Alexandria University
Faculty of Engineering
Electrical Engineering Department

ECE 336: Semiconductor Devices
Lab#2: Forward bias p-n junction

Objectives

The purpose of this exercise is to continue the analysis of the different parameters for the p-n junction device model. This time we examine the p-n junction under forward bias and understand the relationship between various parameters.

By the end of this exercise you should be able to:

1. Describe the effect of I_s on the turn on voltage of a p-n junction.
2. Describe the effect of R_s and *BV* of the diode on different circuits.
3. Enumerate limitations of rectifier circuits using diodes.
4. Understand the effect of diffusion capacitance.

Requirements and Deliverables

In this exercise you are required to use the diode in different clamping and rectifier circuits, tweak its model parameters, observe its behavior in the circuit and conclude how it can be used in a circuit.

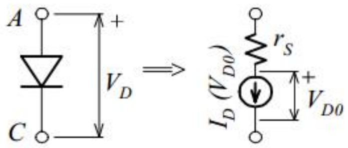
You should deliver a technical report containing the following sections:

- A brief survey on diffusion capacitance and its equations.
- Procedures: A description and snapshots of the lab procedures taken from your PC,
- Results: Numerical and graphical simulation results as requested
- Comments: Your conclusion about the results and your answers for the assignment questions.

Diode Device Model

STATIC PARAMETERS				
Symbol	**Usual SPICE Keyword**	**Parameter Name**	**Typical Value/ Range**	**Unit**
I_S	IS	Saturation current		A
n	N	Emission coefficient	$1-2$	
r_S	RS	Parasitic resistance		Ω
BV	BV	Breakdown voltage (positive number)		V
	IBV	Breakdown current (positive number) Note: $\texttt{IBV} = \texttt{IS}\ \frac{\texttt{BV}}{V_t}$		A

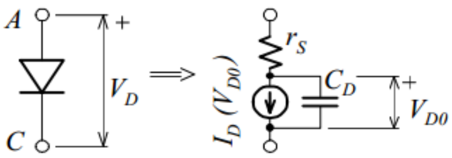
STATIC DIODE MODEL



$$I_D(V_{D0}) = \begin{cases} \texttt{IS}\ (e^{V_{D0}/\ \texttt{N}\ V_t} - 1) + V_{D0}G_{MIN} & \text{if } V_{D0} > \text{-BV} \\ -\texttt{IBV} & \text{if } V_{D0} = \text{-BV} \\ -\texttt{IS}\ [e^{-(\ \texttt{BV}\ + V_{D0})/V_t} - 1 + \frac{\texttt{BV}}{V_t}] & \text{if } V_{D0} < \text{-BV} \end{cases}$$

DYNAMIC PARAMETERS				
Symbol	**Usual SPICE Keyword**	**Parameter Name**	**Typical Value/ Range**	**Unit**
$C_d(0)$	CJO	Zero-bias junction capacitance		F
V_{bi}	VJ	Built-in (junction) voltage	$0.65-1.25$	V
m	M	Grading coefficient	$\frac{1}{3}-\frac{1}{2}$	
τ_T	TT	Transit time		s

LARGE-SIGNAL DIODE MODEL



$I_D(V_{D0})$ is given in Table A.1

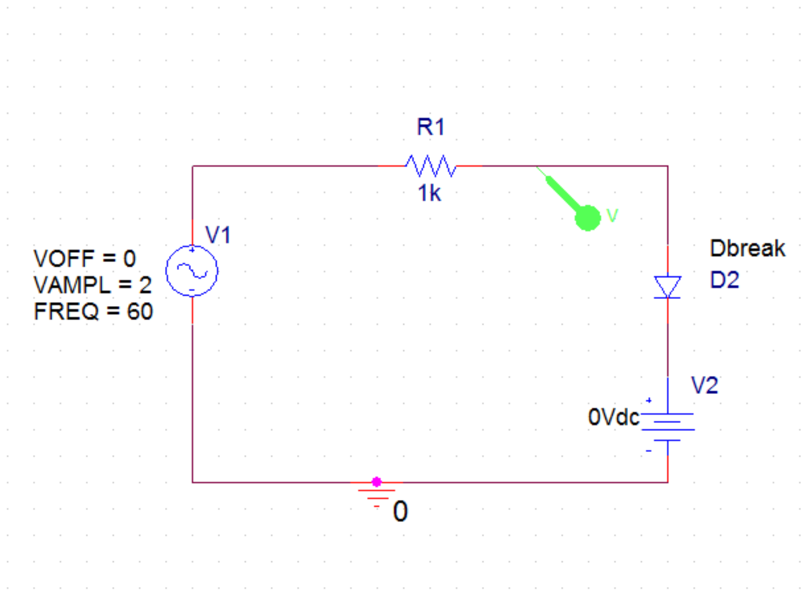
$$C_D = C_d + C_s$$

$$C_d = \texttt{CJO}\ \left(1 - \frac{V_{D0}}{\texttt{VJ}}\right)^{-\ \texttt{M}} \quad (\text{for } V_{D0} < 0.5\texttt{VJ})$$

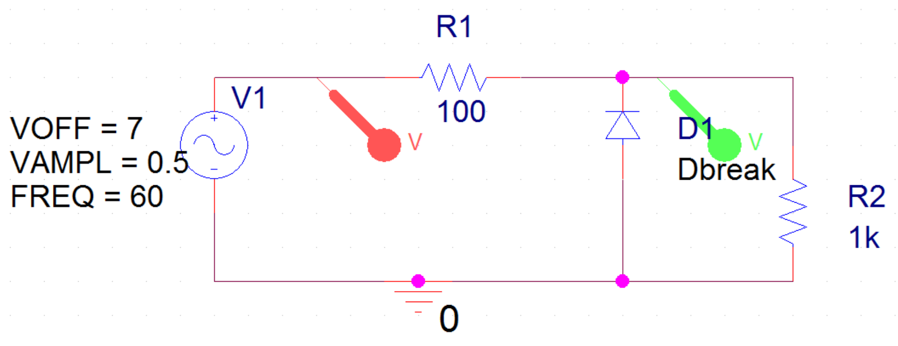
$$C_s = \texttt{TT}\ \frac{dI_D}{dV_{D0}}$$

Procedures:

1. Connect the circuit as shown in the figure.



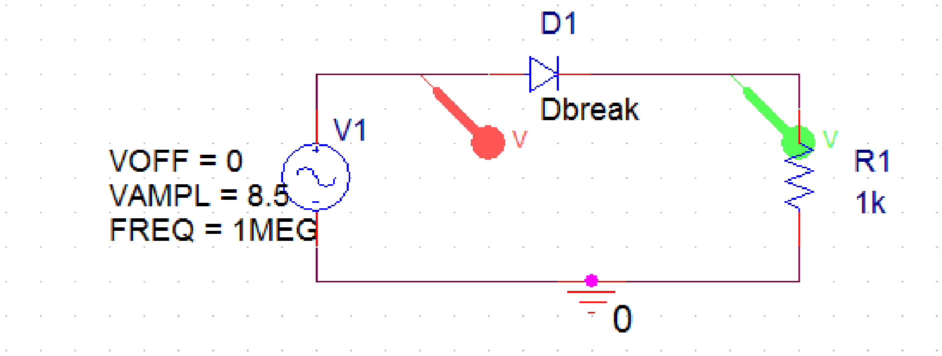
2. Edit diode model to have I_s = *1e-14* , *N* = *1*. Then I_s= *1e-10, N* = *1* and finally I_s = *1e-10, N =2.* Set the simulation profile to transient simulation with run time 0.2 seconds and observe the results each time. Comment on the results. (hint: refer to the diode I-V characteristics and equation to understand the changes in the plot)
3. On the same circuit, change the RS parameter to 0 and 16. Plot the results.
4. Change the resistance from 1K to 50ohms and repeat step number 4. Comment on the results change in 3 and 4.
5. Connect the circuit as shown in the figure.



6. Plot the output without changing any parameters, then change the

BV= 4.7 and RS = 0 , then BV =4.7 and RS = 16. Explain the results (Hint: the default value of breakdown voltage is infinity)

7. Connect the circuit as shown in the figure.



8. Run simulation, then change the diode parameters C_J = *20pF* , *M* = *0.5* and V_J = *0.75V* and explain the results.
9. Return to the 1st circuit, set the amplitude of the sine wave 15V and the frequency 100MEG, set the diode parameters to Is=0.1pA , N = 1 , RS = 16 , CJO = 2pF , M = 0.5, VJ = 0.75 **, TT = 0 and TT = 12ns.** Comment on the results (input and output) (**hint: diffusion capacitance**).