EE 105  RS 9  Solutions

1. a) \( I_D = \frac{1}{2} \mu C_{ox} \left( V_{GS} - V_T \right) = 100 \mu A \quad V_{PB} = V_B \)

\[ \left( V_B - V_T \right)^2 = 0.8 \]

\[ V_S = 1.59 V \]

\( V_o = 5V - I_D R_L \)

\( I_{DR} = 0.5V \)

\( R_L = 95k\Omega \)

b) \( g_m = \mu C_{ox} \left( V_{GS} - V_T \right) = 222 \mu S \)

\[ a_n = g_m R_L = -5.5 \]

c) \( \lambda = 0 \rightarrow R_L = \infty \)

\( \lambda = 0 \rightarrow R_{out} = R_L \)

\[ \overline{V_I} \quad \overline{V_O} \]

\[ R_{in} \]

\[ R_{out} \]

\[ R_L \]

\[ V_O = V_T \]

\[ 5 - \frac{1}{2} \mu C_{ox} \left( V_{GS} - V_T \right)^2 R_L = V_{GS} - V_T \]

can be approximated by the quadratic formula

\[ a = 2 \mu C_{ox} \]

\[ b = - \frac{1}{2} \mu C_{ox} \]

\[ c = 0 \]

\[ x = \frac{-b \pm \sqrt{b^2 - 4ac}}{2a} \]

\[ x = \frac{1}{2} \mu C_{ox} \left( V_{GS} - V_T \right) = 1.11 V \quad V_{GS} = 1.81 V \]

\[ \text{max small signal amplitude in saturation} = V_{BS} = V_B = 220V \]

d) \( \lambda = 0.1 \)

\[ R_o = \frac{1}{\lambda I_D} \quad I_D = 100 \mu A \]

\[ R_o = 100k\Omega \]

\[ R_{out} = R_L / R_o = 20k \]

\[ a_n = g_m R_{out} = -4.44 \]

2. a) \( V_{GS} = -V_i \)

\[ \lambda = g_m V_{GS} - g_m V_i \]

\( V_o = V_o R_L = g_m V_i \) \( R_L \)

\[ f_o / f_i = g_m R_L \]

\( g_m = \mu C_{ox} \left( V_{GS} - V_T \right) \)

\( V_{GS} = 5V - V_B = 2V \)

\( V_{BS} - V_T = 1.3V \)

\( g_m = 325 \mu S \)

\( V_0 / V_i = 3.25 \)

b) \( V_{GS} = V_i = 0 \)

\( \pi = R_L / R_g \)

\[ V_{GS} = \lambda \left( R_L / R_g \right) \]

\[ V_{GS} = \lambda \left( R_L / R_g \right) \]

\[ R_{out} = \frac{R_L}{\lambda} \]

\[ \lambda / \mu = 0.764 \]
c) $v_{gs} = -v_i$

$$L_C = g_m v_{gs} = -g_m v_i$$

$$L_C/v_i = -g_m = -325 \mu S$$

d) $v_o = v_i R_L$

$$h_O/h_i = 1$$

$$v_i = h_i R_L$$

$$v_o/h_i = R_L = 10k\Omega$$

e) Small signal model

\[ V_{gs} \]

\[ V_i = V_{gs} R_C (h_i + s g_m v_{gs}) \]

\[ v_{gs} = v_i = -R_C (h_i + s g_m v_{gs}) \]

\[ v_{gs} (1 + g_m R_C) = -R_L \]

\[ v_{gs} = \frac{-R_L h_i}{1 + g_m R_C} \]

\[ v_{o/i} = \frac{R_L (1/g_m)}{h_i + R_C} = \frac{g_m}{h_i + R_C} \]

\[ = 2.34 \, k\Omega \]

f) $g_{m/A} = R_L$ since $h = 0$

$\approx 10k\Omega$

g) For a voltage input, a high input impedance is desired. For a current input, a Low input impedance is desired.

This amplifier has an input impedance of 2.34 k\Omega, falling in the middle. Either could be used, but it is probably more suitable to a current input. In general, $V_{gs}$ can be very small, so a common gate/biased amplifier is usually used with current input.

h) For a voltage output, a low output impedance is desired. For a current output, a high output impedance is desired.

This amplifier has output impedance of 10k\Omega, making it much more suitable to a current output.

For these reasons, common gate/biased amplifiers are usually used as current buffers, connecting two sets of a circuit but allowing current to flow with a gain close to 1.