University College Dublin
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SEMESTER I EXAMINATIONS - 2013/2014

School of Electrical, Electronic and Communications Engineering

EEEN 30020 Circuit Theory

Professor Green

Professor Brazil

Professor Feely*

Time Allowed: 2 hours

Instructions for Candidates

Answer **any three** questions. All questions carry equal marks. The percentages in the right margin give an approximate indication of the relative importance of each part of the question

Instructions for Invigilators

Non-programmable calculators are permitted.
No rough-work paper is to be provided for candidates.
Graph paper is to be provided

1. (i) A two-port is terminated with a voltage source V_s at port 1 and a 1 Ω resistance at port 2, as shown in Figure 1(a). V_o is the voltage across the 1 Ω resistance. Find the voltage gain V_o/V_s in terms of the ABCD parameters of the two-port. 30%

(ii) Find the transmission (ABCD) matrix of the two-port of Figure 1(b), for sinusoidal excitation at frequency ω. 40%

(iii) Using your answers to (i) and (ii), or otherwise, find

$$\left|\frac{V_o(j\omega)}{V_s(j\omega)}\right|^2$$

for the circuit of Figure 1(c), for sinusoidal excitation at frequency ω. 30%

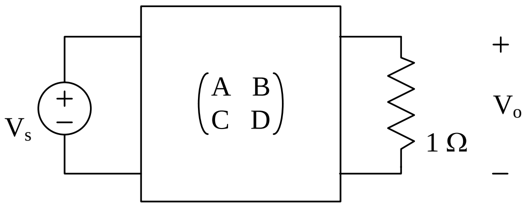

Figure 1(a)

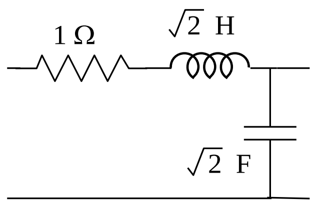

Figure 1(b)

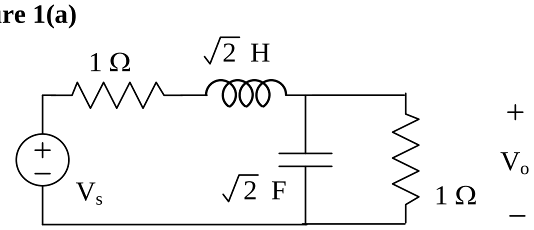

Figure 1(c)

2. (i) If the Laplace transform of f(t) is F(s), write down an expression for the Laplace transform of the time derivative df(t)/dt. Use this result to show how capacitors are transformed when the Laplace transform is applied to a circuit. 20%

(ii) What is the (s-domain) impedance seen by the voltage source in the circuit of Figure 2? 20%

(iii) Find i(t) for $t \geq 0$ in the circuit of Figure 2, if $v_i(t) = 1$ V for $t \geq 0$ and there is no energy stored in the circuit at $t = 0^-$. 30%

(iv) By decomposing Z(s) using the partial fraction expansion, draw a circuit whose input impedance Z(s) is

$$\frac{2s+5}{(s+2)(s+3)}$$

30%

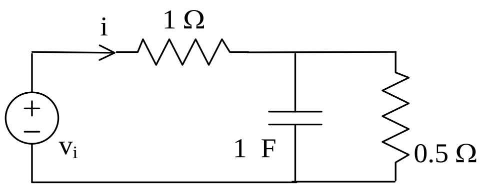

Figure 2

3. (i) Explain why negative feedback is used in the design and implementation of amplifiers. 20%

(ii) Sketch the Bode plots (magnitude and phase) for the transfer function

$$\frac{10^5}{\left(1+\frac{s}{10^5}\right)\left(1+\frac{s}{10^6}\right)\left(1+\frac{s}{10^7}\right)}$$

40%

(iii) An amplifier whose gain is given by the transfer function from (ii) has input signal $\sin(\omega t)$. Using your answer from (ii), or otherwise, estimate the steady-state output signal when ω = (a) 10^3 rad/s; (b) 10^5 rad/s; and (c) 10^7 rad/s. 40%

4. (i) The design of a band-pass filter based on a low-pass prototype involves the frequency transformation

$$j\omega \to \beta\left(\frac{j\omega}{\omega_0}+\frac{\omega_0}{j\omega}\right)$$

Show how the elements of an RLC filter are affected by this transformation. 20%

(ii) Design an RLC filter with 50 Ω terminating resistances to meet the specification shown in Figure 3. 80%

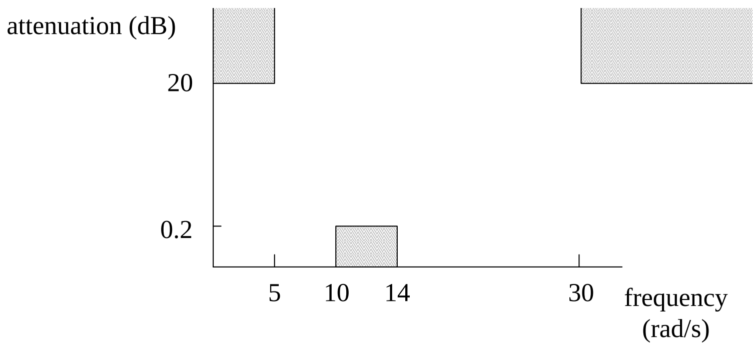

Figure 3

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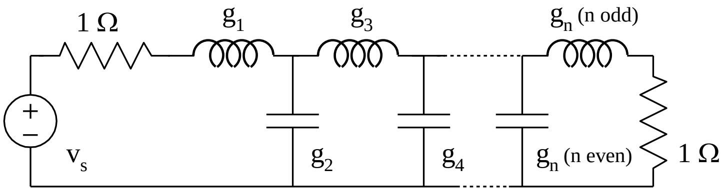
Filter design formulae

Butterworth low-pass filter realisation

A circuit realisation of the n^{th} order normalised Butterworth low-pass filter is shown below, with element values given by

$$g_r = 2\sin\left((2r-1)\frac{\pi}{2n}\right)$$



Frequency transformations:

Low-pass to high-pass: $j\omega \rightarrow \frac{\omega_0}{j\omega}$

Low-pass to band-pass: $j\omega \rightarrow \beta\left(\frac{j\omega}{\omega_0} + \frac{\omega_0}{j\omega}\right)$

Butterworth polynomials:

The Butterworth polynomials for order 1 to 6 are given in the following table:

order	Butterworth polynomial
1	$s+1$
2	$s^2 + 1.414s + 1$
3	$(s + 1)(s^2 + s + 1)$
4	$(s^2 + 0.765s + 1)(s^2 + 1.848s + 1)$
5	$(s + 1)(s^2 + 0.618s + 1)(s^2 + 1.618s + 1)$
6	$(s^2 + 0.518s + 1)(s^2 + 1.414s + 1)(s^2 + 1.932s + 1)$

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