NOTEBOOK:

Let V\_D=**whatever number it is, 0.66? Not sure** be the voltage forward bias.

As seen with circuit 2, diodes don’t fully activate (i.e. effective resistance → infinity) until a certain point. For most silicon diodes (including the one chosen), this point is at around ~0.7V. In the cut-off state, very little current would leak through the transistor, making ic ~= 0 and ie ~= 0. **INSERT OUR DATA SHOWING WHEN Vbe IS < 0.7**

Circuit 3:

METHOD:

An NPN transistor with an h\_fe of ~126 was selected. It’s capabilities were recorded with the aid of the circuit in figure X. To regulate the four i\_b, four resistors were used with a 1.437V battery as in figure Y.

|  |  |  |
| --- | --- | --- |
| index | Resistance (kohm) | Current (mA) |
| 1 | 14.0+-.2 | 0.1026428571 |
| 2 | 32.1+-.3 | 0.04476635514 |
| 3 | 67.5+-.6 | 0.02128888889 |
| 4 | 328 | 0.004354545455 |

FIGURE Y:

In order to regulate v\_ce values of less than one, a voltage divider was used similar to the setup in experiment two. Data was taken with several multimeters at regular intervals of v\_ce ranging from 0-10V. Measurements were taken with multimeters due to the inconsistency of the LabQuests.

ANALYSIS:  
A BJT has three main states: active, cut-off, and saturation.

In the cut-off state, Vbat < VBE=~0.7V. The BE junction of the transistor acts as a diode, which do not activate until 0.7V. Hence, i\_b and i\_c are approximately zero.

If V\_ce > V\_ce,sat, the BE junction is forward biased while the BC junction is reverse biased, and the transistor is in its active state.

The saturation region is when Vce is below Vsat=0.2V (given by the manufacturer).

In saturation mode, the BC junction and BE junction are both forward biased. This configuration allows the current through the transistor to rapidly increase with Vce. The current through the junctions can be modelled with [5]. For the sake of simplicity, the saturation region will be linearly approximated within its domain using KVL with the assumption that Vsat is constant.

Once Ic enters the active region, where the BE junction is forward biased and BC junction is reverse biased, the current appears to plateau. When in the active region, Ic can be approximated to be Ib\*Hfe. However, as Vce is increased, the depletion zone gets larger, allowing for a greater flow of current. This produces a slight increase in Ic with Vce.

The Early potential was found to be (-120±30)V by extrapolating the active regions of the four non-zero base currents. Using [10], the saturation current ($I\_s$) was found to be (2.5±.2)E-9. Using [11], a linear fit for the active region can be produced.

These two fits can be combined to generate a two-part piecewise function.

(put the piecewise regression here and domains)

(put table after)

Caption: Values of Y, m and b. Y is the point at which the BJT enters active mode i.e. where Ic=Ic,max. m and b are coefficients in the linear fit of the active region computed using the Early Effect.

Graph caption: Plot of Ic vs Vce. There are three distinct regions: saturation, active, and cut-off. Ic rapidly increases in the saturation region until it reaches Ic,max and enters the active region. In the active region, Ic steadily increases. In the cut-off region, collector current is zero for all values of Vce.

In the cut-off region, the BE junction is reverse biased. This results in ib~0 and ic~0.

|  |
| --- |
| 0≤Vce≤R2\*Hfe\*b |

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Index | i\_b (mA) |  |  |  |
| 1 | 2.53 |  |  |  |
| 2 | 11.5 |  |  |  |
| 3 | 23.4 |  |  |  |
| 4 | 23.4 |  |  |  |

**ENTER FUNCTION AND TABLE HERE**

The four final amplification curves i\_c vs v\_ce are contained in the following graph.

**Insert super graph here with all 4 curves**

Observe the distinct active and saturation regions. The effective resistance of this junction is never zero, but as v\_ce increases, it becomes increasingly close to zero.

NOTES

|  |  |  |  |
| --- | --- | --- | --- |
| index | beta\*I\_b (mA) | I\_c (mA) | % error |
| 1 | 7.1375 | 6.460 | -9.49 |
| 2 | 2.925 | 2.990 | 2.22 |
| 3 | 1.4375 | 1.428 | -0.661 |
| 4 | 0.30625 | 0.310 | 1.22 |

Picking transistor:

There are two BJT variants: PNP and NPN. An NPN transistor with an hfe of ~125 was selected. NPN transistors are effectively the opposite of PNP transistors with electrons flowing as opposed to “holes” flowing.

It’s clear from KCL (**insert equation number**) that the transistor does not generate ic from ib. Rather, it regulates the current across the collector and emitter terminals. This is important when analyzing the ic-vce curve.

The relationship between ib and Vbe in this transistor setup equivalent to that of a diode in forward bias. The current travels through the base (positively doped) and out of the emitter (negatively doped). This has been taken into account when applying Kirchhoff's laws.

A BJT has three main states: active, cut-off, and saturation.

\*NOTE VD is voltage \_ forward bias

In the cut-off state, Vbe < VD. The BE junction of the transistor acts as a diode. As seen with circuit 2, diodes don’t fully activate (i.e. effective resistance → infinity) until a certain point. For most silicon diodes (including the one chosen), this point is at around ~0.7V. In the cut-off state, very little current would leak through the transistor, making ic ~= 0 and ie ~= 0. **INSERT OUR DATA SHOWING WHEN Vbe IS < 0.7**

When the BE junction is forward biased past its knee point, the transistor is in its on state. If V\_ce > V\_D, the BE junction is forward biased while the BC junction is reverse biased. This state is called the transistor’s active state. Here, ic is nearly linear with ib, and the transistor acts as an amplifier. This linear correlation was verified and conforms to the linear fit predicted by the manufacturer's specifications.

The saturation region is when Vce is below Vsat=0.2V (given by the manufacturer). The current here is given by KVL and is dependent on Vcc.

Using the active region and saturation region, a piecewise function can be generated to model ic vs vce.

This results in a linear increase of ic until it reaches its “maximum” is consistent for all base currents. This also implies that a higher base current will take a larger Vce to reach its “maximum” ic.

After ic reaches its “maximum” it is not constant. It will continue to increase, but by an extremely small amount with respect to Vce. As the potential Vce is increased, the current that is allowed through by the BC junction of the transistor increases, albeit by a small amount. The effective resistance of this junction is never zero, but as Vce is increased, it becomes increasingly close to zero. This results in a higher ic, due to the lower total resistance in the second loop (KVL).