Lecture12: Impedance

Sung-Min Hong (smhong@gist.ac.kr)

Semiconductor Device Simulation Lab.
School of Electrical Engineering and Coumputer Science
Gwangju Institute of Science and Technology

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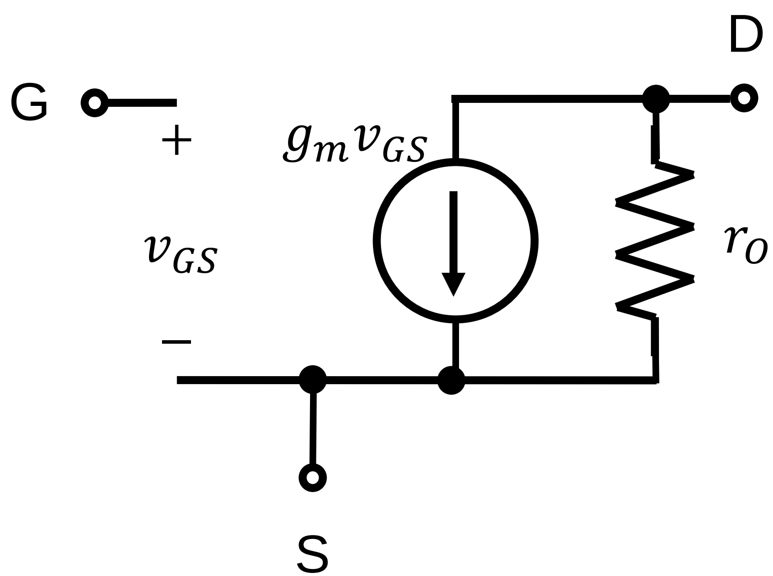
Summary

- Small-signal MOSFET model
  - Two branches are related with two partial derivatives.



Simple math

- Following relations are useful.
  - Sine and cosine functions can be expanded with $e^{+j\omega t}$ and $e^{-j\omega t}$.

$$\sin\omega t = -\frac{j}{2}e^{+j\omega t} + \frac{j}{2}e^{-j\omega t}$$

$$\cos\omega t = \frac{1}{2}e^{+j\omega t} + \frac{1}{2}e^{-j\omega t}$$

  - Therefore, for a function of $f(t) = f_s \sin\omega t + f_c \cos\omega t$, the expansion is

$$f(t) = \left(-j\frac{f_s}{2} + \frac{f_c}{2}\right)e^{+j\omega t} + \left(+j\frac{f_s}{2} + \frac{f_c}{2}\right)e^{-j\omega t}$$

  - A single complex number, $-j\frac{f_s}{2} + \frac{f_c}{2}$, is enough to represent $f(t)$.

Impedances

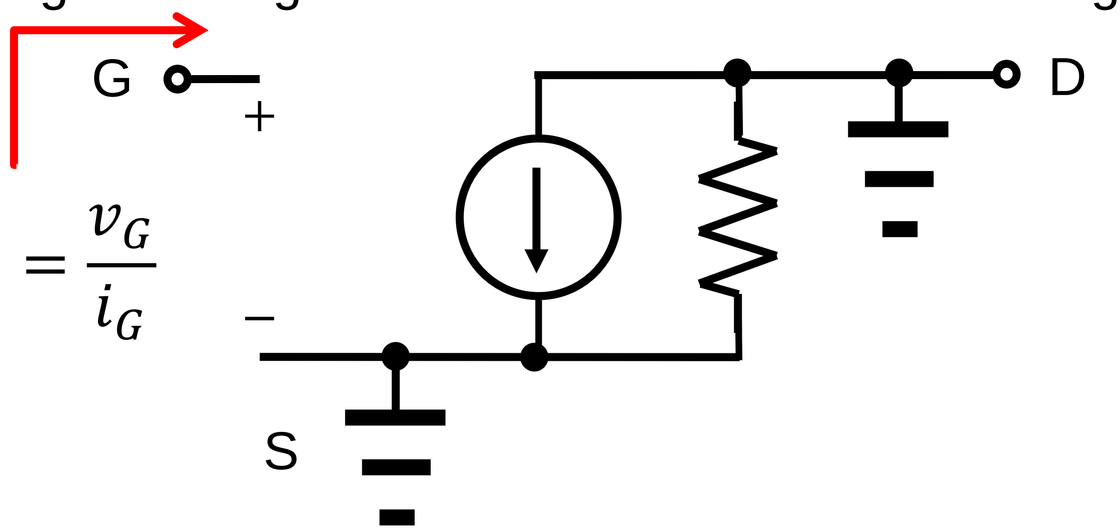
- Resistance, $V(t) = R\ I(t)$
  - It is assumed that $V(t)$ and $I(t)$ are in the same phase.
  - Consider $V(t) = V_0 \sin \omega t$ and $I(t) = I_0 \cos \omega t$. Then, what is the resistance?
  - In this case, we can introduce a phasor voltage, $V(\omega)$, and a phasor current, $I(\omega)$.
  - The relation between $V(t)$ and $V(\omega)$ is
$$V(t) = Re[V(\omega)e^{j\omega t}]$$
  - When $V(t) = V_0 \sin \omega t$, the phasor voltage is $V(\omega) = -jV_0$.
  - When $I(t) = I_0 \cos \omega t$, the phasor voltage is $I(\omega) = I_0$.
- Impedance, $V(\omega) = Z(\omega)I(\omega)$
  - In the above example, $Z(\omega) = -j\frac{V_0}{I_0}$. A purely imaginary number.

Multi-terminal devices

- When the number of terminals is 3,
  - We can defined 9 (= 3 X 3) different impedances.
- Termination condition is important.
  - Depending on the termination condition, the impedance can be heavily changed.
  - In many cases, it is obvious from the problem.

Impedances of MOSFET

- "Looking into the ***TERMINAL***," we see the impedance of the ***TERMINAL***.
  - Consider the following cases:
  - 1) Looking into the gate. The source and drain are ac-grounded.



$$Z_G = \frac{v_G}{i_G}$$

  - 2) Looking into the drain. The source and gate are ac-grounded.
  - 3) Looking into the source. The gate and drain are ac-grounded.