Question 1

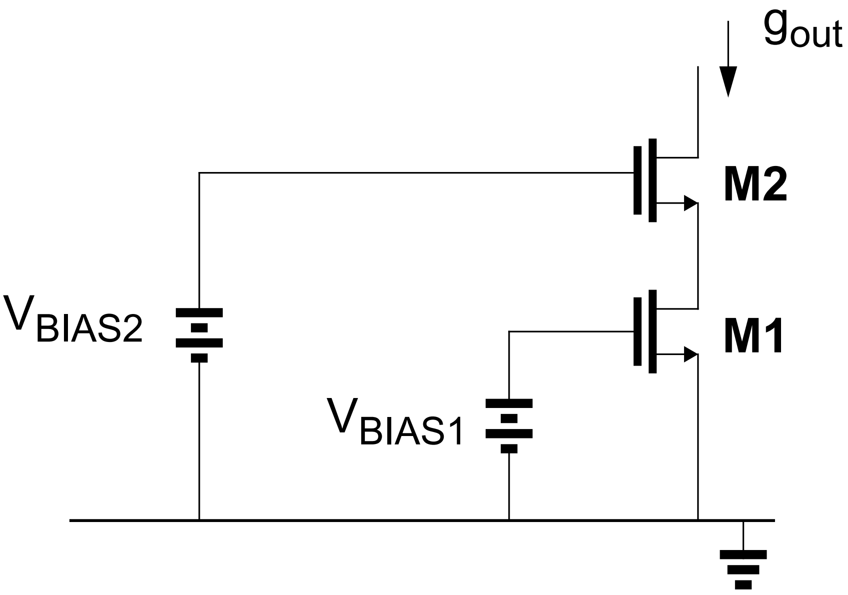


Figure 1

Ignore the body effect.

(i) Draw the small signal model for the circuit shown in Figure 1.
Ignore all capacitances.

(ii) Derive an expression for the output conductance g_{out} in terms of the small signal parameters of M1 and M2.
Reduce the expression to its simplest form assuming
$g_{m1}=g_{m2}=g_m$, $g_{ds1}=g_{ds2}=g_{ds}$, $g_m>>g_{ds}$

(iii) The circuit is to be biased for optimal low-voltage operation. If
V_{BIAS1}=1.2V
V_T = 0.8V
$(W/L)_{M2}=(W/L)_{M1}$
calculate the minimum value of the voltage at the output node (i.e. at the drain of M2) for both M1 and M2 to be in saturation and the value of V_{BIAS2} necessary to achieve this.
Neglect λ for this calculation.

(iv) Repeat the calculations in (iii) if the aspect ratio of M2 is four times that of M1
i.e $(W/L)_{M2}=4*(W/L)_{M1}$

Question 2

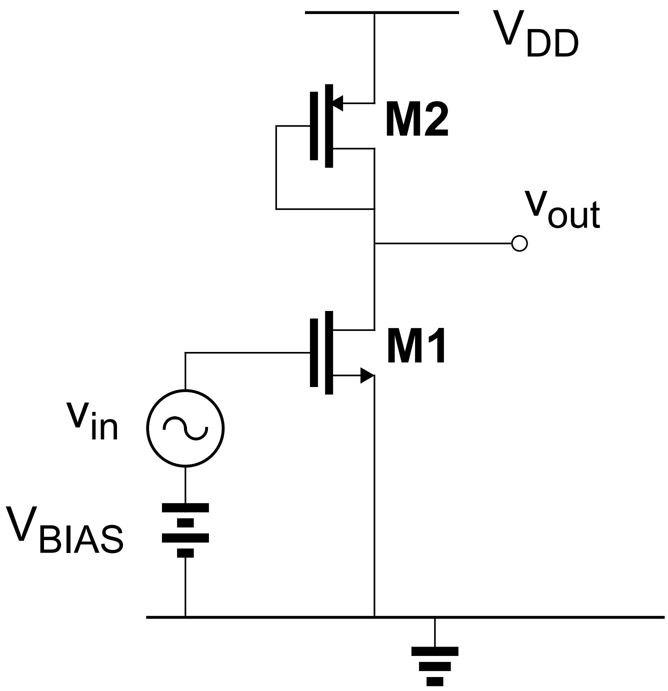


Figure 2

Assume M1 and M2 are operating in saturation and ignore the body effect.

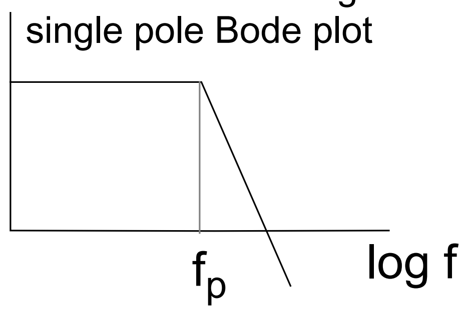
(i) Draw the small signal model for the circuit shown in Figure 2. Ignore all capacitances.

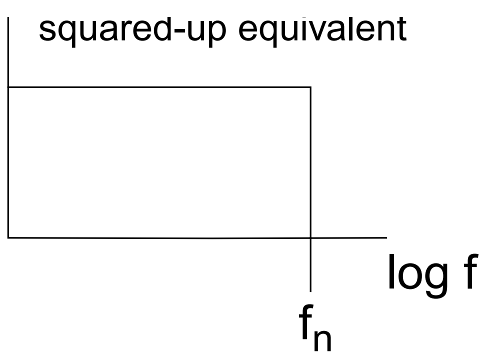
(ii) What is the low-frequency small signal voltage gain (v_{out}/v_{in})? Assume that $g_{m1} >> g_{ds1}, g_{ds2}$ and that $g_{m2} >> g_{ds1}, g_{ds2}$

(iii) What is the input-referred thermal noise voltage in terms of the small signal parameters of M1 and M2, Boltzmann's constant k and temperature T?

(iv) If a capacitor C_L is connected between the output node and ground what is the total integrated thermal noise at the output node?

You may assume the following:





For the area underneath the curves to be the same then $f_n=(\pi/2)*f_p$

(v) Using the result of (iv) calculate the signal-to noise ratio at the output if the input signal v_{in} is a $10mV_{rms}$ sine wave with a frequency much lower than the frequency of the pole at the output node.
For this calculation take $V_{GS1}=1V$, $|V_{GS2}|=2.8V$, $|V_T| = 0.8V$ for M1,M2. $C_L=10pF$.
The drain current of M1 is $100\mu A$.
Assume Boltzmann's constant $k=1.38X10^{-23}J/^oK$, temperature $T=300^oK$.

Question 3

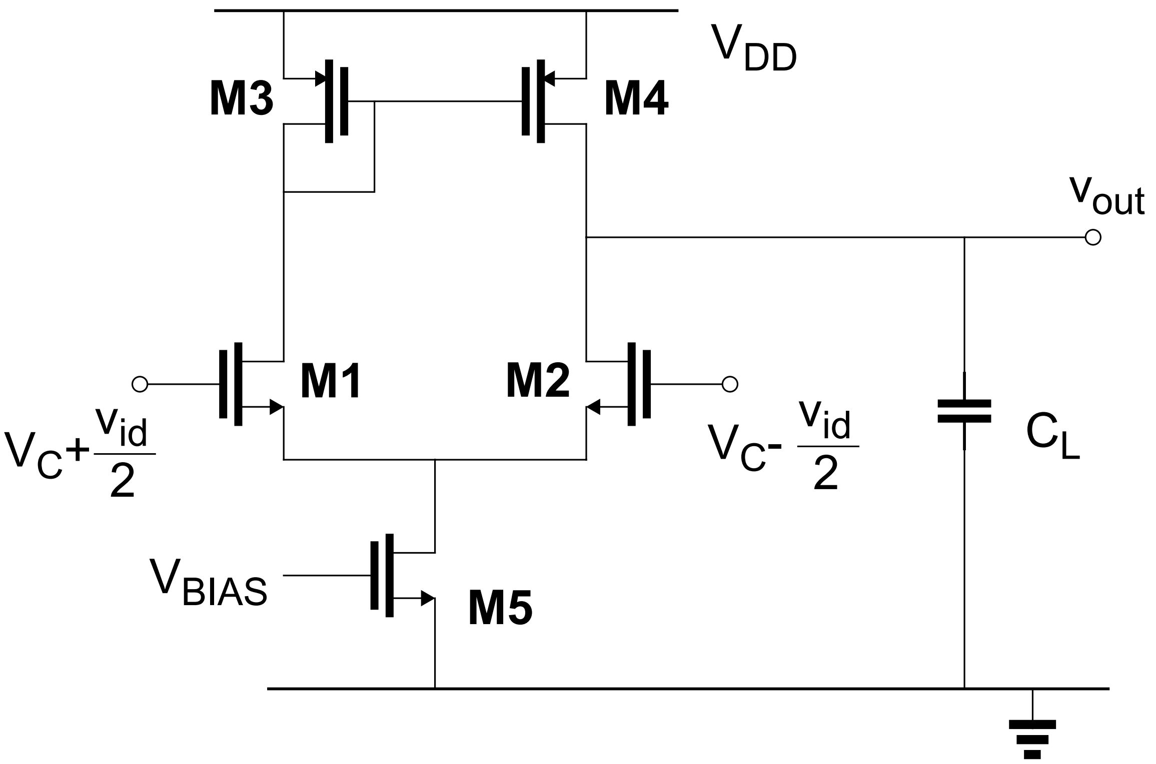


Figure 3.

Assume all devices are operating in saturation. Ignore the body effect.
Use M1=M2, $g_{m1}=g_{m2}=g_{mn}$, $g_{ds1}=g_{ds2}=g_{dsn}$
Use M3=M4, $g_{m3}=g_{m4}=g_{mp}$, $g_{ds3}=g_{ds4}=g_{dsp}$
V_C is the fixed common mode voltage.
A small differential voltage v_{id} is applied to the amplifier.

(i) Derive an expression for the small signal transfer function (V_{out}/v_{id}) of the amplifier in Figure 3 in terms of g_m, g_{ds} and C_L. Consider only capacitance C_L.

(ii) Give expressions for the following: low frequency gain, pole frequency, unity gain frequency.

(iii) Draw a Bode plot identifying the low-frequency gain, pole frequency, and unity gain frequency.

(iv) What is the effect on each of the parameters in (ii) if the bias current is doubled? Assume all devices remain in saturation.

(v) If the signal at the output node is a sine wave given by $V_{out}=A\sin\omega t$, calculate the maximum frequency such that no slewing occurs. Take A=0.5V, C_L=10pF. The drain current through M5 is 100μA.