Nanyang Technological University
School of Electrical & Electronic Engineering
EE2002 Analog Electronics – Tutorial 09

1. (a) Let the drain currents of the 2 transistors in Figure 1a be I_{D1} and I_{D2} respectively. Find the ratio I_{D2}/I_{D1} for the ideal case where (i) $\lambda = 0$ and the non-ideal case (ii) $\lambda = 0.015\ V^{-1}$ respectively. Does this ratio depend on the magnitude of V_{GS}? Do the absolute values of I_{D1} and I_{D2} depend on V_{GS}?
(Ans: (i) $I_{D2}/I_{D1} = 2$ (ii) $I_{D2}/I_{D1} = 1.947$. The ratio is independent of V_{GS} but absolute values depend on V_{GS}.)

   (b) Figure 1b shows a current mirror where the V_{GS} in the earlier picture is generated by a diode connected transistor M_0 that is identical to M_1. Derive the algebraic expression for the ratio I_{D1}/I_{D0} for the ideal case where (i) $\lambda = 0$ and the non-ideal case (ii) $\lambda = 0.015\ V^{-1}$ respectively.
(Ans: (i) $I_{D1}/I_{D0} = 1$ (ii) $I_{D1}/I_{D0} = 1.15/(1+.015*V_{GS})$)

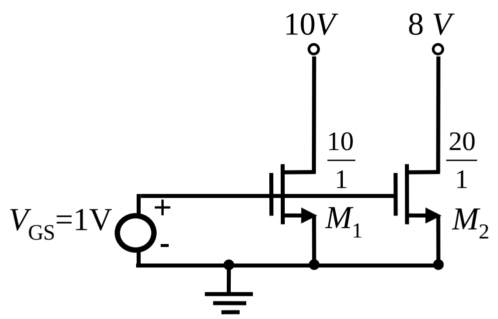

Figure 1a

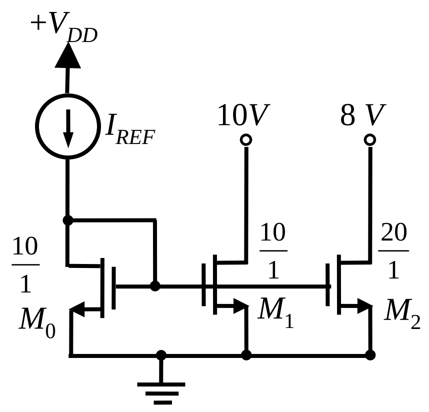

Figure 1b

2. What are the output currents and output resistances for the current sources in Figure 2, if $I_{REF} = 30\ \mu A$, $K_n' = 25\ \mu A/V^2$, $V_{TN} = 0.75$ V and $\lambda = 0.015\ V^{-1}$?
(Ans: *84.3μA, 909kΩ; 164μA, 455kΩ; 346μA, 227kΩ*)

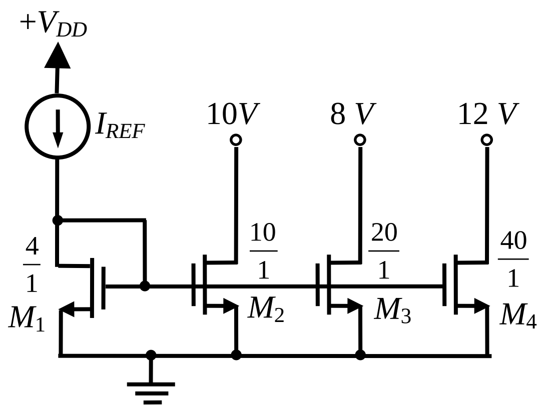

Figure 2

3. (a) What is the reference current I_o in Figure 3(a) if R=43 kΩ and V_{EE}=5V? What is the current if V_{EE}=7.5V? Assume V_{BE}= 0.7V, base currents are negligible and both transistors are identical.

   (b) What is the reference current I_o in Figure 3(b) if K_n= K_p = 400 μA/V^2, V_{TN}= -V_{TP}= 1 V, V_{DD}= 0V and V_{ss}=5V? What is the current when V_{ss}= 7.5V? Assume all NMOS transistors are identical.

   (Ans: (a) *100μA, 158μA* (b) *88.9μA, 450μA*)

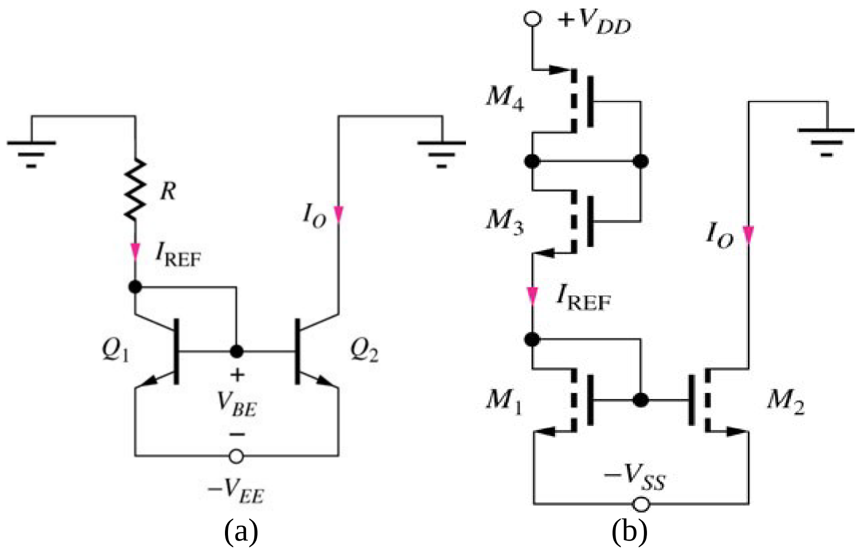

Figure 3