Computational Microelectronics
Lecture 26 Small-Signal Analysis

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Voltage Excitation at 0 Hz

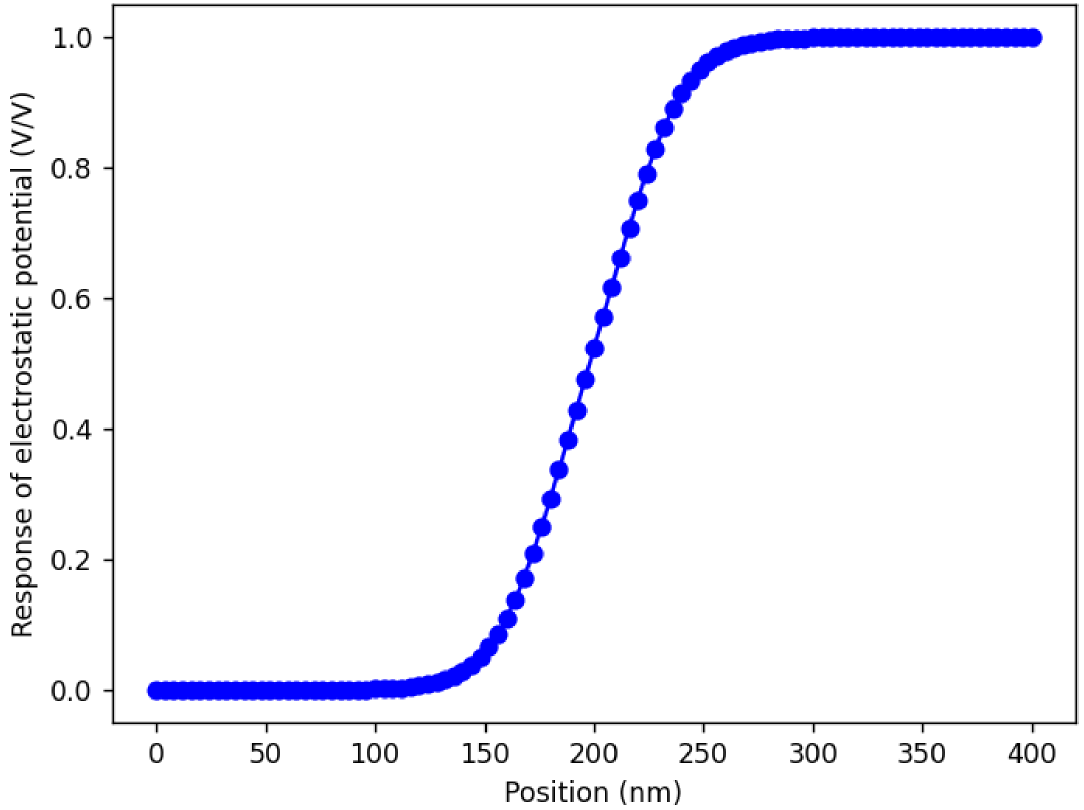
Calculate $\frac{dI_{anode}}{dV_{anode}}$.

- First, prepare the DC solution.
  - Since it is the solution (or very close to the solution), the residue vector is a null vector (or very close to a null vector).
$$A\delta \approx 0$$
  - Then, re-use the Jacobian matrix, A.
  - The boundry condition for the anode potential is given as
$$\phi_{anode} - \phi_{anode,0} - V_{anode} = 0$$
  - Now, the response, $\delta\phi_{anode}$, must satisfy
$$\delta\phi_{anode} = 1$$
  - Therefore, the RHS vector is modified to include 1 for the adode potential.

1 means the unit perturbation.

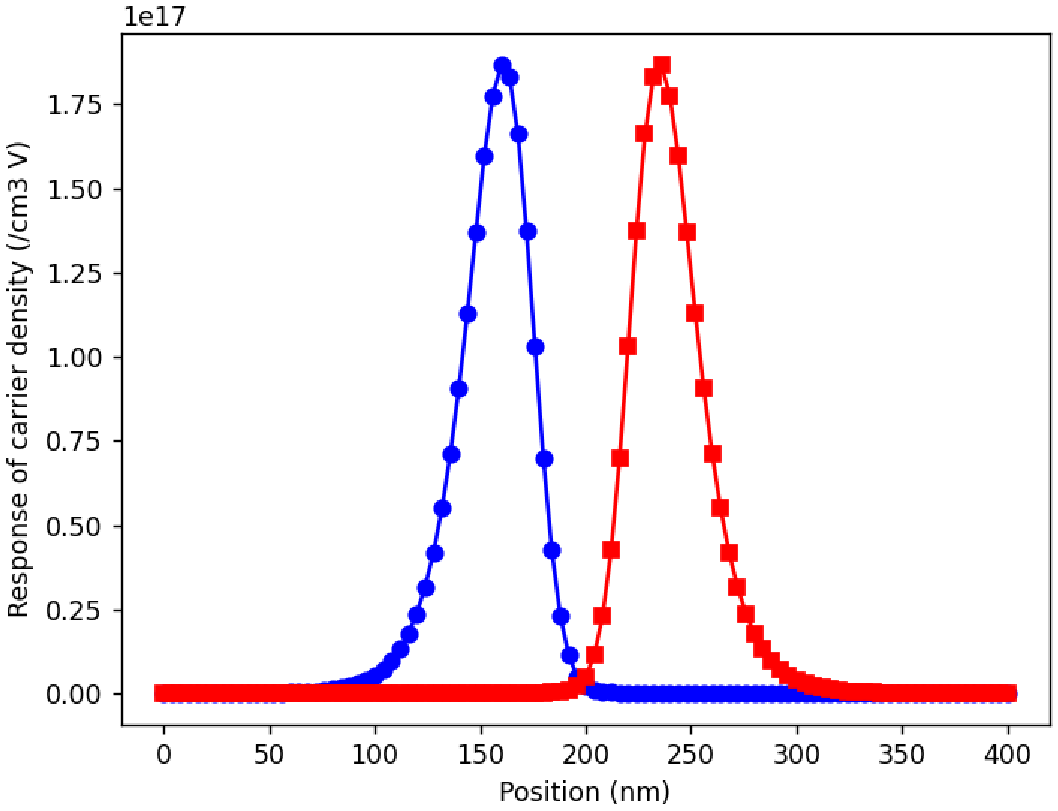
An example for PN junction

- Once again, consider a PN junction at 0.5 V.
  - The response of electrostatic potential is drawn. (line)
  - Difference between 0.5 V and 0.501 V (X 1,000) are drawn, too. (symbol)
  - They agree well.



Responses of carrier densities

- At the same bias, δn and δp are drawn.
  - The depletion region gets narrower.
  - Symbols are obtained from the finite difference.



Response of terminal current

- In a similar way, we can calculate the terminal current.
  - It is 54.708 nA/V.
  - From the difference between 0.5 V and 0.501 V, we obtain 55.766 nA/V, which is quite close.
  - From the difference between 0.5 V and 0.500001 V, we obtain 54.774 nA/V, which is even closer to the small-signal value.

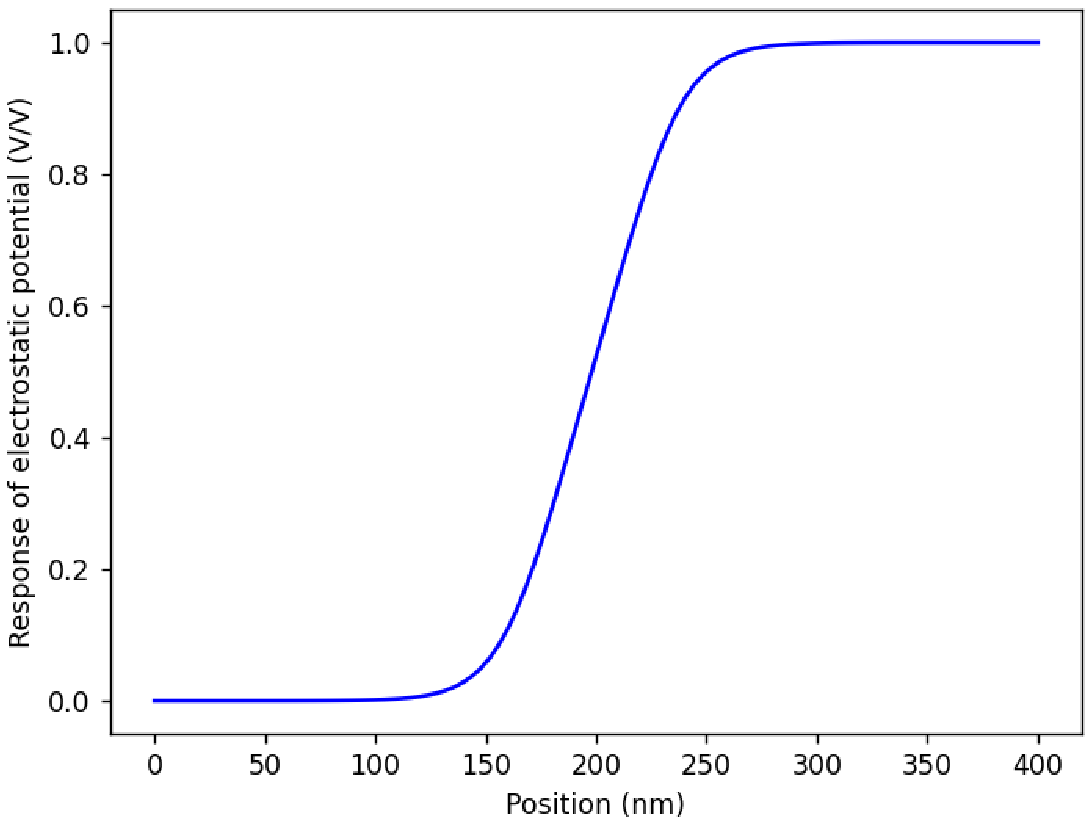
Voltage Excitation at Nonzero Frequency

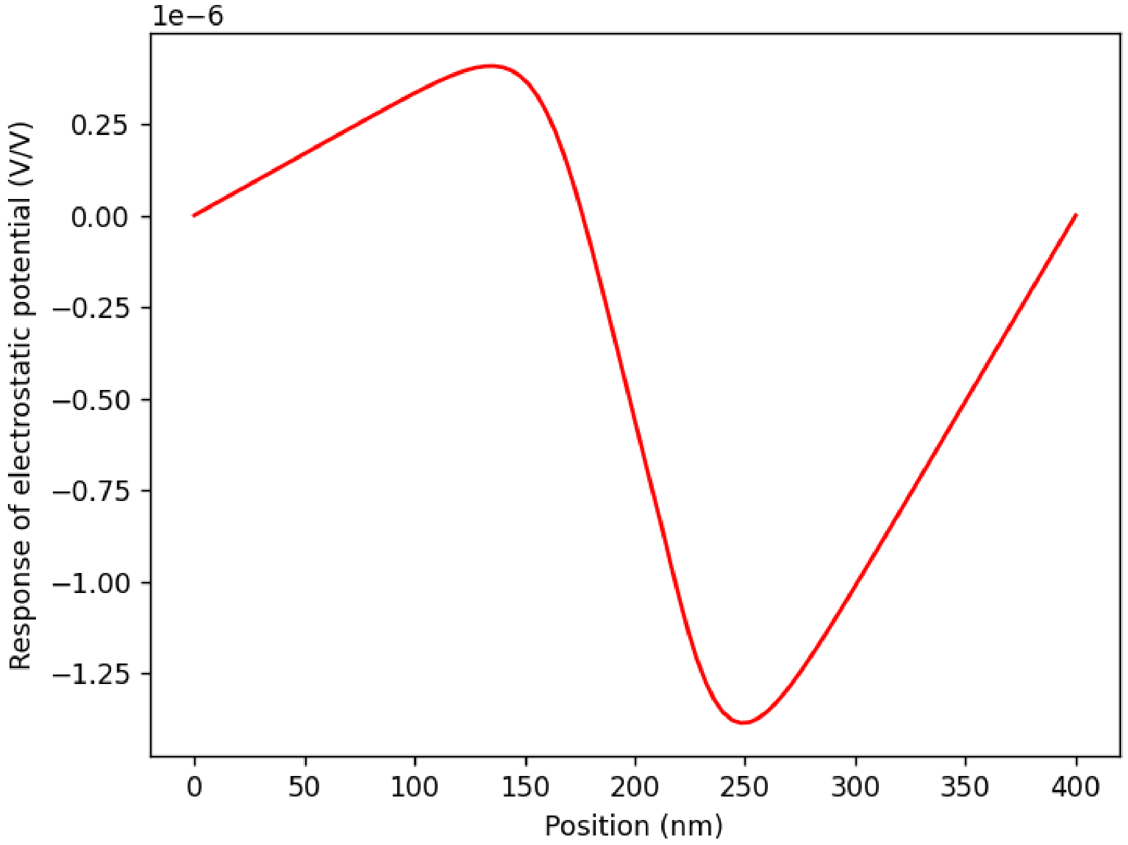
Modification from 0 Hz

- Frequency-dependent terms should be added.
  - It is noted that $\frac{\partial \delta n}{\partial t}$ contributes $(j2\pi f)\delta n$.
- Displacement current
  - Just like the transient simulation, we must include the displacement current.

Relatively low frequency, 1 MHz

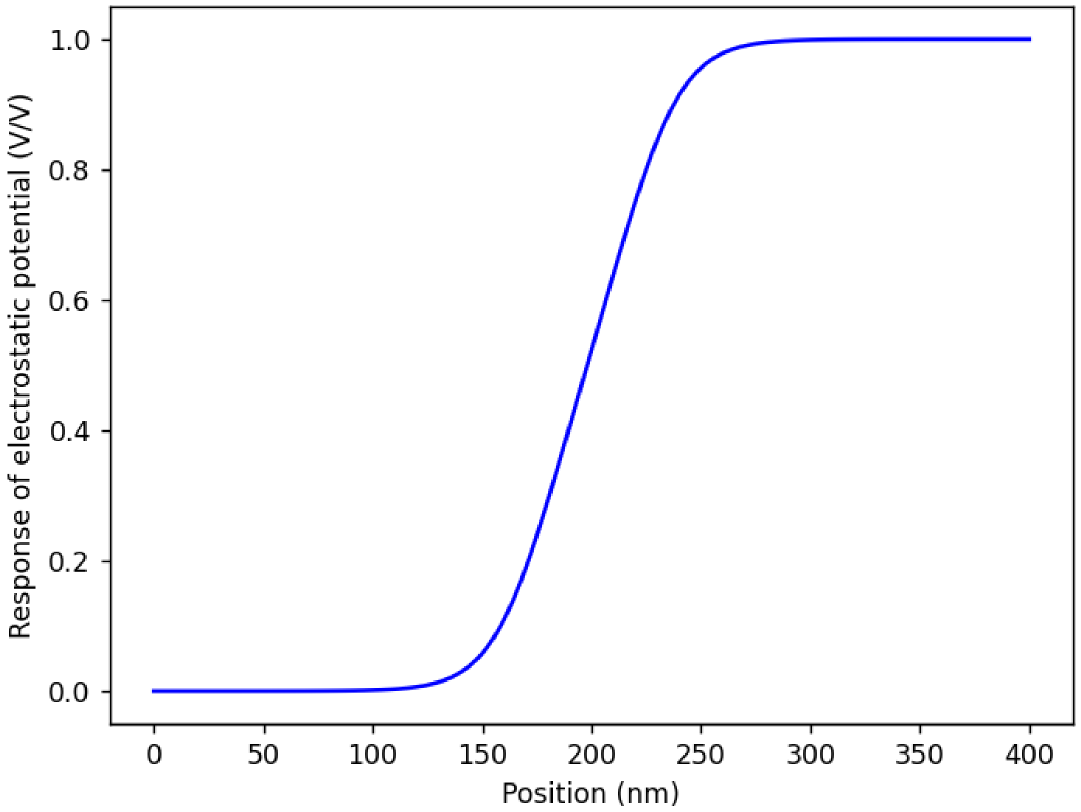
- Real (blue) and imaginary (red) parts of $\delta\phi$
  - We have a non-vanishing imaginary part.

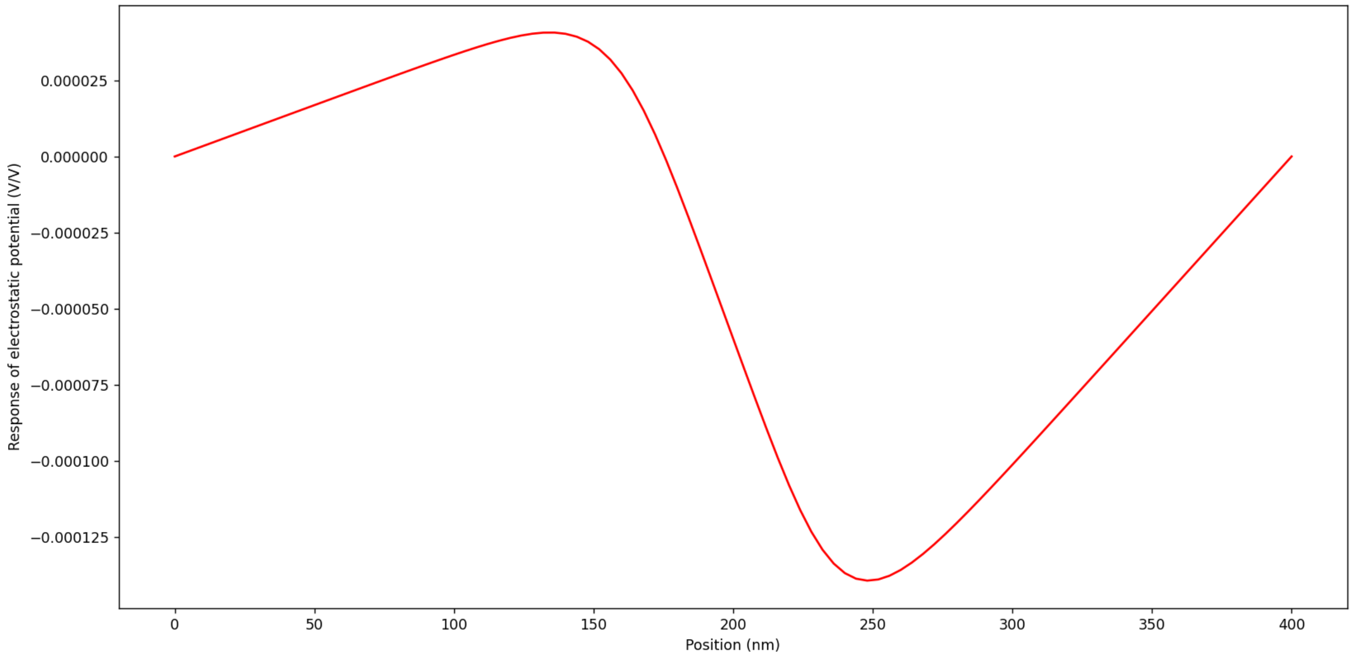




Relatively high frequency, 100 MHz

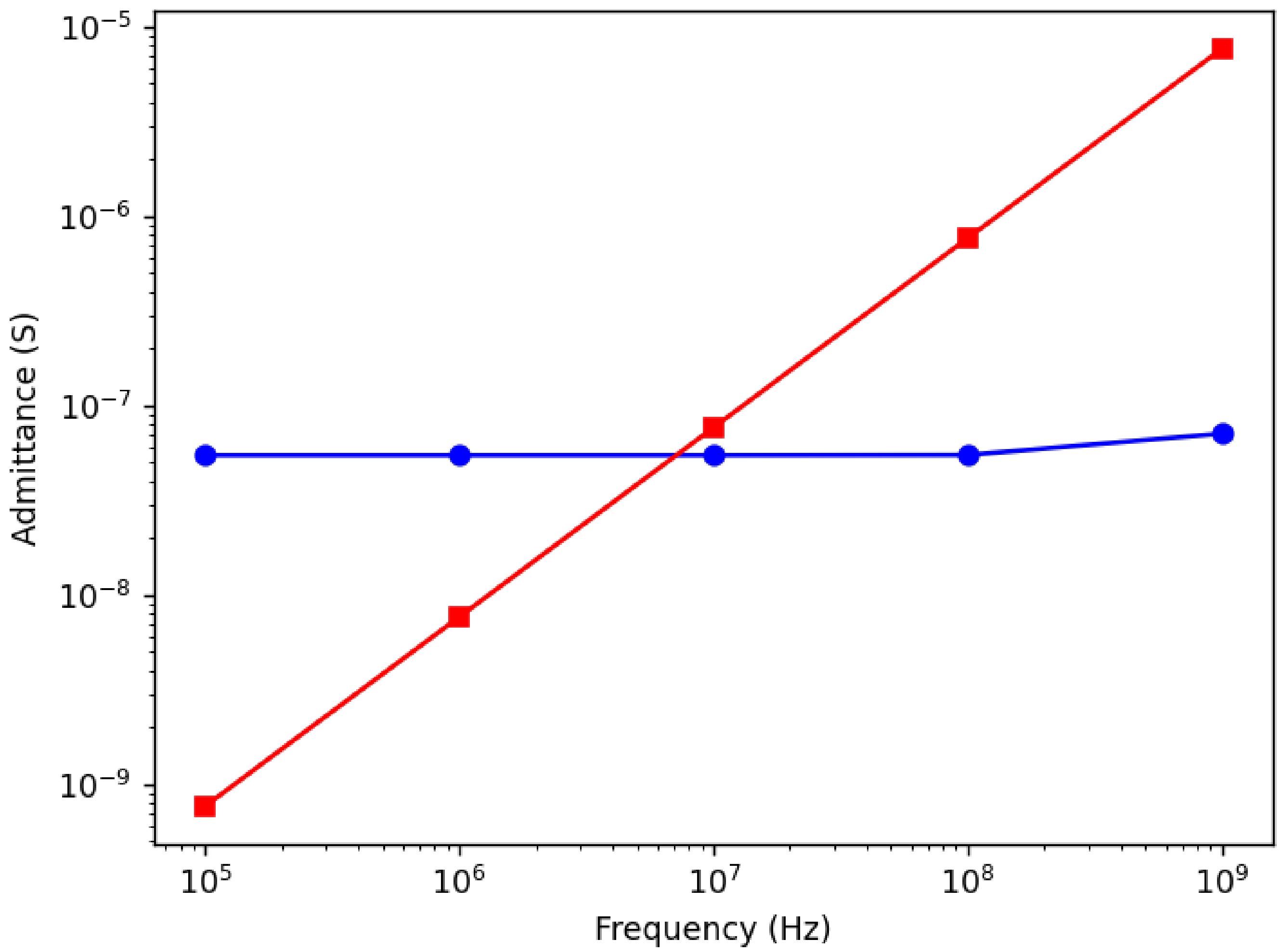
- Real (blue) and imaginary (red) parts of $\delta\phi$
  - Its real part looks similar, but the imaginary one is much larger (x100).





Admittance as a function of frequency

- 100 kHz, 1 MHz, 10 MHz, 100 MHz, and 1 GHz
  - Real (blue)
  - Imaginary (red)
- R and C



Thank you!