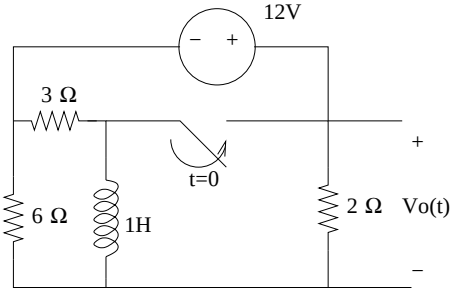
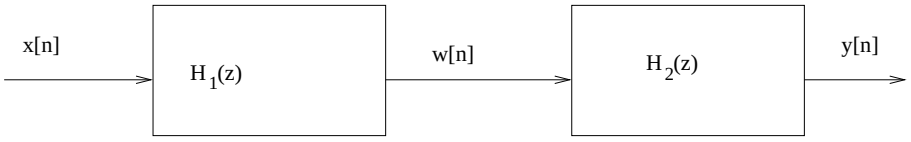
Electrical Engineering Ph.D. Written Qualifying Exam

1. For the circuit shown below, find $v_o(t)$ for $t = 0^+$.



2. Consider two linear time-invariant systems, $H_1(z)$ and $H_2(z)$ cascaded together as shown in the figure below, and the total system function is known to be:

$$H(z) = (1 - z^{-2})(1 - 0.8\exp^{j\pi/4} z^{-1})(1 - 0.8\exp^{-j\pi/4} z^{-1})(1 + z^{-2}).$$



(a) Determine the poles and zeroes of $H(z)$.

(b) Suppose further that $w[n] = x[n] - x[n-4]$. Find $H_2(z)$.

3. We wish to develop a Moore state machine (also called a "synchronous sequential circuit") that is a simple pattern recognizer. There is one 1-bit input to this circuit named 'w'. There is one 1-bit output named 'z'. Bits will come in and our circuit should output a 1 if, and only if, the pattern 1001 was the last four bits to be input to the circuit. Otherwise, the circuit should output a 0. We want to detect repeated or overlapping patterns with our circuit as well. Perform the following tasks for this circuit:

   - Draw the state diagram, clearly labeling inputs, outputs and transitions.
   - From your state diagram, create a state table (which simply represents your diagram in a tabular fashion).
   - Determine how many D flip-flops need to be used for this circuit.
   - Use a simple state assignment scheme (A = 000, B = 001, and so on) to encode the state table from part 2 as a "transition table".
   - Use the minimization method of your choice, create a logic equation for the circuit output, z, in terms of the circuit input and flip-flop states.

4. A singe phase 240-V rms 60-Hz load consumes 4800 Volt-Amps at PF = 0.6 lagging.

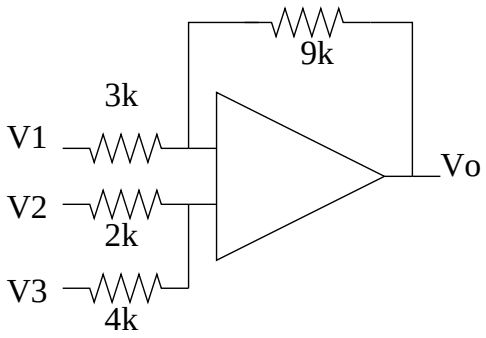
   (a) Determine the values of P, Q, and S of the load and draw its power triangle.

   (b) By adding a parallel capacitor, we wish to improve the power factor to 0.9 lagging. Determine what the resulting power triangle will be (load and capacitor together) and calculate how many Vars the capacitor nees to supply.

   (c) When you purchase the capacitor, what is its reactance X_c in Ohms and what is its capacitance in μF?

   (d) Give a short explanation of power factor correction.

5. The op-amp in the circuit shown below is "ideal." Find the output voltage, v_o, in terms of the input signals v_1, v_2, v_3.



6. Assuming that the complex permittivity for a material can be written as:

$$\hat{\epsilon} = \epsilon - j\frac{\sigma}{\omega},$$

derive the expression for the skin depth of (the distance required to reduce the field to $1/e$ of its initial value) a time-harmonic electric field impinging on that material, assuming a slightly conducting medium, i.e., $\sigma/(\omega\epsilon) \ll 1$.

7. Find the steady-state response, $y_{ss}(t)$ of the system described by the following differential equation with each of the following inputs, $x(t)$.

$$\frac{d^2y(t)}{dt^2} + 2\frac{dy(t)}{dt} + 5y(t) = 20x(t)$$

(a) $x(t) = 10u(t)$

$y_{ss}(t) =$

(b) $x(t) = e^{2t}u(t)$

$y_{ss}(t) =$

(c) $x(t) = 4\sin(2t)u(t)$

$y_{ss}(t) =$

8. Show a state diagram (either Moore or Mealy) for a circuit that outputs a 1 whenever the last four bits have been either 1101 or 1010.