Small Signal Practice Problem Solutions

Notice, for the scope of EE 40, the solutions here ignore the Vbs and \( g_{mb} \).
Intuitively, you can assume \( r_o \) to be 0.5 M\( \Omega \) (high) while \( \frac{1}{g_m} \) is around 0.5k\( \Omega \) (low).

(a) \( R_L \) and \( R_S \) omitted for clarity.

\[
\begin{align*}
V_{G2} & \quad M_2 \\
\downarrow & \quad gm_2 V_{GS2} \quad r_o2 \\
& \quad V_{S2} \quad Rout \\
\text{Rin} \rightarrow & \quad gm_1 V_{GS1} \quad r_o1 \\
& \quad V_{S1} \\
\end{align*}
\]

\[
\begin{align*}
r_{in} &= \infty \\
r_{out} &= \left( \frac{1}{g_{m2}} \right) \quad \text{//} \quad r_{o1} \\
r_{in} &\text{ is high; thus, voltage in} \\
r_{out} &\text{ is low; thus, voltage out} \\
\text{Hence, amplifier is best characterized by a voltage amplifier.}
\end{align*}
\]

(b) Notice \( M_1 \) is a PMOS, so current is \( gm_1 V_{SG1} \)

\[
\begin{align*}
\text{Rin} \rightarrow & \quad V_{S1} \\
\downarrow & \quad gm_1 V_{SG1} \quad r_o1 \\
& \quad V_{G1} \\
& \quad Rout \\
\text{M}_1 \quad & \quad \text{Vs2} \\
\end{align*}
\]

\[
\begin{align*}
r_{in} &= \frac{r_{o1}}{g_{m1}} \quad \text{//} \quad \frac{R_L}{g_{m2}} \\
&\approx \frac{r_{o1}}{g_{m1} \cdot r_{o1}} = \frac{1}{g_{m1}} \\
r_{out} &= \frac{1}{g_{m2}} \quad \text{//} \quad \left( \frac{r_{o1}}{g_{m1} \cdot r_{o1}} \cdot R_S \right) \cdot R_S \\
r_{out} &\approx \frac{1}{g_{m1}} \\
\text{r}_{in} &\text{ is low; thus, current in} \\
r_{out} &\text{ is low; thus, voltage out} \\
\text{Hence, amplifier is best characterized by a transresistance amplifier}
\end{align*}
\]
The lowest that $r_{out}$ can be in value is when $R_X = 0$. Hence, $r_{out} \geq \frac{r_o}{2}$

$r_{in}$ is high; thus, voltage in
$r_{out}$ is high; thus, current out

Hence, amplifier is best characterized by a transconductance amplifier
The lowest that \( r_{\text{out}} \) can be in value is when \( 0 = R_L \). Hence, \( r_{\text{out}} \geq r_{\text{in}} \) is low; thus, current in
\( r_{\text{out}} \) is high; thus, current out
Hence, amplifier is best characterized by a current amplifier

\[
\begin{align*}
\frac{1}{r_{\text{in}}} &= \infty \\
r_{\text{out}} &= \frac{1}{g_{m2}} \quad (r_{\text{in}} + \frac{1}{g_{m2}}) \\
r_{\text{out}} &\approx \frac{1}{g_{m2}}
\end{align*}
\]

\( r_{\text{in}} \) is high; thus, voltage in
\( r_{\text{out}} \) is low; thus, voltage out
Hence, amplifier is best characterized by a voltage amplifier
Hence, amplifier is best characterized by a voltage amplifier
$r_{in} = \infty$

$r_{out} = r_{o2} \parallel \frac{r_{o1} + r_{o2}}{g_{m1} \cdot r_{o1}} = r_{o2} \parallel \frac{2 \cdot r_{o1}}{g_{m1} \cdot r_{o1}}$

$r_{out} \approx \frac{2}{g_{m1}}$

$r_{in}$ is high; thus, voltage in

$r_{out}$ is low; thus, voltage out

Hence, amplifier is best characterized by a voltage amplifier