ECE 312 Experiment 1: BJT Small Signal Parameters (7/13/2017)
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SUMMARY

This lab is an introduction to the use of LabView to determine the four parameters forming the hybrid or h parameter small signal model of a CA3046 bipolar transistor array. With the h parameter discovered, the hybrid π small signal parameters can be determined at particular frequencies. Upon completion, three out of four of our parameters were successfully verified with error remaining in one calculation.

Procedure

The first task was to use circuit analysis on Figure 1.1 to determine the theoretical values. As the summary stated, the goal is to determine the h parameters of the BJT. In order to execute the small signal analysis, these results are dependent on DC analysis results first, such as Ic, Ib, and Ie. So, typically to perform small signal analysis we must do DC analysis first. However, because Ic and Vce were provided for us, the DC analysis is not necessary in order to find out all four parameters.

Vce is given to us, but Vce can also be calculated and verified by knowing the following equation:

Vce = 6 - RcIc + 300Ic → Vce = 6 - 2.7k(1mA) + 300(1mA)→ Vce = 3

Now, we can start by calculating hfe. By knowing:

hfe = $\frac{i_c}{i_b}$, $I_b = \frac{I_c}{\beta}$, $I_c = 1mA$

and also knowing through the TA the beta value to be used for the CA3046 is β ~ 250,

$I_b = \frac{1mA}{250}$ → *4uA*

Hfe = 1mA/4uA → Hfe = 250 (It turns out our Hfe will be equal to our β in this problem)

Next, we can calculate Hie by knowing that Vbe is typically around 0.7V. Thus:

Hie = Vbe / Ib → Hie = 0.7V / 4uA → Hie = 175kΩ

With Vce given and verified as 3V and Vbe estimated, we can solve for Hre:

Hre = Vbe / Vce → Hre = 0.7 / 3 → Hre = 0.233

Lastly, Hoe can be solved:

Hoe = Ic / Vbe → Hoe = 1mA / 0.7 → Hoe = 1.43 * 10^-3

Observations and Discussion

The actual results varied from the calculated results quite a bit. With our circuit designed so that Ic would hopefully be 1mA and Vce 3V, these numbers were actually slightly different. I decided to read the specifications sheet more to determine why these variances were so large. When I looked, the β value that was provided to us was much larger than the typical 40-100 seen by the transistor operating at Ic = 1mA. Without redoing all of these calculations in detail, it can be seen that By changing β, Ib would be higher at 10uA. This would change the value of hfe to 100 instead of 250. This is much closer to the typical value of 110 shown in the spec sheet.

By changing Ib to a higher 10uA, Hie ultimately ends up changing value as well. Vbe also varied slightly from the initial expected 0.7. The spec sheet says that in these conditions, it should be closer to 0.715. This slight variance will cause Hie to be slightly different at 0.715/10uA. Now, the new calculation would be 71.5kΩ.

As stated in the lab, we had to use Figure 1.2 to calculate Hoe and Hre properly. This circuit changes the values for the initially stated Ic and Vce, resulting in major changes in the calculations. Now, Vce is 1V instead of 3V and Ic can be recalculated using:

Vcc = RcIc + Vce + IeRe → Ie ~ Ic → Vcc = RcIc + Vce +IcRe → Ic = Vcc – Vce / (Rc + RE) → Ic = 1.6mA

Hre = Vbe / Vce → Hre = Vbe / 1 → Hre = Vbe

Hoe = Ic / Vbe → Hoe = 1.6mA / Vbe

So, even with these adjusted calculations, it can be seen that the only parameter that was fixed by using the spec sheet was Hfe. The Hie was still much higher than the spec sheet indicated and Hre and Hoe are dependent on a value of Vbe that is not mentioned in the spec sheet. As mentioned in the beginning, DC analysis can be performed to determine this value, but even with a new Vbe, unless it were to equate to 102V, which is completely unrealistic, these parameters would never line up with the values in the spec sheet. This leads me to believe that somehow my calculations were messed up, but at this point I do not see where the issue lies.

When the circuit was evaluated instead of just calculated, the results were actually much more in line with the spec sheet.

To determine Hie in the circuit, Vs was set so that Vce = 0. This value was 15mV, which resulted in Vbe to be about 10mV. Because Vce = 0, we cannot use the equation we used to initially calculate Hie; but, now we can use the equation $hie = \frac{Rs}{\frac{V_S}{V_{BE}}-1}$ → Hie = 5.3kΩ. This value is much closer to the expected 3.5kΩ than the calculated value.

Measuring Ic to be about 0.180mA, Hfe can now be recalculated and is approximately 103. Once again, this is close to the spec sheet and our one result that actually calculated correctly.

By creating the circuit in Figure 1.2, the unknown value for Vbe can be determined as 100mV. Ic was also much lower than what was calculated at 2.4uA. Now, when calculated Hoe is 24uS, which is close to the expected 15.6uS.

The last parameter, Hre equates to Vbe, which was said to be 100mV, so it is 0.1. This does not match the data sheet of 1.8*10^-4. My calculation from the original circuit, from the spec sheet, and from the design did not meet the expected value.

Conclusion

My initial estimates based on the given values for Vce and Ic did not lead to the correct parameter values. My recalculation using the spec sheet fixed one of the parameters, but three of them still did not align. In my actual design, ¾ of the parameters were within reason. The one that was not correct for my design was also wrong in calculation, which leads me to believe that I was doing my calculations wrong for this parameter. Overall, the circuit functioned as expected with one parameter not fully understood.

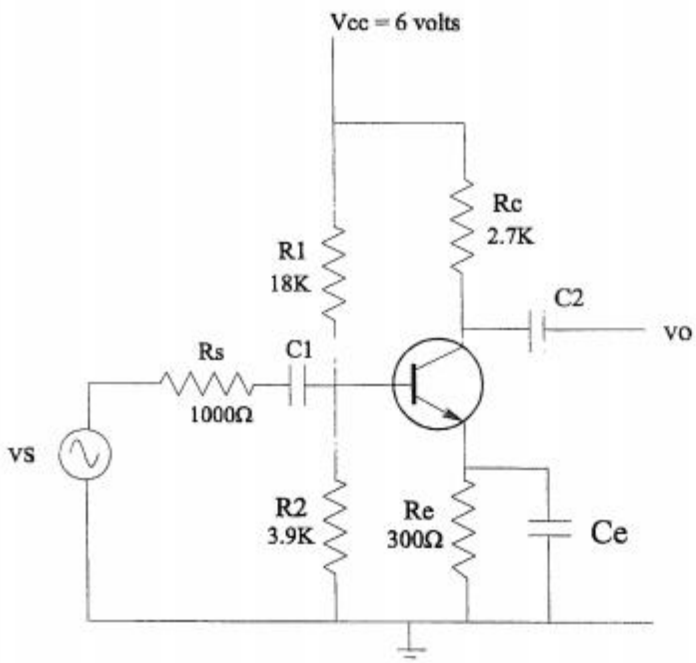

Figure 1.1 Single stage CE BJT amplifier

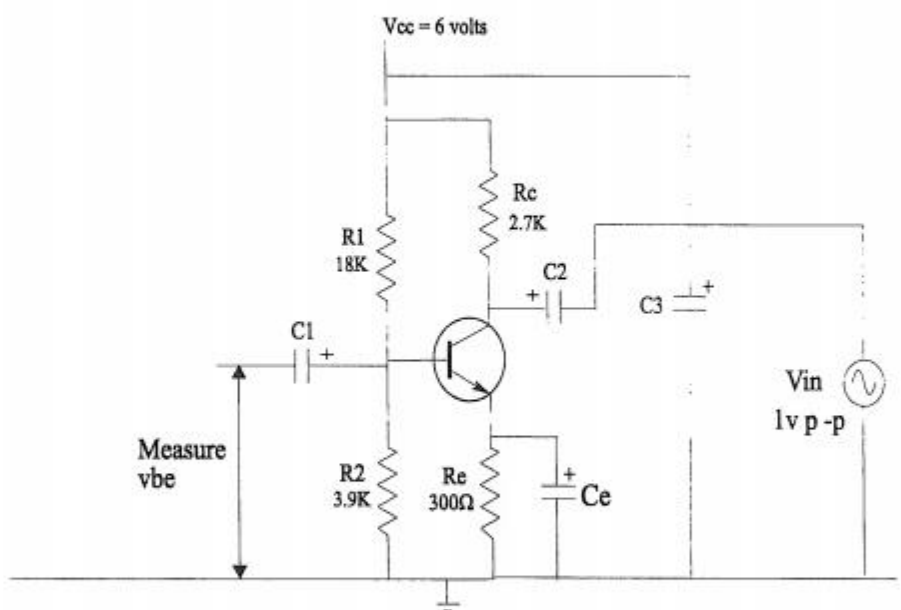

Figure 1.2 Modification for the measurement of Hre and Hoe