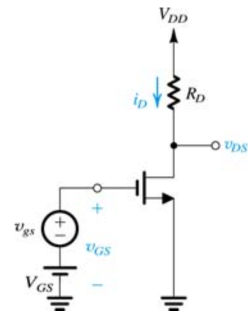
Small Signal Operations

- The signal v_{gs} is superimposed on V_{GS}
- $v_{GS} = V_{GS} + v_{gs}$
- $I_D = \frac{1}{2} k_n V^2{}_{OV}$
- $i_D = \frac{1}{2} k_n (V_{OV} + v_{gs})^2$



$$i_D = \frac{1}{2} k_n V_{OV}^2 + k_n V_{OV} v_{gs} + \frac{1}{2} k_n v_{gs}^2$$

Small Signal Operation

- To minimize the nonlinear part

$$\frac{1}{2} k_n v_{gs}^2 << k_n V_{OV} v_{gs}$$
$$v_{gs} << 2V_{OV}$$

- $i_D \approx I_D + i_d$

$$v_{DS} = V_{DD} - i_D R_D$$
$$v_{DS} = V_{DD} - (I_D + i_D) R_D$$
$$v_{DS} = V_{DS} - i_d R_D$$

Small Signal Operation

$$i_D = \frac{1}{2} k_n V_{OV}^2 + k_n V_{OV} v_{gs} + \frac{1}{2} k_n v_{gs}^2$$

Assuming small

$$i_d = k_n V_{OV} v_{gs}$$

$$g_m = \frac{i_d}{v_{gs}} = k_n V_{OV}$$

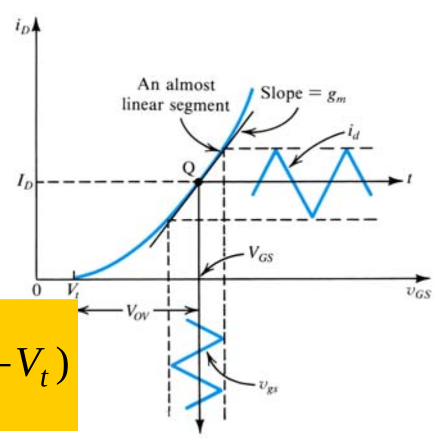
$$g_m = \left. \frac{\partial i_D}{\partial v_{GS}} \right|_{v_{GS} = V_{GS}}$$

$$A_V = -g_m R_D$$

- Transconductance: relates i_d and v_{ds}

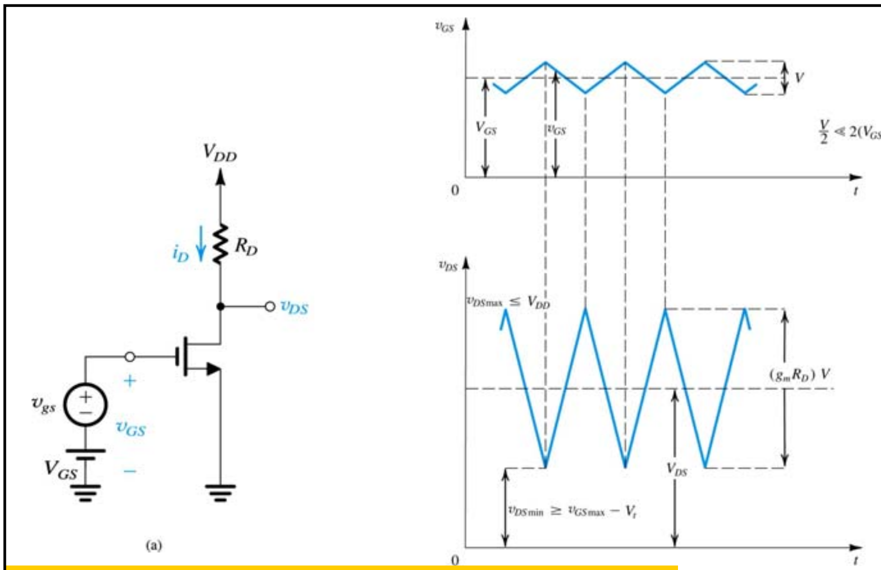
Transconductance

- The slope of the i_{DS}-v_{GS} characteristics at the Q point (DC bias point)
- As shown, almost linear.



$$g_m = \frac{i_D}{v_{GS}} = k_n' \left(\frac{W}{L} \right) (V_{GS} - V_t)$$

Microelectronic Circuits, Sixth Edition Sedra/Smith



$$v_D = V_{DD} - R_D i_D = V_{DD} - R_D (I_D + i_d)$$

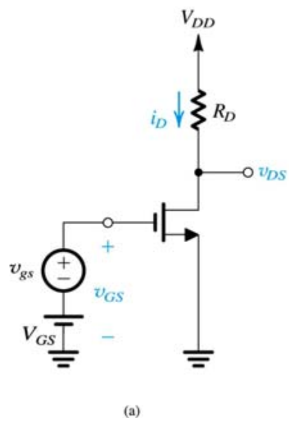
$$v_D = V_D - R_D i_D$$

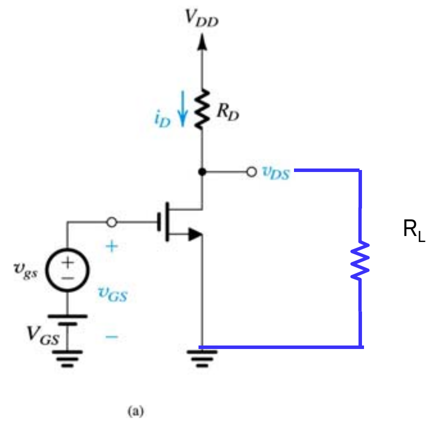
Separating DC Analysis and Signal Analysis

- Signal quantities are superimposed on DC quantities.
- We can separate DC and AC Analysis.
- The DC Analysis determine the Q Point
- (Bypass) Capacitors are added to prevent disturbing the DC bias (Q point). **WHY?**
- Draw the circuit from the signal point of view
  - DC voltages (current) are short (open)
  - Capacitors are short
  - MOSFET replaced by **small signal equivalent Circuit**

Why Capacitors

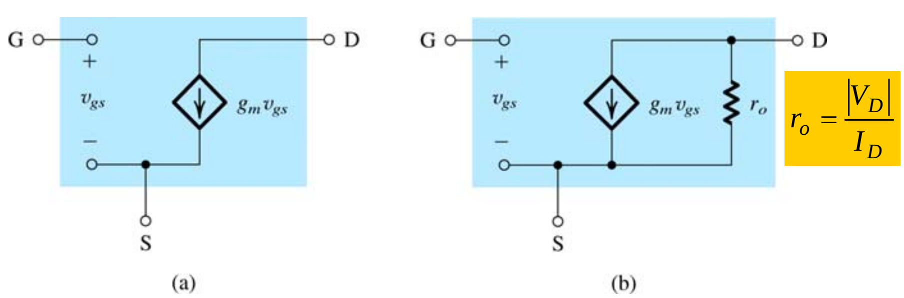
- Adding the load





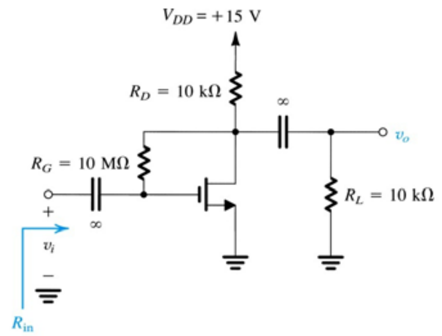
Small Signal Equivalent Circuit

- Represents only time varying component (DC only determine the bias point)
- What is the difference between (a) and (b).



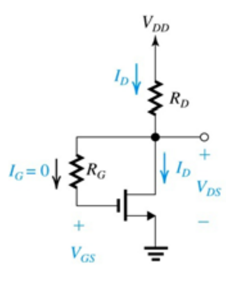
Example

- Find the small signal voltage gain, input resistance, and the largest allowable input signal. V_t=1.5V, k'_n=0.25mA/V^2, VA=50 V.



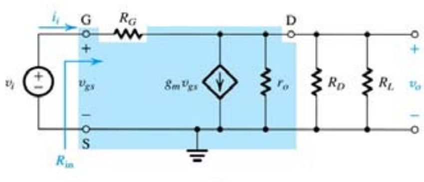
(a)

Example cont.

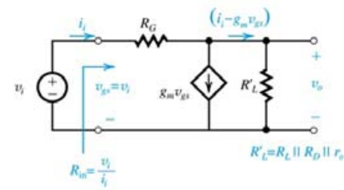


(b)

Example cont.

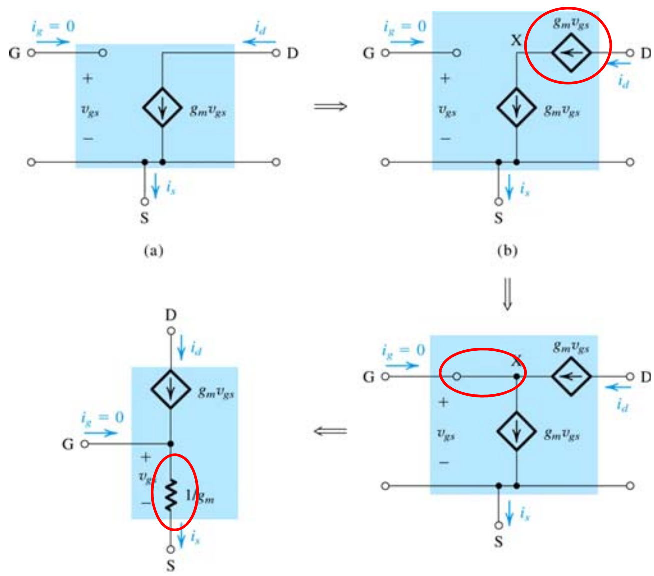


(c)

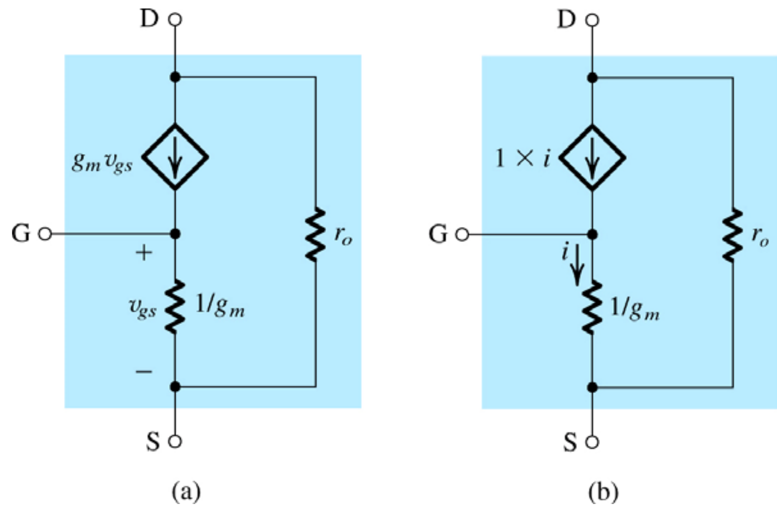


(d)

T-Equivalent-Circuit Model



Incorporating r_0



Example

- Assume saturation, find gain and input