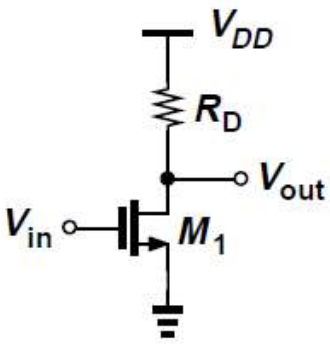
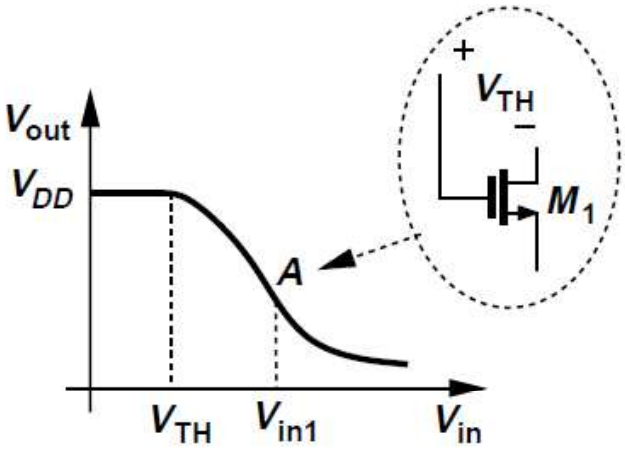
Common-Source Stage with Resistive Load





- Very high input impedance at low frequencies
- For $V_{in} < V_{TH}$, M_1 is off and $V_{out} = V_{DD}$

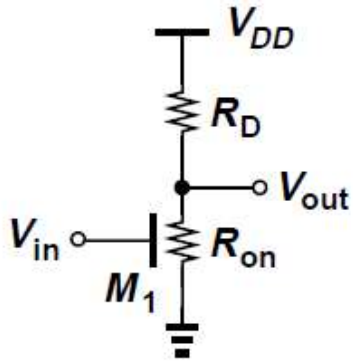
$$V_{out} = V_{DD} - R_D \frac{1}{2}\mu_n C_{ox}\frac{W}{L}(V_{in} - V_{TH})^2$$

- When $V_{in} > V_{TH}$, M_1 turns on in saturation region, V_{out} falls
- When $V_{in} > V_{in1}$, M_1 enters triode r

$$V_{in1} - V_{TH} = V_{DD} - R_D \frac{1}{2}\mu_n C_{ox}\frac{W}{L}(V_{in1} - V_{TH})^2$$

- At point A, $V_{out} = V_{in1} - V_{TH}$

Common-Source stage with Resistive load



- For $V_{in} > V_{in1}$,

$$V_{out} = V_{DD} - R_D \frac{1}{2} \mu_n C_{ox} \frac{W}{L} \left[2(V_{in} - V_{TH}) V_{out} - V_{out}^2 \right]$$

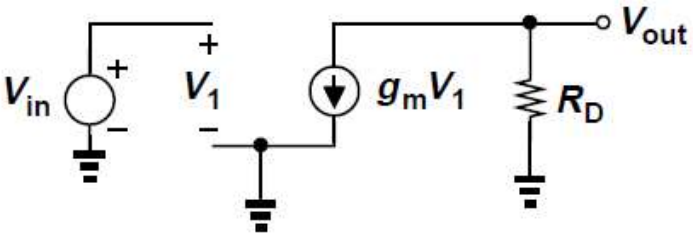
- If V_{in} is high enough to drive M_1 into deep triode region so that

$$\begin{aligned} V_{out} &= V_{DD} \frac{R_{on}}{R_{on} + R_D} \\ &= \frac{V_{DD}}{1 + \mu_n C_{ox} \frac{W}{L} R_D (V_{in} - V_{TH})} \end{aligned}$$

Common-Source Stage with Resistive Load

$$\begin{aligned} A_v &= \frac{\partial V_{out}}{\partial V_{in}} \\ &= -R_D \mu_n C_{ox} \frac{W}{L}(V_{in} - V_{TH}) \\ &= -g_m R_D. \end{aligned}$$

- Taking derivative of I_D equation in saturation region, small-signal gain is obtained



- Same result is obtained from small-signal equivalent circuit

$$V_{out} = -g_m V_1 R_D = -g_m V_{in} R_D$$

- g_m *and* A_v vary for large input signal swings according to

$$g_m = \mu_n C_{ox}(W/L)(V_{GS} - V_{TH}).$$

- This causes non-linearity

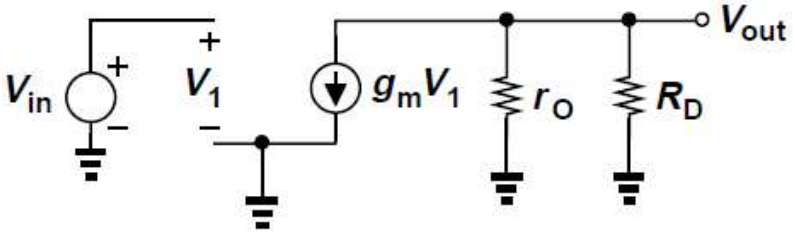
Common-Source Stage with Resistive Load

- For large values of R_D, channel-length modulation of M_1 becomes significant, V_{out} equation becomes

$$V_{out} = V_{DD} - R_D \frac{1}{2}\mu_n C_{ox}\frac{W}{L}(V_{in} - V_{TH})^2(1 + \lambda V_{out})$$

- Voltage gain is $$A_v = -g_m \frac{r_O R_D}{r_O + R_D}$$

- Above result is also obtained from small-signal equivalent circuit



$$V_1 = V_{in}$$

$$g_m V_1 (r_O \| R_D) = -V_{out}$$

$$V_{out}/V_{in} = -g_m(r_O \| R_D)$$