EE 40 – Introduction to Microelectronic Circuits

Fall 2005, **Prof. A. R. Neureuther**
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Problem Set # 12

Due: 5 PM Thursday, Dec. 8th, 2005 in 240 Cory

12.1 Latency and Throughput of Lumped and Pipelined Logic

Answer Problem 11.3 in Problem Set #11.

12.2 Sinusoidal Forcing Functions

A sinusoidal current source $I_S(t) = 10mA*\cos(2\pi*2GHz*t)$ is connected to a parallel RLC circuit by a switch that closes at t = 0, as shown in Figure 1. The initial conditions are $i_C(0) = 0$ and $v_o(t) = 0$. Assume component values as follows: R = 500Ω, L = 3nH, C=1pF.

a. Find the forced (steady-state) response for $v_o(t)$ for t > 0, using phasors.
b. Find the difference between the initial values $i_C(0)$ and $v_o(0)$ of the forced response and the given initial conditions.
c. Find the natural (transient) response for $v_o(t)$ for t > 0. Is the circuit overdamped, underdamped, or critically damped? Which circuit elements determine the time it takes for the transient response to decay?
d. Find the total response for $v_o(t)$ for t > 0. Qualitatively sketch the forced response, the natural response, and the total response as a function of time.

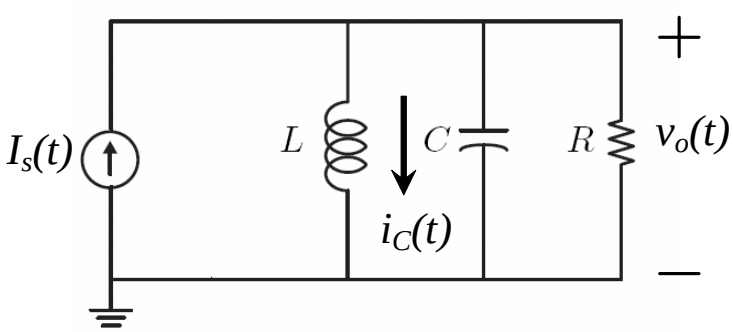

Figure 1 – Parallel RLC Circuit

12.3 2nd Order Transient

A man driving a tractor (let's call him Kent) has a mass of 100kg. The seat of the tractor that Kent is sitting on can be modeled as a mass-spring system as shown in Figure 2. As Kent is driving his tractor he hits a bump which causes the seat to move 30cm below the resting position at x = 0 (i.e., the initial condition is x(t=0) = -30cm; assume the initial velocity is 0). The system will restore the driver seat position to $x(t=\infty) = 0$. Assume component values as follows: $k = 6*10^4$ N/m, $b = 7*10^3$ N*s/m.

a. Find the differential equation describing x(t), the position of the mass as a function of time, for t > 0 (a free-body diagram may help here). Recall that the force due to the spring is given by $F_{spring} = -k*x(t)$ and the force due to the damper is given by $F_{damper} = -b\frac{dx(t)}{dt}$, and neglect the force of gravity.
b. Find a circuit analog to the mechanical system by finding an equivalent *series* RLC circuit which gives the same differential equation found in part (a). *Let electrical charge be analogous to the position of the mass.* Give the values for R, L, C, and the initial conditions.
c. Use a circuit simulation program (e.g., PSPICE or MultiSIM) to plot the position of the mass as a function of time, by running a transient analysis on the circuit found in part (b). **Don't forget to set the initial conditions in your schematic; there should be two of them.** In PSPICE, you can set the initial voltage between two nodes using the "IC2" part in the "SPECIAL" library. Attach a copy of your schematic and the plot of the transient response. What is the damping condition of the system?
d. Find the damping factor b required for critical damping, and determine the time it takes for the mass to get 3cm away from x = 0.
e. Find the damping factor b required for a damping ratio of 0.2, and determine the time it takes for the mass to settle to within ±3cm of x = 0.
f. Find the maximum force Kent experiences in parts (d) and (e) and compare to the force of gravity.

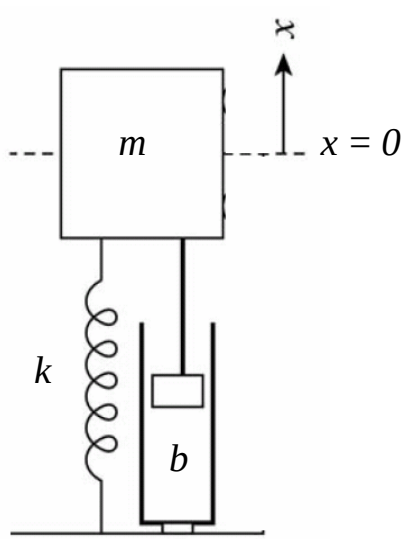

Figure 2 – Mass-Spring System