ECE 202: Linear Circuit Analysis II – Fall 2013

HOMEWORK SET 5: DUE THURSDAY, SEPTEMBER 12, 5 PM IN MSEE 180

ALWAYS CHECK THE ERRATA on the web.

Main Topics: The Past, Impulse response $h(t)$; step response, initial/final value theorems. Nodal and mesh analyses in the s-domain.

17. In the so-called feedback configuration of the figure below, $E(s)$ is the Laplace transform of the error between the reference signal $x_{ref}(t)$ and some function or modification of the response $y(t)$.

$G_1(s) = \dfrac{n_g(s)}{d_g(s)}$ is called the *plant* of the system and represents a physical process or special circuit while

$F(s) = \dfrac{n_f(s)}{d_f(s)}$ is a *feedback controller* to be designed. You will need to use the initial and final value theorems here.

(a) As a first step, determine $E(s)$ in terms of $X_{ref}(s)$, $Y(s)$, and $F(s)$, but not $G_1(s)$.

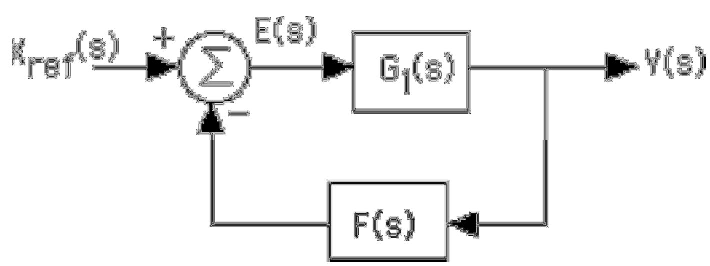
(b) Find the transfer function $H(s) = \dfrac{E(s)}{X_{ref}(s)}$ in terms of $n_g(s)$, $n_f(s)$, $d_g(s)$, and $d_f(s)$.

(c) Under what conditions does $e(t) \to 0$ as $t \to \infty$ when $x_{ref}(t) = K_0 u(t)$?

(d) Under what conditions does $e(t) \to K_e \neq 0$ (nonzero constant) as $t \to \infty$ when $x_{ref}(t) = K_0 u(t)$?

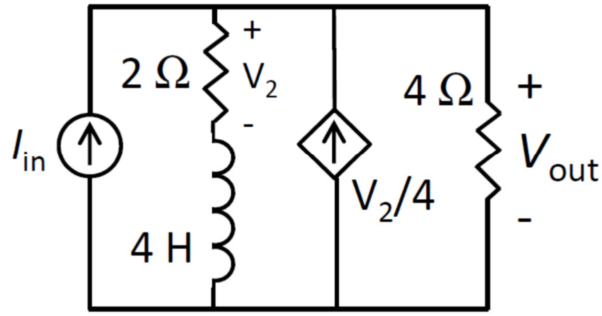
(e) Under what conditions and how could you determine $e(0^+)$ from $E(s) = H(s)X_{ref}(s)$.

(f) Suppose $d_g(s)$ had a pair of poles on the imaginary axis. How could you design an $F(s)$ to cancel these poles?

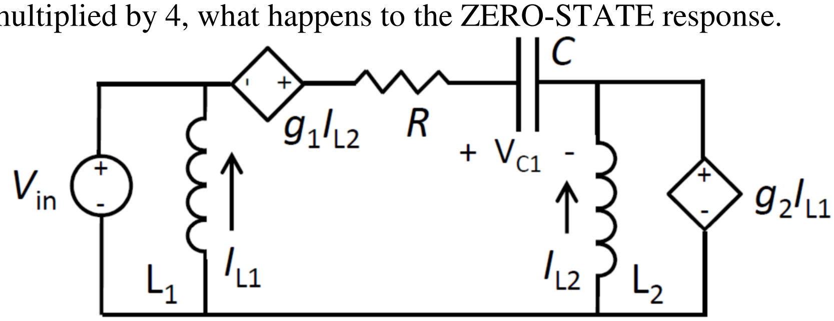


CHECK: $E(s) = \dfrac{X_{ref}(s)}{1+F(s)G_1(s)} = \dfrac{d(s)X_{ref}(s)}{d(s)+n(s)}$ where $F(s)G_1(s) = \dfrac{n_f(s)n_g(s)}{d_f(s)d_g(s)} = \dfrac{n(s)}{d(s)}$.

18. For the circuit below, find the transfer function $H(s) = \dfrac{V_{out}(s)}{I_{in}(s)}$, by writing a single node equation in $V_{out}(s)$ and $I_{in}(s)$. Determine the Thevenin equivalent impedance seen by the independent current source. Finally, determine the response $v_{out}(t)$ to the input $i_{in}(t) = 3e^{-t}\cos 2t$ A, assuming the inductor has zero initial current.



19. Consider the circuit below. You are to write a set of nodal equations, put in matrix form, and compute the various responses via **Cramer's rule** as indicated in the steps below.
(a) Assume $i_{L1}(0^-) \neq 0$. Assume all other initial conditions are ZERO. Draw the equivalent circuit in the s-domain accounting for $i_{L1}(0^-) \neq 0$.
(b) Write a set of 3 (modified) nodal equations in the variables $V_{in}(s)$, $V_{C1}(s)$, $I_{L1}(s)$, $I_{L2}(s)$, and the parameters R, C, L_1, L_2, g_1, and g_2. Then put the equations in matrix form.
(c) Now suppose R=1 kΩ, C=12 mF, L_1=0.1 H, L_2=0.2 H, g_1=8, g_2=0.5, and $V_{in}=8e^{-2t}u(t)$ V. Rewrite the matrix equations of step (b) in matrix form using the given numbers.
(d) Assuming the response is $I_{L1}(s)$, solve the equations for $I_{L1}(s)$ using Cramer's rule. Then find $i_{L1}(t)$. Identify the zero-input and zero-state parts of the response.
(e) If the input is multiplied by 4, what happens to the ZERO-STATE response.



Suggestion: use the symbolic toolbox to solve this problem in MATLAB. Consider the following code:

```
syms M b s t SolVec
M = [1  2  s+1; 3 s+2 4; s+5   5  6]
b = [1/s; 50; 0]
SolVec = M\b
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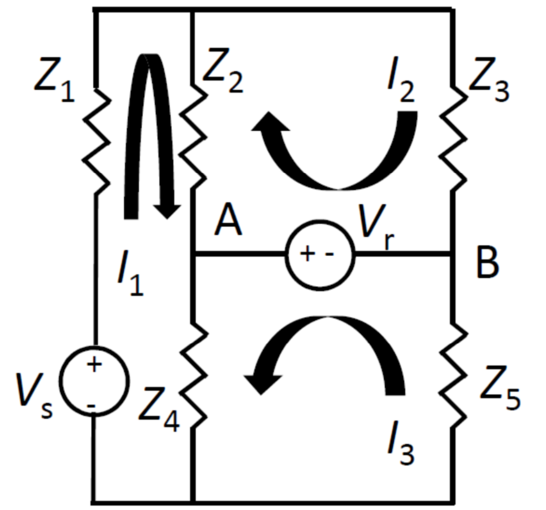
20. **(a)** Write a set of modified loop equations in terms of the literals indicated on the circuit diagram below. You will need to insert an appropriate voltage label. Put equations in matrix form.



(b) Write down a set of modified loop equations and put in matrix form. Assume $v_{C1}(0^-) = 8$ V, $v_{C2}(0^-) = 2$ V, and both inductor currents are initially zero. The key to solving this problem is determining what equivalent frequency domain circuit to use for the inductor and capacitor that does NOT increase the number of loops. So which ones should you use?