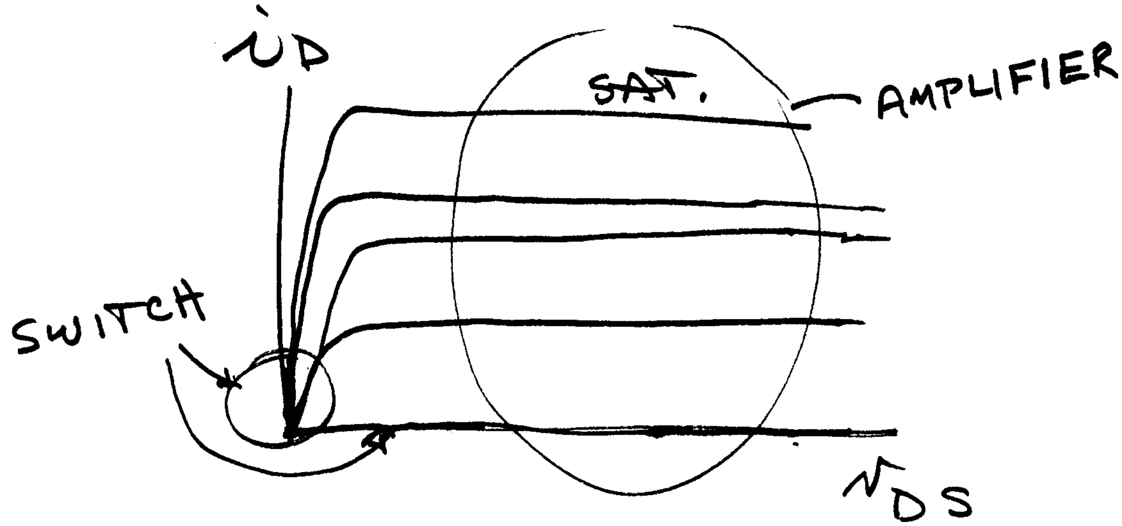


iD
SAT.
AMPLIFIER
SWITCH
vDS

Small-signal equivalent circuits for MOSFET amplifiers.

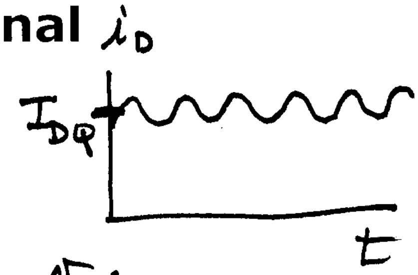
Notation: voltages and currents contain a DC component and a small-signal component.

Small-signal means a time-varying voltage or current that is small in amplitude.

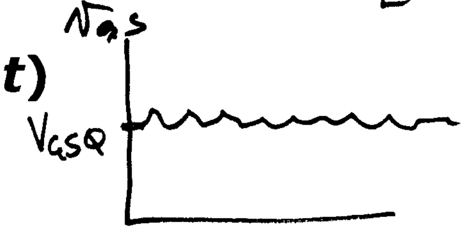
The total voltage or current is the sum of the DC and small-signal components.

total = DC + small-signal

$$i_D(t) = I_{DQ} + i_d(t)$$



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



MOSFET amplifiers always operate with the MOSFET in saturation.

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

Total Total

$$I_{DQ} + i_d(t) = K(V_{GS} + v_{gs}(t) - V_{TN})^2$$

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

$$I_{DQ} + i_d(t) = K_n(\underbrace{V_{GS}}_{\text{DC}} + v_{gs}(t) - \underbrace{V_{TN}}_{\text{"DC"}})^2$$

$$= K_n[(V_{GS} - V_{TN}) + v_{gs}(t)]^2$$

$$= \underbrace{K_n(V_{GS} - V_{TN})^2}_{I_{DQ}} + \underbrace{2K_n(V_{GS} - V_{TN})\,v_{gs}(t)}_{i_d(t)} + \underbrace{K_n v_{gs}^2}_{\approx 0}$$

DC term + small-signal + very small

Neglect the very small term. Then,

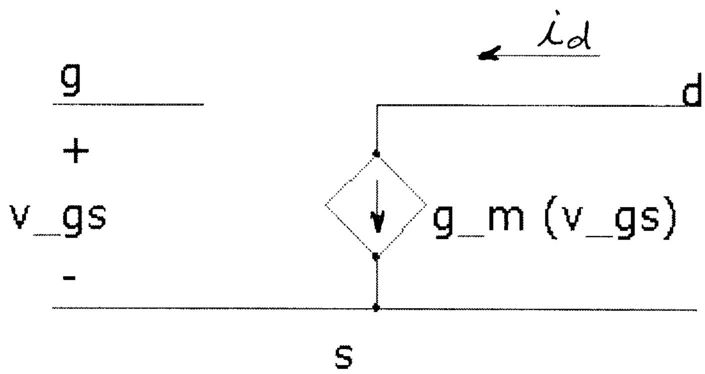
$$i_d(t) \approx [2K_n(V_{GSQ} - V_{TN})]\,v_{gs}(t)$$

$$g_m = 2K_n(V_{GSQ} - V_{TN})$$

$$i_d(t) = g_m v_{gs}(t)$$

g_m is called the *transconductance*

SMALL-SIGNAL EQUIVALENT CIRCUIT



MODEL FOR THE MOSFET SMALL-SIGNAL COMPONENT

v_{gs} is the time-varying portion of the gate-to-source voltage. i_d is the resulting time-varying portion of the drain current.

$$g_m = 2K_n(V_{GSQ} - V_{TN})$$

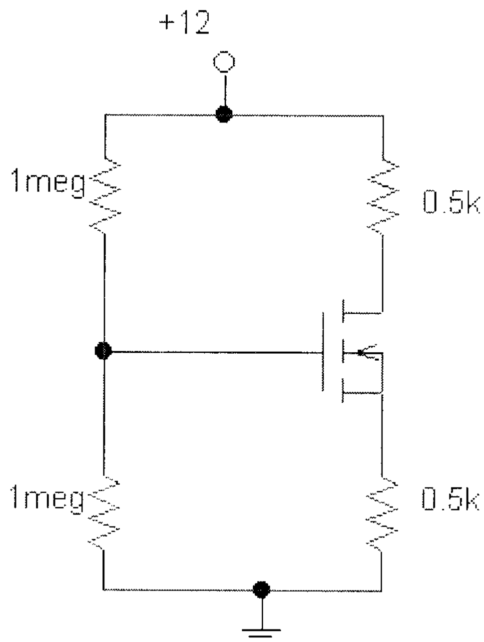
$$I_{DQ} = K_n(V_{GSQ} - V_{TN})^2$$

$$(V_{GSQ} - V_{TN}) = \sqrt{\frac{I_{DQ}}{K_n}}$$

$$\therefore \quad g_m = 2\sqrt{K_n I_{DQ}}$$

$$K_n = \left(\frac{W}{L}\right)\frac{k_n'}{2}$$

$$k_n' = \mu_n C_{ox}$$



SOLVE FOR:

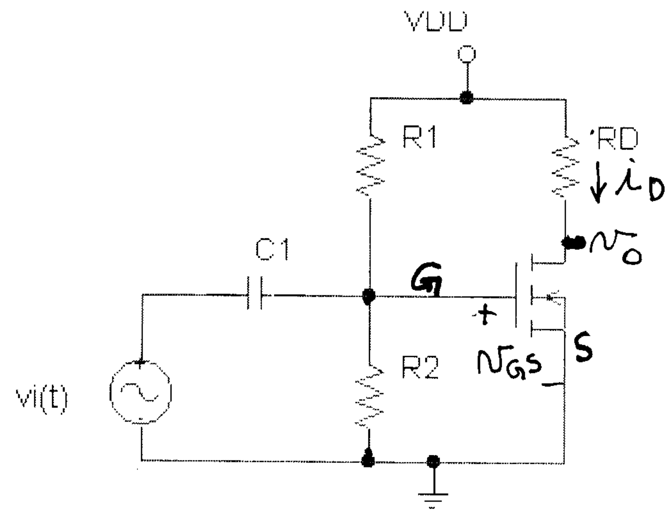
$I_{DQ} = 6$ mA

$V_{GSQ} = 3$ V.

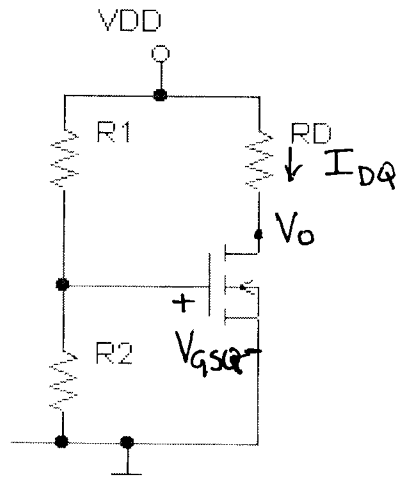
$K_n = 1.5$ mA /V^2

$$g_m = 2\sqrt{K_n I_{DQ}} = 2\sqrt{1.5(6)} = 6\ mA/V$$

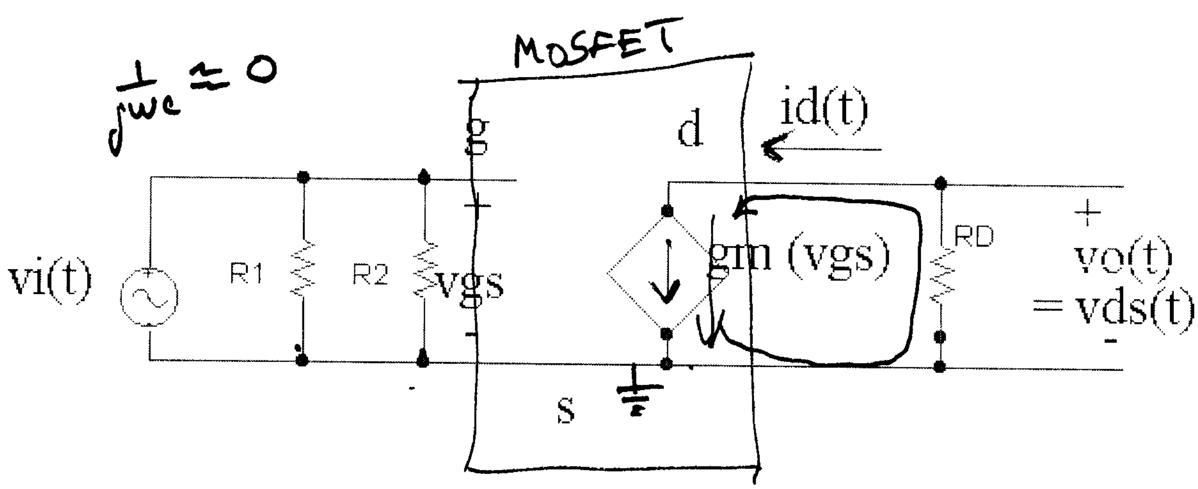
TOTAL

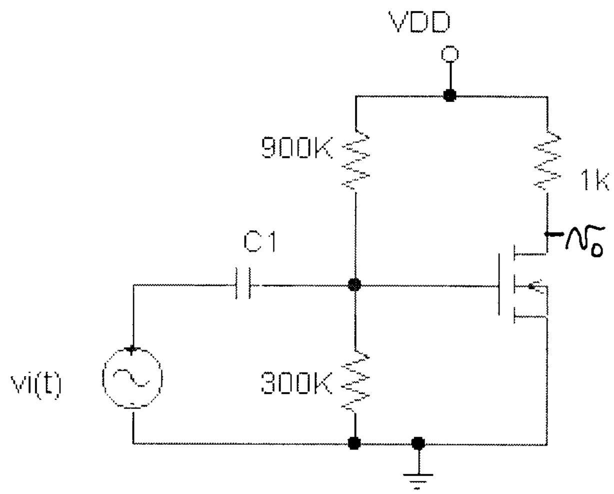


DC ONLY



SMALL-SIGNAL ONLY



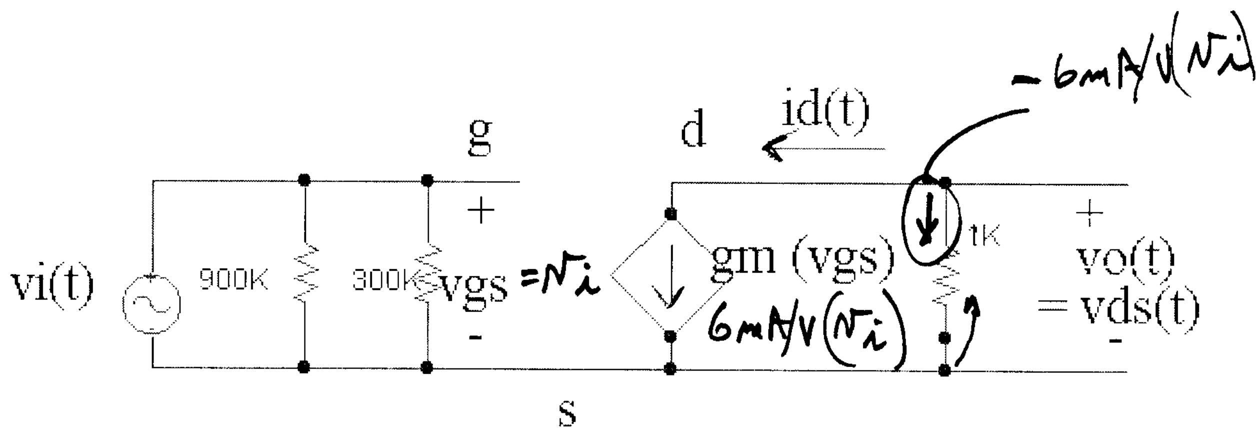


$I_{DQ} = 6\ mA$

$V_{GSQ} = 3\ V.$

$K_n = 1.5\ mA\ /V^2$

$$g_m = 2\sqrt{K_n I_{DQ}} = 2\sqrt{1.5(6)} = 6\ mA/V$$



$$v_o(t) = -g_m v_{gs} R_D = -(6mA/V)\, v_{gs}(1k)$$

$$v_o(t) = -6\, v_{gs}(t)$$

$$\textit{voltage gain} = \frac{v_o}{v_{gs}} = -6$$