EE 140/240A **ANALOG INTEGRATED CIRCUITS** **FALL 2013**

C. NGUYEN

PROBLEM SET #1A

Issued: Monday, Oct.14th, 2013

Due: Friday, Nov. 8th, 2013, 8:00 a.m. in the EE 140/240A homework box

1. Determine the value of sensitivity S of output current to supply voltage for the circuit in Fig. PSA1.1, where $S = (V_{CC}/I_{OUT})(\partial I_{OUT}/\partial V_{CC})$.

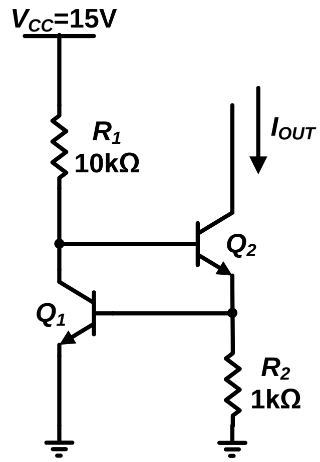


Fig. PSA1.1

2. Fig. PSA1.2 depicts a self-biasing V_t reference circuit capable of providing bias currents nearly independent of supply voltage.

(a) Provide expressions for the DC output current I_{OUT} and bias currents I_{BIAS1} and I_{BIAS2} in terms of circuit elements and transistor parameters and calculate numerical values. Ignore body effect and channel length modulation.

(b) Calculate the ratio of small-signal variations in I_{OUT} to small-signal variations in V_{DD} at low frequencies, i.e., find the gain from v_{dd} to i_{out}. Ignore body effect but include finite transistor r_o in this calculation.

MOS parameters:

$|V_{th}|$=0.5V, k_n'=200μA/V^2, k_p'=100μA/V^2, λ=0.05V^{-1}, V_{DD}=3V, R=1.75kΩ,

$(W/L)_1$=12.5μm/0.25μm, $(W/L)_2$=6.25μm/0.25μm, $(W/L)_3$=31.25μm/0.25μm,

$(W/L)_4$=6.25μm/0.25μm, $(W/L)_5$=12.5μm/0.25μm, $(W/L)_6$=15.5μm/0.25μm.

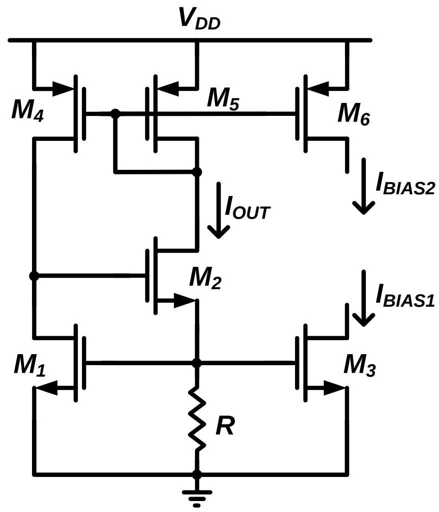


Fig. PSA1.2

3. The circuit of Fig. PSA1.3 is used to provide a bandgap reference voltage V_{OUT}. In the circuit, R_1 = 1kΩ and R_2 = 2kΩ. For simplicity, assume that M_1-M_2 and M_3-M_4 are identical pairs with $(W/L)_{1\text{-}4}$ = 50/0.5 and $I_{D1} = I_{D2}$ = 50μA. Also assume $\lambda = \gamma = 0$, and Q_3 is identical to Q_1 whereas Q_2 consists of n unit transistors identical to Q_1 and Q_3, in parallel. For calculations, assume $\partial V_{BE}/\partial T$ = -1.5mV/°K and $\partial V_T/\partial T$ = +0.087mV/°K at room temperature.

(a) If $(W/L)_5$ is the same as $(W/L)_{1\text{-}4}$, determine the value of n such that V_{OUT} has zero TC_f at room temperature.

(b) If $(W/L)_5$ is 4× that of $(W/L)_{1\text{-}4}$, again determine the value of n such that V_{OUT} has zero TC_f at room temperature.

(c) Now, assume $(W/L)_5$ is α× that of $(W/L)_{1\text{-}4}$, calculate α and n values so that V_{OUT} has zero TC_f at room temperature with minimum α+n value. (Numerical solution is allowed.)

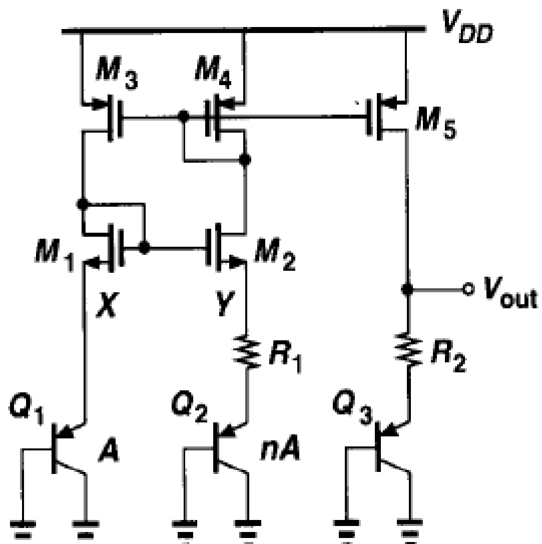
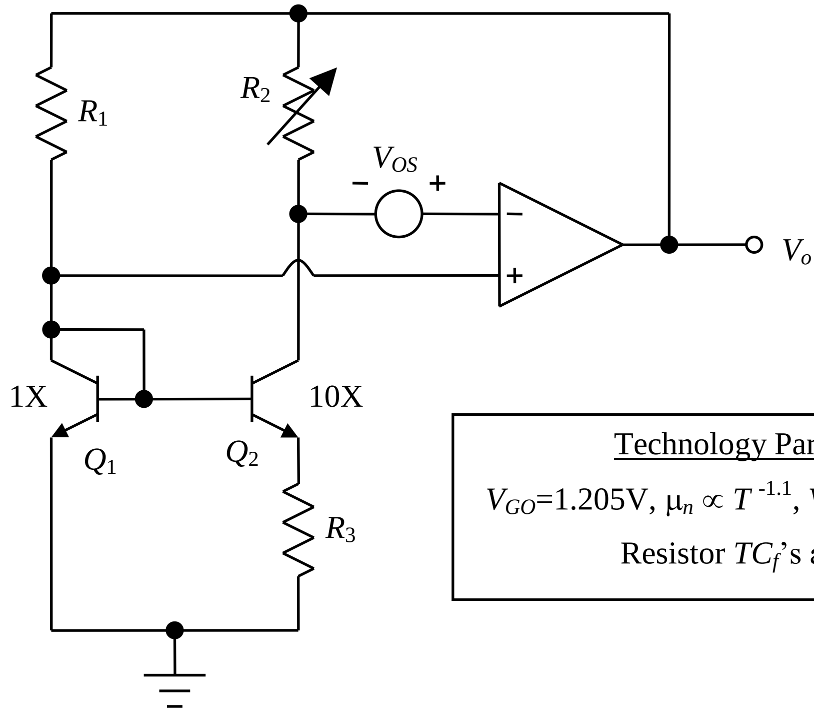


Fig. PSA1.3

4. For the voltage reference below in Fig. PSA1.4, resistor R_2 is trimmed after fabrication to produce an output voltage that for the particular technology used (and assuming an ideal op amp) is known to give a zero output voltage temperature coefficient TC_f at room temperature (300K). In solving this problem, assume that $R_1 \approx R_2$, even after trimming, since the trim range will normally be small. (Note that you do not need to know the values of the resistors to do this problem.)



Technology Parameters:

V_{GO}=1.205V, $\mu_n \propto T^{-1.1}$, V_T=26mV @ 300K

Resistor TC_f's are zero.

Fig. PSA1.4

(a) Assuming an ideal op amp (i.e., with V_{OS} = 0V), determine the output voltage V_o that sets the output voltage temperature coefficient to zero at room temperature.

(b) Suppose now that the op amp actually has an offset voltage V_{OS} of 3mV. Calculate the resulting deviation from the actual zero TC_f output voltage that would result after R_2 is trimmed to make V_o equal to the answer of part (a).

(c) What is the TC_f of V_o at room temperature when V_{OS} is 3mV and R_2 is trimmed as in part (b)?