GX565

OLLSCOIL NA hÉIREANN, GAILLIMH
NATIONAL UNIVERSITY OF IRELAND, GALWAY

SEMESTER II EXAMINATIONS, 2000/2001

SECOND YEAR ELECTRONIC ENGINEERING
SECOND YEAR ELECTRONIC AND COMPUTER ENGINEERING
SECOND YEAR MECHANICAL ENGINEERING
SECOND YEAR BIOMEDICAL ENGINEERING
SECOND YEAR INDUSTRIAL ENGINEERING
SECOND YEAR MANAGEMENT ENGINEERING
EXAMINATION

ELECTRICAL CIRCUITS AND SYSTEMS

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

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

---

1. *(a)* Derive and sketch (in your answer book) the essential nature of the BODE plot (gain and phase) of the general second-order transfer function $G(s) = \frac{\omega_n^2}{s^2 + 2\zeta w_n s + \omega_n^2}$. In particular, derive and draw the low-frequency and high-frequency asymptotes for both gain and phase. Show that the l.f. and h.f. gain asymptotes intersect at the frequency $\omega = \omega_n$ (the corner frequency). Proceed to show that the exact gain at the corner frequency will be $20\,log_{10}\left(\frac{1}{2\zeta}\right)$ and that the corresponding phase angle will be – 90°.

[10 marks]

(b) For *optional* **bonus** marks, show that the phase of a general second-order system will be – 45° when $\frac{\omega}{\omega_n} = -\zeta + \sqrt{\zeta^2 + 1}$ and will be –135° when $\frac{\omega}{\omega_n} = +\zeta + \sqrt{\zeta^2 + 1}$ **[+5 marks]**

(c) Using log-linear graph paper supplied in the examination hall, draw the approximate BODE plot (gain and phase) of the transfer function $H(s) = \frac{100}{(s^2 + 0.5s + 1)(s + 10)}$. If you wish, use separate log-linear graph sheets for the gain and phase, respectively. Use formulas given in parts *(a)* and *(b)* to refine your sketches of the gain and phase characteristics. [*Hint*: start by showing that the l.f. gain will be 20dB]

[10 marks]

2. Fig.2 shows a 50Hz substation supplying an inductive load impedance of $R + jX = 0.3 + j0.32\Omega$. The wattmeter shown in the circuit reads 75.0kW.

(a) From the given wattmeter reading, and from the given value of the load impedance, deduce the amounts of real and reactive power absorbed by the load. Specify the load kVA and power factor. Also specify the load current and confirm that the load voltage will be 220V. **[8 marks]**

(b) Given that the load voltage is 220V, determine the amount of reactive power supplied by the power-factor correcting capacitor. **[3 marks]**

(c) Specify the kVA and power factor of the load as seen by the feeder (i.e. that of the load inclusive of power factor correction). Hence, show that the current flowing down the feeder will be 341 Amps. **[4 marks]**

(d) Determine the amounts of real and reactive power absorbed by the feeder and proceed to deduce the voltage at the substation terminals. **[5 marks]**

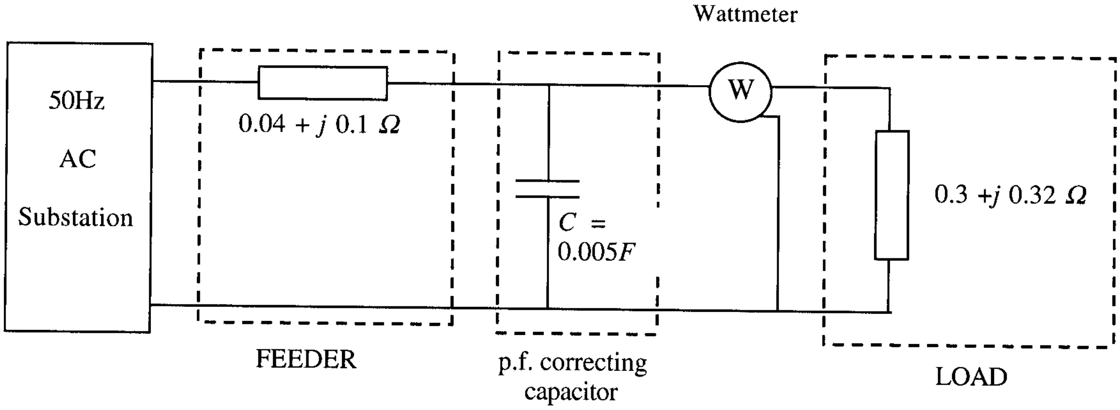

Fig.2

3. By a process of systematic block diagram reduction, show that the system of Fig.3 has the transfer function

$$\frac{C(s)}{R(s)} = \frac{16(s+3)}{(s+4)(s^2+8s+6)}$$ **[8 marks]**

Draw the pole-zero map of this transfer function and sketch the nature of the system response to a unit step input. Use the final-value theorem to determine the final value of the response, clearly show the time scale involved, and show the nature of any decay. **[8 marks]**

Determine the **steady-state** response, $c(t)$, of the system in Fig.3 to the input $r(t) = 10\sin(2t)$. [*Hint*: you do not need to invert any Laplace transforms to obtain the required result] **[4 marks]**

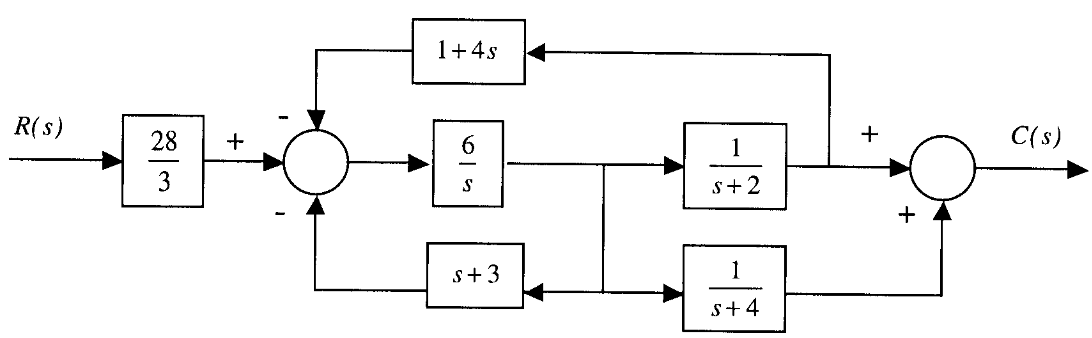

Fig.3

4. Fig.4 shows the circuit diagram of a power amplifier in the complex-frequency domain. Note that both sources in the amplifier circuit are *dependent* sources.

(a) Show that the amplifier has the transfer function

$$\frac{V_{out}(s)}{V_{in}(s)} = -\frac{\beta R_L}{r + \beta R_L G(s)}$$

[6 marks]

(b) With $\beta R_L / r = 200$, and if $G(s) = K/(s+10)^3$, show that the amplifier will be stable if $K = 10$ but will be only marginally stable if K is raised to $K = 40$. **[6 marks]**

(c) Determine the value of K required such that the amplifier will have poles at $s = -7.5 \pm j4.33$. Specify the damping ratio ζ associated with these pole locations. **[5 marks]**

(d) Write down the linear differential equation relating $v_{out}(t)$ to $v_{in}(t)$ for the case $K = 0.625$. **[3 marks]**

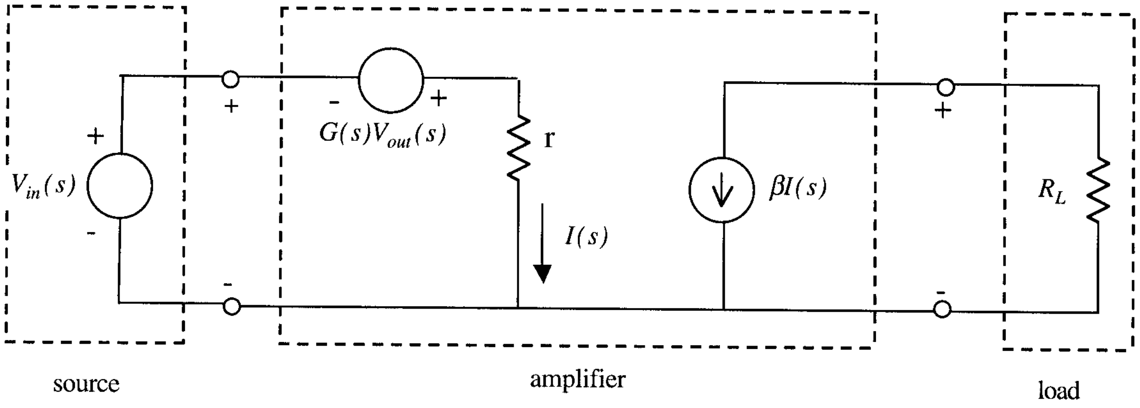

Fig.4