Example: D.C. Analysis of a BJT Circuit

Consider again this circuit from lecture:

\[ \text{Q: } \text{What is } I_B, I_C, I_E \text{ and also } V_{CE}, V_{CB}, V_{BE} \text{ ??} \]

\[ \text{A: } \text{I don't know! But, we can find out—IF we complete each of the five steps required for BJT DC analysis.} \]
**Step 1** - **ASSUME** an operating mode.

Let's **ASSUME** the BJT is in the **ACTIVE** region!

Remember, this is just a **guess**; we have no way of knowing for sure what mode the BJT is in at this point.

**Step 2** - **ENFORCE** the conditions of the assumed mode.

For active region, these are:

\[ V_{BE} = 0.7 \, \text{V} \quad \text{and} \quad I_C = \beta I_B = 99 \, I_B \]

**Step 3** - **ANALYZE** the circuit.

This is the **BIG** step!

**Q:** Where do we even start?

**A:** Recall what the hint sheet says:

“Write KVL equations for the base-emitter "leg""

I think we should try that!
The base-emitter KVL equation is:

\[ 5.7 - 10I_B - V_{BE} - 2I_E = 0 \]

This is the circuit equation; note that it contains 3 unknowns \((I_B, I_C, \text{and } V_{BE})\).

Now let's add the relevant device equations:

\[ V_{BE} = 0.7 \text{ V} \]

\[ I_E = (\beta + 1)I_B = 100I_B \]

Look what we now have! 3 equations and 3 unknowns (this is a good thing).

Inserting the device equations into the B-E KVL:

\[ 5.7 - 10I_B - 0.7 - 2(99 + 1)I_B = 0 \]

Therefore:

\[ 5.0 - 210I_B = 0 \]

1 equations and 1 unknown!
Solving, we get:\[ I_B = \frac{5.0}{210} = 23.8 \mu A \]

**Q:** Whew! That was an awful lot of work for just one current, and we still have two more currents to find.

**A:** No we don’t! Since we determined one current for a BJT in active mode, we’ve determined them all!

I.E.,

\[ I_C = \beta I_B = 2.356 \text{ mA} \]

\[ I_E = (\beta + 1) I_B = 2.380 \text{ mA} \]

(Note that \( I_C + I_B = I_E \))

Now for the voltages!

Since we know the currents, we can find the voltages using KVL.

For example, let’s determine \( V_{CE} \). We can do this either by finding the voltage at the collector \( V_C \) (wrt ground) and voltage at the emitter \( V_E \) (wrt ground) and then subtracting \( (V_{CE} = V_C - V_E) \).

**OR,** we can determine \( V_{CE} \) directly from the C-E KVL equation.
\[ V_C = 10.7 - I_C \quad (1) \]
\[ = 10.7 - 2.36 \]
\[ = 8.34 \text{ V} \]

and:
\[ V_E = 0 + I_E \quad (2) \]
\[ = 0 + 4.76 \]
\[ = 4.76 \text{ V} \]

Therefore,
\[ V_{CE} = V_C - V_E = 3.58 \text{ V} \]

Note we could have likewise written the C-E KVL:
\[ 10.7 - I_C \quad (1) - V_{CE} - I_E \quad (2) = 0 \]

Therefore,
\[ V_{CE} = 10.7 - I_C \quad (1) - I_E \quad (2) = 3.58 \text{ V} \]

Q: So, I guess we write the collector-base KVL to find \( V_{CB} \)?

A: You can, but a wiser choice would be to simply apply KVL to the transistor!
I.E., \( V_{CE} = V_{CB} + V_{BE} \) !

Therefore \( V_{CB} = V_{CE} - V_{BE} = 2.88 \text{ V} \)

**Q:** This has been hard. I’m glad we’re finished!

**A:** Finished! We still have 2 more steps to go!

**Step 4** - CHECK to see if your results are consistent with your assumption.

For active mode:

\[
V_{CE} = 3.58 \text{ V} > 0.7 \text{ V} \checkmark
\]

\[
I_B = 23.8 \mu\text{A} > 0.0 \checkmark
\]

Are assumption was correct, and therefore so are our answers!

No need to go on to Step 5.