GX541

OLLSCOIL NA hÉIREANN, GAILLIMH
NATIONAL UNIVERSITY OF IRELAND, GALWAY

SEMESTER I EXAMINATION, 2000/2001

SECOND YEAR ELECTRONIC ENGINEERING
SECOND YEAR ELECTRONIC AND COMPUTER ENGINEERING
SECOND YEAR MECHANICAL ENGINEERING
SECOND YEAR BIOMEDICAL ENGINEERING
SECOND YEAR MANAGEMENT ENGINEERING WITH LANGUAGE
SECOND YEAR INDUSTRIAL ENGINEERING

ELECTRICAL CIRCUITS AND SYSTEMS

Professor L.E. Davis
Professor D.J. Wilcox

Duration of Examination: *two* hours
Instructions: Answer *three* questions

1. Fig.1 shows the equivalent circuit of a power amplifier.

(a) Show that the voltage gain of the amplifier is given by

$$\frac{v_{out}}{v_{in}} = \frac{(1+\beta)R_L}{2r+(1+\beta)R_L}$$ **[5 marks]**

(b) Determine an expression for the signal input power ($P_{in} = v_{in}i_{in}$) and an expression for the power (P_{out}) absorbed by the load resistance R_L. Hence show that the power gain of the amplifier is given by

$$\frac{P_{out}}{P_{in}} = \frac{(1+\beta)^2 R_L}{2r+(1+\beta)R_L}$$ **[5 marks]**

(c) Determine the open-circuit output voltage (i.e. the value of v_{out} when R_L is removed) and the value of the output short-circuit current. Proceed to determine the Thévenin equivalent of the amplifier circuit. **[6 marks]**

(d) With circuit values $R_L = 3\Omega$, $r = 15\Omega$ and $\beta = 99$, and with $v_{in} = 5.5$ Volts, specify *(i)* the voltage gain of the amplifier, *(ii)* the power gain of the amplifier, *(iii)* the amount of power absorbed by the load resistance and *(iv)* the amount of power supplied by the 10V source. **[4 marks]**

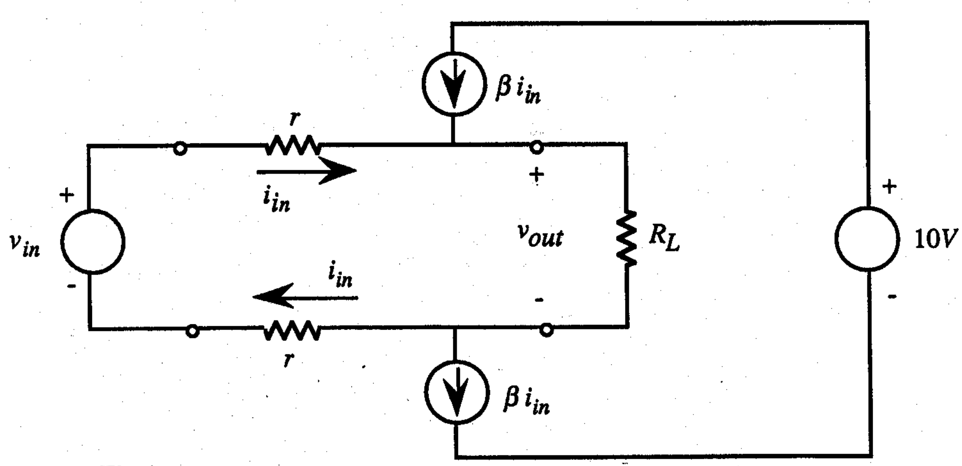

Fig.1

2. Fig.2 shows the circuit of Owen's Bridge which can be used to find the resistance R and the inductance L of a coil.

(a) Draw the circuit in the form required for phasor analysis, in terms of R, L, C_2, R_2, etc. **[4 marks]**

(b) With the given circuit values for C_2, R_2 and C_4, and with $\omega = 100$ rad/s, show that the voltage at ***a*** will be given by :

$$v_a(t) = \frac{2}{3} V\sqrt{2}\, sin(100t - 36.9°)$$ **[6 marks]**

(c) For the case $R = 20\Omega$ and $L = 0.9$H, and for the same angular frequency $\omega = 100$ rad/s, determine an expression for the voltage $v_b(t)$ in terms of V. What will be the reading on a voltmeter connected between points ***a*** and ***b*** in this case? **[4 marks]**

(d) Show that the voltage between points ***a*** and ***b*** in the circuit will always be zero, regardless of the values of V and ω, whenever the following two conditions are satisfied :

$$L = R_3 C_4 R_2 \qquad \text{and} \qquad R = \frac{R_3 C_4}{C_2}$$ **[6 marks]**

[*Hint*: it is sufficient to show that the phasors V_a and V_b will be equal when the above conditions are satisfied]

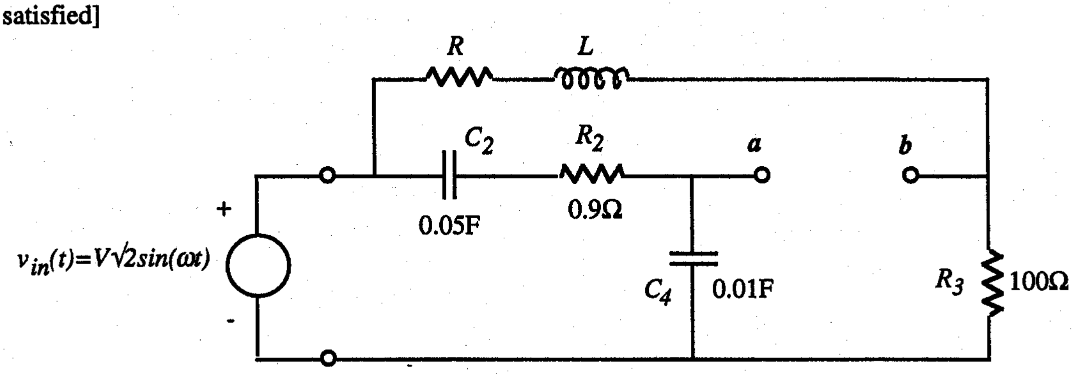

Fig.2

3. In the circuit of Fig.3, the switch has been closed for a long time before being opened at $t = 0$.

(a) Determine the capacitor voltage, and the inductor current, at the instant the switch opens. **[4 marks]**

(b) Draw the transform network applicable to t > 0. Is the switch open or closed in this network? **[5 marks]**

(c) Determine an expression for the Laplace transform of the output voltage, i.e. find $V_{out}(s)$, and draw its pole-zero map. **[6 marks]**

(d) Use the initial and final value theorems, respectively, to determine the initial and final values of $v_{out}(t)$ applicable to the time range $0 < t < \infty$. Proceed to sketch the expected nature of $v_{out}(t)$ showing the time scale involved. **[5 marks]**

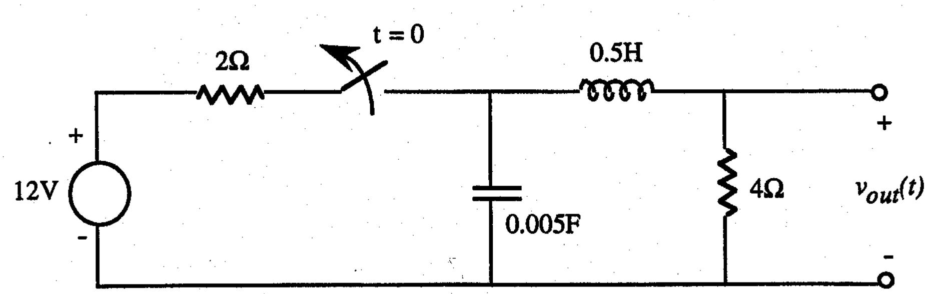

Fig.3

4. *(a)* A certain Butterworth Low-Pass Filter, with a 3dB cutoff frequency of 10 rad/s, has the pole-zero diagram shown in Fig.4a. The low-frequency gain of the filter is unity. Determine the transfer function of the filter. **[4 marks]**

(b) Re-draw the circuit shown in Fig.4b in the form required for analysis in the complex frequency (Laplace Transform) domain. Proceed to show that the transfer function of the circuit is given by

$$\frac{V_{out}(s)}{V_{in}(s)} = \frac{\alpha\beta}{s^3 + \alpha s^2 + 4\beta s + \alpha\beta} \qquad \text{where} \quad \alpha = \frac{R}{L} \quad \text{and} \quad \beta = \frac{1}{3LC}$$

If the circuit values are chosen as $R = 100\Omega$, $L = 5H$, and $C = \frac{1}{750}F$, show that the circuit transfer function will have the same pole-zero map as that shown in Fig.4a. **[10 marks]**

(c) If the input signal to the filter specified in part *(b)* (including the given values for *R*, *L*, and *C*) is $v_{in}(t) = \sin(t) + \sin(100t)$, calculate the (steady-state) response of the filter in the form

$$v_{out}(t) = A\sin(t-\theta) + B\sin(100t-\phi)$$

[*hint*: calculate the responses to *sin(t)* and *sin(100t)* separately and superpose the results].

Hence confirm that the filter will have effectively suppressed the high-frequency component whilst allowing the low-frequency component to pass through more or less unchanged. **[6 marks]**

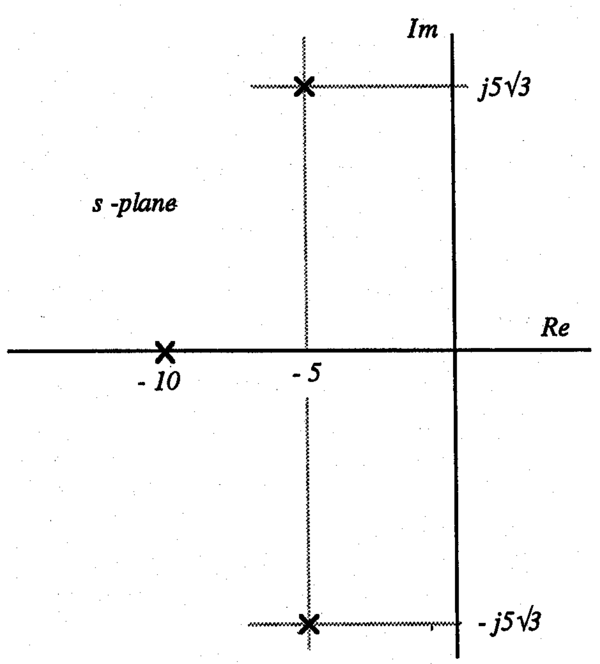

Fig.4a

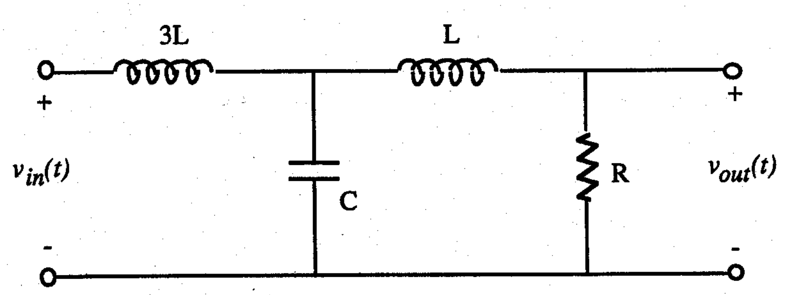

Fig.4b

TABLE OF LAPLACE TRANSFORM PAIRS

f(t)	F(s)
$\delta(t)$	1
$u(t)$	$\frac{1}{s}$
t	$\frac{1}{s^2}$
e^{-at}	$\frac{1}{s+a}$
$t e^{-at}$	$\frac{1}{(s+a)^2}$
$\frac{1-e^{-at}}{a}$	$\frac{1}{s(s+a)}$
$\frac{e^{-at}-e^{-bt}}{b-a}$	$\frac{1}{(s+a)(s+b)}$
$\sin(\omega t)$	$\frac{\omega}{s^2+\omega^2}$
$\cos(\omega t)$	$\frac{s}{s^2+\omega^2}$
$t\sin(\omega t)$	$\frac{2\omega s}{(s^2+\omega^2)^2}$
$t\cos(\omega t)$	$\frac{s^2-\omega^2}{(s^2+\omega^2)^2}$