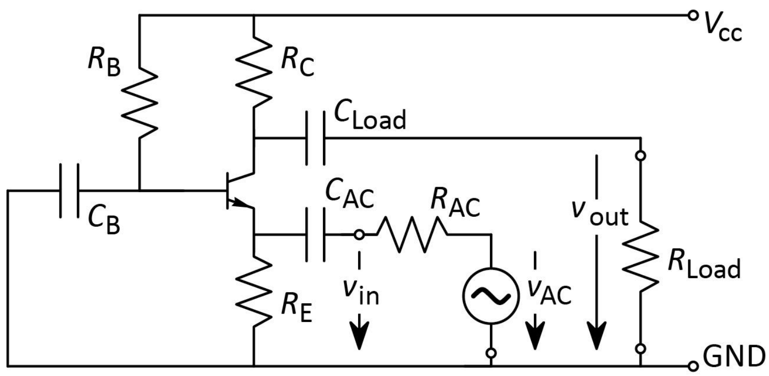
Homework 07

1. ***Small signal equivalent circuit***: Consider the amplifier circuit shown below. The circuit has an input signal source and an output load. Assume that V_{cc} = 12 V. Assume further that all capacitors are large enough to let pass AC signals (zero impedance of capacitors for AC) and block DC supply voltages (infinite impedance of capacitors for DC). The transistor has an α = 0.99. Assume that R_{AC} = 1 kΩ and R_{Load} = 500 Ω.



(a) Which mathematical symbol (latin or greek letter) do we generally use for the current amplification of a transistor in the common-emitter (common-E) configuration? What is the current amplification of the transistor in the common-E configuration (symbolic expression and numerical value)?

(b) The diagram of the circuit above is a bit unusual in that both input and output are on the RHS (right-hand side) of the transistor. Redraw the diagram above so that the input is on the very LHS (left-hand side) and the output is on the very RHS.

(c) Which transistor terminal is shared (for AC signals) between input and output? Which of the three basic transistor amplifier configurations has the circuit shown above?

(d) Assume that $R_C = R_E$ = 500 Ω. Assume further that at the Q-point, the voltage drop across R_C is 3.0 V. Determine the three transistor currents at the Q-point (I_E, I_C, and I_B). Determine R_B.

(e) Determine the differential emitter resistance r_E (numerical value).

(f) Draw the AC small-signal equivalent circuit. Closely follow the layout shown above. Feel free to assume that all capacitances have zero impedance under AC conditions.

(g) Redraw the AC small-signal equivalent circuit so that the input is on the very LHS and the output is on the very RHS.

(h) Calculate the input impedance of the circuit. Would the value you just calculated be considered a relatively *low value* or a *high value*?

(i) Calculate the output impedance of the circuit.

(j) Calculate A_{VOC} (open-circuit voltage amplification; $R_{Load} = \infty$), and give its numerical value.

(k) Calculate A_{ISC} (short-circuit current amplification; $R_{Load} = 0$), and give its numerical value.

(l) Calculate the voltage amplification of the circuit above (taking into account the load resistance), and give its numerical value.

(m) Calculate the current amplification of the circuit above (taking into account the load resistance), and give its numerical value.
(n) There is a capacitor between the collector and the load resistor. Does the capacitor (plus surrounding resistors) act as a low-frequency-pass filter or as a high-frequency-pass filter? Give an expression for the cutoff frequency (symbolic expression).
(o) Choose the numerical value of the capacitance for the cutoff frequency to be 1 kHz.

2. ***Differential amplifier***: Consider a 2-transistor (BJT) differential amplifier with two collector resistors (R_C, equal value, connected to V_{CC}), one shared emitter resistor (R_E, connected to ground, GND), and two base resistors (R_B, equal value, connected to V_{CC}). The transistors have a current amplification of $\beta = 100$. The power supply has a voltage of $V_{CC} = 12$ V.
   (a) Sketch the circuit diagram and label all circuit elements.
   (b) At the quiescent point, assume that a current of 20 mA flows through R_E causing a voltage drop of 1 V across R_E. Also assume that $V_{CE} = 5$ V. Determine the values of R_E, R_C, and R_B (numerical values).
   (c) Give the quiescent point of the circuit, that is, values of V_E, V_C, V_{CE}, and I_C. Explain why V_E can be considered a "virtual ground." Draw the transistor output characteristics, the R_C load line, and indicate all significant points (hand-drawn quantitative drawing).
   (d) Give the value of r_E. Sketch the small signal equivalent circuit.
   (e) Derive the formula (symbolic expression) for the small-signal voltage amplification (A_{VOC}) for differential input (two-ended input) and differential output (two-ended output).
   (f) Calculate the numerical value of the open-circuit voltage amplification A_{VOC}.
   (g) Assume that two such amplifier stages are circuited in series. What would be the total amplification of the two-stage amplifier?

3. ***True / false questions***: Are the following statements true or false? Explain your answer with one or two sentences.
   (a) Under normal operation conditions, the collector current of a BJT is smaller than the emitter current.
   (b) If an engineer reverses the base and collector terminal of a BJT, the circuit will not work.
   (c) If an engineer reverses the emitter and collector terminal of a BJT, the circuit will not work optimally.
   (d) If an engineer reverses the emitter and collector terminal of a BJT, the circuit will not work at all.
   (e) If an engineer reverses the emitter and collector terminal of a BJT, the amplification of the transistor decreases (which is undesirable).
   (f) Under normal operation conditions, the base current of a BJT, I_B, is the smallest of the three terminal currents I_E, I_B, and I_C.
   (g) Under normal BJT operation conditions, the base-emitter junction is forward biased, and the base-collector junction is reverse-biased.