Problem 1.3 (2 points) Find the small-signal output resistance $R_o$ assuming the bias conditions in Problem 1.1.

Small Signal model:

\[ V_i = V_{gs1} = V_{gs2} \]

\[ r_{o1} = \frac{1}{\lambda I_0} = \frac{1}{(0.1)(75 \mu A)} = 133 \text{ k}\Omega \quad (116 \text{ k}\Omega \text{ for } I_0 = 78 \mu A) \]

\[ r_{o2} = r_{o1}, \quad R_{out} = r_{o1} || r_{o2} = \frac{66.5 \text{ k}\Omega}{58.6} \text{ k}\Omega \]

Problem 1.4 (3 points) Find the small-signal gain assuming the bias conditions in Problem 1.1.

\[ A_V = -G_m R_o = - (g_{m1} + g_{m2}) (r_{o1} || r_{o2}) \]

\[ g_{m1} = K_n (\frac{W}{L})_1 (V_{gs1} - V_{t1}) = (300 \mu A/V^2) (2) (1.5 V - 1 V) = 300 \mu A/V \]

\[ g_{m2} = K_p (\frac{W}{L})_2 (V_{gs2} - V_{t2}) = (100 \mu A/V^2) (6) (1.5 V - 1 V) = 300 \mu A/V \]

\[ A_V = 39.9 \times 40 \]

Problem 1.5 (2 points) Suppose that $\gamma$ is nonzero and that through source-well biasing, $V_{tn} = 1.25 \text{ V}$ and $V_{tp} = -1.25 \text{ V}$. How does this affect the small-signal gain (assume the bias conditions in Problem 1.1)?

\[ A_V = - (g_{m1} + g_{m2}) (r_{o1} || r_{o2}) = - \frac{g_{m1} r_{o1}}{r_{o1} + r_{o2}} + \frac{r_{o1} (g_{m2} r_{o2})}{r_{o1} + r_{o2}} \]

\[ g_{m1} r_{o1} = \frac{1}{\lambda} \left( \frac{2}{V_{gs1} - V_{t1}} \right) = \left( \frac{1}{0.1} \right) \left( \frac{2}{1.5 - 1} \right) = 40 \text{ for } V_{t1} = 1.0 \quad g_{m1} r_{o1} = 80 \text{ for } V_{t1} = 1.25 \]

\[ A_V \text{ doubles, } A_V \approx 80 \]