PROBLEM SET #4

Issued: Thursday, Feb.14, 2013

Due (at 8 a.m.): Friday, Feb. 22, 2013, in the EE 140/240A HW box near 125 Cory.

1. Fig. PS4.1 shows different active loads being used in analog circuits.

(a) Calculate the DC operating points including the current flowing through each branch and DC voltage at each node and transistor small-signal parameters (i.e. g_m, r_o, C_{gs}, C_{gd})

(b) Provide expressions and calculate the numerical values for the output resistance, R_{out}; and gain, v_{out}/v_{in}.

(c) Estimate the high-frequency cut-off f_H of the amplifiers.

MOS parameters:

V_{GS1}=1V, $|V_{th}|$=0.5V, k_n'=200μA/V^2, k_p'=100μA/V^2, λ=0.05V^{-1}, V_{DD}=3V, V_{B1}=2.7V, V_{B2}=V_{B3}=1.5V, C_{ox}=4fF/μm^2, C_{ol}=3fF, C_{sb}= C_{db}=5fF;

$(W/L)_1$=10μm/0.25μm, $(W/L)_{2,3}$=2.5μm/0.25μm, $(W/L)_4$=10μm/0.25μm;

$(W/L)_{5,6}$=5μm/0.25μm, $(W/L)_7$=4.5μm/0.25μm, $(W/L)_8$=0.5μm/0.25μm.

Note that the active load in circuit (iii) is depletion-mode NMOS and hence its threshold voltage is negative (i.e. V_{th4}=-0.5V).

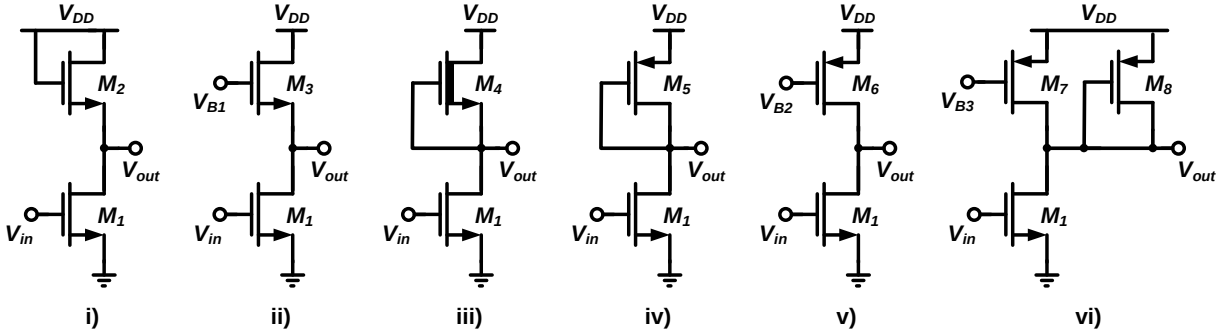

Fig. PS4.1

2. Due to a manufacturing error, resistor R_P has appeared in series with the base of Q_{REF} in Fig. PS4.2. If I_1 is 10% greater than its nominal value, express the value of R_P in terms of other circuit parameters. Assume Q_{REF} and Q_1 are identical.

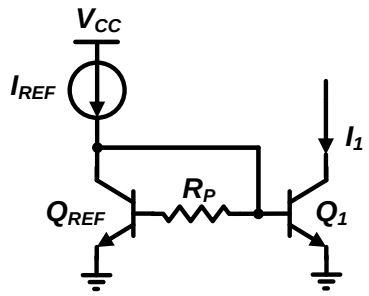

Fig. PS4.2

3. Determine the value of R_P in the circuit of Fig. PS4.3 such that $I_1 = I_{REF}/2$. With this choice of R_p, does I_1 change if the threshold voltage of both transistors increases by ΔV?

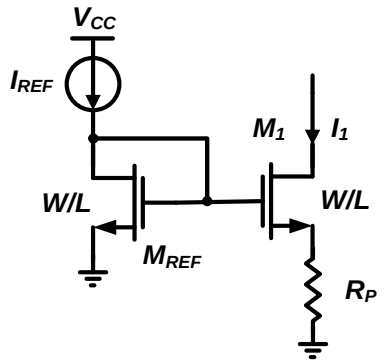

Fig. PS4.3

4. Fig. PS4.4 depicts a simple amplifier circuit using active load. Assume that the output voltage is set at 1V.

(a) Calculate the DC operating points including the current flowing through each branch and DC voltage at each node.

(b) Calculate transistor small-signal parameters (i.e. g_m, g_{mb}, r_o, C_{gs}, C_{gd}).

(c) Provide expressions and calculate the numerical values for the output resistance, R_{out}; and gain, v_{out}/v_{in}.

(d) Estimate the high-frequency cut-off f_H of the amplifier.

MOS parameters: (for both NMOS and PMOS, unless otherwise stated)

$|V_{th}|$=0.5V, k_n'=200μA/V^2, k_p'=100μA/V^2, V_{DD}=2.5V,

λ=0.05V^{-1}, χ=0.1, C_{ox}=5fF/μm^2, C_{ol}=3fF, C_{sb}= C_{db}=5fF

$(W/L)_1$=2.25μm/0.25μm, $(W/L)_2$=4.5μm/0.25μm, $(W/L)_{3,4}$=3.75μm/0.25μm,

$(W/L)_{5,6}$=11.25μm/0.25μm, $(W/L)_7$=37.5μm/0.25μm ,$(W/L)_8$=7.5μm/0.25μm,

$(W/L)_9$=6.25μm/0.25μm, $(W/L)_{10}$=12.5μm/0.25μm, $(W/L)_{11}$=11.25μm/0.25μm.

Hint: Since the current into the transistor M_1 is fixed by the ideal current source, there is no change at its gate voltage, i.e. it is *ac* ground. You can assume the same is true for M_3 and M_4, too.

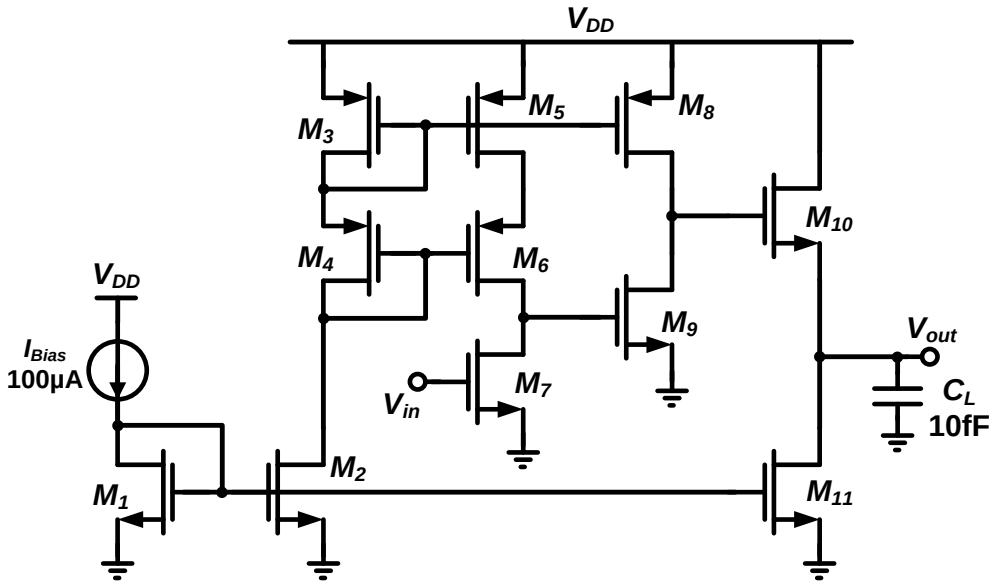
VDD
M5
M8
M3
M10
M4
M6
VDD
M9
Vout
IBias
100µA
Vin
M7
CL
10fF
M2
M1
M11

Fig. PS4.4