Lecture11: MOSFET, small-signal model

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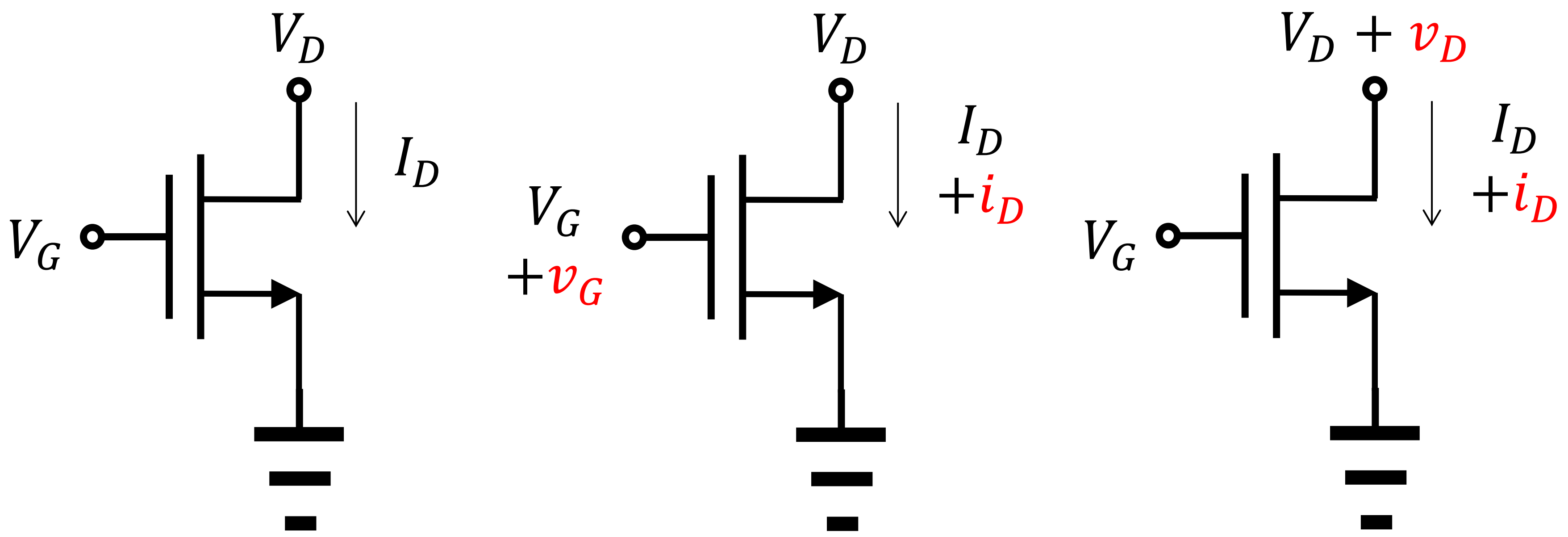
Summary

- We can define two derivatives.
  - First, $\frac{\partial I_D}{\partial V_{GS}}$. It is the transconductance, g_m.
  - Second, $\frac{\partial I_D}{\partial V_{DS}}$. It is the inverse of the output resistance, r_O.



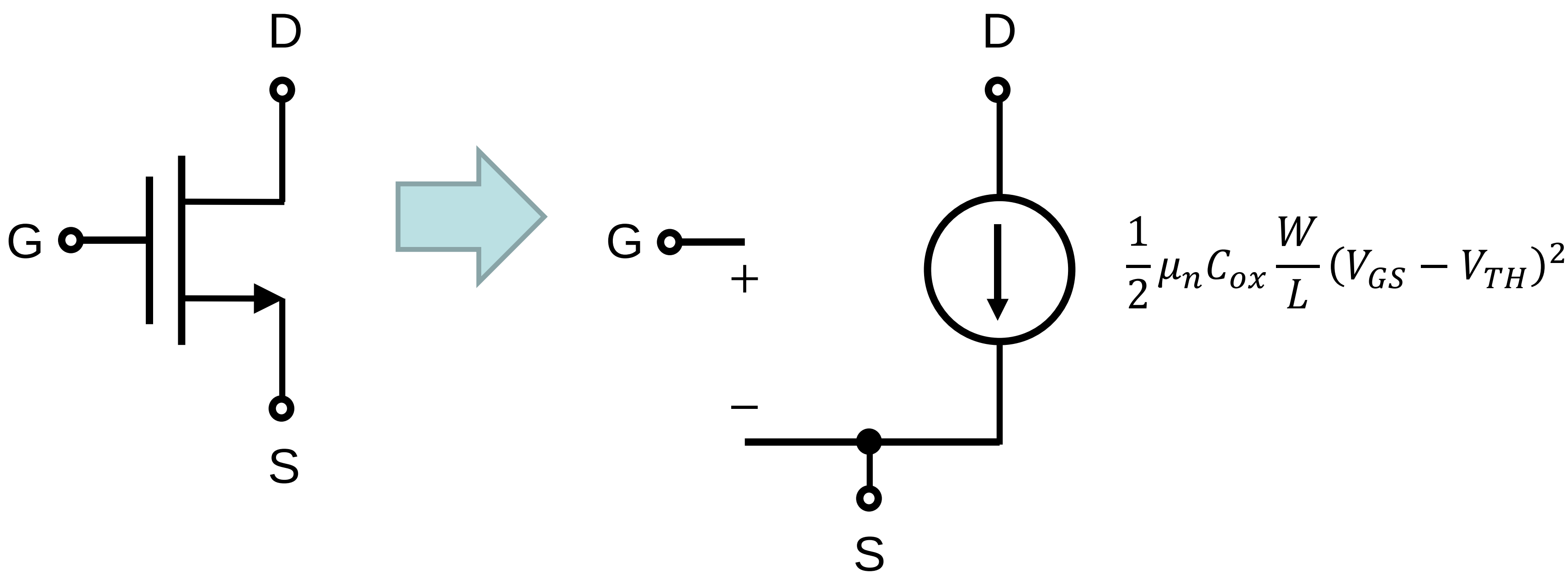
Large-signal model (1/2)

- Saturation region

$$I_D = \frac{1}{2}\mu_n C_{ox}\frac{W}{L}(V_{GS} - V_{TH})^2$$

  – Drain current is determined by gate voltage. (*voltage-controlled current source*)

  – *<u>Channel-length modulation?</u>*

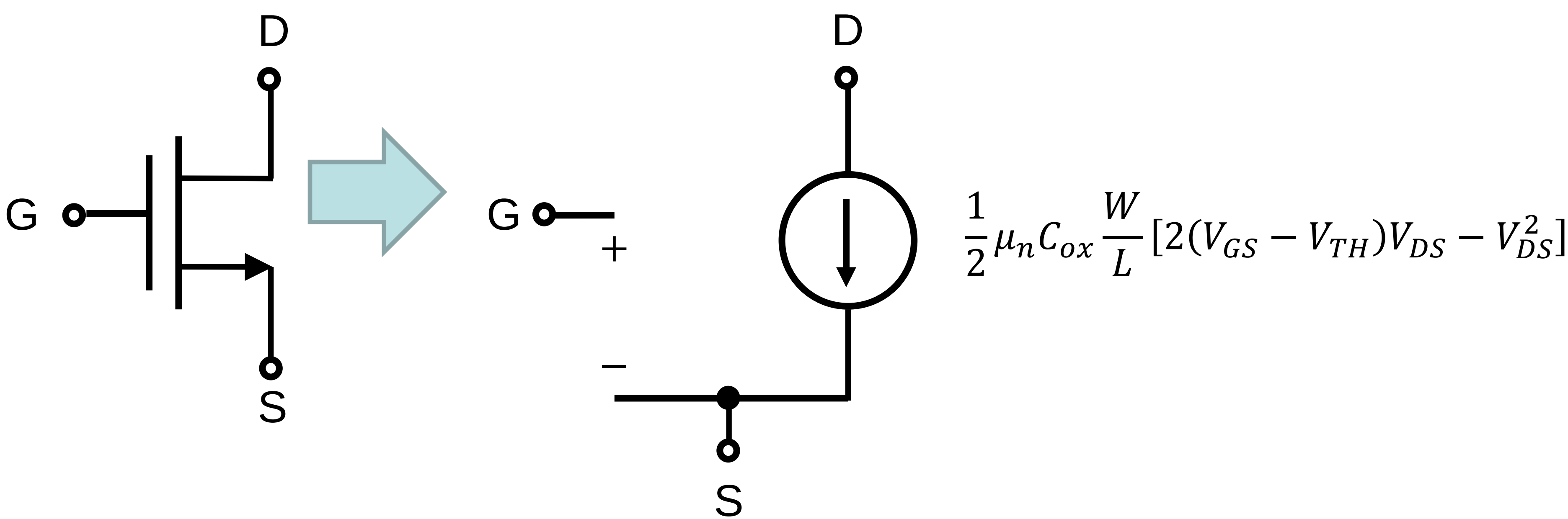


Large-signal model (2/2)

- Triode region

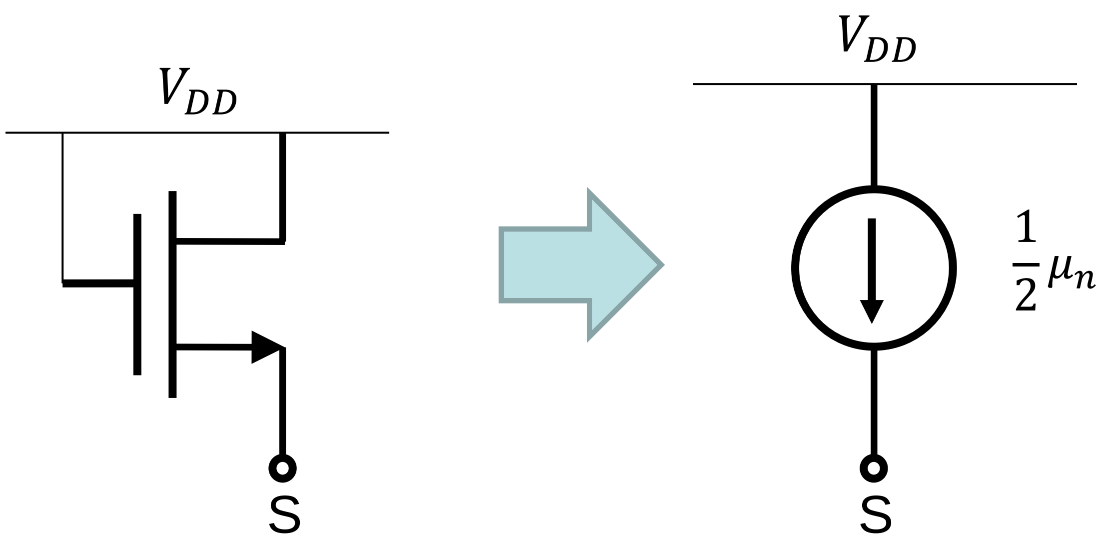
$$I_D = \frac{1}{2}\mu_n C_{ox}\frac{W}{L}[2(V_{GS} - V_{TH})V_{DS} - V_{DS}^2]$$

  – Still, it can be described by a *voltage-controlled current source*.



Example 6.13 (Razavi)

- Always in the saturation region!
  - Any necessary condition?



$$\frac{1}{2}\mu_n C_{ox}\frac{W}{L}(V_{DD}-V_S-V_{TH})^2$$

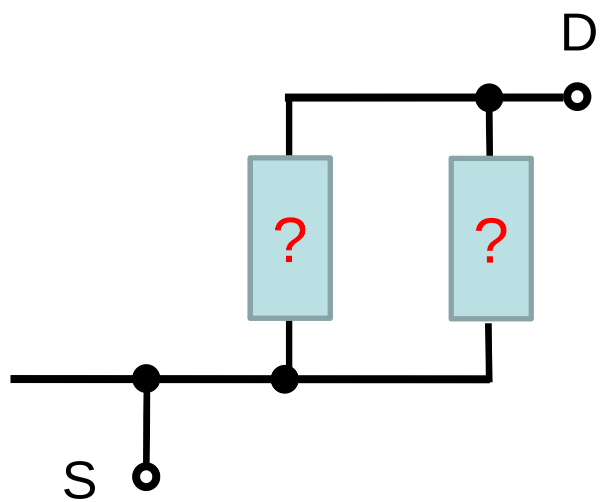
Gate and drain are tied.
They are connected to V_{DD}.

Small-signal current

- Using the transconductance (g_m) and the output resistance (r_O),
  - The small-signal drain current is given as

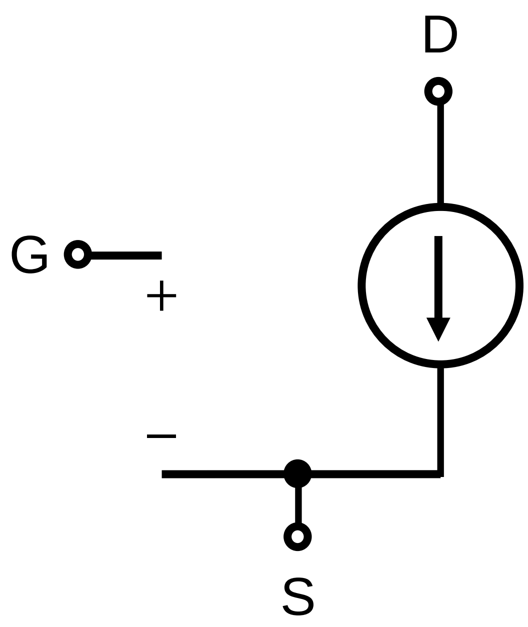
$$i_D = g_m v_G + \frac{v_D}{r_O}$$

  - When we build a small-signal model, two contributions must be separately considered.

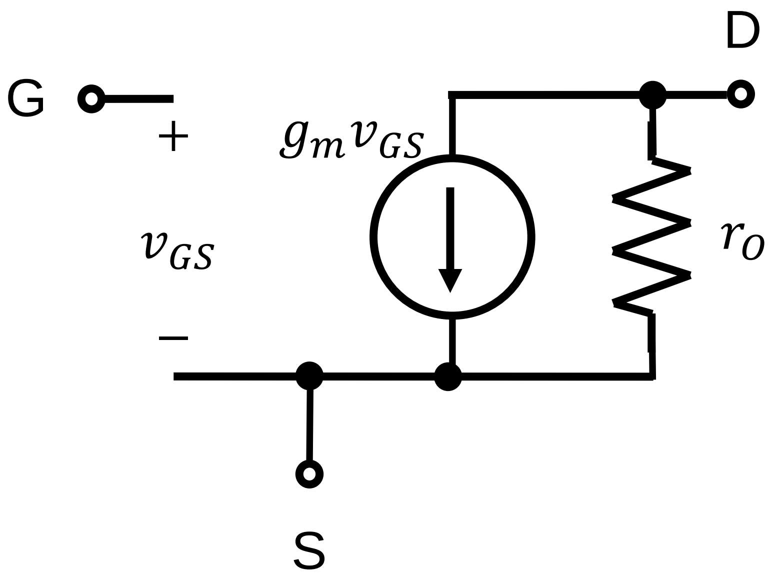


Small-signal model

- The large-signal model is complete (within its accuracy limitation).
  - But, for small-signal analysis, it is convenient to have the small-signal model.



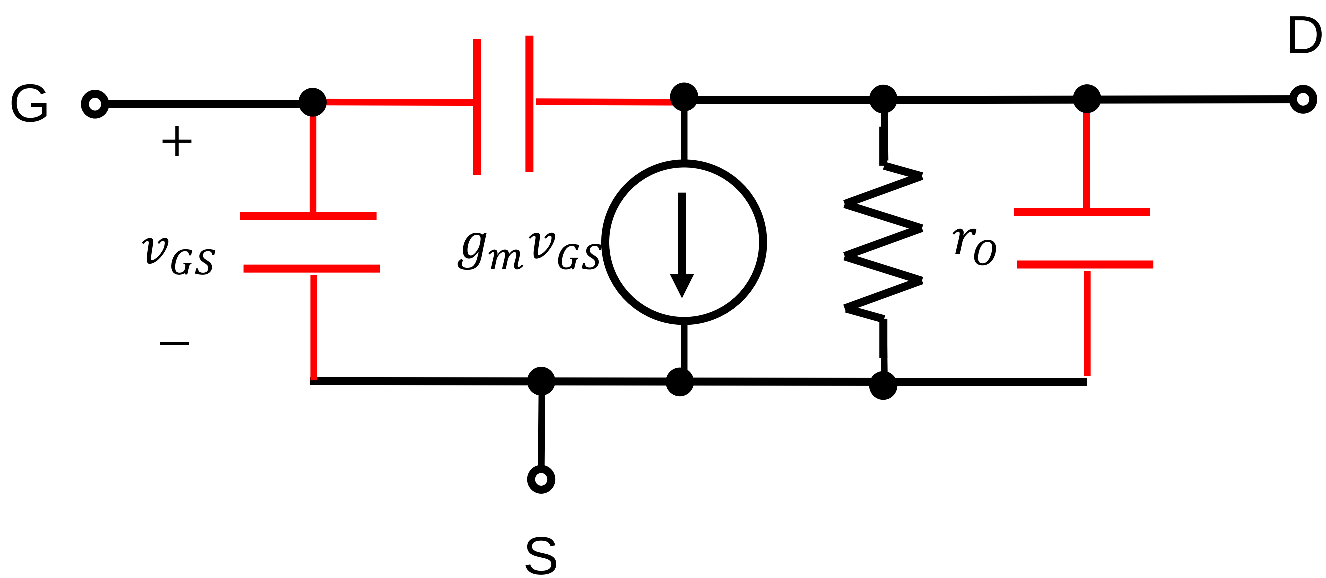
$$I_D = \frac{1}{2}\mu_n C_{ox}\frac{W}{L}(V_{GS} - V_{TH})^2(1 + \lambda V_{DS})$$



What is g_m and r_O?

Time-dependent one?

- Everything was in the dc steady-state…
  - How about the frequency-dependent case?
  - Capacitive components can be seen.
  - *Their physical origin?*



High-frequency, equivalent-circuit model for the case in which the source is connected to the substrate

At low frequencies

- Capacitor current is $I = C\frac{dV}{dt}$.
  - When a sinusoidal dependence, for example $\sin \omega t$, is assumed, the capacitor current is proportional to ω.
  - At low frequencies, ω can be regarded as a small number.
  - In other words, the electric conduction between two nodes becomes rather weak.
  - Therefore, we often neglect the capacitive components in the small-signal model.
  - Of course, at higher frequencies, they become very important.