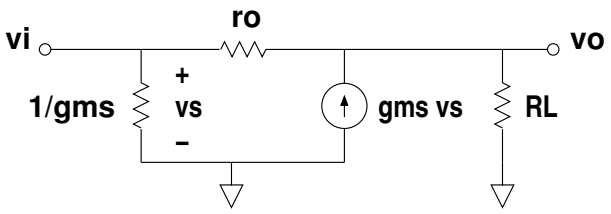
ENGI 5131
Sample Problems for Final — Winter 2016

ACM parameters: $I_{SQn} = 280$ nA, $V_{thn} = 0.5$ V, $|\partial L/\partial V_{DS}|_n = 0.03$ μm/V, $I_{SQp} = 80$ nA, $V_{thp} = -0.55$ V, $|\partial L/\partial V_{DS}|_p = 0.04$ μm/V, $L_D = 0$ and $n_n = n_p = 1.3$. Assume $L \geq 1$ μm for good matching.

1. Explain what is the *Latchup* phenomenon and what must be done in the circuit layout to prevent it.

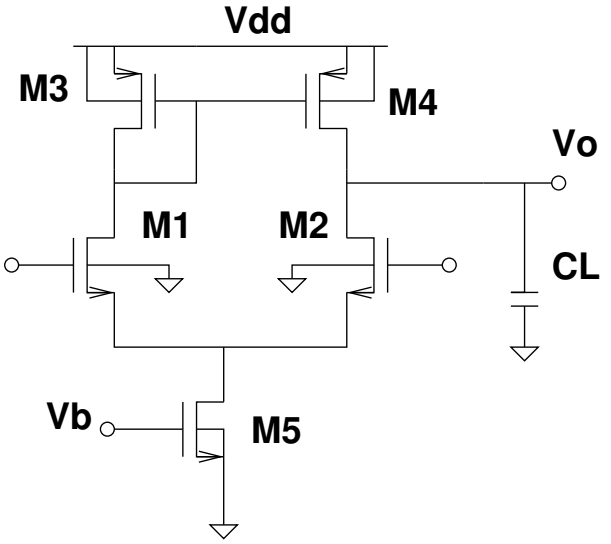
2. Symbolically, derive the small-signal gain (v_o/v_i) for the following amplifier. Simplify the result for $r_o \gg 1/g_{ms}$.



3. The differential amplifier shown in the figure has been designed to operate as follows: $i_{f1} = i_{f2} = 15$, $i_{f3} = i_{f4} = 140$, $i_{f5} = 200$. Other circuit paramenters: $V_{DD} = 2$ V, $C_L = 0.5$ pF. Supply voltage is $V_{DD} = 3$ V. Make reasonable assumptions for any missing data. Justify your answers and derive expressions for full marks.

   (a) Calculate the input common-mode voltage range.

   (b) Calculate the output voltage range as a function of the input common-mode voltage.



4. Estimate the maximum input-referred offset voltage of the amplifier of the previous problem assuming M1 and M2 have a mismatch in V_{th} of 1.5 mV and a mismatch in I_{SQ} of 3 nA.

5. Design a differential amplifier based on the schematic for the previous problem with the following specifications: $V_{DD} = 3.3$ V differential gain must be greater or equal than 1000, CMRR *ge* 70 dB, tail current is 10 μA and input common-mode range must include V_{DD}.

6. Using the same transistor aspect ratios of the previous problem and same biasing current, ($M_3 \equiv M_{3'}$ and $M_4 \equiv M_{4'}$), design M_5 and $M_{5'}$ in the schematic below to increase the gain to 1300 and an output voltage range lower limit of 0.2 V.