Lab 9 Calculations

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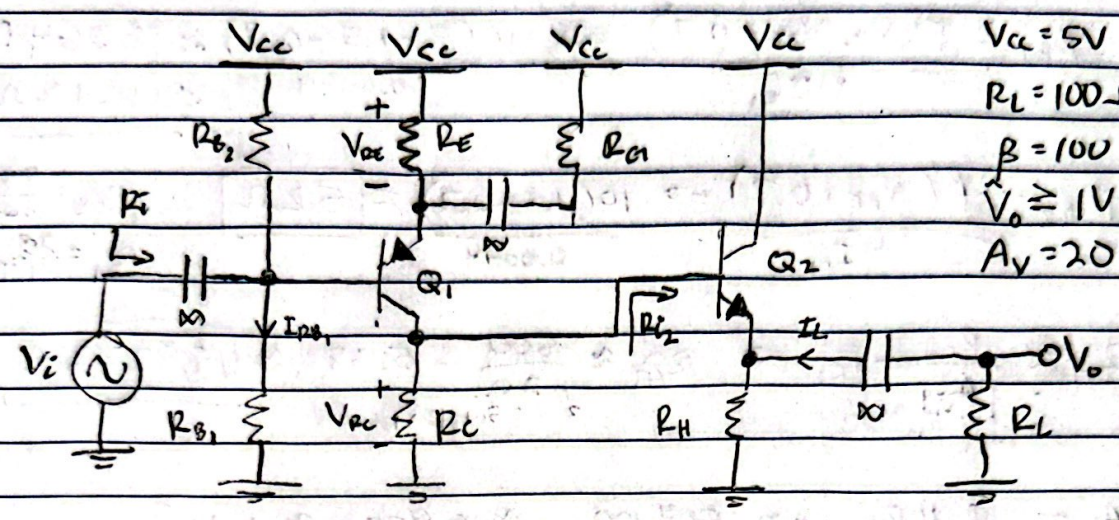


$V_{cc} = 5V$ | $R_i \geq 1k\Omega$
$R_L = 100\Omega$ | $THD \leq 5\%$
$\beta = 100$
$\hat{V}_o \geq 1V$
$A_V = 20$

$A_V = A_{V_1} A_{V_2}$
$\hat{V}_{be1} \ll V_T$
$I_{RB_1} \gg I_{B_1}$
$I_{C_1} \gg I_{B_2}$
$V_{RE} \gg 0.1V$

* Assume $A_{V_2} \approx 1$ & $R_{i_2} \gg R_L \Rightarrow A_{V_1} = 20$ & $R_i = 1K$
* $\boxed{V_{RE} = 1.5V} \gg 0.1V$ ✓
* $\boxed{\hat{V}_o = 1V} \geq 1V$ ✓
* $V_{CE,sat} = 0.3V \geq 0.2V$
* $N = 10$

$$V_{RC,max} = V_{cc} - \hat{V}_o - V_{RE} - |V_{CE,sat}| \Rightarrow 5 - 1 - 1.5 - 0.3 = \boxed{2.2V}$$

$$\frac{V_{RC} - 0.7 - \hat{V}_o}{R_H} \geq \frac{\hat{V}_o}{R_L} \Rightarrow \frac{2.2 - 0.7 - 1}{R_H} \geq \frac{1}{100} \Rightarrow 50 \geq R_H$$

$\boxed{R_H = 50\Omega}$

$$I_{C_2} = \frac{V_{RC} - 0.7}{R_H} \Rightarrow \frac{2.2 - 0.7}{50} = \boxed{0.03A}$$

$$N\left(\frac{I_{C_2}}{\beta}\right) \leq I_{C_1} \leq \frac{\beta}{R_i}\left(\frac{1}{\frac{N}{V_{RE}+0.7} + \frac{N}{V_{cc}-V_{RE}-0.7} + \frac{|AV|}{V_{RC}}}\right)$$

$$\frac{0.03}{10} \leq I_{C_1} \leq 0.1\left(\frac{1}{\frac{10}{2.2} + \frac{10}{2.8} + \frac{20}{2.2}}\right) \Rightarrow 0.003 \leq I_{C_1} \leq 0.0058$$

$\boxed{I_{C_1} = 0.0044\ A} = 4.4\ mA$ $\quad R_C = \frac{V_{RC}}{I_{C_1}} = \boxed{500\Omega}$, $R_E = \frac{V_{RE}}{I_{C_1}} \approx \boxed{341\Omega}$

(1) $R_{B1} = \frac{\beta(V_{CC} - V_{RE} - 0.7)}{N I_{C1}} \Rightarrow \frac{10(5 - 1.5 - 0.7)}{0.0044} \approx \boxed{6364\,\Omega} \approx \boxed{6.4\,k\Omega}$

$R_{B2} = \frac{\beta(V_{RE} + 0.7)}{N I_{C1}} \Rightarrow \frac{10(1.5 + 0.7)}{0.0044} \approx \boxed{5\,k\Omega}$

$r_{e2} = \frac{25}{30} = 0.83\,\Omega$

$r_{e1} = \frac{25}{4.4} = 5.68\,\Omega$

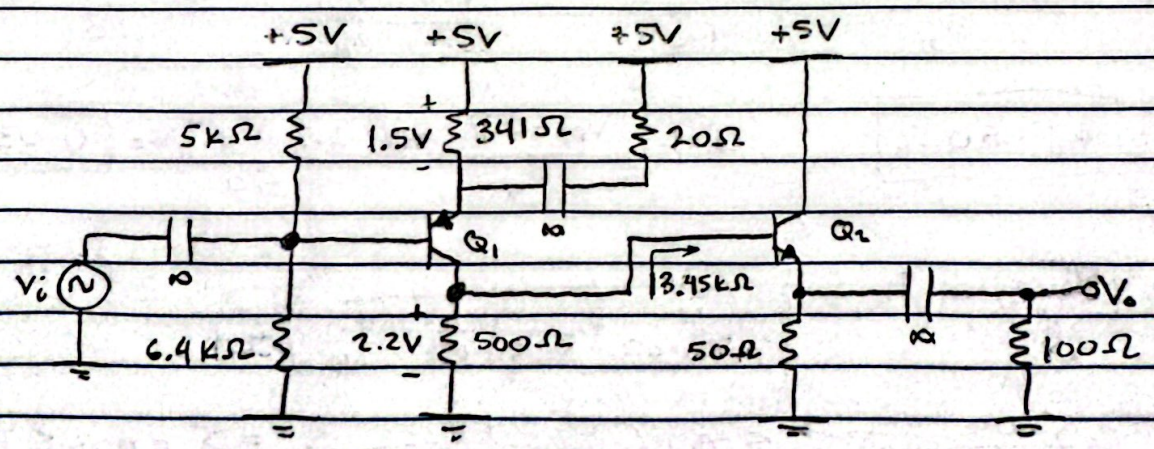
$R_G \approx \frac{R_C}{|A_V|} - r_{e1} \Rightarrow R_G \approx \frac{500}{20} - 5.68 \approx \boxed{19.32\,\Omega \approx 20\,\Omega}$

$A_{V_2} = \frac{R_H \| R_L}{r_{e2} + (R_H \| R_L)} \Rightarrow \frac{50 \| 100}{0.83 + (50 \| 100)} \approx 0.9756 \approx 1$ ✓

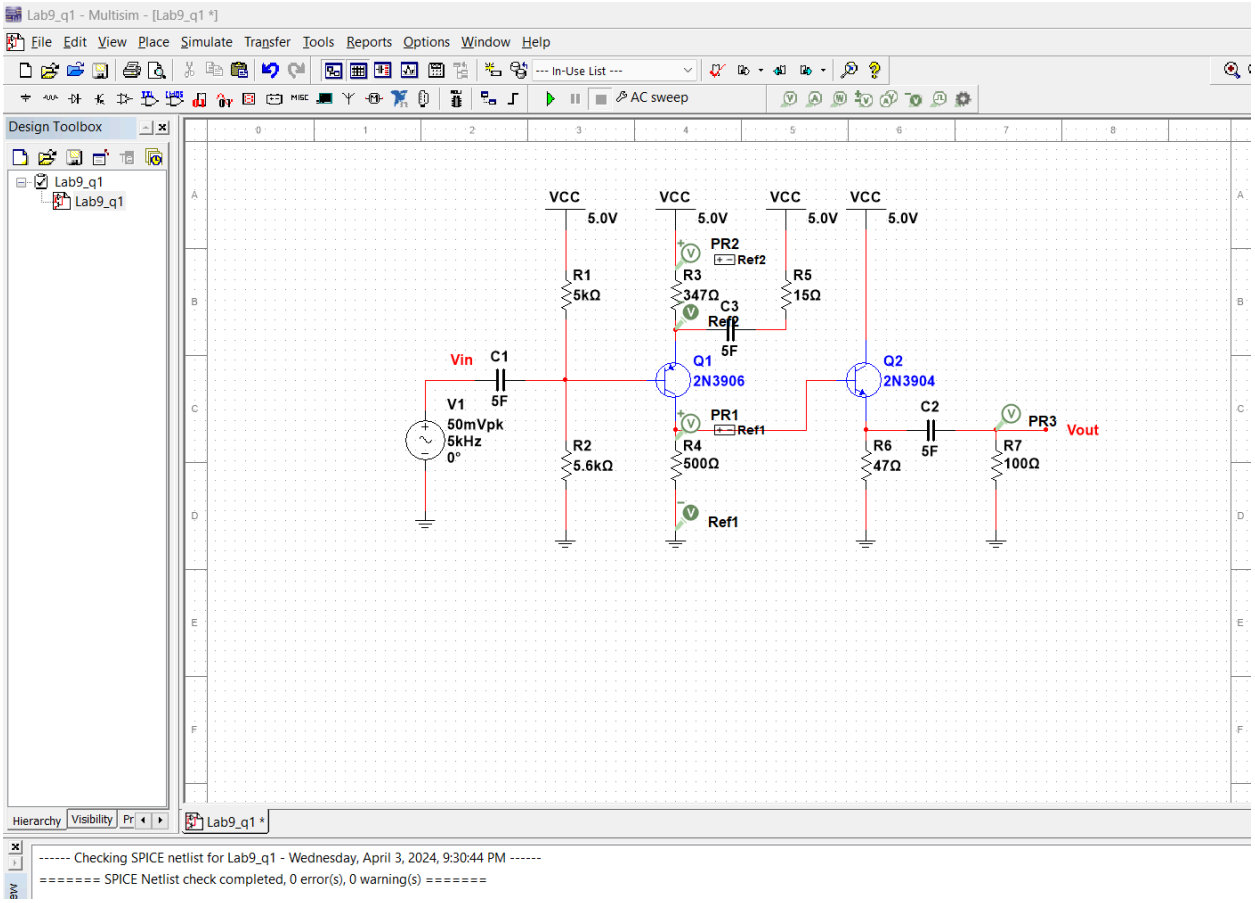
$R_{i_2} = (\beta + 1)(r_{e_2} + (R_H \| R_L)) \Rightarrow (101)(0.8333 + 33.33) \approx 3450\,\Omega$

$3450\,\Omega \gg 500$ ✓

Final circuit:



Schematic:



Here is a picture of the schematic that I used for the simulations.
Some changes I made were for R_{B1} and R_G, I adjusted the values to 5.6k and 15 respectively since the DC operating point and A_V was slightly off. I also used 347 for R_E and 47 for R_H, in order to make it more convenient to use for the lab.

DC Operating Point:

Lab9_q1

DC Operating Point Analysis

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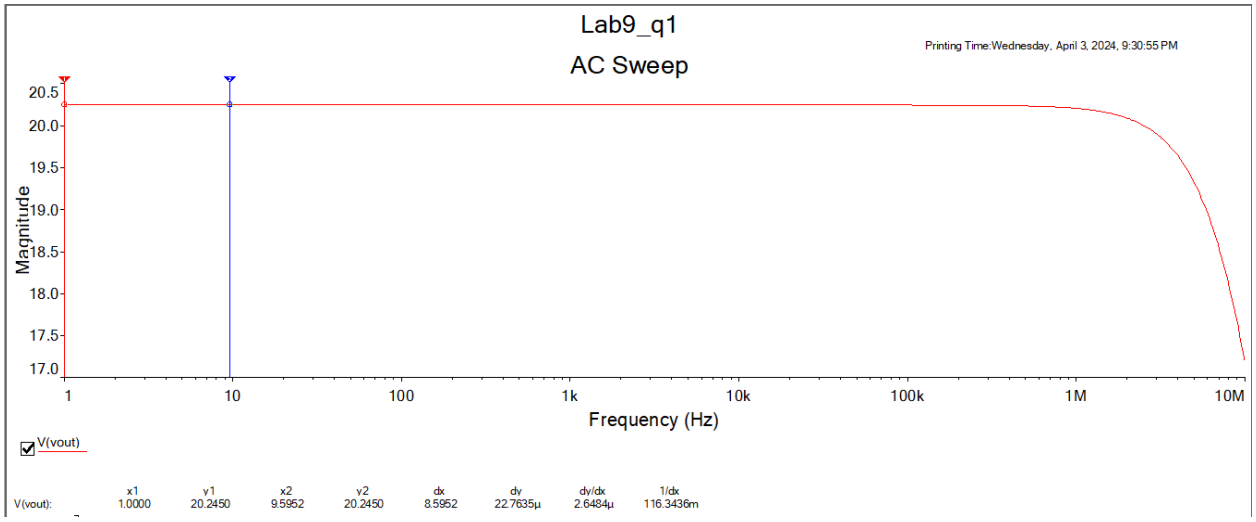
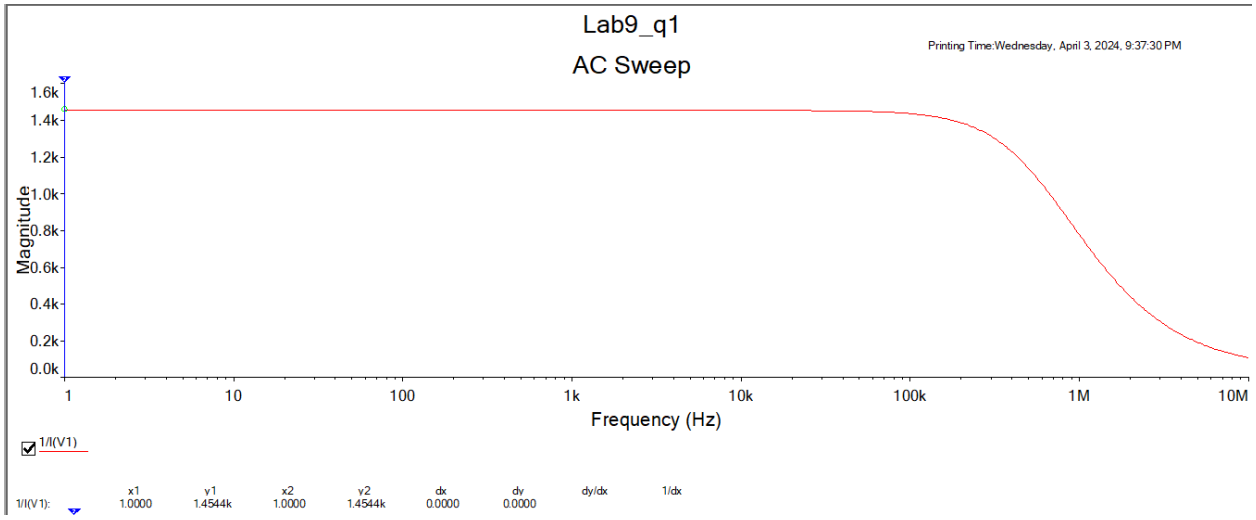
	Variable	Operating point value
1	V(5) - V(0) | V(PR1)	2.12329
2	V(vcc) - V(3) | V(PR2)	1.54712
3	V(vout) | V(PR3)	0.00000e+00
4	I(Q1[IC])	4.43348 m
5	I(Q2[IC])	28.77482 m

For the DC Operating point, we can see that the values for V_{RC} (2.12V), V_{RE} (1.54V), I_{C1} (4.43mA), and I_{C2} (28.7mA) are consistent with the calculated values.

A_V and R_i magnitude plots:

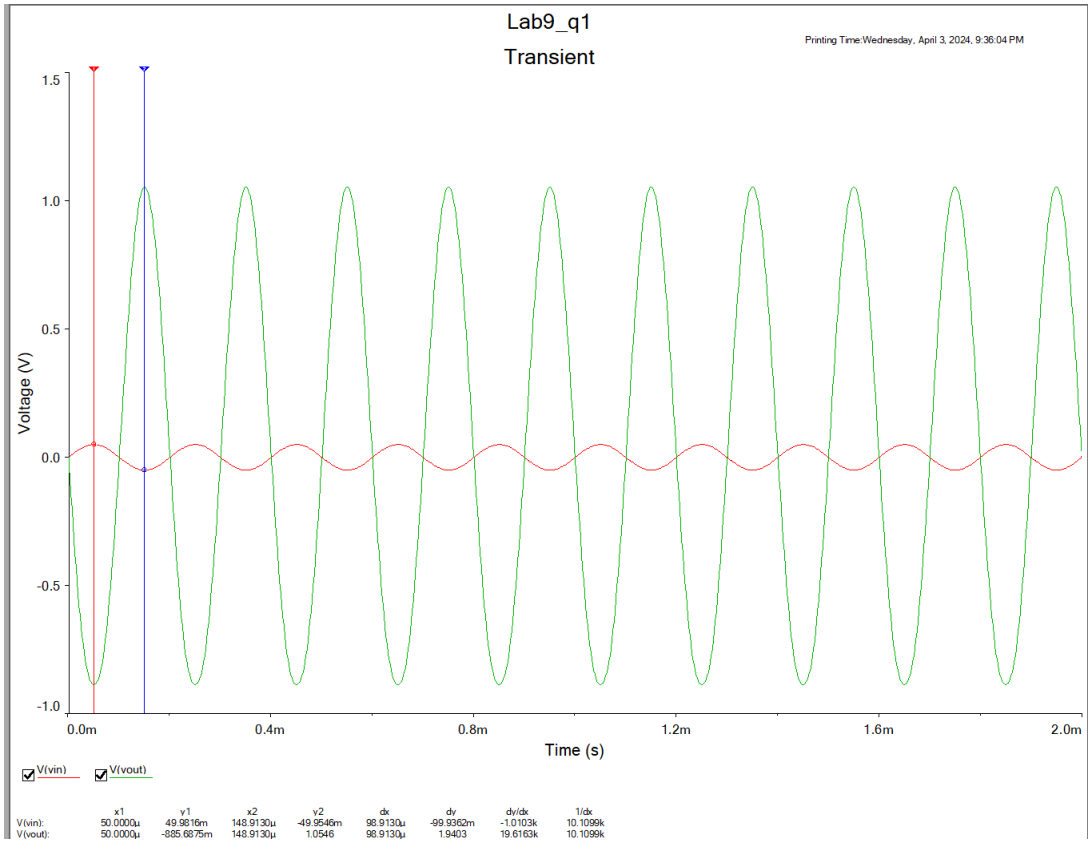


Here we can see that the magnitude of A_V for this circuit is 20.25 which has little to no difference to the parameter.



Here we can see that the input resistance is 1.45k which satisfies the parameter for R_i >= 1k.

Time domain waveform:



Here is a photo of the transient plot which shows the output voltage amplitude at 1.05V.

THD:

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1	Fourier analysis for V(vou					
2	DC component:	0.0388689				
3	No. Harmonics:	10				
4	THD:	4.4047 %				
5	Grid size:	256				
6	Interpolation Degree:	1				
7						
8	Harmonic	Frequency	Magnitude	Phase	Norm. Mag	Norm. Phase
9	0	0	0.0388689	0	0.0394844	0
10	1	5000	0.984412	179.98	1	0
11	2	10000	0.0416922	-90.117	0.0423524	-270.1
12	3	15000	0.0112555	-179.91	0.0114337	-359.89
13	4	20000	0.00340069	89.7275	0.00345454	-90.253
14	5	25000	0.00167415	0.112637	0.00170066	-179.87
15	6	30000	0.000727165	-90.335	0.000738679	-270.32
16	7	35000	0.000496544	-179.99	0.000504406	-359.97
17	8	40000	0.000164716	89.6648	0.000167324	-90.315
18	9	45000	0.000166168	0.0371392	0.000168799	-179.94
19	10	50000	2.12207e-05	-91.555	2.15568e-05	-271.53
20						

Here, the THD is 4.4% which satisfies the parameter for THD <= 5%.