Pre-Lab 3

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1. We may begin by finding a DC equivalent circuit (capacitors become open circuits):

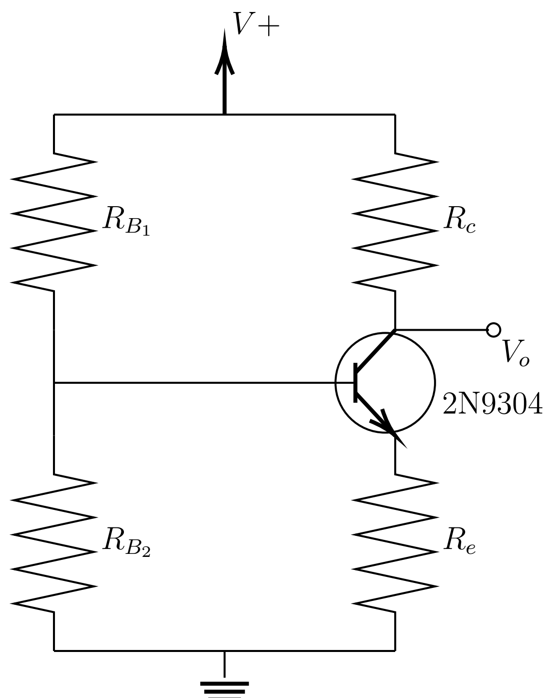

Figure 1: DC-Equivalent Circuit

We then use a Thévenin equivalent at the voltage source:

$$V_{Th} = V^+ \left(\frac{10k}{47k + 10k} \right)$$
$$V_{Th} = 1.7544[\text{V}]$$

$$R_{Th} = \frac{(47)(10)}{47+10}[\mathrm{k}\Omega]$$
$$R_{Th} = 8.2456[\mathrm{k}\Omega]$$

This gives us the following circuit:

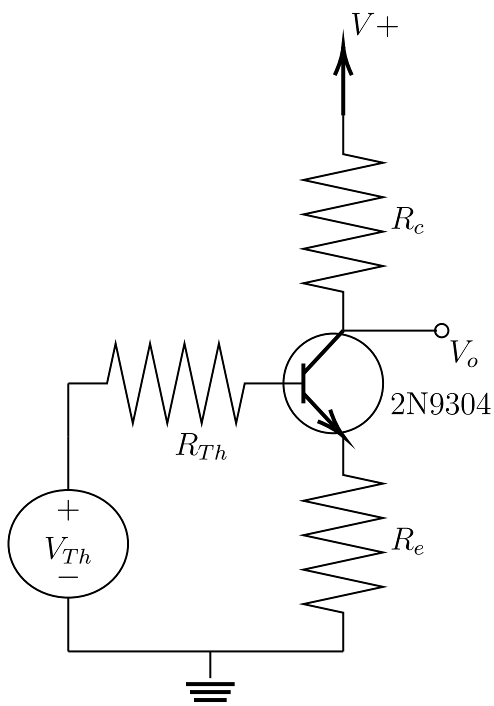

Figure 2: Thévenin Equivalent Circuit

From here, we see that I_B flows through R_{Th}, I_C flows through R_C, and I_E flows through R_E. We may begin by writing the KVL for the loop:

$$-V_{Th} + I_B R_{Th} + V_{BE} + I_E R_e = 0$$

Per our equations, we know that $I_E = (1+\beta)I_B$, so we substitute and rearrange to get:

$$I_B = \frac{V_{Th} - V_{BE}}{R_{Th} + (1+\beta)R_e}$$

We can then analyze the provided cases:

- $\beta = 80$:

$$I_B = \frac{1.7544 - .7}{8.2456 \cdot 10^3 + (1+80)(220)}$$

$$\boxed{I_B\Big|_{\beta=80} = 40.452[\mu\text{A}]}$$

$$I_C = 80 I_B$$

$$\boxed{I_C = 3.236[\text{mA}]}$$

$$V_C = V^+ - I_C R_C$$

$$V_C = 10 - (3.236)(1)$$

$$\boxed{V_C = 6.764[\text{V}]}$$

$$V_B = V_{Th} - I_B R_{Th}$$

$$V_B = 1.7544 - (40.452 \cdot 10^{-3})(8.2456)$$

$$\boxed{V_B = 1.7541[\text{V}]}$$

Given that $V_C > V_B$, the collector-to-base junction is reverse-biased, meaning that the transistor is active. Thus, the Q-point is stable.

- $\beta = 300$:

$$I_B = \frac{1.7544 - .7}{8.2456 \cdot 10^3 + (1 + 300)(220)}$$

$$\boxed{I_B\Big|_{\beta=300} = 14.16[\mu\text{A}]}$$

$$I_C = 300 I_B$$

$$\boxed{I_C = 4.248[\text{mA}]}$$

$$V_C = V^+ - I_C R_C$$

$$V_C = 10 - (4.248)(1)$$

$$\boxed{V_C = 5.752[\text{V}]}$$

$$V_B = V_{Th} - I_B R_{Th}$$

$$V_B = 1.7544 - (14.16 \cdot 10^{-3})(8.2456)$$

$$\boxed{V_B = 1.6376[\text{V}]}$$

Given that $V_C > V_B$, the collector-to-base junction is reverse-biased, meaning that the transistor is active. Thus, the Q-point is stable.

We may see that, since the transistor is active for both $\beta = 80$ and $\beta = 300$, the Q-point is stable. As such, the operating point is stable for such variation of β.

2. Read through, no questions ✓

3. We know that the amplifier will be of the form:

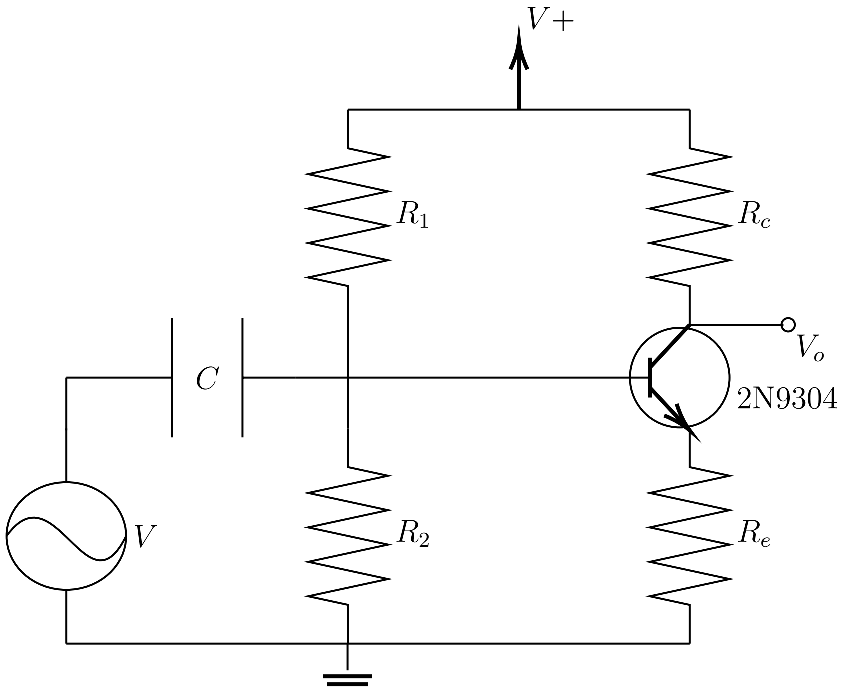

Figure 3: Amplifier Design

We want to use the most extreme values so that the circuit can tolerate these. Furthermore, we know that the gain will be:

$$A_v = -\frac{R_c}{R_e}$$
$$R_c = 21R_e$$

Thus, let us take values such that:

$$R_c = 21[\mathrm{k}\Omega] \quad \text{and } R_e = 1[\mathrm{k}\Omega]$$

From here, we want to make sure that the BJT remains active, and, therefore:

$$V_{CE} \leq \frac{V^+}{2}$$

$$V_{CE} \leq 6[\mathrm{V}]$$

This gives us the KVL equation as:

$$V_{CE} = V_{CC} - (R_c + R_e)I_C$$
$$I_C = \frac{12 - 6}{(21 + 1)k} = .27[\mathrm{mA}]$$

To find the correct R_B values for stability, we analyze the Thévenin equivalent circuit:

$$V_{Th} = .7 + (.27)(1) = .97[\mathrm{V}]$$

This gives us:

$$\frac{V_{Th}}{V^+} = \frac{R_2}{R_1 + R_2}$$

We can then ensure stability (using a factor of 1) to write:

$$1 + \beta \left(\frac{R_e}{R_{Th} + R_e} \right) = 1 + \beta \rightarrow (1 + \beta)R_e >> R_{Th}$$

This gives us a very large β, say $\beta \approx 500$. We can use this to write:

$$R_{Th} = \frac{(1 + 500)(1k)}{10} = 50[\mathrm{k}\Omega]$$

We can combine the equation above with the voltage equation to write:

$$R_1 = \frac{V^+ R_{Th}}{V_{Th}}$$
$$R_1 = \frac{(12)(50)}{.97}$$
$$R_1 = 618.56[\mathrm{k}\Omega]$$

And, finally, we get:

$$R_2 = \frac{R_1 R_{Th}}{R_1 - R_{Th}}$$
$$R_2 = \frac{(50)(618.56)}{568.56}$$
$$R_2 = 54.397[\mathrm{k}\Omega]$$

Thus, we get the following circuit:

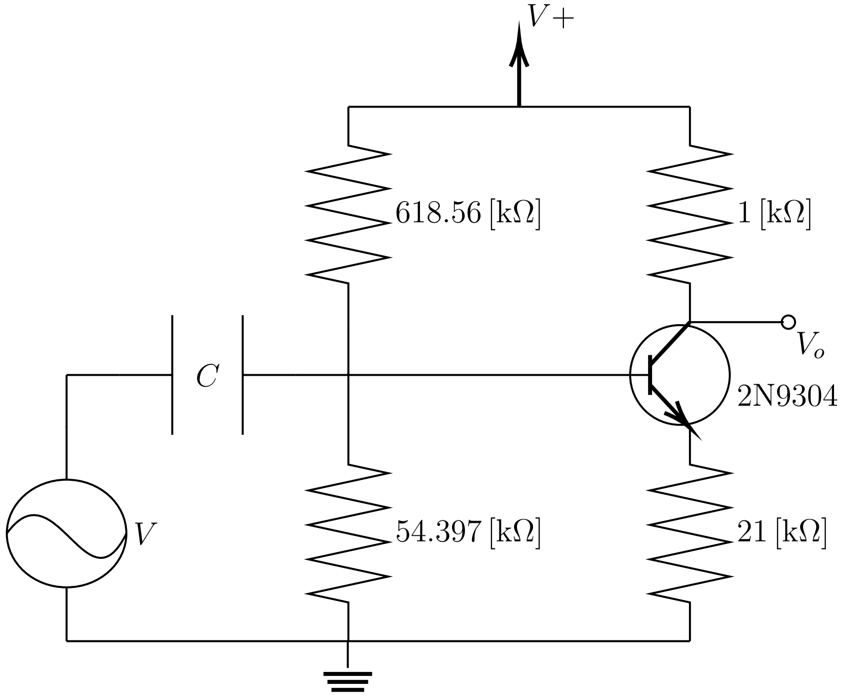

Figure 4: Final Circuit Design