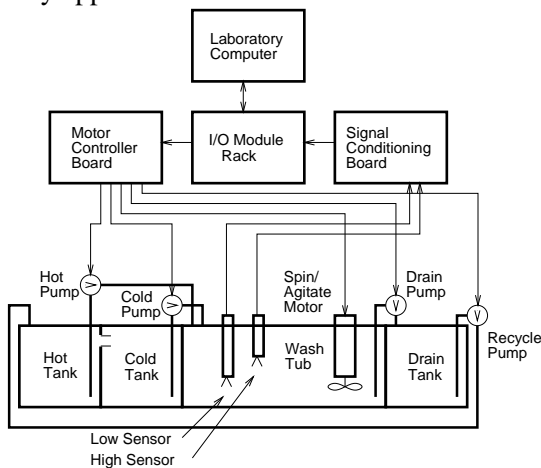# Lab 3 - Washing Machine Controller

Introduction

The purpose of this experiment is to use the lab computer to control a simulated washing machine machine.

Laboratory Apparatus

The diagram below shows a block diagram of the laboratory apparatus.

It consists of five major components:

- The *laboratory computer*. Refer to Lab 2 for a description.

- An *I/O module rack* which provides an interface between the laboratory computer's logic-level parallel I/O card and the circuitry that senses and drives the I/O devices: the water level sensors, the agitator motor and the pump motors. This I/O module rack allows different types of I/O interface modules (input, output, AC and DC) to be plugged in. Each module is isolated via an optical interface consisting of an LED and a phototransistor in order to protect the computer's circuitry from damage:

    - The level sensor inputs to the computer are connected via optically-isolated DC input modules plugged into the I/O module rack.

    - The interface between the computer and the motors for the pumps and agitators consists of an optically isolated DC output module plugged into the I/O module rack.

- The *signal conditioning board* contains special-purpose liquid-level sensor ICs. When no liquid is present a low level (logic 0) appears at the output of the module. This logic level is inverted on the interface card so that the computer receives a logic 1. When liquid is present at the sensor the computer receives a logic 0.

- The *motor controller board* contains the electronics to switch the pump and agitator motors on and off. When the computer writes a logic 1 to the I/O module it turns on the motor connected to the module.

- The *tanks, pumps, motors and sensors* simulate a washing machine.

  The washing machine has four tanks. The left-most tank is for hot water storage, the next tank is for cold water storage, the next is a wash tank and the right-most tank is a drain tank. Note that overflow from the hot water tank drains into the cold water tank.

  Four pumps control the flow of water between tanks. You will be controlling three of them to run the washing machine. The fourth pump recycles the water in the drain tank back into the hot and cold water tanks.

  A motor with an attached propeller simulates the wash-cycle agitator as well as the spin-cycle motor.
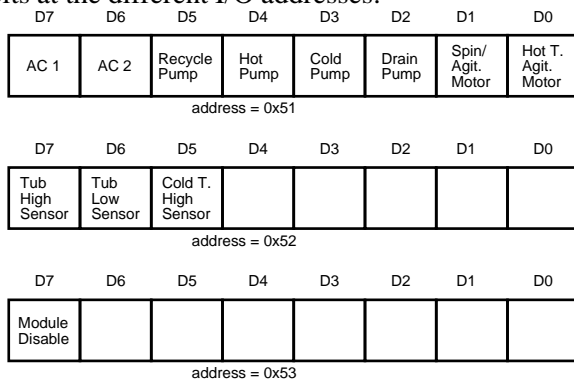
  There are two water level sensors (high– and low–level) in the wash tank and one level sensor (full–level) in the cold water tank (not shown in the diagram above).

The I/O module can also control two 120 volt AC outlets and a heater in the hot water tank. These facilities will not be used in this experiment.

The I/O Interface

From the programmer's point of view the interface between the I/O modules and the computer consists of three memory locations. Memory locations 0x51 through 0x53 are mapped to three 8-bit parallel I/O ports. Each of the available 24 bits is assigned to one module in the I/O module rack.

The following diagram gives the functions of the bits at the different I/O addresses:

D7	D6	D5	D4	D3	D2	D1	D0
AC 1	AC 2	Recycle Pump	Hot Pump	Cold Pump	Drain Pump	Spin/ Agit. Motor	Hot T. Agit. Motor

address = 0x51

D7	D6	D5	D4	D3	D2	D1	D0
Tub High Sensor	Tub Low Sensor	Cold T. High Sensor					

address = 0x52

D7	D6	D5	D4	D3	D2	D1	D0
Module Disable							

address = 0x53

The 8 bits of the port at address 0x51 are connected to 8 output modules. The bits of an output module can be set by writing the appropriate bit pattern to the appropriate location.

The port at 0x52 is connected to input modules. Data from input modules can be obtained by reading the appropriate location and "masking in" (using the bitwise AND operator) the appropriate bit in the byte.

Location 0x53 has only one active output bit which controls the power to all of the I/O modules on the rack. If the bit is set to 1, the I/O modules are disabled.

Washing Machine Operation

The washing machine should operate as follows:

1. Display "WASH?" on the LED display.

2. Wait for the "hot-wash" button (0) or "cold-wash" button (1) on the keypad to be pressed.

3. Fill the wash tank with hot or cold water depending on the cycle selected. Filling continues until the high level is sensed in the wash tank.

4. Turn on the agitator motor on for 15 seconds. During this time the motor should be cycled on and off with a pattern of 1 second on and 2 seconds off.

5. Empty the wash tank into the drain tank until a low level is sensed in the wash tank.

6. Fill the wash tank with cold water. Filling continues until a high level is sensed in the wash tank.

7. Repeat the operations described in 4.

8. Repeat the operations described in 5.

9. Run the spin (agitator) motor continuously for 10 seconds.

10. Go back to 1 to wait for another command.

If the recycle key (2) is pressed instead of 0 or 1 the washing machine should recycle the water from the drain tank to the hot water tank until the high level is sensed in the cold water tank.

The display on the keypad/display card should indicate the cycle which is being executed (HOT WASH, COLDWASH, RINSE, SPIN, or RECYCLE).

Procedure

Design a state machine that implements the washing machine behavior described above. As inputs include the level sensor byte in binary (use 'X' to indicate "don't care") and the keypad character. As outputs include the LED display string and the pump control byte in binary. You may also include state transition conditions involving elapsed time (e.g. "15 s"). You need not include the on/off sequences during agitation in your state machine.

Design and write a C program to operate the washing machine as described above. Use the keypad and LED display handler routines you wrote for Lab 2. Use the function sleep() to pause your program while running the agitator motor. Use symbolic constants for i/o port addresses and bit-masks.

You will have to prepare a project file, say `lab3.prj`, containing the name of your C file and the file name `iolib.lib` as in Lab 2. You must also use the Project→Project Name menu item to set the project name when you start Turbo C.

Please do *not* adjust any of the connections on any of the boards or move the sensors without first consulting with the technician or the TA. You should not need to do this.

Demonstration

Demonstrate successful operation of your washing machine control program to the lab demonstrator.

Report

Submit your state machine state transition diagram, a program listing and answers to the following questions:

- Describe the changes to both hardware and software that would be necessary if you were to add a warm wash function to your washing machine.

- Describe some advantages and disadvantages of building real washing machines with microcomputer controllers as opposed to the conventional method using a motor and cam-operated switches.