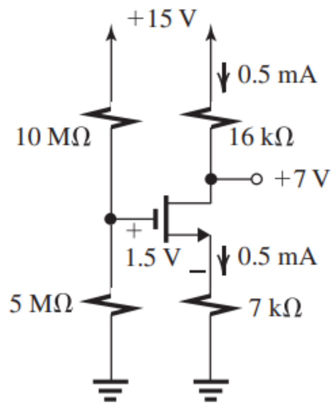
4.1:

Solution

(a) Open-circuit the capacitors to obtain the bias circuit shown in Figure 1, which indicates the given values.



From the voltage divider, we have $V_G = 15\frac{5}{10+5} = 5$ V

From the circuit, we obtain $V_G = V_{Gs} + 0.5 \times 7 = 1.5 + 3.5 = 5$ V. Which is consistent with the value provided by the voltage divider.

Since the drain voltage (+7 V) is higher than the gate voltage (+5 V), the transistor is operating in saturation.

From the circuit:

$V_D = V_{DD} - I_D R_D = 15 - 0.5 \times 16 = +7$

$V_{GS} = 1.5$ V, thus $V_{OV} = 1.5 - V_t = 1.5 - 1 = 0.5$ V

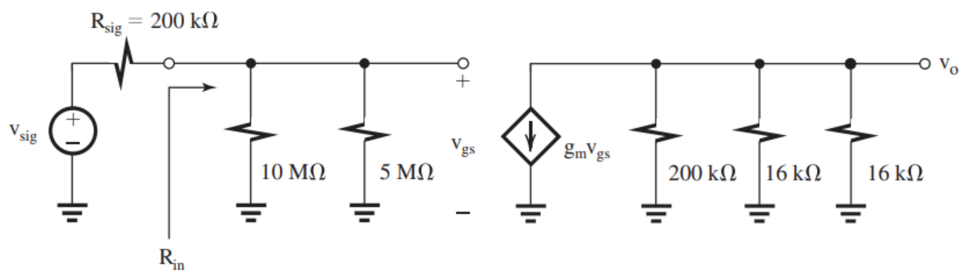
$$I_D = \frac{1}{2} k_n V_{OV}^2 = \frac{1}{2} \times 4 \times 0.5^2 = 0.5 \text{ mA}$$

(b)

$$g_m = \frac{2I_D}{V_{OV}} = \frac{2 \times 0.5}{0.5} = 2\ \frac{\text{mA}}{\text{V}}$$

$$r_o = \frac{V_A}{I_D} = \frac{100}{0.5} = 200\ \text{k}\Omega$$

(c)



(d)

$R_{in} = 10\ M\Omega || 5\ M\Omega = 3.33\ M\Omega$

$$\frac{V_{gs}}{V_{sig}} = \frac{R_{in}}{R_{in} + R_{sig}} = \frac{3.33}{3.33 + 0.2} = 0.94$$

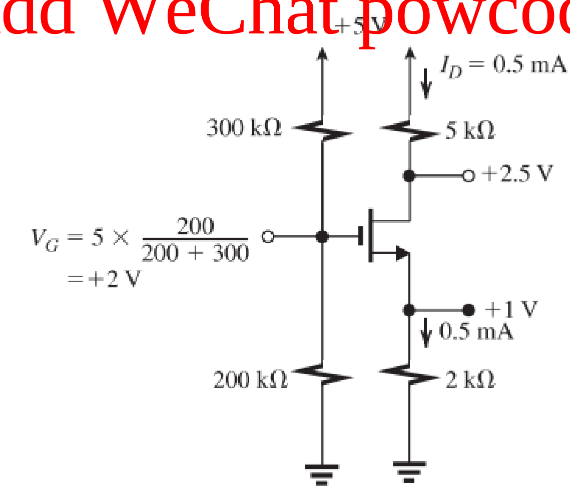
$$\frac{V_o}{V_{gs}} = -g_m(200||16||16) = -2 \times 7.69 = -15.38$$

$$\frac{V_o}{V_{sig}} = \frac{V_{gs}}{V_{sig}} \times \frac{V_o}{V_{gs}} = -0.94 \times 15.38 = -14.5$$

4.2:

Solution

(a) DC circuit is shown in Figure 2:



$V_G = 2 \times I_D = 2 \times 0.5 = 1 \ \rightarrow \ V_{GS} = 2 - 1 = 1\ V$

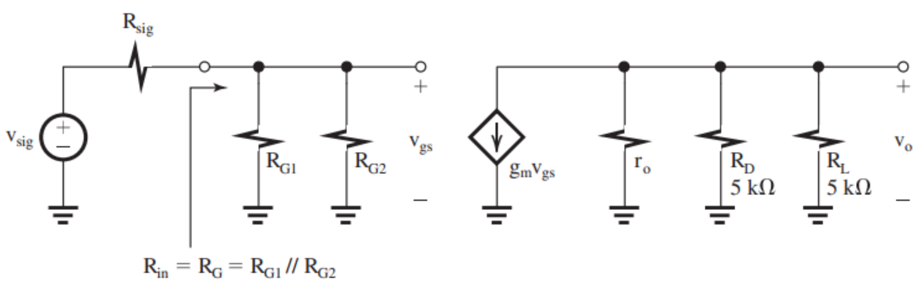
$V_{OV} = V_{GS} - V_t = 1 - 0.7 = 0.3\ V$

$V_D = 2.5\ V$ is higher than $V_G - V_t = 1.3\ V$ by 1.2 V, so the circuit operating in saturation.

$$I_D = \frac{1}{2}k_n V_{OV}^2 \rightarrow 0.5 = \frac{1}{2}k_n \times 0.3^2 \rightarrow k_n = 11.1\ \mathrm{mA/V^2}$$

(b)

The amplifier small-signal equivalent-circuit model is shown in figure 3:



$$R_{in} = R_{G1}||R_{G2} = 300||200 = 120\ \mathrm{k\Omega}$$

$$g_m = \frac{2I_D}{V_{OV}} = \frac{2\times 0.5}{0.3} = 3.33\frac{\mathrm{mA}}{\mathrm{V}}$$

$$r_o = \frac{V_A}{I_D} = \frac{50}{0.5} = 100\ \mathrm{K\Omega}$$

$$G_V = -\frac{R_{in}}{R_{in}+R_{sig}} g_m (r_o||R_D||R_L) = -\frac{120}{120+120} \times 3.33 \times (100||5||5) = -4.1$$

(C)

$V_G = 2\ \mathrm{V}, \quad V_D = 2.5\ \mathrm{V}$

$\widehat{V_{GS}} = 2 + \widehat{V_{gs}},$

$\widehat{V_{DS}} = 2.5 - |A_V|\widehat{V_{gs}}$, $|A_V| = g_m(r_o||R_D||R_L) = 8.1$

To remain in saturation,

$\widehat{V_{DS}} \geq \widehat{V_{GS}} - V_t$

$2.5 - 8.1\widehat{V_{gs}} \geq 2 + \widehat{V_{gs}} - 0.7$ if we have equality: $\widehat{V_{gs}} = \frac{2.5-1.3}{9.1} = 0.132\ \mathrm{V}$

So, the corresponding value of $\widehat{V_{gs}}$ is:

$\widehat{V_{sig}} = \widehat{V_{gs}}\left(\frac{120+120}{120}\right) = 2\times 0.132 = 0.264\ \mathrm{V}$. The corresponding amplitude at the output will be:

$|G_V|\widehat{V_{sig}} = 4.1 \times 0.264 = 1.08\ \mathrm{V}$

4.3:

Solution:

(a) DC bias: When all capacitors eliminated:

R_{in} at gate $= R_G = 10\ \text{M}\Omega$

$V_G = 0$, thus $V_S = -V_{GS}$, where V_{GS} can be obtained from: $I_D = \frac{1}{2} k_n V_{OV}^2 \rightarrow 0.4 = \frac{1}{2} \times 5 \times V_{OV}^2 \rightarrow$

$V_{OV} = 0.4\ \text{V} \quad \rightarrow V_{GS} = V_t + 0.4 = 0.8 + 0.4 = 1.2\ \text{V}$

$V_S = -1.2\ \text{V}$

$$R_S = \frac{-1.2 - (-5)}{0.4} = 9.5\ \text{k}\Omega$$

To remain in saturation, the minimum drain voltage must be limited to $V_G - V_t = 0 - 0.8 = -0.8\ \text{V}$. Now, to allow for 0.8 V negative signal swing, we must have:

$V_D = 0\ \text{V}$

$$R_D = \frac{5 - 0}{0.4} = 12.5\ \text{k}\Omega$$

(b)

$$g_m = \frac{2I_D}{V_{OV}} = \frac{2 \times 0.4}{0.4} = 2\ \frac{\text{mA}}{\text{V}}$$

$$r_o = \frac{V_A}{I_D} = \frac{40}{0.4} = 100\ \text{k}\Omega$$

(c)

If terminal Z connected to ground. The circuit becomes a CS amplifier,

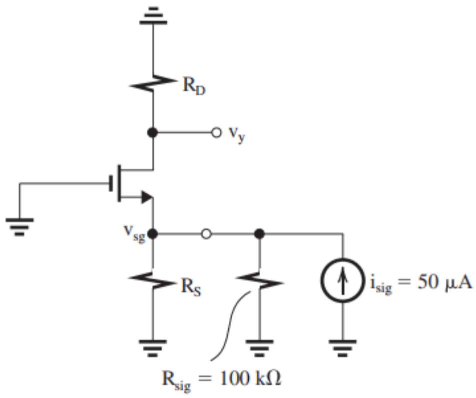
$$G_V = -\frac{V_y}{V_{sig}} = \frac{R_G}{R_G + R_{sig}} \times -g_m(r_o||R_D||R_L) = -\frac{10}{10+1} \times 2 \times (100||12.5||10) = -9.6$$

(d) If terminal Y is grounded, the circuit becomes a CD or source-follower amplifier:

$$\frac{V_Z}{V_x} = \frac{(R_S||r_o)}{(R_S||r_o) + \frac{1}{g_m}} = \frac{(9.5||100)}{(9.5||100) + \frac{1}{2}} = 0.946$$

Looking into terminal Z, we see $R_o = R_s||r_o||\frac{1}{g_m} = 9.5||100||\frac{1}{2} = 473\ \Omega$

(e) IF X is grounded, the circuit becomes a CG amplifier:



The figure shows the circuit prepared for signal calculations:

$$V_{sg} = i_{sig} \times \left[R_{sig}||R_S||\frac{1}{g_m}\right] = 50 \times 10^{-3}\left[100||9.5||\frac{1}{2}\right] = 0.024\ V$$

$$V_y = (g_m R_D)V_{sg} = (2 \times 12.5) \times 0.024 = 0.6\ V$$