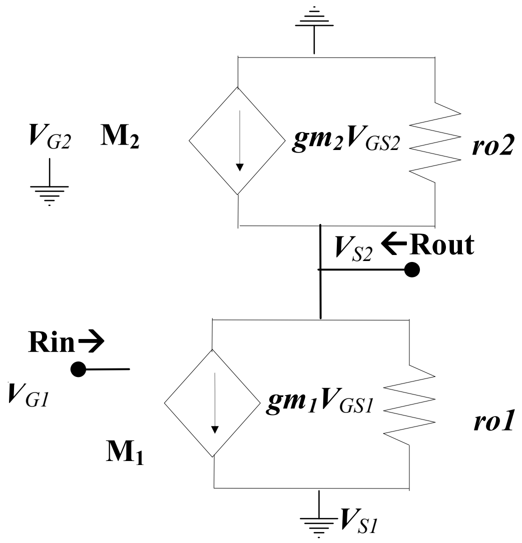
# Small Signal Practice Problem Solutions

Notice, for the scope of EE 40, the solutions here ignore the Vbs and $g_{mb}$.

Intuitively, you can assume ro 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.**




**(a)**

$$r_{in} = \infty$$

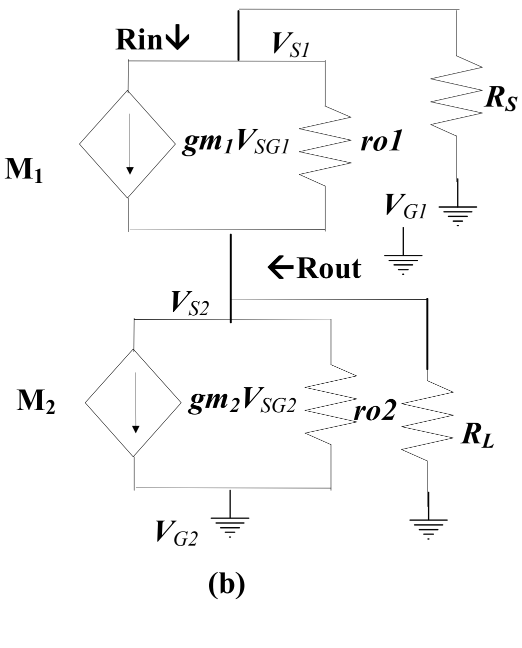
$$r_{out} = (\frac{1}{g_{m2}}) \ // \ r_{o1}$$

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

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

Hence, amplifier is best characterized by a voltage amplifier.

**(b) Notice $M_1$ is a PMOS, so current is $gm_1V_{SG1}$**




**(b)**

$$r_{in} = \frac{r_{o1} + (\frac{1}{g_{m2}} \ // \ R_L)}{g_{m1} \cdot r_{o1}} \approx \frac{r_{o1}}{g_{m1} \cdot r_{o1}} = \frac{1}{g_{m1}}$$

$$r_{out} = \frac{1}{g_{m2}} \ // \ (r_{o1} + R_S + g_{m1} \cdot r_{o1} \cdot R_S)$$

$$r_{out} \approx \frac{1}{g_{m2}}$$

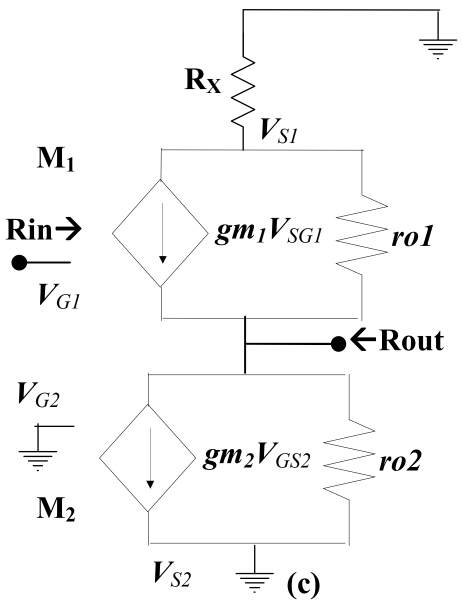
$r_{in}$ is low; thus, current in

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

Hence, amplifier is best characterized by a transresistance amplifier

**(c)**




$r_{in} = \infty$

$r_{out} = (r_{o1} + R_X + g_{m1} \cdot r_{o1} \cdot R_X) \ // \ r_{o2}$

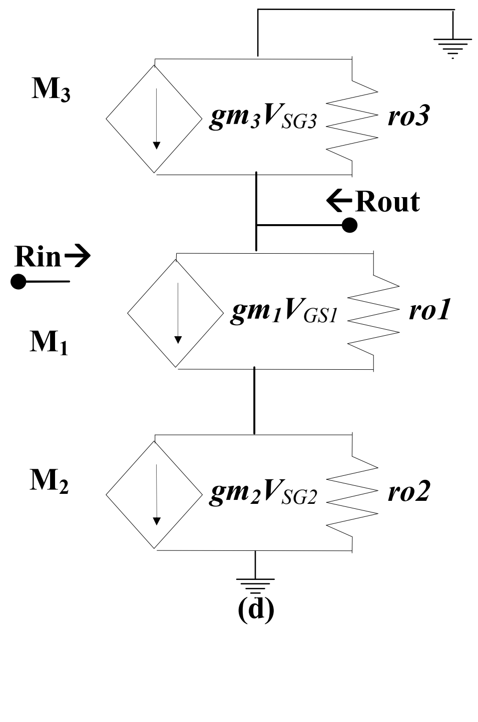
The lowest that $r_{out}$ can be in value is when $R_X = 0$. Hence, $r_{out} \geq \frac{r_o}{2}$

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

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

Hence, amplifier is best characterized by a transconductance amplifier

**(d)**




$r_{in} = \infty$

$r_{out} = r_{o3} \ // \ (r_{o1} + \frac{1}{g_{m2}} + g_{m1} \cdot r_{o1} \cdot \frac{1}{g_{m2}})$

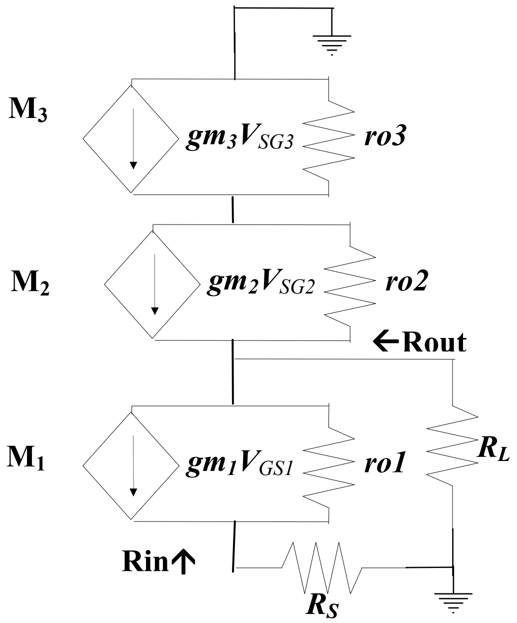
$r_{out} \approx r_{o3} \ // \ (2 \cdot r_{o1})$

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

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

Hence, amplifier is best characterized by a transconductance amplifier

**(e)**




$$r_{in} = \frac{r_{o1} + (r_{o2} + r_{o3} + g_{m2} \cdot r_{o2} \cdot r_{o3}) \ // \ R_L}{g_{m1} \cdot r_{o1}}$$

The value for $r_{in}$ depends heavily on $R_L$. Let's assume that $R_L << r_o$. Hence,

$$r_{out} = (r_{o1} + R_S + g_{m1} \cdot r_{o1} \cdot R_S) \ // \ (r_{o2} + r_{o3} + g_{m2} \cdot r_{o2} \cdot r_{o3})$$

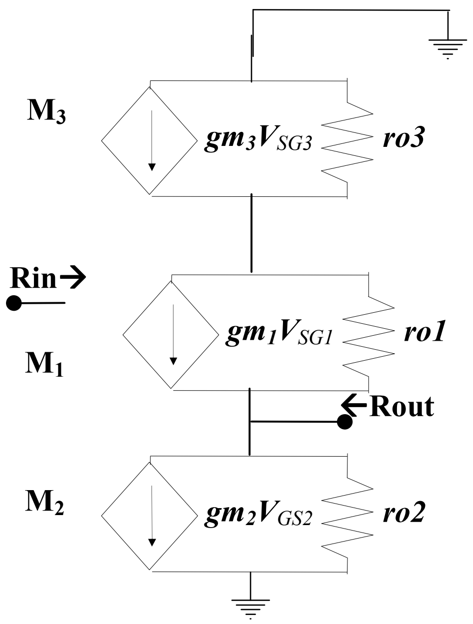
The lowest that $r_{out}$ can be in value is when $R_S = 0$. Hence, $r_{out} \geq r_{o1}$

$r_{in}$ is low; thus, current in

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

Hence, amplifier is best characterized by a current amplifier

**(f)**




$r_{in} = \infty$

$$r_{out} = \frac{1}{g_{m2}} \ // \ (r_{o1} + \frac{1}{g_{m3}} + g_{m1} \cdot r_{o1} \cdot \frac{1}{g_{m3}})$$

$$r_{out} \approx \frac{1}{g_{m2}}$$

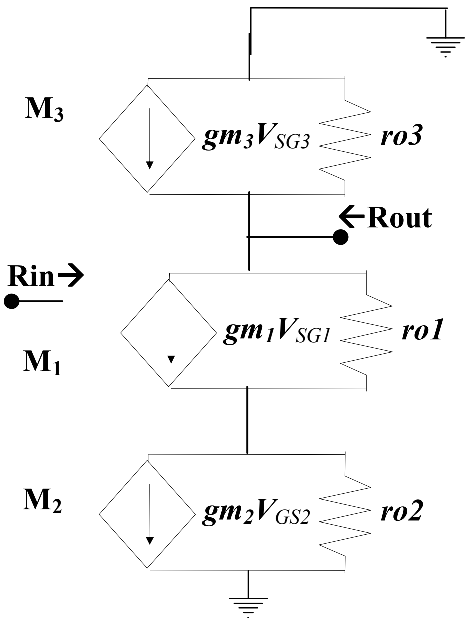
$r_{in}$ is high; thus, voltage in

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

Hence, amplifier is best characterized by a voltage amplifier

**(g)**




$$r_{in} = \infty$$

$$r_{out} = \frac{1}{g_{m3}} \;//\; \frac{r_{o1} + \frac{1}{g_{m2}}}{g_{m1} \cdot r_{o1}}$$

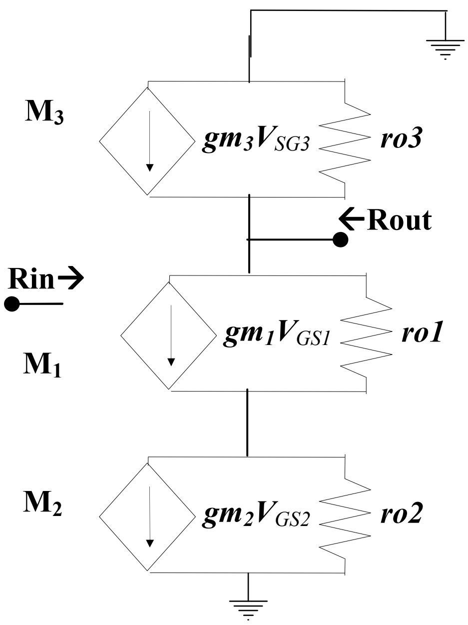
$$r_{out} \approx \frac{1}{g_{m3}} \;//\; \frac{1}{g_{m1}}$$

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

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

Hence, amplifier is best characterized by a voltage amplifier

**(h)**




$$r_{in} = \infty$$

$$r_{out} = r_{o3} \;//\; (r_{o1} + r_{o2} + g_{m1} \cdot r_{o1} \cdot r_{o2})$$

$$r_{out} \approx r_{o3}$$

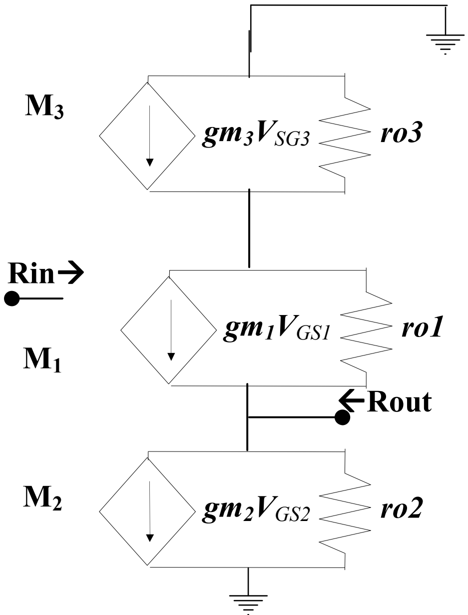
$r_{in}$ is high; thus, voltage in

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

Hence, amplifier is best characterized by a transconductance amplifier

**(i)**




$r_{in} = \infty$

$r_{out} = r_{o2} \; // \; \frac{r_{o1} + r_{o3}}{g_{m1} \cdot r_{o1}} = r_{o2} \; // \; \frac{2 \cdot r_{o1}}{g_{m1} \cdot r_{o1}}$

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

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

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

Hence, amplifier is best characterized by a voltage amplifier

Reference

Meghdad Hajimorad ("Amin"). Year 2004

↳Original version for EE 105 Midterm Review.

Bill Hung. 16 August 2006

↳Simplified and added-picture version for EE 40 Final Review