ECEN 204 Lab 5
BJT Applications

Niels Clayton : 300437590
Lab Partner: Nickolai Wolfe

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1 BJT as a switch

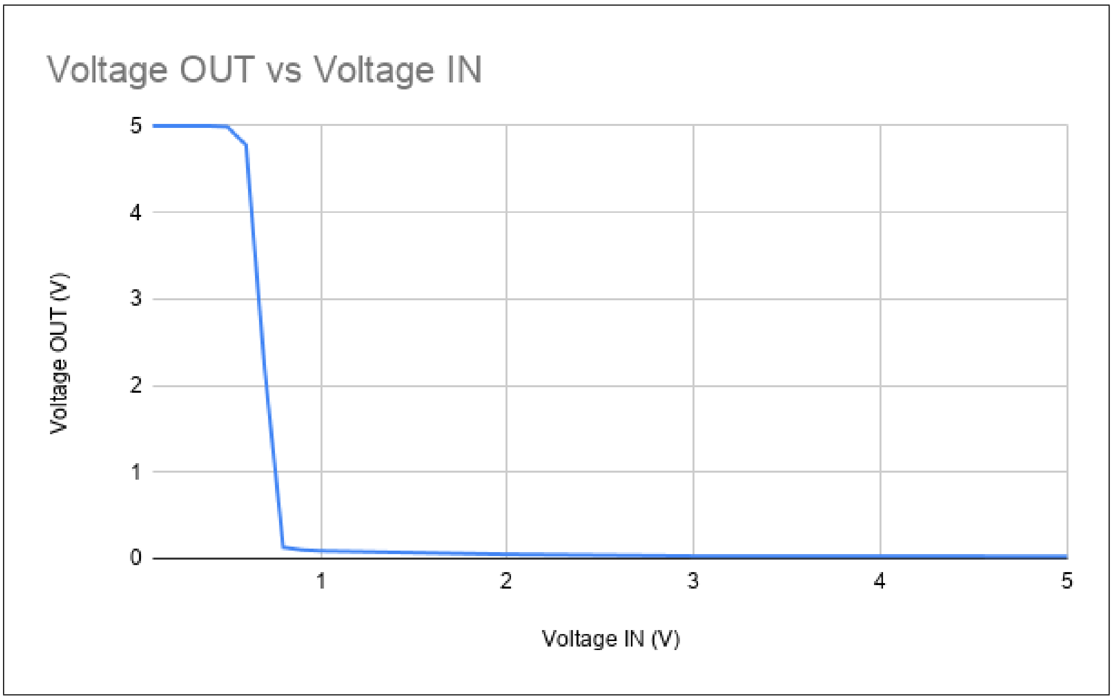

Figure 1: Base voltage in vs collector voltage out

It can be seen in figure 1 that when the voltage into the base of the transistor (V_B) is below 0.7V, the BJT is not considered to be operating, and when V_B is larger than 0.7V the BJT is considered to be operating. Because of this, when $V_B < 0.7V$ there is a large voltage difference between the collector and the emitter due to the BJT not being active and having near infinite resistance, This can be considered a logical HIGH. When $V_B > 0.7V$ there is little to no voltage difference between the collector and the emitter, which can be seen as a logical LOW. From this the following logic table can be constructed, simulating a logical NOT operation.

IN	OUT
LO	HI
HI	LO

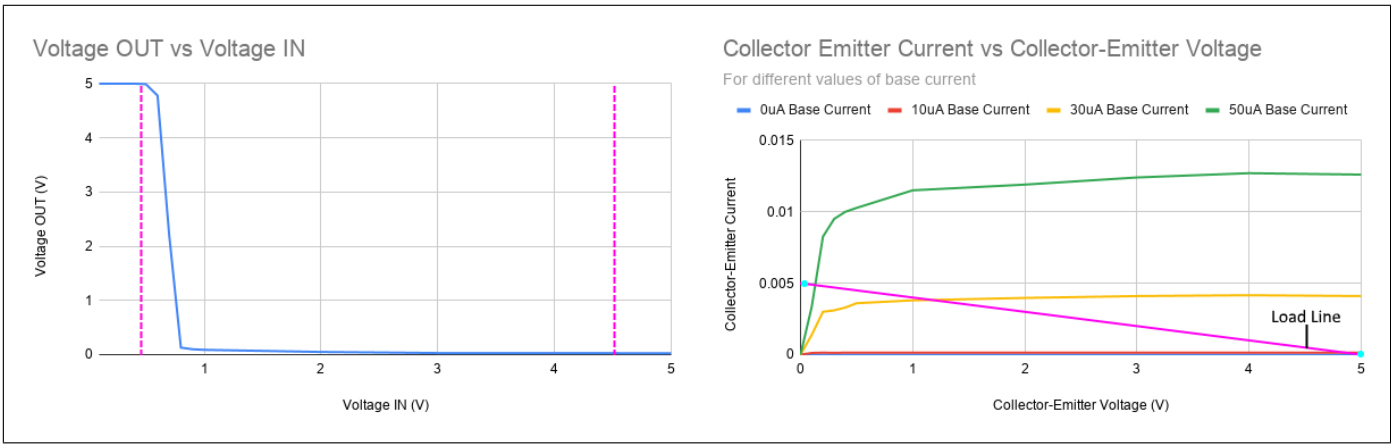

Figure 2: On the left, the input-output voltage characteristics of a BJT, On the right the load-line of the BJT with Q-points marked

In the first image in figure 2, the collector emitter voltages are taken at different base voltages (0.4V for LO and 4.5V for HI). These then give corresponding outputs of $\approx$ 5V for LO input, and $\approx$ 0V for HI input.

On the second image, the load-line was then plotted by taking a line between the short-circuit voltage of 5V, and the open-circuit current of 0.005mA. the Q-points were then plotted by marking the outputs of $\approx$ 5V for LO, and $\approx$ 0V for HI on the curve.

from this, it can be seen that for an input voltage of LO, the Q-point will be located within the cut-off region of the transistor characteristic curve, and when the input is HI, the Q-point is located within the saturation region of the curve.

From figure two it can also be seen that for an input voltage of 2.5V, the output voltage of the BJT will be $\approx$ 5V, leading to a logical HI.

2 Value of β in the active region

I_B	V_{CE} (V)	I_C	β
0uA	4	0.7uA	NaN
10uA	1	0.14mA	14
10uA	4	0.14mA	14
30uA	1	3.8mA	126.7
30uA	4	4.15mA	138.7
50uA	1	11.5mA	230
50uA	4	12.7mA	254

From the above table it can be seen that as the current into the base of the transistor increases, the beta value will increase dramatically, however once V_{CE} is achieved to saturate the current through the transistor, there will be very little gain in the β value by raising the voltage.

Measurement	β average	β maximum	β minimum
Own	129	254	14
Another 1			
Another 2			
Another 3			

From this table it can be seen that the use of β for calculations would not be advised as the β value can vary wildly from one transistor to another, as well as varying based on the voltages and currents applied to the transistor.

2.1 Calculation of V_{CE} & I_C with varying β

3 BJT as a switch

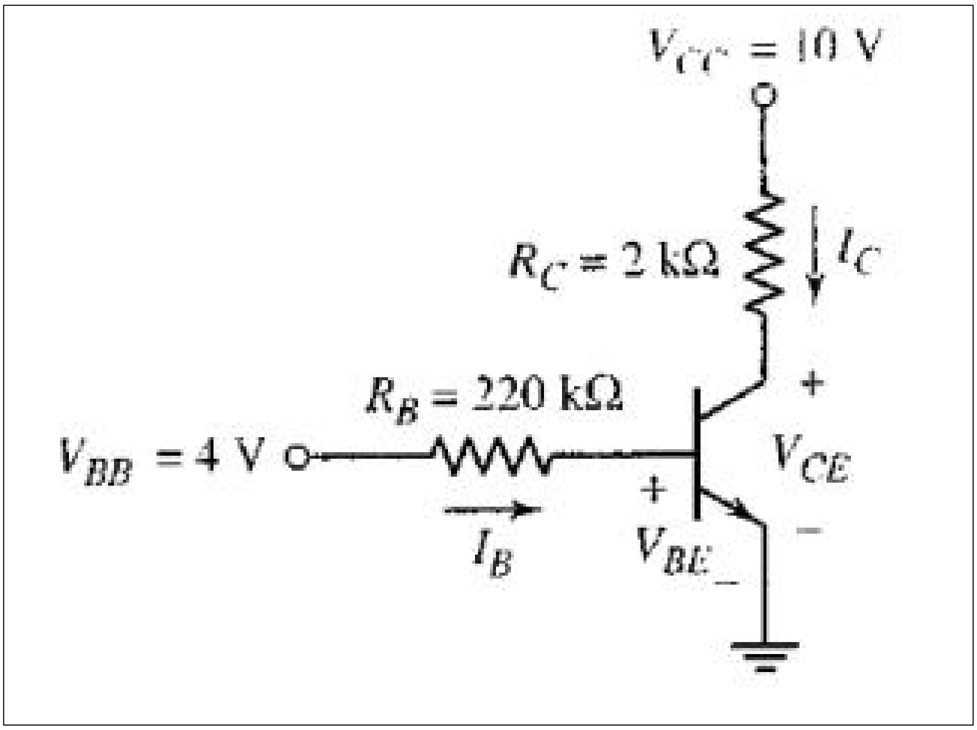

Figure 3: example circuit for β calculations

$$I_B = \frac{V_{BB} - V_{BE}}{R_B} = \frac{4 - 0.7}{220k} = 15uA$$

$$I_C = \beta I_B$$

For $\beta = 14$:

$$I_C = 0.21mA$$

For $\beta = 254$:

$$I_C = 3.81mA$$

$$V_{CE} = V_{CC} - I_C R_C$$

For $\beta = 14$:

$$V_{CE} = 9.58$$

For $\beta = 254$:

$$V_{CE} = 2.38$$

4 BJT as an amplifier

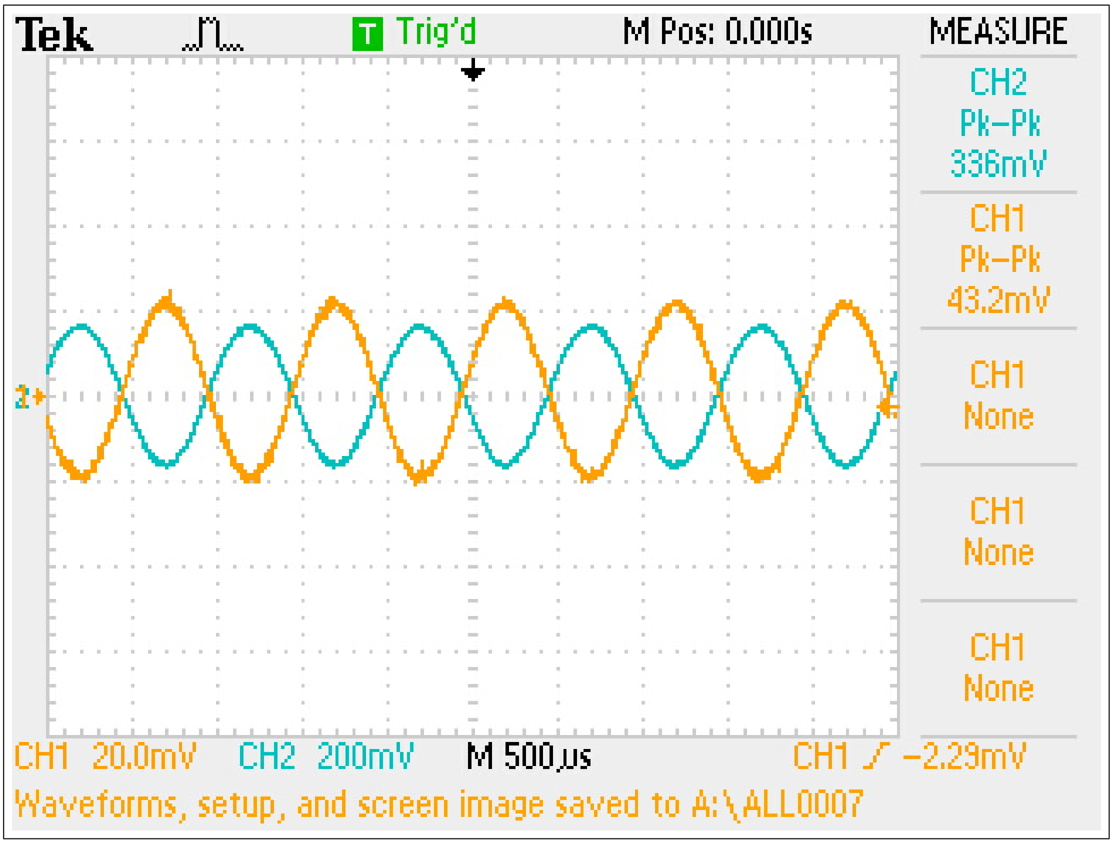

Figure 4: V_{in} (blue) and V_{out} (orange) with R_{B1} and R_C at mid range

It can be seen that for mid range values of R_{B1} and R_C, there is little to no gain in the signal, however there is a phase shift of 180^o present on the output due to the capacitor between the collector and V_{out}, and the capacitor between V_{IN} and the base.

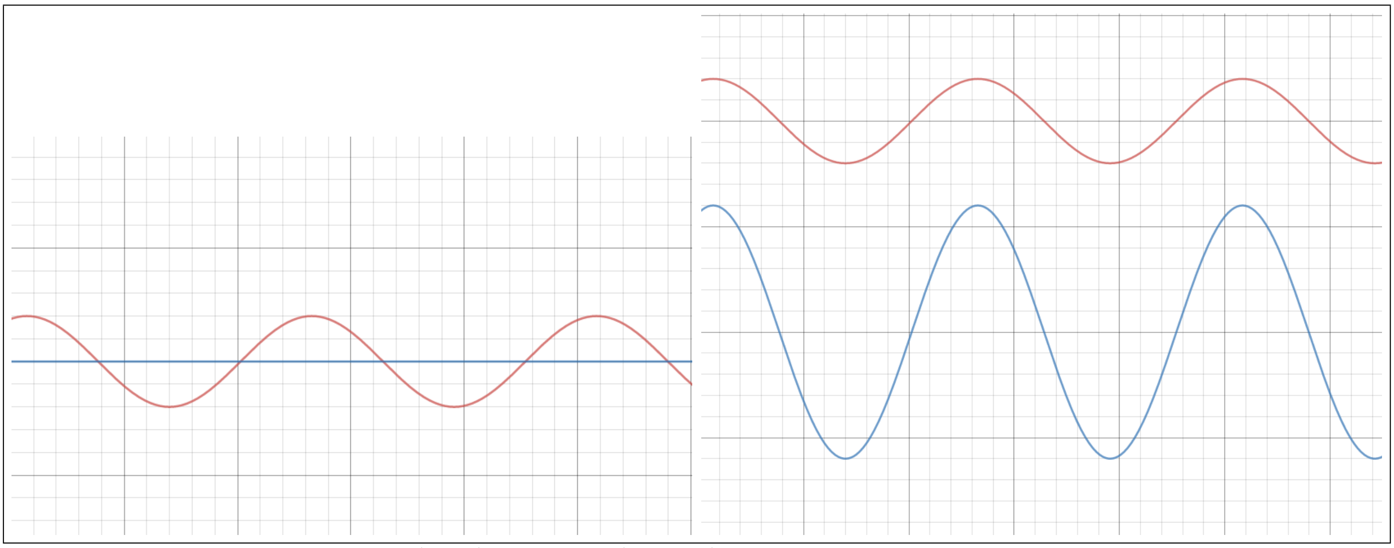

Figure 5: V_{in} (blue) and V_{out} (orange) with R_{B1} and R_C at mid range

Our oscilloscope images for the measurements at points 1 and 2 were not recorded, however figure 5 is what would be expected at these points. When R_{B1} is set to a maximum, there will be no current, and no voltage into point 1 from the DC source, meaning that we will see only the V_{IN} at this point, and seeing as the transistor is not active, there will be 0V on the output. Once we lower R_{B1}, there will be a DC voltage applied to the base which will have V_{IN} superimposed upon it. this will then cause the transistor to become active, however the oscillating voltage on V_B will cause it to shift along its voltage current curve, changing how much voltage will be dropped across the transistor.

4.1 Voltage gain

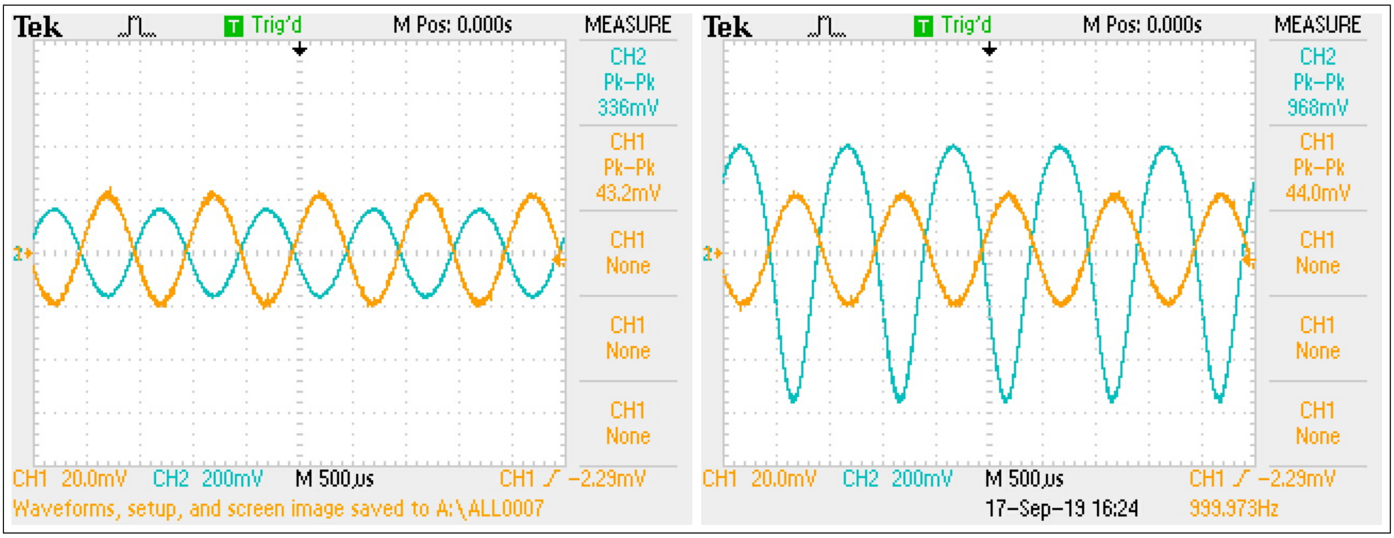

Figure 6: Gain of the transistor

$$A = \frac{V_o}{V_i}$$

$$A_{left} = \frac{336}{43.2} = 7.78$$

$$A_{right} = \frac{968}{44} = 22$$

4.2 Circuit operation

The capacitor C_1 serves to superimpose the signal V_{IN} onto whatever DC voltage is allowed into the base by R_{B1}. this will then cause the transistor to become active, however the oscillating voltage on V_B will cause the β value of the transistor to vary greatly, which will in turn greatly vary what current is allowed through the transistor. This increase and decrease in current will charge and discharge the C_2 capacitor from which we are reading V_{OUT}.

Apendix

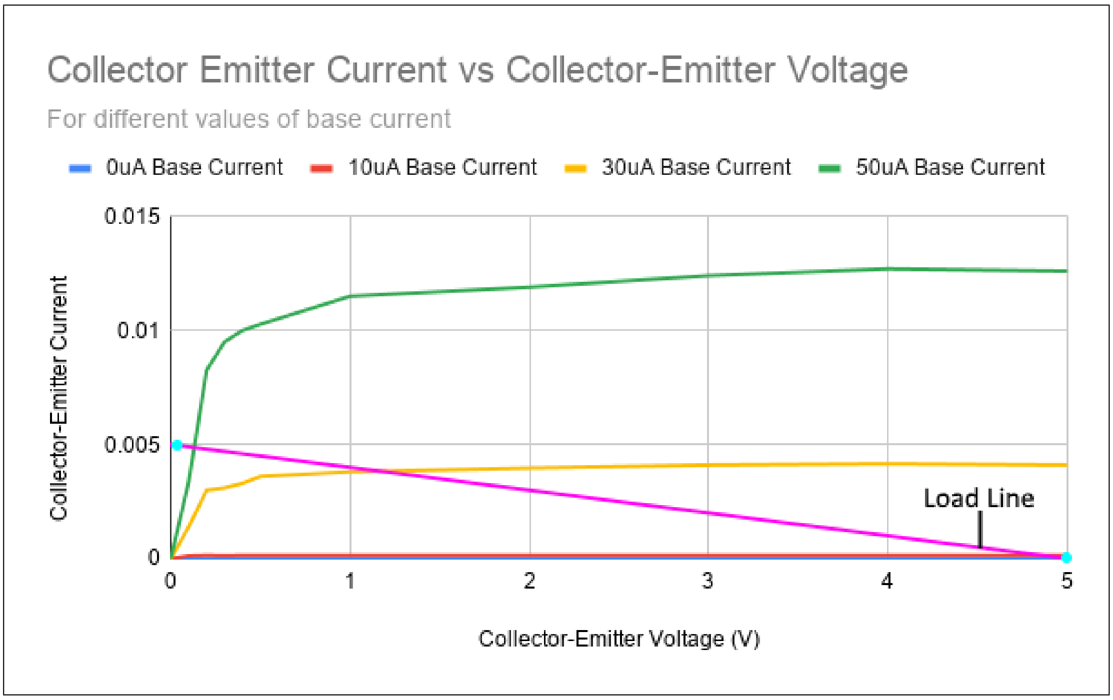

Figure 7: Load line of BJT, with Q-points

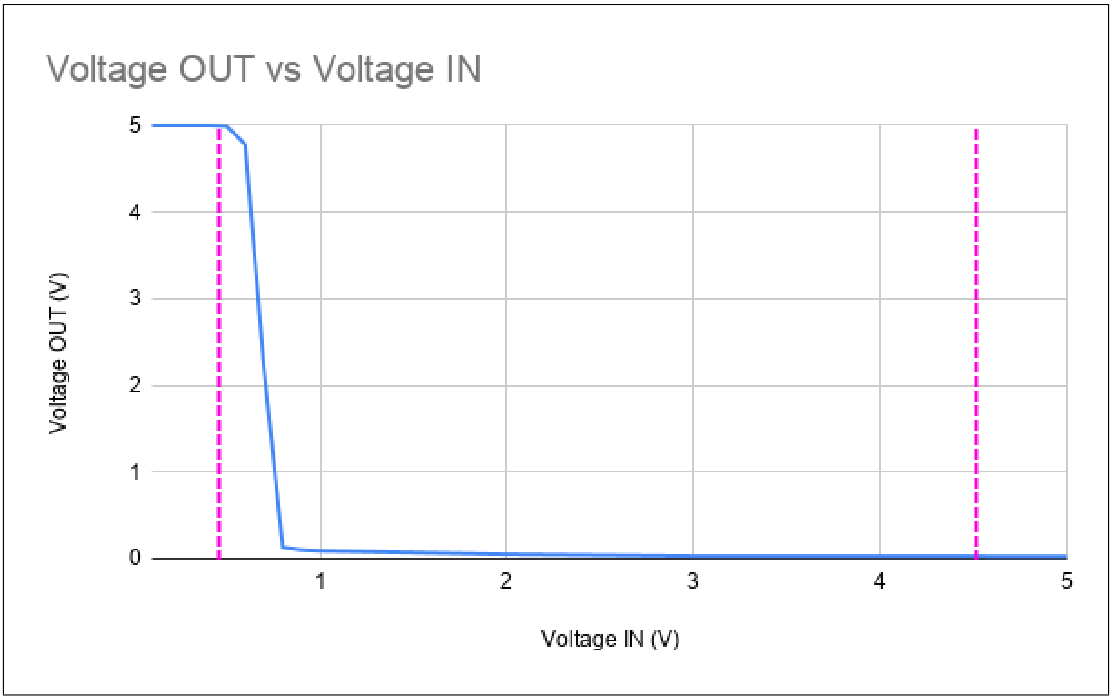

Figure 8: Input-output voltage characteristics of a BJT