Homework problem solutions

Problem 0.1 – AND and OR rungs
Set up a ladder-logic program with two switch (latched) inputs, which are connected to pins I:1 and I:2. Have two outputs too, O:1 and O:2, which are indicator lights. Let O:1 turn on if both switches are on (the AND function). Have O:2 turn on if either switch is on or if both are on (the OR function).

Solution:

Problem 0.2 – XOR
Create a ladder-logic program that works exactly as described in the previous problem. But add a third output O:3, which turns on only if one and only one of the inputs is high. If both inputs are high, O:3 remains unilluminated. (This is called the exclusive OR function, XOR.)

Solution:

Problem 0.3 – Latching a momentary pushbutton
Create a ladder diagram that uses a NO, momentary pushbutton as input to start a motor, but latch the motor on, so that it runs until a second NO, momentary pushbutton is pushed.

Solution:
“MR” stands for “motor relay”.

**Problem 0.4 – Discrete tank level controller, version 1**

Consider the following situation:

A tank is placed in a process plant to dispose of liquid accumulated in a process. The tank is emptied by a pump. The in-flow into the tank is controlled elsewhere. Unlike the steady tank level controller discussed in Chapter 3, here the tank level fluctuates between two extreme levels. You do not want the tank to overflow nor do you want the pump to run when the tank is dry. The tank is equipped with two level sensors—high and low. The control logic is:

- When the tank level drops below the low-level sensor the discharge pump is turned off and the red, low-level indicator light is turned on. The pump is latched off.
- When the tank level rises above the low-level sensor, the red, low-level indicator light is turned off.
- When the tank level rises above the high-level sensor, the pump is turned on and the yellow, high-level indicator light is turned on too. The pump is latched on.
- When the tank level falls below the high-level sensor, the yellow, high-level indicator light turns off.

Let the inputs and outputs accord with the following table.

<table>
<thead>
<tr>
<th>High-level sensor</th>
<th>I:1</th>
</tr>
</thead>
<tbody>
<tr>
<td>Yellow light</td>
<td>O:1</td>
</tr>
<tr>
<td>Low-level sensor</td>
<td>I:2</td>
</tr>
<tr>
<td>Red light</td>
<td>O:2</td>
</tr>
</tbody>
</table>
Also assume that the sensors send out a positive signal when they are uncovered and 0 when they are uncovered.

**Solution:**

First work the problem using labels that are meaningful, then convert those to the I/O pins for the particular devices.

The tricky part is the first rung. The lower three rungs just handle the status lights. Note that the first rung implements the and/or logic: If the high-level sensor is covered OR the pump is on AND the low-level sensor is covered, let the pump be on. Note that once the low-level sensor is uncovered, the make command in the center of the rung is unmade, and the pump shuts off. With the pump off, this logic then becomes, turn the pump back on when both the high-level and the low-level sensors are covered. So once the pump turns off because the low level sensor is uncovered, it will not turn back on until the
high-level sensor is covered too. But once that happens, once the tank level rises above the high-level sensor, the pump will turn on and stay on, even when the high-level sensor is uncovered again.

**Problem 0.5 – Discrete tank level controller, version 2**

Let's look at another type of tank level controller. The tank shown in the figure below has an outflow that is controlled from elsewhere. That is, the tank contains a liquid, a supply to a downstream process, so there must always be this ingredient on hand to mix to make the final product (it could be paint, ketchup, medication, etc.). The tank’s supply of the ingredient is supplied by an inlet, whose valve controls the level in the tank. If the level drops below a certain point, the valve opens. If it rises to a high level, the valve closes. Since this is a discrete level control system, the valve is either open or closed.

The tank is equipped with a low-level sensor and a high-level sensor. These both go “high” when they are covered with liquid. I.e., that is their “on” state. Thus, when the high-level sensor is on, the valve should be closed. When the low-level sensor is uncovered (off), the valve should open. It should latch open until the high-level sensor is again covered.

Can you write the ladder-logic code to effect this operation. Let the inputs and outputs accord with the following table.

<table>
<thead>
<tr>
<th></th>
<th>I:1</th>
<th>I:2</th>
<th>O:1</th>
<th>O:2</th>
<th>O:3</th>
</tr>
</thead>
<tbody>
<tr>
<td>High-level sensor</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Low-level sensor</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Valve</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Green light</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Red light</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Also assume that the sensors send out a positive signal when they are uncovered and 0 when they are uncovered. Assume too that the valve opens with a positive signal and closes with a 0 signal. Let the lights work as follows: the red light turns on when the valve is closed; the green light is on when the valve is open.

What would the tank level do if the output of the tank were at a steady flow rate?
Convert this system to a heating system for a house. In lieu of the valve actuator, let O:01 be connected to a burner system. If the burner is on, the green light is lit. If the burner is off, the red light is lit. The high-temperature sensor goes high when the temperature at which it is set is achieved. The low-temperature sensor goes low when the temperature drops below the temperature at which it is set. That is, both sensors are high when the house temperature is above the temperatures at which they are set; thus, they behave just like the tank-level sensors do.

With heat leaking out of the house on a winter day, what the temperature profile inside the house look like as this system operates to keep the house warm? How would the temperature profile inside the house differ in these two cases: 1) a cold winter day vs. 2) a really cold winter day?

**Solution:**

Tank/Valve system:

If the tank were drained at a steady rate, the level would drop at a steady rate until the lower sensor were uncovered. Then the inlet valve would open, and the tank level would rise again, assuming the inlet flow were greater than the outlet flow. Once the tank had filled, the inlet valve would close again, and the tank level would fall again, as it had done before. Thus the tank level would oscillate between full and empty.

Heating house:
The ladder-logic diagram is exactly the same as the tank/valve system. In fact, the PLC is not even aware that it is controlling a heating system in a house rather than a tank level control.

The house would cool due to heat leakage into the atmosphere until it dropped to the low-temperature setting of the low-temperature sensor. Then the burner would turn on and heat the house back up to the high-temperature setting. Then the cycle would start over again. The burner should have enough capacity to heat the house up faster than heat can escape. That is the heating rate is faster than the cooling rate. But on a cold, cold day, the cooling rate of the house would be faster than it would be on only a cold day. On a cold only day, the house would cool slower, and also it would heat faster with the burner on.
On a cold, cold day, the burner would cycle on and off more frequently than on just a cold day. This would demand more fuel for the heating too, as would be expected.