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HW 4

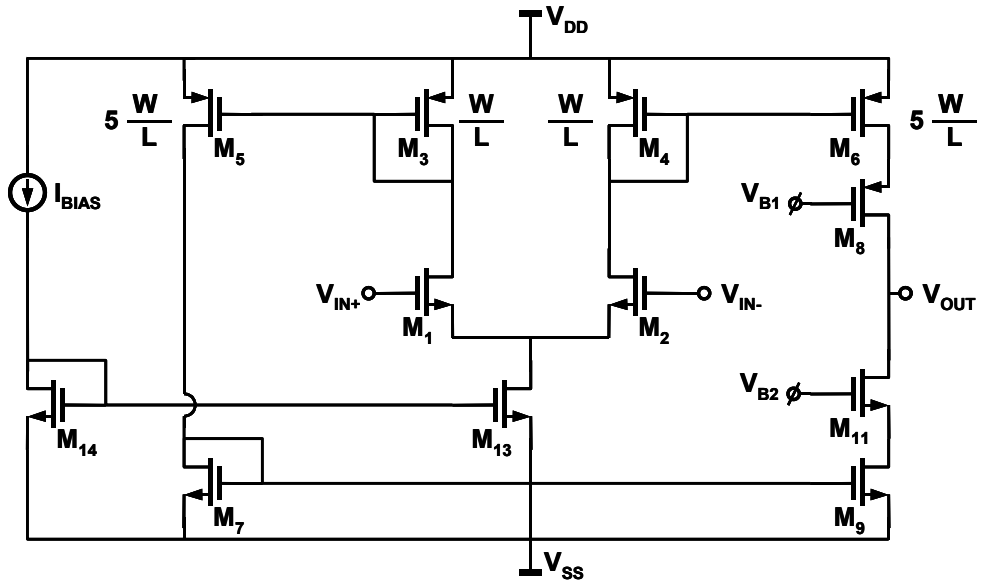

Figure 4: M1=M2; M3=M4; M7=M9; M13=M14; M11=M9; M8=M6
The bulk of all transistors is connected to their source

Figure 4 shows an operational amplifier with differential input and single ended output. The relevant sizes of some transistors are shown. Further assume V_{DD}=5, V_{SS}=0, and assume that all transistors are sized so that V_{Tn}=-V_{Tp}=0.8V and $(V_{GS} - V_T)_n$ =-$(V_{GS} - V_T)_p$=0.2V. You can also assume that M1, M2, M3, M4, M5, M7, M13 and M14 have a lambda=0.

A. Calculate the maximum value of V_{B1} so that all transistors are in the active region.

Expression:	$V_{B1\text{-}max}$ =
Value:	$V_{B1\text{-}max}$ =

B. Derive the minimum value of V_{B2} so that all transistors are in the active region.

Expression:	$V_{B2\text{-}min}$ =
Value:	$V_{B2\text{-}min}$ =

For all the following questions, assume the values of V_{B1} and V_{B2} that you calculated in A & B.

C. Derive symbolically the gain of the amplifier for a differential input signal i.e. V_{OUT}/V_{IN}

NAME:	

Expression:	V_{OUT}/V_{IN} =

D. Derive common mode input range so that all transistors remain in the active region. Indicate for each limit which transistor(s) go(es) out of active region first.

Transistor(s)		----------	
Expression:	<= $V_{Incommon\text{-}mode}$ <=		
Values:	<= $V_{Incommon\text{-}mode}$ <=		

E. Derive output range so that all transistors remain in the active region. Indicate for each limit which transistor(s) go(es) out of active region first.

Transistor(s)		----------	
Expression:	<= V_{OUT} <=		
Values:	<= V_{OUT} <=		

F. Now assume that the devices have a non-zero output conductance (i.e. lambda is not zero). Find an expression for the common mode gain. You can make approximations if necessary. Explain your reasoning and justify your assumptions.

G. Find a expression for the CMRR i.e. (differential mode gain)/(common mode gain).