AUTOMATIC WASHING MACHINE

Question No: 11

Submitted by: Group 28

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Contents

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With due regards.

Problem Statement

Description: An Automatic washing machine with Dryer.
The Washing Machine can handle three different types of load: Light, Medium and Heavy
The Washing Machine has three different cycles: Rinse, Wash and Dry.
Depending on the load the number of times a cycle is done and the duration of the cycle varies.

Light Load: Rinse- 2 mins, Wash- 3 mins, Rinse – 2 mins, Dry Cycle –2 mins
Medium Load: Rinse- 3 mins, Wash- 5 mins and Rinse – 3 mins Dry Cycle –4 mins
Heavy load: Rinse- 3 mins, Wash- 5 mins and Rinse – 3 mins, Wash- 5 mins and Rinse – 3 mins, Dry Cycle – 4 mins

- The Washing Machine is a single tub machine.
- The Washing machine is made of a Revolving Tub and an Agitator. The Agitator is activated during the Rinse and Wash cycle; revolving tub is active only during the Dry cycle.
- The door of the washtub should remain closed if the agitator is active. If the door is not closed the system should not start and should indicate that the door is open by sounding the alarm.
- Before each cycle the water level is sensed. At the beginning of the cycle the water level should be at the maximum possible level, the water should be completely drained during dry cycle. The cycle should begin only when the water level is correct.
- There are relays that control the opening and closing of relays to let in water via the inlet pipe and drain the water via the outlet pipe.
- At the beginning of the wash cycle the user should have add the detergent.
- At the end of the complete wash process the Buzzer is sounded.
- User can turn off system by pressing STOP Button
- Different sounds are used for different events.

The number of times the load button is pressed determines load: 1press- light; 2 presses – medium and 3 presses –heavy.
To begin washing process START is pressed.
Pressing STOP can stop the process.

User Requirements & Technical Specifications

Design an Automatic washing machine with a dryer that can handle three types of loads.

The Technical Specifications are as follows

- There are three kinds of loads: light, medium and heavy
    - Light mode comprises of Rinse - 2 mins, Wash - 3 mins, Rinse - 2 mins, Dry - 2 mins
    - Medium mode comprises of Rinse - 3 mins, Wash - 5 mins, Rinse - 3 mins, Dry - 4 mins
    - Heavy mode comprises of Rinse - 3 mins, Wash - 5 mins, Rinse - 3 mins, Wash - 5 mins, Rinse - 3 mins, Dry - 4 mins
- At the end of the complete wash, cycle buzzer is sounded
- There are 4 buttons for the user to control the washing machine: Load, Start, Resume and Stop
    - Load: The number of presses of this button determines the load. 1 press - Light, 2 press - medium, 3 press - heavy
    - Start : Washing process begins when start is pressed. Has to be pressed after load is decided
    - Stop : This can stop the process
    - Resume : This button can resume the process after it has been stopped or in case of any other issue.
- The door remains locked during the entire wash process

Assumptions & Justifications

Assumptions:

1. The machine will pause only in case of inappropriate water levels during the water input or water output process and resumes when the user resolves the issue.
2. The detergent is already added to the machine by the user.
3. The user doesn't fiddle with the door within 1 minute of the starting of the process and for 1 minute after the ending of the process.
4. In case of any issue, the user will need to intervene and fix the issue.

Justifications:

1. The only type of issue that can occur is related to the source of water (filling and emptying of water from the machine). The machine will sound an alarm if the water-filling/emptying process takes more than usual.
2. The detergent is added at the starting of the process because the door cannot be unlocked in the middle of the process to add detergent before every wash cycle. The detergent is initially

present inside a container and gets added to the tub before every wash cycle by the opening of a valve.

3. The metallic strips used in the bi-metallic door interlock take about 1 minute to get heated and change shape during locking and unlocking of the door.
4. Any resolvable malfunction that might occur will be related to the source of water/jamming of the paths for water i/p or o/p. Since these are not a part of the control circuit, they need to be fixed manually.

Components used with justification wherever required:

- 8086
- 8284(Clock generator)
- Water Level Sensor (FS-IR02) with convert board - 2 nos (Manual Attached)
    - Sensor gives input to the convert board which gives a high output if the sensor is submerged in water and low if not.
    - Sensor o/p range(i/p to convert board) - 0-5V(<0.1V for low o/p and >4.6V for high o/p)
    - Voltage o/p of convert board (5V if high, else 0)
    - 4-pin connector to the convert board(GND,GND,VCC,o/p(of sensor))
    - There are two sensors, one on top of the revolving tub and other at the bottom of it. When the o/p of the top sensor goes high, it indicates that the water is full. When the bottom sensor goes low, it indicates that the water has been emptied.

Liquid Level Sensor-FS-IR02 Pin Mapping

Num.	Name	Description
1(Red)	GND	Probe_GND
2(Yellow)	GND	Probe_GND
3(Blue)	VCC	Probe_VCC
4(White)	OUT	Signal Output

Liquid Level Sensor-FS-IR02(Covert Board) Pin Mapping

Num.	Name	Description
Left_1	GND	Probe_GND
Left_2	GND	Probe_GND
Left_3	VCC	Probe_GND
Left_4	IN	Signal Input
Right_1	OUT	Signal Output
Right_2	VCC	VCC
Right_3	GND	GND

- Water-In, Water-Out, Lock and Detergent Relays - Used to display the status of Water-In, Water-Out, Lock and Detergent Valves on red and green LEDs.
- Magnetic Contact Reed Switch - For Door Sensor(Reed Switch Datasheet and product manual attached)
    - One end connected to Vcc and other to the Microprocessor
    - A magnet attached to the lid and the reed switch near the door's contact on the body
    - When door closed magnet comes in contact with the reed switch which gets closed and a high i/p is given to 8255
- Piezoelectric Buzzer(KPI 1410) (with RKi-4076 hardware)(Buzzer Datasheet and Hardware manual attached)
    - Gives continuous sound of different frequencies depending on the frequency of the i/p square wave. Hence, can be used for sounding buzzer/alarms with different sounds for different purposes
    - RKI-4076 hardware inputs: VCC,I/O,GND
    - Buzzer operating voltage - 3-16 VDC
    - Max Rated Current - 7mA at 12VDC
    - Resonant Frequency - 4.0 (+/-) 0.5 KHz
    - RKI-4706 Operating Voltage - 3-5V
- Door Latch (Bi-metallic Interlock)(Product manual and relay datasheet attached)

    - Used in traditional washing machines to lock the door
    - Allows us to lock and unlock the door using a control signal and DC to AC relay
    - Relay used - FOTEK SSR 40DA
        - DC CONTROL SIGNAL
        - Input Operating Voltage (DC) = 3-32 VDC
        - Output Operating Voltage(AC) = 24-380 VAC
        - PCB mountable
- Agitator/Revolving Tub Motors and Motor Drivers(Motor and motor driver datasheets attached):
    - Motors : Crouzet 801405 BLDCs
        - Max Speed : 10000rpm
        - Peak torque : 500mN-m
    - Motor Drivers : Allegro A4915 Motor Drivers
    - Enable us to switch the motors on/off with a digital control signal
- 8255 – Interface 8253, agitator, revolving tub, water level sensor, buzzer, user interface buttons, the door and water in and water out relays
- 8259 – Interrupt from stop whenever stop button is pressed.
- 8253 – 2 nos. To generate Clock for agitator and revolving tub. Also to generate input square wave with 50% duty cycle for buzzer hardware(RKI-4076)
- 2716 – 2 nos. Smallest ROM chip available is 2K and as we need to have even and odd bank and ROM is required at reset address which is at $FFFF0_H$ and 00000_H - where there is the IVT
- 6116 – 2 nos. Smallest RAM chip available is 2 K and we need odd and even bank. We need RAM for stack and temporary storage of data
- LS 138 – 2 decoders, to generate chip select signals for 8255 and 8253s
- LS 373 – 3 latches, used for demultiplexing the address lines
- LS 245 – 2 latches, used for demultiplexing the data lines
- required gates – or, not, and
- Buttons – 4 nos. Used as user interface in the form of start, stop, resume and load
- Green LED - 6 nos. - Used to display the active status of valves, door lock closed, agitator and revolving tub.
- Red LED - 4 nos. - Used to display the inactive status of valves and door lock open.

Address Map:

Memory Map:

ROM1 – 00000_H – $00FFF_H$

RAM – 02000_H – $02FFF_H$

ROM2 – $FF000_H$ – $FFFFF_H$

I/O Map:

8255 – 00 – 06_H

8253(1) – 10 – 16_H

8253(2) – 20 – 26_H

8259 – 30 – 36_H

Design Summary

Complete design shown with proper labelling (design attached)

8255 Base Address: 00h
Ports:
Port A: Output
Port B: Input
Port C: Lower Input Higher Output

Outputs:
PA0: I/P to lock (to latch the lock)
PA1: Water-In Valve (Relay device)
PA2: Water-Out Valve (Relay device)
PA3: Process End (Dry Cycle End - Buzzer Sound 1)
PA4: Alarm (Door Open - Buzzer sound 2)
PA5: Detergent Valve (Relay)
PA6: Issue (Inappropriate water levels)
PA7: NC

PC4: 8253(1) Gate2
PC5: 8253(2) Gate1
PC6: 8253(2) Gate0
PC7: STOP EN'

Inputs:
PB0: Water-Full Sensor
PB1: Water-Empty Sensor
PB2: Resume
PB3: Door Sensor (High when gate is closed)
PB4: Output from 8253(1) counter-2 (for CNTR signal-Agitator)
PB5: Output from 8253(2) counter-0 (for CNTR signal-Revolving Tub)
PB6: Output from 8253(2) counter-1 (for any intermediate issue)
PB7: NC

PC0: Load
PC1: Start
PC2: NC
PC3: NC

8253(1) : Base Address : 10H

CNT 0 : Used for generating freq 100Hz
Mode 3
Clk : 2.5MHz PCLK
Count: 25000
Out : 100 Hz square wave used as clk in CNT1

CNT 1: Used for generating freq 1Hz
Mode 3
Clk : 100 Hz
Count: 100
Out : 1 Hz square wave used as CLK

CNT 2: Used for counting timings for Wash & Rinse cycle
Mode 1
CLK : 1 Hz (8253(1) OUT1) AND with STOP EN (to pause the counter when stop is pressed)
Count: 120s,180s, etc.(depending on mode)
Out : PB4

8253(2): Base Address: 20H

CNT 0: Used for counting timings for Dry cycle
Mode 1
Clk : 1 Hz (8253(1) OUT1) AND with STOP EN (to pause the counter when stop is pressed)
Count: 120s,180s, etc.(depending on mode)
Out : PB5

CNT1: For checking malfunction
Mode 1
Clk : 1 Hz (8253(1) OUT1) AND with STOP EN (to pause the counter when stop is pressed)
Count : 600
Out : PB6

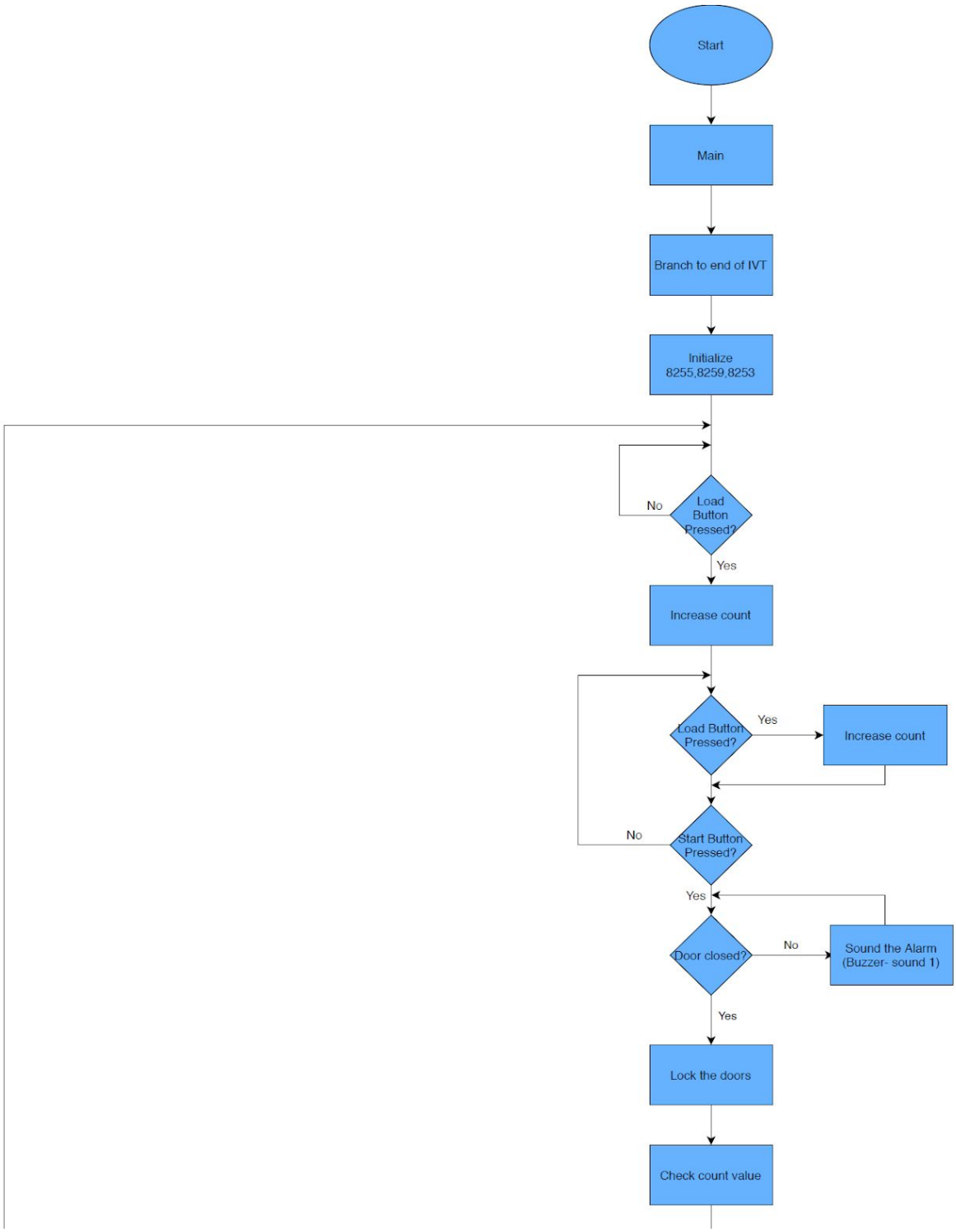
CNT 2: For alarm and buzzer
Mode 3
Clk : 1 Hz (8253(1) OUT1) AND with STOP EN (to pause the counter when stop is pressed)
Count : (depending on the event sound is decided)
Out : BUZZER FREQ

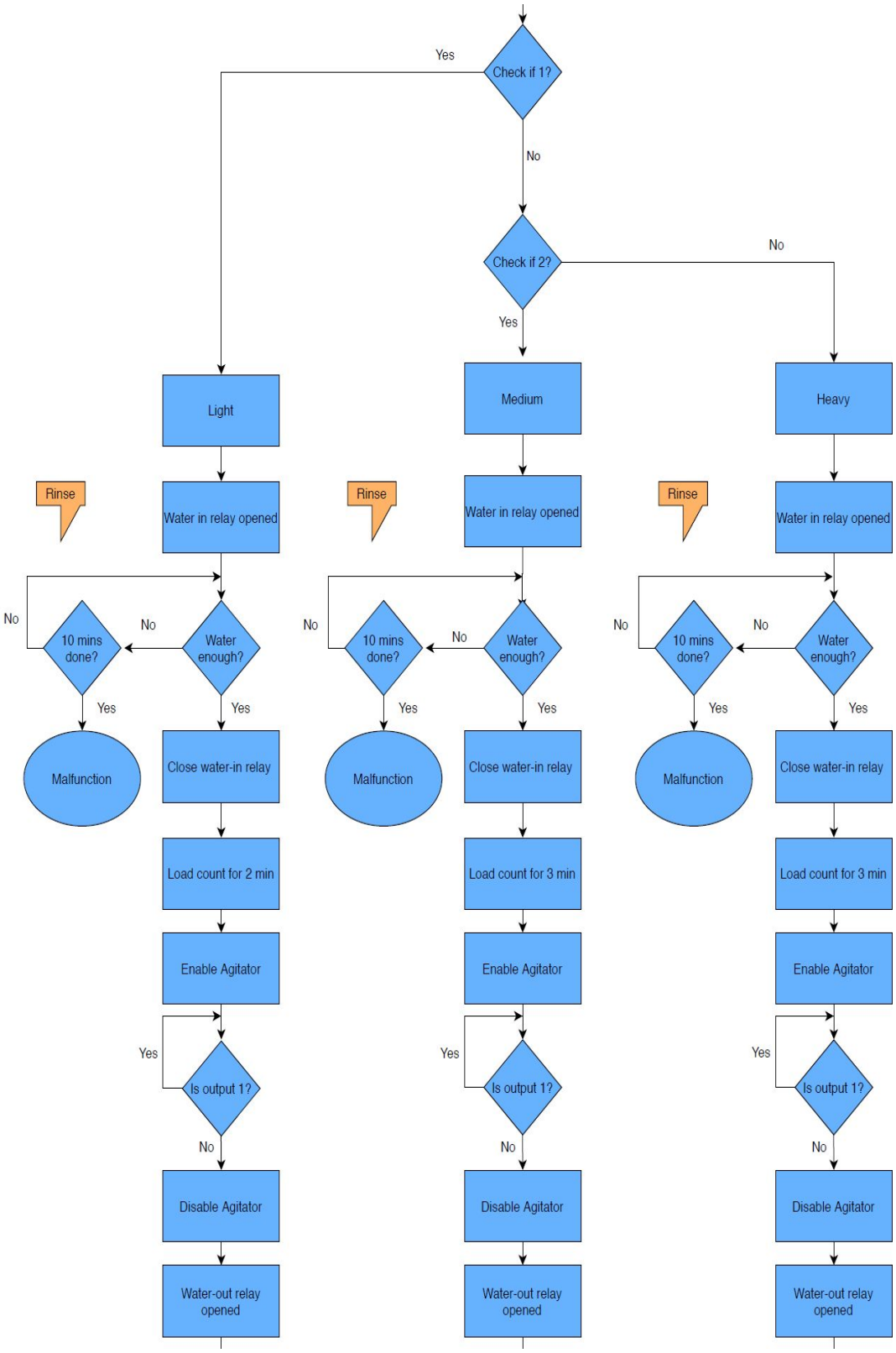
8259 : Base Address: 30H

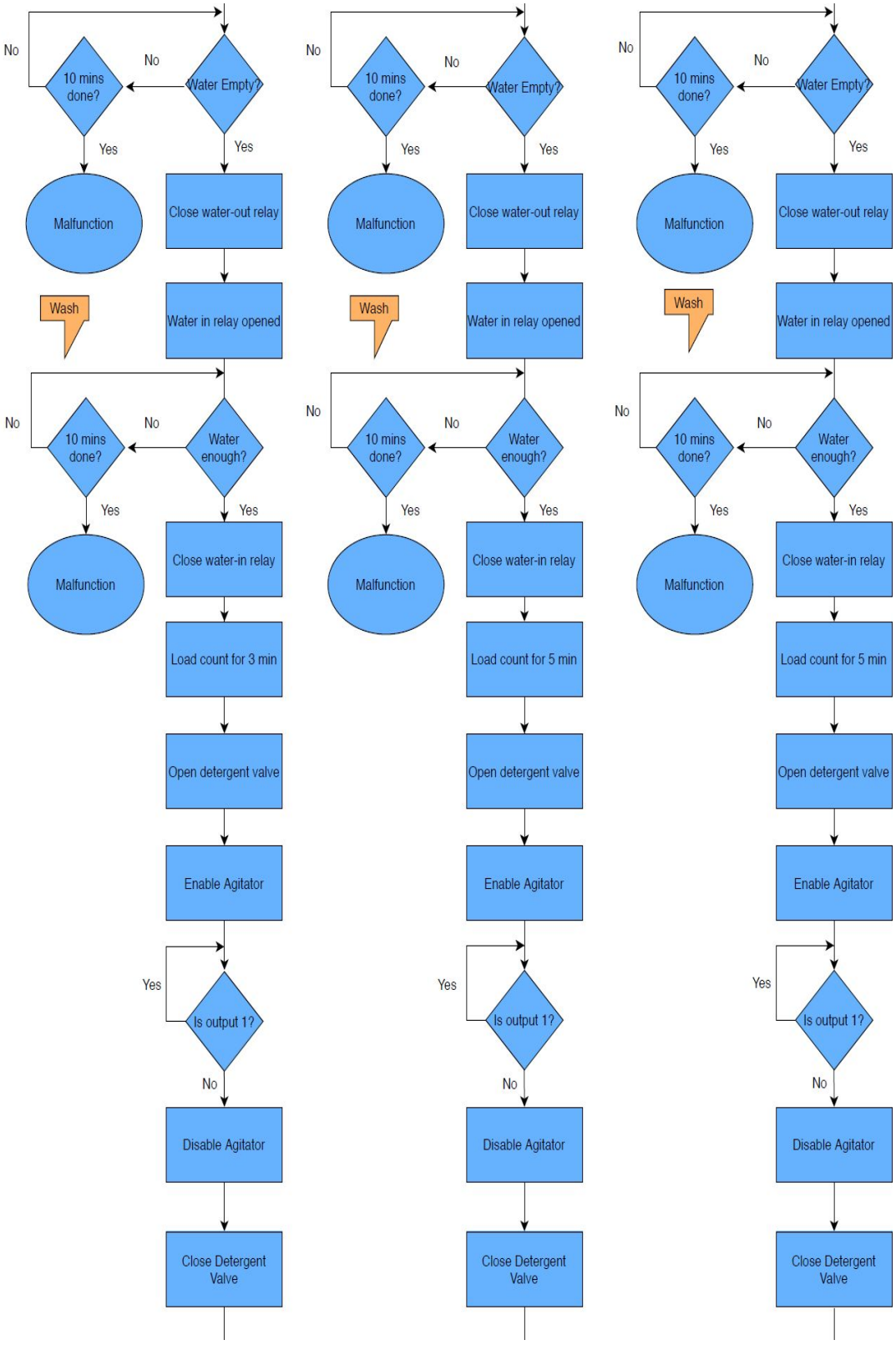
IR0: STOP Input
Vector Numbers : 80h - 87h

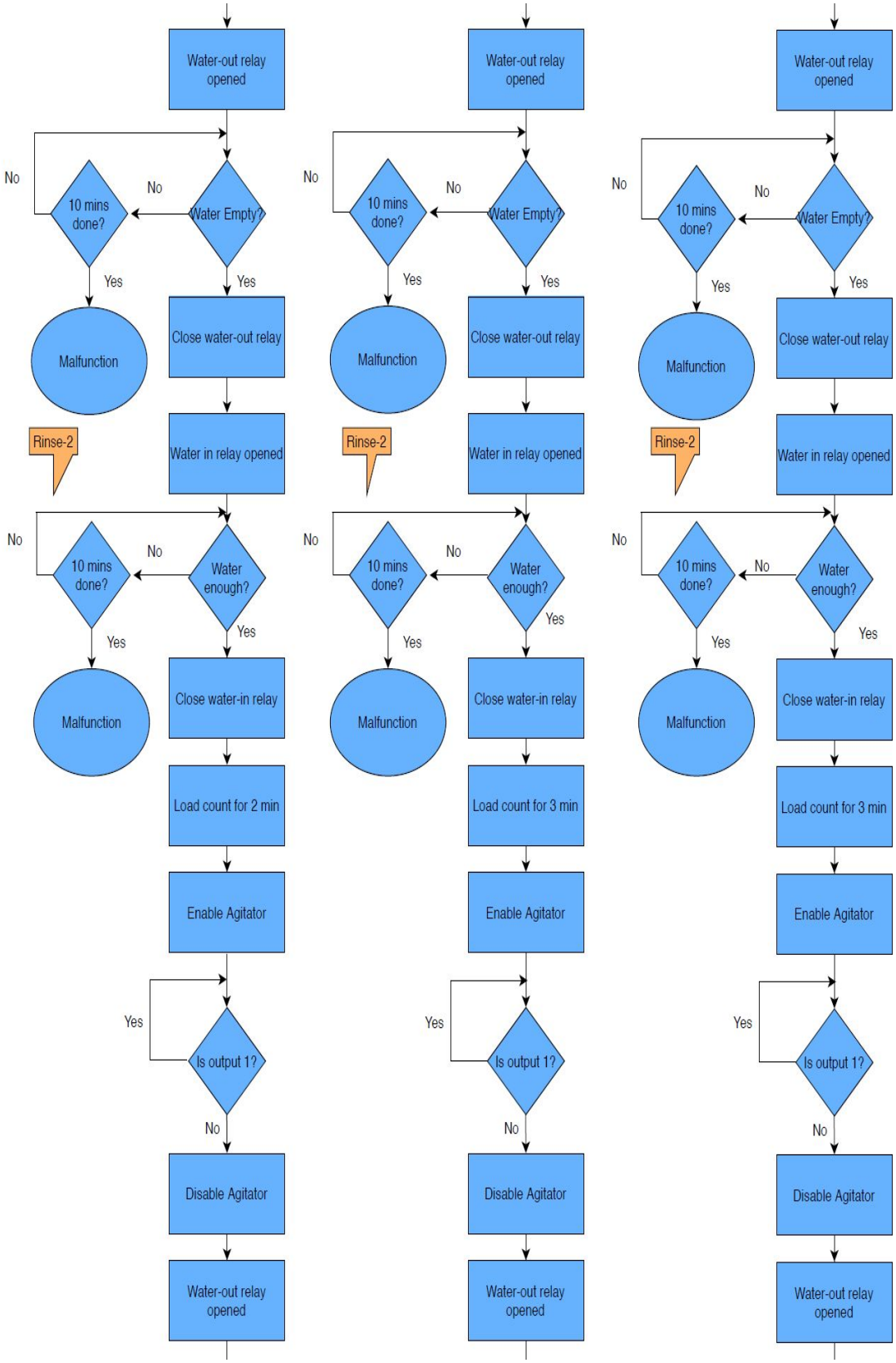
Flow Chart

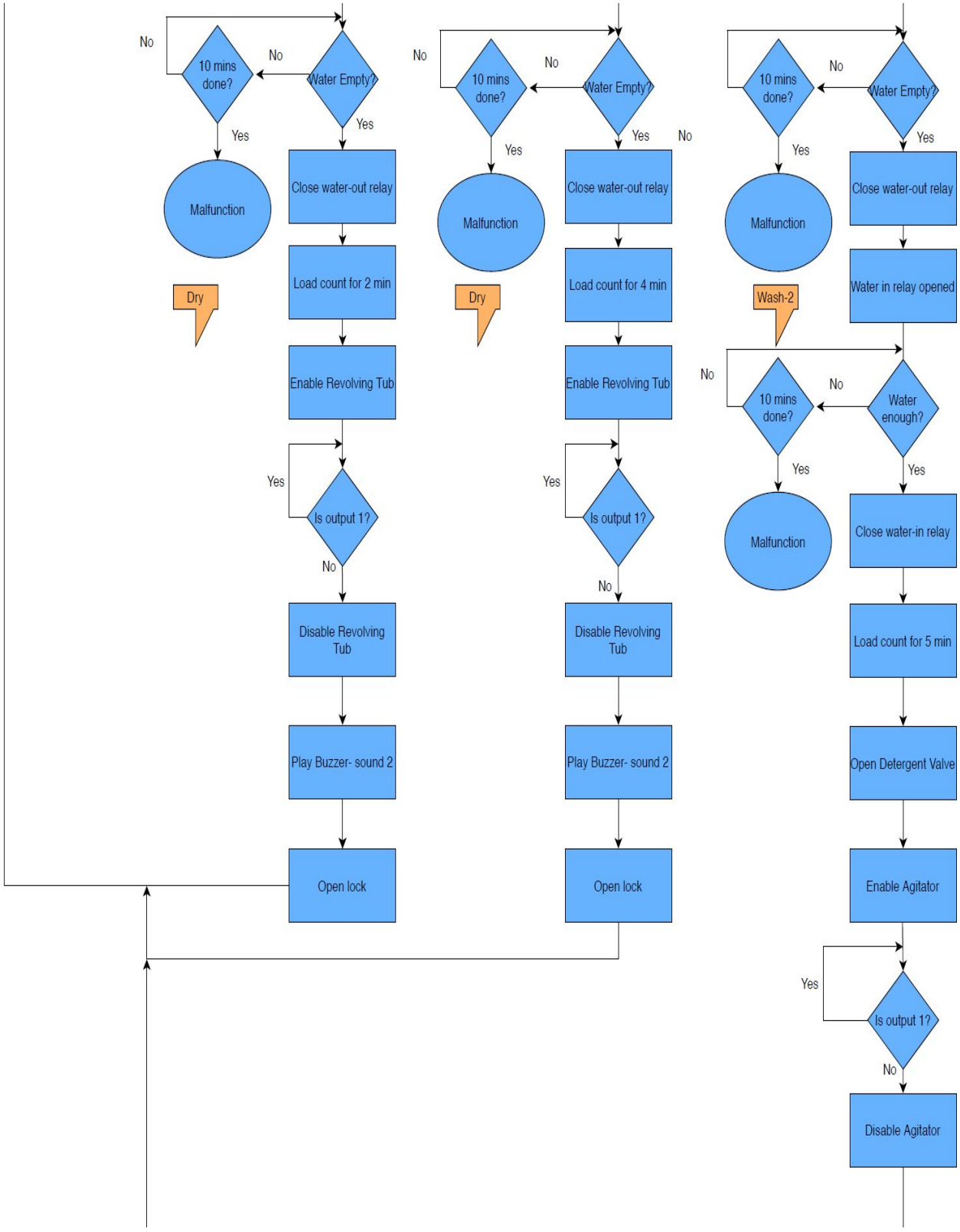
Note:- is output 1 function in the flow chart, polls for the output of the respective counter for the cycle and changes only once the count ends.

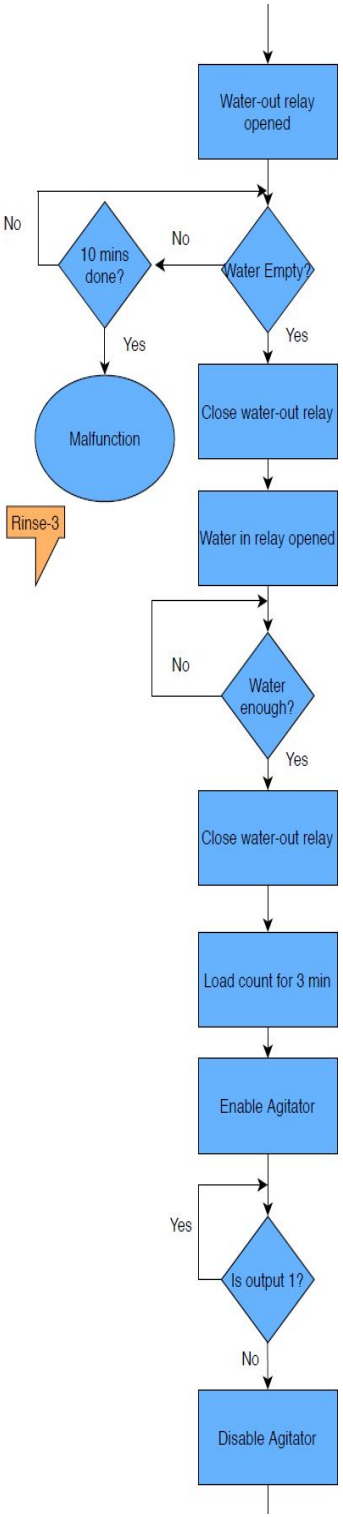


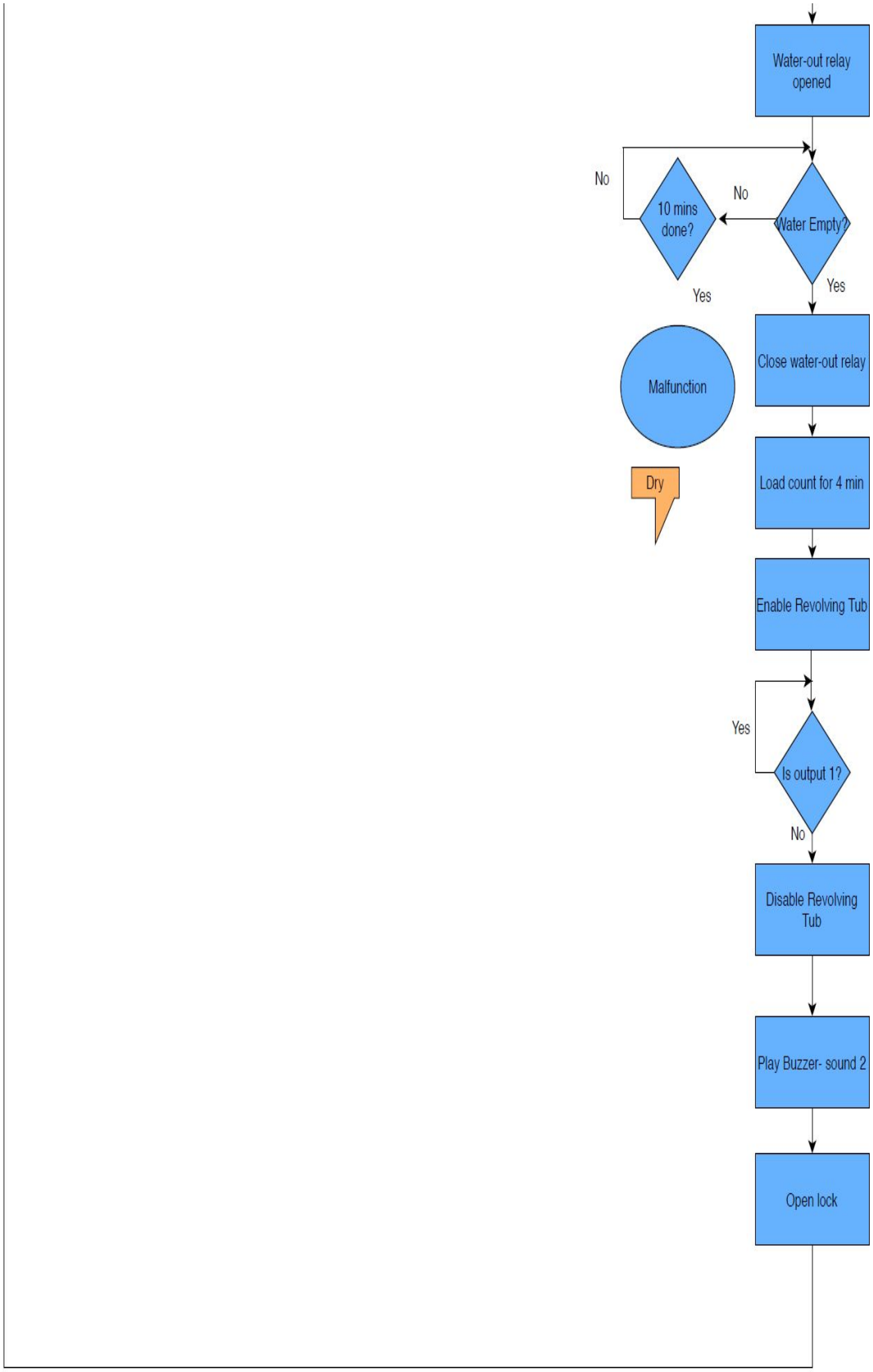

Check if 1?
Yes
No
Check if 2?
No
Yes
Light
Medium
Heavy
Rinse
Rinse
Rinse
Water in relay opened
Water in relay opened
Water in relay opened
No
No
No
10 mins done?
Water enough?
10 mins done?
Water enough?
10 mins done?
Water enough?
Yes
Yes
Yes
Yes
Yes
Yes
Malfunction
Close water-in relay
Malfunction
Close water-in relay
Malfunction
Close water-in relay
Load count for 2 min
Load count for 3 min
Load count for 3 min
Enable Agitator
Enable Agitator
Enable Agitator
Yes
Yes
Yes
Is output 1?
Is output 1?
Is output 1?
No
No
No
Disable Agitator
Disable Agitator
Disable Agitator
Water-out relay opened
Water-out relay opened
Water-out relay opened


No
10 mins done?
No
Water Empty?
Yes
Yes
Malfunction
Close water-out relay
Wash
Water in relay opened
No
10 mins done?
No
Water enough?
Yes
Yes
Malfunction
Close water-in relay
Load count for 3 min
Open detergent valve
Enable Agitator
Yes
Is output 1?
No
Disable Agitator
Close Detergent Valve
No
10 mins done?
No
Water Empty?
Yes
Yes
Malfunction
Close water-out relay
Wash
Water in relay opened
No
10 mins done?
No
Water enough?
Yes
Yes
Malfunction
Close water-in relay
Load count for 5 min
Open detergent valve
Enable Agitator
Yes
Is output 1?
No
Disable Agitator
Close Detergent Valve
No
10 mins done?
No
Water Empty?
Yes
Yes
Malfunction
Close water-out relay
Wash
Water in relay opened
No
10 mins done?
No
Water enough?
Yes
Yes
Malfunction
Close water-in relay
Load count for 5 min
Open detergent valve
Enable Agitator
Yes
Is output 1?
No
Disable Agitator
Close Detergent Valve

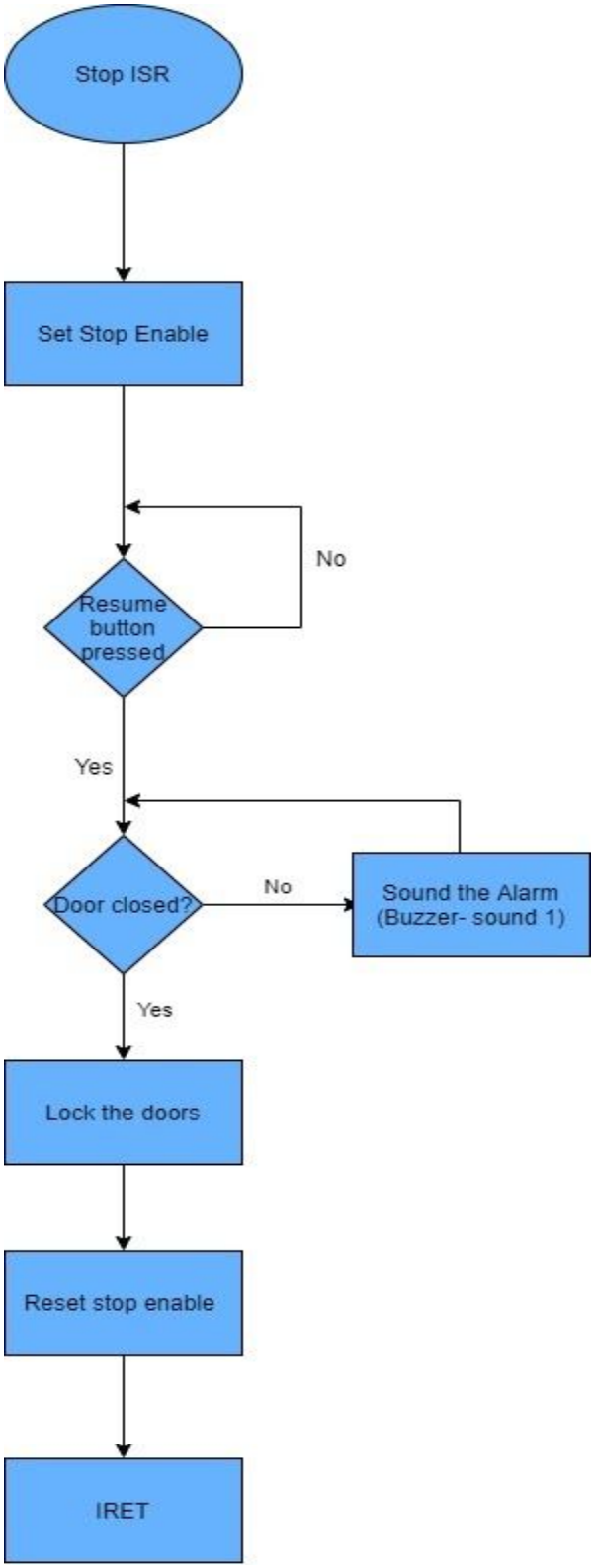

Water-out relay opened
No
10 mins done?
No
Water Empty?
Yes
Yes
Malfunction
Close water-out relay
Rinse-2
Water in relay opened
No
10 mins done?
No
Water enough?
Yes
Yes
Malfunction
Close water-in relay
Load count for 2 min
Enable Agitator
Yes
Is output 1?
No
Disable Agitator
Water-out relay opened
Water-out relay opened
No
10 mins done?
No
Water Empty?
Yes
Yes
Malfunction
Close water-out relay
Rinse-2
Water in relay opened
No
10 mins done?
No
Water enough?
Yes
Yes
Malfunction
Close water-in relay
Load count for 3 min
Enable Agitator
Yes
Is output 1?
No
Disable Agitator
Water-out relay opened
Water-out relay opened
No
10 mins done?
No
Water Empty?
Yes
Yes
Malfunction
Close water-out relay
Rinse-2
Water in relay opened
No
10 mins done?
No
Water enough?
Yes
Yes
Malfunction
Close water-in relay
Load count for 3 min
Enable Agitator
Yes
Is output 1?
No
Disable Agitator
Water-out relay opened


No
10 mins done?
No
Water Empty?
Yes
Yes
Malfunction
Close water-out relay
Dry
Load count for 2 min
Enable Revolving Tub
Yes
Is output 1?
No
Disable Revolving Tub
Play Buzzer- sound 2
Open lock
No
10 mins done?
No
Water Empty?
Yes
No
Yes
Malfunction
Close water-out relay
Dry
Load count for 4 min
Enable Revolving Tub
Yes
Is output 1?
No
Disable Revolving Tub
Play Buzzer- sound 2
Open lock
10 mins done?
No
Water Empty?
Yes
Yes
Malfunction
Close water-out relay
Wash-2
Water in relay opened
No
10 mins done?
No
Water enough?
Yes
Yes
Malfunction
Close water-in relay
Load count for 5 min
Open Detergent Valve
Enable Agitator
Yes
Is output 1?
No
Disable Agitator


Water-out relay opened
No
10 mins done?
No
Water Empty?
Yes
Yes
Malfunction
Close water-out relay
Rinse-3
Water in relay opened
No
Water enough?
Yes
Close water-out relay
Load count for 3 min
Enable Agitator
Yes
Is output 1?
No
Disable Agitator

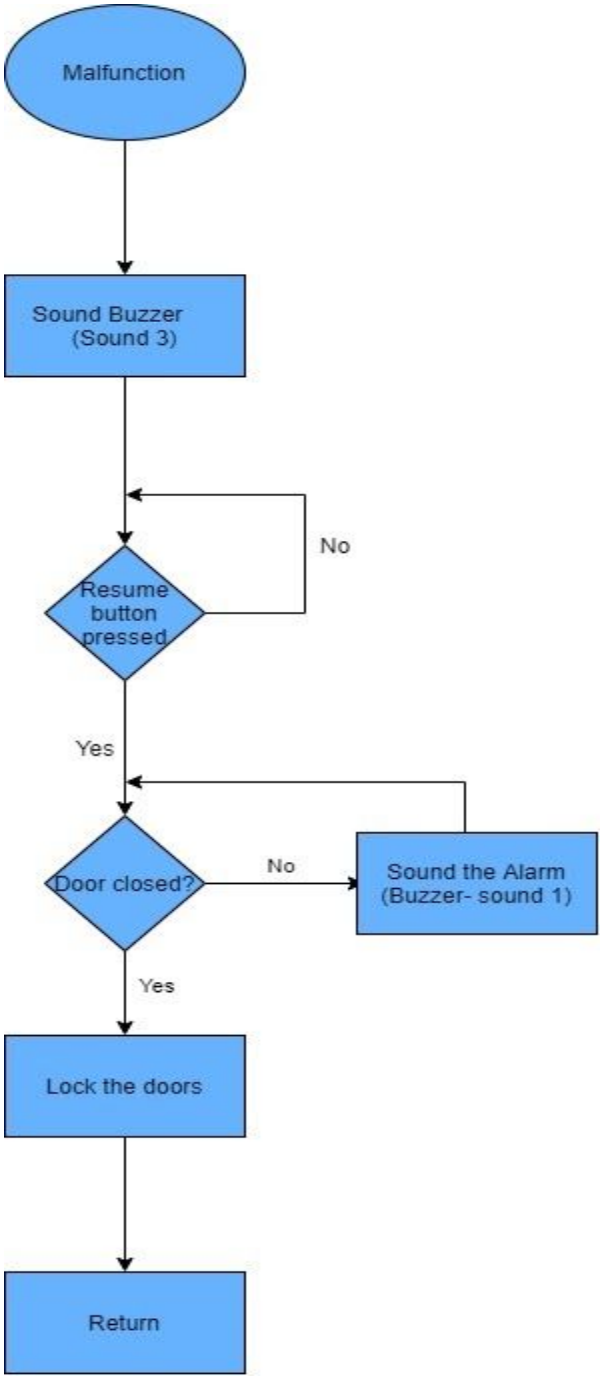

Water-out relay opened
Water Empty?
No
10 mins done?
No
Yes
Yes
Malfunction
Dry
Close water-out relay
Load count for 4 min
Enable Revolving Tub
Yes
Is output 1?
No
Disable Revolving Tub
Play Buzzer- sound 2
Open lock

Stop ISR:


Stop ISR
Set Stop Enable
Resume button pressed
No
Yes
Door closed?
No
Sound the Alarm (Buzzer- sound 1)
Yes
Lock the doors
Reset stop enable
IRET

Issue:

Used in case there is inadequate water supply from the external source, or a case when water cannot be emptied from the tub.



Variations in Proteus Implementation with Justification:

1. Stop interrupt using 8259 does not work in proteus – Stop signal is used as NMI
2. ROM in only 00000h – as proteus allows to change reset address.
3. 2732 is used as 2716 – not available in Proteus. So, we had to use 8KB of ROM from 00000h to 01FFFh in Proteus instead of 00000h to 00FFFh for IVT.
4. Using a gate-based circuit for memory – does the same as LS 138 here
5. 8259 not there – justification is as per point 1.
6. The water level sensors in proteus have been simulated using two push buttons (pressing the water full button indicates that the top water level sensor is submerged. Similarly, pressing the water empty button indicates that the lower water-level sensor is not submerged in water(water has drained out)) (holdable) since the water level sensors that have been used aren't available in proteus.
7. The i/p to lock(PA0) in the proteus design goes to an LED and relay(electrical) circuit to show when it's high and when it's low since the door latch cannot be simulated in proteus. In proteus simulation, whenever the lock is on, a green LED glows and whenever the door is unlocked, a red LED glows. However, in the design, the i/p to lock(PA0) goes into a solid-state relay as a control signal to open and close the lock(bimetallic interlock).
8. A simple motor is used instead of an agitator and a revolving tub(with motor drivers) as they are not available in Proteus.
9. Door sensor i/p to 8255 is simulated using manual push buttons since magnetic contact reed switches(used in the design) aren't available in proteus
10. An LED is used to represent the sounding of the buzzer in Proteus design because it is not possible to use a buzzer enable signal to sound the buzzer.
11. Reset in 8086 is connected to a switch as 8284 is not available in Proteus
12. The water-in, water-out and detergent valve signals in the design go to water-in, water-out and detergent valve relays respectively. However, in proteus, these signals have been simulated using LED and relay(electrical). Whenever a valve is open, a green LED glows and when the valve is closed, a red LED glows.
13. LS138 is not used for memory decoding in Proteus, because only 1 ROM and RAM has been used whose decoding is carried out through OR gates.

Firmware

Implemented using emu8086 attached.

Proteus Simulation- Procedure

1. Press the Load button according to the instructions given in the problem statement to select the wash mode.
2. Press the DOOR SENSOR button. This will lock the door and is indicated by lighting up the Green LED and turning off the Red LED.
3. Press the Start button, indicating that the Load button has been pressed for the required number of times and the door has been locked. Failing to lock the door before pressing the START button would trigger the alarm, indicated by sounding the buzzer.
4. After the start button is pressed, the WATER-IN LED switches from red to green, indicating that the water has started flowing into the machine.
5. Now, press the WATER FULL button, conveying that the upper water level sensor is submerged in water and hence, the water is full. If the WATER FULL is not pressed for 10 minutes, then it is assumed that there is an issue with the water flow, and the alarm(buzzer) is sounded conveying the same to the user.
6. After this, the corresponding cycle of the given load mode gets started and the agitator or the revolving tub will start revolving. This continues until the time of the current cycle is reached.
7. After the cycle is done, the WATER-OUT LED switches from red to green, indicating the water in the tub is being emptied.
8. Now, press the WATER EMPTY button, conveying that the lower water level sensor is not submerged in water and hence, the tub is empty.
9. This completes one cycle (Rinse/ Wash/ Dry) of the entire wash process.
10. Repeat from Step 5 for the execution of the remaining cycles.
11. Before the dry cycle, the WATER FULL need not be pressed, as all the water is drained out before the dry cycle and the tub need not be filled again.
12. After completion of all cycles, the buzzer gets sounded for 10 seconds indicating the end of the complete wash process.

Note: The user needs to wait for around 5-10 seconds between each button press because Proteus usually doesn't run in real-time simulation. This causes a mismatch between the frequencies of 8086 and other IO devices.

List of Attachments

1. Complete Hardware Real World Design – example.pdf
2. Manuals
    a. FS-IR02 and FS-IR02 convert board
    b. Reed Switch Door Sensor : ORD213
    c. KPI 1410 : Piezoelectric Buzzer
    d. RKI-4076 : Buzzer Hardware
    e. Bimetallic Interlock : Door Latch
    f. FOTEK SSR 40DA : Relay of Door Latch
    g. Crouzer 801405 BLDCs
    h. Allegro A4915 Motor Drivers : Motor Drivers
3. Proteus File – washing_machine.dsn
4. EMU8086 ASM File: – washing_machine.asm
5. Binary File after assembly – washing_machine.bin
6. Flowcharts - Main - Flowchart.pdf, Issue - Flowchart.pdf, Stop ISR - Flowchart.pdf