BAB X ANALISIS SINYAL KECIL FET

FET dapat dibuat rangkaian penguat sinyal kecil untuk penguatan tegangan pada impedansi input sangat tinggi. BJT mengontrol arus collector yang besar dari input arus basis yang lebih kecil sedangkan FET mengontrol output arus drain dari input tegangan gate source yang lebih kecil.
Rangkaian ekivalen ac FET lebih simpel dibandingkan BJT yaitu dengan BJT adalah β sedangkan FET adalah g_m (transkonduktansi).

9.1 Model Sinyal Kecil FET

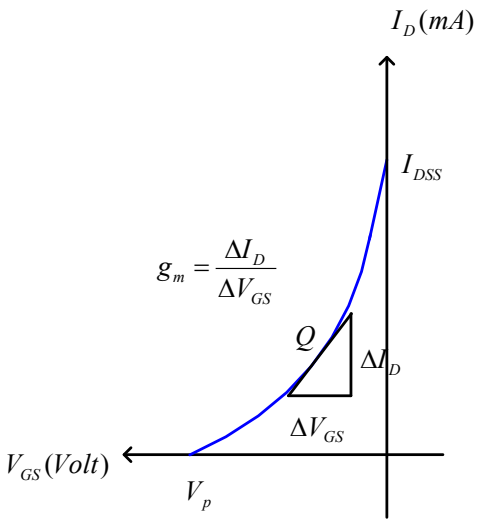
Tegangan gate ke source mengontrol arus drain source.
g_m = Arus drain source / Tegangan gate source
Persamaan Shockley :

$$g_m = \frac{\Delta I_D}{\Delta V_{GS}}$$

$$g_m = g_{mo}\left(1 - \frac{V_{GS}}{V_p}\right)$$

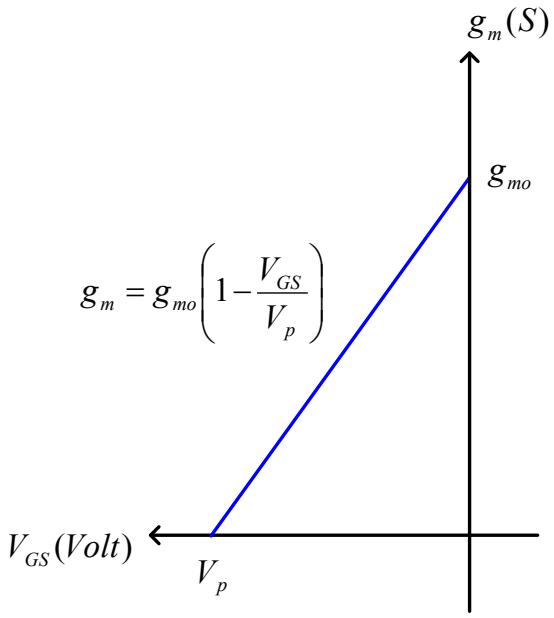
$$g_{mo} = \frac{2I_{DSS}}{|V_p|}$$

Grafik g_m



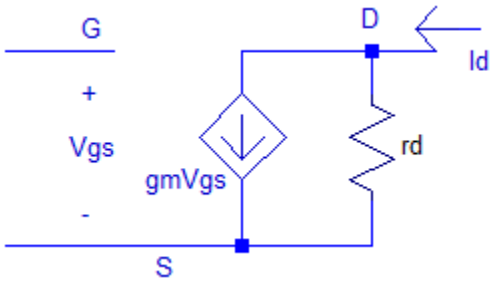
Gambar 9.1 Grafik g_m

Grafik g_m terhadap V_{GS}



9.2 Grafik g_m terhadap V_{GS}

Rangkaian Ekivalen ac FET



9.3 Ekivalen ac FET

dimana :

$r_d = \left.\frac{\Delta V_{DS}}{\Delta I_D}\right|_{V_{GS}=kons\tan}$ → output resistansi FET

$r_d = \frac{1}{y_{os}}$ → output konduktansi pada datasheet

$g_m = y_{fs}$ → nilai pada datasheet (forward transfer admitansi)

Impedansi Input

$Z_i = \infty$

Impedansi Output

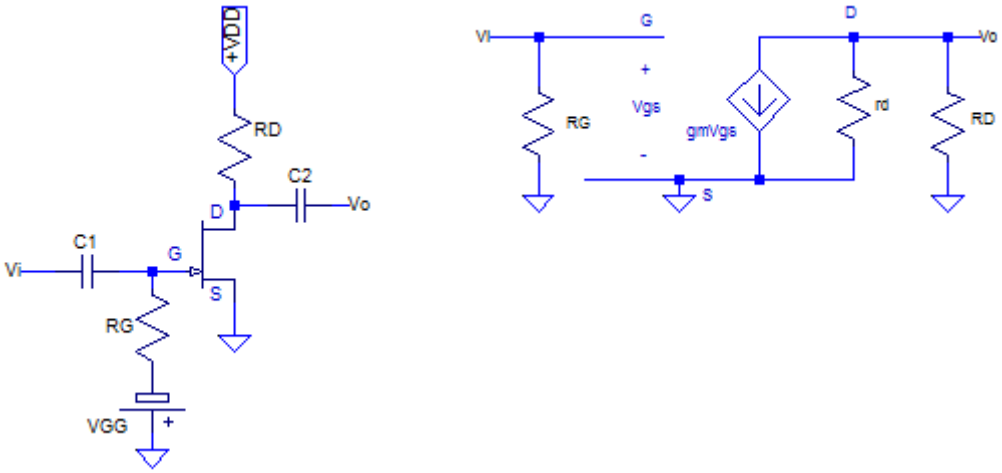
$Z_o = r_d = \frac{1}{y_{os}}$

Penguatan Tegangan

$$A_v = \frac{V_o}{V_i} = \frac{-g_m V_{gs} r_d}{V_{gs}} = -g_m r_d$$

9.2 Dasar Rangkaian JFET

9.2.1 Penguat JFET dengan DC Bias Tetap



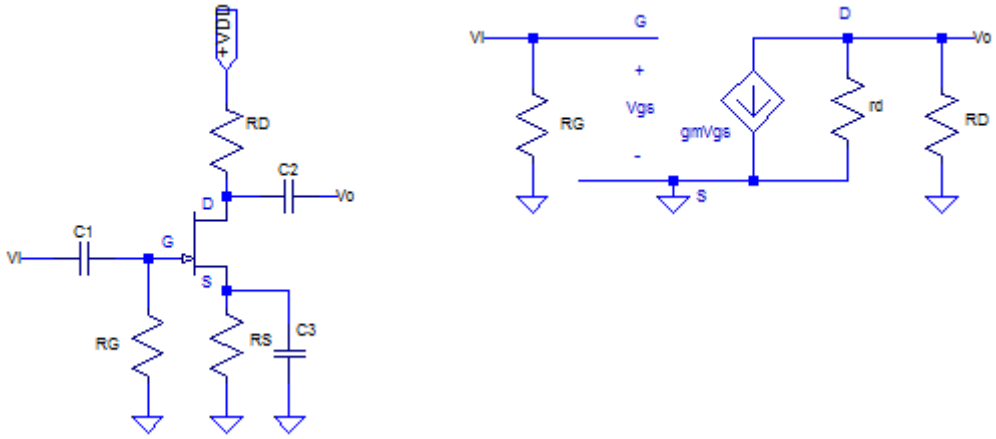
9.4 DC bias tetap

$$Z_i = R_G$$

$$Z_o = r_d \,//\, R_D$$

$$A_v = \frac{V_o}{V_i} = \frac{-g_m V_{gs}\left(r_d \,//\, R_D\right)}{V_{gs}} = -g_m\left(r_d \,//\, R_D\right)$$

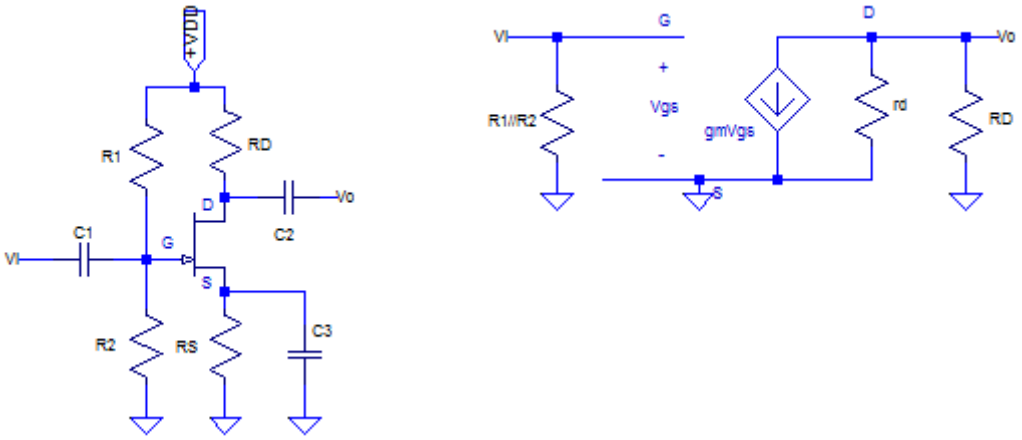
9.2.2 Penguat JFET dengan Bias Sendiri



9.5 Bias sendiri

$$Z_i = R_G$$
$$Z_o = r_d \,//\, R_D$$
$$A_v = \frac{V_o}{V_i} = \frac{-g_m V_{gs}\left(r_d \,//\, R_D\right)}{V_{gs}} = -g_m\left(r_d \,//\, R_D\right)$$

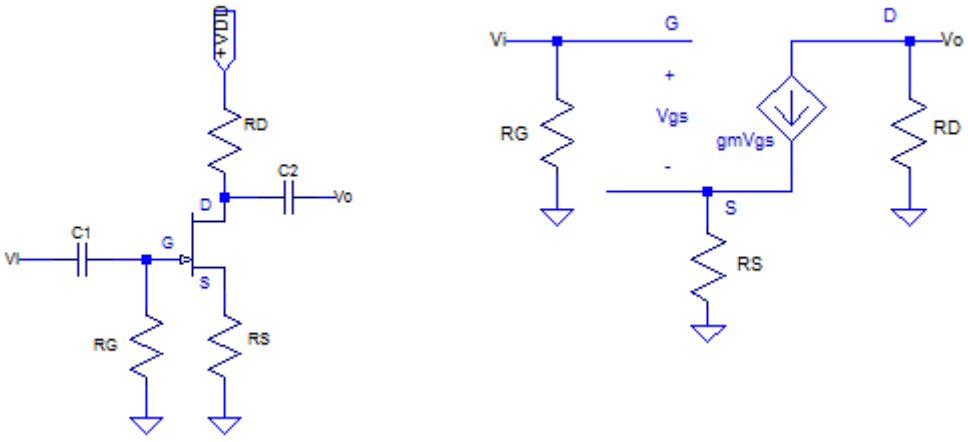
9.2.3 Penguat JFET dengan Pembagi Tegangan



9.6 Pembagi tegangan

$$Z_i = R_1 \,//\, R_2$$
$$Z_o = r_d \,//\, R_D$$
$$A_v = \frac{V_o}{V_i} = \frac{-g_m V_{gs}\left(r_d \,//\, R_D\right)}{V_{gs}} = -g_m\left(r_d \,//\, R_D\right)$$

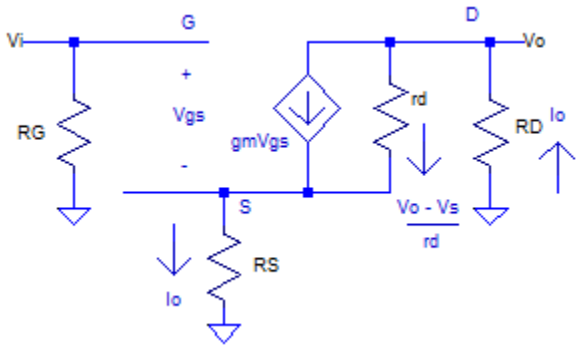
9.2.4 Penguat JFET dengan Resistansi Source (abaikan r_d)



9.7 Resistansi *source*

$$Z_i = R_G$$
$$Z_o = R_D$$
$$A_v = \frac{V_o}{V_i} = \frac{-g_m V_{gs} R_D}{V_{gs} + g_m V_{gs} R_s} = \frac{-g_m R_D}{1 + g_m R_s}$$

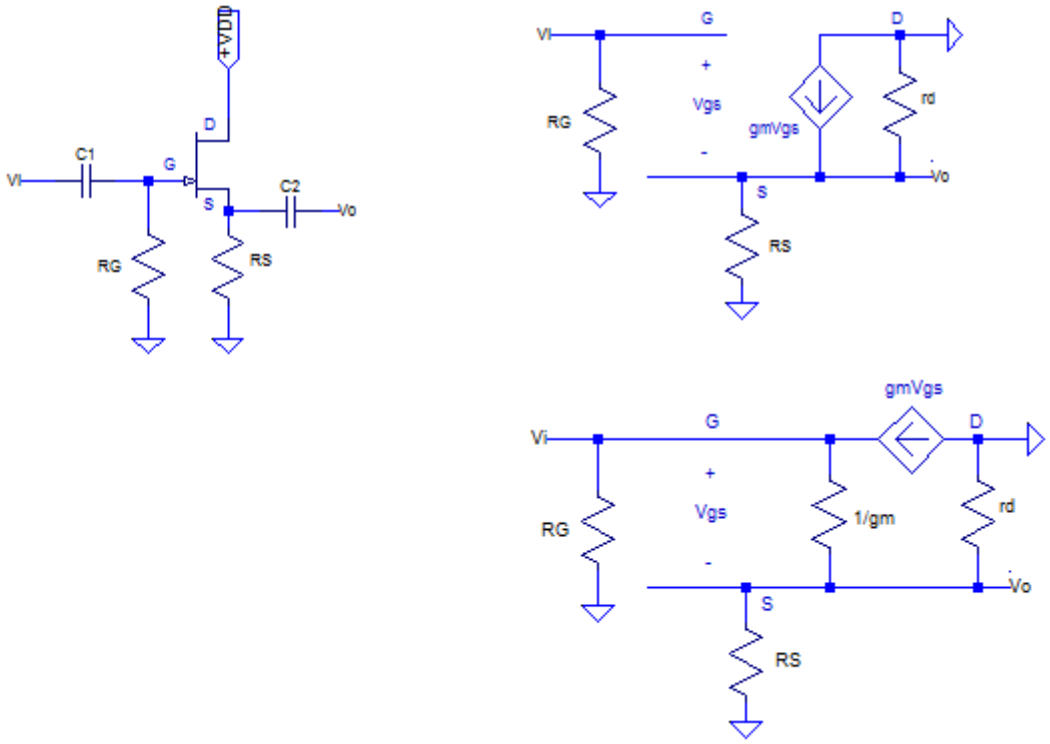
Asumsi r_d ada



9.8 Resistansi *source* dengan r_d

$$Z_i = R_G$$
$$Z_o = R_D \,//\, (r_d + R_s)$$
$$I_o = g_m V_{gs} + \frac{V_o - V_s}{r_d} = g_m V_{gs} + \frac{-I_o R_D - I_o R_s}{r_d} = g_m (V_i - V_s) + \frac{-I_o R_D - I_o R_s}{r_d}$$
$$I_o = g_m (V_i - I_o R_s) + \frac{-I_o R_D - I_o R_s}{r_d} \Rightarrow I_o = \frac{g_m V_i}{1 + g_m R_s + \frac{R_D + R_s}{r_d}}$$
$$V_o = -I_o R_D = \frac{-g_m R_D V_i}{1 + g_m R_s + \frac{R_D + R_s}{r_d}}$$
$$A_v = \frac{V_o}{V_i} = \frac{-g_m R_D}{1 + g_m R_s + \frac{R_D + R_s}{r_d}}$$

9.2.5 Penguat JFET Common Drain (Source Follower)



9.9 Common drain (source follower)

$$Z_i = R_G$$

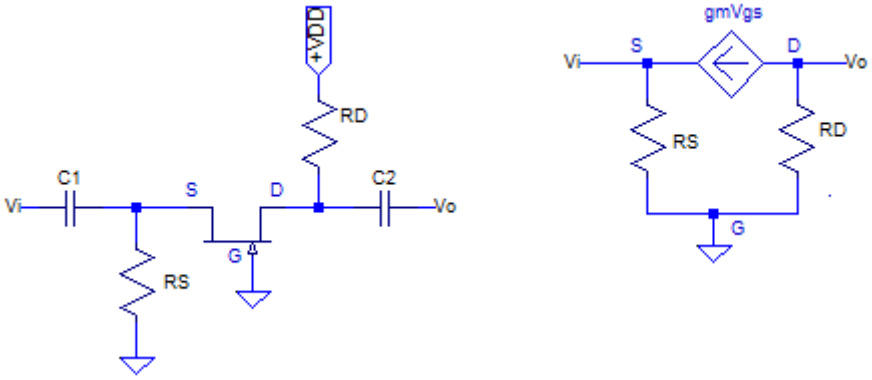
$$Z_o = R_s \,//\, r_d \,//\, \frac{1}{g_m}$$

$$V_i = V_{gs} + V_o \Rightarrow V_{gs} = V_i - V_o$$

$$V_o = g_m V_{gs}\left(r_d \,//\, R_s\right) = g_m\left(V_i - V_o\right)\left(r_d \,//\, R_s\right)$$

$$A_v = \frac{V_o}{V_i} = \frac{g_m\left(r_d \,//\, R_s\right)}{1 + g_m\left(r_d \,//\, R_s\right)}$$

9.2.6 Penguat JFET Common Gate (abaikan r_d)



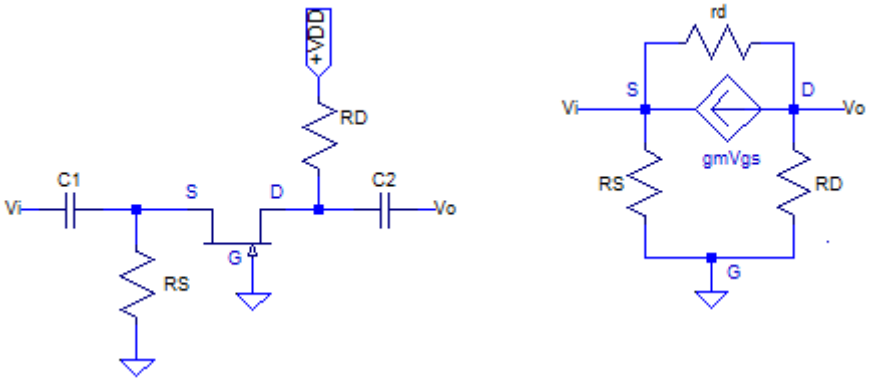
9.10 Common gate

$$Z_i = R_S$$

$$Z_o = R_D$$

$$A_v = \frac{V_o}{V_i} = \frac{-g_m V_{gs} R_D}{-V_{gs}} = g_m R_D$$

Asumsi r_d ada



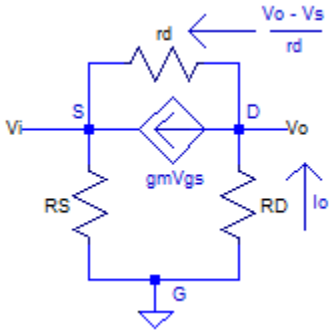
9.11 Common gate dengan r_d

$$Z_i = R_S \,//\, \frac{1}{g_m}$$

$$Z_o = R_D \,//\, r_d \qquad 1$$

$$A_v = \frac{V_o}{V_i} = g_m \left(R_D \,//\, r_d\right)$$

Penyelesaian :

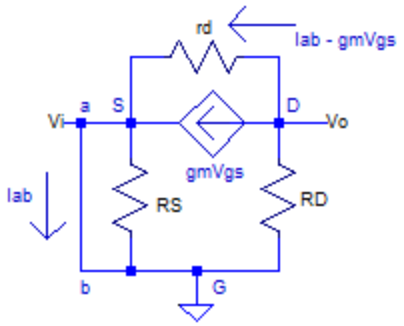


$$V_i = -V_{gs}$$

$$V_o = -I_o R_D$$

$$I_o = g_m V_{gs} + \frac{V_o - V_i}{r_d} \Rightarrow -\frac{V_o}{R_D} = g_m V_i + \frac{V_o - V_i}{r_d}$$

$$A_v = \frac{V_o}{V_i} = \frac{g_m + 1/r_d}{1/R_D + 1/r_d} = \left(g_m + 1/r_d\right)\left(R_D \,//\, r_d\right) \approx g_m \left(R_D \,//\, r_d\right)$$



$$V_{ab} = V_i = -V_{gs}$$

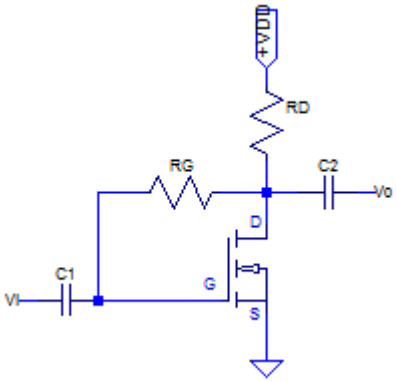
$$I_{ab} = I_{sc}$$

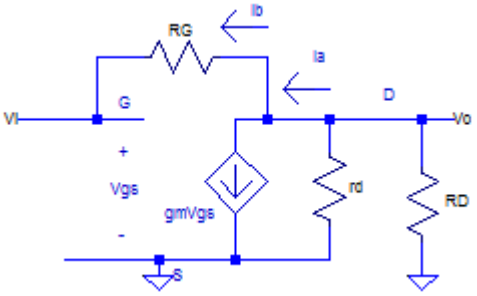
$$I_{sc}R_D + r_d\left(I_{sc} - g_m V_{gs}\right) = 0 \Rightarrow I_{sc} = \frac{g_m V_{gs} r_d}{R_D + r_d}$$

$$R_{th} = \frac{V_{ab}}{I_{sc}} = -\frac{\left(R_D + r_d\right)}{r_d}\frac{1}{g_m} \approx \frac{1}{g_m}$$

$$Z_i \approx R_s \,//\, R_{th} \approx R_s \,//\, \frac{1}{g_m}$$

9.3 Penguat e MOSFET





9.12 e MOSFET

$$I_a = I_b + g_m V_{gs} = \frac{V_o - V_i}{R_G} + g_m V_{gs}$$

$$V_o = -i\left(R_D \,//\, r_d\right) = -\left(\frac{V_o - V_i}{R_G} + g_m V_{gs}\right)\left(R_D \,//\, r_d\right) = -\left(\frac{V_o - V_i}{R_G} + g_m V_i\right)\left(R_D \,//\, r_d\right)$$

$$A_v = \frac{V_o}{V_i} = \frac{\left(\frac{1}{R_G} - g_m\right)\left(R_D \,//\, r_d\right)}{1 + \frac{R_D \,//\, r_d}{R_G}} = \frac{\left(1 - g_m R_G\right)\left(R_D \,//\, r_d\right)}{R_G + R_D \,//\, r_d}$$

Impedansi Input

$$Z_i = \frac{V_i}{I_i} = \frac{V_i}{\frac{V_i - V_o}{R_G}} = \frac{V_i}{\frac{V_i - A_v V_i}{R_G}} = \frac{R_G}{1 - A_v}$$

Impedansi Output

$$Z_o = R_D \,//\, r_d \,//\, R_G$$

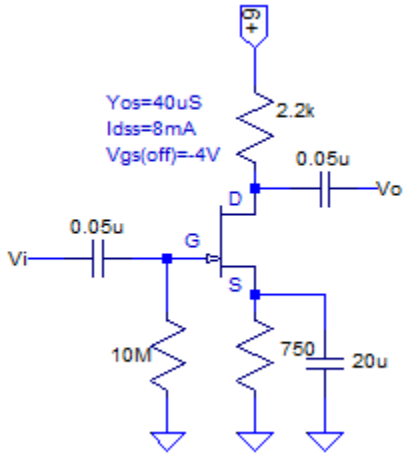
$$g_m = \frac{\Delta I_D}{\Delta V_{gs}}$$

$$I_D = k\left(V_{GS} - V_T\right)^2$$

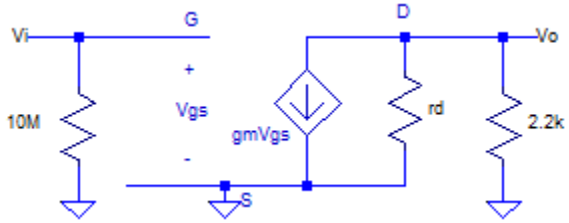
$$g_m = \frac{\Delta I_D}{\Delta V_{gs}} = 2k\left(V_{GS} - V_T\right) \Rightarrow k = 0{,}3mA/V^2$$

Latihan Soal :

1. Tentukan A_V

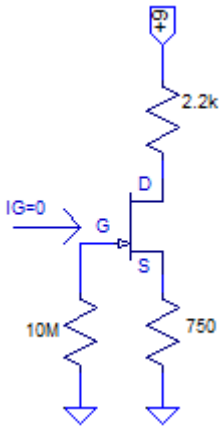


Jawaban :



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

V_{GS} dicari dengan analisis DC :



$$I_G = 0$$
$$V_{1M} = 1M.I_G = 0$$
$$+V_{GS} + 750I_S = 0 \Rightarrow V_{GS} = -0{,}75kI_D$$
$$I_D = I_{DSS}\left(1-\frac{V_{GS}}{V_P}\right)^2 = 8mA\left(1-\frac{0{,}75kI_D}{4}\right)^2$$
$$0{,}0352{I_D}^2 - 0{,}5I_D + 1 = 0$$

Rumus ABC :

$$I_{D1,2} = \frac{0{,}5 \pm \sqrt{0{,}5^2 - 4.1.0{,}0352}}{2.0{,}0352} = \frac{0{,}5 \pm 0{,}331}{0{,}0704}$$
$$I_{D1} = 11{,}804mA \Rightarrow V_{GS} = -0{,}75kI_D = -8{,}853V$$
$$I_{D2} = 2{,}4mA \Rightarrow V_{GS} = -0{,}75kI_D = -1{,}8V$$

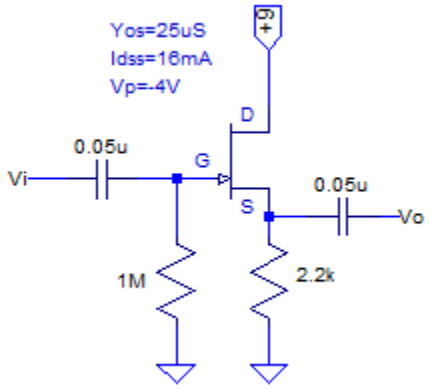
V_{GS} = -8,853V tidak mungkin karena $V_{GS(off)}$ = -4V

Analisis ac :

$$g_m = \frac{2I_{DSS}}{|V_P|}\left(1-\frac{V_{GS}}{V_P}\right) = \frac{2.8mA}{|-4|}\left(1-\frac{1,8}{4}\right) = 2,2mS$$

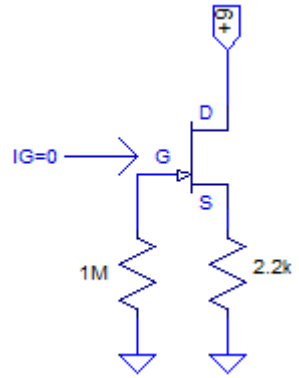
$$A_V = \frac{V_o}{V_i} = \frac{-g_m V_{gs}\left(r_d \,//\, 2,2k\right)}{V_{gs}} = -g_m\left(r_d \,//\, 2,2k\right) = -2,2\left(25k \,//\, 2,2k\right) = -4,45$$

2. Tentukan penguatan tegangan, impedansi input, dan impedansi output !



Jawaban :

Analisis DC :



$$I_G = 0$$

$$V_{1M} = 1M.I_G = 0$$

$$V_{GS} + 2,2kI_S = 0$$

$$V_{GS} = -2,2kI_D$$

$$I_D = I_{DSS}\left(1-\frac{V_{GS}}{V_P}\right)^2 = 16mA\left(1-\frac{2,2kI_D}{4}\right)^2$$

$$0,3025{I_D}^2 - 1,1625I_D + 1 = 0$$

Rumus ABC :

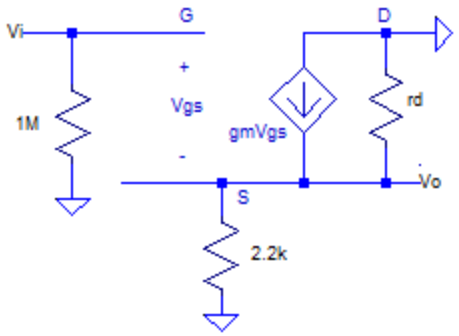
$$I_{D1,2} = \frac{1,1625 \pm \sqrt{1,1625^2 - 4.1.0,3025}}{2.0,3025} = \frac{1,1625 \pm 0,376}{0,605}$$

$$I_{D1} = 2,543mA \Rightarrow V_{GS} = -2,2kI_D = -5,5946V$$

$$I_{D2} = 1,3mA \Rightarrow V_{GS} = -2,2kI_D = -2,6V$$

V_{GS} = -5,594V tidak mungkin karena $V_{GS(off)}$ = -4V

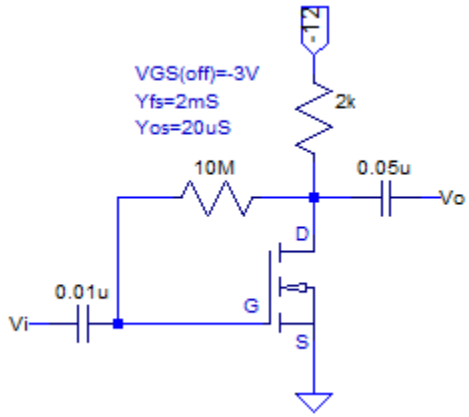
Analisis ac :



$$g_m = \frac{2I_{DSS}}{|V_P|}\left(1-\frac{V_{GS}}{V_P}\right) = \frac{2.16mA}{|-4|}\left(1-\frac{2,86}{4}\right) = 2,28mS$$

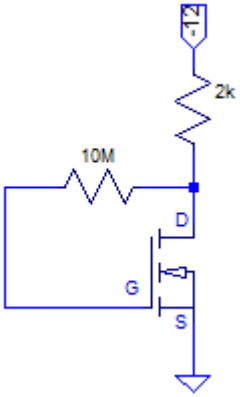
$$A_V = \frac{V_o}{V_i} = \frac{g_m V_{gs}\left(r_d \,//\, 2,2k\right)}{V_{gs} + g_m V_{gs}\left(r_d \,//\, 2,2k\right)} = \frac{2,28\left(40k \,//\, 2,2k\right)}{1+2,28\left(40k \,//\, 2,2k\right)} = 0,826$$

3. Tentukan V_o



Jawaban :

Analisis DC :



$$I_G = 0$$

$$V_{10M} = 10M.I_G = 0$$

$$V_{GS} = V_{DS}$$

$$+12 - 2kI_D + V_{GS} = 0$$

$$V_{GS} = -12 + 2kI_D \Rightarrow I_D = \frac{V_{GS}+12}{2k}$$

$$I_D = k\left(V_{GS} - V_T\right)^2$$

$$\frac{V_{GS}+12}{2k} = 0,3\left(V_{GS}+3\right)^2$$

$$V_{GS}{}^2 + 4,33V_{GS} - 11 = 0$$

Rumus ABC :

$$V_{GS1,2} = \frac{-4{,}33 \pm \sqrt{4{,}33^2 + 4.11.1}}{2.1} = \frac{-4{,}33 \pm 7{,}92}{2}$$

$$V_{GS1} = 1{,}795V$$

$$V_{GS2} = -6{,}125V$$

V_{GS} = -1,79V tidak mungkin karena e-MOSFET kanal P harus nilainya negatif.

$$g_m = 2k(V_{GS} - V_T) = 2.0{,}3(-6{,}125 + 3) = -1{,}875$$

$$r_d = \frac{1}{y_{os}} = 50k$$

$$A_V = \frac{V_o}{V_i} = \frac{(1 - g_m R_G) r_d \,//\, R_D}{R_G + r_d \,//\, R_D} = 3{,}6$$