University College Dublin
An Coláiste Ollscoile, Baile Átha Cliath

SEMESTER I EXAMINATIONS - 2014/2015

School of Electrical, Electronic and Communications Engineering

EEEN30020 Circuit Theory

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Time Allowed: 2 hours

Instructions for Candidates

Answer **any three** questions. All questions carry equal marks. The distribution of marks in the right margin, shown as a percentage, gives 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.

Question 1.

(i) List five two-port representations you have studied in this module. What is the transmission matrix and how does one find its elements? 20%

(ii) Find the admittance (Y) matrix of the two-port in Figure 1(a). 40%

(iii) If port 2 of the circuit from figure 1(a) is terminated in a 1 Ω resistance, as shown in figure 1(b), what is the input impedance of this two-port circuit? 40%

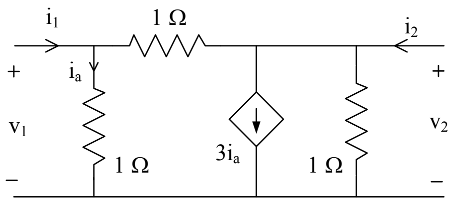


Figure 1(a)

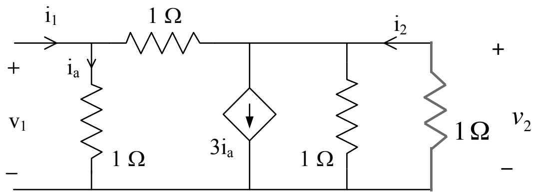


Figure 1(b)

Question 2.

The Newton-Raphson method generates successive estimates $v^{(k)}$ of the solution of the nonlinear equation F(v)=0 from the following expression:

$$v^{(k)} = v^{(k-1)} - \frac{F(v^{(k-1)})}{F'(v^{(k-1)})}$$

(i) Show how the application of the Newton-Raphson method leads to a companion circuit model for a diode modelled by the nonlinear equation 30%

$$i = 10^{-15}(\exp(40v) - 1)$$

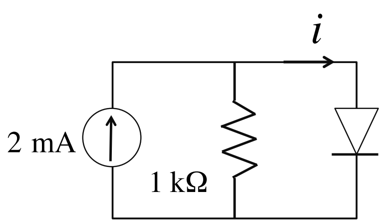


Figure 2.

(ii) Estimate the diode voltage in the circuit of Figure 2 using the Newton-Raphson algorithm: from an initial estimate v=0.65 V, run the algorithm for two iterations and show the successive estimates of the solution. The diode is modelled as in Q2(i). 70%

Question 3.

(i) Describe the relationship between phasor analysis and Laplace transform analysis of linear circuits. 10%

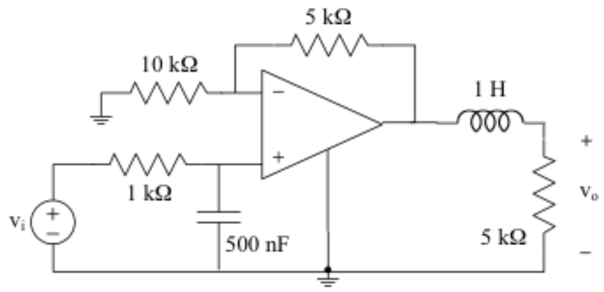


Figure 3.

(ii) Find the transfer function $V_o(s)/V_i(s)$ for the circuit of Figure 3, assuming the op amp to be ideal with infinite gain and operating in the linear region. What are the natural frequencies of the circuit? Is this circuit stable? 50%

(iii) Sketch the Bode plots (magnitude and phase) of the transfer function obtained in Q3(ii). Comment on the resulting Bode plot. What is the corner frequency of this transfer function? 40%

Question 4.

(i) Discuss, giving equations as appropriate, the process of frequency scaling in filter design. Indicate what it involves and why it is useful. 30%

(ii) Design an RLC filter with 1kΩ terminating resistances to meet the specification shown in figure 4. 70%

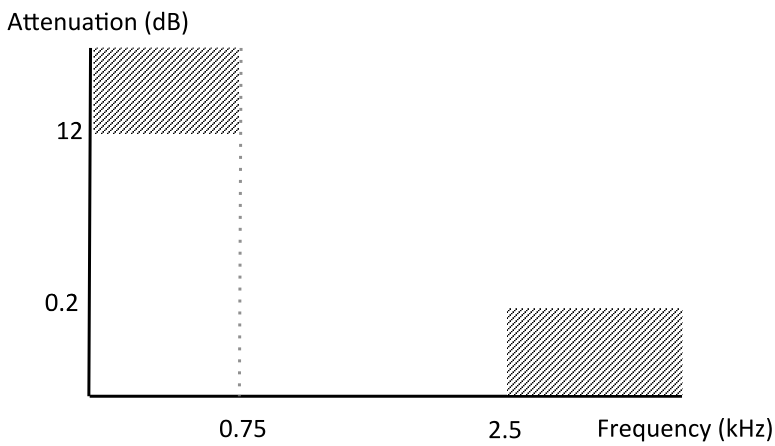


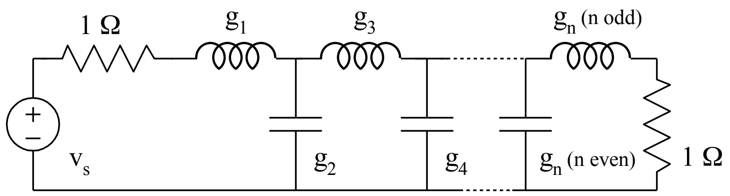
Figure 4.

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: $j\omega \to \frac{\omega_0}{j\omega}$

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

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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