Report of Lab 1:
Static and Dynamic Diode Responses Using OrCAD

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1 Introduction

Before we delve into a detailed exploration of the dynamic and static aspects of diodes and their associated parameters, it's essential to acknowledge the significance of these characteristics in electronic circuits. Diodes are the unsung heroes of the electronics world, serving as key building blocks in a wide range of applications. Their ability to control the flow of current in one direction and their unique behaviors in response to dynamic changes in voltage and current make them indispensable. Understanding diode characteristics is the foundation upon which efficient circuit design, signal processing, and power management are built. In the following subsections, we will thoroughly examine the dynamic and static behaviors of diodes, shedding light on their applications and the critical parameters, such as capacitance, that underpin their functionality.

1.1 Dynamic Diode Response

Diodes play a crucial role in dynamic circuit operations, especially in switching applications. In this subsection, we will explore how diodes respond to transient changes in voltage and current. This dynamic behavior is vital in various applications such as rectification, pulse shaping, and signal clamping.

1.1.1 Diode Switching Characteristics

One of the fundamental dynamic aspects of diodes is their switching behavior. When subjected to abrupt changes in voltage, diodes experience a finite transition time between their on (conductive) and off (non-conductive) states. Understanding the switching characteristics of diodes is vital in applications like high-speed data transmission and power electronics.

1.1.2 Recovery Time and Reverse Recovery Current

During the transition from the forward-biased to the reverse-biased state, diodes exhibit a phenomenon known as reverse recovery. This behavior leads to a delay in the diode's ability to block current in the reverse direction. The parameters associated with this dynamic response include the reverse recovery time t_{rr} and the reverse recovery current I_{rr}. These parameters are vital when designing circuits that require fast switching, as they can significantly impact circuit performance.

1.1.3 Diode Capacitance

Capacitance in diodes is another critical dynamic parameter. Diodes inherently possess capacitance due to the nature of their construction. Two key capacitance parameters are the junction capacitance C_j and the diffusion capacitance C_d. These capacitances can influence high-frequency response and signal integrity in diode circuits. Engineers must consider these capacitance parameters when designing radio-frequency (RF) and microwave circuits, as well as high-speed digital systems.

1.2 Static Diode Response

In static conditions, diodes primarily operate as rectifiers, allowing current to flow in one direction while blocking it in the reverse direction. Understanding the static characteristics of diodes is essential for designing power supplies, signal conditioning circuits, and voltage regulation.

1.2.1 Voltage-Current Characteristics

Diodes have distinctive voltage-current VI characteristics, particularly when they are forward-biased and reverse-biased. In the forward-biased state, the diode has a low forward voltage drop and exhibits exponential behavior, while in the reverse-biased state, it acts as an open circuit, allowing minimal reverse leakage current.

1.2.2 Ideal vs. Practical Diodes

In real-world applications, diodes deviate from ideal behavior. Practical diodes exhibit characteristics like non-zero reverse leakage current, voltage drop in the forward-biased state, and dynamic resistance. Understanding the differences between ideal and practical diodes is essential for accurate circuit design and analysis.

In summary, dynamic and static responses of diodes are essential aspects of electronic circuit design. Diodes are not just static components used for rectification; they also exhibit dynamic behaviors that influence the performance of circuits in various applications. Moreover, parameters such as reverse recovery time, capacitance, and voltage-current characteristics must be considered to harness the full potential of diodes in different circuit scenarios. In the following sections of this report, we will discuss the experimental methods and results related to these dynamic and static characteristics of diodes using OrCAD.

2 Results on Resistance

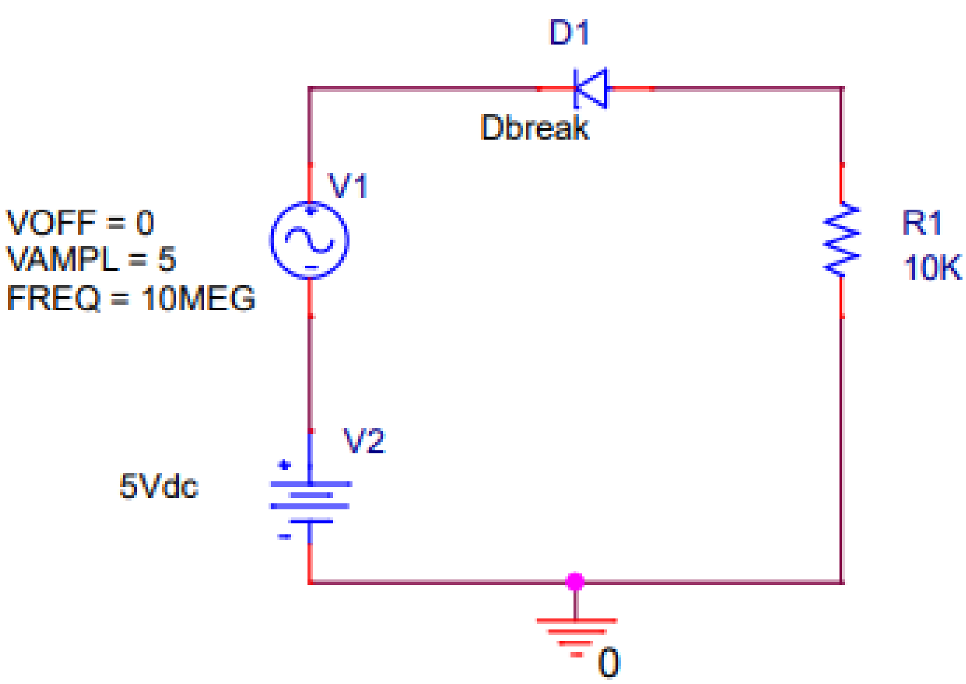
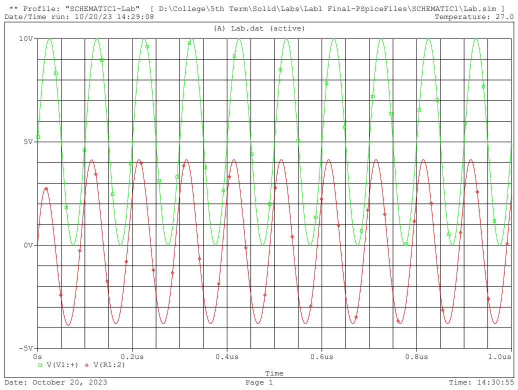
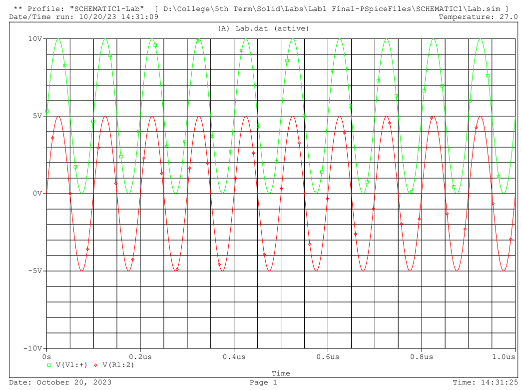


Figure 1: 1^{st} Circuit Simulation

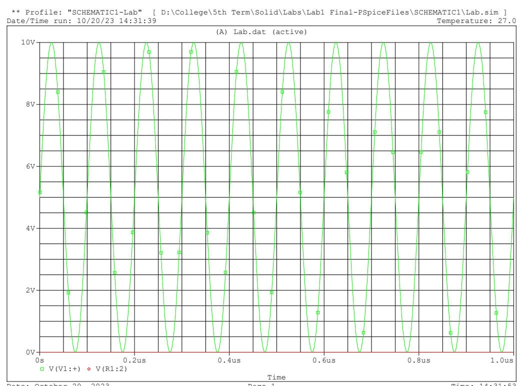
2.1 C_{jo} Change with Time



(a) $C_{jo} = 5pF$



(b) $C_{jo} = 15nF$



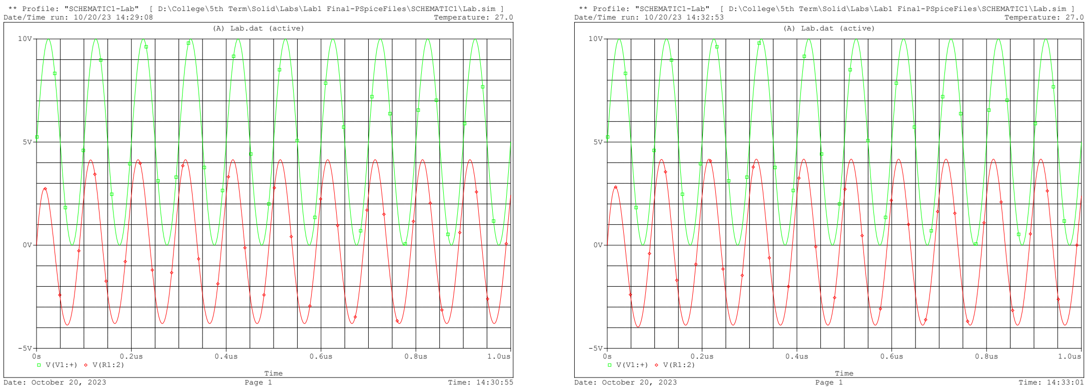
(c) $C_{jo} = 10^{-20}F$

Figure 2: C_{jo} Change Simulation Plots

2.1.1 Discussion

Analyze the results obtained we understand that more C_{jo} value gives more impedance in the circuits as it make diode behave as capacitor in the reverse bias also when the C_{jo} reaches some tiny point it back to normal open circuit model.

2.2 Adding M and VJ with Time



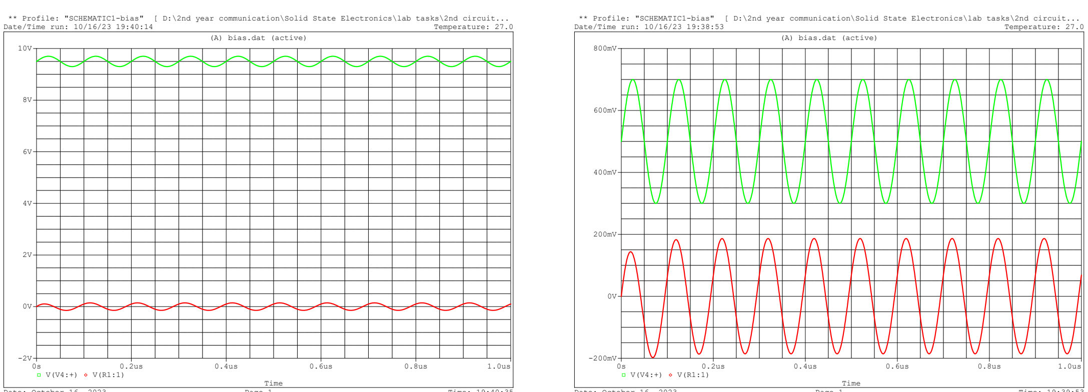
(a) $C_{jo} = 5pF$ (b) $C_{jo} = 5pF, M = 0.42, VJ = 0.75V$

Figure 3: Adding M and VJ Simulation Plots

2.2.1 Discussion

Due to Relation $C_D = C_d + C_s$ as $C_d = C_{Jo}(1 - \frac{V_{Do}}{VJ})^{-M}$ the result of the fig 3.b must have lower capacitance making circuit have higher impedance which make slight difference in the voltage on resistance.

2.3 Changing V_{DC} with Time



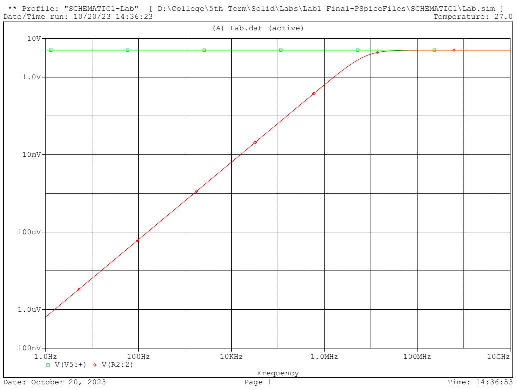
(a) $C_{jo} = 5pF, V_{DC} = 9.5V$ (b) $C_{jo} = 5pF, V_{DC} = 0.5V$

Figure 4: Changing V_{DC} Simulation Plots

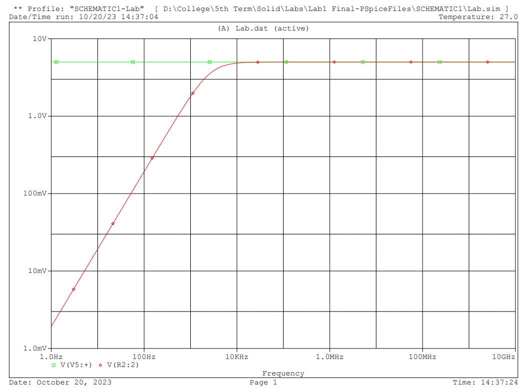
2.3.1 Discussion

Due to Relation $C_j = A\sqrt{\frac{q\epsilon}{2(V_o - V)}\frac{N_d N_a}{N_d + N_a}}$ the results would have difference as inverse relation between C_j and V.

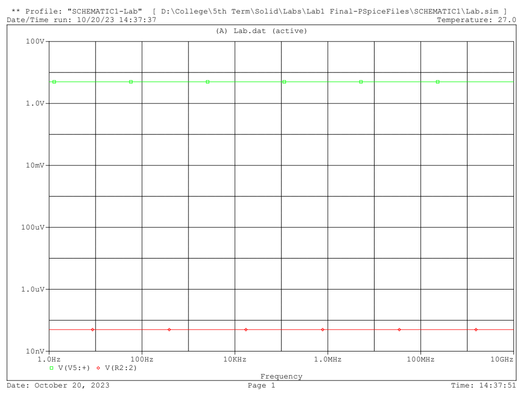
2.4 C_{jo} Change with Frequency (log Scale)



(a) $C_{jo} = 5pF$



(b) $C_{jo} = 15nF$



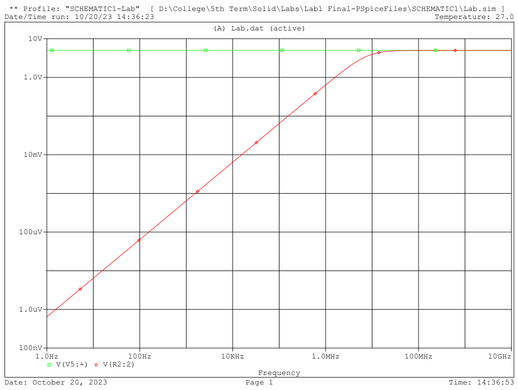
(c) $C_{jo} = 10^{-20}F$

Figure 5: C_{jo} Change Simulation Plots

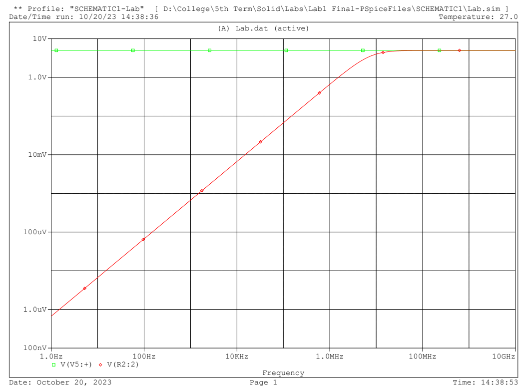
2.4.1 Discussion

Analyze the results obtained we understand that more C_{jo} value need higher frequency to reach short circuit state and at very small C_{jo} it will nearly always open circuit with all frequencies. Also, those have applications are called high pass filters.

2.5 Adding M and VJ with Frequency (log Scale)



(a) $C_{jo} = 5pF$



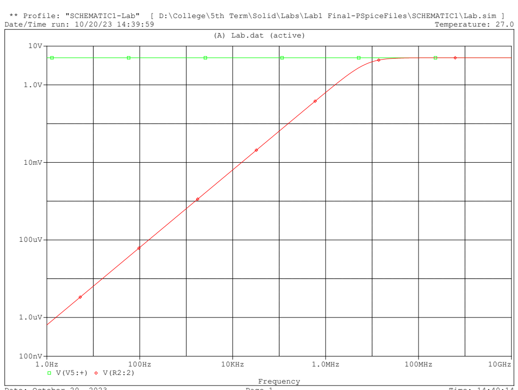
(b) $C_{jo} = 5pF, M = 0.42, VJ = 0.75V$

Figure 6: Adding M and VJ Simulation Plots

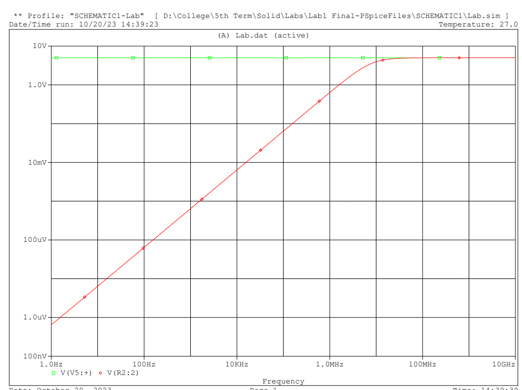
2.5.1 Discussion

Due to Relation $C_D = C_d + C_s$ as $C_d = C_{Jo}(1 - \frac{V_{Do}}{VJ})^{-M}$ the result of the fig 6.b must have lower capacitance which response with lower frequencies to reach short circuit.

2.6 Changing V_{DC} with Frequency (log Scale)



(a) $C_{jo} = 5pF, V_{DC} = 9.5V$



(b) $C_{jo} = 5pF, V_{DC} = 0.5V$

Figure 7: Changing V_{DC} Simulation Plots

2.6.1 Discussion

It will not make much difference as it was with Time because the DC does not have frequency change but it contribute in C_j so might have slight change.

3 Results on Diode

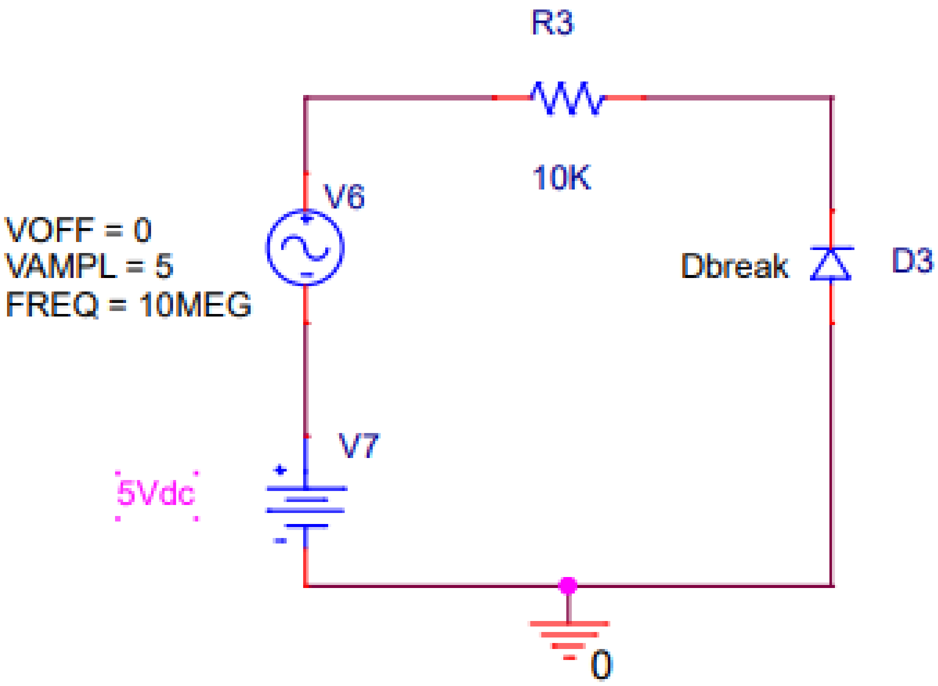
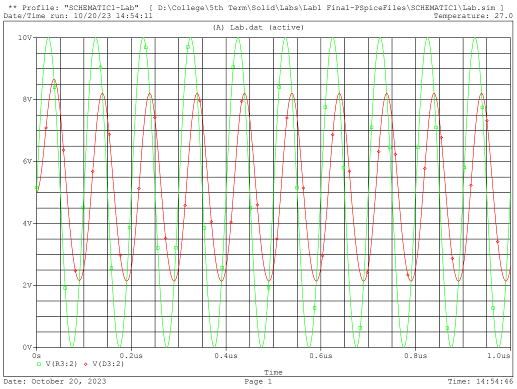
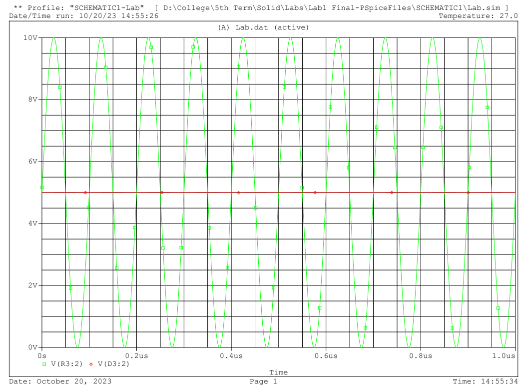


Figure 8: 2^{nd} Circuit Simulation

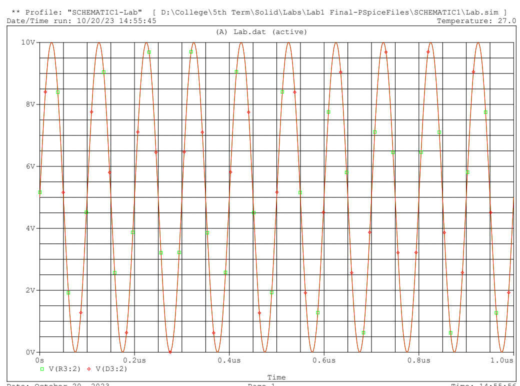
3.1 C_{jo} Change with Time



(a) $C_{jo} = 5pF$



(b) $C_{jo} = 15nF$



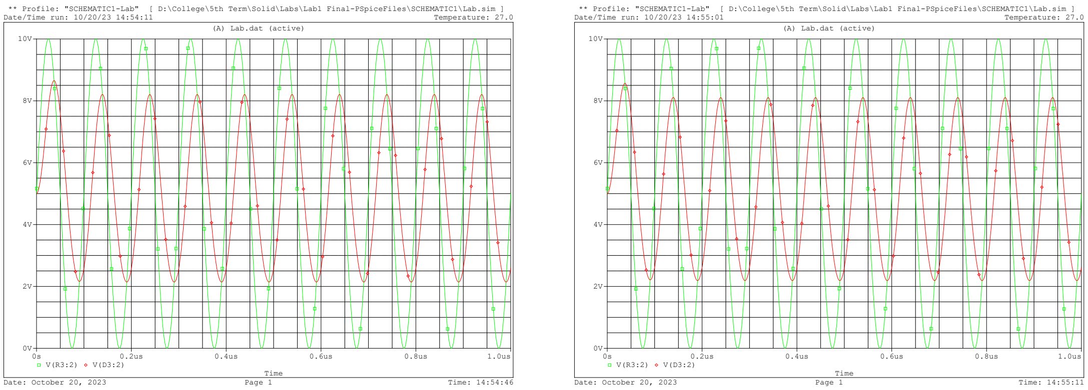
(c) $C_{jo} = 10^{-20}F$

Figure 9: C_{jo} Change Simulation Plots

3.1.1 Discussion

Analyze the results obtained we understand that more C_{jo} value gives more impedance in the circuits as it make diode behave as capacitor in the reverse bias also when the C_{jo} reaches some tiny point it back to normal open circuit model as fig 9.c, also in fig 9.b act as short circuit.

3.2 Adding M and VJ with Time



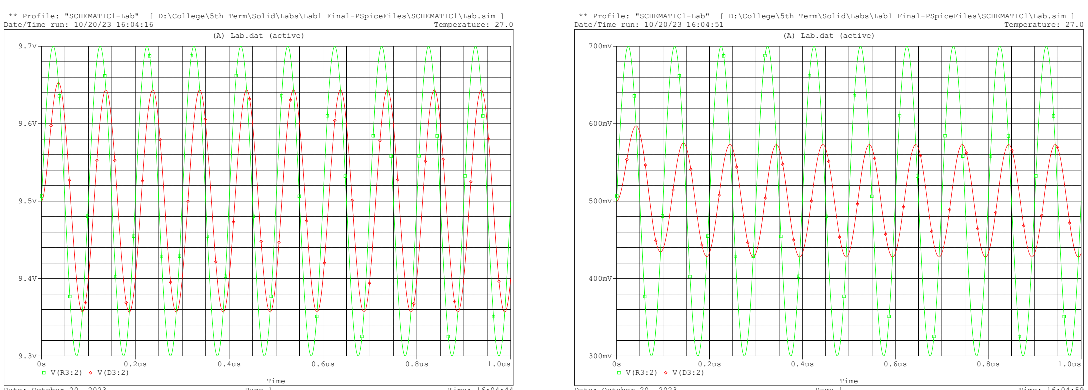
(a) $C_{jo} = 5pF$ (b) $C_{jo} = 5pF, M = 0.42, VJ = 0.75V$

Figure 10: Adding M and VJ Simulation Plots

3.2.1 Discussion

Due to Relation $C_D = C_d + C_s$ as $C_d = C_{Jo}(1 - \frac{V_{Do}}{VJ})^{-M}$ the result of the fig 10.b must have lower capacitance making circuit have higher impedance which make slight difference in the voltage on diode.

3.3 Changing V_{DC} with Time



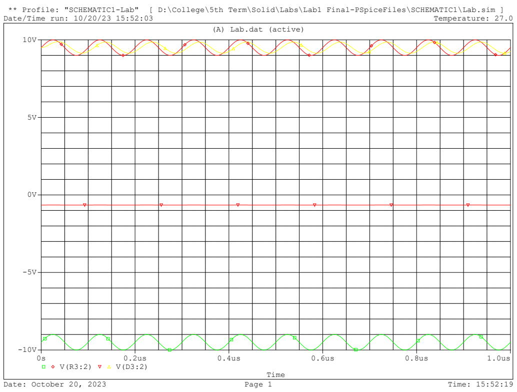
(a) $C_{jo} = 5pF, V_{DC} = 9.5V$ (b) $C_{jo} = 5pF, V_{DC} = 0.5V$

Figure 11: Changing V_{DC} Simulation Plots

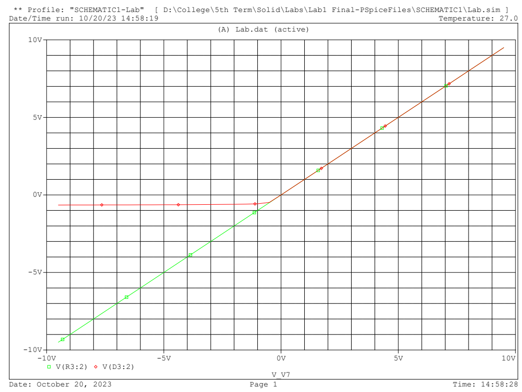
3.3.1 Discussion

Due to Relation $C_j = A\sqrt{\frac{q\epsilon}{2(V_o - V)} \frac{N_d N_a}{N_d + N_a}}$ the results would have slight difference as inverse relation between C_j and V.

3.4 Parametric and DC



(a) Parametric Sweep



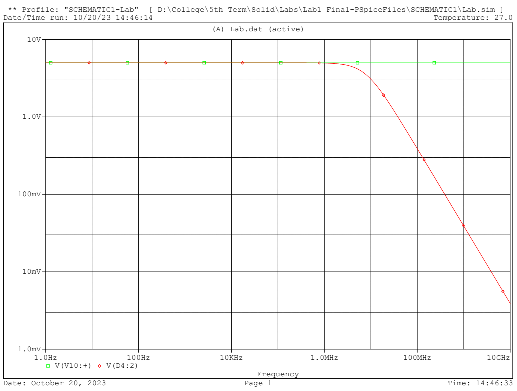
(b) DC Sweep

Figure 12: Changing V_{DC} Simulation Plots

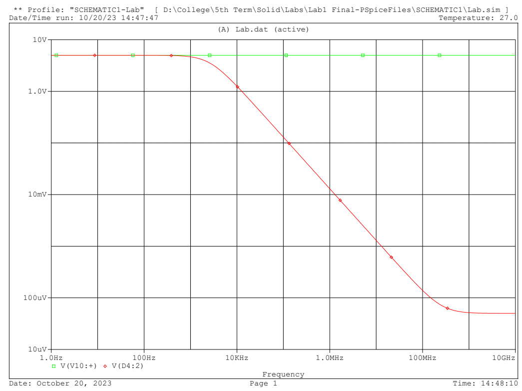
3.4.1 Discussion

Fig. 12.b shows that the diode remains forward bias as it constant value then become backward bias. As Fig. 12.a shows that when dc is +ve or -ve so when it negative it be short circuit as ideal model and when it positive it be backward bias and act as open circuit.

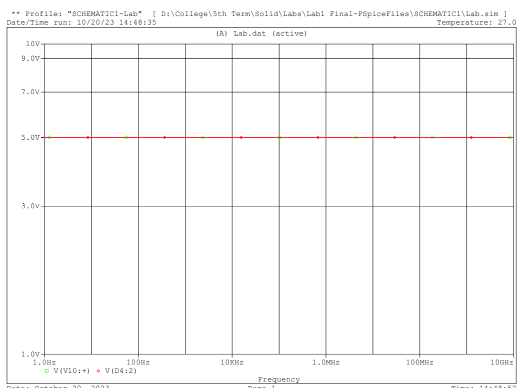
3.5 C_{jo} Change with Frequency (log Scale)



(a) $C_{jo} = 5pF$



(b) $C_{jo} = 15nF$



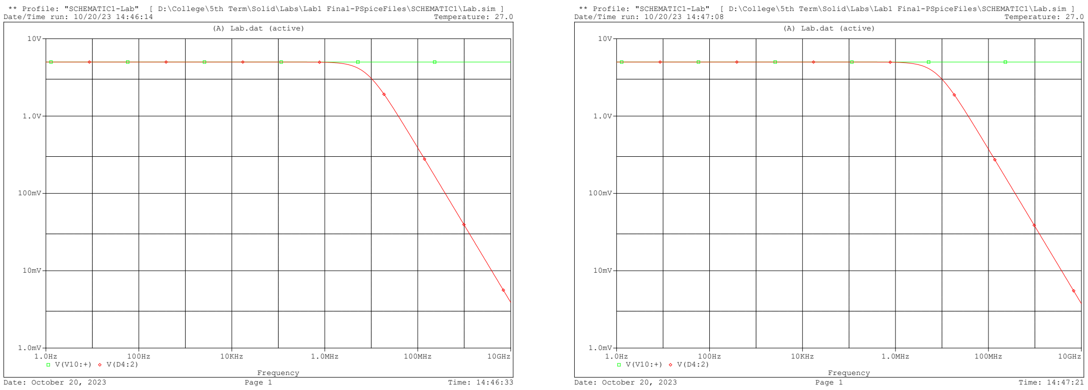
(c) $C_{jo} = 10^{-20}F$

Figure 13: C_{jo} Change Simulation Plots

3.5.1 Discussion

Analyze the results obtained we understand that more C_{jo} value need higher frequency to break the short circuit state and reach open circuit state and at very small C_{jo} it will nearly always open circuit with all frequencies. Also, those have applications called low pass filter.

3.6 Adding M and VJ with Frequency (log Scale)



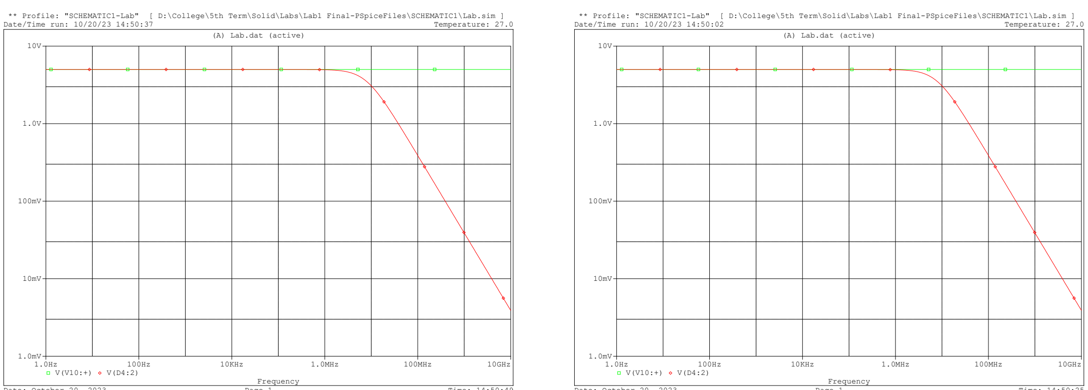
(a) $C_{jo} = 5pF$ (b) $C_{jo} = 5pF, M = 0.42, VJ = 0.75V$

Figure 14: Adding M and VJ Simulation Plots

3.6.1 Discussion

Due to Relation $C_D = C_d + C_s$ as $C_d = C_{Jo}(1 - \frac{V_{Do}}{VJ})^{-M}$ the result of the fig 14.b must have lower capacitance which response with lower frequencies to break short circuit state.

3.7 Changing V_{DC} with Frequency (log Scale)



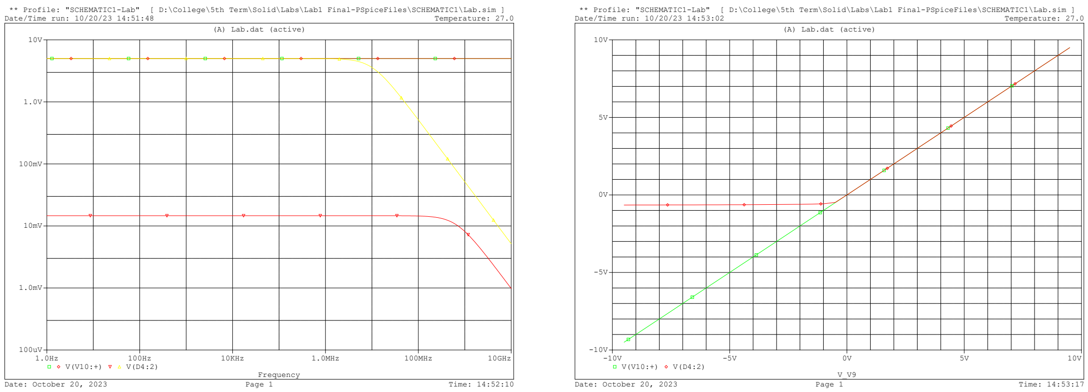
(a) $C_{jo} = 5pF, V_{DC} = 9.5V$ (b) $C_{jo} = 5pF, V_{DC} = 0.5V$

Figure 15: Changing V_{DC} Simulation Plots

3.7.1 Discussion

It will not make much difference as it was with Time because the DC does not have frequency change but it contribute in C_j so might have slight change.

3.8 Parametric and DC



(a) Parametric Sweep (log Scale)

(b) DC Sweep

Figure 16: Changing V_{DC} Simulation Plots

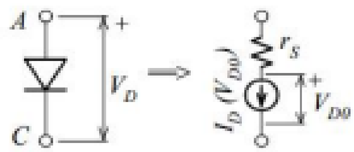
3.8.1 Discussion

Fig. 16.b shows that the diode remains forward bias as it constant value then become backward bias. Fig. 16.a Shows that voltage when it become negative it enlarge the C_j as it inverse proportional and operates on more frequency bandwidth before filtering.

4 Appendix

		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)		A
		Note: $\mathtt{IBV} = \mathtt{IS}\ \frac{\mathtt{BV}}{V_t}$		

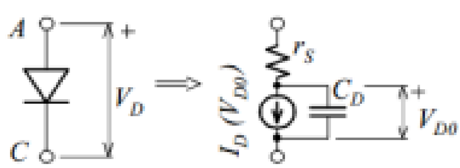
STATIC DIODE MODEL



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

		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

$C_D = C_d + C_s$

$C_d = \mathtt{CJO}\ (1 - \frac{V_{D0}}{\mathtt{VJ}})^{-\ \mathtt{M}}$ (for $V_{D0} < 0.5\mathtt{VJ}$)

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