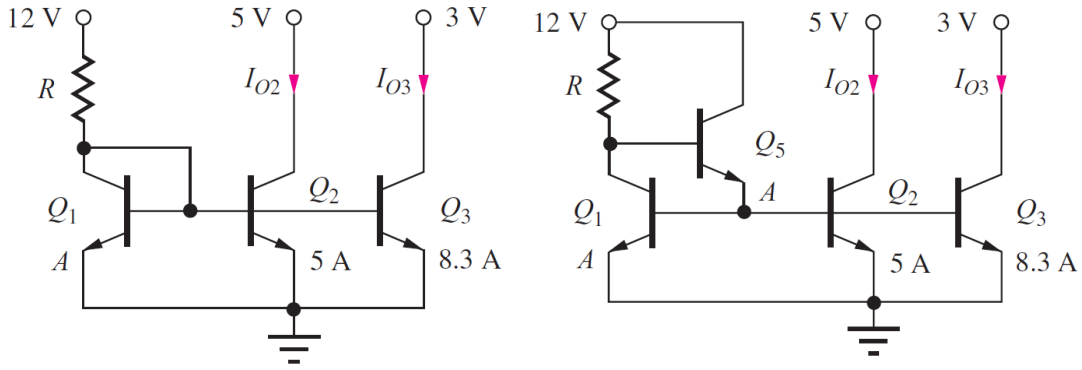
PROBLEM SET #5

Issued: Tuesday, Feb. 21, 2012

Due: Tuesday, Feb.28, 2012, 6:00 p.m. in the EE 140 homework box in 240 Cory

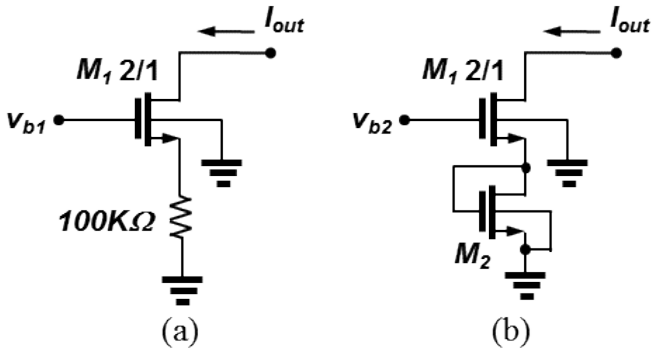
1. For the two current sources shown in Fig. PS5.1, assume R = 68kΩ, β_f = 50, V_A = 60V, and $V_{BE(on)}$ = 0.7V, calculate the output currents (I_{O2} and I_{O3}) and the corresponding output resistances for each circuit. For the circuit in Fig. PS5.1(b), assume $V_A = \infty$.



(a) (b)

Fig. PS5.1

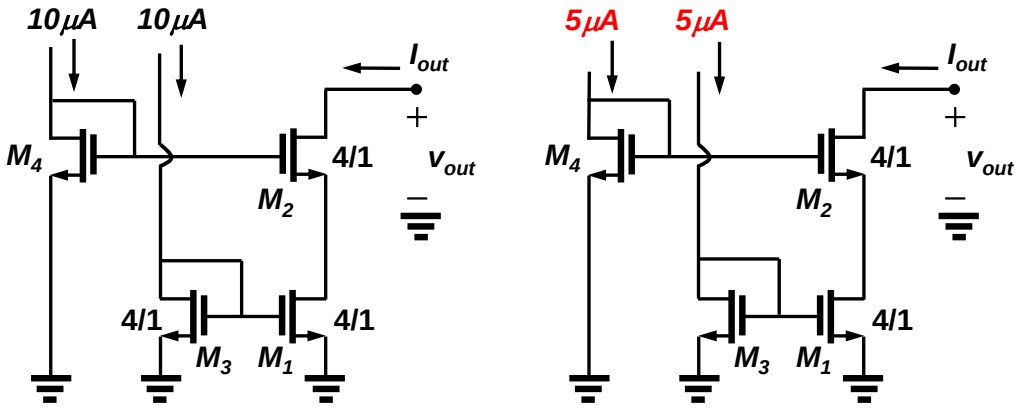
2. For the current source circuit shown in Fig. PS5.2, assume V_t = 0.7V, k' = 110μA/V^2, γ = 0.4, λ = 0.04, $2|\phi_f|$ = 0.7.
   a) For Fig.PS5.2 (a), calculate the bias V_{b1} in order to achieve an output current I_{out} = 10μA.
   b) Continuing from part a), calculate the output resistance and the minimum output voltage required to keep the transistor in saturation in the circuit of Fig. PS5.2 (a).
   c) Suppose the source degenerated resistor in Fig. PS5.2 (a) is replaced by a transistor M_2 as shown in Fig. PS5.2 (b). Design the size of M_2 to achieve I_{out} = 10μA with the same output resistance as the circuit in Fig. PS5.2 (a). Calculate the required bias voltage V_{b2}. What is the minimum output voltage required to keep the transistors in saturation?



(a) (b)

Fig. PS5.2

3. For the current source circuit shown in Fig. PS5.3, assume $V_t = 0.7$V, $k' = 110\mu$A/V^2, $\gamma = 0.4$, $\lambda = 0.04$, $2|\phi_f| = 0.7$.
   a) For Fig. PS5.3 (a), design the size of M_4 to achieve the minimum output voltage $2V_{OV,M1}$. (You may ignore body effect for this part.)
   b) From part a), considering the body effect, what is the minimum output voltage that ensures all transistors are in saturation region? What is the output resistance?
   c) Suppose the reference current sources are reduced by half as shown in Fig. PS 5.3 (b). Size M_3 and M_4 to achieve the same output current as that of the circuit in Fig. PS 5.3 (a).



(a) (b)

Fig. PS5.3

4. In the circuit of Fig. PS5.4, a source follower using a wide transistor M_4 and a small bias current I_1 is inserted in series with the gate of M_3 so as to bias M_2 at the edge of saturation. Assuming M_0-M_3 are identical with a size of (W_0/L_0) and $\lambda \neq 0$, write an expression for I_{out} / I_{REF} for a) $\gamma = 0$; b) $\gamma \neq 0$.

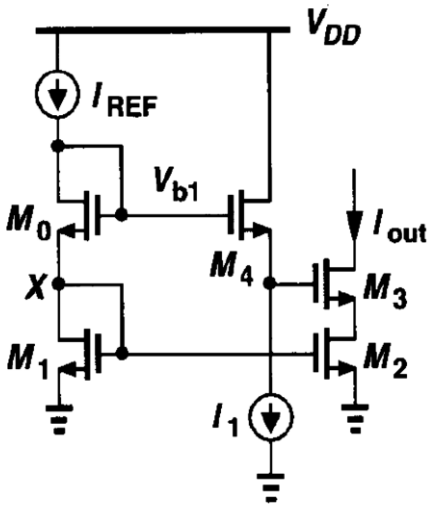


Fig. PS5.4