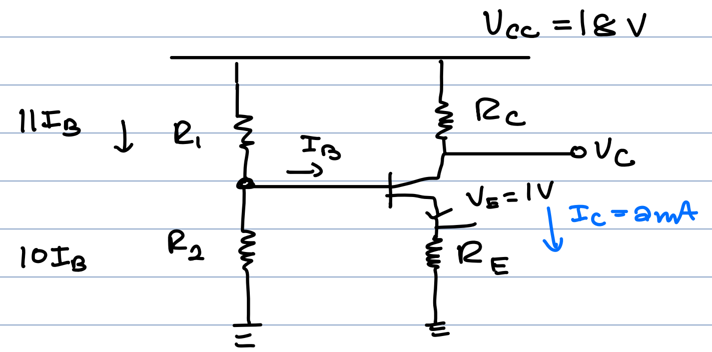
$C_c = 100\mu F$, $C_{in} = C_{out} = 10\mu F$

1) $V_{CC} = 18V$ $I_C = 2mA$ ☆ Design for max A_V ☆

Standard Bias Design CE Topology



$V_C = V_{CC}/2$

$V_{BE} = 0.7V$

$R_E = \frac{V_E}{I_E} = \frac{1}{2mA} = \boxed{500}$

$I_E \approx I_C$

$R_C = \frac{V_{CC} - V_C}{I_C} = \frac{V_{CC} - V_{CC}/2}{I_C} = \frac{V_{CC}}{2I_C} = \frac{18}{4mA}$

$R_C = 4.5K$

Typical I_B

$I_B = \frac{I_C}{B}$

$B = 140$ Based on data sheet

$R_2 = \frac{V_B}{I_{R_2}} = \frac{V_B}{10 I_B} = \frac{V_{BE} + V_E}{10 I_B} = \frac{1.7}{10 I_B}$

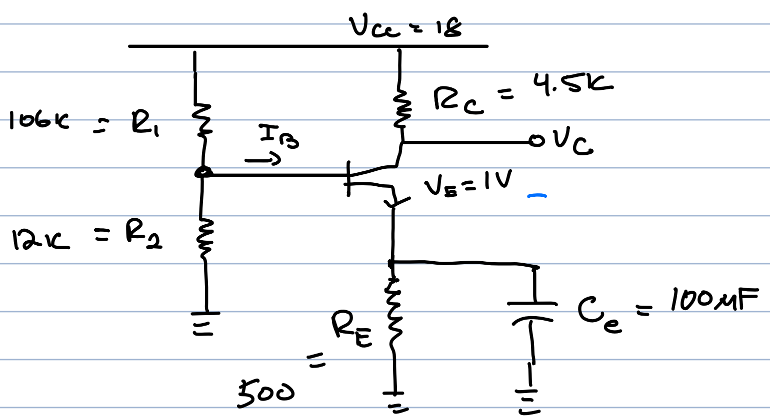
$I_{B_{Typ}} = \frac{2mA}{140} = \boxed{14\mu A}$

$R_2 = \frac{1.7}{10 \cdot 14\mu A} = \boxed{12k}$ $R_1 = \frac{V_{CC} - V_B}{11 \cdot I_B} = \frac{18 - 1.7}{11 \cdot 14\mu A} = \boxed{106k}$

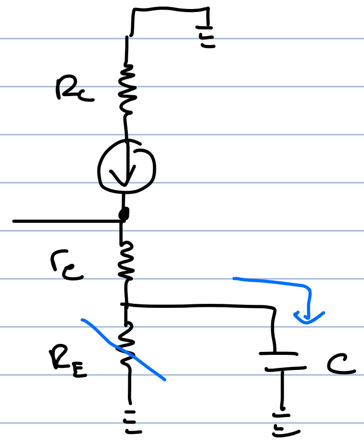
$R_2 = 12k$ $R_1 = 106K$ $R_C = 4.5K$ $R_E = 500$

$A_V = \frac{-R_C}{R_E}$

- Introducing Bypass Cap @ Emitter Will maximize Voltage Gain.



DC Model



· Ce will Short to gnd @ desired Frequency

$$A_v = \frac{V_o}{V_{in}} = \frac{V_c}{V_B} = \frac{-I_c R_c}{I_E r_e} = \frac{\beta I_B R_c}{I_B(\beta+1) r_e} = \boxed{-\frac{R_c}{r_e}}$$

$$A_v = -\frac{4500}{12.5}$$

$$\boxed{A_v = -360}$$

$$r_e = \frac{V_T}{I_e} = \frac{V_T}{I_c}$$

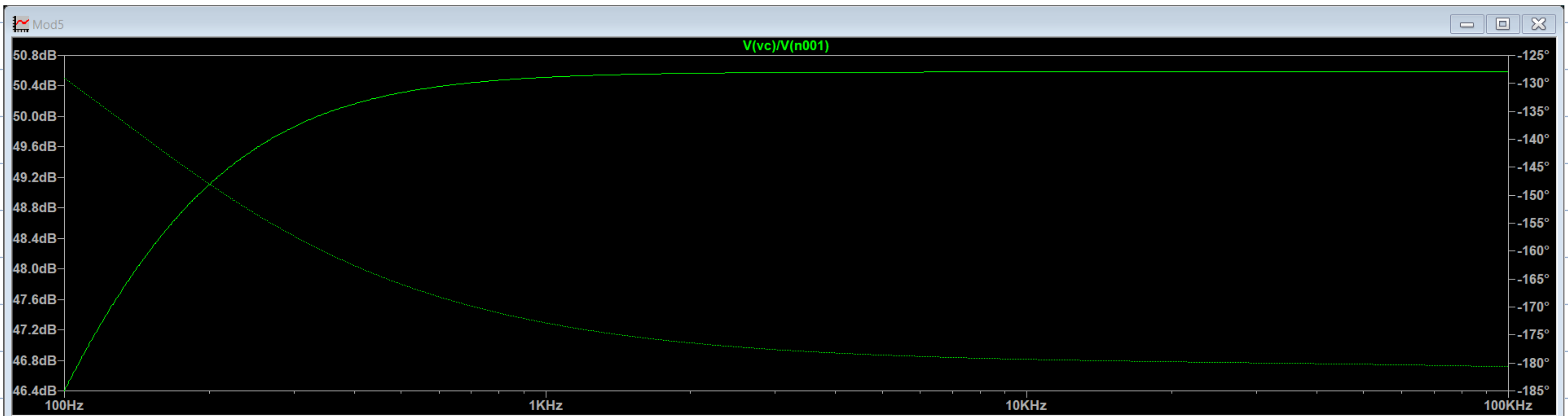
$$r_e = \frac{25mV}{2mA} = 12.5$$

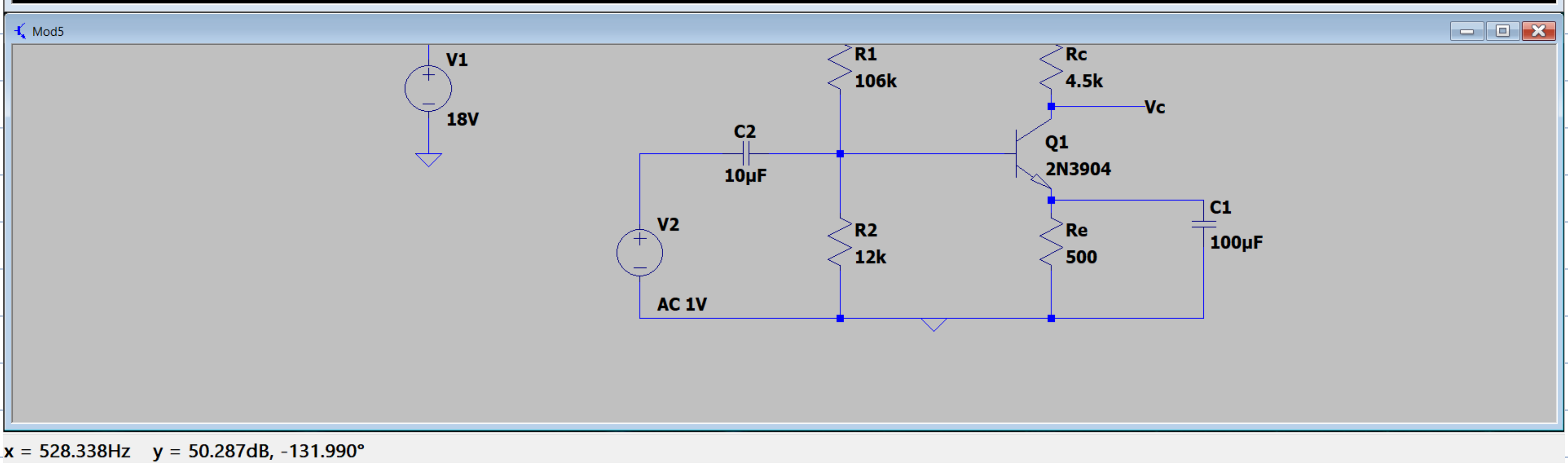
	A_v	I_c	V_c
By Hand	-360	2mA	9V
Simulation	-320	2.15mA	8.28

$$\text{Gain}_{dB} = 20\log_{10}\left(\frac{V_o}{V_{in}}\right)$$

$$52dB = 20\log_{10}(x)$$

$$316 = x$$

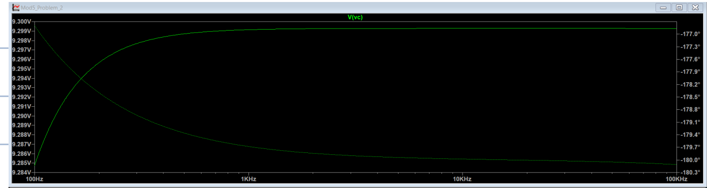


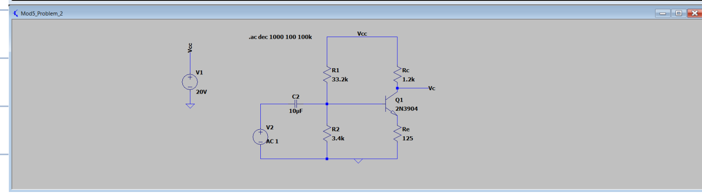


• Simulation # for I_c and V_c are really close, I think they are pretty accurate. The difference between simulation and my values was around 8%. The gain difference is similar too at around 8-10% so the numbers seem consistent.

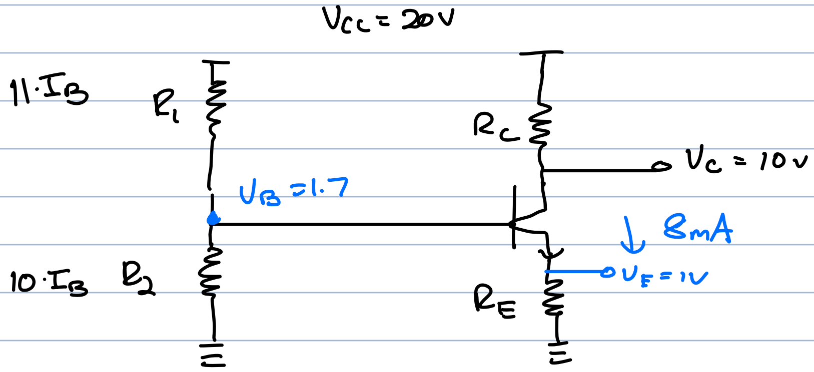
2) CE Amp

$V_{CC} = 20V$ $\quad I_C = 8mA$ $\quad V_C = 10V$





b) $A_V = -125$



R_1, R_2, R_C, R_E

Min gain Circuit

$I_E \approx I_C$

$$R_E = \frac{V_E}{I_E} = \frac{1V}{8mA} = \boxed{125}$$

$$R_C = \frac{V_{CC} - V_C}{I_C} = \frac{V_{CC} - V_{CC}/2}{I_C} = \frac{V_{CC}}{2I_C}$$

$$V_B = V_{BE} + V_E = 1.7$$

$$R_C = \frac{20}{2(8mA)} = \boxed{1.2k}$$

8mA Based on Datasheet

$\beta_{typ} \approx 160$

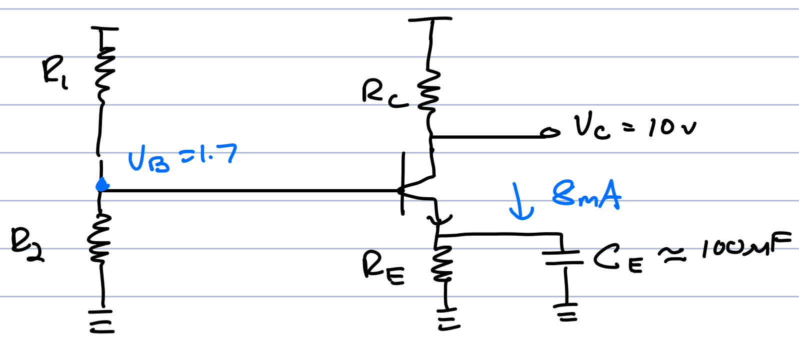
$$I_{B_{typ}} = \frac{I_C}{\beta_{typ}} = \frac{8mA}{160} = .05mA$$

$$R_1 = \frac{V_{CC} - V_B}{11 \cdot I_B} = \frac{20 - 1.7}{11 \cdot (0.05mA)} = \frac{18.3}{.55mA} = \boxed{33.2k}$$

$$R_2 = \frac{V_B}{10 \cdot I_B} = \frac{1.7}{.5mA} = \boxed{3.4k}$$

$R_1 = 33.2k$, $R_2 = 3.4k$, $R_C = 1.2k$, $R_E = 125$

→ This is regular Standard Bias and will give us gain of $\boxed{9.6}$ (Minimum gain)



- Adding this C_E will allow for max gain at High Frequency.

$$A_V = -\frac{R_C}{r_e} \qquad r_e = \frac{26mV}{8mA}$$

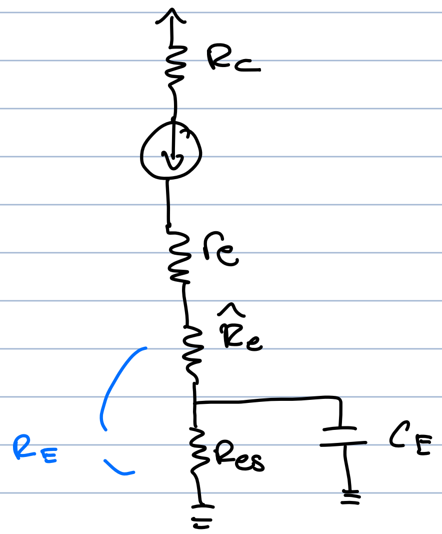
$$r_e = 3.25$$

$X_{C_E} \| R_E \to 0$

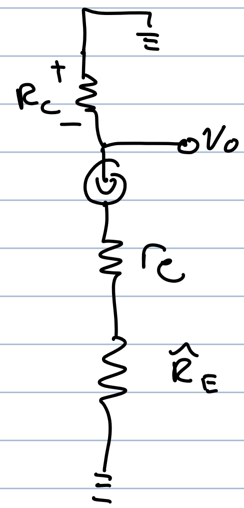
$A_v = -\frac{1200}{3.25} = \boxed{-370}$ Max gain

• Bypassing all of R_E gives max A_v. We want to bypass only a portion of it.

DC



AC



$\hat{R}_E \to$ Part of R_E that isn't bypassed

$A_v = -125$

$$A_v = -\frac{R_C}{r_e+\hat{R}_E} = -125$$

$$-125 = \frac{R_C}{r_e+\hat{R}_E}$$

$R_C = 1.2k$

$r_e = 3.25$

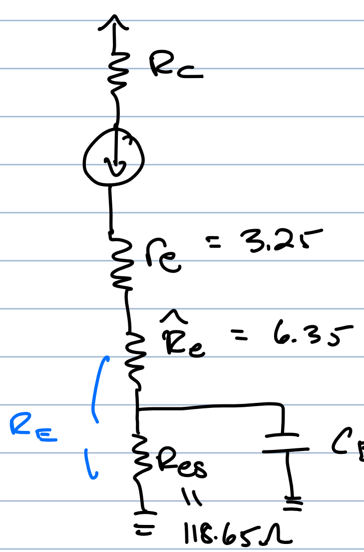
$$\hat{R}_E = \frac{R_C}{125} - r_e = \frac{1200}{125} - r_e = \boxed{6.35}$$

$R_E = 125 = \hat{R}_E + R_{es}$

$R_{es} = 125 - \hat{R}_E$

$= 125 - 6.35 = \boxed{118.65}\ \Omega$

we going to need to bypass this Res amount



$$A_v = -\frac{R_C}{r_e+\hat{R}_E} = -\frac{1200}{3.25+6.35} \approx \boxed{-126}$$

(controlled) Gain

R_E partial Bypass

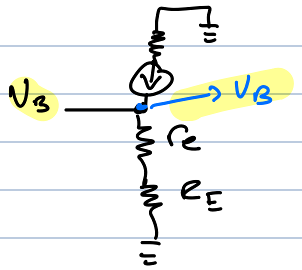
C_E freq dependency

3) **Current Gain for Min A_v**

$$A_i = \frac{I_o}{I_{in}} = \frac{V_o/Z_o}{V_i/Z_i} = \frac{V_o}{V_i} \cdot \frac{Z_{in}}{Z_o} = A_V \cdot \frac{Z_{in}}{Z_o}$$

$$\text{Min } A_V = \frac{-R_C}{R_E} = -9.6$$

$$A_i = -9.6 \frac{Z_{in}}{Z_o}$$



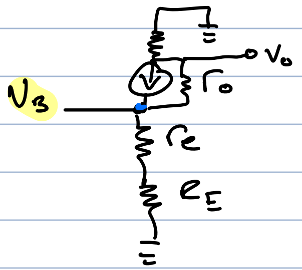
$$Z_{in} = \frac{V_B}{I_B} = \frac{I_E(r_e+R_E)}{I_B} = \frac{I_B(1+\beta)(r_e+R_E)}{I_B}$$

$$Z_{in} = \underbrace{(\beta+1)}_{\approx \beta}\underbrace{(r_e+R_E)}_{\approx R_E} \approx \beta R_E \approx 160(125)$$

r_e is small

$Z_{in} = 20K$

Z_o



$$Z_o = r_o \| R_C$$

$$h_{oe}\Big|_{I_C = 8mA} \approx 50 \mu\Omega$$

$$r_o = \frac{1}{h_{oe}} = 20K$$

$$Z_o = \frac{20K(1.2K)}{21.2K} = 1.1K$$

$$A_i = -9.6 \frac{Z_i}{Z_o} = -9.6 \frac{20K}{1.1K} = \boxed{-174}$$

→ Current gain for min A_V, close to Bmp, entire circuit

Device only current gain.

$$\beta = \frac{8mA}{.05mA} = \frac{I_C}{I_B} = \boxed{160}$$

Difference most likely from approximations

	Circuit A_i	BJT A_i
Min A_V	174	160

Absolute Values ✓

$A_v = -125$	308	160
Max A_v	160	160

Current Gain For Max A_V

$$A_i = \frac{I_o}{I_{in}} = \frac{\frac{V_o}{Z_o}}{\frac{V_{in}}{Z_{in}}} = \frac{V_o}{V_{in}} \frac{Z_{in}}{Z_o} = A_V \frac{Z_{in}}{Z_o}$$

$r_o = 20k$

$\downarrow$

$\frac{1}{h_{oe}}$

BJT only

$\hookrightarrow$ $Z_{in} = (B+1)(r_e) = 160(3.25) = \boxed{520}$

$\hookrightarrow$ No R_E

$Z_o = r_o \| R_C \approx 20k \| 1.2k \approx R_C$

$\uparrow$

Dominates

$$A_i(BJT) = -370 \frac{520}{1200} = \boxed{-160}$$

Circuit Current Gain (Max A_V)

$Z_{in} = R_1 \| R_2 \| Z_Q$

$= R_1 \| R_2 \| (1+B)(r_e)$ $\longrightarrow$ No R_E as C_E bypasses it.

$Z_{in} = 33.2 \| 3.4 \| 520$

$\boxed{Z_{in} \approx 520}$

$Z_o = \underset{\substack{\uparrow \\ 1.2k}}{\overset{\substack{20k \\ \downarrow}}{r_o \| R_C}} \approx R_C \approx 1.2k$

$$A_i(\text{Circuit}) = -370 \frac{Z_{in}}{Z_o} = -370 \frac{520}{1.2k} = -160$$

For $A_V = -125$

Circuit A_i

$$Z_{in} = R_1 \| R_2 \| Z_Q = R_1 \| R_2 \| (1+B)(r_e + \hat{R}_e)$$

$(1+160)(3.25+6.35)$

$$= 33.2 \| 3.4 \| 1.5$$

$$Z_{in} = 1K$$

$Z_o = R_C = 1.2k$

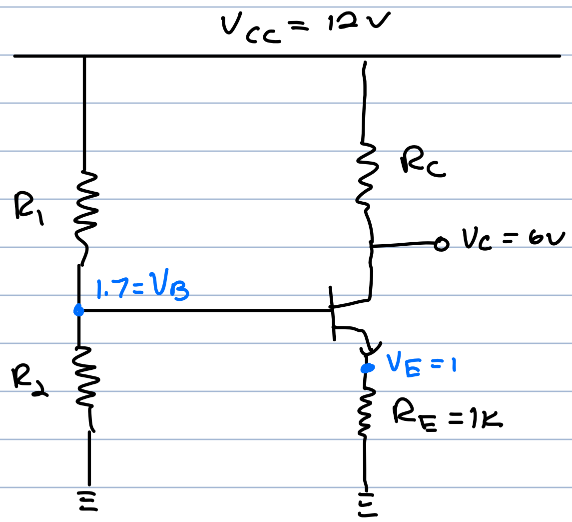
★ Current Gain is a device property and is unaffected by circuit ★

$A_i = -370\left(\frac{1}{1.2}\right) = -308$

4) ★

$V_C = 6V \qquad V_{CC} = 12V \qquad I_C = 1mA$

$Z_{in} \geq 5k$



$I_E \approx I_C$

$R_E = \frac{V_E}{I_E} = \frac{1}{I_C} = \frac{1}{1mA}$

$\boxed{R_E = 1k}$

$\boxed{R_C = \frac{6}{I_C} = \frac{6}{1mA} = 6k}$

$I_B = \frac{I_C}{B} = \frac{1mA}{120} = 8.3\mu A$

$R_1 = \frac{V_{CC} - V_B}{11 \cdot I_B} = \frac{12 - 1.7}{11 \cdot 8.3\mu A} = \boxed{112k}$

$\boxed{R_2 = \frac{V_B}{10 \cdot I_B} = \frac{1.7}{10 \cdot 8.3\mu A} = 20k}$

$\geq$ this is too low

$Z_{in} \approx 1k$

$A_v = -\frac{R_c}{r_e}$

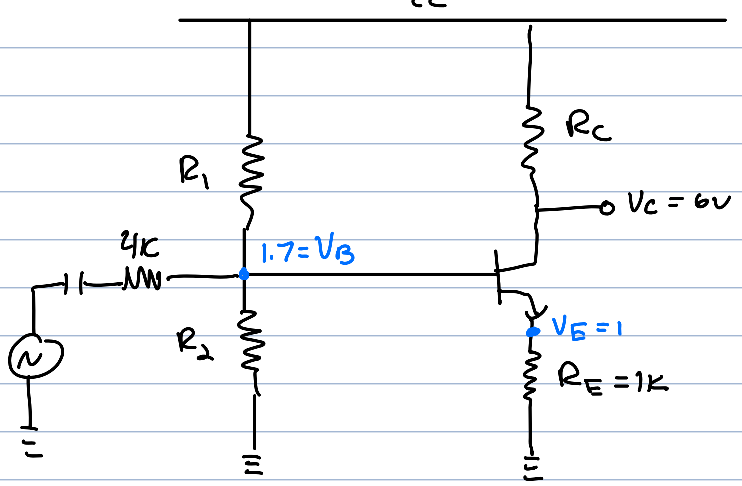
$r_e = \frac{25mV}{1mA} = 25\Omega$

Max R_c for Max gain

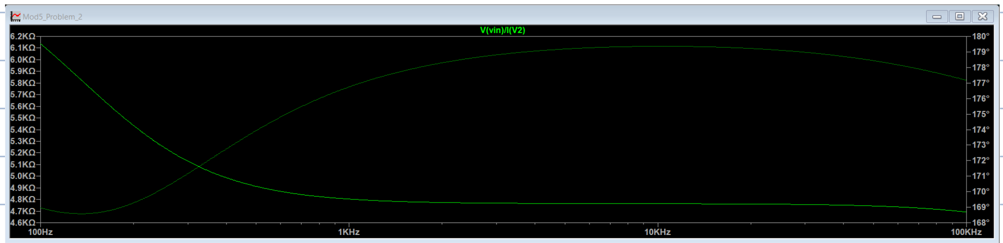
- We can add Base resister to get 5k

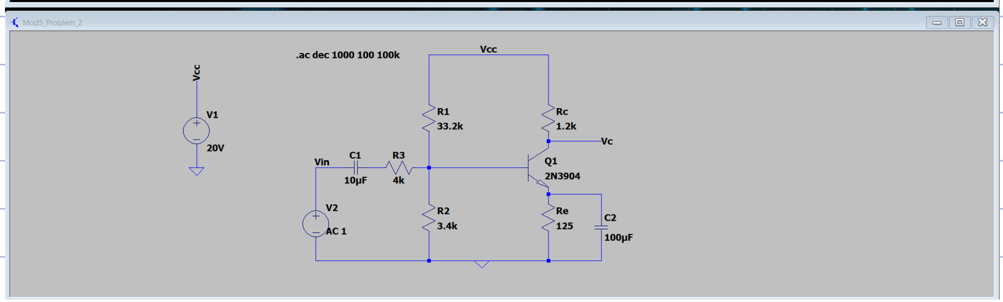
Add 4k resistor

$V_{cc} = 12V$

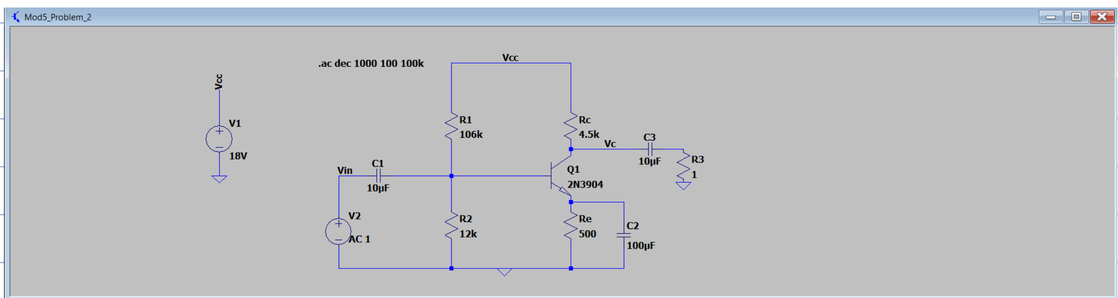


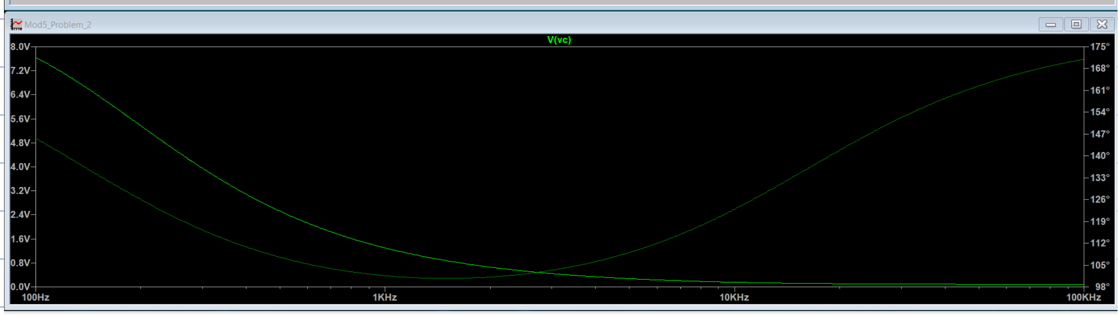
$$A_V = -\frac{R_C}{R_E} = -\frac{6k}{1k} = -6$$





Adding 4k Resistor to increase Zin. I know the gain is horrible but this is what I have. Input impedance is similar, we get to see the frequency dependence.





SO, adding even $1\,\Omega$ Destroyed the gain. It looks weird now too...