Assignment 3

Preliminaries

1. You can reuse and build upon your previous code for this assignment.

2. We provide you with the following additional functions that help to handle BJT elements.

a) npnBJT.m is function that adds the element BJT to the list of the BJTs. It serves a similar functionality as the diode.m function.
b) *fvect.m* is the function that adds the nonlinear stamp to the vector $\boldsymbol{F}(\boldsymbol{X})$**.** You can use this function to fill the $\boldsymbol{F}(\boldsymbol{X})$ vector.
b. *nljacobian.m* is the function that creates/ updates the Jacobian for the nonlinear elements. Similar, to diode add the Jacobian for the BJT in this function.

3. For adding the AC sources to the circuit, use the function named *vol_ac.m.* The vol_ac.m function creates a global variable *bac*. The variable *bac* contains the contribution of DC sources.

The addition of DC sources to the circuit can be done using the *vol.m* function.

4. In your submission please provide all code in a zip file in a way that allows us to run the testbenches ourselves (include all code, not just the recent one).

4. Also submit a pdf file containing the answers to the questions, the output plots and the code for functions you have written for this assignment.

Question I

Write a matlab function *dcsolvealpha.m* that finds the dc solution of the augmented system:

$$GX + f(X) = \alpha B_{dc}$$

The functions is defined as follows:

```
function Xdc = dcsolvealpha(Xguess,alpha,maxerr)
% Compute dc solution using newtwon iteration for the augmented system
% G*X + f(X) = alpha*b
% Inputs:
% Xguess is the initial guess for Newton Iteration
% alpha is a paramter (see definition in augmented system above)
% maxerr defined the stopping criterion from newton iteration: Stop the
% iteration when norm(deltaX)<maxerr
% Oupputs:
% Xdc is a vector containing the solution of the augmented system
```

Deliverables:

1. Submit the matlab file *dcsolvealpha.m* containing your function
2. Include the code above in your PDF file submission for the assignment.

Question II

1. Write a matlab function dcsolvecont.m that finds the dc solution using the power ramping continuation method. Hint: It may be convenient for you to use the function you developed in Question I. The dcsolvecont.m function is defined as follows:

```
function Xdc = dcsolvecont(n_steps,maxerr)
% Compute dc solution using newtwon iteration and continuation method
% (power ramping approach)
% inputs:
% n_steps is the number of continuation steps between zero and one that are
% to be taken. For the purposes of this assigments the steps should be
% linearly spaced (the matlab function "linspace" may be useful).
% maxerr is the stopping criterion for newton iteration (stop iteration
% when norm(deltaX)<maxerr
```

2. Test this function by finding the dc solution (at node Vo) of the following diode circuit at three different values of Vi (-10V, -2V, and 8V). Use 10 continuation steps in this test. Note, we provide the netlist for this circuit in the file Sedra4_93.m. All diodes in this circuit have Is=2e-15A and Vt=26e-3V.
3. Run the provided script: *TestBenchDiodeckt4_93.m* shown in Figure 1, This script will use your *dcsolvecont.m* function in order to compute and plot Vo as a function of Vi.

Deliverables

1. The matlab function *dcsolvecont.m*
2. A pdf file containing the matlab function *dcsolvecont.m*. The solutions found in part 2, and the plot provided by the script in part

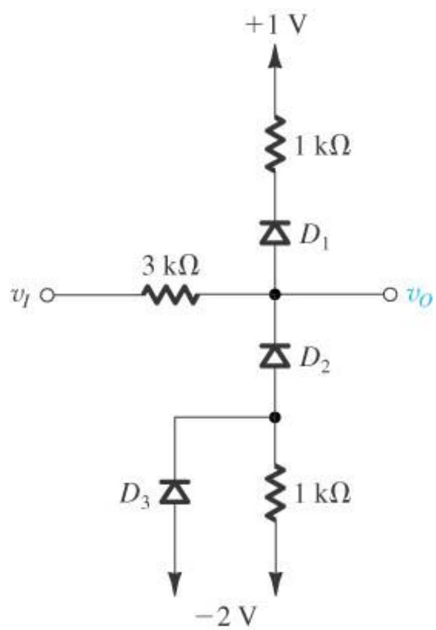

Figure 1: Diode circuit.

Question III

Using the transistor model shown in Appendix, add the contribution of the BJT in the circuit simulator. Complete the contribution of BJT in MATLAB functions named *f_vect.m* and *nlJacobian.m.*

Deliverables:

After completing the stamp of the BJT in circuit simulator. Run the file named *BJT_CB.m* containing the circuit shown below in Figure 2.

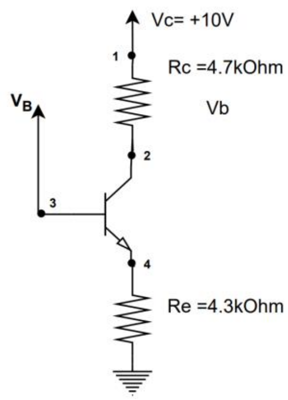

Figure 2: BJT circuit.

Compute the DC solution of the circuit shown in Figure 2 for the following values of base node, V_B = 4V, 6V and 0V.

1. Run the *BJT_CB.m* using the *dcsolve.m* function you implemented in Assignment 1. Report your observations.

2. Run the *BJT_CB.m* using the *dcsolvecont.m* function you implemented in Question II. Report the values of the nodal voltages obtained after using *dcsolvecont.m.*

Question IV

Plot the AC response of the circuit shown in Figure 3 between 0Hz to 5000Hz. Complete the function names *nlACresponse.m* and write your algorithm for computing the AC response. To run the file named *BJT_CE.m* containing the circuit shown below in Figure 3.

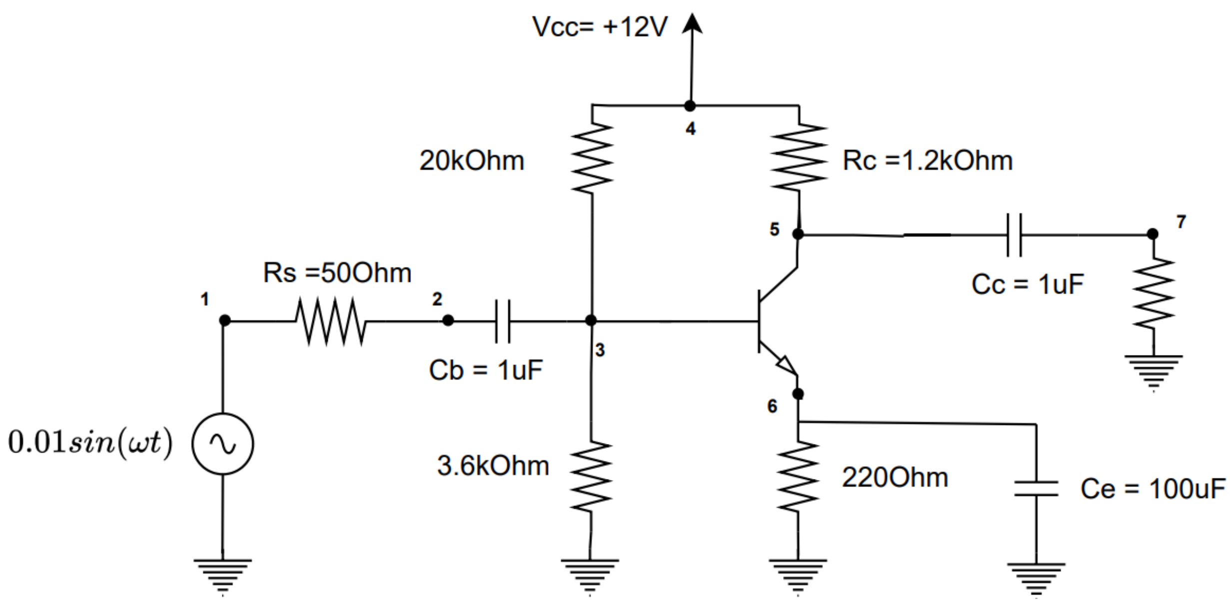

Figure 3: Common Emitter circuit.

1. Run the *BJT_CE.m* and plot the gain at node 7 for the frequencies between 0 to 10^6Hz obtained and include it in the assignment.

Appendix

Figure 1 below shows the Ebbers-Moll model of a NPN BJT transistor. In this assignment you are required to model the BJT using the MNA equations.

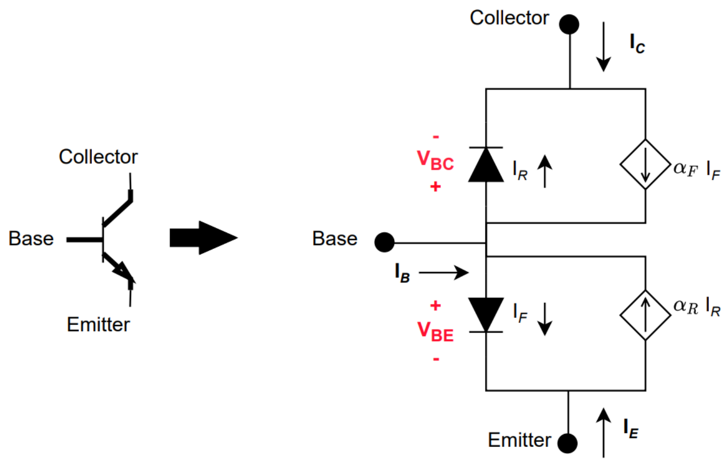

Figure 4: Ebbers-Moll model of BJT.

The currents I_F and I_R, are the currents in the Base-Emitter and Base-Collector Junction, respectively. The equations of junction currents I_F and I_R are shown below in (1.1) and (1.2), respectively.

$$I_F = I_S\,(e^{\frac{V_{BE}}{V_T}} - 1) \tag{1.1}$$
$$I_R = I_S\,(e^{\frac{V_{Bc}}{V_T}} - 1) \tag{1.2}$$

V_{BE} is voltage difference between base and emitter nodes. V_{BC} is voltage difference between base and collector nodes. I_S and V_T are the saturation current and thermal voltages for the Base-Emitter and Base-Collector Junctions. α_F and α_R are forward and reverse coefficients.

The using the Ebers-Moll model for I_E, emitter current, and I_C, collector current, are obtained as shown in (1.3) and (1.4)

$$I_E = -I_F + \alpha_R I_R \tag{1.3}$$
$$I_C = -I_R + \alpha_F I_F \tag{1.4}$$

Using the Kirchhoff's Law, we can obtain the equation for base current

$$I_B = -(I_E + I_C) \tag{1.5}$$
$$I_B = I_F - \alpha_F I_F + I_R - \alpha_R I_R \tag{1.6}$$

These are the nonlinear equations of currents and can be stamped in the MNA equation as shown in (1.7)

$$\underbrace{\begin{bmatrix} 0 & 0 & 0 \\ 0 & 0 & 0 \\ 0 & 0 & 0 \end{bmatrix}}_{\boldsymbol{G}} \underbrace{\begin{bmatrix} V_C \\ V_B \\ V_E \end{bmatrix}}_{\boldsymbol{X}} + \underbrace{\begin{bmatrix} -I_R + \alpha_F I_F \\ I_F - \alpha_F I_F + I_R - \alpha_R I_R \\ -I_F + \alpha_R I_R \end{bmatrix}}_{\boldsymbol{F}(\boldsymbol{X})} = \underbrace{\begin{bmatrix} 0 \\ 0 \\ 0 \end{bmatrix}}_{\boldsymbol{B}} \tag{1.7}$$

As can be in seen in (1.7), only nonlinear vector $\boldsymbol{F}(\boldsymbol{X})$ contains the contribution of the BJT.