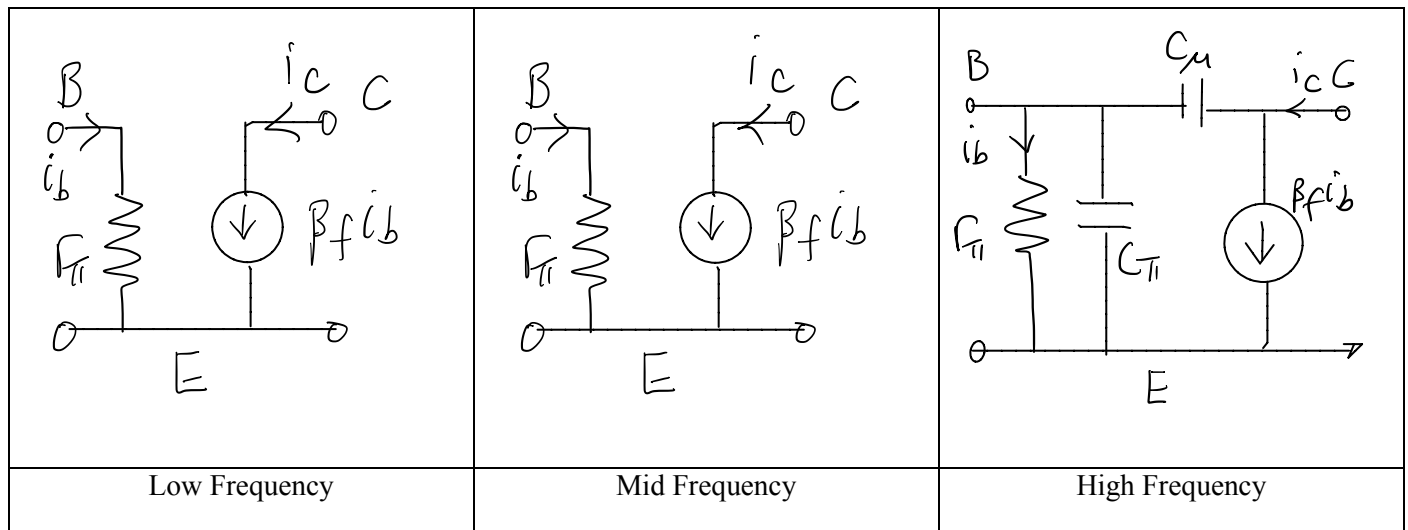


Figure 1



2. Figure 2 shows a transmitter for a visible light communication link. T1 is a connector for an external resistor. And it is initially short-circuited. (28 marks)

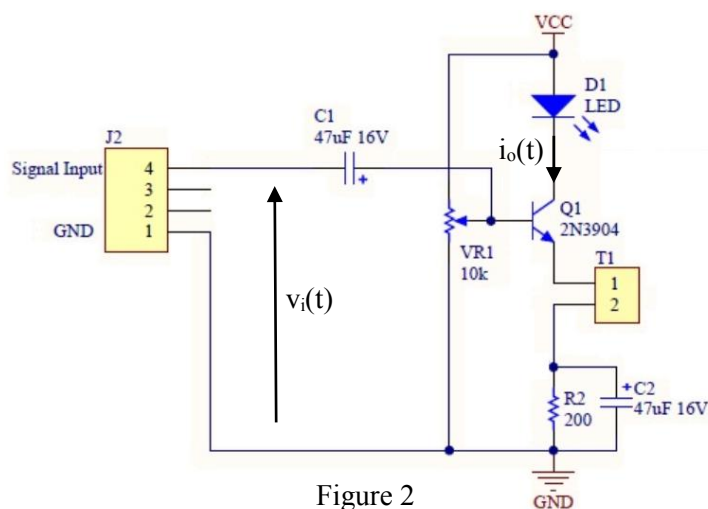


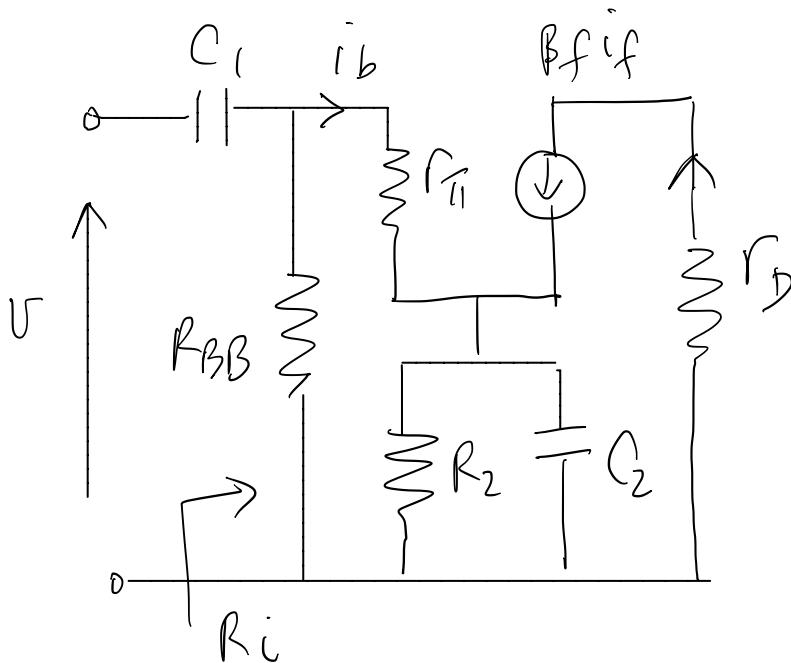
Figure 2

- a) What is the configuration of Q_1 , (CE, CC, CB, CS, CD, CG)? What is the phase relationship (in-phase or out-of-phase) between (i) $v_i(t)$ and $i_o(t)$ for the transmitter? Justify all your answers. (4 marks)

Q1 is CE because Q1 is a BJT; "B" is input and "C" is output

Since i_o is proportional to Q1 base current i_b , and i_b is proportional to v_i , so i_o and v_i must be in phase.

- b) Draw the small signal ac equivalent circuit for figure 2 at low frequency using the simplified hybrid-pi model in figure 1. Discuss which component should dominate the lower 3dB cut-off frequency of this transmitter. You may assume the ac resistance of the LED is r_D . (8 marks)



C_1 will result in lower 3dB cut-off point $\omega_1 = \frac{1}{C_1 R_i}$ when C_2 is short-cct.

C_2 will result in lower 3dB cut-off point ω_a, ω_b when C_1 is short-cct

$$\omega_a = \frac{1}{C_2 (R_2 \parallel \frac{r_{\pi}}{\beta + 1})}$$

$$\omega_b = \frac{1}{C_2 R_2}$$

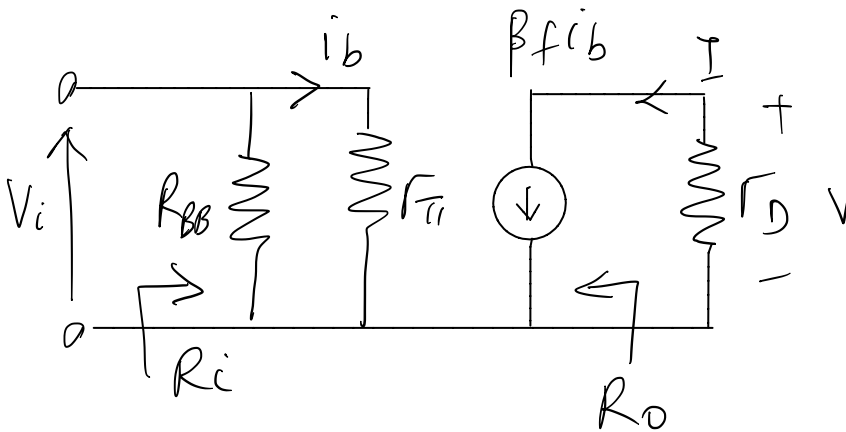
Since C_1, C_2 have the same capacitor value and $R_2 \parallel \frac{r_{\pi}}{\beta + 1} \ll R_i$

$\therefore \omega_a \gg \omega_b$ and ω_1

$\therefore C_2$ should dominate the lower 3dB cut off frequency

Remark V_H $\begin{array}{c} +V_{CC} \\ \downarrow \\ R_a \\ \leftarrow \\ R_b \\ \downarrow \\ 0V \end{array} \Rightarrow R_{BB} = R_a \parallel R_b$

- c) Draw the small signal ac equivalent circuit for figure 2 at mid frequency. Hence, derive the input resistance R_i seen by C_1 , the output resistance R_o seen by D_1 and the transfer gain $A = i_o/v_i$ for the transmitter. Please include unit for A. What type of amplifier for A? (12 marks)



$$R_i = R_{BB} \parallel r_{\pi}$$

$$R_o = \left. \frac{V}{I} \right|_{V_i=0} = \infty$$

$$A = \frac{\hat{i}_o}{V_i} = \frac{\beta f \hat{i}_b}{r_{\pi} \hat{i}_b} = \frac{\beta f}{r_{\pi}} \text{ (S)}$$

It is a trans conductance amplifier

- d) If T_1 is now replaced by a 20Ω resistor, discuss how the values of A and R_i will change respectively. (4 marks)

When the 20Ω resistor is inserted, a negative feedback will form, so A will decrease and R_i will increase because input is series feed back.

3. Figure 3 shows is a two-stage transistor amplifier. (34 marks)

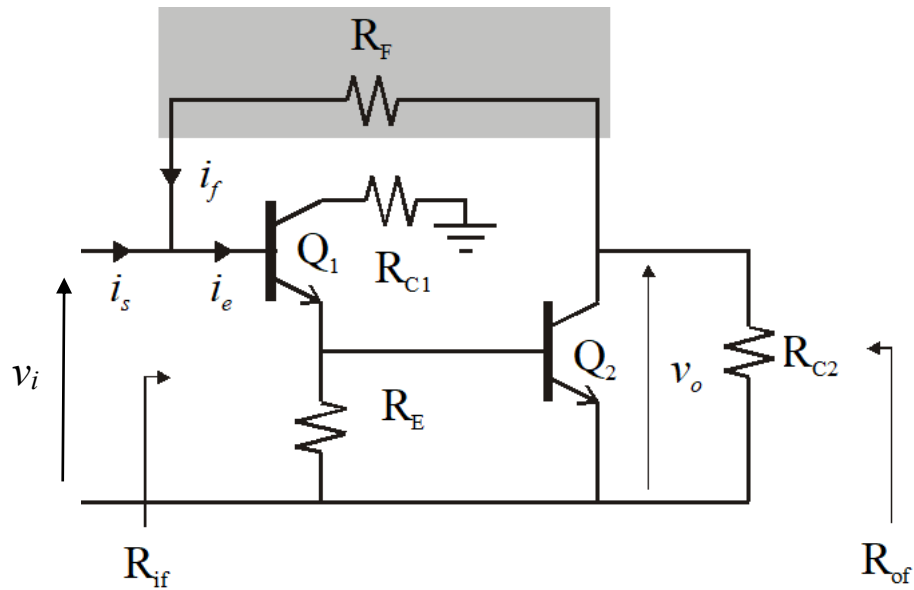


Figure 3

- a) Discuss whether R_F can form a negative feedback between the base of Q_1 and the collector of Q_2 . (4 marks)

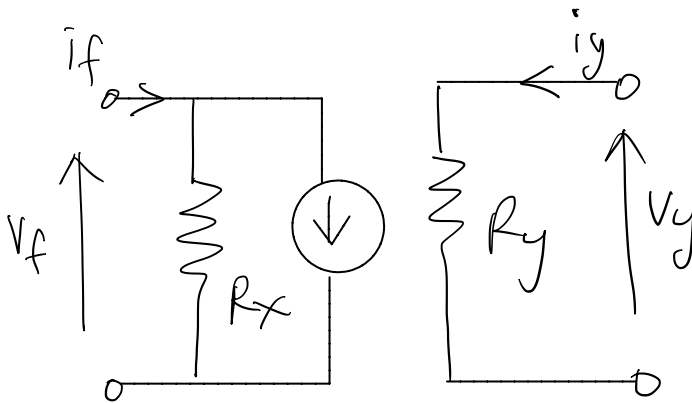
The phase between the base and the emitter of Q_1 are in phase, the phase between the base and the collector of Q_2 are out of phase, so the phase between the base of Q_1 and the collector of Q_2 are out of phase. Therefore R_F can form a negative feedback.

- b) Identify the type of feedback topology. Justify your answer. (4 marks)

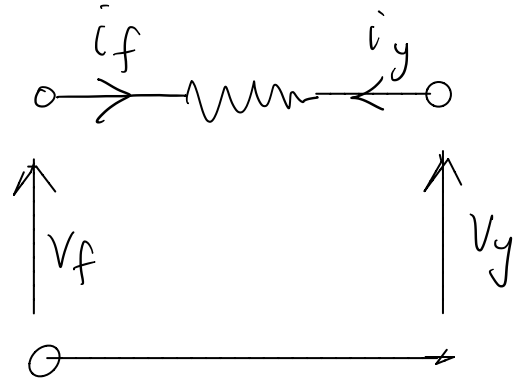
It is a shunt-shunt topology. It is because one end of R_F is connected in parallel to the base of Q_1 , while the other end of R_F is connected in shunt to the collector of Q_2 .

- c) Draw the equivalent circuit of the feedback network. Define and determine the parameters R_x , R_y and β in terms of the feedback network resistor(s). Discuss whether it is a non-ideal feedback network. (18 marks)

Equivalent
circuit of
feedback network



Feedback
Components



$$R_x = \left. \frac{V_f}{i_f} \right|_{V_y=0} = R_F$$

$$R_y = \left. \frac{V_y}{i_y} \right|_{V_f=0} = R_F$$

$$\beta_z = \left. \frac{i_f}{V_y} \right|_{V_f=0} = -\frac{1}{R_F}$$

Since R_x is not infinite and R_y is not zero, the feedback network is non-ideal.

- d) If the value of R_F is decreased, discuss how the closed-loop gain A_{fy} , closed-loop input resistance R_{if} and closed-loop resistance R_{of} will change. (4 marks)

$$\text{closed loop gain} : A_{fy} = \frac{A_y}{1 + \beta_z A_y}$$

$$\therefore R_F \downarrow ; \beta_z \uparrow ; A_{fy} \downarrow$$

closed loop resistance

$$R_{if} = \frac{R_{i'}}{1 + \beta_z A_y}$$

$$\therefore R_F \downarrow ; \beta_z \uparrow ; R_{if} \downarrow$$

- e) Beside R_F which forms a feedback path between transistor Q1 and Q2, identify any other feedback path in the circuit shown in figure 3. Name the feedback component and its type of feedback topology. Justify your answer (4 marks)

R_E is a feedback component, it is series-shunt feedback topology. It is because the input is voltage feedback, while the output is voltage feedback.