Question 1

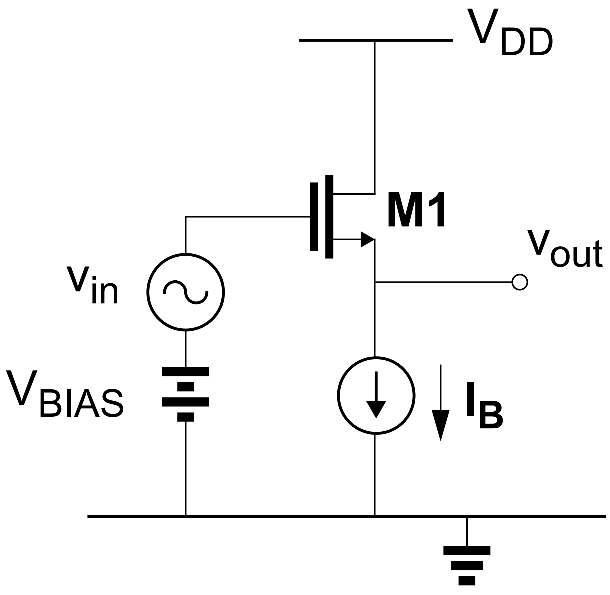


Figure 1

Assume M1 is operating in saturation and that $g_{m1} >> g_{ds1}$.
I_B is an ideal current source
The body effect may be ignored in the analysis.

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

(ii) Derive an expression for the impedance at the output node.

(iii) What is the low-frequency small signal voltage gain (v_{out}/v_{in})?

(iv) The circuit shown in Figure 1 is required to drive a resistive load of 1kΩ. What is the requirement on g_{m1} if the small-signal attenuation of the stage is not to be greater than 6dB?

Question 2

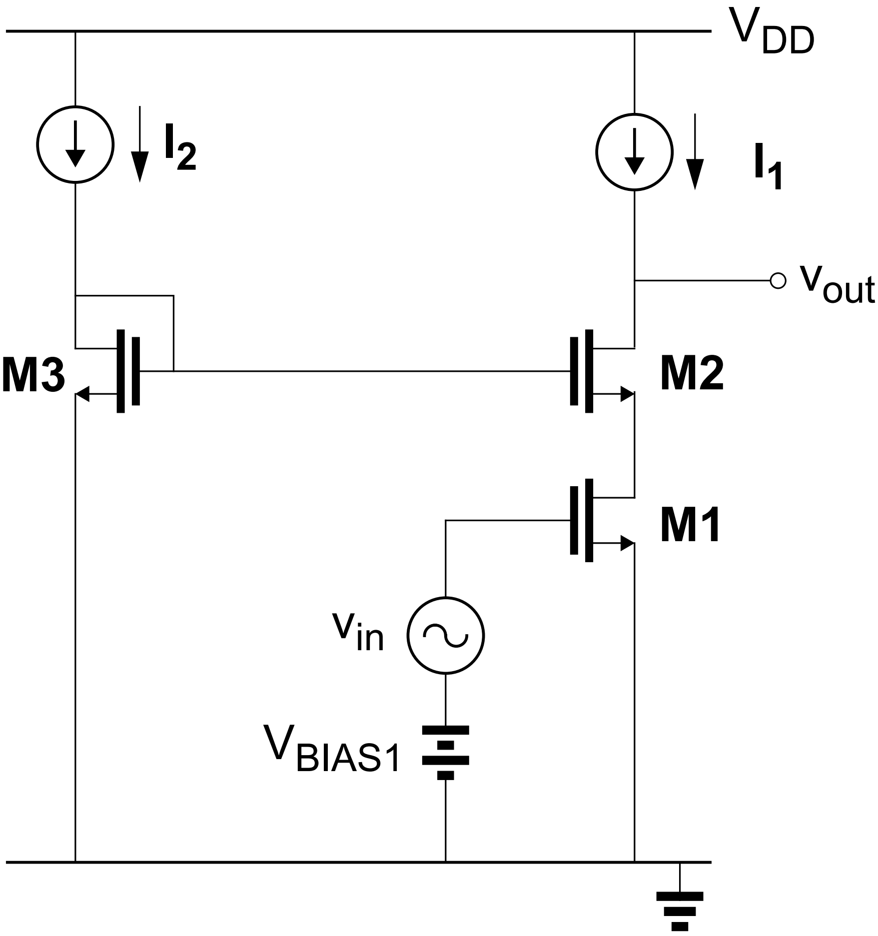


Figure 2

Figure 2 shows a cascode gain stage. I_1 and I_2 are ideal current sources.

For the questions below ignore the body effect.

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

(ii) The voltage gain of this stage can be approximated by
$v_{out}/v_{in}=g_{m1}r_{out}$
where r_{out} is the impedance at the output node.
Derive an expression for v_{out}/v_{in} in terms of the small signal transistor parameters.
Reduce the expression to its simplest form assuming
$g_{m1}=g_{m2}=g_{m3}=g_m$, $g_{ds1}=g_{ds2}=g_{ds3}=g_{ds}$, $g_m>>g_{ds}$

(iii) The circuit is to be biased for optimal low-voltage operation. If
V_{BIAS1}=1.25V, V_T = 1V, I_1=100µA
$(W/L)_{M1}=(W/L)_{M2}=(W/L)_{M3}$=16µm/1µm
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 I_2 necessary to achieve this.
Neglect λ for this calculation.

(iv) For low power I_2 is changed to 40µA.
What value of $(W/L)_{M3}$ is required to preserve the bias conditions of M1 and M2.

Question 3

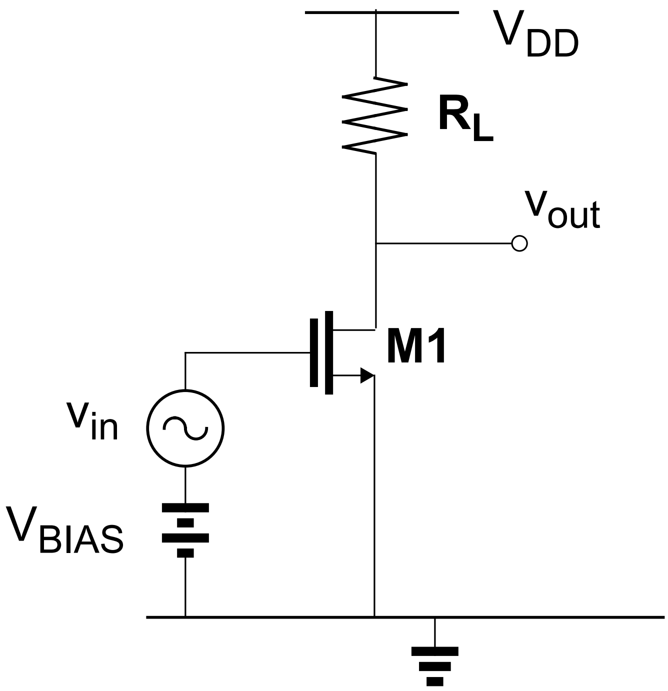


Figure 2

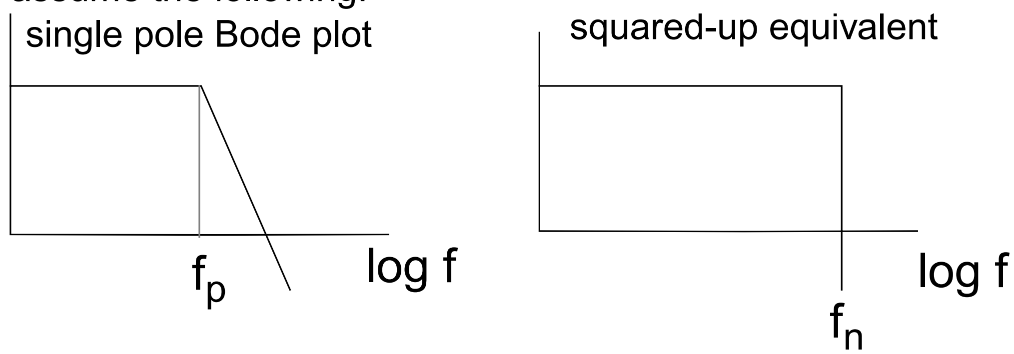
Assume M1 and M2 are operating in saturation and ignore the body effect.
Assume that $g_{m1} >> g_{ds1}$

(i) Draw the small signal model for the circuit shown in Figure 2.
Ignore all capacitances.
What is the low-frequency small signal voltage gain (v_{out}/v_{in})?

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

(iii) 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 $f_n=(\pi/2)*f_p$

(iv) Using the result of (iii) calculate the signal-to noise ratio at the output if the input signal v_{in} is a $20mV_{rms}$ sine wave with a frequency much lower than the frequency of the pole at the output node.
For this calculation take V_{GS1}=1V, $|V_T|$ = 0.75V , R_L=5kΩ, C_L=1pF.
The drain current of M1 is 100μA.
Boltzmann's constant k=1.38X10^{-23}J/^{o}K, temperature T=300^{o}K.