Phys2610 (2019) Prelab 7 solutions

Experiment 7: The Common Emitter Amplifier

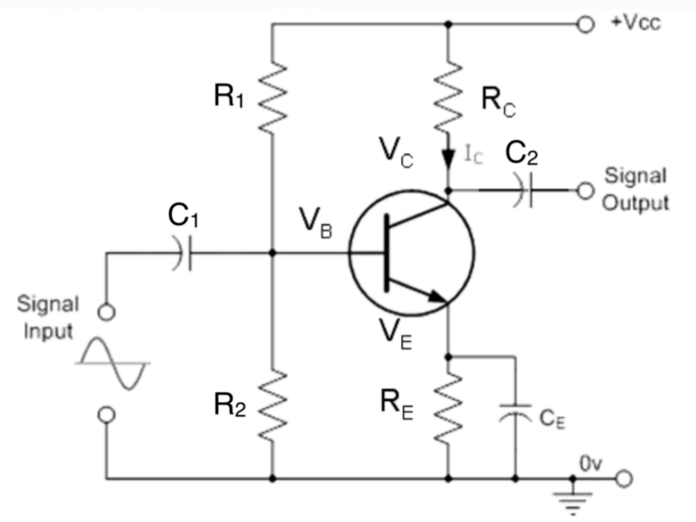
Goal: To construct a common emitter amplifier using the NPN bipolar junction transistor that was characterized last week in experiment 6.

Amplifier Circuit and Prelab Exercises:

(Refer to the introductory notes for experiment 6 as needed.)

With no ac input, the dc power supply ($+V_{cc}$) and the bias resistors establish the operating point.

The circuit will be built with and without capacitor C_E to see how it affects the performance of the circuit.



We will use: $V_{CC} = 18$ V, $R_1 = 33$ kΩ, $R_2 = 2.2$ kΩ, $R_C = 3.3$ kΩ, $R_E = 220$ Ω, $C_1 = C_2 = 0.47$ µF, $C_E = 10$ µF.

a) Assuming I_b is small, and that $V_{BE} = 0.6$ V when the BE junction is forward biased, determine the dc currents I_2 (flowing through R_2) and I_C for these component values.

b) What is the value of V_{CE}?

c) Using your measurement of β from expt. 6 ($\beta \approx 200$), what is the value of I_b?

d) On a copy of the transistor characteristic curves from expt. 6, plot the load line: I_C versus V_{CE} for $V_{cc} = 18$ V. Identify and mark the operating point (I_C, V_{CE} and I_b).
(You may interpolate between the measured characteristic curves to illustrate this.)

e) Suppose $V_B \rightarrow V_B + \delta V_B$. Assume V_{BE} and V_{CC} are constant. What are the corresponding changes in I_E and I_C? What is δV_C? Show that $\delta V_C / \delta V_B \approx -R_C / R_E$. (This is essentially the gain of the amplifier circuit; the – sign indicates a phase shift of π)

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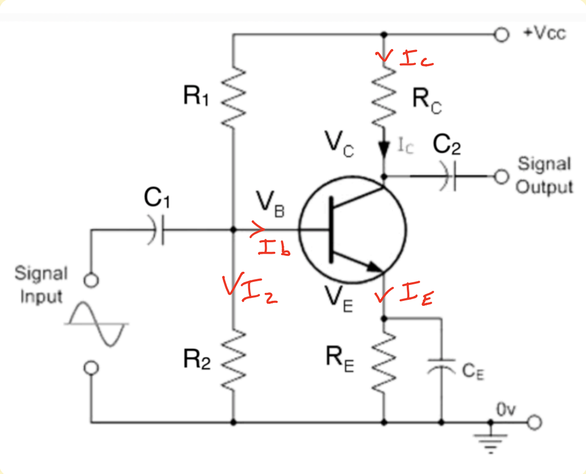


Assuming I_b is small,

$$V_B = V_{cc} \frac{R_2}{R_1 + R_2} = 1.12\,V$$

Then, $I_2 = \frac{V_B}{R_2} = \boxed{0.51\,mA}$

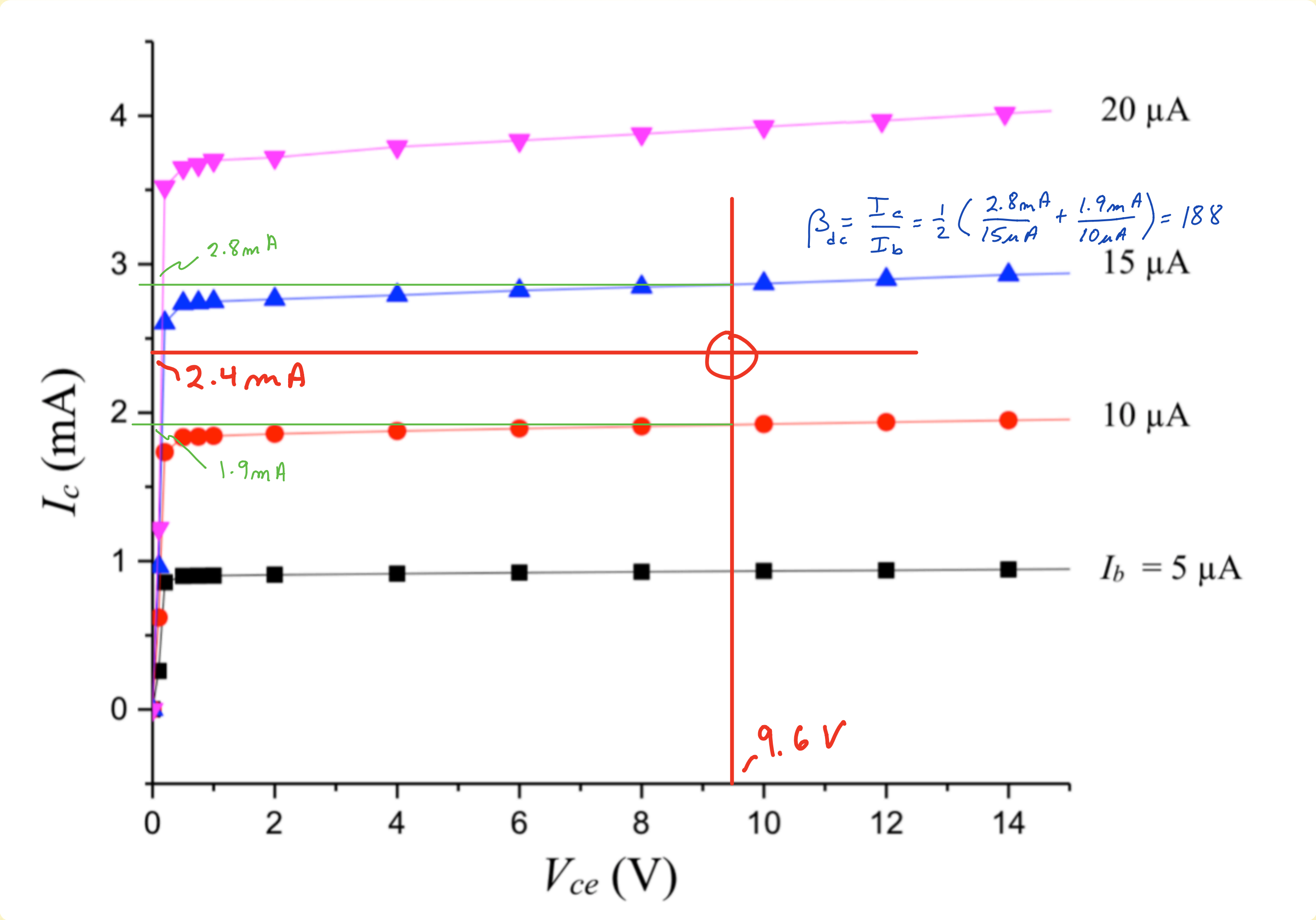
and $V_B - V_{BE} - I_E R_E = 0 \rightarrow I_E = \frac{V_B - V_{BE}}{R_E} = 2.82\,mA \rightarrow I_c \cong I_E = \boxed{2.39\,mA}$

b) What is the value of V_{CE}?

Applying KVL, $V_{cc} - I_c R_c - V_{CE} - I_c R_E = 0$

gives $V_{CE} = V_{cc} - I_c(R_c + R_E) = \boxed{9.6V}$

c) Using your measurement of β from expt. 6 ($\beta \approx 200$), what is the value of I_b?

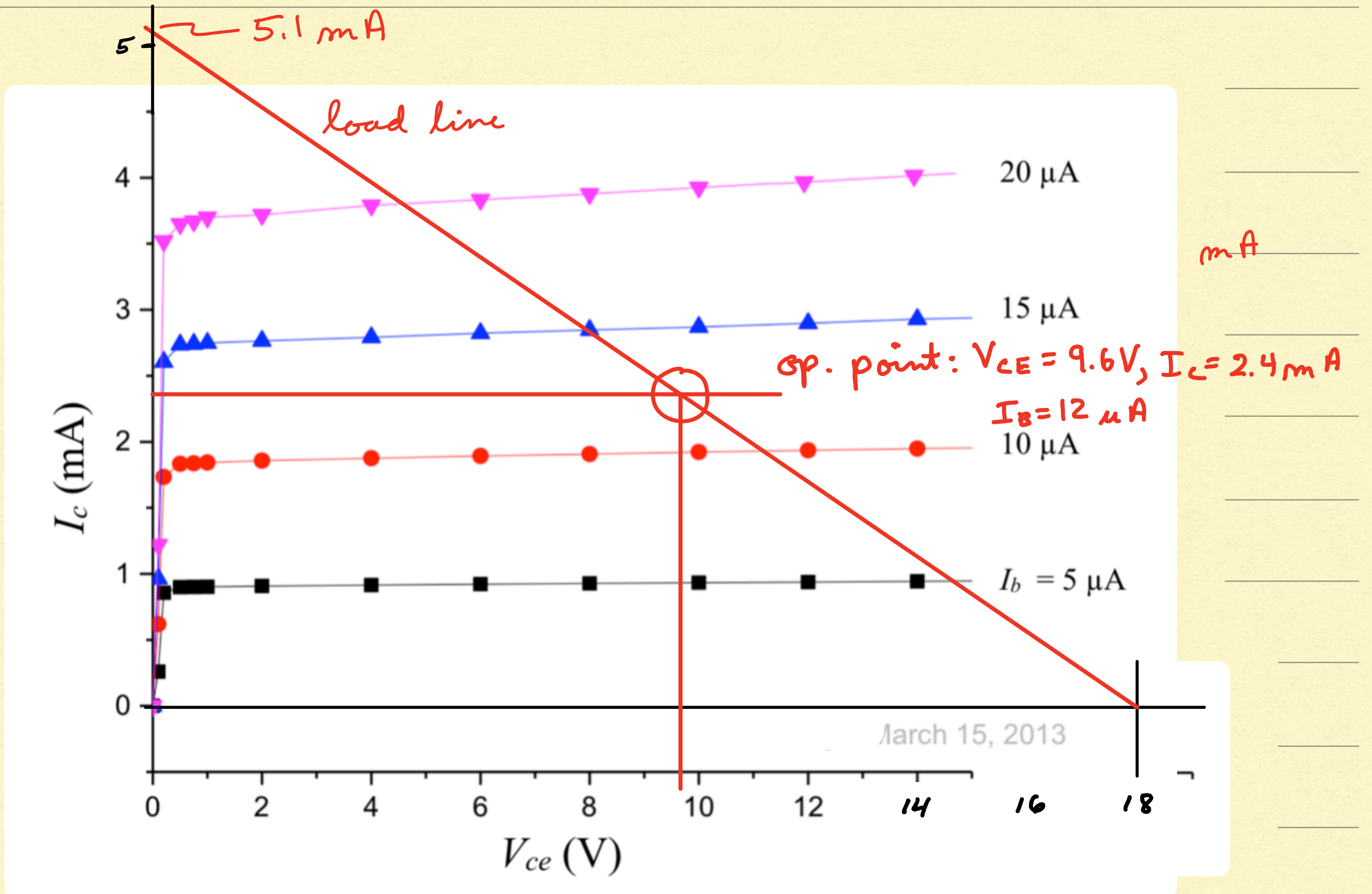


From the sample data supplied with experiment 6,
at $V_{CE} = 9.6\,V$ and $I_C = 2.4\,mA$, the value of β_{dc} can be
taken as the average of the values on the $I_b = 10\mu A$ and $I_b = 15\mu A$ curves.
This gives $\beta_{dc} = 188$, so $I_b = I_c/\beta = \frac{2.4mA}{188} = \boxed{12.2\mu A}$ (which
is consistent with simply interpolating between the I_B curves.

d) On a copy of the transistor characteristic curves from expt. 6, plot the load line: I_C versus V_{CE} for V_{cc} = 18 V. Identify and mark the operating point (I_C, V_{CE} and I_b).
(You may interpolate between the measured characteristic curves to illustrate this.)

Load line: $I_C = \frac{V_{CC}}{R_C + R_E} - \frac{V_{CE}}{R_C + R_E} = 5.11\,mA - V_{CE}\left(\frac{1}{3.52\,k\Omega}\right)$

Operating point: $\boxed{I_C = 2.8\,mA,\ V_{CE} = 8.1\ V,\ I_B = 15\,\mu A}$



e) Suppose $V_B \to V_B + \delta V_B$. Assume V_{BE} and V_{CC} are constant. What are the corresponding changes in I_E and I_C? What is δV_C? Show that $\delta V_C / \delta V_B \approx -R_C / R_E$. (This is essentially the gain of the amplifier circuit; the – sign indicates a phase shift of π)

For $V_B \to V_B + \delta V_B$, $V_E \to V_E + \delta V_B$ since $V_E = V_B - V_{BE}$ and V_{BE} is const.

Then, I_E (and I_C) $\to I_E + \dfrac{\delta V_B}{R_E}$

so $\delta I_C = \dfrac{\delta V_B}{R_E}$

Since $V_C = V_{CC} - I_C R_C$

$$\delta V_C = = - \delta I_C R_C = - \delta V_B \frac{R_C}{R_E}$$

and the gain is $\dfrac{\delta V_C}{\delta V_B} = - \dfrac{R_C}{R_E}$