University College Dublin
An Coláiste Ollscoile, Baile Átha Cliath

SEMESTER II 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) Define the term *two-port*, and explain why this concept can be a useful one. 20%

(ii) For the two-port shown in Figure 1, with sinusoidal excitation at frequency ω, find 80%

(a) the impedance matrix Z;

(b) the transmission (ABCD) matrix T.

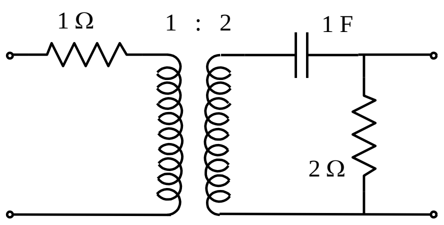

Figure 1

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%

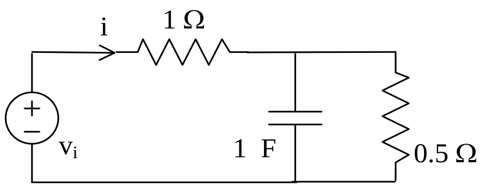

Figure 2

3 The op amps in the circuit of Figure 3 are ideal with infinite gain and operating in the linear region.

(i) Find the transfer function $V_{LP}(s)/V_1(s)$, and show that it is of the form

$$\frac{k}{s^2 + as + b}$$

40%

(ii) Find the transfer function $V_{BP}(s)/V_1(s)$. 20%

(ii) If k = -1, $a = \sqrt{2}$ and b = 1 in the transfer function from (i), what will be the steady state output $v_{LP}(t)$ if $v_1(t) = \sin t$ V? 40%

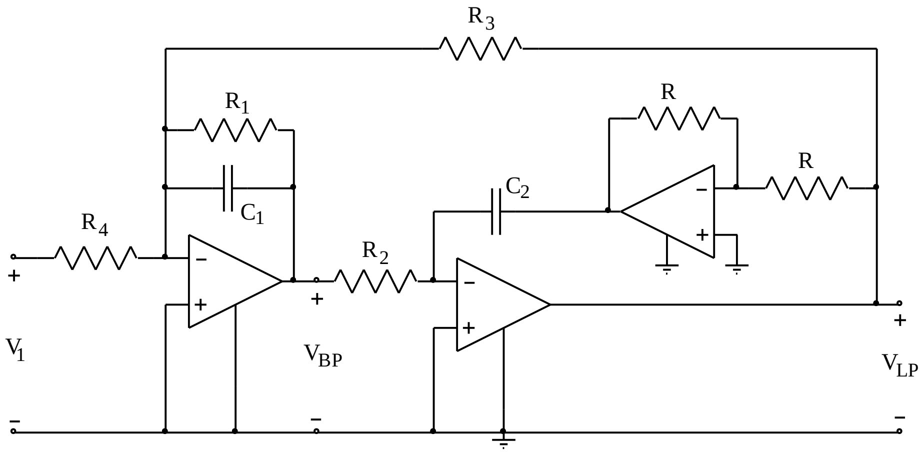

Figure 3

4. (i) Discuss, giving equations as appropriate, the process of impedance scaling in filter design. Indicate what it involves, why it is useful, and how it can be applied to an RLC circuit. 20%

(ii) Design an RLC filter with 1 kΩ terminating resistances to meet the specification shown in Figure 4. 80%

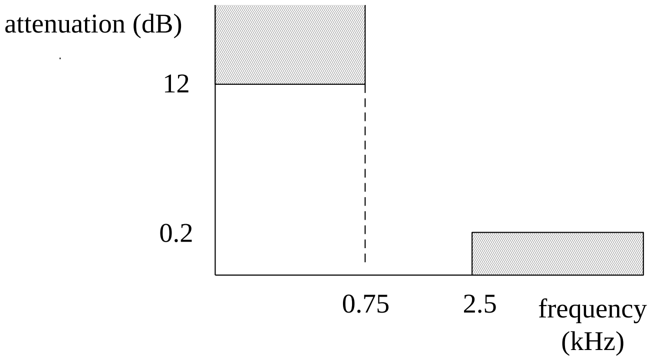

Figure 4

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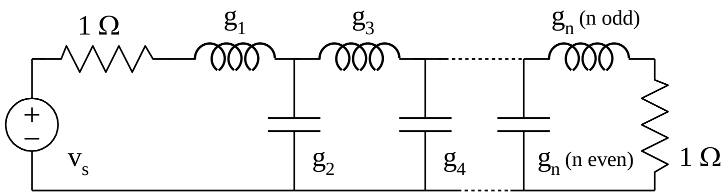
Filter design formulae

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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