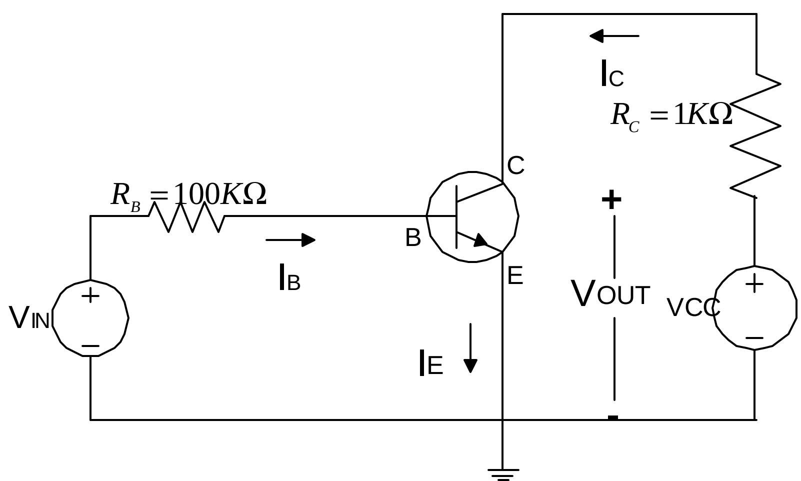
EXPERIMENT # 8
TRANSISTOR BIASING TECHNICS

Transistor Biasing

In the last two labs the concept of biasing was introduced i.e. to set the output operating point at the DC voltage so that the amplified wave can swing up and below that point in equal amount and hence give us the maximum range of amplification. The inverter circuits that were used in the last two labs though give us the basic concept of biasing but they are inadequate for achieving stable, reproducible amplifiers. In this lab the problems concerning to the biasing of amplifiers will be studied along with a practical method for obtaining stable operating point.

BJT Biasing

- The circuit that was used in Lab # 6 is following



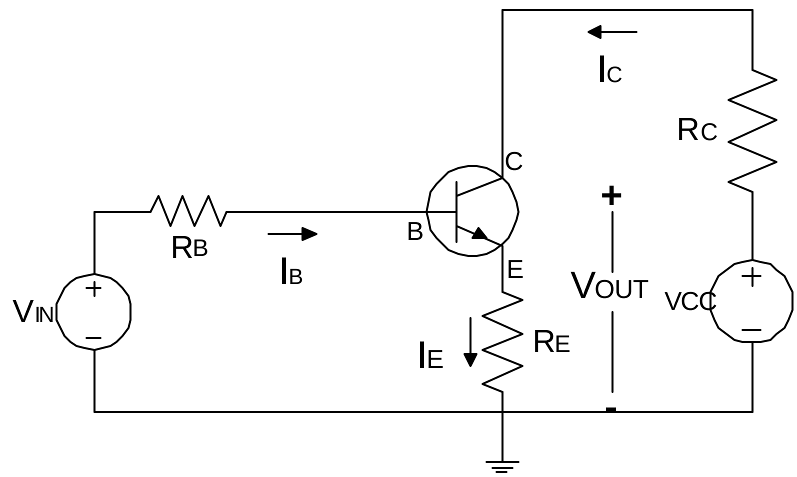
Circuit # 1

- The input and output voltage in the active region will be:

$$v_{out} = V_{CC} - Bf\frac{R_C}{R_B}(v_{IN} - V_f)$$

- Now in this equation as v_{IN} is changed v_{out} will be changed linearly since all other quantities are assumed to be constant, but what happens if a transistor burned out and is replaced by same transistor model, Bf can be different. Similar transistor models have a range of Bf (for 2N3904 it goes from say 130-200). Now in the above expression if for one transistor you set the output DC level say at 2.5 Volts (middle point of active region) and to set that output the input voltage is say 1.2 volts. Now suppose you need to change your transistor and the new transistor you got have different value of Bf . This will change your operating point and you might go from active region to the saturation region. So we need a biasing scheme that will allow for the change of Bf .

- If an Emitter resistance R_E is added to circuit # 1, the operating point can be made quite insensitive with the changes of Bf



Circuit # 2

- Now applying KVL in the input loop

$$V_{IN} = I_B R_B + V_f + I_E R_E$$

also

$$I_E = I_C + I_B \,\&\, I_C = B_f I_B$$

$$I_E = (B_f + 1) I_B$$

which leads to

$$I_C = \frac{B_f (V_{IN} - V_f)}{R_B + (B_f + 1) R_E}$$

- Now if we choose $R_B << (B_f + 1) R_E$ then we can write

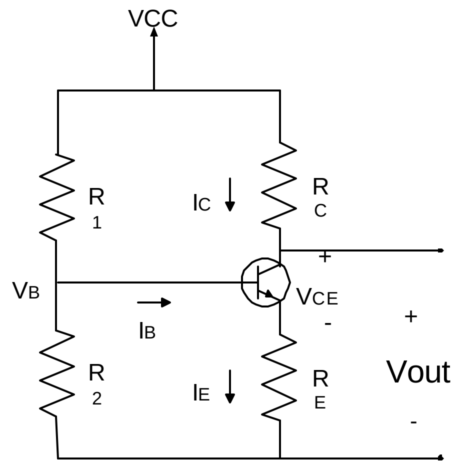
$$I_C \approx \frac{V_{IN} - V_f}{R_E}$$

and hence output will be

$$V_{out} = V_{CC} - I_C R_C = V_{CC} - \frac{R_C}{R_E}(V_{IN} - V_f)$$

independent of B_f

- Circuit # 2 can further be reduced using its Thevnin equivalent such that we only require one voltage source instead of two as shown in circuit # 3



Circuit # 3

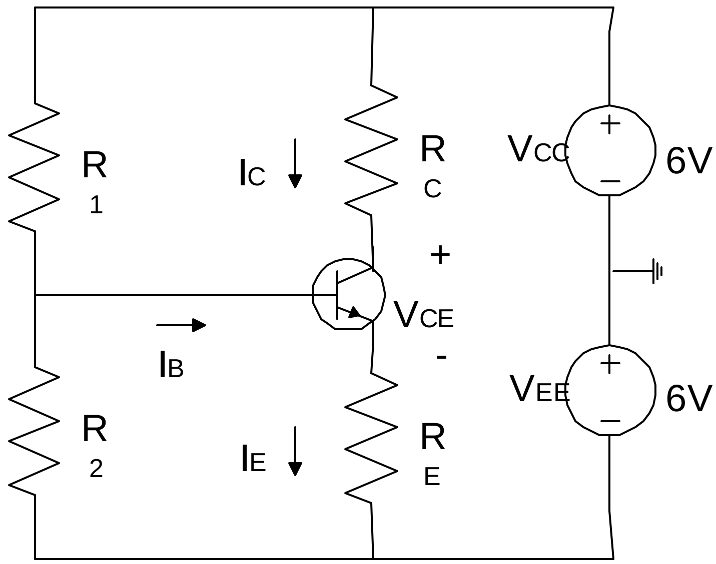
- The Thevnin equivalent of V_{CC}, R_1 and R_2 in circuit # 3 is V_{IN} and R_B in circuit # 2.

$$V_{IN} = V_{CC}\frac{R_2}{R_1 + R_2} \& R_B = R_1 \parallel R_2$$

- The emitter resistor R_E acts as a negative feedback to stabilize the operating point. Since the base voltage V_B is set essentially by the voltage divider (R_1 and R_2), it is pretty much independent of the transistor parameters. If B_f increases for any reason such as either temperature change or change of transistor, a resulting rise in I_E will increase the voltage drop across R_E, and thereby increase V_E. V_{BE} thus become smaller, causing a drop in I_B that counteracts the increase in I_E.
- The goal of bias design is to set V_{CE} so that transistor remains in the active region when the collector node swings above and below the operating point under the influence of the input voltage.
- Bias design is typical of many engineering tasks, which have no unique solution because not enough conditions are specified. The intuition and creativity of an engineer are crucial to accomplish the bias design.

Procedure for BJT Biasing

- You have to design the following circuits by choosing the resistances R_C, R_B, R_1 and R_2 based on the information and rules given below.
- Note that the ground in circuit # 4 is in between two sources and not going into the circuit. You can get 6 volts from red end of your supply and -6 from the green end. When you measure the voltage of some point say V_B, you'll measure it from base to the ground i.e. black terminal between red and green of your supply.



Circuit # 4

- You have to choose R_E, R_C, R_1 and R_2 to complete your design. There is no hard and fast rule to select these resistances but there are some observations on the basis of which you can find these resistances and come up with a good stable circuit. Most of the times R_C and R_E are close to each other and they are in the range of 2K to 10K Ohms with R_C a little higher than R_E. Say you choose R_C = 5K and R_E = 4K, next you have to decide a suitable value of R_B fulfilling condition $R_B << (B_f + 1)R_E$ where Bf is assumed to be the one you evaluated in one of the previous lab. Say Bf is 160 so $R_E(Bf+1)$ is almost equal to 640,000. So you can choose R_B = 40K or 30K. When you choose R_B, you have to decide how to split it between R_1 and R_2 since R_1 and R_2 when combine in parallel yields R_B (usually R_2 is smaller than R_1 so that less current go inside base and transistor remain in active region). When you select all these values, you have to check that your transistor is in active region. For that, check the following
  - V_{CE} will be well in the active region say between 3.5 to 5.5 volts
  - V_C should be roughly at the midway of V_{CC} and V_B.
  - V_{BE} is in the forward active region i.e. between .65 to .7 volts.
  - I_C should be around 0.8 to 1 mA. It can be a little different but if it is different then point 5 should be satisfied
  - Ratio of I_c and I_B should give you a Bf, which matches your Bf from previous lab.

- Substitute one or two other transistors (same model) and verify that the output operating points i.e. V_{CE}, V_C and I_C remains unchanged even if I_B and Bf are different.

MOSFET Biasing

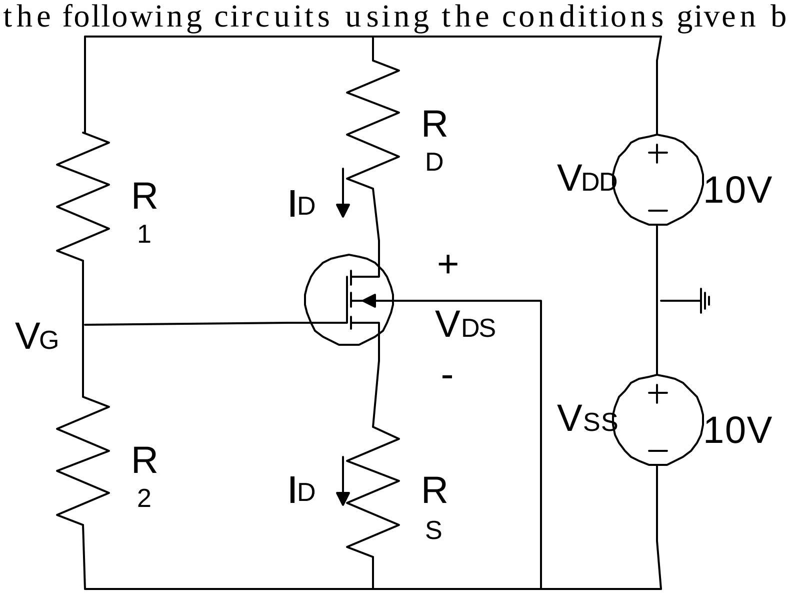
- The basic condition that you have to fulfill in order to get a stable output operating point is

$$2R_S(V_{IN} - V_{TR}) >> 1/K$$

where K is the same constant you evaluated in one of the previous labs. Its normal value is 0.5E-3 A/V². $V_{IN} = V_{DD}\frac{R_2}{R_1 + R_2}$ from circuit # 3 switching BJT by a MOSFET.

Procedure for MOSFET Biasing

- Design the following circuits using the conditions given below



Circuit # 5

- Since no current flows inside the gate hence it is relatively easy to choose values of resistors for MOSFET circuit.
- First choose R_s that fulfills the condition for the MOSFET stable biasing point.
- Now choose R_1 and R_2 to have
  - o I_D should be around 1mA
  - o V_D approximately between V_{DD} and V_G
  - o V_{DS} should satisfy the condition for the constant current region i.e. $V_{DS}>(V_{GS}-V_{TH})$.

- Replace the MOSFET with another of the same type and note the output operating points.