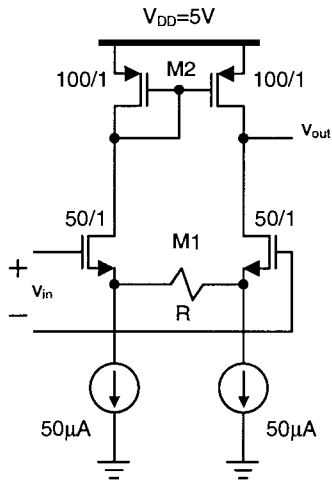


2. [20 pts total] What is the input to output small-signal gain in the amplifier shown below? Do this by finding Norton-equivalent G_m (expression only) [10pts] and R_{out} (expression only)[10pts].

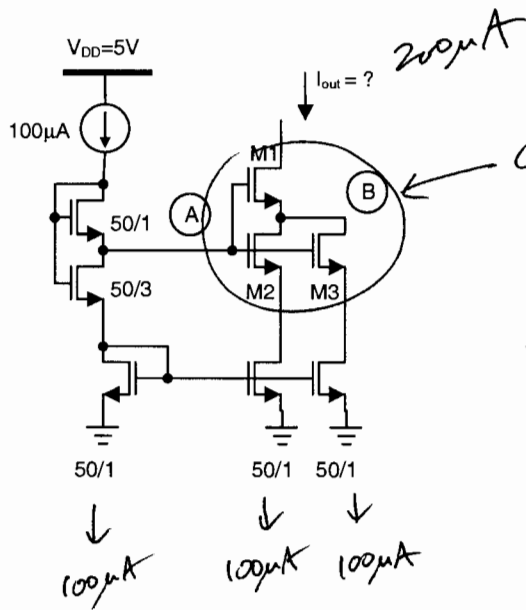


$$G_m = \frac{g_{m1}}{1 + g_{m1} \left(\frac{R}{2} \right)}$$

$$R_{out} \approx r_{o2} \parallel \left[\frac{r_{o1} + r_{o1} g_{m1} \left(R + \frac{1}{g_{m1}} \right)}{2} \right]$$

$$= r_{o2} \parallel \left[r_{o1} + \frac{r_{o1} g_{m1} R}{2} \right]$$

3. [20 pts total] Specify appropriate transistor dimensions (just use $L=1$) for M1/M2/M3 [9pts]. What is the output current I_{OUT} [3pts]? Find the voltage (numerical) at node A [4pts], and corresponding voltage (numerical) at node B [4pts].



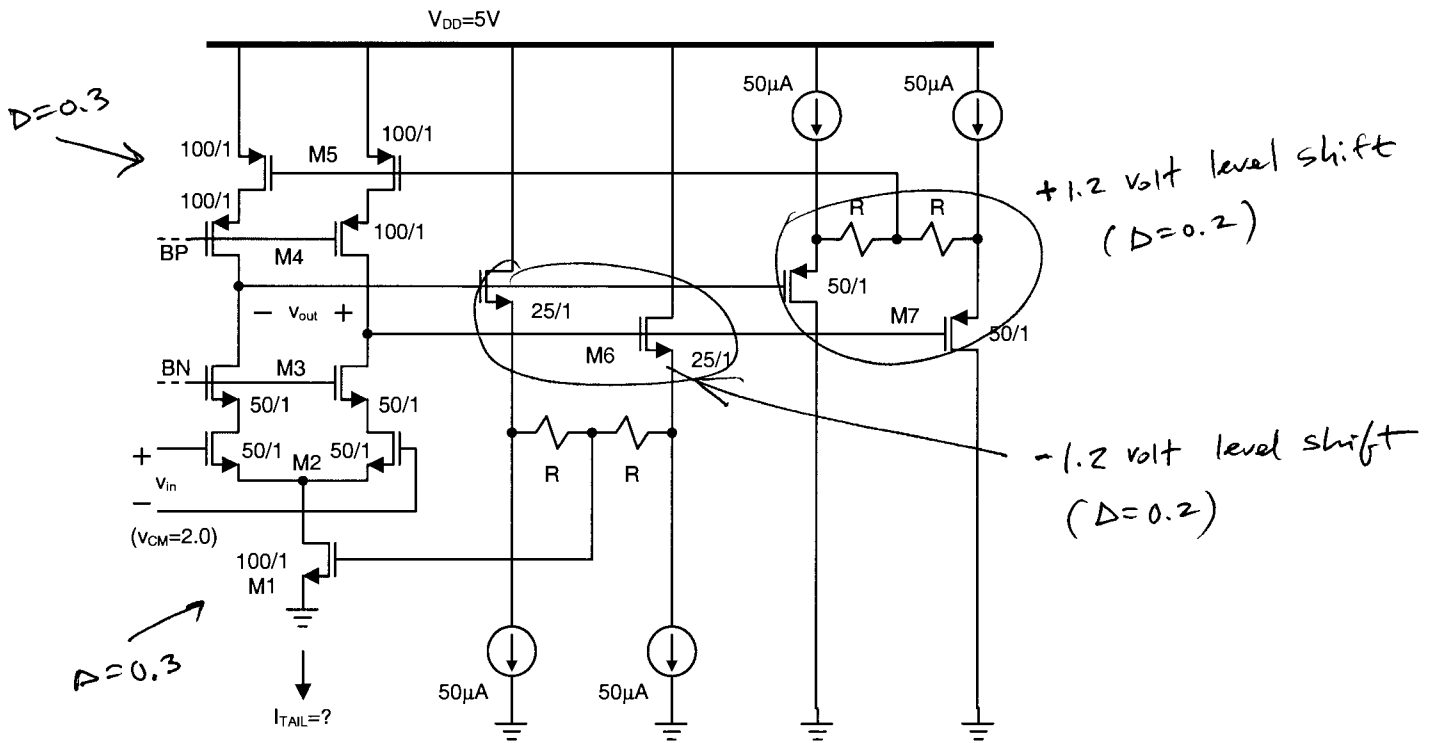
Composite should be " $\frac{100}{1}$ " device.
 $M2 = M3 = \frac{100}{1} \times M1 = \frac{200}{1}$ will work.

$$V_{(A)} = V_T + 2\Delta = 1.4 \text{ volt}$$

$$V_{(B)} = V_{(A)} - \left(V_T + \frac{1}{\sqrt{2}} \Delta \right) \cong 0.26 \text{ volt}$$

↑
for $\frac{200}{1}$ device

4. [25 pts total] Find the resulting output common-mode voltage (numerical) in the opamp below [10pts]. What is the resulting tail current I_{TAIL} [5pts]? Find the small-signal common-mode feedback loop gain (expression only) [10pts].



"n" & "p" are scaled "2:1" (balanced), thus $V_{CM,out} = 2.5V$

$$D_{M1} = 0.3 \rightarrow I_{tail} = \frac{1}{2} (100 \times 10^{-6}) \frac{100}{1} (0.3)^2 = 450 \mu A$$

$$CMFB_{loopgain} = (g_{m1} + 2g_{m5}) \left(\frac{r_{o4} g_{m4} r_{o5}}{2} \parallel \frac{r_{o3} g_{m3} r_{o2} g_{m2} [2r_{o1}]}{2} \right)$$