CE 3111.103

Lab 4: BJT Amplifiers – Part I

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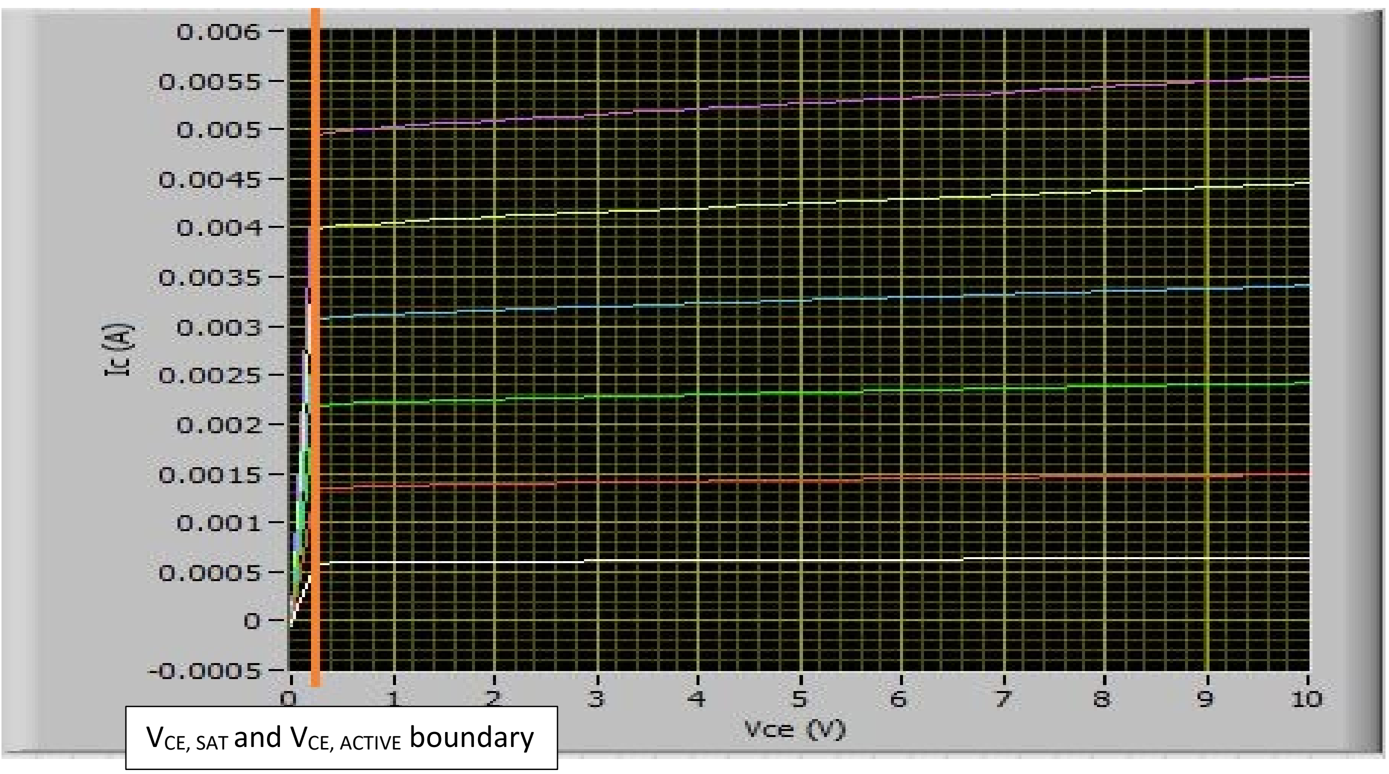
Objective

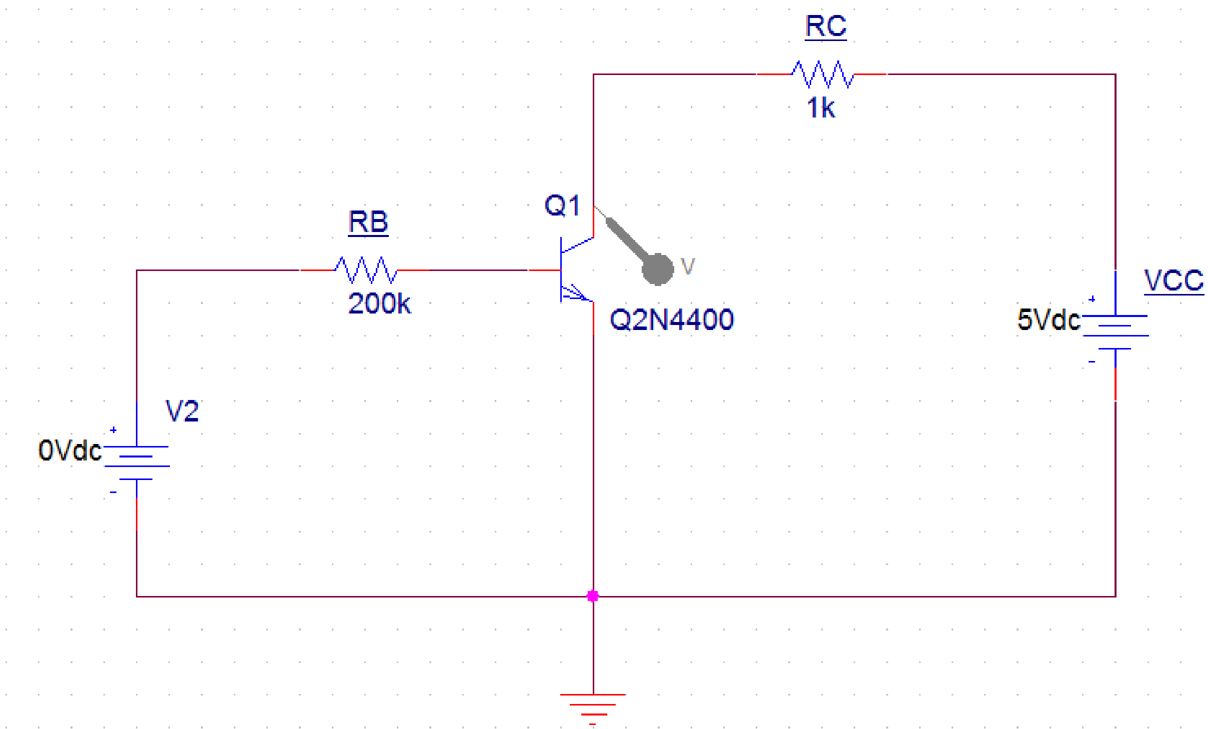
The physical meaning of the low-frequency small-signal parameters of BJT, the transfer function for two of the three BJT amplifier configurations and the meaning of biasing for transistor circuits, and how to bias a BJT in the forward-active region (FAR).

Experimental Results

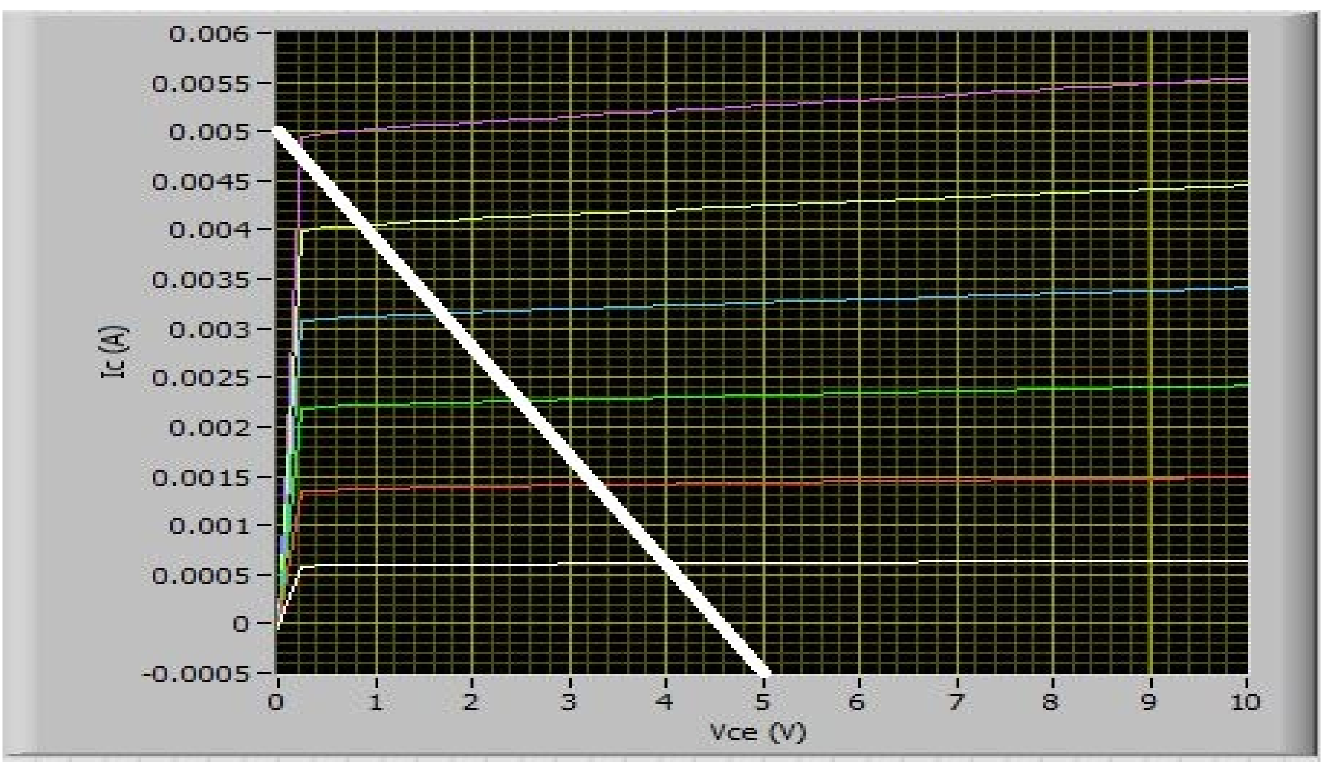
- BJT Small Signal Parameters
  - g_m, β_0, r_π, r_0 calculations:
    - $g_m = \frac{0.00227A - 0.0006A}{4.97V - 4.99V} = -0.0835$
    - $\beta_0 = \frac{0.00227A - 0.0006A}{(30-10)\times 10^{-6}} = 83.5$
    - $r_\pi = \frac{4.97V - 4.99V}{(30-10)\times 10^{-6}} = 1000\Omega$
    - $r_0 = \frac{3V - 2V}{0.0015A - 0.0014A} = 10000\Omega$
  - VCE,SAT boundary



- CE amplifier
  - Circuit:

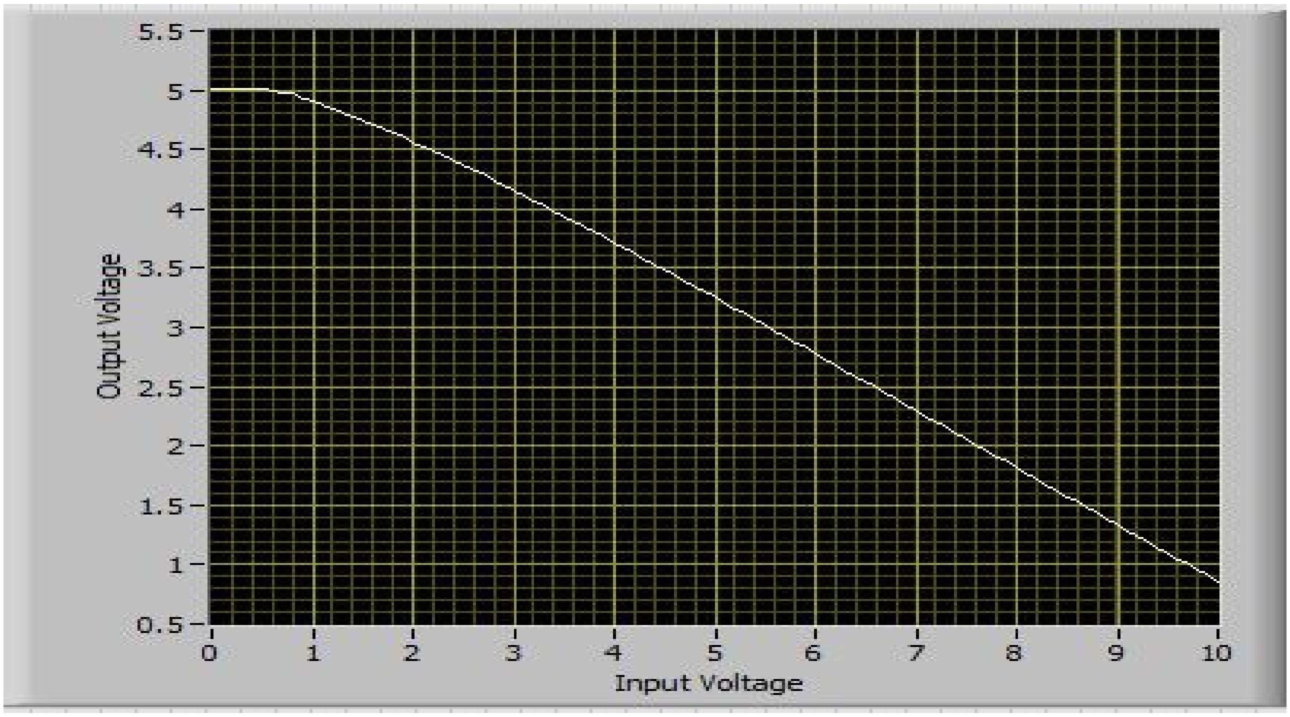


- Load line Graph

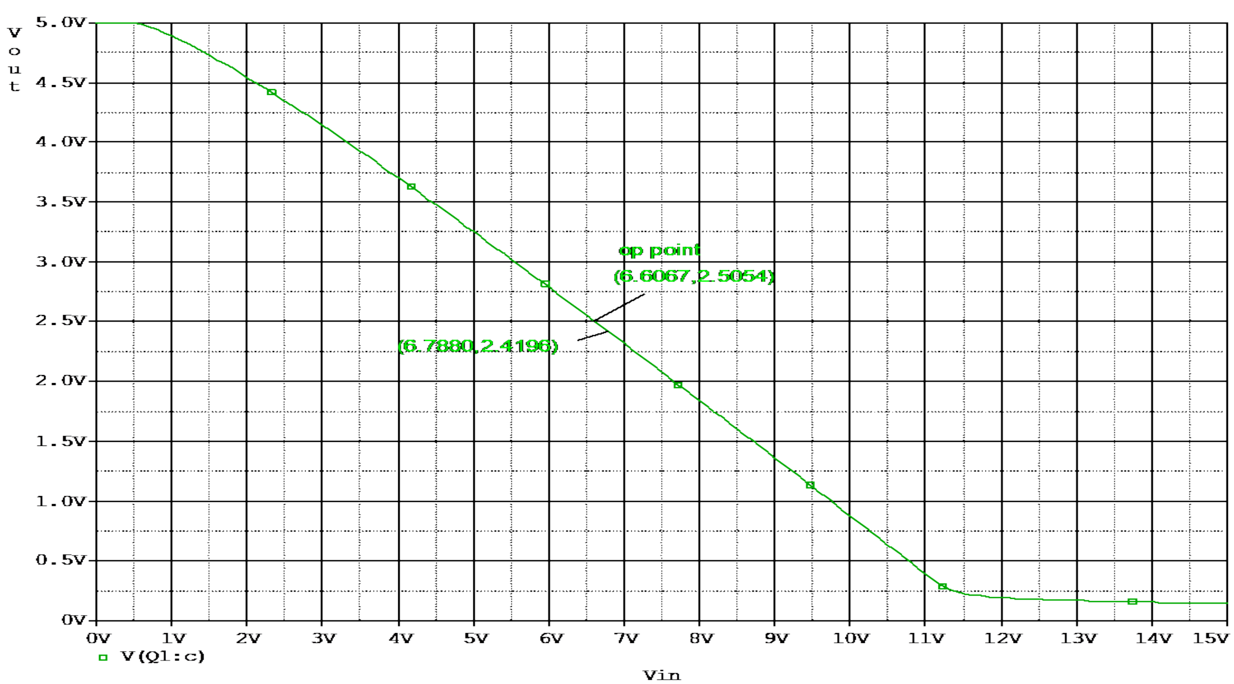


  - Load line: $I_C = \frac{V_{CC}-V_{CE}}{R_C} = \frac{5V-V_{CE}}{1000}$
- Transfer function *step g was omitted during the lab

- Step b

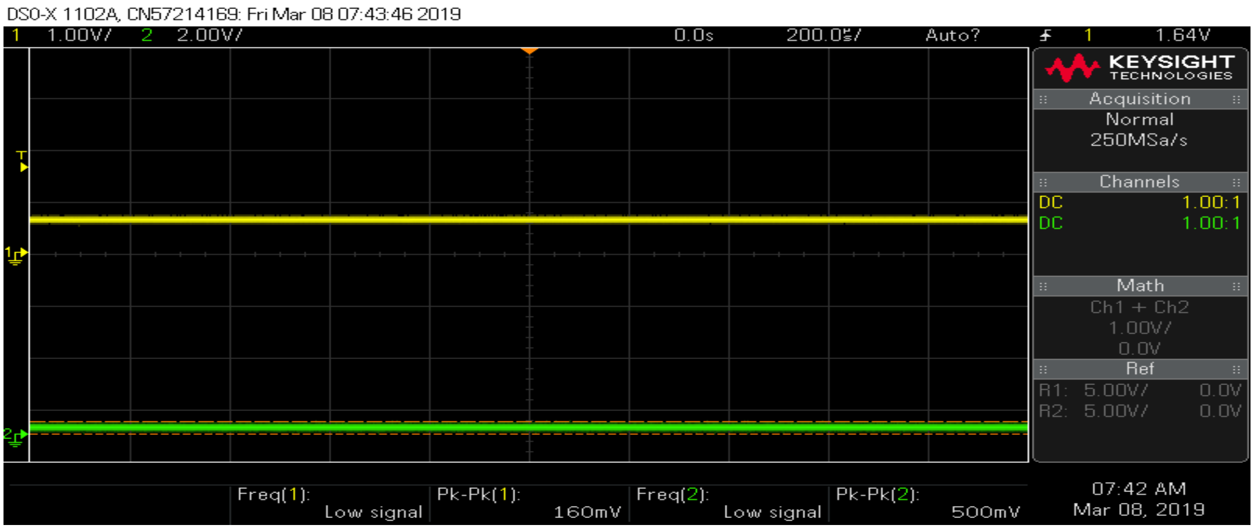


- ($V_{in,min}$, $V_{out,max}$)=(0.8, 4.9), ($V_{in,max}$, $V_{out,min}$)=(10, 0.85), ($V_{in,middle}$, $V_{out,middle}$)=(5.4, 2.875)
- $\frac{V_{out}}{V_{in}} = \frac{0.85-4.9}{10-0.8} = -0.4402$
- Simulated curve



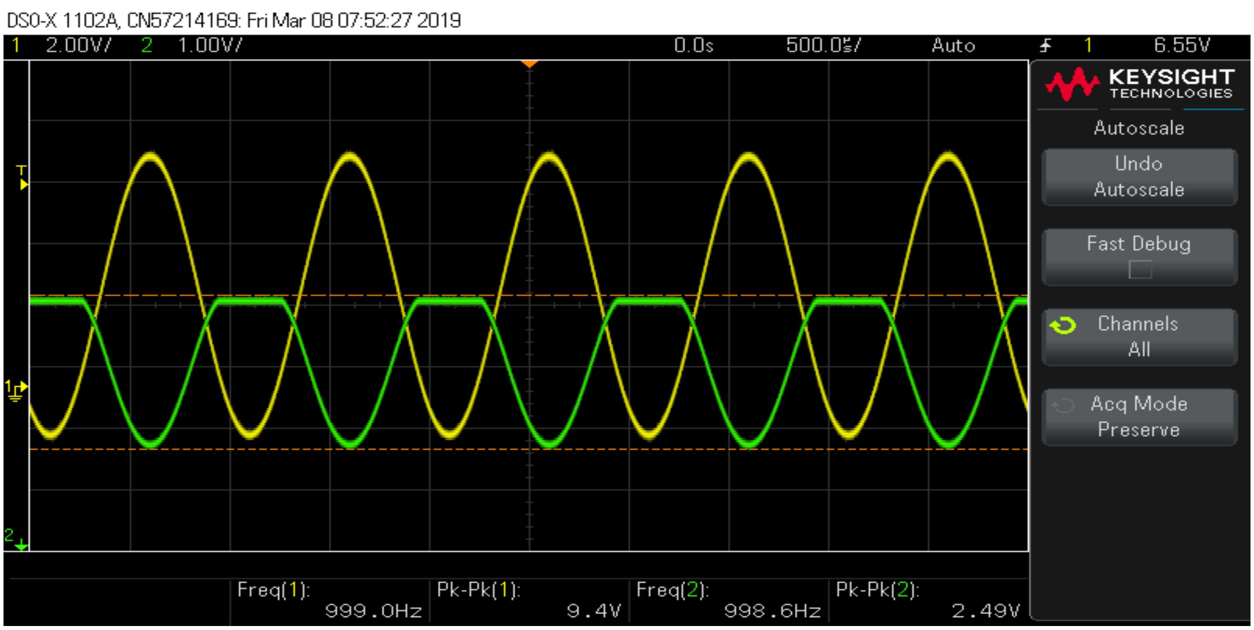
- $(V_{in,min}, V_{out,max})=(0.6, 4.9)$, $(V_{in,max}, V_{out,min})=(11.3, 0.6)$, $(V_{in,middle}, V_{out,middle})=(6.6067, 2.5054)$
- $\frac{V_{out}}{V_{in}} = \frac{2.4196-2.5054}{6.7880-6.6067} = \frac{0.0858}{0.1813} = 0.4732$

○ Small signal gain picture in step e



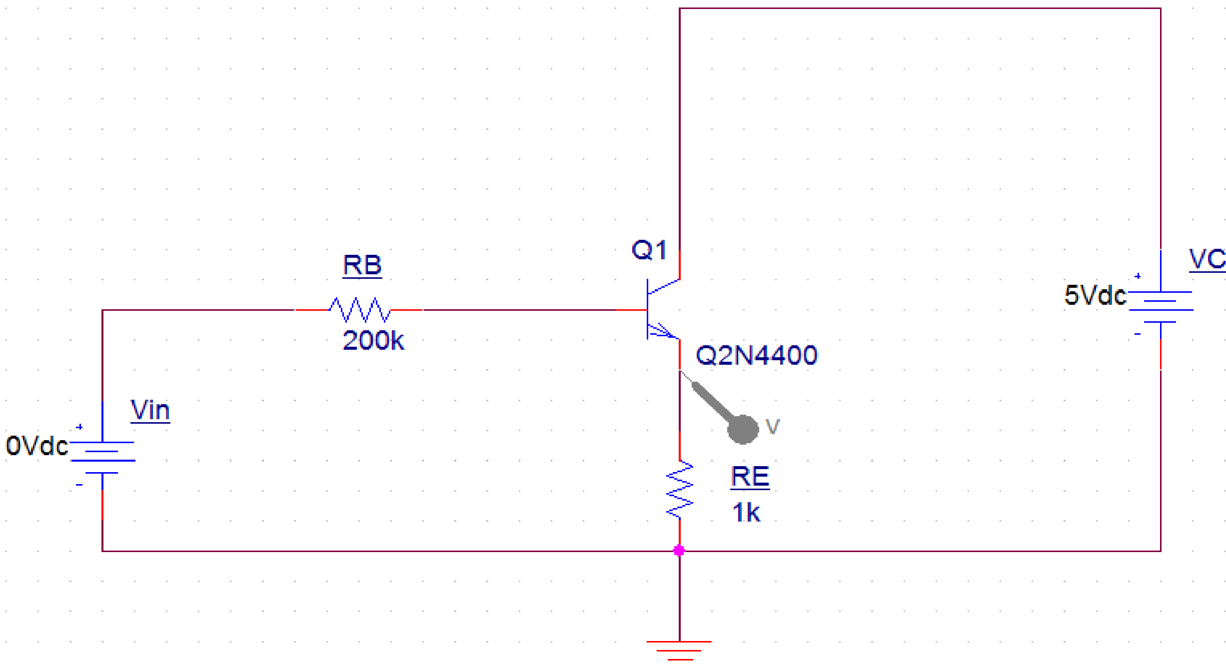
- The collector voltage
- I_c=0.002632A V_{CE}=2.5V
- Av=$\frac{500mV}{1100mV}$=0.4545

○ Clipping

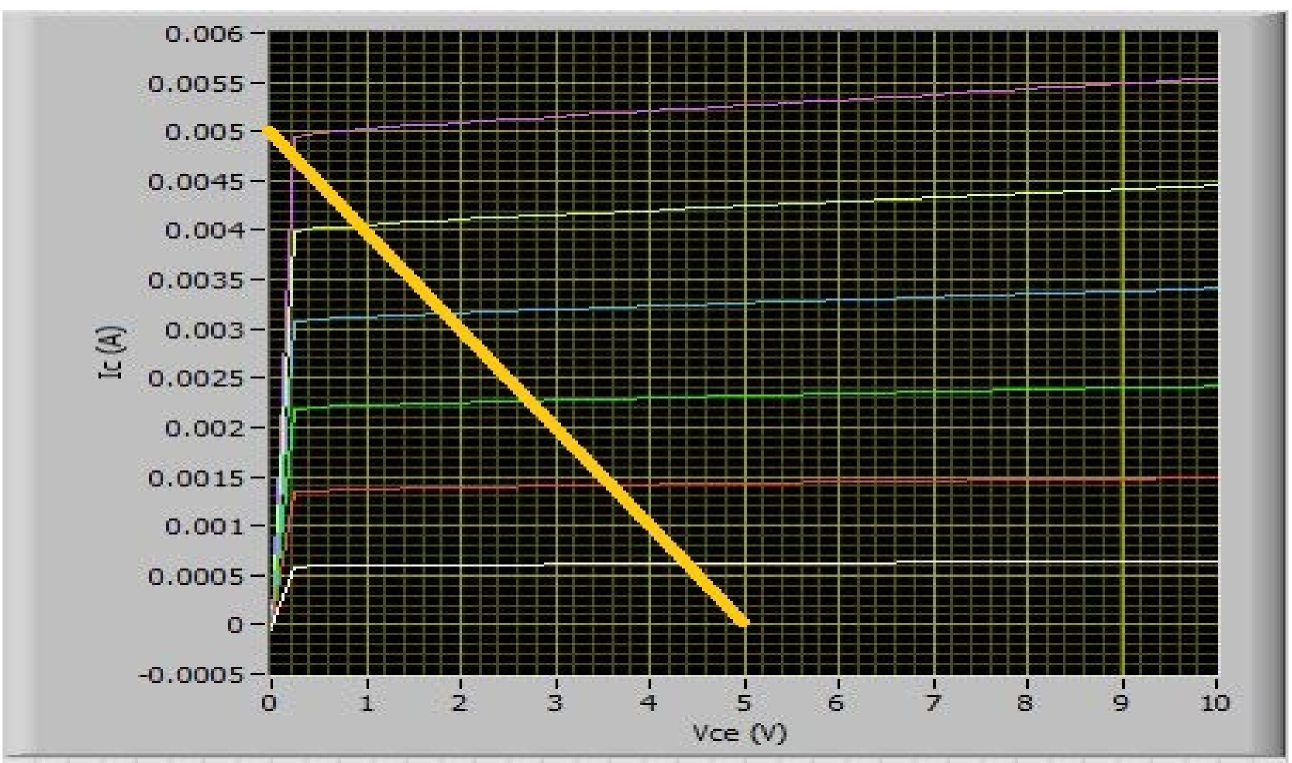


Clipping occurs because of the negative gain characteristic of the amplifier, and the transfer function rules the V_{out} decreases as V_{in} increases.

- Emitter Follower
    - Circuit

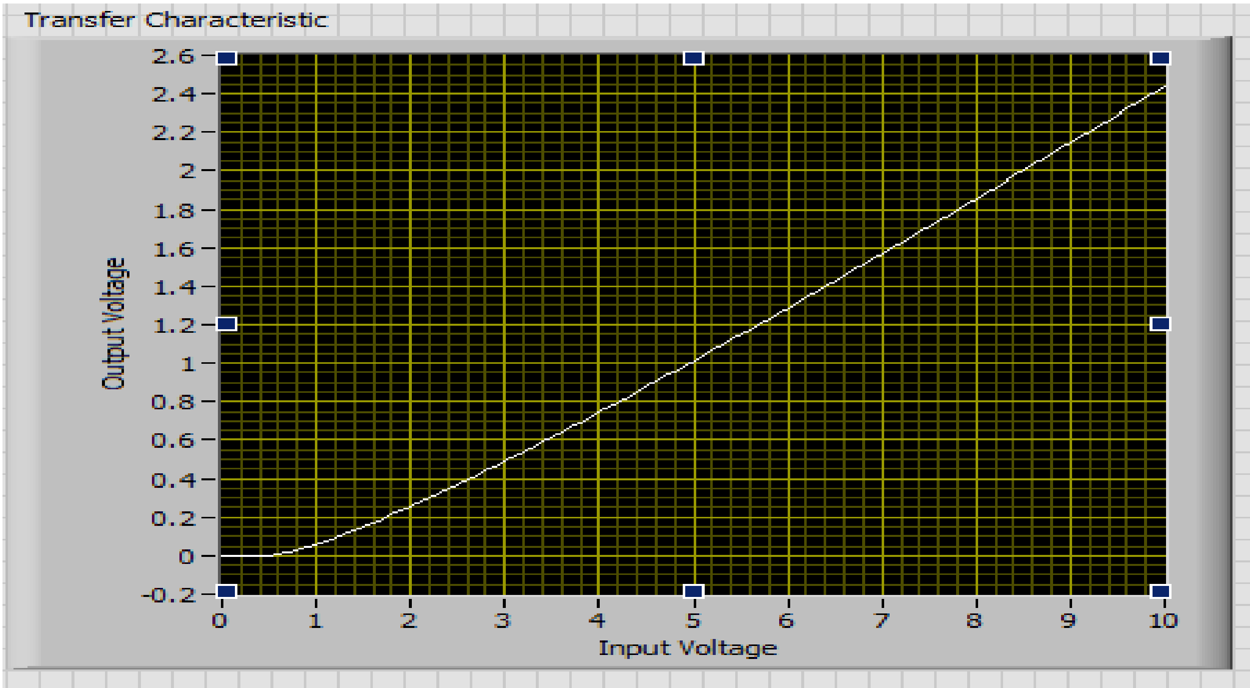


    - I-V curve with load line

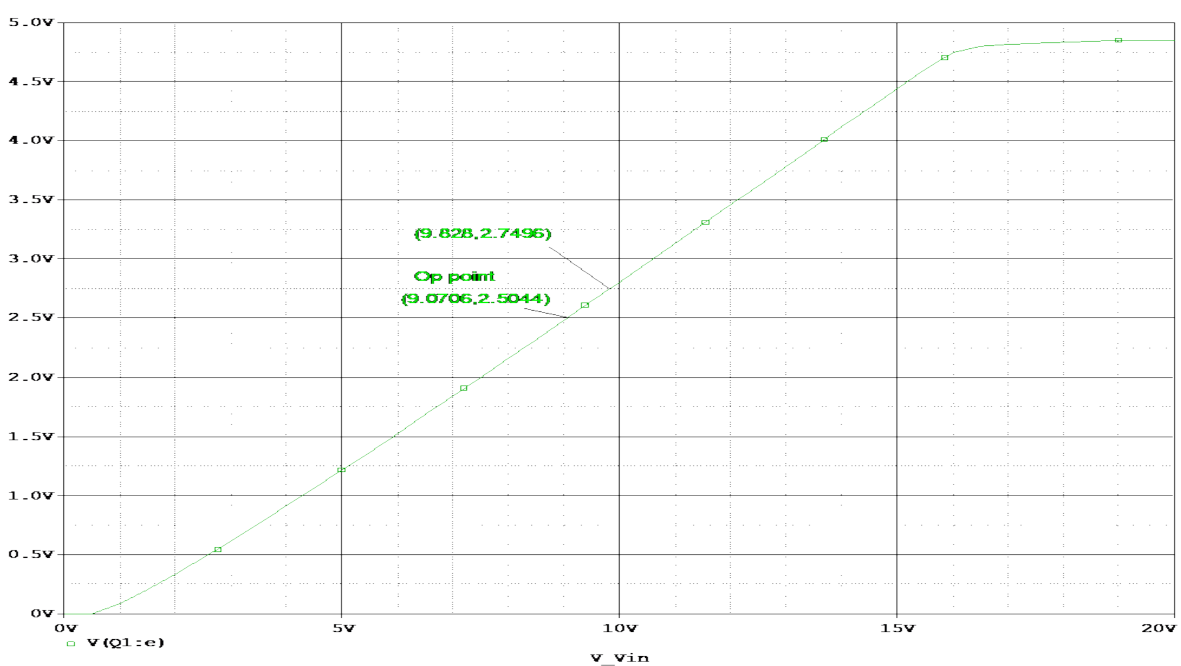


        - Load Line: $I_E = \frac{V_{CC} - V_{EC}}{R_E} = \frac{5V - V_{EC}}{1000}$

- Transfer function *step g was omitted during the lab
  - Step b

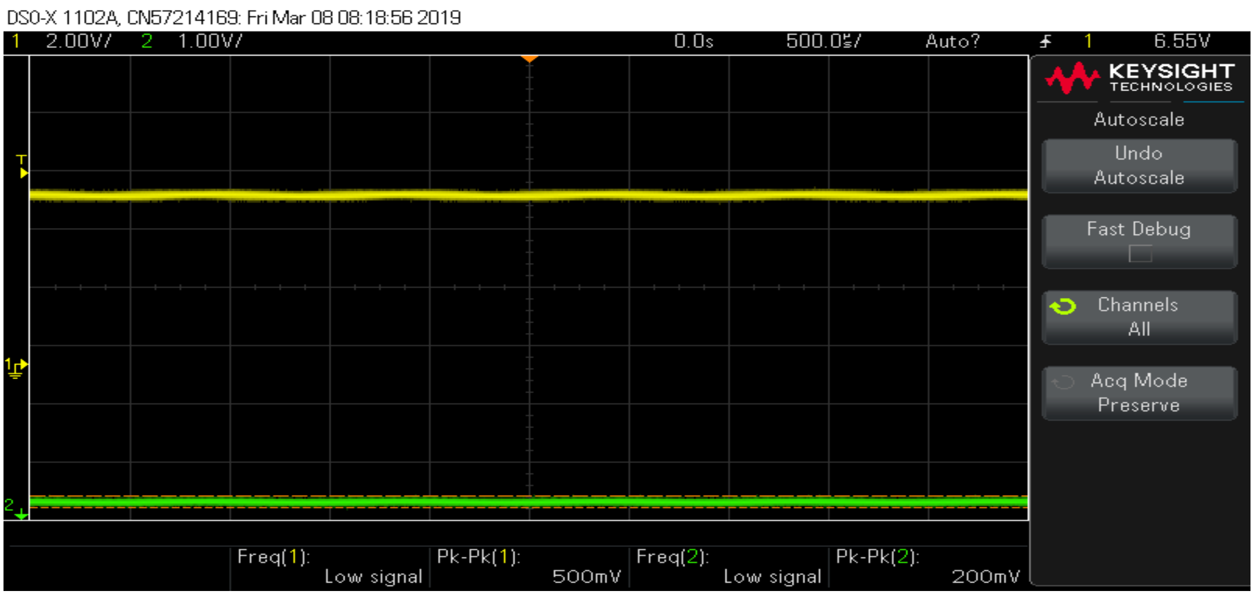


  - ($V_{in,min}$, $V_{out,max}$)=(0.6, 0.01), ($V_{in,max}$, $V_{out,min}$)=(10, 2.45), ($V_{in,middle}$, $V_{out,middle}$)=(5.4, 1.15)
  - $\frac{V_{out}}{V_{in}} = \frac{2.45-0.01}{10-0.6} = 0.2595$
  - Simulated result



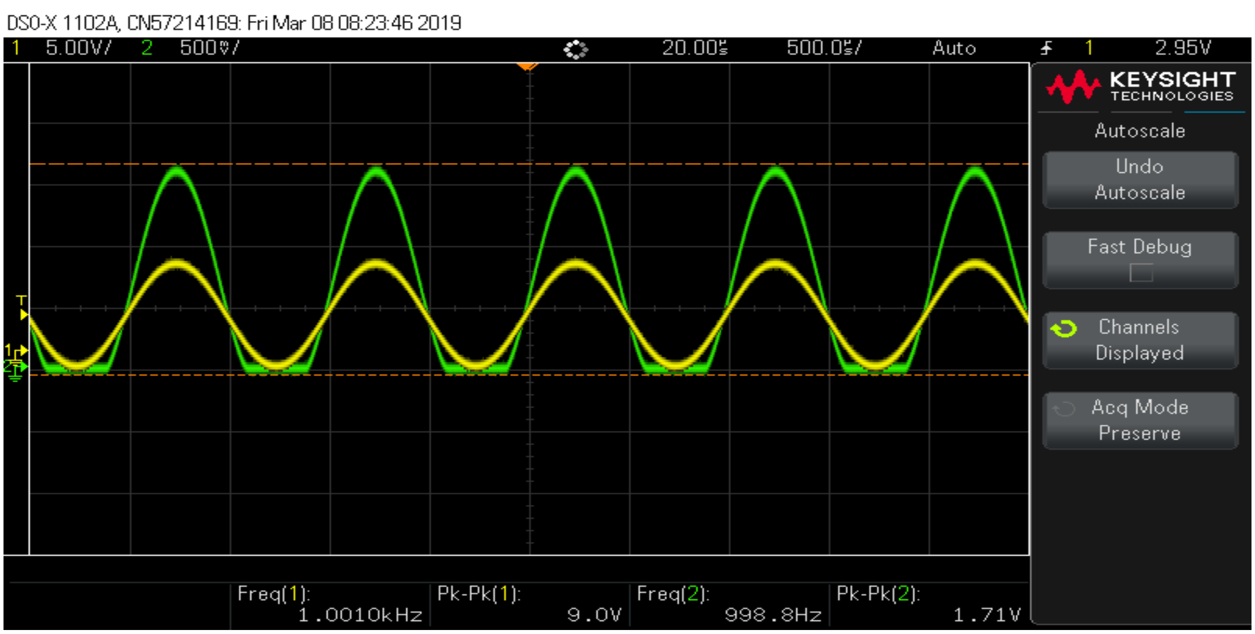
- ($V_{in,min}$, $V_{out,max}$)=(0.5, 0.01), ($V_{in,max}$, $V_{out,min}$)=(16, 4.75), ($V_{in,middle}$, $V_{out,middle}$)=(9.0706,2.5044)
- GAIN=$\frac{4.75-0.01}{16-0.5} = \frac{0.2452}{0.7574} = 0.3058$
- Discrepancy in gain due to different range of V_{in} between the experiment and simulation

- Small signal gain



- I_c=0.000010943A V_{CE}=2.5V
- Av=$\frac{200mV}{650mV}$=0.3077

- Clipping



Clipping occurs because of the positive gain characteristic of the amplifier, and the transfer function rules the V_{out} increases as V_{in} increases.

Analysis

1. The linear portion (Forward active region) of the transfer function for both CE amplifier and the emitter follower can be sketched by hand. Pspice adds the ability to simulate the saturation, early effect and the cut off regions of a BJT.
2.
    a. For CE emitter

$I_c = \beta I_B$, The edge of saturation point is when $V_{BE} = V_{CE}$

$\frac{V_{in}-V_{BE}}{R_B} = \beta\frac{V_{CC}-V_{CE}}{R_C} \rightarrow \frac{V_{in}-V_{BE}}{R_B} = \beta\frac{V_{CC}-V_{BE}}{R_C} \rightarrow \frac{6.58V-2.5V}{R_B} = 83.5\frac{5-2.5}{1000}$

$R_B = 19.544\Omega$

$$I_c = \frac{V_{CC}-V_{CE,SAT}}{R_C} = \frac{5V-0.2V}{1000} = 4.8mA$$

$I_c = \beta I_B$

$$I_B = \frac{4.8\text{mA}}{83.5} = 5.749\times10^{-5}A$$

$$R_B = \frac{V_{in}-V_{BE}}{I_B} = \frac{5-0.7}{57.49\mu A} = 102287.5\Omega$$

$$19.544 \le R_B \le 102287.5$$

    b. For Emitter follower

$\frac{V_{in}-V_{BE}}{R_B} = \beta(\frac{V_{CC}-V_{CE}}{R_E})(\frac{\beta}{\beta+1}) \rightarrow \frac{V_{in}-V_{BE}}{R_B} = \beta\frac{V_{CC}-V_{BE}}{R_C}(0.98) \rightarrow \frac{5.85V-2.5V}{R_B} = 83.5\frac{5-2.5}{1000}$

$R_B = 16.0479\Omega$

$$I_E = \frac{V_{CC}-V_{CE,SAT}}{R_E} = \frac{5V-0.2V}{1000} = 4.8mA$$

$$I_c = \frac{4.8\text{mA}}{84.5/83.5} = 0.0047432A$$

$$I_B = \frac{0.0047432\text{A}}{83.5} = 5.6804\times10^{-5}A$$

$$R_B = \frac{V_{in}-V_{BE}}{I_B} = \frac{5-0.7}{56.804\mu A} = 75698.89\Omega$$

$$16.0479 \le R_B \le 75698.89$$