IIT ROORKEE

NPTEL ONLINE CERTIFICATION COURSE

MICRORLECTRONICS: DEVICES TO CIRCUITS

Biasing of MOS Amplifier and its Behavior as an analog switch

SUDEB DASGUPTA

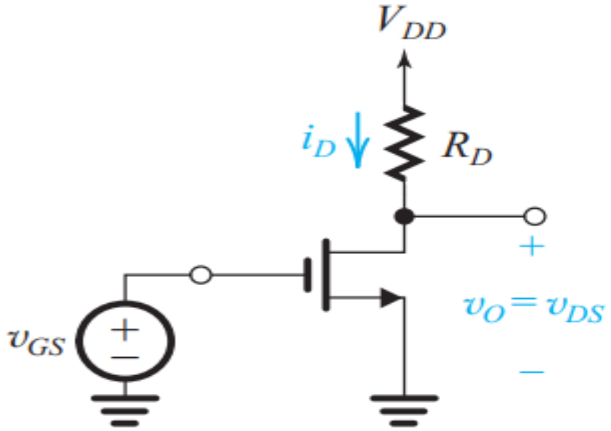
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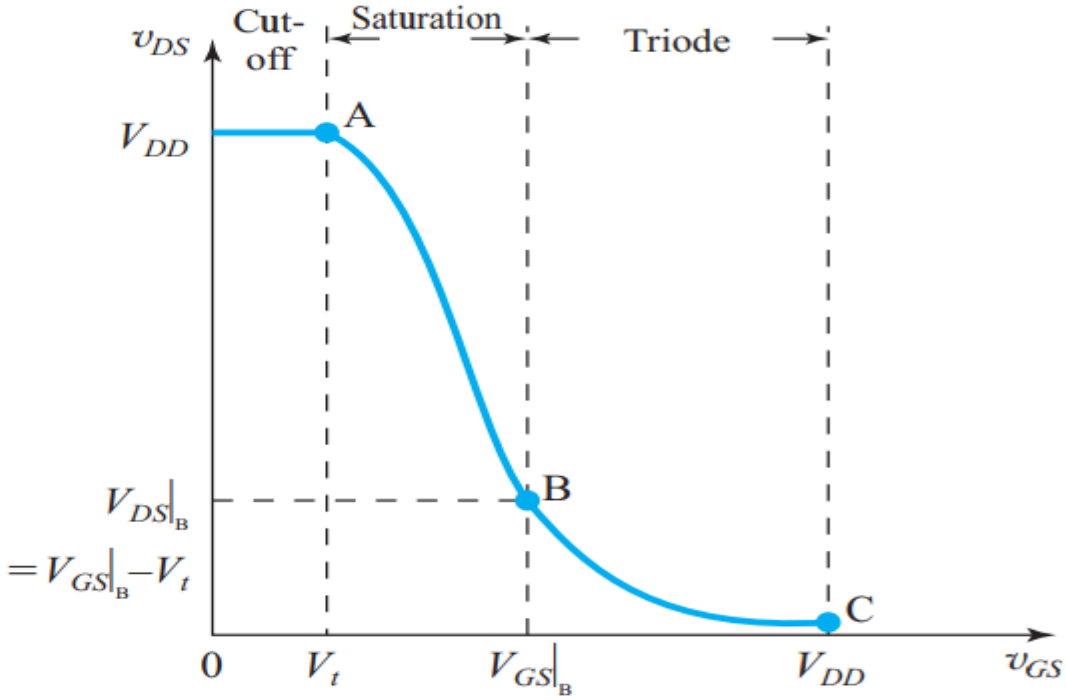


Outline

- VTC of MOS Amplifier
- Determining VTC by graphical analysis
- Biasing of MOS Amplifier
- Small signal Model (NMOS)
- Small signal Model (PMOS)
- Small signal Model with body bias
- MOS as Analog Switch
- Recapitulation

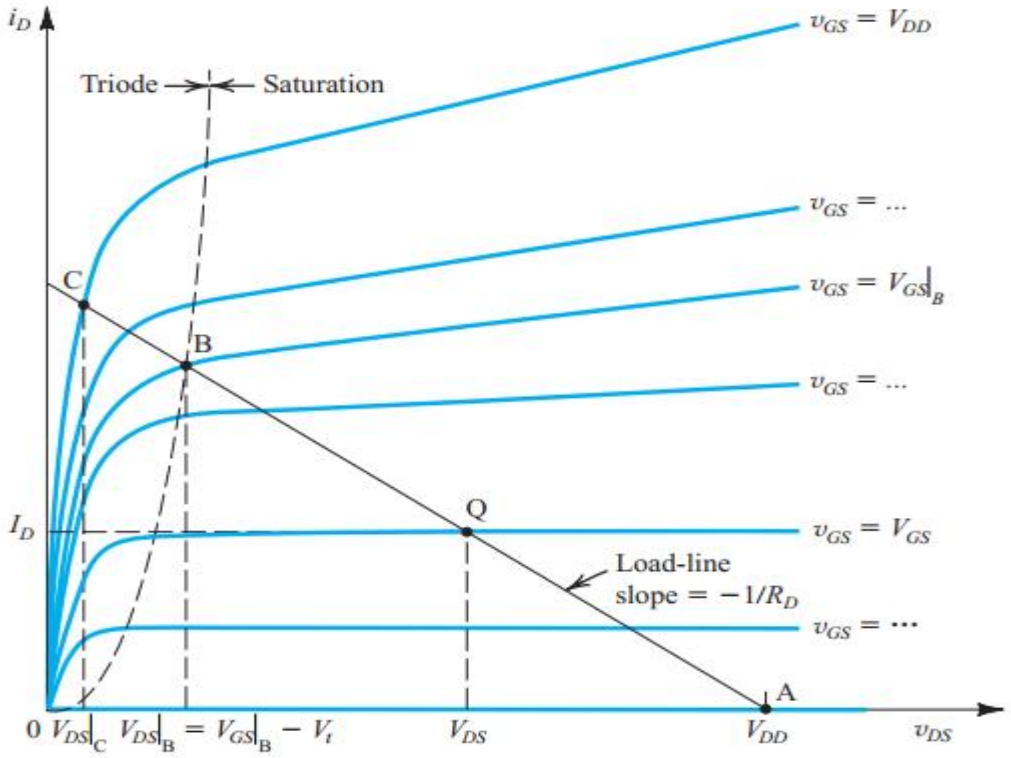
VTC of MOS Amplifier





Source: Microelectronics Circuits, Sedra and Smith, Fifth edition

Determining VTC by graphical analysis

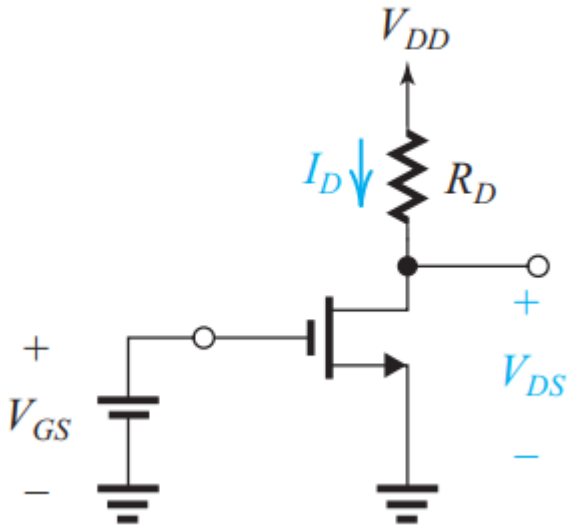


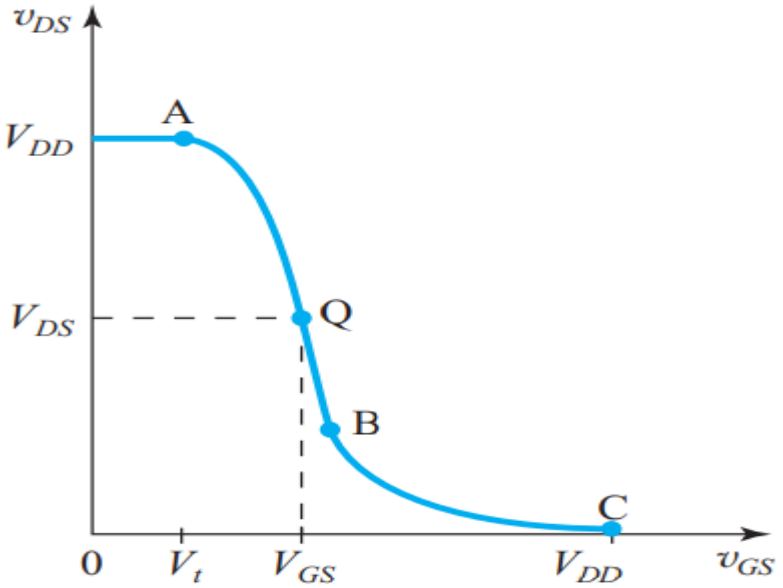
$$i_D = \frac{V_{DD}}{R_D} - \frac{1}{R_D} v_{DS}$$

Source: Microelectronics Circuits, Sedra and Smith, Fifth edition

Biasing of MOS Amplifier

- Biasing enables us to obtain almost linear amplification from the





Source: Microelectronics Circuits, Sedra and Smith, Fifth edition

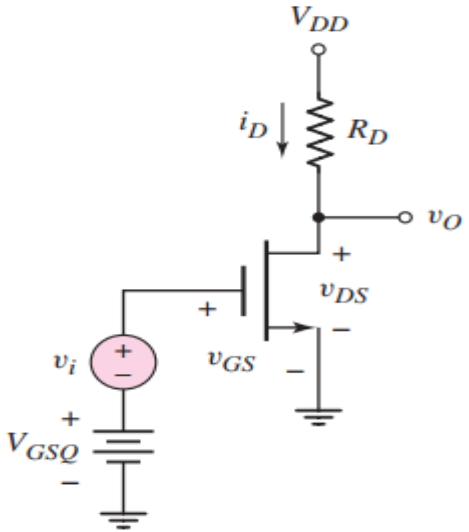
$$V_{DS} = V_{DD} - \frac{1}{2} K_n R_D \left(V_{GS} - V_t\right)^2$$

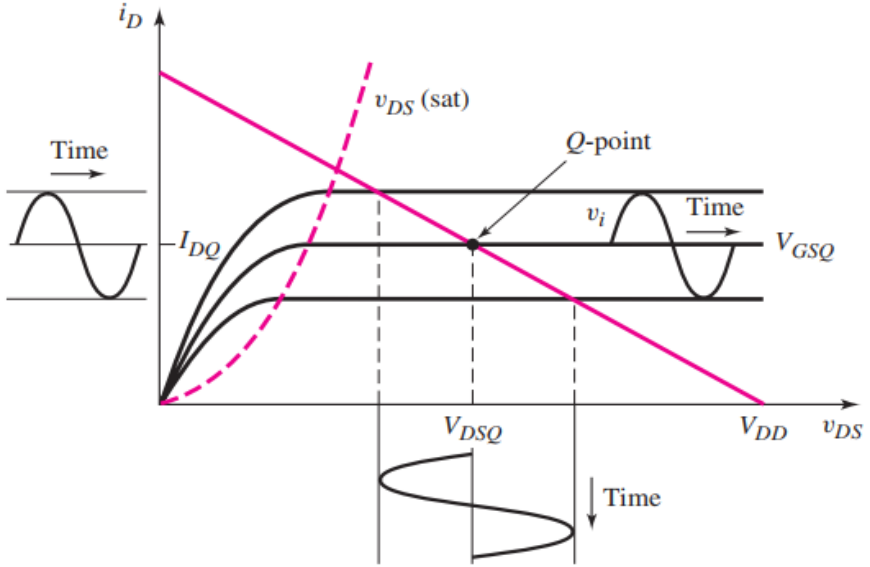
Q is known as the bias point or the dc operating point or quiescent

$$v_{GS}(t) = V_{GS} + v_{gs}(t)$$

- The output voltage to be linear function of the input voltage, the transistor must be biased in the saturation.
- Symmetrical sinusoidal signals are applied to the input of an amplifier, symmetrical sinusoidal signals are generated at the output.

Source: Microelectronics Circuits, Sedra and Smith, Fifth edition





- The load line used to determine the maximum output symmetrical swing.
- If the output exceeds this limit, a portion of the output signal will be clipped and signal distortion will occur.

Source: Microelectronics Circuit Analysis and Design Donald A. Neamen, Fourth edition

i_D, v_{GS}	Total instantaneous values
I_D, V_{GS}	DC values
i_d, v_{gs}	Instantaneous ac values
I_d, V_{gs}	Phasor values

Instantaneous gate to source voltage is $v_{GS} = V_{GSQ} + v_i = V_{GSQ} + v_{gs}$

Instantaneous drain current is $i_D = K_n\left(v_{GS} - V_{TN}\right)^2$

$$i_D = K_n\left[\left(V_{GSQ} - V_{TN}\right) + v_{gs}\right]^2$$

$$i_D = K_n\left(V_{GSQ} - V_{TN}\right)^2 + 2K_n\left(V_{GSQ} - V_{TN}\right)v_{gs} + K_n v_{gs}^2$$

Source: Microelectronics Circuit Analysis and Design Donald A. Neamen, Fourth edition

❑For a sinusoidal input signal, the squared term produces undesirable harmonics or nonlinear distortion in the output voltage.

To minimize these harmonics, we require $v_{gs} << 2(V_{GSQ} - V_{TN})$

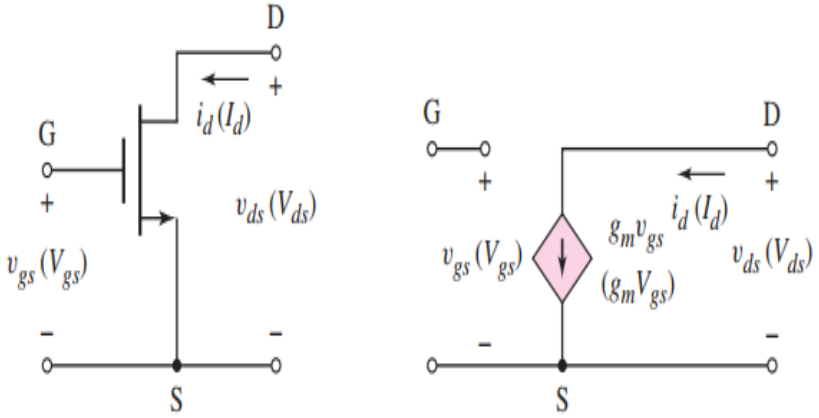
Neglecting the term v_{gs}^{2} than $i_D = i_{DQ} + i_d$

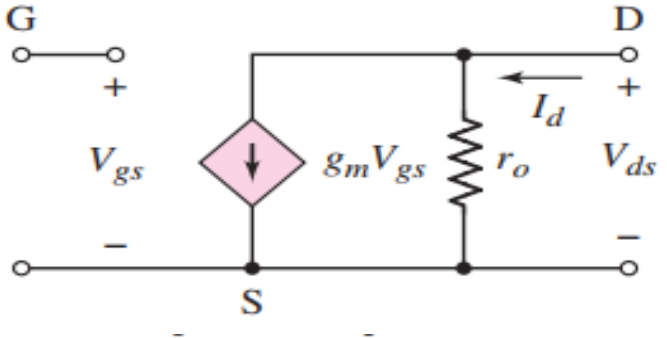
The ac drain current is given by $i_d = 2K_n(V_{GSQ} - V_{TN})v_{gs}$

$$g_m = \frac{i_d}{v_{gs}} = 2K_n(V_{GSQ} - V_{TN}) \qquad g_m = \left.\frac{\partial i_D}{\partial v_{GS}}\right|_{v_{gs}=V_{GSQ}=constant} = 2K_n(V_{GSQ} - V_{TN})$$

Source: Microelectronics Circuit Analysis and Design Donald A. Neamen, Fourth edition

Small signal Model (NMOS)

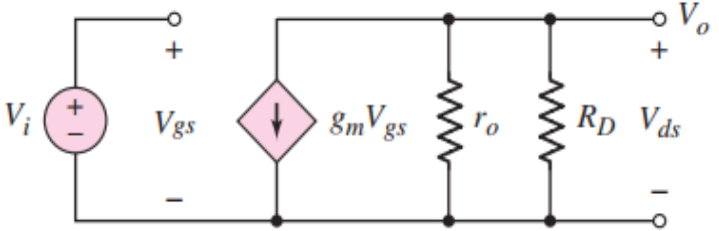




$$i_D = K_n\left[(v_{GS} - v_{TN})^2(1 + \lambda v_{DS})\right]$$

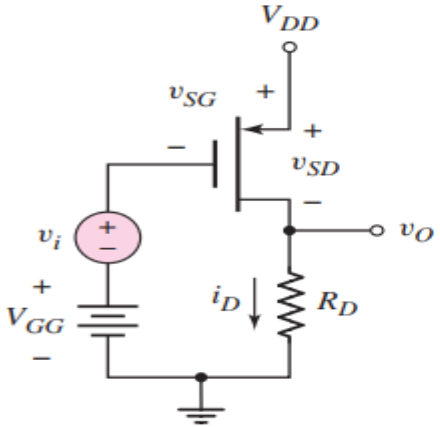
$$r_0 = \frac{1}{\lambda i_{DQ}}$$

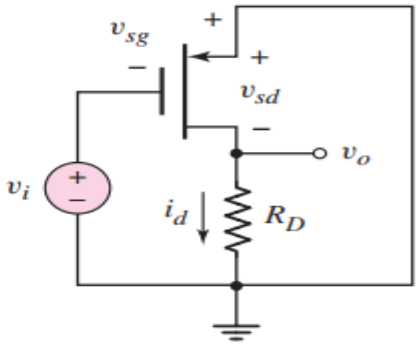
r_0 Output resistance

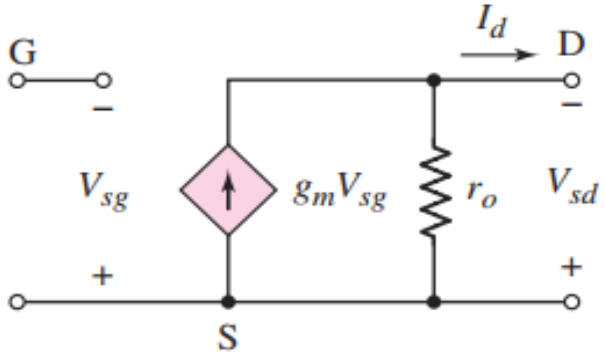


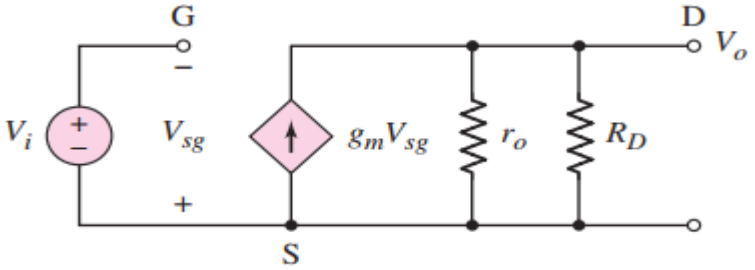
Source: Microelectronics Circuit Analysis and Design Donald A. Neamen, Fourth edition

Small signal Model (PMOS)







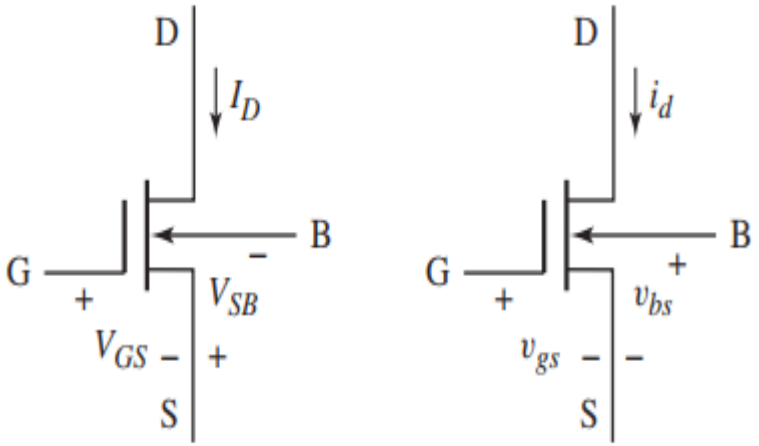


$$A_v = -g_m (r_0 \parallel R_D)$$

Source: Microelectronics Circuit Analysis and Design Donald A. Neamen, Fourth edition

Small signal Model with body bias

- The body effect occurs in a MOSFET in which the substrate , or body ,is not directly connected to the source.

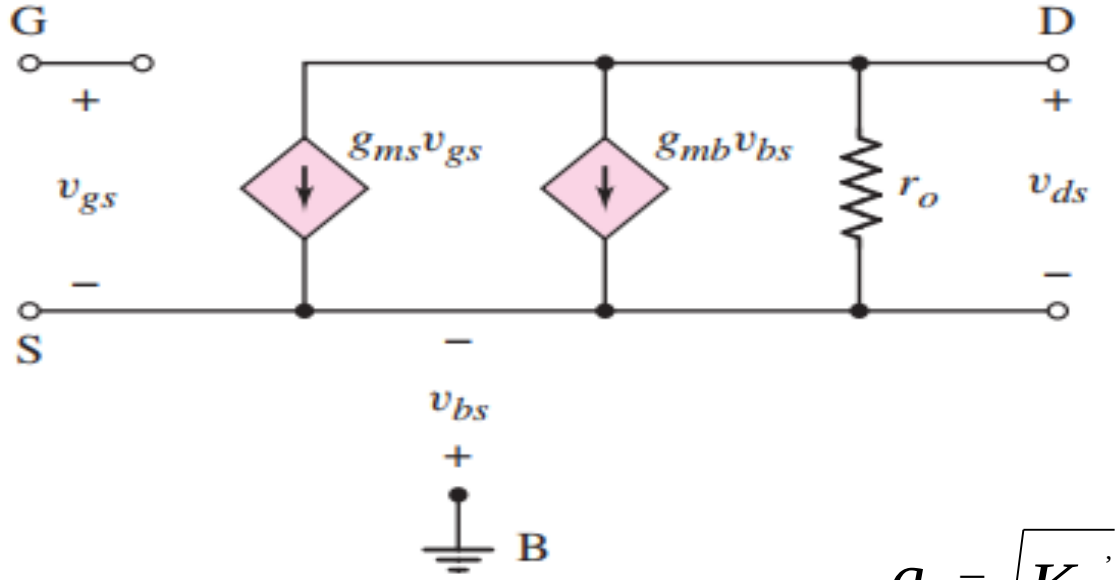


$$i_D = K_n\left(v_{GS} - V_{TN}\right)^2$$

$$V_{TN} = V_{TNO} + \gamma\left[\sqrt{2\phi_f + v_{SB}} - \sqrt{2\phi_f}\right]$$

$$\eta = \frac{\gamma}{2\sqrt{2\phi_f + v_{SB}}} \qquad g_{mb} = \eta g_m$$

Source: Microelectronics Circuit Analysis and Design Donald A. Neamen, Fourth edition

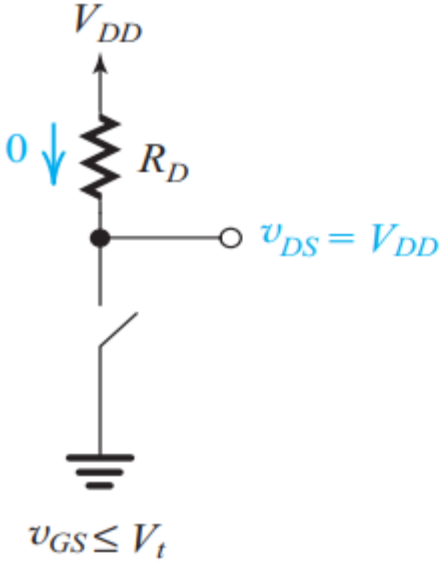


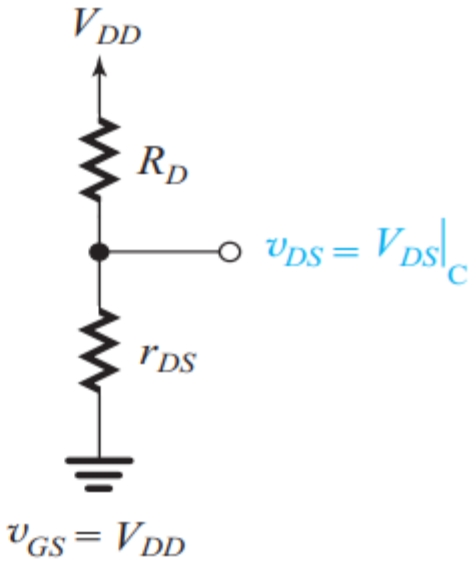
$$g_m = \sqrt{K_n'}\sqrt{W/L}\sqrt{I_D}$$

$$g_m = K_n'(W/L)V_{OV}$$

Source: Microelectronics Circuit Analysis and Design Donald A. Neamen, Fourth edition

MOS as Analog Switch





Source: Microelectronics Circuits, Sedra and Smith, Fifth edition

Recapitulation

- For a given MOSFET g_m is proportional to square root of the dc current.
- At a given dc bias current g_m is proportional to $\sqrt{\frac{W}{L}}$.
- Linear amplification can be obtained by biasing the MOSFET in the saturation region and by keeping the input signal small.
- The bias point Q is determine by the value of V_{GS} and load resistance R_D.
- Two important factor parameter depends on the location of Q, which are gain and signal swing at the output.
- MOSFET used as switch in deep triode region.

Thank You