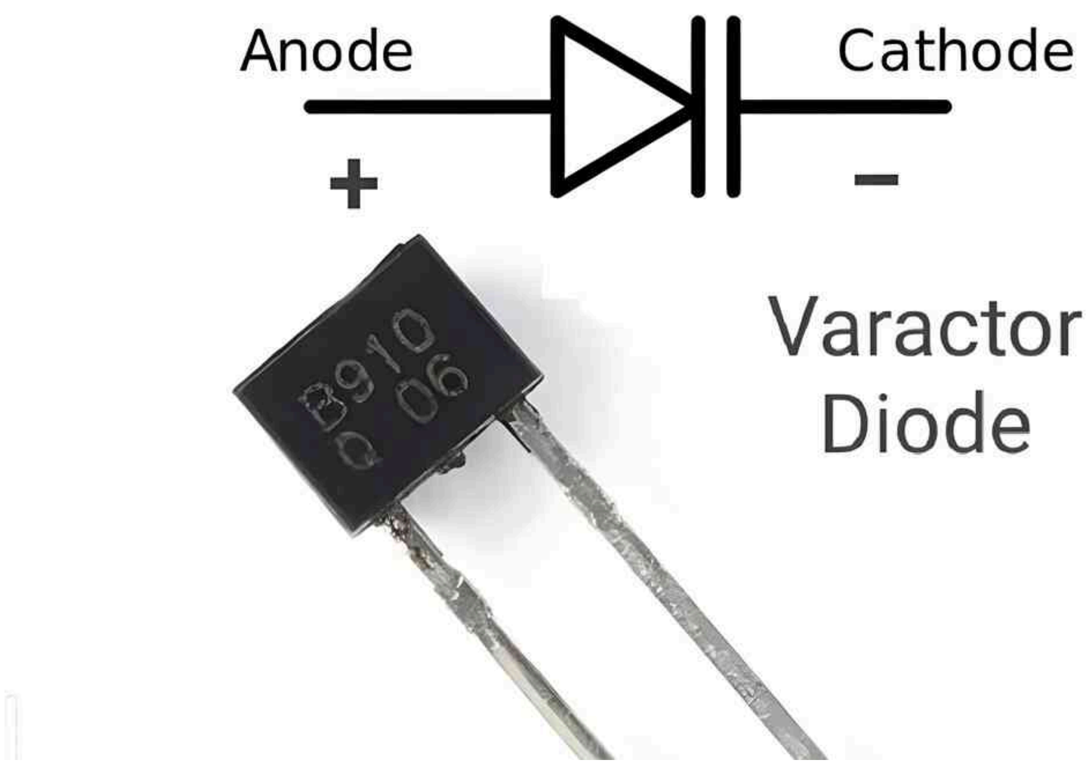
Varactor Diode



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INTRODUCTION

In this report we explain the Varactor Diode. We will explain the difference between it and a normal diode in terms of manufacture, discuss how it functions under different voltage inputs and how we can use it in different applications.

What is a Varactor Diode?

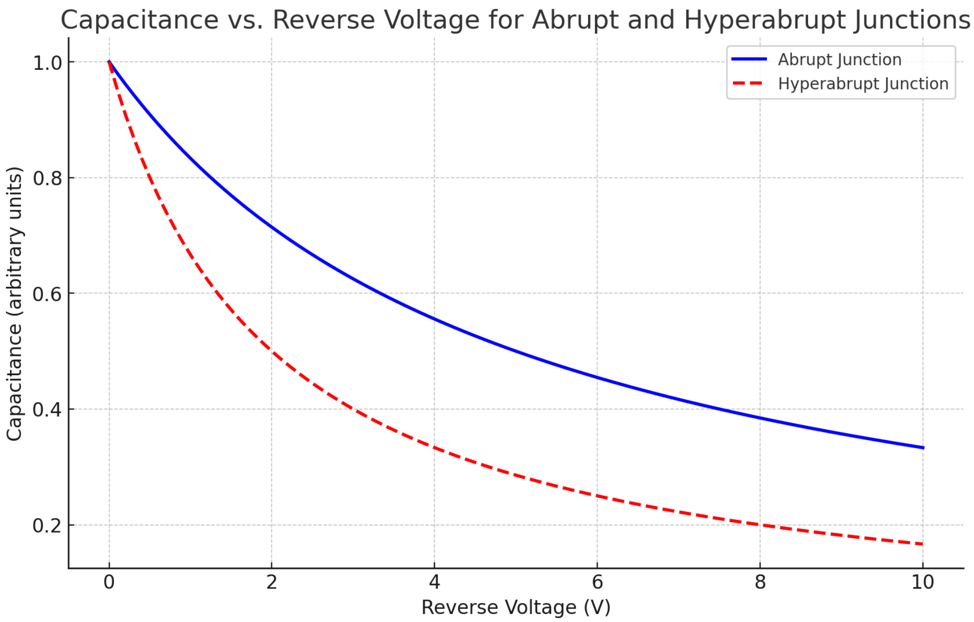
A Varactor Diode, like any other diode, is a P-N junction that operates in “forward-bias” if the anode is connected to the positive terminal of a voltage source and the cathode is connected to the negative terminal, and operates in “reverse-bias” if it was connected the other way around. However, the Varactor Diode is of high importance due to its variable capacitive nature when connected in reverse bias. Ultimately, acting as a variable capacitor with respect to the changing “reverse” voltage.

What is the difference between a Varactor Diode and a normal diode?

Unlike a normal diode that is designed for optimum current flow in forward-bias and the blockage of it in reverse-bias, the Varactor Diode is mainly designed to be operated in reverse-bias and provide smooth variations in capacitance with respect to the applied reverse voltage.

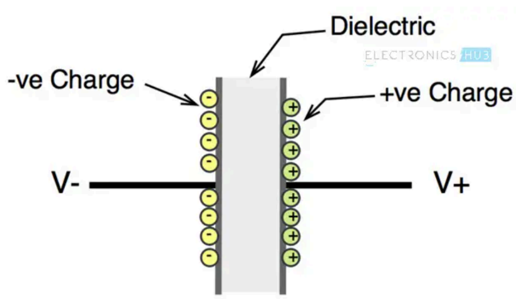
Junction and Doping:

1. Abrupt junction has a sharp transition between P and N regions but are lightly doped compared to normal diodes for better capacitance variation
2. Hyperabrupt junction is characterized by heavy doping near the junction that drops as you move away from the junction which enhances the rate at which capacitance changes with applied voltage (see figure in next page).



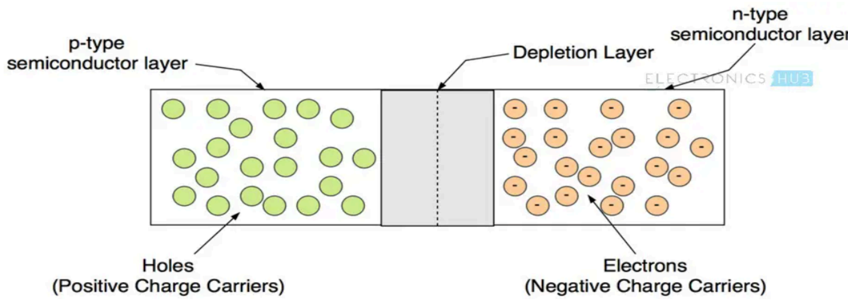
How reverse voltage controls capacitance?

First we need to understand how a variable capacitor operates. For a simple parallel plate capacitor the capacitance is given by $C=\varepsilon \cdot A/d$ where C = capacitance in farads (F), ε = permittivity of the dielectric material, A = area of the plate, and d = distance between the plates. So in order to "vary" the capacitance we could change the area "A" or the distance "d" between the plates.

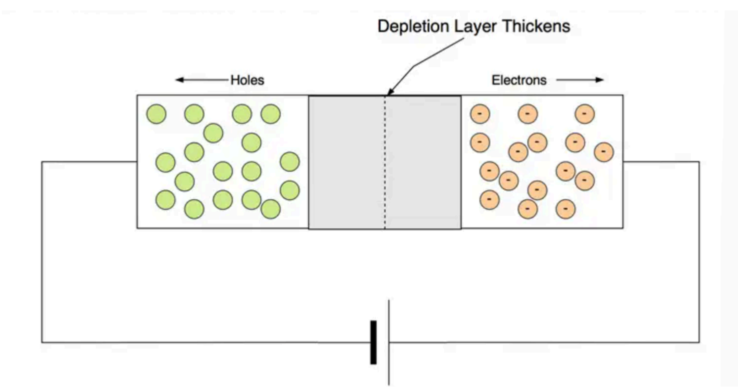


Understanding depletion region in reverse bias:

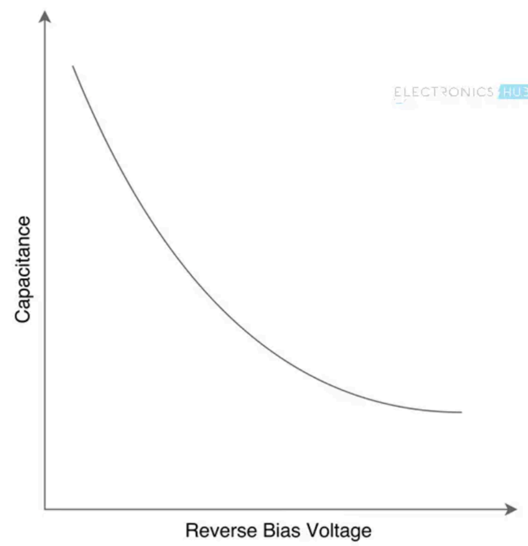
When a diode is connected in reverse-bias the depletion region "thickens" not allowing electrons or holes to pass and so no current flow.



As the reverse voltage is increased, the depletion region thickens even more creating a large area where there are no electrons or holes.



The depletion layer here is equivalent in meaning to the dielectric material in between the plates of a capacitor with distance "d" between the negatively charged side (N side) and the positively charged region (P side). Therefore, we have a capacitance which can vary with the thickness "d" of the depletion layer which in turn varies with the applied (reverse) voltage.



Consequently, as reverse bias voltage increases, the depletion region thickens and so the capacitance of the Varactor Diode decreases.

The capacitance "C" of a **varactor diode** as a function of reverse bias voltage is often approximated by the following formula:

C=Co/(1+VR/Vj)^n

where:

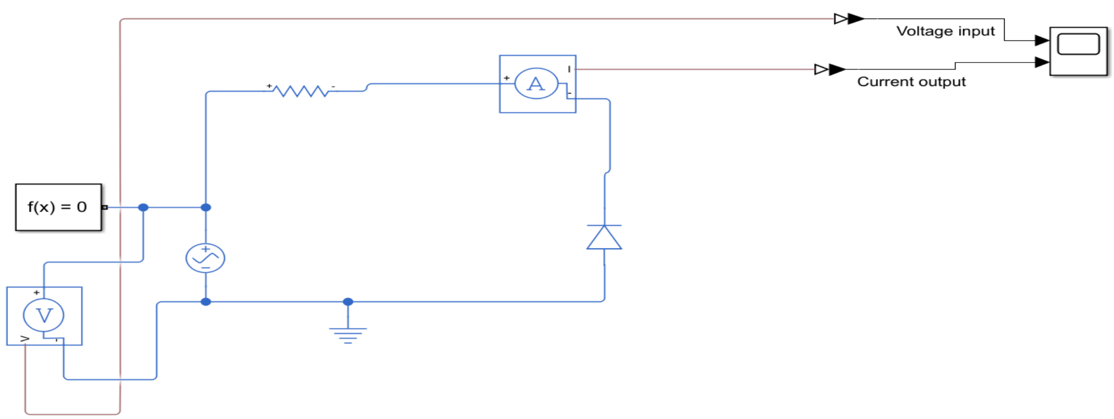
- C = capacitance at a given reverse bias voltage VR,
- Co = capacitance when VR=0 (zero bias capacitance),
- VR = reverse bias voltage applied across the diode,
- Vj = junction potential (a constant for the diode, usually in the range of 0.6–0.7 V for silicon diodes),
- n= a constant that depends on the doping profile of the varactor:
    - n=0.5 for an **abrupt junction** varactor,
    - n>0.5 (often around 0.33) for a **hyperabrupt junction** varactor.

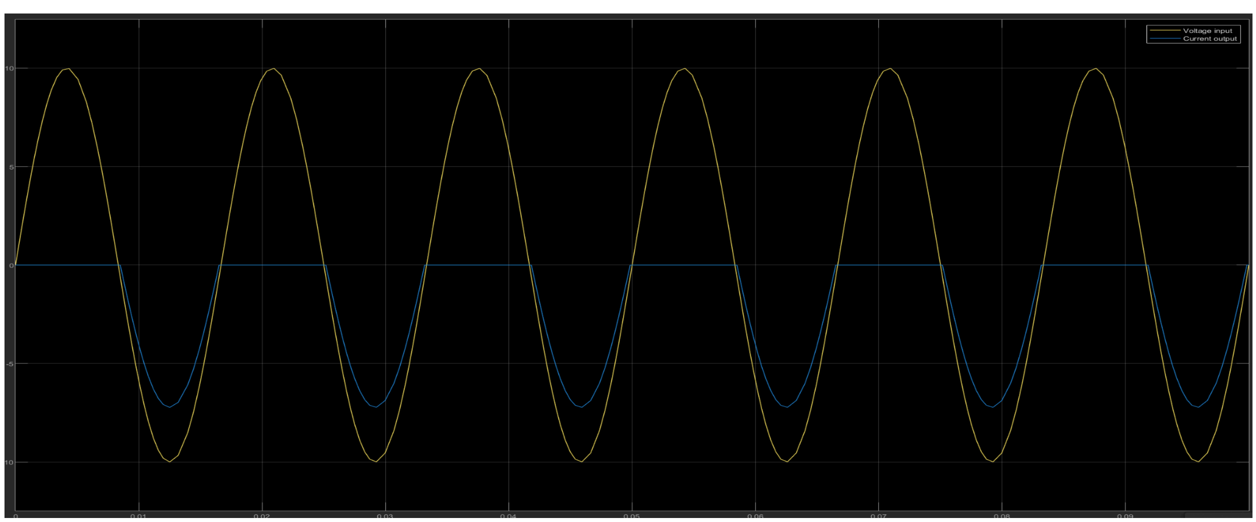
Applications

Varactor diodes are used mostly in applications which require fast frequency adjustments which require variable capacitance (no need for mechanical adjustments). These include:

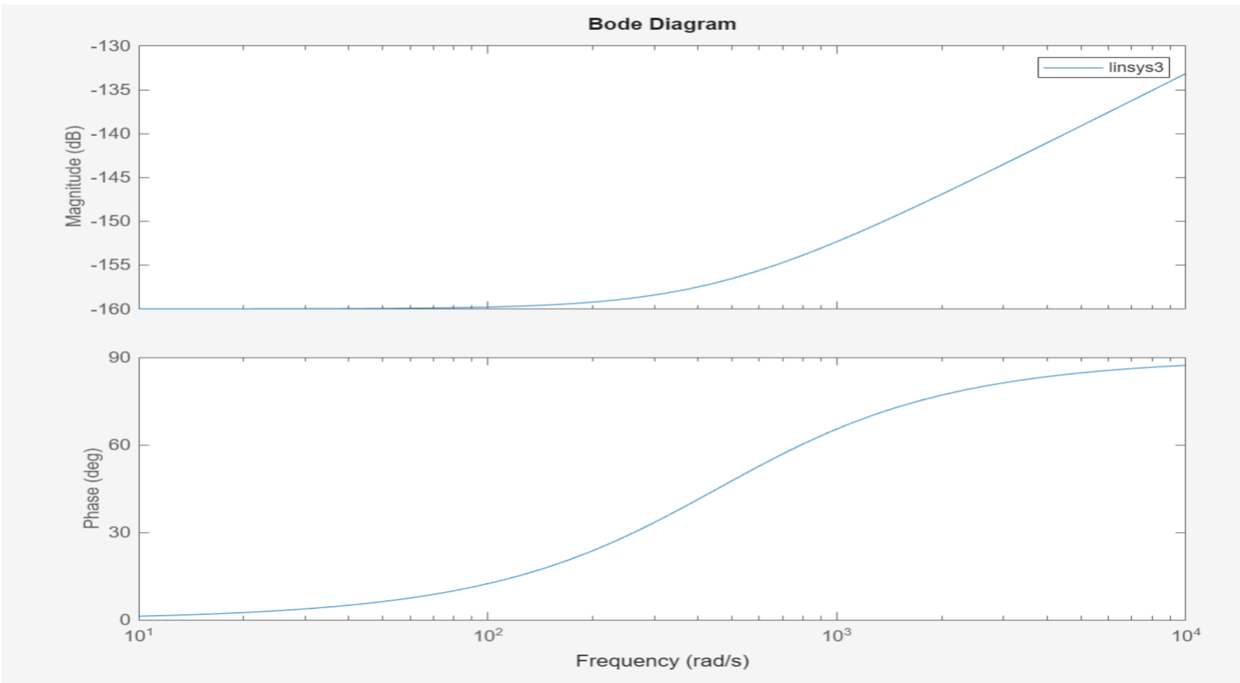
1. Tuning Circuits
2. Frequency Modulation
3. RF (Radio Frequency)
4. Optical Communication Systems

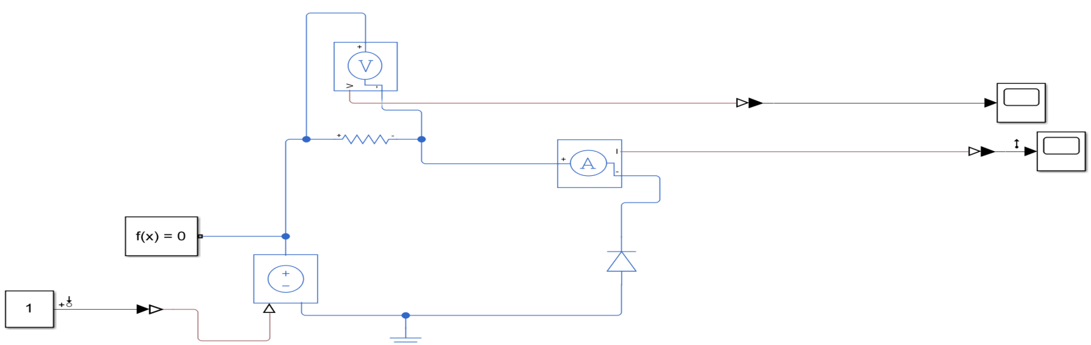
Simulation Results



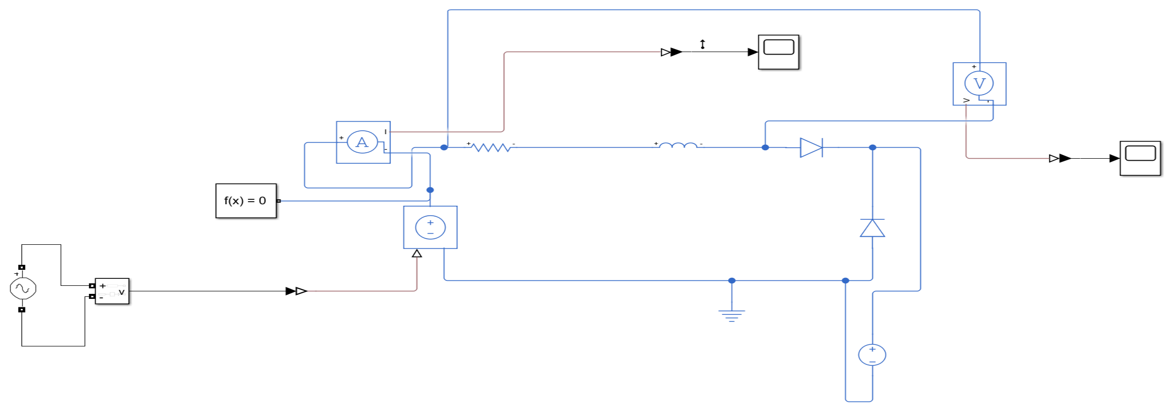


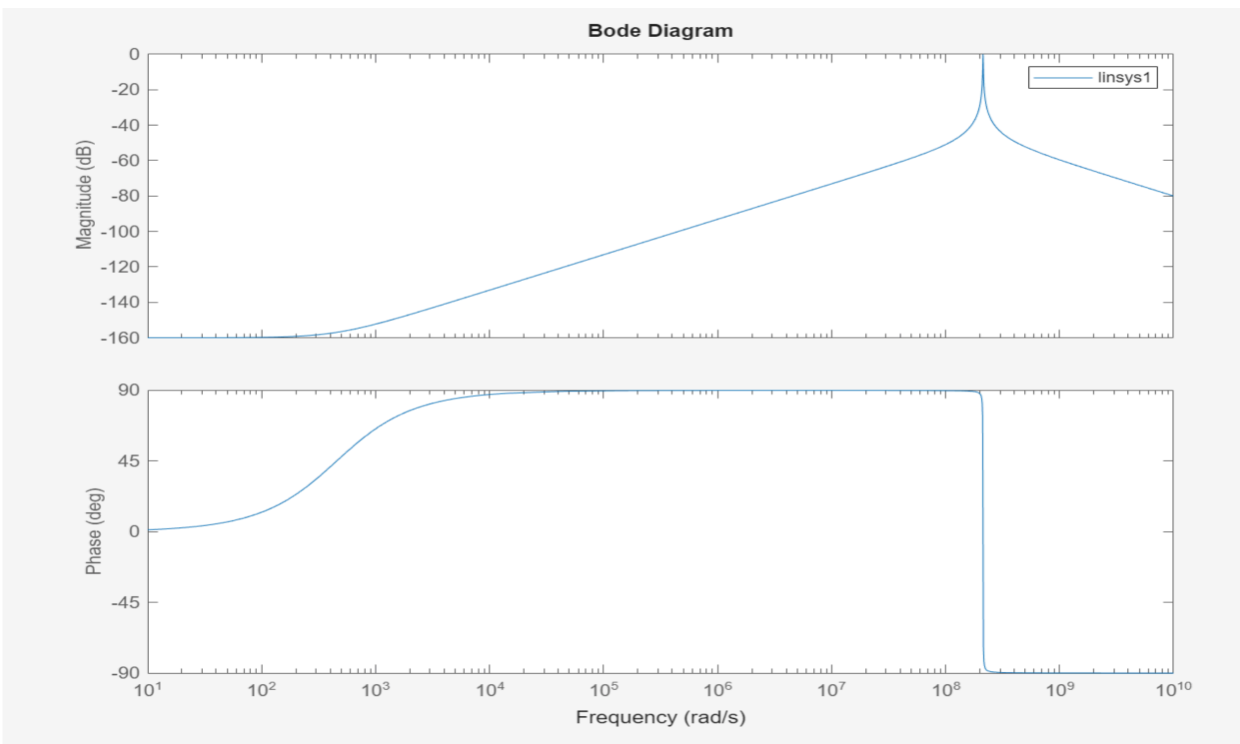
From the diagram it can be seen that with an AC voltage supply, the varactor diode still acts like a normal diode conducting current when it is in Forward Bias, and conducting a negligible amount of current in Reverse Bias.



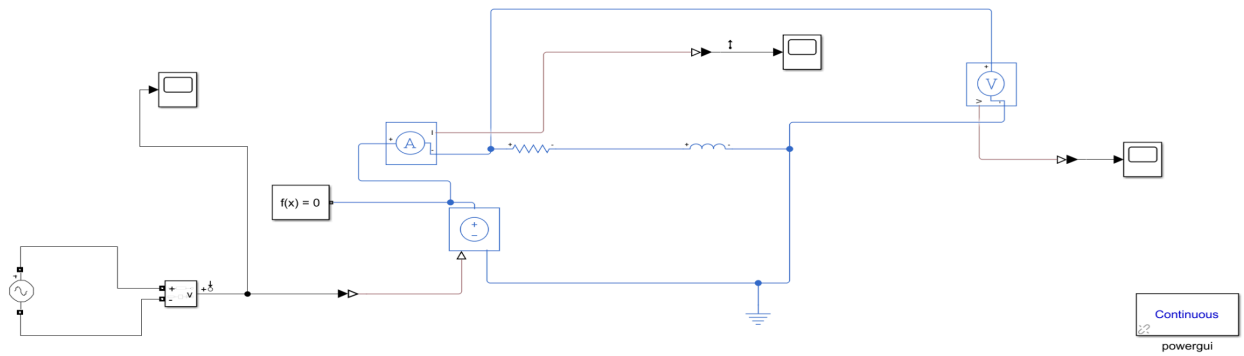


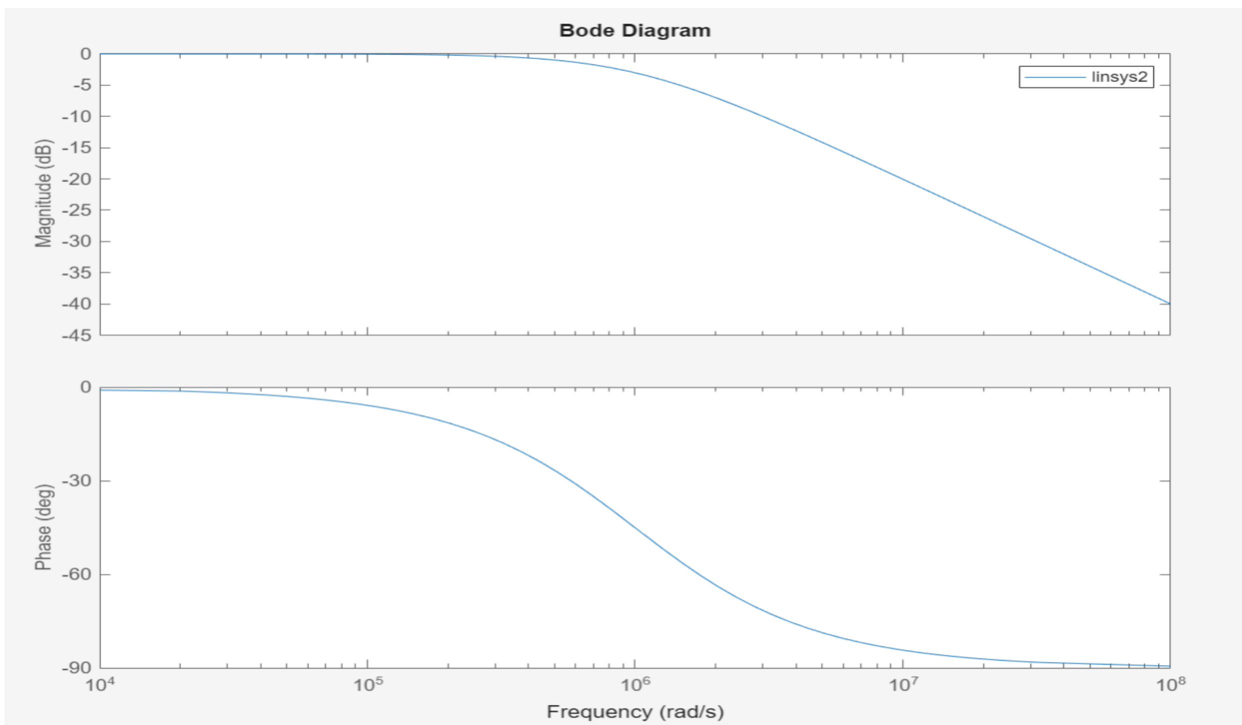
When the Varactor diode is connected as shown above (RC circuit) its capacitive nature can be seen clearly since it acts as a capacitor and thus the circuit acts as a high-pass filter.





In the RLC tuning circuit shown above , the varactors act with a capacitance and so the circuit resonates at a particular frequency as shown in the Bode diagram.





When the varactor diodes are disconnected in addition to their biasing voltage source, the circuit act as an RL circuit, and hence, a low-pass filter.

REFERENCES

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2. Varactor Diode - Definition, Characteristics, Working and Construction
3. What is a Varactor Diode? Defintion, Construction, Working, Characteristics and Applications of Varactor Diode - Electronics Desk