→ FET Small-Signal Model

→ We can express the drain current i_D as a function of gate voltage v_{GS} & drain voltage v_{DS} by $i_D = f(v_{GS}, v_{DS})$

Transconductance g_m & Drain Resistance r_d

→ If both the gate & drain voltages are varied, the change in drain current is given by Taylor's series expansion of $i_D = f(v_{GS}, v_{DS})$

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

→ We can write $\Delta i_D = i_d$, $\Delta v_{GS} = v_{gs}$ & $\Delta v_{DS} = v_{ds}$, so

$$i_d = g_m v_{gs} + \frac{1}{r_d} v_{ds}$$

where $g_m \equiv \left.\frac{\partial i_D}{\partial v_{GS}}\right|_{V_{DS}} = \left.\frac{\Delta i_D}{\Delta V_{GS}}\right|_{V_{DS}} = \left.\frac{i_d}{v_{gs}}\right|_{V_{DS}}$ is mutual conductance or transconductance.

→ It is also designated by y_{fs} & g_{fs} & called (common source) forward transadmittance

→ The parameter r_d is the drain (or o/p resistance) & is defined by

$$r_d = \frac{\partial V_{DS}}{\partial i_D}\bigg|_{V_{GS}} \simeq \frac{\Delta V_{DS}}{\Delta i_D}\bigg|_{V_{GS}} = \frac{V_{ds}}{i_d}\bigg|_{V_{GS}}$$

→ The reciprocal of r_d is the drain conductance g_d.

→ It is also designated by y_{os} & g_{os} & called the (common-source) o/p conductance.

$$\rightarrow \quad \mu = \frac{\partial V_{DS}}{\partial V_{GS}}\bigg|_{i_D} = \frac{\Delta V_{DS}}{\Delta V_{GS}}\bigg|_{i_D} = \frac{V_{ds}}{V_{gs}}\bigg|_{i_D}$$

→ By setting $i_d = 0$ in $i_d = g_m V_{gs} + \frac{1}{r_d} V_{ds}$

$$g_m r_d = \frac{V_{ds}}{V_{gs}}$$

So $\mu = g_m r_d$

→ Applying the definition of g_m to $I_{DS} = I_{DSS}\left(1 - \frac{V_{GS}}{V_P}\right)^2$

$$\frac{\partial I_{DS}}{\partial V_{GS}} = I_{DSS}\, 2\left(1 - \frac{V_{GS}}{V_P}\right)\left(\frac{-1}{V_P}\right)$$

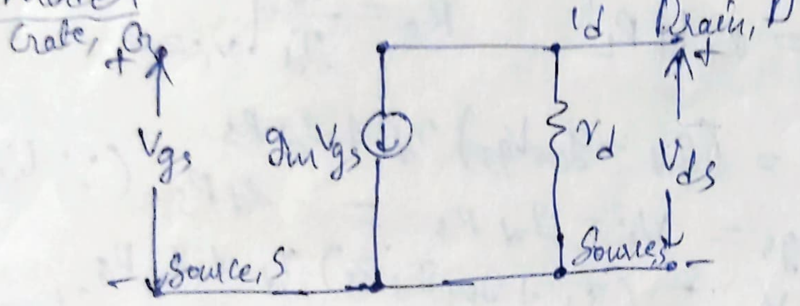
$$= \frac{-2 I_{DSS}}{V_P}\left(1 - \frac{V_{GS}}{V_P}\right)$$

So $g_m = g_{mo}\left(1 - \frac{V_{GS}}{V_P}\right)$ where g_{mo} is the value of g_m for $V_{GS} = 0$ & is given by

$$g_{mo} = \frac{-2 I_{DSS}}{V_P}$$

→ Since I_{DSS} & V_P are of opposite sign, g_{mo} is always +ve.

FET Model



→ This low freq. small-signal FET model satisfies

$$i_d = g_m v_{gs} + \frac{1}{r_d} v_{ds}$$