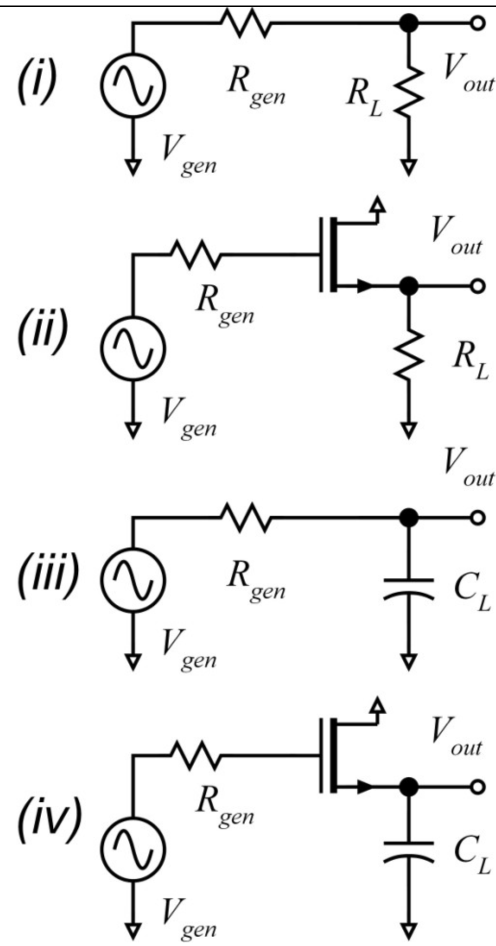
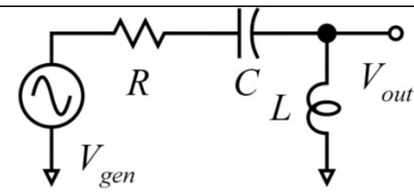
ECE2c Problem set #7:

Problem 1: Frequency response of FET source-follower. Ignore DC bias: you don't need it. **(a)** Starting with circuit (i), compute $V_{out}(s)/V_{gen}(s)$. **(b)** Now work with circuit (ii), taking a FET with $g_m \neq 0\,\text{S}$, $G_{ds} = 0\,\text{S}$, $C_{gs} = 0\,\text{F}$, $C_{gd} = 0\,\text{F}$, again compute for small-signals $V_{out}(s)/V_{gen}(s)$. **(c)** Taking $R_{gen} = 1\text{M}\Omega$, $R_L = 1\text{k}\Omega$, $g_m = 1\text{mS}$, $G_{ds} = 0\,\text{S}$ compare the circuits (i) and (ii). Which one provides a larger output signal ? The answer to this question is why we might use a source follower. In circuit (iii) a resistive generator drives a capacitive load. **(d)** Compute $V_{out}(s)/V_{gen}(s)$ for this circuit with R_{gen} and C_L as algebraic variables. **(e)** Now assuming $R_{gen} = 1\text{M}\Omega$ and $C_L = 1\,\text{pF}$, compute $V_{out}(s)/V_{gen}(s)$ and make a Bode plot. In circuit (iv), a FET source follower drives a capacitive load. **(d)** Compute $V_{out}(s)/V_{gen}(s)$ for this circuit with R_{gen} , g_m, and C_{gs}, and C_L as algebraic variables. Please assume that C_{gd} and G_{ds} are both zero, but *do not assume* that C_{gs} is zero. **(e)** Now taking $R_{gen} = 1\text{M}\Omega$, $g_m = 1\text{mS}$, $G_{ds} = 0\,\text{S}$, $C_{gd} = 0\,\text{F}$, $C_{gs} = C_L = 1\text{pF}$, compute $V_{out}(s)/V_{gen}(s)$ and make a Bode plot. Compute and state the damping factor and the natural resonant frequency. Note: in part (e) you should find strongly resonant behavior despite the absence of inductors in the ciruit. Source-followers can be highly resonant when driving capacitive loads, particularly if the generator impedance is high.

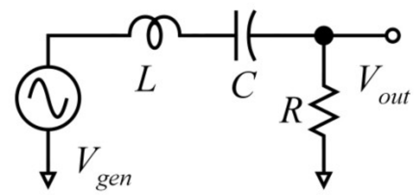


Problem 2: The three circuits all have a natural resonant frequency of 1.0 GHz and a Q of 10. $R = 1000\,\Omega$. **(a)** Find the values of L and C. **(b)** Compute $V_{out}(s)/V_{gen}(s)$ for all three circuits. **(c)** Make Bode magnitude plots of the transfer functions of all three circuits. **(d)** The circuit of figure (ii) is driven by a rectangular pulse of 1mV amplitude and 1 ps duration. Approximating this as a delta function (think: how ?), compute $v_{out}(t)$ and make a clean hand-drawn graph of this with the oscillation period and amplitude accurately and clearly shown.

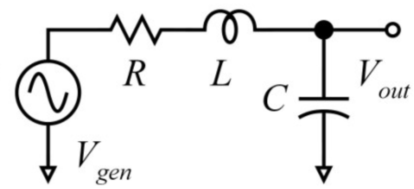
(i)



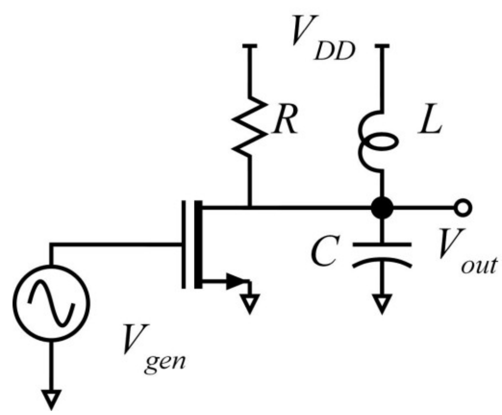
(ii)



(iii)



Problem 3: Ignore DC bias: you don't need it. The FET has $g_m = 20\text{mS}$, but G_{ds}, C_{gs}, C_{gd} are all zero. The circuit is an RF front-end stage amplifier for a 2.0 GHz Wi-Fi receiver. The gain is to be 20 dB at 2.0 GHz, but must have 40 dB rejection of unwanted signals at 1.5 GHz, meaning that the gain at 1.5 GHz must be -20 dB. **(a)** Find R,L, and C. **(b)** When the 2.0 GHz Wi-Fi signal is carrying digital data, its modulation spreads the desired signal over a $2.0 \pm 0.2\,\text{GHz}$ band. Find in dB the variation of the amplifier gain over this bandwidth. In a real system, if this in-band gain variation were much more than 1.0 dB, it is likely that we would need to re-design our filter.



Problem 4: In this circuit, G_{ds} and C_{gd} are both zero, $g_m = 1\text{mS}$, $R_{gen} = 10\text{k}\Omega$, $C_{gs} = 100\text{fF}$ and $C_L = 1\text{pF}$. **(a)** Compute $V_{out}(s)/V_{gen}(s)$. **(b)** Now simplify the problem by ignoring the zero in the transfer function. If $v_{gen}(t)$ is a 1 mV step-function, find and plot $v_{out}(t)$. What is the 10%-90% risetime ? Does the step response overshoot at all ?