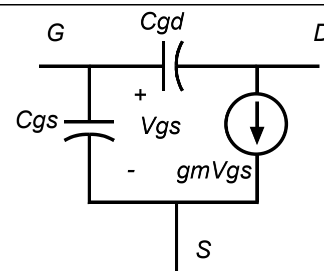
ECE2c Problem set #6:

model statement: for old-fashioned mobility-limited NFETs, $I_d=(\mu C_{ox}W_g/2L_g)(V_{gs}-V_{th})^2(1+\lambda V_{ds})$ for $V_D>V_g-V_{th}$ and

$I_d=(\mu C_{ox}W_g/2L_g)\left(2(V_{gs}-V_{th})V_{DS}-V_{DS}^2\right)(1+\lambda V_{ds})$ for $V_D<V_g-V_{th}$.

As is discussed in the notes, for PFETs, the polarities of V_{gs} and V_{ds}, and the direction of I_D, are all reversed.

Problem 1: The problem uses the MOSFET equivalent circuit to the right. Note the capacitances Cgs and Cgd which model high-frequency effects.

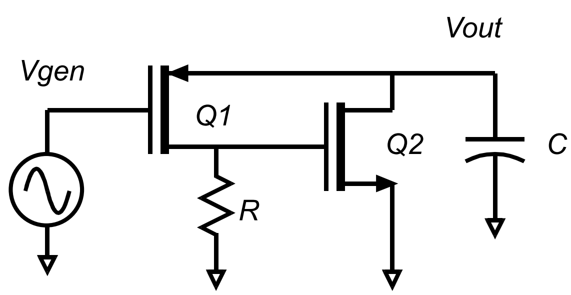


The circuit is called a super-buffer. Ignore DC bias; you don't need it.

Q1: $C_{gs}=C_{gd}$=0. R_{ds}=infinity.

Q2: C_{gs}= 200 fF, C_{gd}=0. R_{ds}=infinity

g_{m1}=100 mS , g_{m2}=200 mS, R=1000 Ohm, C=400 fF



(a) Draw a small-signal equivalent circuit of the circuit.

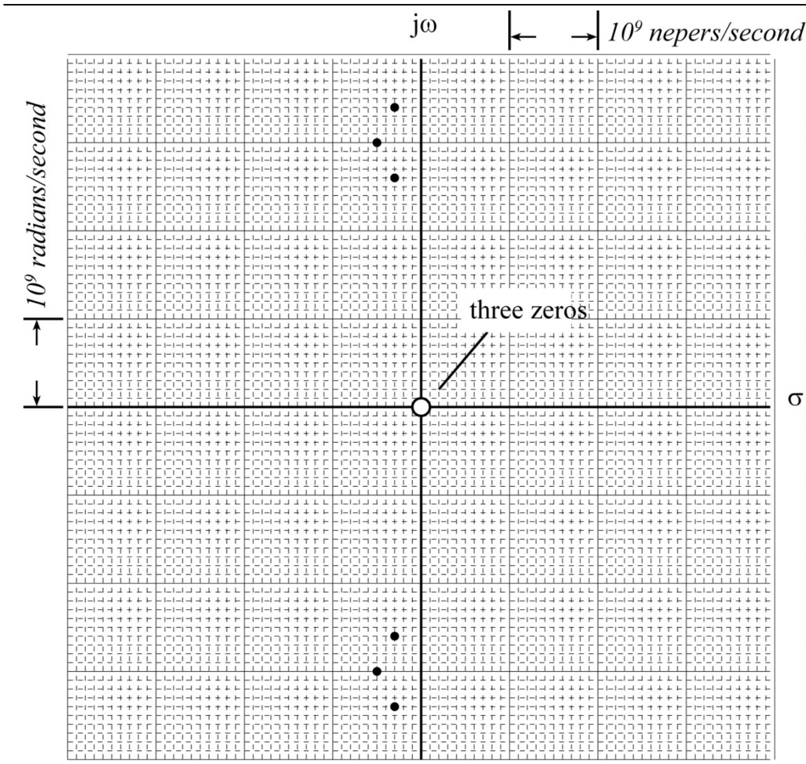
(b) Compute by nodal analysis the small signal transfer function Vout/Vgen , with the answer given in dimensionless ratio-of-polynomials form:

$$Ks^m\frac{1+a_1s+a_2s^2+\ldots}{1+b_1s+b_2s^2+\ldots}$$

(c) Find the damping factor ζ and the resulting natural resonant frequency f_n.

(d) Plot an accurate root locus. (e) Accurately plot the Magnitude of the frequency response in Bode Form on semilog paper. (f) If Vgen(t) is a 1 mV step-function, compute and plot Vout(t).

Problem 2: A circuit has a transfer function H(s) with root locus as below. $H(s)=1$ when $s=\sigma+j\omega=0+j(3\cdot 10^9)$rad/sec



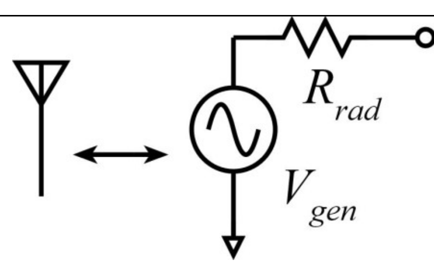
(a) The answer must be in this standard form:

$H(s) = Ks^3 \times \frac{1}{(1-s/s_{p1})(1-s/s_{p2})...}$ where K has units of $(\text{seconds})^3$.

(b) By measuring distances on the the graph itself with a rule , hand-draw a **Bode** plot of $\| H(j2\pi f) \|$ from 1MHz to 1 GHz, with at least 3 points in the (500MHz +/- 100MHz) filter passband, and other points at 159, 318, 636, and 795 MHz.

(c) using your favorite computer program (speadsheet, matlab...), generate a similar graph by computer.

Problem 3: The problem concerns the input stage of a radio receiver. To the right is shown a Thevenin equivalent model of an antenna. Please assume $R_{rad} = 50\ \Omega$. In the lower circuit, the FET has $(\mu C_{ox} W_g / 2L_g) = 1\ \text{mA}/\text{V}^2$, $\lambda = 0.05\ \text{V}^{-1}$, and V_{th} =0.3 V.

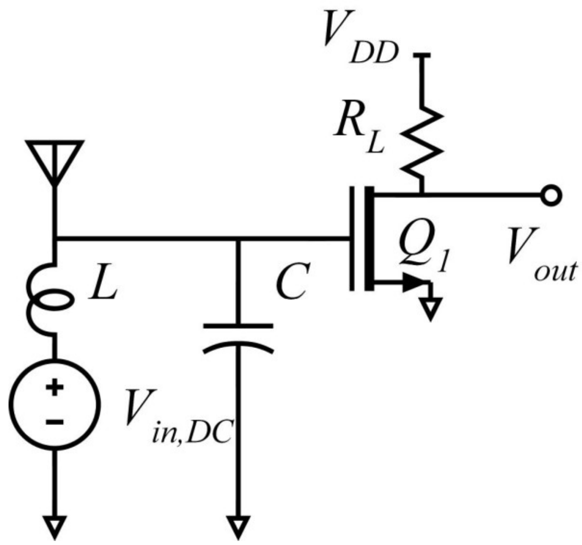


(a) Find $V_{in,DC}$ such that the drain current of Q1 is 0.1 mA. (b) Setting V_{DD}=3.3 V, select R_L such that the DC drain voltage of

Q1 is 1.5 V. (c) find the small-signal parameters of Q1. The FET has C_{gd} = 0 fF and C_{gs} =31.8 pF. (d) replacing the FET and the antenna with their equivalent (small signal) models, draw a small-signal diagram of the overall circuit. (e) Setting L=0.797 nH, compute Vout(s)/Vgen(s). The answer must be in this standard form:

$$H(s) = Ks^1 \times \frac{1}{(1 - s/s_{p1})(1 - s/s_{p2})...}$$ where

K has units of $(\text{seconds})^1$.



(f) Plot an accurate root locus. (g) Accurately plot the Magnitude of the frequency response in Bode Form on semilog paper. (h) If Vgen(t) is a 1 mV step-function, compute and plot Vout(t).

larger copy of graph from problem 2