CALIFORNIA STATE UNIVERSITY
SACRAMENTO

DEPARTMENT OF ELECTRICAL AND ELECTRONIC ENGINEERING

EEE 108L
Electronics I_ Laboratory, 1 unit

Summer_ 2022

Lab - 06 Report

Submitted to

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By

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INTRODUCTION:

In this laboratory, the student will be introduced on the factors affecting the DC bias of a common-emitter amplifier stage. The collector current is stabilized against variations in transistor parameters by the inclusion of an emitter resistor. After the stage is biased, the base voltage will be driven with an AC signal to illustrate principles of common-emitter amplifier operation. To further investigate, this laboratory is divided into three parts. The first part of this laboratory will use the equations and formula that were learned from the previous lecture and apply it to solve the given circuit and questions. The student will be calculate the voltage drop and the changes in collector current as well as evaluating the gain for the given circuit. We are also need to investigate the difference when the temperature increases. For the second part of this laboratory, the student will use the knowledge using SPICE simulation and input the given circuit and values. The student must analyze the graph that will generate from the simulation as well as record the data. Lastly, the student must construct the circuit to the breadboard using the given components from the laboratory equipment. Using the AD2, the student needs to simulate and record the data.

Part1 – Preliminary Calculations

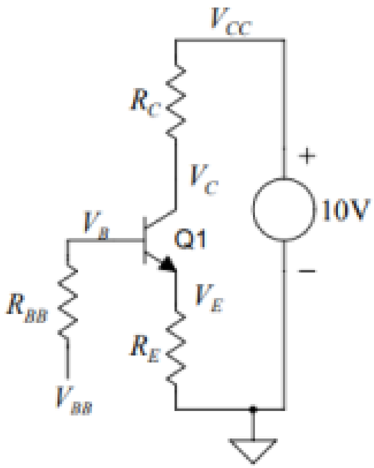


Figure 1

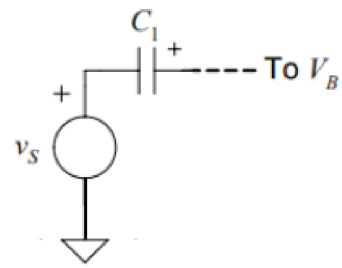


Figure 2

1. The voltage drop across $\boldsymbol{R_{BB}}$ at this bias is 1.2728 V.
2. If the value of $\boldsymbol{\beta}$ were to increase by 50%, the collector current $\boldsymbol{I_C}$ will be 0.5220 mA in which increase by 4.4%.
3. If the temperature increases by 40°C, the new collector current will be 0.5947 mA which is 18.94% increase.
4. The approximate expression for $\Delta \boldsymbol{V_C} / \Delta \boldsymbol{V_B}$ is -9.45.

Part2 - Simulations Results

For this part of the laboratory, the student simulated the circuit from the figure 1 into the SPICE and use the 2N3904 as transistor Q1. After, it needs to set the DC value of the source V_{BB} equal to the value found before run a bias point simulation.

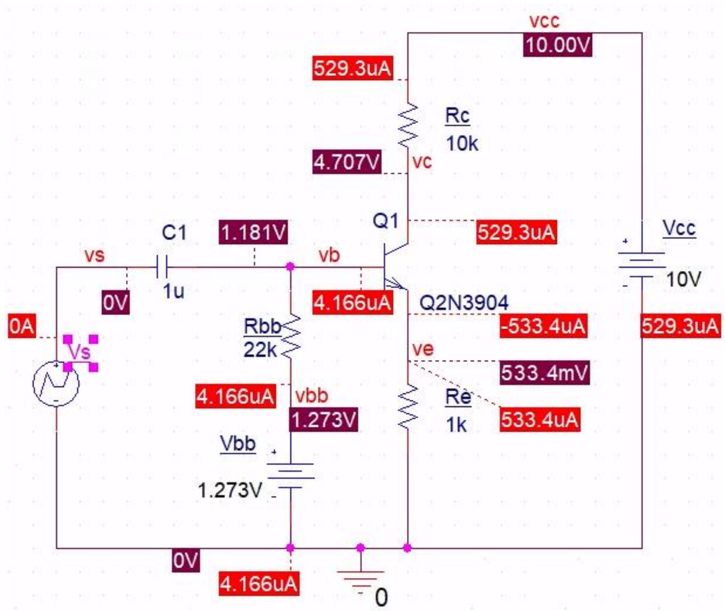


Figure 3. Constructed circuit from figure 1 and 2.

After the simulation, the student was able to gathered values that are needed shown in table 1.

Table 1. Recorded values from figure 3.

V_B = 1.181 V	I_C = 529.3 μA
V_E = 533.4 mV	I_B = 4.166 μA
V_C = 4.707 V	

After, the student increased the value of β by 50% for the transistor and resulted to Bf equal to 624.6. The circuit is shown in figure 4 and the recorded values are in table 2.

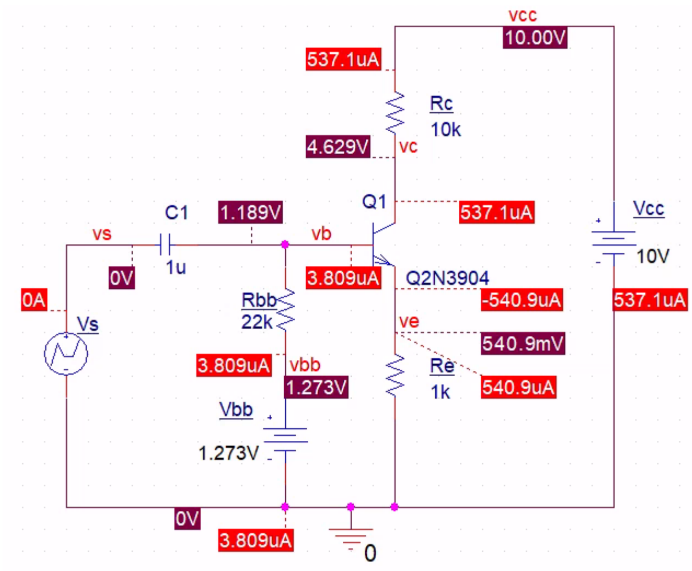


Figure 4. Circuit with an increased value of β by 50%

Table 2. Recorded values from figure 4.

V_B = 1.189 V	I_C = 537.1 μA
V_E = 540.9 mV	I_B = 3.809 μA
V_C = 4.629 V	

After that, the student return the SPICE model parameter Bf to its original value and then increase the temperature by 40°C by using Analysis / Setup / Temperature shown in figure below.

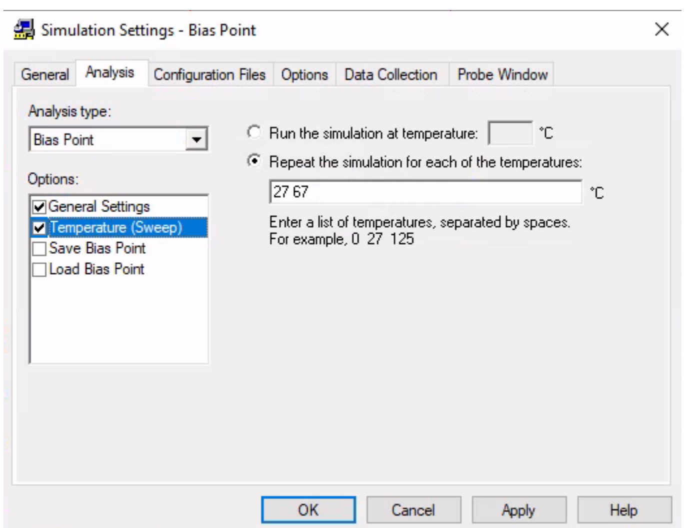


Figure 5. Setting to increase the temperature by 40°C

With this setup, the student repeated the simulation and recorded the values shown in figure 6 and table 3.

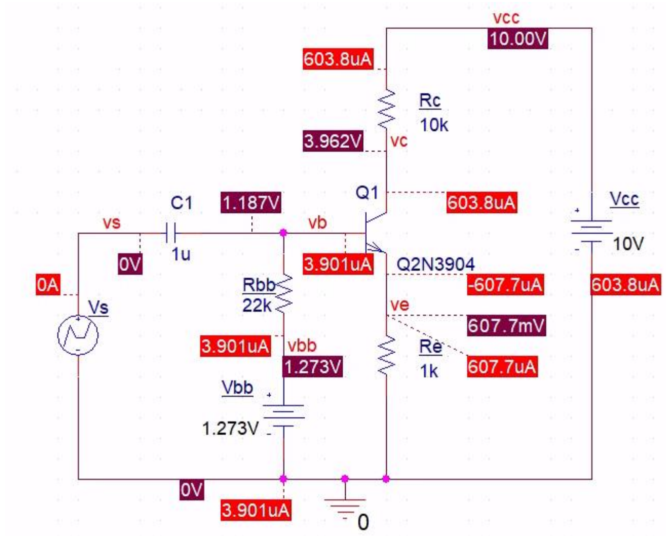


Figure 6. Circuit with increase in temperature by 40°C

Table 3. Recorded values from figure 6.

V_B = 1.187 V	I_C = 603.8 μA
V_E = 607.7 mV	I_B = 3.901 μA
V_C = 3.962 V	

Then, the student set up the analysus to perform a DC sweep of V_{BB} from 0 to 5V. The student was able to generate a graph. With the output, the student investigate the graph which shown in the figure below.

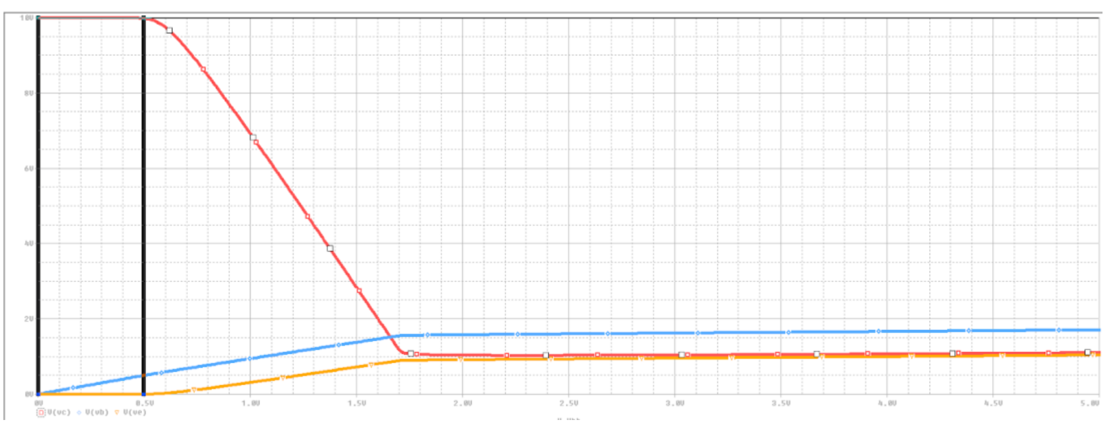


Figure 7. Simulated graph with the cutoff region

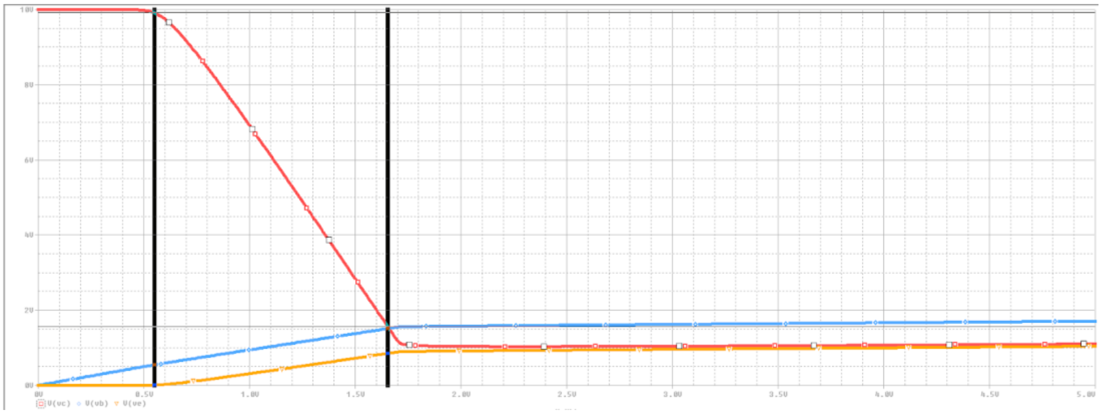


Figure 8. Simulated graph with the forward active region

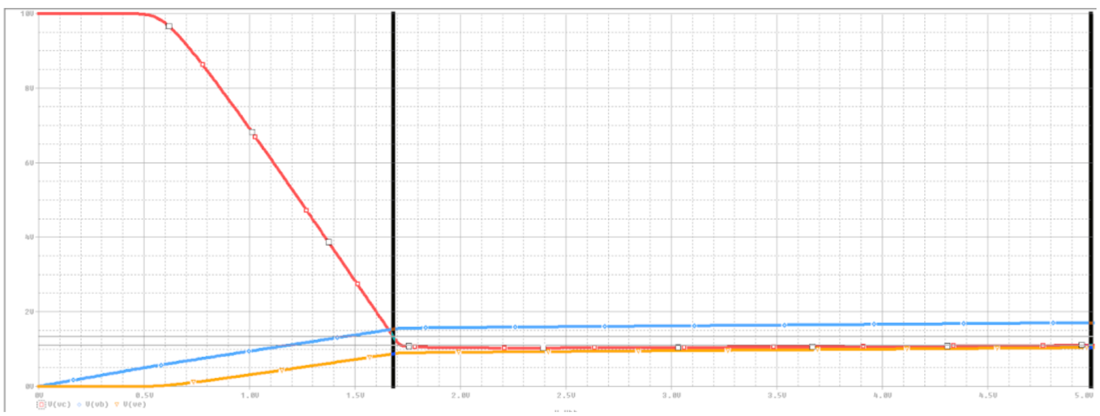


Figure 9. Simulated graph with the saturation region

With the simulated graph, we can see the different region that were divided by the black vertical lines and the traces: the red trace is V_C, the blue trace is V_B, while the orange trace is V_e. We can see from figure 7, the cutoff region showed in the leftmost part within the vertical lines. On the other hand, figure 8 showed the saturation region and the figure 9 showed the saturation region which seems the biggest portion of the graph.

Using the cursors, the student find the corresponding values of V_B and V_C within the forward active region and calculated the ${}^{\Delta V_C}/_{\Delta V_B}$ which is -9.50 shown in figure below.

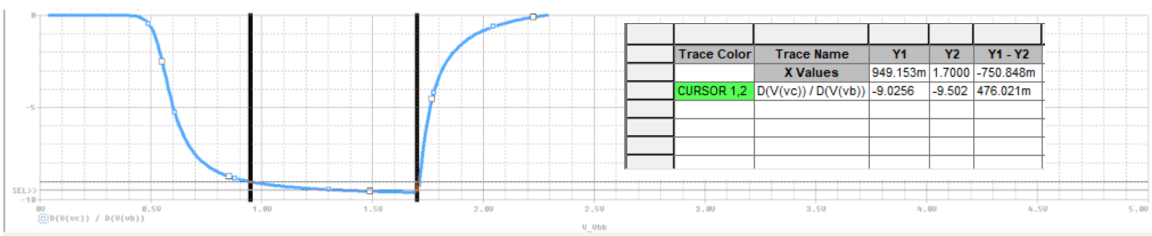


Figure 10. Simulated part of the graph looking for V_B and V_C

Part3 – Laboratory Measurements

In this part of the laboratory, the student constructed the circuit from figure 1 into the breadboard using the laboratory kit given shown in figure 11.

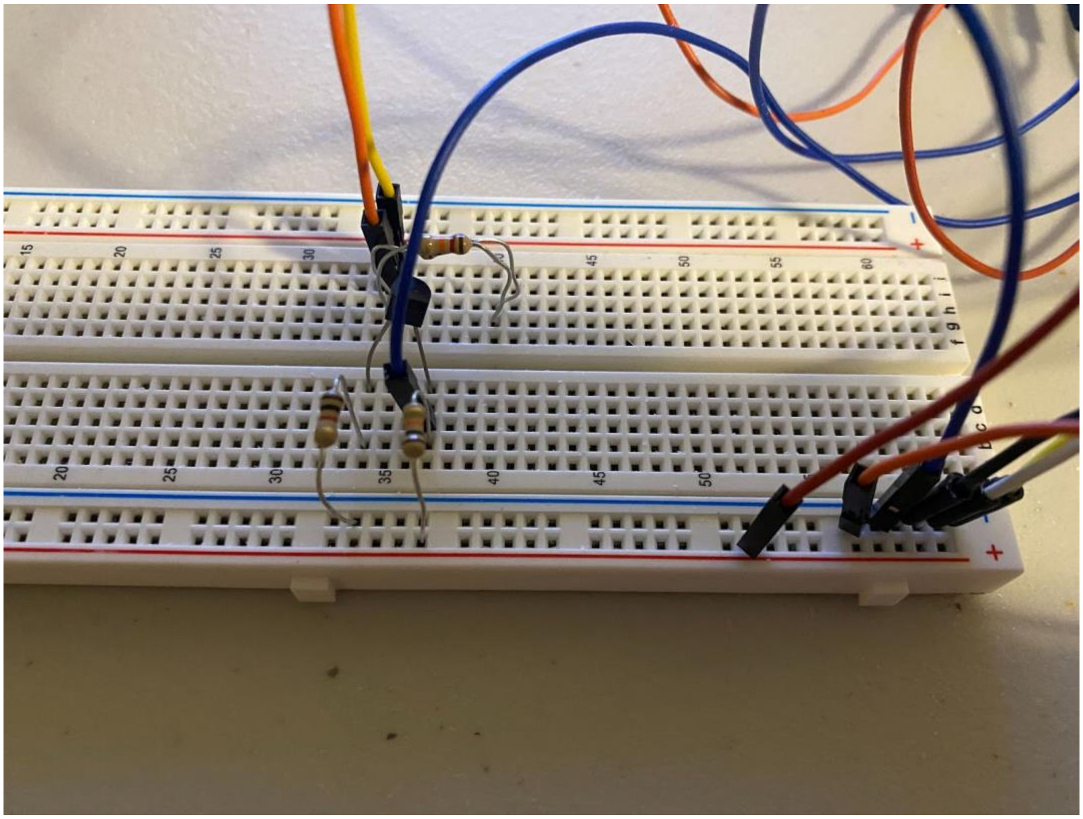


Figure 11. Constructed circuit from figure 1 to the breadboard

After that, the student sweep V_{BB} from 0.5V to at least 4V and recorded the resulting values shown in the table below.

Table 4. Recorded values from the first sweep

V_B (V)	V_C (V)	I_C (mA)
0.0985	9.943	0.00569
0.644	9.463	0.0536
0.80	8.222	0.177
1.016	6.257	0.374
1.152	5.00	0.5
1.578	1.061	0.893

Using the same circuit, the student set V_{BB} to the value that causes I_C= 0.5 mA. The student also added the components of figure 2 to the constructed circuit shown in figure 11 adjust the given settings from the laboratory manual. After the setup, the student observed the waveforms with and recorded the looking values in the table below.

Table 5. Recorded values with the new setup I_C= 0.5 mA

V_B (DC)	V_b (AC)	V_C (DC)	V_c (AC)
0.197 V	1.21	1.81 V	5.04

From this recorded values, the student was able to find and calculate the small-signal gain V_C/V_B which is equal to -9.18. Comparing this value to the simulation analysis, it is 0.32 difference. After that, the student increased the AC signal amplitude until V_C shows clipping at both peaks and simulated the graph shown below.

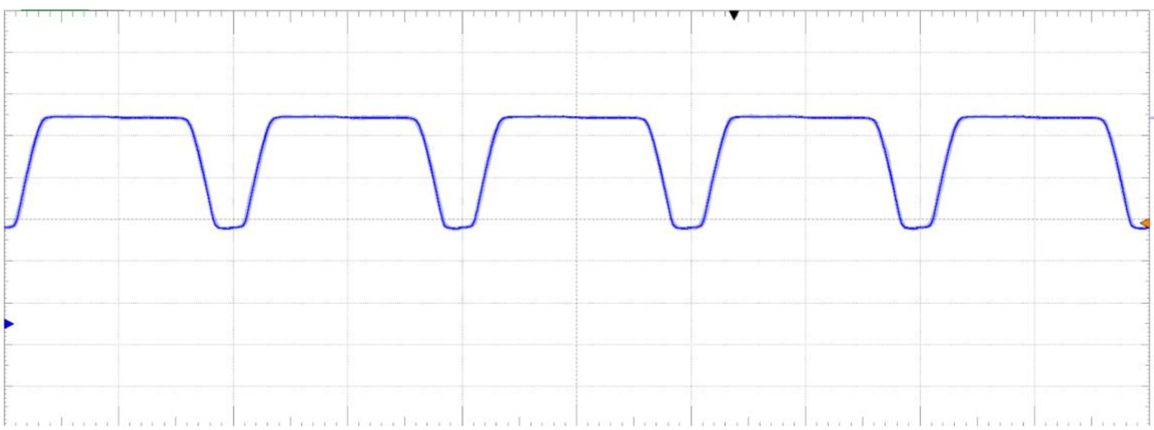


Figure 12. Simulated graph from increasing AC signal amplitude

Analyzing the graph, we can see the blue trace shows the line of V_C. Within the graph, the student was able to record the maximum and minimum value of V_C which the maximum is 9.98 V and minimum is 1.10 V.

CONCLUSION:

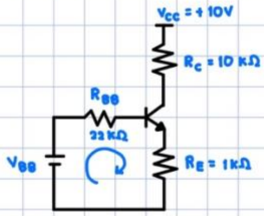
In this laboratory, the student explored the factors affecting the DC bias of a common-emitter amplifier stage. Using the knowledge from the previous laboratory and the lecture part, the student investigate this laboratory using the equations and setup the given circuit. From the preliminary calculation, the student was able to solve the circuit and given question applying the equations. We are able to investigate the changes within the values of β as well as changes in temperature. With these changes, we confirmed the values changes in the new collector current and as well as found the approximate expression for the gain $\boldsymbol{\Delta V_C}/\boldsymbol{\Delta V_B}$. For the simulation results, the student was able to draw the circuit using SPICE simulation and recorded the values. We also did the same changes such as increasing the value of β by 50% and increase the temperature by 40°C. With each changes, we observed the different voltages as well as the currents. We also ran a DC sweep to investigate the different regions and also calculate the gain within the forward active region. Lastly, we constructed the circuit into breadboard using the components from the laboratory kit. In there, we sweep V_{BB} and recorded the values. We also recorded the different voltages with the new setup using I_C = 0.5 mA. We also found the small-signal gain as well as recorded the maximum and minimum values of V_C.

Table 6. The comparison for three parts of the laboratory

	Preliminary Calculation	Simulation	Laboratory Measurement
$\Delta V_C/\Delta V_B$	-9.45	-9.50	-9.18

APPENDIX

PRELIMINARY CALCULATION



1. $V_{BB} = I_B R_{BB} + V_{BE} + I_E R_E$ $\quad I_B = \dfrac{I_E}{\beta+1}$ $\quad I_E = I_C$

$$V_{BB} = \frac{I_E R_{BB}}{\beta+1} + V_{BE} + I_E R_E$$

$$V_{BB} = \frac{(0.5mA)(22\,k\Omega)}{150+1} + 0.7V + (0.5mA)(1\,k\Omega)$$

$$V_{BB} = 1.2728\ V$$

2. $V_{BB} = \dfrac{I_E R_{BB}}{\beta+1} + V_{BE} + I_E R_E$

$$= V_{BE} + I_E\left[R_E + \frac{R_{BB}}{\beta+1}\right]$$

$$I_E = \frac{V_{BB} - V_{BE}}{R_E + \frac{R_{BB}}{\beta+1}} = \frac{1.2728V - 0.7V}{1\,k\Omega + \frac{22\,k\Omega}{150+1}} = 0.5220\ mA$$

4.4% increase in I_E

3. Temp ↑ V_{BE} ↓ : $(-2mV/°C)(40°C) = -80mV$

- V_{BE} drops : 700 mV - 80 mV = 620 mV = V_{BE} NEW
- β increases by +1.25% /°C : (+1.25%)(40°C) = 50%

  β increases by 50% : $\beta_{NEW} = (1.5)(150) = 225$

$$I_E = \frac{V_{BB} - V_{BE}}{R_E + \frac{R_{BB}}{\beta+1}} = \frac{1.2728 - 0.62V}{1\,k\Omega + \frac{22\,k\Omega}{225}} = 0.5947\ mA$$

18.94 % increase in I_E

4. $A_V = \dfrac{-\beta R_C}{R_B + r_\pi + (\beta+1)R_E}$

let $R_B = 0$:

$$A_V = \frac{-\beta R_C}{r_\pi + (\beta+1)R_E}$$

$$g_m = \frac{I_C}{V_T} = \frac{0.5mA}{26mV} = 19.231\ m$$

$$r_\pi = \frac{\beta}{g_m} = \frac{150}{19.231m} = 7.8\ k\Omega$$

$$A_V = \frac{-150(10)}{7.8 + (151)(1)} = -9.45$$