UNIVERSITY OF CALIFORNIA AT BERKELEY
College of Engineering
Department of Electrical Engineering and Computer Sciences

EE105 Lab Experiments

Prelab 3: Bipolar Junction Transistor Characterization

Solutions

1. For the NPN device shown below in Figure 1, fill in I_C, I_B, and I_E next to the current arrows.

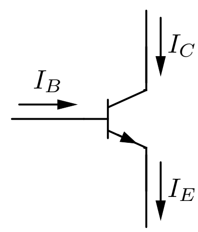

Figure 1: A simple NPN device for warming up

2. What is β in terms of I_C and I_B? What is α in terms of I_C and I_E? Express α in terms of β.

$$\beta(I_C, I_B) = \frac{I_C}{I_B}$$

$$\alpha(I_C, I_E) = -\frac{I_C}{I_E}$$

$$\alpha(\beta) = \frac{\beta}{1+\beta}$$

3. SPICE

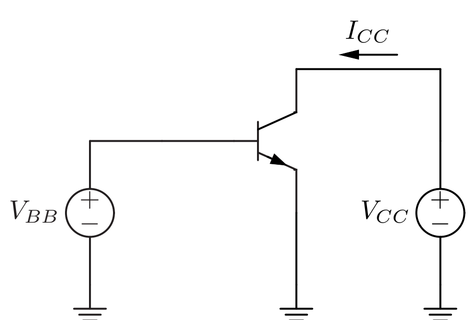

Figure 2: Circuit to simulate in SPICE

- Write a SPICE netlist for the BJT test circuit shown in Figure 2. *Refer to the HSPICE Tutorial if you have trouble with SPICE.*

- Use the 2N4401 SPICE model provided on the course website.
- Using the `.dc` command, sweep V_{CC} from 0 V to 5 V in 0.01 V increments and step V_{BB} from 0.6 V to 0.7 V in 0.025 V increments.
- Run the simulation and check the output file for any errors.
- If there are no errors, plot I_{CC} versus V_{CC} and print out a copy of the plot. *Note: If you notice that I_{CC} is negative, use Awaves to plot the absolute value of I_{CC}. I_{CC} appears to be negative because SPICE defines I_{CC} to be going out of the BJT.*

SPICE netlist:

```
* EE105 Lab3 Prelab Solution

Vbb  vb gnd 1
QBJT Vc Vb  gnd N4401
Vcc  Vc gnd 3

.model N4401 NPN(Is=26.03f xti=3 Eg=1.11 vaf=90.7 Bf=4.292k Ne=1.244
+ Ise=26.03f Ikf=.2061 xtb=1.5 Br=1.01 Nc=2 Isc=0 Ikr=0 Rc=.5
+ Cjc=11.01p Mjc=.3763 Vjc=.75 Fc=.5 Cje=24.07p Mje=.3641 Vje=.75
+ Tr=233.7n Tf=466.5p Itf=0 Vtf=0 xtf=0 Rb=10)
.dc Vcc 0 5 0.01 Vbb 0.6 0.7 0.025
.option post=2
.end
```

4. The configuration shown below in Figure 4 is known as the Darlington pair. Assume Q_1 has a DC current gain of β_1 and Q_2 has a DC current gain of β_2. Derive the overall current gain, $\beta_{tot} = I_{C2}/I_{B1}$, as a function of β_1 and β_2. Do not neglect any currents.

$$I_{C1} = \beta_1 \cdot I_{B1}$$
$$I_{B2} = -I_{E1} = I_{B1} + I_{C1} = I_{B1}(1 + \beta_1)$$
$$I_{C2} = \beta_2 \cdot I_{B2} = \beta_2 \cdot I_{B1}(1 + \beta_1)$$
$$\beta_{tot} = \frac{I_{C2}}{I_{B1}} = \beta_2(1 + \beta_1)$$

$$\boxed{\beta_{tot} = \beta_2(1 + \beta_1)}$$

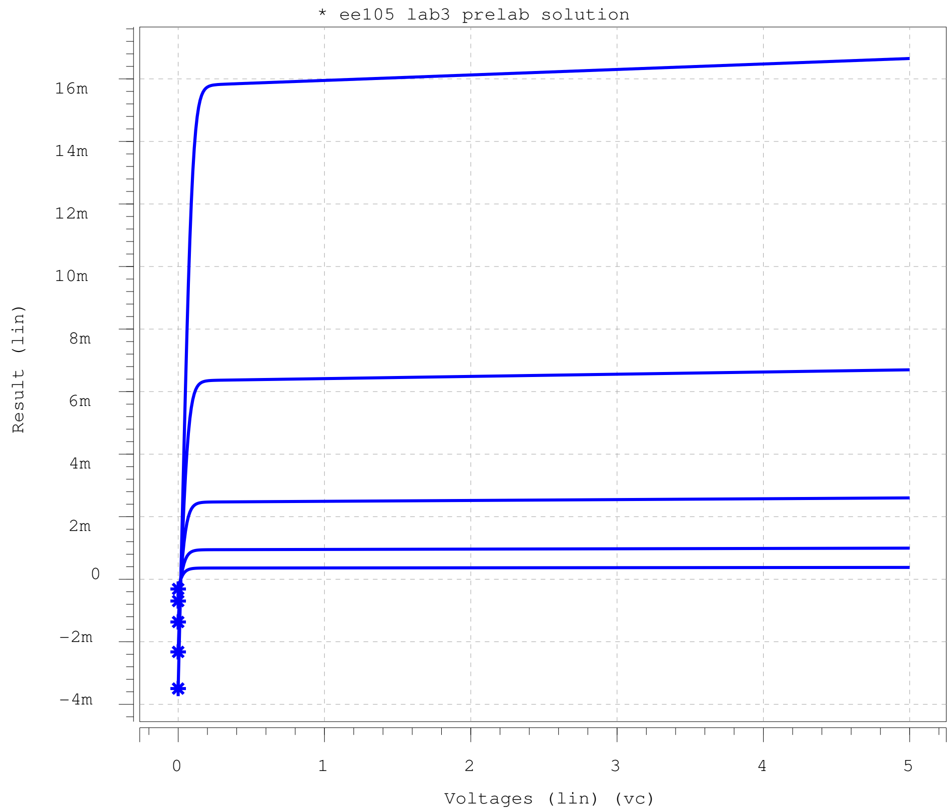

Figure 3: SPICE output of I_{CC} versus V_{CC}

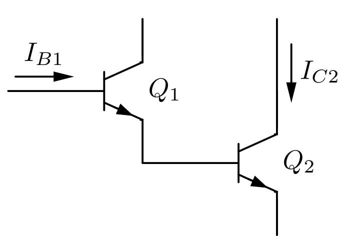

Figure 4: Darlington configuration