EE140/240A Problem Set 1

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Problem 1. Small-signal analysis. **4+3+3 points**

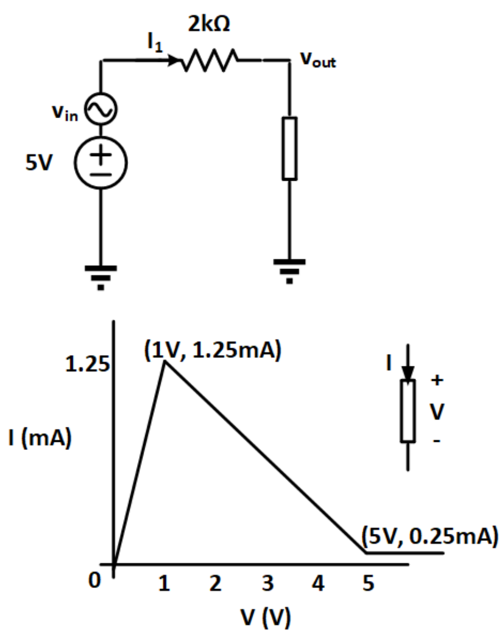

Figure 1: Problem 1

(a) Calculate the DC operating point of the non-linear circuit shown in Figure 1. Compute the current I_1 and the DC voltage at the node v_{out}. Assume the small signal voltage $v_{in} = 0$ for this part.

(b) Draw the small-signal equivalent circuit for the circuit in Figure 1.

(c) Compute the small-signal gain from v_{in} to the output v_{out}.

Problem 2. Notion of small-signal. **3+3 points**
Consider two amplifiers whose characteristics are given by

$$V_{out} = \frac{V_{in}^2}{V_A} \tag{1}$$

and

$$V_{out} = \frac{V_{in}^3}{V_A^2} \tag{2}$$

Assume that the two amplifiers are biased at $V_{in} = V_A$.

(a) Compute two small-signal gains A of the two amplifiers.

(b) In class, we saw that the "small-signal" approximation is valid only if the higher order terms of the Taylor series can be neglected with respect to the linear term. Comparing against just the second order term, which of the two amplifiers has a higher range of input voltage swings for which the small signal approximation is valid?

Problem 3. (Compulsory for EE240A, Bonus for EE140) 4 points
Repeat both parts of Problem 2 for two amplifiers whose characteristics are given by

$$V_{out} = \frac{V_{in}^2}{V_A} \tag{3}$$

and

$$V_{out} = \frac{V_{in}^n}{V_A^{n-1}} \tag{4}$$

Problem 4. 2-Port Parameters **3+3+6 points**

(a) We have been introduced to y-parameters and z-parameters in lecture. Given a 2-port network whose y-parameter matrix is given by $\begin{bmatrix} \mathrm{y}_{11} & \mathrm{y}_{12} \\ \mathrm{y}_{21} & \mathrm{y}_{22} \end{bmatrix}$, find the z-parameter matrix of the 2-port in terms of y_{11}, y_{12}, y_{21} and y_{22}.

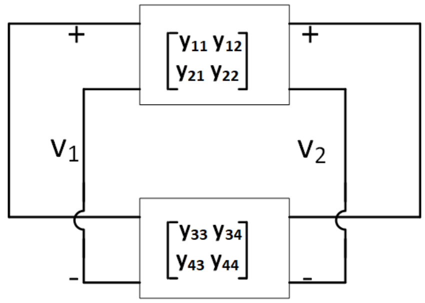

Figure 2: Parallel 2-Ports

(b) Two 2-port networks are connected in parallel as shown in Figure. 2. Calculate the y-parameter matrix of the effective parallel 2-port network.

(c) **(Compulsory for EE240A, Bonus for EE140)** Two 2-port networks are connected in series as shown in Figure. 3. Calculate the y-parameter matrix of the effective series 2-port network. (Hint: First try to calculate the z-parameter matrix of the series 2-port and use results derived from a previous part).

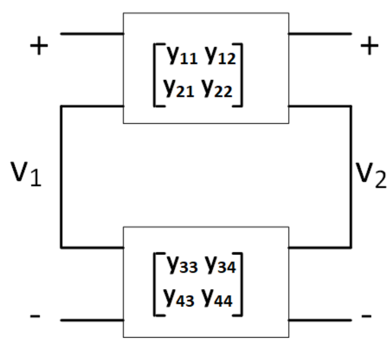

Figure 3: Series 2-Ports

Problem 5. 2-port model of a BJT 3+3 points

The bipolar junction transistor (BJT) is a three-terminal two-port device. The base (B), collector (C) and emitter (E) are the three terminals, The base and emitter nodes BE and the collector and emitter nodes CE form the two-ports. The collector-emitter, base-emitter and emitter currents, I_{CE}, I_{BE} and I_E are given by

$$
\begin{aligned}
I_{CE} &= I_S \left[\exp\left(\frac{V_{BE}}{V_T}\right)\right]\left(1 + \frac{V_{CE}}{V_A}\right) \\
I_{BE} &= \frac{I_{CE}}{\beta} \\
I_E &= I_{CE} + I_{BE}
\end{aligned}
\tag{5}
$$

where the saturation current I_S and the Early voltage V_A are properties of the device.

(a) Compute the y-parameters of the BJT. You may assume that V_{CE}/V_A is much smaller than 1, and make suitable approximations to make calculations easier. Assume that the following quiescent voltages for the BJT: $V_B = V_{B1}$, $V_C = V_{C1}$ and $V_E = 0$.

(b) Similar to what was discussed in lecture, we are now going to use the BJT to make an amplifier as shown in Fig 4. Compute the small-signal gain $\frac{v_{out}}{v_{in}}$ of this amplifier. Assume that the following quiescent voltages for the BJT: $V_B = V_{B1}$, $V_C = V_{C1}$ and $V_E = 0$. Assume that the Early voltage $V_A = \infty$ for this part.

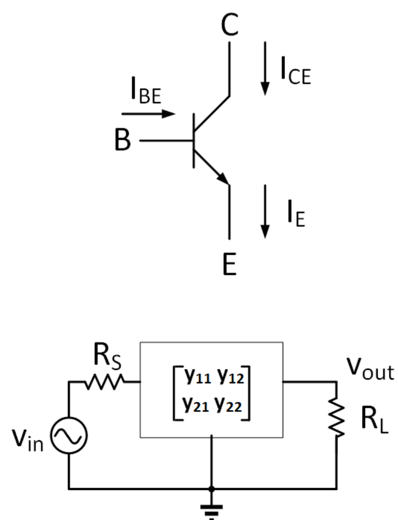

Figure 4: Figure for Problem 5