GX551

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NATIONAL UNIVERSITY OF IRELAND, GALWAY

SUMMER EXAMINATIONS, 1999

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

ELECTRICAL CIRCUITS AND SYSTEMS

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Professor D.J. Wilcox

Duration of Examination: *Three* hours
Instructions: Answer *five* questions

1. *(a)* Fig.1a shows the equivalent circuit of a simple transistor amplifier. Note that the output of the current source is not constant but is proportional to the current i_{in} defined in the figure. Show that the voltage gain of the amplifier is given by the formula

$$\frac{v_{out}}{v_{in}} = \frac{-\beta}{r_b + (1+\beta)R_E} \cdot \frac{R_C R_L}{R_C + R_L}$$

(b) Find the Thévenin equivalent of the circuit shown in Fig.1b. If a resistance $R = 2.8\Omega$ is connected across the output terminals, determine the voltage which will appear across R.

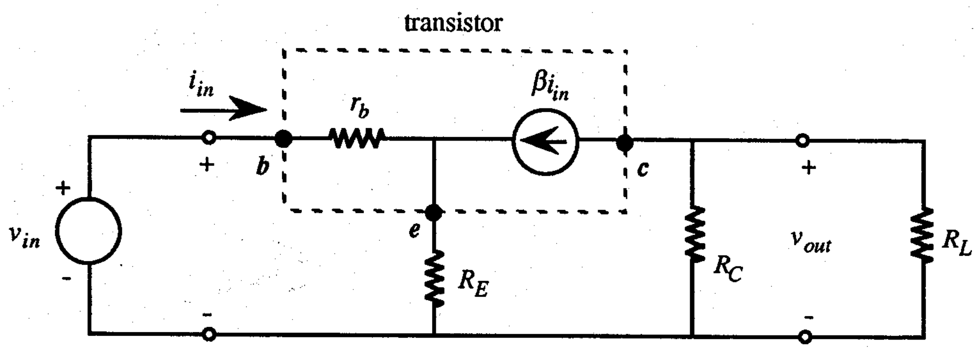

Fig.1a

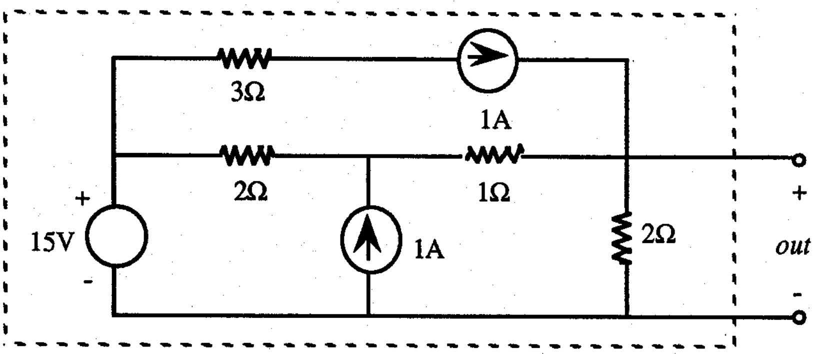

Fig.1b

2. With the switch S open, the load in Fig.2 draws 2.0kW and 20A from the 260V supply. Deduce the values of R and X. Determine the phasor $\mathbf{I}_L$ and show it on a phasor diagram relative to the phasor $\mathbf{V}$.

If the switch S is now closed with $C = 100\mu F$, determine the phasor $\mathbf{I}_C$ and show it on a phasor diagram relative to $\mathbf{V}$ and $\mathbf{I}_L$. Proceed to deduce the amount of current drawn from the supply and its phase angle relative to the supply voltage. Hence specify the power factor of the load as seen from the supply terminals. To what value would C need to be changed to correct the power factor to unity?

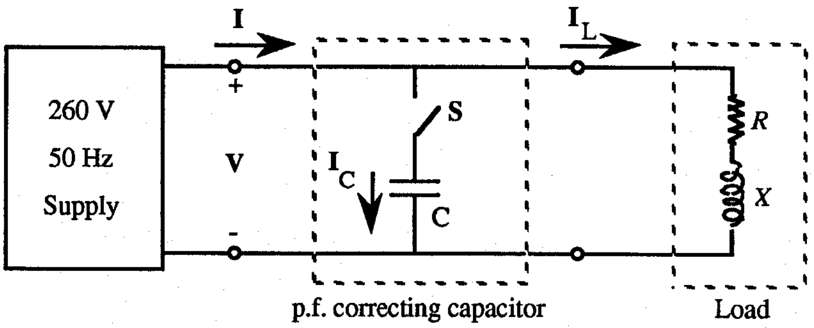

Fig.2

3. What is a transform network ? Derive the transform network representation of an inductor.

In the circuit of Fig.3, the switch S has been open for a long time, with C uncharged, before being closed at the instant t=0. Draw the transform network representing the behaviour of the circuit for $t \geq 0$ and proceed to obtain an expression for $V_o(s)$. Draw the pole-zero map of $V_o(s)$ and proceed to sketch the nature of $v_o(t)$ showing the time scale involved and the final value.

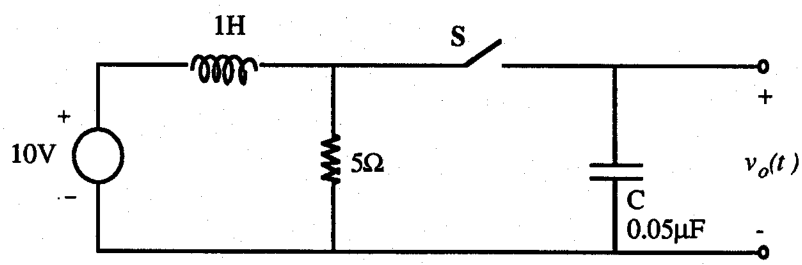

Fig.3

4. The plant in Fig.4, tested with the input $x(t) = u(t)$ [a unit step], gave the output response

$$y(t) = t - 0.5(1 - e^{-2t})$$

[A table of Laplace transform pairs is given on p.5 of this question paper]

(a) Deduce the transfer function $G(s) = Y(s) \div X(s)$ of the plant.

(b) The plant is now connected into the feedback loop of Fig.4 with the gain set at $K = \frac{25}{6}$.

If the transfer function of the compensator is chosen as

$$G_c(s) = \frac{3(s+2)}{s+6} \quad ,$$

show that the transfer function of the closed-loop system will be

$$\frac{C(s)}{R(s)} = \frac{25}{(s+3)^2 + 4^2}$$

Draw the pole-zero map of this transfer function and proceed to sketch the nature of the unit step response of the system showing the time scale and final value.

(c) If the compensator action is suppressed, by changing $G_c(s)$ to $G_c(s) = 1$, determine the new closed-loop transfer function and proceed to sketch the unit step response of the changed system. Comment on the advantages of including the original compensator.

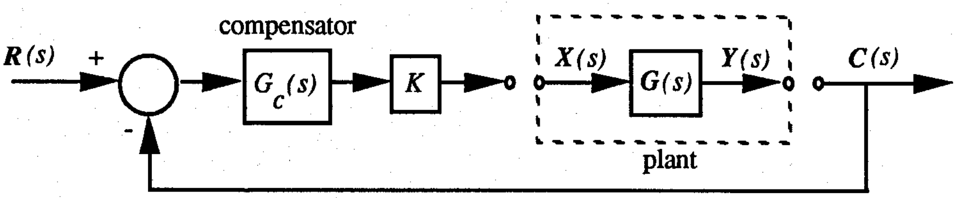

Fig.4

5. Fig.5 shows the block diagram of a system in which α and K are adjustable parameters.

(a) Show that the transfer function of the system of Fig.5 is given by

$$\frac{C(s)}{R(s)} = \frac{\alpha K s}{s^3 + (1+K)s^2 + \alpha K s + \alpha K}$$

(b) Show that if the input is a ramp of unit slope, i.e. $r(t) = t.u(t)$, then $c(t) \to 1$ as $t \to \infty$ regardless of the values of α and K.

(c) For the case $\alpha = 1.5$ and $K = 3$, show that $C(s)/R(s)$ has a simple pole at $s = -3$. Locate the other two poles and draw the pole-zero map.

(d) What values of α and K will cause $C(s)/R(s)$ to have a triple pole ?

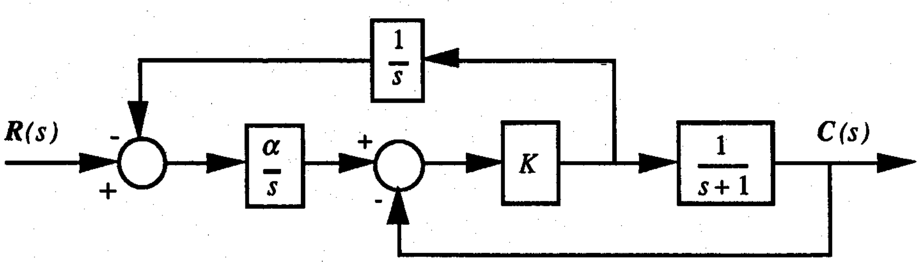

Fig.5

6. It is required to design the phase-lag network of Fig.6a to have the amplitude characteristic shown in Fig.6b.

(a) Deduce the transfer function corresponding to the amplitude characteristic of Fig.6b.

(b) Determine the transfer function $V_o(s)/V_i(s)$ of the circuit of Fig.6a in terms of R_1, R_2 and C.

(c) Given $R_2 = 1000\Omega$, determine values for R_1 and C to give the desired transfer function.

(d) Without using special graph paper [i.e. using your answer book] sketch the nature of the phase characteristic corresponding to the amplitude characterstic of Fig.6b. Compute values for the phase lag at $\omega = 4$ rad/s, $\omega = 11.3$ rad/s and $\omega = 32$ rad/s and use these to produce an improved sketch of the phase characteristic.

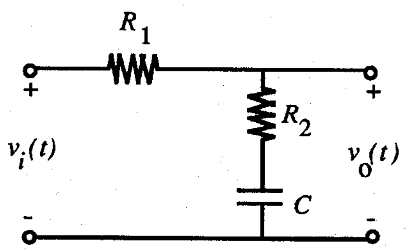

Fig.6a

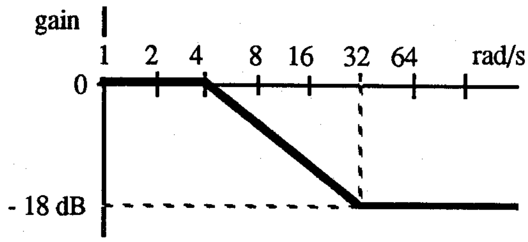

Fig.6b

7. (a) Using the Routh-Hurwitz criterion, or otherwise, determine the value of K at which the control system of Fig.7 becomes marginally stable.

(b) With the gain set at $K = 2.72$, show that the system will have closed-loop poles at $s = -4$ and $s = -1 \pm j4$. Write down the closed-loop transfer function with this gain and sketch its BODE plot (amplitude only) [this may be done in your answer book or on log-linear graph paper] [*Hint*: approximate $\sqrt{17}$ as 4]. Start with an asymptotic plot and THEN adjust shape in the vicinity of the corner frequency. Use the Bode plot to *estimate* the steady-state amplitudes of the responses to the sinusoidal inputs $r(t) = \sin(0.4t)$, $r(t) = \sin(4t)$ and $r(t) = \sin(40t)$.

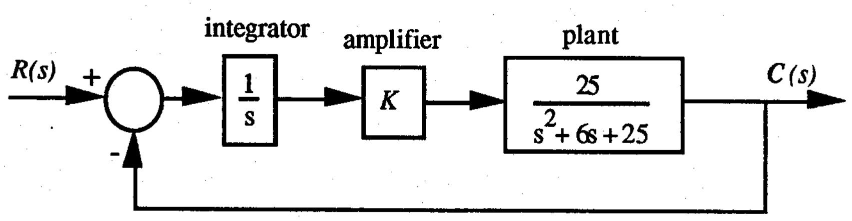

Fig.7