EXAMINATION MARKING SCHEME

EXAM DIET: In Class Test 2014-15
COURSE: B.Eng. in Electronic Engineering
COURSE: B.Eng. in Mechatronic Engineering
COURSE: Study Abroad (Engineering & Computing)

MODULE: EE406 Systems

QUESTION 1

(a) An expression for the error $E(s)$ in terms of the signals $R(s)$ and $N(s)$ only is found as:

$$\begin{aligned} E(s) &= R(s) - Y(s) = \\ Y(s) &= \frac{CG}{1+CGH}.R(s) - \frac{CGH}{1+CGH}.N(s) \\ E(s) &= \left(1 - \frac{CG}{1+CGH}\right).R(s) + \frac{CGH}{1+CGH}.N(s) \end{aligned}$$

[Q 1(a) 5 marks]

(b) The transfer function between the process output and the disturbance input is found in **Q 1(a)** above:

$$T_N = \frac{Y(s)}{N(s)} = \frac{-CGH}{1+CGH}$$

The sensitivity of this transfer function, to the controller parameter, k_C, is given as :

$$S_{kC}^{TN} = \frac{k_C}{T_N}.\frac{\partial T_N}{\partial k_C}$$

The chain rule version of this definition for the system is:

Incorrect version of Chain Rule,
Should be as per final line below (*)

$$S_{kC}^{TN} = S_{TN}^{C}.S_{C}^{kC}$$

This rule is then used to find the sensitivity of the closed loop system to variations in k_C:

$$\begin{aligned} S_{kC}^{C} &= \frac{k_C}{k_C}.\frac{\partial C}{\partial k_C} \\ &= \frac{k_C}{k_C}.1 \\ S_{C}^{TN} &= \frac{C}{T_N}.\frac{\partial T_N}{\partial C} \\ &= \frac{1}{1+CGH} \\ S_{kC}^{TN} &= S_C^T.S_{kC}^{C} = 1.\frac{1}{1+CGH} \end{aligned}$$

* Correct version of Chain Rule

[Q 1(b) 5 marks]

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QUESTION 1 CONTINUED

(c) The steady–state error is given as:

$$E_{ss} = \lim_{s \to 0} s.E(s)$$

This formula is used to calculate the value of k_C to give a steady–state error of 0.25 for a disturbance input of $N(s) = 0.5/s$ when $R(s) = 0$.

$$\begin{aligned}
E(s) &= \frac{CGH}{1 + CGH}.N(s) \\
E_{ss} &= \lim_{s \to 0} s.E(s) = \lim_{s \to 0} \frac{s.\frac{0.5}{s}.CGH}{1 + CGH} \\
&= \frac{9k_C}{180 + 18k_C} \\
0.25 &= \frac{9k_C}{180 + 18k_C} \\
k_C &= 10
\end{aligned}$$

[Q 1(C) 5 marks]

(d) MATLAB can be used to find the steady–state error due a unit step input and the steady–state error due to a noise input of $N(s) = 0.5/s$; the MATLAB commands needed are *feedback, series* and *dcgain*. The steady–state output is predicted as $R_{ss} - E_{ss}$, where E_{ss} is the addition of the two separate steady–state errors (linear superposition).

The steady–state error due to the step input is found to be $E_{Rss} \approx 0$, the steady–state error due to the disturbance input is found to be $E_{Nss} = 0.25$ and the predicted output steady–state value is $1 - E_{Rss} - E_{Nss} = 0.75$.

[Q 1(d) 5 marks]

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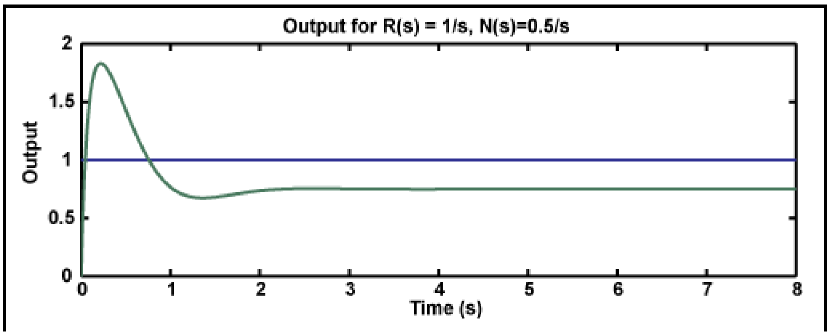
QUESTION 1 CONTINUED

(e) SIMULINK is used to simulate the complete closed loop system; care must be taken when implementing $N(s)$ to set the magnitude of the step to 0.5. The output from the simulation is plotted on the same plot as the input signal.



MATLAB is used to measure the steady–state output and this output is found to be 0.75 which matches that predicted in part **Q 1(d)(iii)**. The steady–state output matches very accurately because it does not rely on dominance of poles but on the actual values of the system.

[Q 1(e) 5 marks]

[Total: 25 marks]