STAFFORDSHIRE POLYTECHNIC
DEPARTMENT OF MECHANICAL AND COMPUTER AIDED ENGINEERING

Session 1991/92

BEng(HONS) MECHANICAL ENGINEERING

Control For Manufacture - BM3CH

Date: Friday 31st January 1992
Time: 9.30 am - 12.30 pm
Time Allowed: 3 Hours

Examiners: M D Butler
P J Ogrodnik

Answer FIVE questions. All questions carry equal marks.

1. (a) Describe the relative merits of and the essential differences between each of the following devices:-

(i) A Cathode Ray Oscilloscope;
(ii) A Digital Storage Oscilloscope, and;
(iii) A Spectrum Analyser.

(12 marks)

(b) Sketch graphs of the following signals in both time domain and frequency domain, indicate clearly the salient features;

(i) A pure sinewave of frequency 50 Hz, and;
(ii) A square wave of frequency 50 Hz.

(8 marks)

2. (a) Define the following terms relating to instrumentation characteristics. Use sketches to aid your description, where appropriate;

(i) Bandwidth;
(ii) Resolution;
(iii) Deadband;
(iv) Linear Range, and;
(v) Sensitivity.

(10 marks)

(b) Sketch graphs showing the response of each of the following filter types, give an example of their use in each case;

(i) Low Pass Filter;
(ii) High Pass Filter, and;
(iii) Notch Filter.

(6 marks)

(c) A simple low pass filter is illustrated in Figure Q2. Determine the cut off frequency for this filter.

(4 marks)

3. (a) What is meant by the terms Step Input and Ramp Input when applied to the testing of an instrumentation or control system?

(4 marks)

(b) (i) Determine the closed loop transfer function for the system whose block diagram is given on Figure Q3.

(8 marks)

(ii) Sketch the response of the system to a step input, for each of the following values of damping coefficient, δ ; 3.2, 8 and 40 Nm/(rad/s).

(6 marks)

(iii) Show, on your sketches, what is meant by the terms; Response Time and Settling Time.

(2 marks)

4. (a) Nyquist discovered that the closed loop response of a system could be predicted from open loop test results. Explain why this has major benefits for testing and analysing control systems.

(2 marks)

(b) (i) Derive the closed loop transfer function for the system shown on Figure Q4.

(5 marks)

(ii) Sketch the response of the system to a step input of, θ_{in}=5 volts. Clearly label the important features.

(4 marks)

(iii) Derive the transfer function relating the error, θ_{err}, to the input, θ_{in}.

(5 marks)

(iv) Determine the steady state velocity error which would occur if the system was subjected to a constant velocity input of, θ_{in}=4 volts/s.

(4 marks)

5. The block diagram for a position control system is given on Figure Q5, along with values for the system parameters. Study the diagram carefully then:

(i) Determine the closed loop transfer function for this system.

(10 marks)

(ii) Calculate the values of the natural frequency, ω_n, and the damping ratio, ζ.

(6 marks)

(iii) Determine a value for Tacho gain, K_t , which would increase the damping ration, ζ, to 0.8.

(4 marks)

6. Figure Q6 shows a block diagram for a control system. You are asked to:

(i) Draw the Bode diagrams for this system; (12 marks)

(ii) Determine the gain and phase margins using the stated value of controller gain, K;

(6 marks)

(iii) Determine the new value of controller gain, K, which is required to give a gain margin of 10 dB.

(2 marks)

7. (a) Draw a diagram of a basic micro-processor based computer control system. Clearly label all the main components and buses.

(6 marks)

(b) What is meant by the terms ROM and RAM when applied to a microprocessor system?

(2 marks)

(c) What are the advantages of using a microprocessor based control system in, for example, a washing machine?

(6 marks)

(d) Explain what is meant by an interrupt, and why they are used in control systems.

(6 marks)

8. An industrial water heating system and its associated microprocessor based control system is illustrated diagrammatically by Figure Q8. The control program for the system is given below.

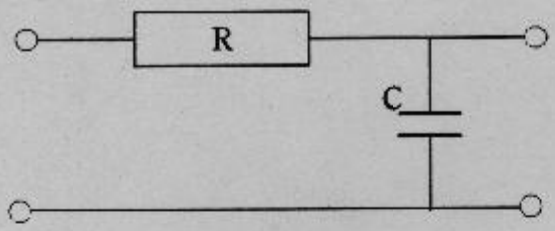
```
        ORG 3500H
        MVI A,02H
        OUT 40H
        MVI A,08H
        OUT 42H
LOOP1:  IN 41H
        ANI 01H
        JZ LOOP1
        MVI A,02H
        OUT 42H
LOOP2:  IN 41H
        ANI 02H
        JZ LOOP2
        MVI A,04H
        OUT 42H
```

(i) Using Figure Q8 and the program given above describe the operation of the system, in your discussion state the primary function of the system. Rewrite the program with comments or draw a flow diagram to support your description.

(12 marks)

(ii) Incorporate the low level switch into the system and modify the program to close valve 2 and make the system repeat the operation continuously.

(8 marks)



$R=3k\Omega \quad C=1\mu F$

Figure Q2

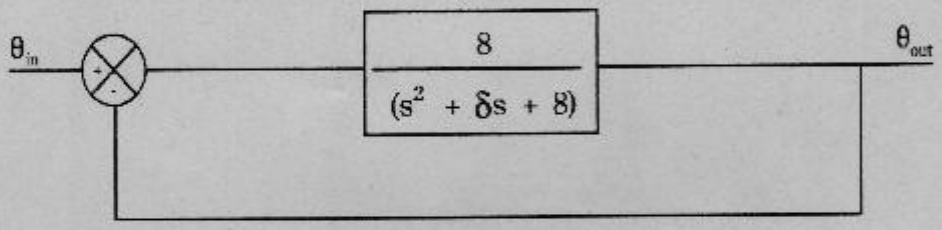


Figure Q3

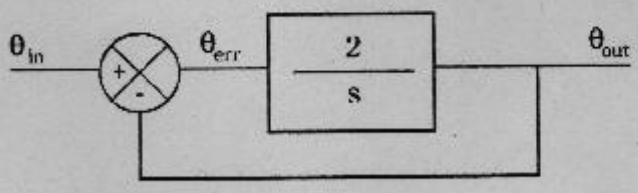
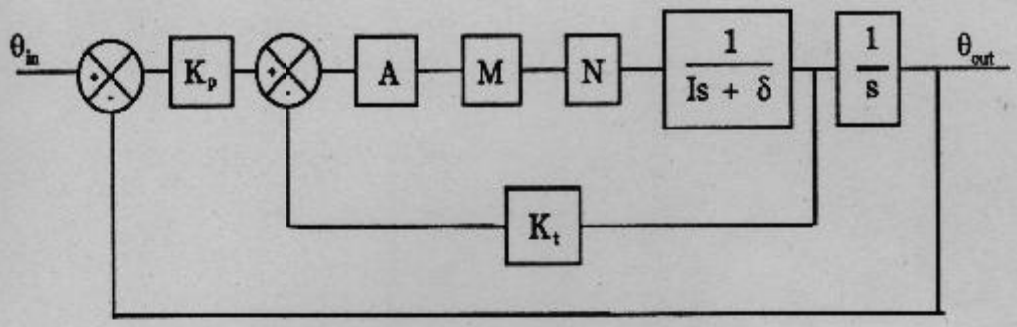


Figure Q4



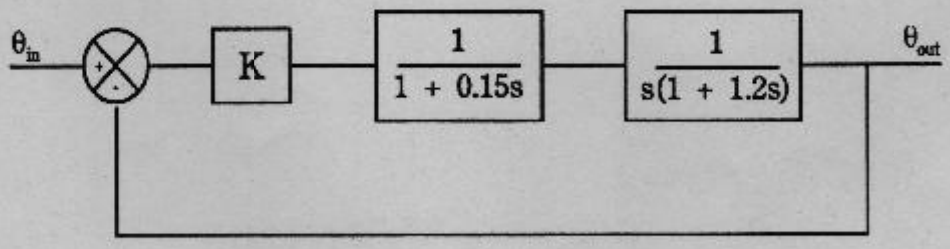
K_p = 200 mV/rad $\quad$ K_t - 8 mV/(rev/min)

A - 1 Amp/volt $\quad$ I - 250 kgm^2

M - 50 Nm/Amp $\quad$ δ - 25 Nm/(rev/s)

N - 100

Figure Q5



Initial setting, K = 1

Figure Q6

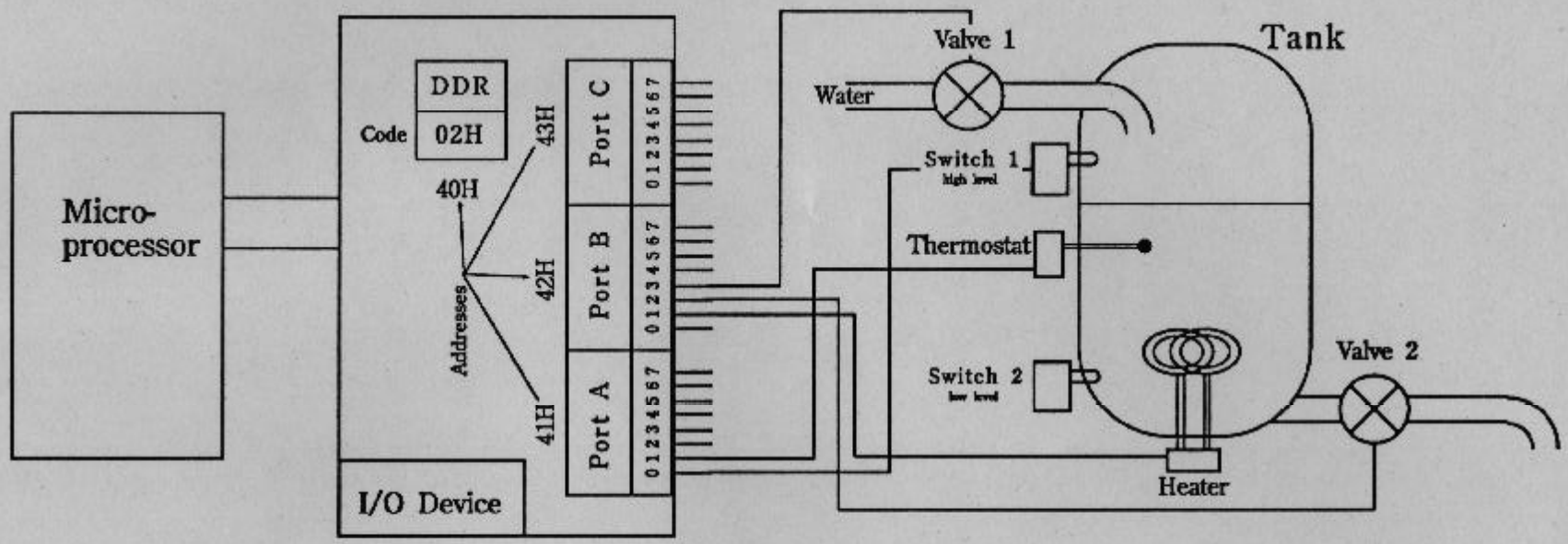

Micro-
processor
DDR
Code
02H
43H
40H
42H
41H
Addresses
Port C
Port B
Port A
01234567
01234567
01234567
I/O Device
Valve 1
Water
Tank
Switch 1
high level
Thermostat
Switch 2
low level
Valve 2
Heater

Figure Q8