Samvel Manukyan
Chloe Ta

ECE 10BL: Lab 4- Bipolar Junction Transistor Characteristics

Introduction:
In this lab, we get to know BJTs by constructing equations that describe gain, input resistance, output resistance, and operating range in terms of variable resistances and circuit layout. We also see how a BJT can be used as an amplifier as well as a buffer as well as in multi-stages, taking measurements and analyzing them for each circuit.

Pre-Lab 1:

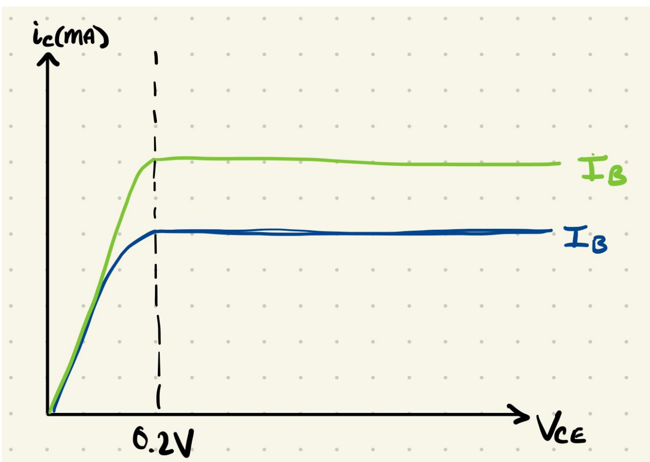


Figure 1. I-V Characteristic of a BJT with constant I_B and swept V_{cc} (blue curve). The green curve represents a higher I_B value.

At higher I_B values, the resulting I_c increases when active mode is reached. **[RP1]**

Pre-Lab 2:

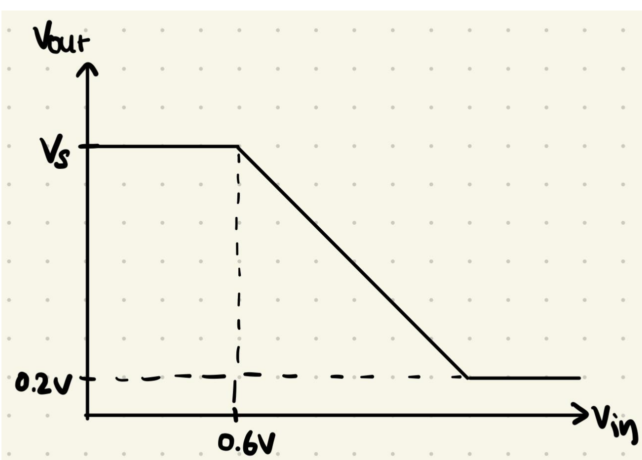
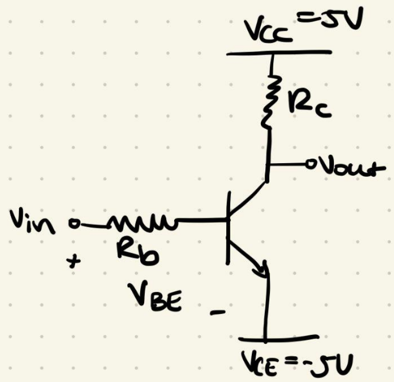


Figure 2. BJT input output transfer characteristics.
A BJT acts as an amplifier since the collector and emitter currents are scaled by the base current, and therefore, V_{OUT} is an amplified value of V_{IN}. **[RP2]**

Pre-Lab 3:

a)



ASSUME ACTIVE MODE

a) $I_B = \frac{V_{in} - (0.6V - 5V)}{R_b} = \frac{V_{in} + 4.4V}{R_b}$

$I_C = \frac{V_{cc} - V_{out}}{R_c} = \frac{5V - V_{out}}{R_c} = \beta I_B$

$\frac{5V - V_{out}}{R_c} = \beta\left(\frac{V_{in} + 4.4V}{R_b}\right)$

$V_{out} = 5 - \frac{\beta R_c (V_{in} + 4.4V)}{R_b}$

[RP3]

b)

$\beta = 150,\ R_c = 1K\Omega,\ R_b = 30K\Omega$

$V_{CE} > 0.2V$

$V_{out} - (-5) > 0.2$

$V_{out} > -4.8V$

$V_{out} = 5 - \left(\frac{\beta R_c}{R_b}\right)(V_{in} + 4.4) > -4.8$

$= -\frac{\beta R_c}{R_b}(V_{in} + 4.4) > -9.8$

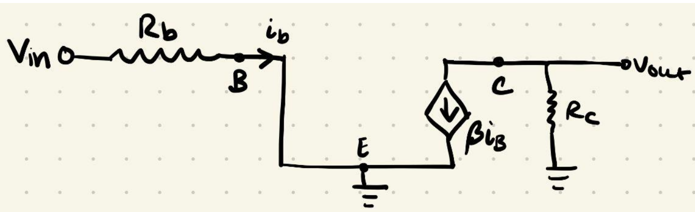
$V_{in} < \frac{9.8 R_b}{\beta R_c} - 4.4 \Rightarrow V_{in} < -2.44V$

$V_{in} > -4.4V$

$-4.4V < V_{in} < -2.44V$

[RP4]

c)



$V_{out} = -i_c R_c = -\beta i_b R_c$

$V_{in} = i_b R_b$

$A = \frac{V_{out}}{V_{in}} = \frac{-\beta i_b R_c}{i_b R_b} = \frac{-\beta R_c}{R_b}$

[RP5]

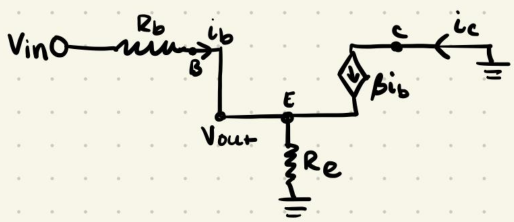
d)

$$r_{in} = \frac{V_{test}}{i_{test}} = R_b \Rightarrow r_{in} = R_b$$

$$r_{out} = \frac{V_{test}}{i_{test}} = R_c \Rightarrow r_{in} = R_c$$

[RP6]

Pre-Lab 4:



$$i_b = \frac{V_{in} - V_{out}}{R_b}$$

$$i_e = \frac{V_{out}}{R_e} = i_b + \beta i_b$$

$$= \left(\frac{V_{in} - V_{out}}{R_b}\right)(1+\beta) = \frac{V_{out} R_b}{R_e(1+\beta)}$$

$$V_{in} = V_{out}\left(1 + \frac{R_b}{R_e(1+\beta)}\right)$$

$$A = \frac{V_{out}}{V_{in}} = \frac{R_e(1+\beta)}{R_e\left(1+\beta+\frac{R_b}{R_e}\right)} \quad \text{so } \lim_{R_e \to \infty} A = 1$$

[RP8]

$$i_{test} = \frac{V_{test} - V_{out}}{R_b}$$

$$V_{test} = (\beta+1) i_{test} R_e$$

$$i_{test} = \frac{V_{test} - (\beta+1) i_{test} R_e}{R_b}$$

$$V_{test} = i_{test}\left[R_b + R_e(\beta+1)\right]$$

$$V_{in} = \frac{V_{test}}{i_{test}} = R_b + R_e(\beta+1)$$

$$i_{test} = -\beta i_b - i_b$$

$$= -(\beta+1)\frac{V_{test}}{R_b}$$

$$V_{out} = \frac{V_{test}}{i_{test}} = \frac{R_b}{\beta+1}$$

[RP9]

Lab 4:

$V_{ce} = V_{in1} - I_c R_c - V_{ee}$

$Ic = (V_{in1} - V_{ee} - V_{ce}) / R_c$

$= (5 + 5 - V_{ce}) / 1000$

Vin2 (V)	Vce (V)	Ic (mA)
-5	10	0
-4	9.9	0.1
-3	8.6	1.4
-2	7.2	2.8
-1	5.7	4.3
0	4.3	5.7

Table 1. I_c vs V_{ce} with swept V_{in} plot. **[RP10]**

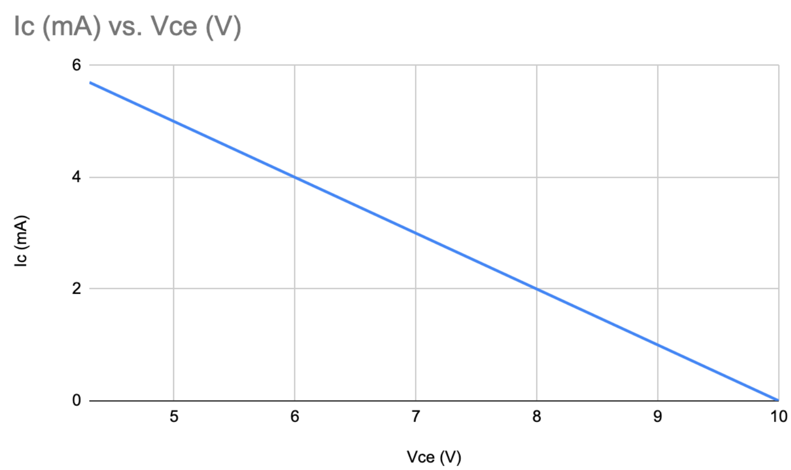


Figure 3. I_c vs V_{ce} with swept V_{in2} plot. **[RP11]**

$V_{in} = V_{in2}$ (V)	$V_{out} = V_c$ (V)
-5	5
-4	4.9
-3	3.6
-2	2.2
-1	0.7
0	-0.7

Table 2. V_{out} vs V_{in} data

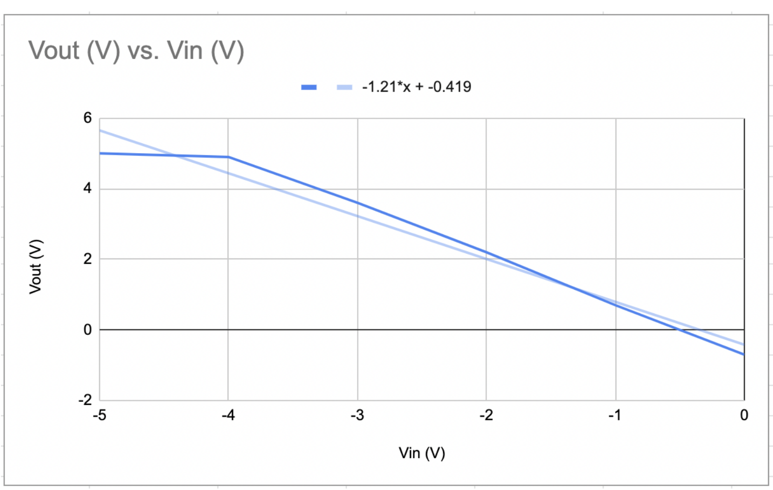


Figure 4. V_{out} vs V_{in} plot **[RP12]**

$V_b = V_{be} + V_e = 0.6 - 5 = -4.4$ V
$I_b = (V_{in} - V_b) / 120k\Omega$
When ($V_{in} = -2V$, $V_{out} = 2.2V$): $I_b = (-2 + 4.4) / 120k\Omega = 20\mu A$
$I_c = \beta\ I_b$
$\beta = I_c / I_b = 2.8\ mA / 20\mu A$
$\beta = 140$
Increasing base resistance decreases Ib, which increases β since $\beta = I_c / I_b$.
Decreasing the base resistance increases Ib, which decreases β since $\beta = I_c / I_b$.
[RP13]

$V_{in,PP} = 1.475V$
$V_{out,PP} = 2.5V$
[RP14]

$V_{in} = 1.475V$
$i_{in} = 0.02mA$
$r_{in} = V_{in} / i_{in} = 73.75k\Omega$
[RP15]

Re = 5kΩ
$V_{in,PP} = 502mV$
$V_{out,PP} = 587mV$
[RP16]

$R_e = 50k\Omega$
$V_{in,PP} = 502mV$
$V_{out,PP} = 506mV$
[RP17]

When R_e= 5kΩ, $A = V_{out} / V_{in} = 1.169$
when R_e = 50kΩ, $A = V_{out} / V_{in} = 1.006$
As R_e increases, the gain approaches 1.
The common-collector circuit is also called an emitter follower because the voltage output follows the voltage input such that the signals give a gain around 1. **[RP18]**

$V_{in} = 502mV$
$i_{in} = 0.02mA$
$r_{in} = V_{in} / i_{in} = 25.1k\Omega$
[RP19]

$V_{in,PP} = 604mV$
$V_{out,PP} = 3.275V$
$A = V_{out,PP} / V_{in,PP} = 5.42$
[RP20]

No, the output voltage of the common-emitter amplifier does not change when its output is fed into an emitter follower. Initially, the common-emitter amplifier will scale the input voltage to produce some magnified voltage output. This amplified signal will be fed into the emitter follower, such that the output resembles the input and the gain is 1. **[RP21]**

Conclusion:
This lab improved our comprehension of a BJT's amplification characteristics. The BJT was first constructed as a buffer, and then the two circuits were brought together to create a multi-state amplifier. As we observed, the relationship between the base resistance and beta value is precisely proportional. We established that the gain of an emitter-follower circuit approaches one as the load resistor value grows. The input signal was amplified linearly in the common emitter. In the combined circuit, we observed that reading the amplifier's output without using the amplifier's current required feeding the amplifier's output into the buffer.