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Mike Chen	**(Due 4/06/04)**	**Spring 2004**

1) Given the differential amplifier in figure 1, assuming $(W/L)_3 = (W/L)_4 =$ 0.15um/0.13um, $(W/L)_1 = (W/L)_2 =$ 10um/0.13um, $(W/L)_s =$ 5um/0.25um, VIC=0.6V, vb=0.7V, input resistance = 10 kΩ, all bodies tied to Vdd/Gnd.
    a) Let CL1=CL2=0, find out the frequency response (poles and zeros) of differential mode gain, Adm, in figure 1a.
    b) Let CL1=CL2=1 pF, redo part (a).
    c) Let CL1=CL2=0, find out the dominant pole (lowest frequency pole) of differential mode gain, Adm, in figure 1b (cascoded amplifier). Explain the difference between part (c) and (a).
    d) Verify (a)-(c) with SPICE. Explain any difference larger than 10%.

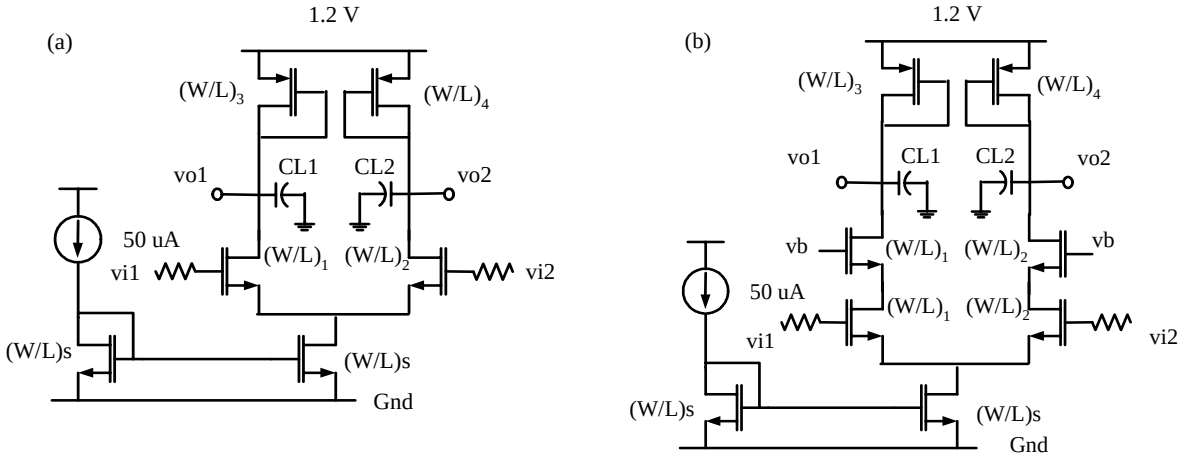

Figure 1

Device model:

```
.model nch nmos LEVEL=1 tox=2.6n vt0=0.3 gamma=0.2 phi=0.6 u0=250 ld=0.025u
+ capop=0 acm=3 ldif=0 hdif=0.2u cj=8e-4 cjsw=8e-12 cjgate=8e-11
+ lambda=0.2
.model pch pmos LEVEL=1 tox=2.6n vt0=-0.3 gamma=0.2 phi=0.6 u0=100 ld=0.025u
+ capop=0 acm=3 ldif=0 hdif=0.2u cj=8e-4 cjsw=8e-12 cjgate=8e-11
+ lambda=0.15
```

Spice Hint:

1. AC analysis can plot the frequency response (Bode plot): '.ac dec 10 1 1T'
2. .pz can list the poles and zeros of the transfer function from input independent source vin to output node v(out): '.pz v(out) vin'

MOSFET capacitance calculation (saturation region):
Use the following formulas for the MOSFET capacitances to get your hand calculations to agree with Spice.
C_{gs} = 2/3 $W\ (L\text{-}2LD)C_{ox}$ +$W\ C_{gso}$ = 2/3 $W\ (L\text{-}2LD)C_{ox}$ +$W\ LD\ C_{ox}$
C_{gd} =$W\ C_{gdo}$=$W\ LD\ C_{ox}$

C_{ox} can be calculated from the Spice parameter *tox*. C_{ox} = ε / *tox* =3.453e-11/ *tox*
LD is a Spice parameter.

$$C_{db} = \frac{C_j A_D}{(1+\frac{V_{DB}}{PB})^{m_j}} + \frac{C_{jSW} P_D + C_{jgate} W}{(1+\frac{V_{DB}}{PB_{SW}})^{m_{jsw}}}$$

A_D = W 2 *HDIF*
P_D = W + 4*HDIF*
C_j , C_{jsW} , C_{jgate}, *PB*, *mj* and *HDIF* are Spice paramers.
Default values: $PB = PB_{SW}$ = 0.8V, m_j = 1/2, m_{jSW} = 1/3.

2) Given the RF amplifier shown in figure 2,
   a) Consider only Cgs of the transistors. Derive frequency response of input impedance: Zin(s) as a function of gm, inductors and capacitors (including Cgs) as denoted in figure 2.
   b) Consider only Cgs of the transistors. The amplifier is designed to operate at 5 GHz. For the matching purpose, the input impedance has to be 50 ohm (purely real resistance). Calculate the value of L2. Assume (W/L)=100um/0.13um, biasing current is 5 mA, Kn'=150 uA/V^2,Cox= 0.015 F/m^2 , Cgso=Cgdo=5e-10 F/m, λ=0. [Hint: The impedance of inductor is s*L]

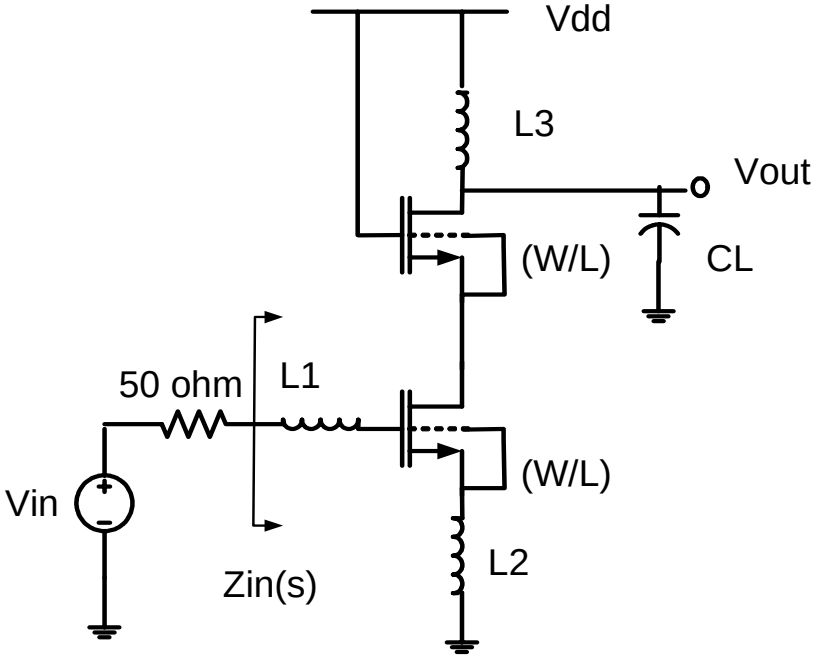

Figure 2