Lecture11: MOSFET, small-signal model

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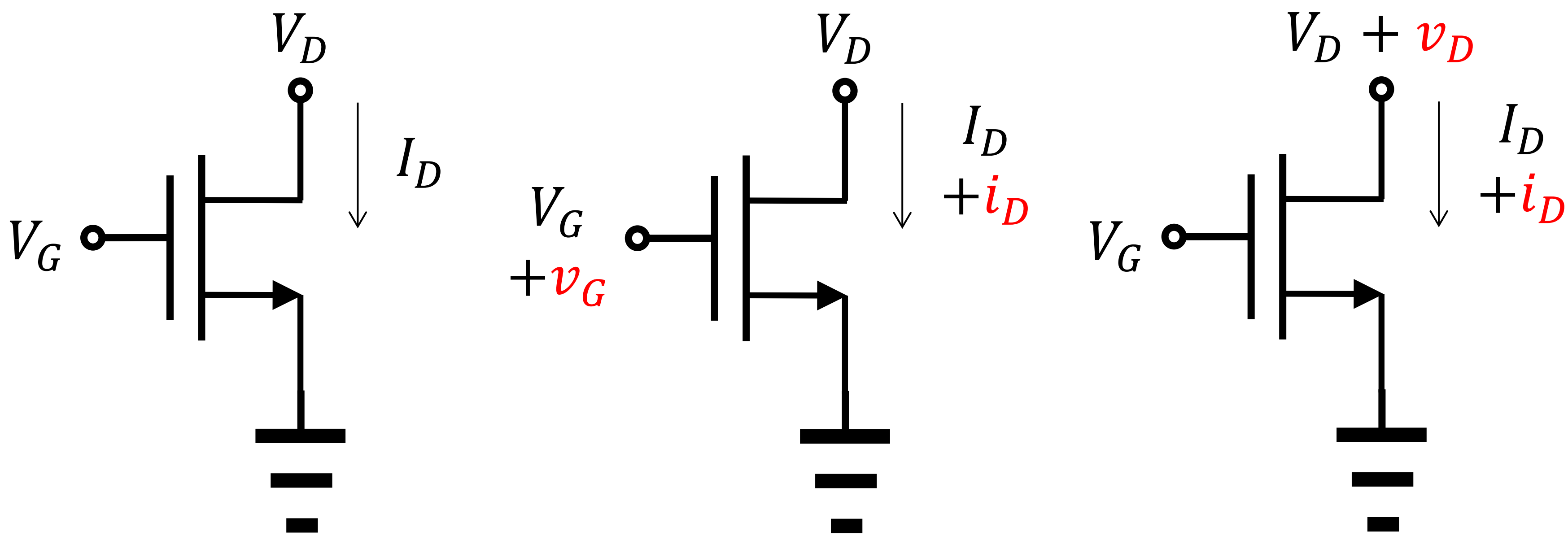
Summary

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

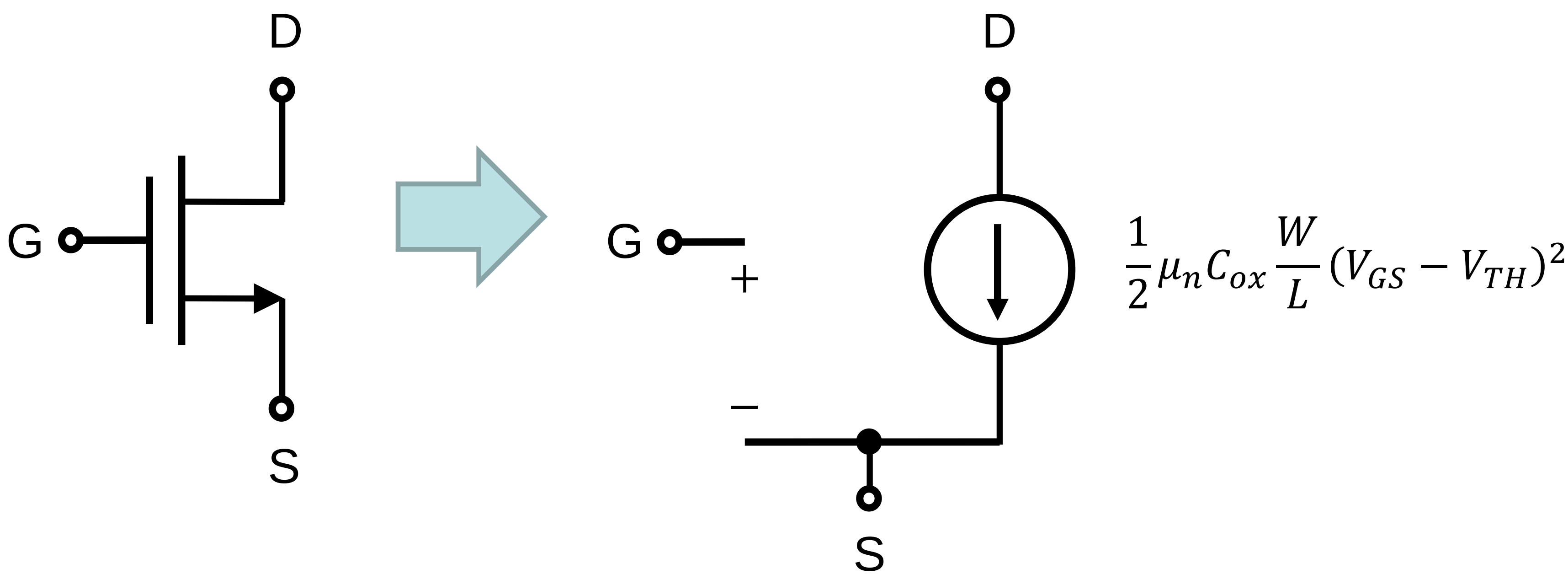


Large-signal model (1/2)

- 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*)
  - *Channel-length modulation?*

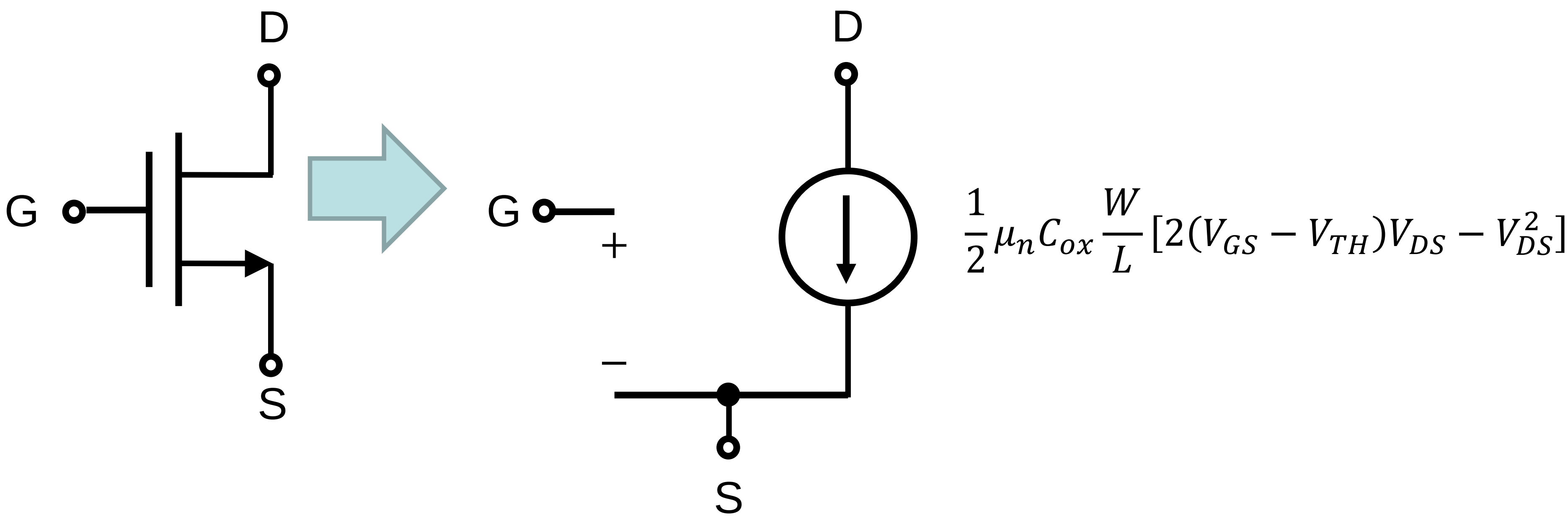


Large-signal model (2/2)

- Triode region

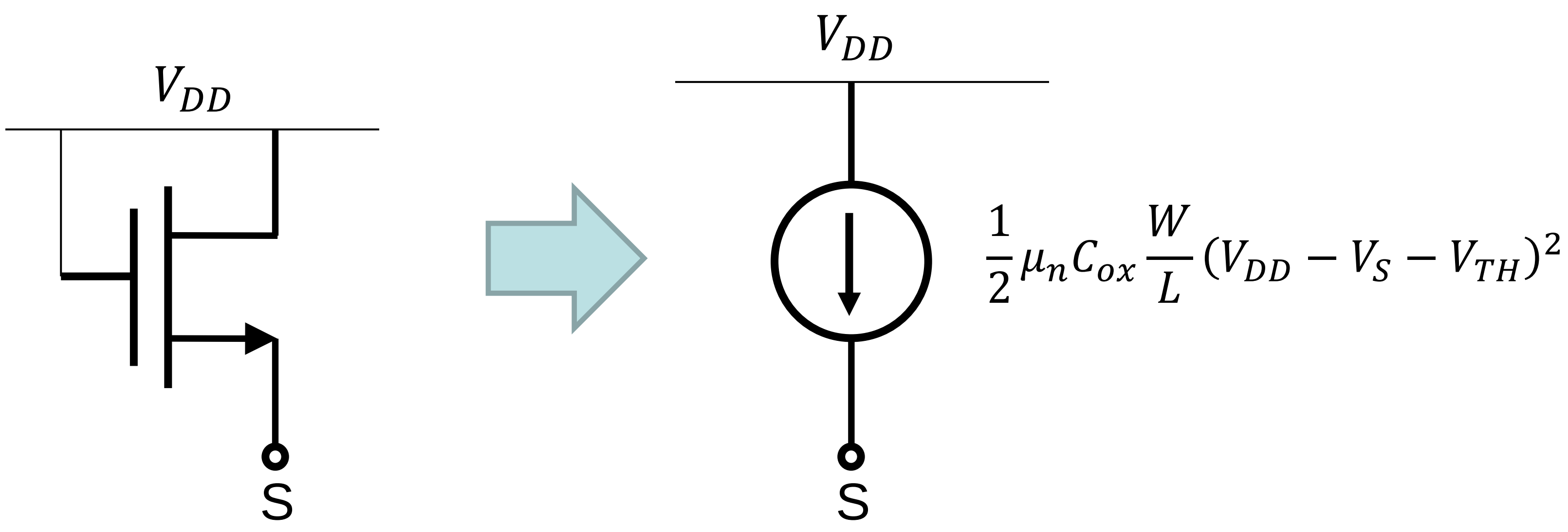
$$I_D = \frac{1}{2}\mu_n C_{ox}\frac{W}{L}[2(V_{GS} - V_{TH})V_{DS} - V_{DS}^2]$$

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



Example 6.13 (Razavi)

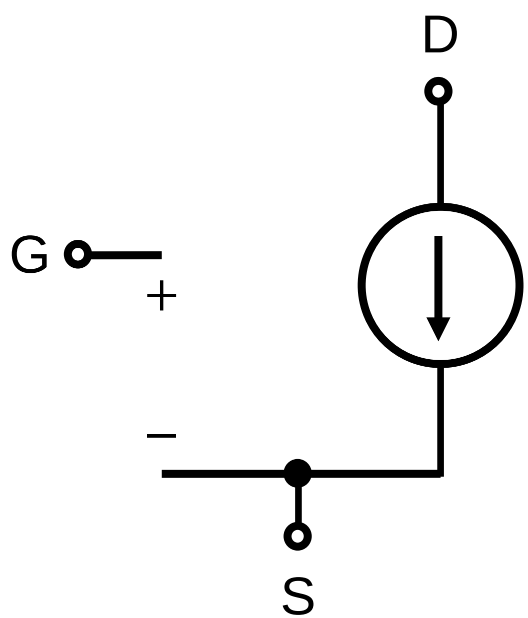
- Always in the saturation region!
  - Any necessary condition?



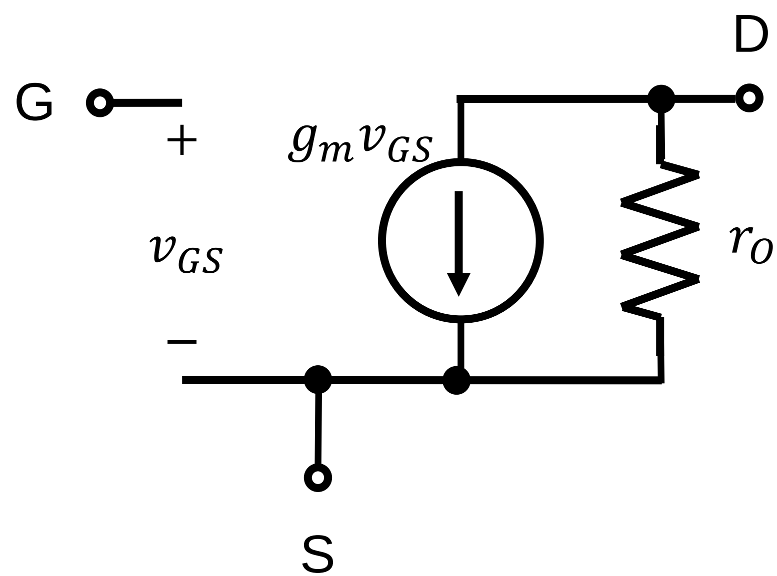
Gate and drain are tied.
They are connected to V_{DD}.

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.



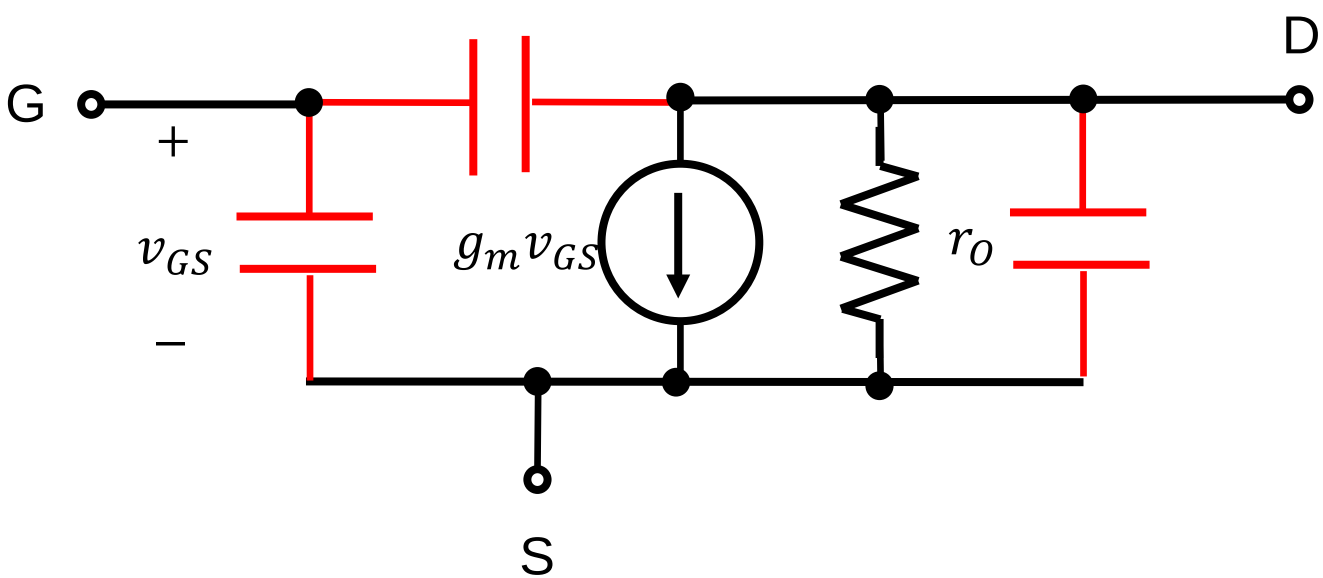
$$I_D = \frac{1}{2}\mu_n C_{ox}\frac{W}{L}(V_{GS} - V_{TH})^2(1 + \lambda V_{DS})$$



What is g_m and r_O?

Time-dependent one?

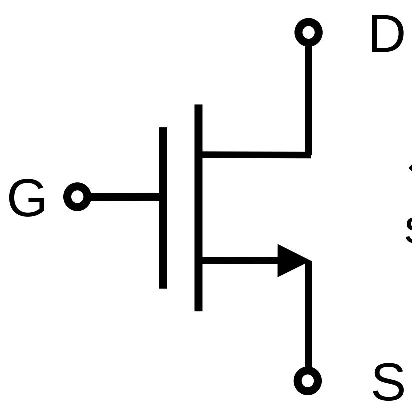
- Everything was in the dc steady-state…
  - How about the frequency-dependent case?
  - Capacitive components can be seen.
  - *Their physical origin?*



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

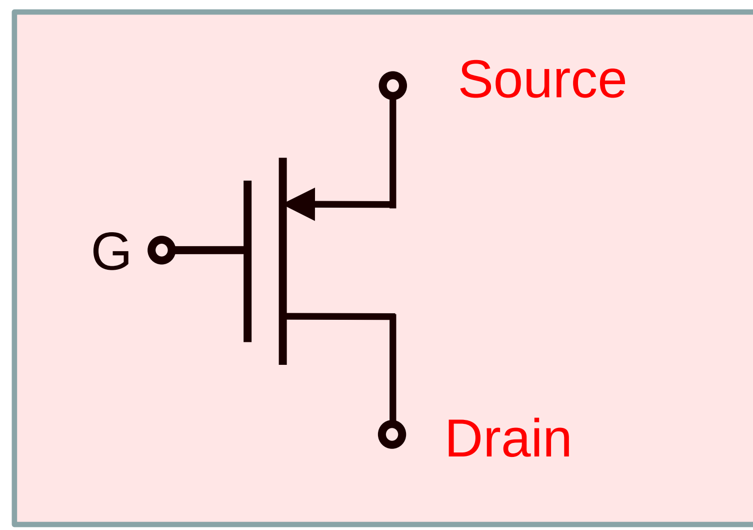
CMOS

- 9’s complementary of 123?
  - 876
- Complementary MOS
  - Here we have an NMOSFET.
  - A device where the transport is dominated by holes



← NMOSFET symbol

PMOSFET symbol →



- Why is it important?

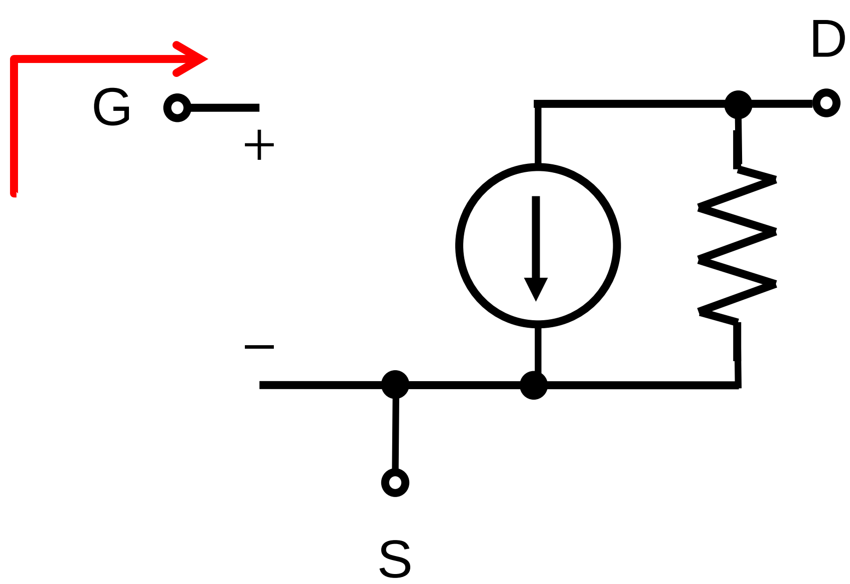
Why amplifiers?

- Signal amplification
  - Usually, signals are “weak.” (in the $\mu\mathrm{V}$ or mV range)
  - It is too small for reliable processing.
  - If the signal magnitude is made larger, processing is much easier.

- Desirable properties
  - Low power consumption
  - High speed operation
  - Low noise

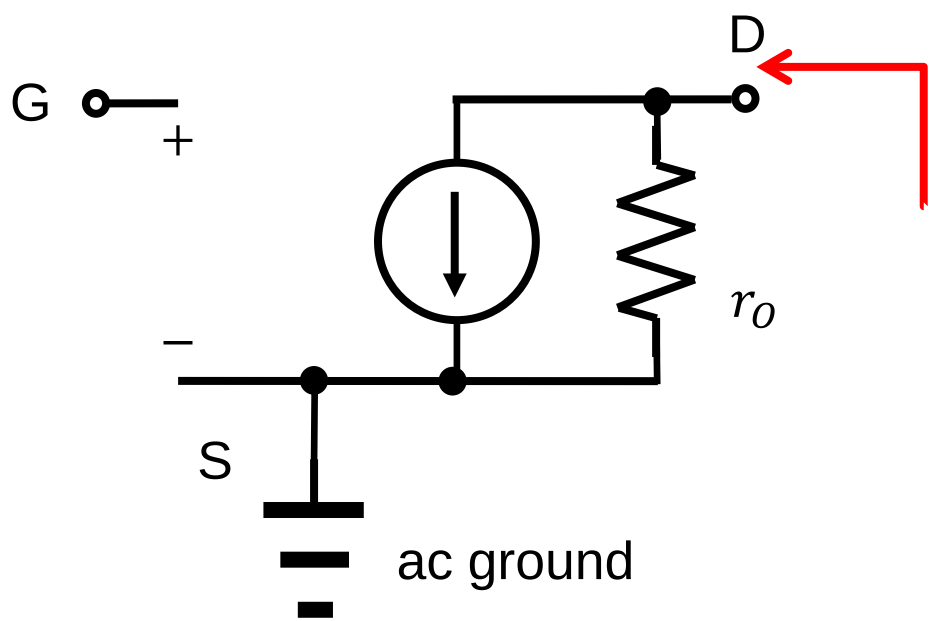
Impedances (1/3)

- A MOSFET with three terminals
  - Looking into the gate, we see the infinite impedance.
  - (Strictly valid at the low-frequency range)



Impedances (2/3)

- A MOSFET with three terminals
  - Looking into the drain, we see r_o if the source is ac grounded.



Impedances (3/3)

- A MOSFET with three terminals
  - Looking into the source, we see $1/g_m$ if the gate is ac grounded and channel-length modulation is neglected.