EXAMINATION MARKING SCHEME

EXAM DIET: In-Class Test 2017-18
COURSE: B.Eng. in Electronic and Computer Engineering
COURSE: B.Eng. in Mechatronic Engineering

MODULE: EE458 Control Systems Analysis

QUESTION 1

[Q1 - Read Question ≈ 5 mins]

(a) (i)

$$\begin{aligned}
G_{inner} &= \frac{G}{1+a.G} \\
G_{forward} &= \frac{1}{s}.G_{inner} \\
Y_m &= K_D.D + K_C.G_{forward}\left(R - K_H.Y_m\right) \\
Y_m &= \frac{K_D}{1+K_C.K_H.G_{forward}}.D + \frac{K_C.G_{forward}}{1+1+K_C.K_H.G_{forward}}.R
\end{aligned}$$

(ii)

$$\frac{Y_m}{D} = \frac{K_D}{1+K_C.K_H.G_{forward}}$$

(iii)

$$\begin{aligned}
G_{inner} &= \frac{0.5s+1}{3.5s+5} \\
G_{forward} &= \frac{0.5s+1}{s\left(3.5s+5\right)} \\
\frac{Y_m}{D} &= \frac{K_D}{1+K_C.K_H.G_{forward}} = \frac{0.2}{1+K_C.10.\frac{0.5s+1}{s(3.5s+5)}} \\
&= \frac{0.2s\left(3.5s+5\right)}{s\left(3.5s+5\right)+10.K_C\left(0.5s+1\right)} \\
&= \frac{0.2s\left(3.5s+5\right)}{3.5s^2+5s+5.K_C s+10K_C}
\end{aligned}$$

[Q 1(a) 6 marks]

[Q 1(a) ≈ 15 mins]

(b) (i)

$$\begin{aligned}
E &= R - Y_m \\
&= \left[1 - \frac{K_C.G_{forward}}{1+K_C.K_H.G_{forward}}\right].R - \frac{K_D}{1+K_C.K_H.G_{forward}}.D
\end{aligned}$$

(ii)

$$E_{ss} = \lim_{t\to\infty} e(t) = \lim_{s\to 0} s.e(s)$$

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QUESTION 1 CONTINUED

(iii)

$$
\begin{aligned}
E_{ssD} = \lim_{s\to 0} sE_D &= \lim_{s\to 0} \frac{-s.K_D}{1+K_C.K_H.G_{forward}}.D \\
&= \lim_{s\to 0} -s.\frac{1}{s^2}.\frac{K_D}{1+K_C.K_H.G_{forward}} \\
&= \lim_{s\to 0} \frac{-K_D}{s+s.K_C K_H.\frac{(0.5s+1)}{s(3.5s+5)}} \\
&= \frac{-K_D}{K_C.K_H.\frac{1}{5}} \\
-0.04 &= \frac{-0.2}{10.K_C.(0.2)} \\
\Rightarrow K_C &= \frac{1}{10.(0.04)} = 2.5
\end{aligned}
$$

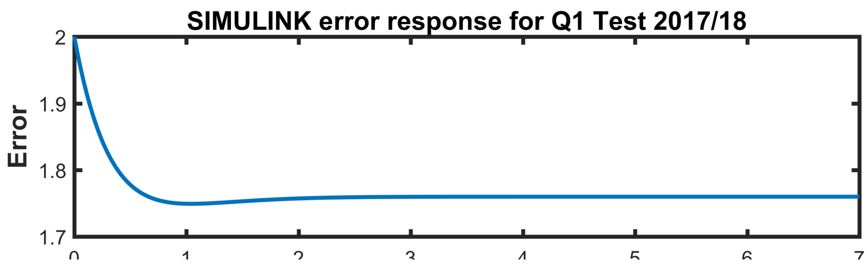
(iv) The MATLAB *feedback* and *dcgain* (or *evalfr*) are used with the expression for E_{ssR} found in **Q 1(b)(i)** to predict that the overall steady-state error will be 1.76. Care must be taken to allow for the amplitude of the step input.

[Q 1(b) 7 marks]

[Q 1(b) $\approx$ 15 mins]

(c) (i) SIMULINK is used to simulate the system; an appropriate step input with amplitude

(ii) This simulation produced error response plot (students can capture error within model or using MATLAB code):



(iii) The steady-state ramp error was measured using MATLAB and was found to be 1.7600; this is exactly the same as the prediction. This match is expected as the steady-state error calculation is based on the actual system and not on an assumed 2nd order system.

[Q 1(c) 7 marks]

[Q 1(c) $\approx$ 15 mins]

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QUESTION 1 CONTINUED

(d) (i) $S_p^F = \frac{p}{F}\frac{\partial F}{\partial p}$

(ii)

$$
\begin{aligned}
\text{Let } \; T_D &= \frac{Y_m}{D} \\
S_{KC}^{TD} &= \frac{K_C}{T_D}\frac{\partial T_D}{\partial K_C} \\
&= \frac{K_C.denTD}{numTD}.\frac{[denTD.0 - numT\,(5s+10)]}{(denTD)^2} \\
&= \frac{K_C}{numTD}.\left[\frac{-numTD\,(5s+10)}{denTD}\right] \quad \text{one denTD cancelled} \\
&= \frac{-K_C\,(5s+10)}{denTD} \quad \text{numTD cancelled} \\
&= \frac{-K_C\,(5s+10)}{3.5s^2+5s+5K_C+10K_C}
\end{aligned}
$$

[Q 1(d) 5 marks]

[Q 1(d) $\approx$ 10 mins]

[Total: 25 marks]

[END OF Q1 SOLUTIONS]