1. Analyze the circuit shown below to determine the voltages \( V_D, V_G, V_S \) at all nodes and the currents through all branches \( I_1, I_2, I_G, I_D, I_S \). Let \( V_t = 2\) V and \( k_n'(W/L) = 180\mu A/V^2 \). Neglect the channel length modulation effect (i.e. \( \lambda = 0 \)).

2. If an AC source is applied at node \( V_G \), state the condition that needs to be satisfied for the ac input amplitude. (what is the small-signal condition?)

\[
I_D = I_S \\
I_G = 0 \\
-I_1(1k) + 8 - I_1(1k) = 0 \\
I_1 = \frac{8}{2k} = 4mA \\
V_G = I_2(1k) = 4mA(1k) = 4V \\
+V_S + 9 - I_S(2\Omega) = 0 \\
V_S = I_S(2\Omega) - 9
\]

\[
V_S = \frac{1}{3} \left( \frac{1}{12} \right) \left( \frac{4 - I_S(2\Omega) + 9 - 2}{11 - I_S(2\Omega)} \right) \\
I_S(n, m) = \left( \frac{1}{12} \right) (440I_S + 400I_S^2) \\
0 = 440I_S^2 - 11,551I_S + 121 \\
I_S = \frac{11,551 \pm \sqrt{(11,551)^2 - 4(121)(440)}}{2(440)} = 28.9, 0.0105 A \\
V_S = -8.79 \\
V_{GS} = 12.79 V
\]

\[
+I_D(10) - 9 + V_D = 0 \\
V_D = I_D(10) + 9 = (0.0105)(10) + 9 = 8.9 V \\
V_{DS} \geq V_{GS} - V_t \\
8.9 = V_D \geq (V_G - V_t) = 2V \\
\text{sat}
\]

2. \( V_{ac} < 2(V_{GS} - V_t) \)
\( V_{ac} < 2*(12.8-2) \)
\( V_{ac} < 2*(10.8) \)
Let $V_i=2V$, $k_n'(W/L)=180\mu A/V^2$, $I_D=I_S=10mA$, and $\lambda=0$.

2. Draw the small-signal equivalent circuit by assuming all capacitors become shorts.

3. Analyze the circuit to find $A_v=V_o/V_{in}$, $R_{in}(\text{remove } 10\Omega)$ and $R_{out}$

4. Explain how to make the input resistance, $R_{in}$ more ideal. State exact resistors that could be changed and how they could be changed. If this resistors were changed, how does this effect the gain?

5. How could the overall gain be increased. By making that change, what is the tradeoff or what do you have to be careful about?

6. Derive the frequency response transfer function for $V_o/V_{in}$ in terms of $C_{sig}$.

7. Find the value of $C_{sig}$ where the low 3db frequency value, $f_L = 10$ Hz (note this is in Hz – not rad/sec).

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4. $R_{in}$ can be increased to become more ideal $\Rightarrow$ Change into Mega Ohms. No effect on gain.

5. Increase $g_m$ which means to increase $I_D$. This will put the circuit at risk of moving out of the saturation region. Increasing the 20ohm will increase gain.