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GEORGIA INSTITUTE OF TECHNOLOGY

The George W. Woodruff
School of Mechanical Engineering

Ph.D. Qualifiers Exam - Fall Quarter 1995

Automation in Manufacturing

EXAM AREA

Assigned Number **(DO NOT SIGN YOUR NAME)**

-- Please sign your name on the back of this page --

Problem 1:

Manufacturing Automation Qualifying Exam Question

A manufacturing enterprise has control at many levels. A robot or machine tool is controlled and the finances of the company are controlled. Discuss the control at at least three distinct levels of the manufacturing enterprise. Give specifics on what is to be controlled and how, the performance measures, and how the control interacts with other levels. How is the process modeled? How is the control problem different and how is it similar at each level? How can the problems be analyzed given the nature of the problem? What are the unsolved problems in control at the levels, both theoretical and practical?

In your discussion you will be graded on conciseness and insight as well as accuracy. Length of the discussion is not rewarded.

We are interested to implement the design of a computer-controlled robotic cell using a HC11 micro-controller. The purpose of the robot cell is to pick up parts, one at a time, from the seven part trays (labeled as parts 0, 1, 2, 3, 5, 6, 7). Each of these trays contains a number of identical parts. The task of the robotic cell is to pack sets of different component parts specified by different customers.

A typical cycle starts with the arrival of an order of component parts. The order is transmitted to the HC11-based controller via a bi-directional 8-bit parallel port, Port C. (The data direction register (DDRC) and the data register for port C are located at $1007 and $1003 respectively. Bit 4 of Port C is designated as input bit which signal the HC11 that the completion of the pickup task, and all other bits are designated as outputs.) Each of the output bits signals the robot a particular tray that contains the part. The robot has in memory the location of the component parts in each of the seven part trays. With that information, it picks up the parts and drops them into the collector for subsequent packing (not shown). When all the ordered parts are placed in the collector, the robot sends a "flag" to the HC11 via a serial port of 2400 baud, which in turn signals a quality control unit (not shown) to perform an inspection via a second serial port of 2400 baud. The cycle is then repeated.

EXAMPLE CUSTOMER PACKING OPTION:

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F = parts 0, 3, 7

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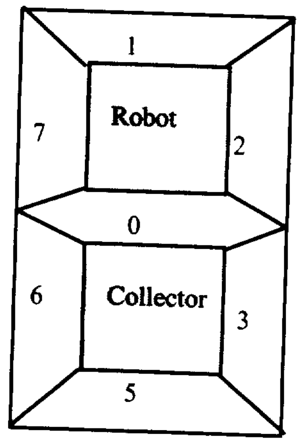


INFORMATION SENT VIA SERIAL PORTS:

From robot to HC11:

PARTS=0,3,7-DONE

From HC11 to the Quality Control Unit:

OPTION F-PARTS=0,3,7

Answer the following questions using the above information:

(1) At J cycle, the robot is to pack Customer Option F. Determine the content (in Hex) $1003 and $1007 and estimate the time required to complete the J cycle. Assume that the time required to execute the robot motion is negligible. State any other assumptions that you feel appropriate.

(2) We are interested to implement a robot joint motor control using an eight-bit HC11 micro-controller so that the motor speed will follow a pre-determined velocity profile as shown in the following figure. We shall assume here that the controller is based on the method of

successive approximation and the motor is controlled by varying the pulse width of a periodic signal of constant magnitude with an optical encoder.

In addition, a programmable real-time clock, the pulse width modulation, and the encoder counting are implemented on the following Interrupt Service Routines. Assume that the HC11 has as sixteen bit timer each tick of which represents 8 microseconds.

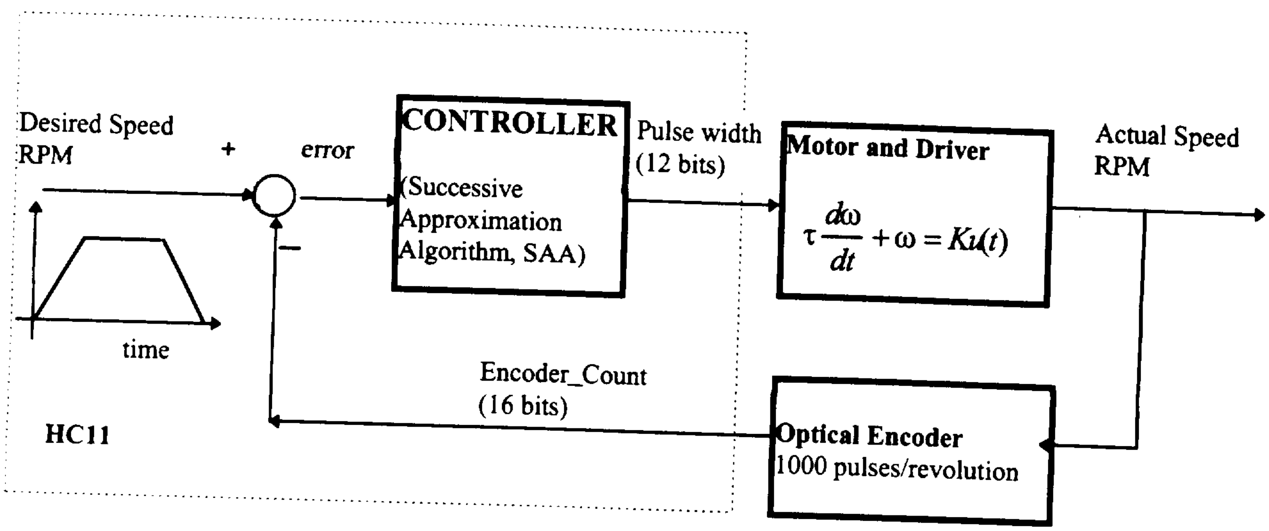
Interrupt	Start Address	Comment
OC1_ISR	$B686	Pulse width modulation Sets the fixed period for the duty cycle equal to CP*8 microseconds. Also sets the motor on for the fraction of the duty cycle selected by memory locations TO.
OC3_ISR	$B6A6	Encoder counting Updates the value of DM every SP*8 microseconds.
OC4_ISR	$B6DC	Programmable real-time clock Generates interrupts every CV*8 microseconds. Stores a count of the number of such interrupts at TC.

Withe the above information, answer the following questions:

(a) Derive an expression for the resolution and sensitivity of the optical encoder. How would you determine an appropriate value for SP?

(b) Sketch a flowchart illustrating the main program that will perform the motor speed control. Indicate clearly on the flowchart the design parameters which can be pre-determined off-line and the system variables which must be updated each cycle.

(c) Discuss how would you determine the appropriate value for the fixed period of the duty cycle CP and the number of bits N for the parameter TO.



Problem 3:

Consider a manufacturing workstation in which a part undergoes two operations, one on machine M1 and the other on machine M2 in any order (M1 followed by M2 or vice versa). The processing times of M1 and M2 are assumed to be exponentially distributed continuous random variables with rates μ_1 and μ_2, respectively. Also assume that a raw part is always available and neglect loading, fixturing, and transporting times. When a raw part finds both M1 and M2 free, it will be assigned to M1. After finishing the first operation, the part will go to the next machine if it is available; otherwise it waits on the machine (thus *blocking* it) until the other machine becomes free and then moves to the other machine. If a fresh part and in-process part vie for a machine the latter will be assigned the machine.

a) Develop a Continuous-Time Markov-Chain (CTMC) model for the system by first choosing an appropriate state-space and then constructing the corresponding state transition diagram and the infinitesimal generator matrix. In developing your CTMC note that each machine is either processing a part or it is blocked; neither one is ever idle.

b) Describe the procedure for computing the mean throughput of the system.