Lab Note Book

Real-Time Leak Detection and Equipment Protection System for the UWPTF Water Circulation Setup

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Tapendra B C

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Contents

1 Motivation

To safeguard the electronics equipment and UWPTF room from potential water leakage in the circulation system, we will monitor both the inlet and outlet flow rates of the UWPTF tank's water circulation. The system will rely on two FL-808 flow sensors to continuously measure the flow rates at both points.

A Raspberry Pi 4 Model B will process the flow sensor outputs, converting the pulse signals into real-time flow rates. If a discrepancy arises—where the outlet flow rate falls below the inlet flow rate by more than an experimentally determined threshold—this may indicate a leak or blockage.

In such an event, the Raspberry Pi will activate a relay to immediately shut off both the water circulation motor and the chiller, preventing further risk. This real-time monitoring and response system will mitigate potential damage from leaks, ensuring the safety of the room and equipment.

2 FL-808. Water Flow Sensor :

The water flow sensor is mainly composed of a plastic valve body, a water flow rotor assembly and a Hall sensor. When the water passes through the water flow rotor assembly, the magnetic rotor rotates and the speed changes with the flow rate. The Hall sensor outputs the corresponding pulse signal.

Figure 1: FL-808 Flow Sensor

2.1 Installation Instructions :

The FL-808 flow sensor can be installed in either a vertical or horizontal orientation; however, the inlet and outlet directions must be configured according to the guidelines illustrated in Fig: 2

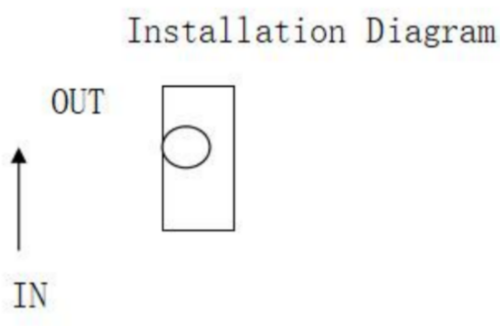


Figure 2: Installation Diagram

2.2 Wire Label

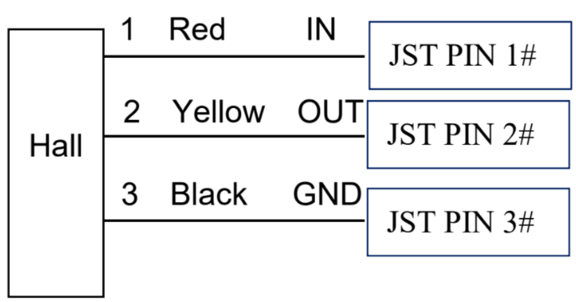


Figure 3: Wire Label

The FL-808 flow sensor is powered through its red and black wires, while the yellow wire provides the signal output. This signal is a square wave, where the frequency corresponds to the flow rate of the water. However, there is some discrepancy regarding the operating voltage of the sensor. Digiten's website specifies a range of 3–24 V, while the datasheet lists it as 4.5–12 V. Since the Raspberry Pi operates at a 3.3V logic level, we supply 3.3V to the sensor. Despite the conflicting voltage specifications, the sensor functions correctly when tested with an oscilloscope at 3.3V. Therefore, we opted to power the sensor directly from the Raspberry Pi's 3.3V pin without needing a logic level shifter.

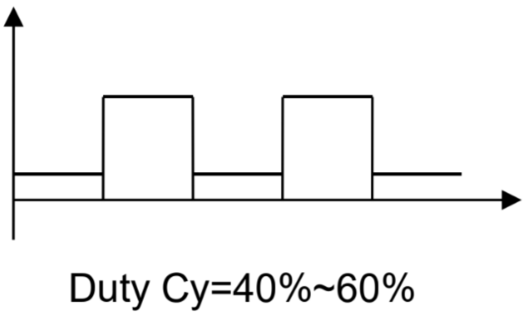
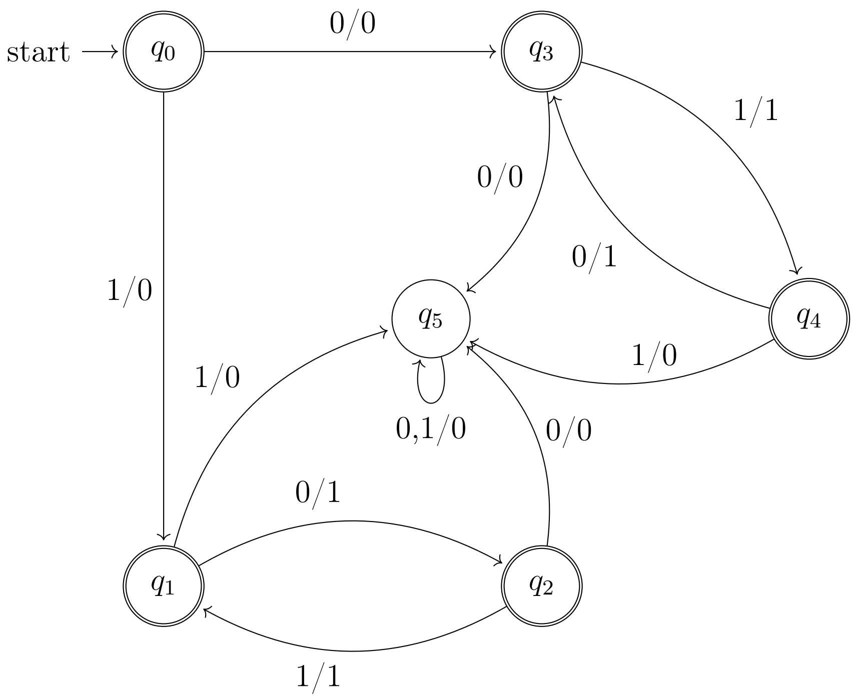


Figure 4: Output Signal

3 Flow Meter Mealy Machine Design



3.1 States (Q):

Q $= \{q_0, q_1, q_2, q_3, q_4, q_5\}$

- q_0 = WAIT FOR EDGE
- q_1 = RISING EDGE DETECTED
- q_2 = FALLING EDGE DETECTED
- q_3 = FALLING EDGE AT START
- q_4 = RISING EDGE AFTER FALLING

- q_5 = ERROR STATE

3.2 Input Alphabet (Σ):

$\Sigma =$ {0, 1}

- 0 = Falling Edge Detected
- 1 = RISING EDGE DETECTED

3.3 Output Alphabet (Λ):

$\Lambda =$ {0, 1}

- 0 = Don't increment cycles detected
- 1 = Increment cycles detected

3.4 Transition Function ($\delta : Q \times \Sigma \to Q$):

$\delta = \{ (q_0, 0, q_3) , (q_0, 1, q_1) , (q_1, 0, q_2) , (q_1, 1, q_5) , (q_2, 0, q_5) , (q_2, 1, q_1) , (q_3, 0, q_5) , (q_3, 1, q_4) , (q_4, 0, q_3) , (q_4, 1, q_5) , (q_5, 0, q_5) , (q_5, 1, q_5) \}$

3.5 Output Function ($G : Q \times \Sigma \to \Lambda$):

$G = \{ (q_0, 0, 0) , (q_0, 1, 0) , (q_1, 0, 1) , (q_1, 1, 0) , (q_2, 0, 0) , (q_2, 1, 1) , (q_3, 0, 0) , (q_3, 1, 1) , (q_4, 0, 1) , (q_4, 1, 0) , (q_5, 0, 0) , (q_5, 1, 0) \}$

3.6 Accepting States (F) :

F = Q/$\{q_5\}$

3.7 Transition Table

Current State(q)	Input	Next State	Output(G)
q_0	0	q_3	0
q_0	1	q_1	0
q_1	0	q_2	1
q_1	1	q_5	0
q_2	0	q_5	0
q_2	1	q_1	1
q_3	0	q_5	0
q_3	1	q_4	1
q_4	0	q_3	1
q_4	1	q_5	0
q_5	0	q_5	0
q_5	1	q_5	0

The Deterministic Finite Automaton (DFA) described above was used to count the total number of half cycles. Specifically, the state machine is a Mealy machine, meaning the output is a function of both the current state and the input. It also incorporates error detection when edges are not properly registered. For example, if a rising edge is followed by another rising edge without an intervening falling edge, this signals an error. In such cases, the state machine transitions to an error state to indicate the detection failure.

4 References:

Mealy Machine : https://en.wikipedia.org/wiki/Mealy_machine#:~:text=In%20the%20theory%20of%20computation,solely%20by%20its%20current%20state.

Appendix

FL-808 Flow Sensor Technical Document

Feature

1. The product is light in appearance, small in size and easy to install.
2. The impeller is inlaid with stainless steel beads, which is always wear-resistant.
3. The sealing ring is of up and down force structure and will never leak.
4. The Hall element is originally imported from Germany and is encapsulated by potting glue to prevent water from entering and will not age.
5. All raw materials meet ROSH testing standards.

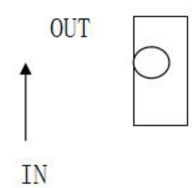
Product Instruction

The water flow sensor is mainly composed of a plastic valve body, a water flow rotor assembly and a Hall sensor. It is installed at the water inlet end of the water heater to monitor the water flow rate. When the water passes through the water flow rotor assembly, the magnetic rotor rotates and the speed changes with the flow rate. The Hall sensor outputs the corresponding pulse signal and feeds it back to the controller. The water flow is judged and adjusted by the controller.

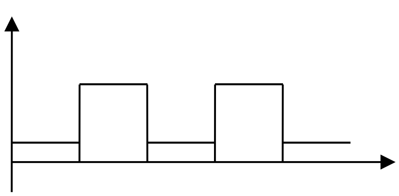
Attentions

- Severe impact and chemical erosion are strictly prohibited.
- Throwing or collision is strictly prohibited.
- Can be installed horizontally or vertically.
- The temperature of the medium should not exceed 120°C.

Installation Diagram

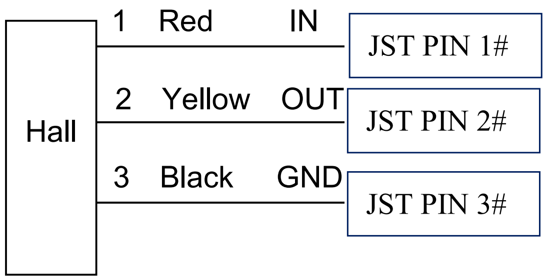


Output Waveform



Duty Cy=40%~60%

Lead Way



Parameter

- Inlet / Outlet Size: BSP G1”
- Rate Work Voltage: DC 4.5V-12V
- Max Work Current: 15mA (DC 5V)
- Operating Voltage: DC 4.5V-12 V
- Load Capacity: ≤10mA (DC 5V)
- Operating Temperature Range: ≤80℃
- Operating Humidity Range: 35%~90%RH (No Frosting)
- Allowable Pressure: Below 1.75Mpa
- Storage Temperature: -25~+80℃
- Storage Humidity: 25%~95%RH
- Output Pulse High Level: >DC 4.5 V (Input Voltage DC 5 V)
- Output Pulse Low Level: <DC 0.5 V (Input Voltage DC 5 V)
- Accuracy (Flow Rate - Pulse Output): 1~60L/min Within ±5%
- Output Pulse Duty Cycle: 50±10%
- Output Rise Time: 0.04μS
- Output Fall Time: 0.18μS
- Characteristics of Flow-Pulse: Horizontal Test Pulse Frequency (Hz)=[4.8* Q]±3% (Horizontal Test) (Q is flow rate L/min)