Design of a digital system for the efficient management of water in a tank.

Authors

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Type of activity

This exercise is applicable in digital electronics, automation and industrial control classes. It relates to SDGs 6, 9 and 12, which promote access to clean water, the development of efficient infrastructure and the responsible use of resources.

Recommended educational level

Aimed at students in the final years of secondary education (Baccalaureate) and Higher-Level Training Cycles (especially those related to electronics and technology). It can also be addressed to university students of Electrical, Mechanical and Computer Engineering Degrees, among others.

Gathering information

Efficient control of water use is a key challenge in industry, where this resource is essential for processes such as cooling, cleaning, production and power generation. In addition, in industrial systems, it is common to use liquid storage tanks that require automatic level control to ensure a continuous supply without loss or interruption. Inefficient use not only increases operating costs, but also contributes to the overexploitation of water sources and the environmental impact of wastewater discharge. Optimising water management helps to reduce environmental impact, minimise waste, improve the sustainability of industrial processes and comply with increasingly stringent environmental regulations.

In this context, digital electronics play an essential role in solving these problems, providing tools for the automation and efficient control of the water level. Through level sensors and control systems based on digital circuits or microcontrollers, it is possible to regulate the inflow and outflow of water in real time, ensuring that the tank is kept within the appropriate levels without manual intervention. In this case, the use of an H-bridge allows the pump motor to be controlled precisely, activating it only when necessary to fill or empty the tank. In addition, in more advanced applications, optimisation algorithms and machine learning could anticipate consumption patterns, improve operational efficiency and avoid unnecessary waste. In this way, the integration of digital technologies not only facilitates significant water savings, but also contributes to sustainability in industrial environments.

Problem statement

A tank (see figure below) has two sensors, S1 and S2, which indicate the minimum and maximum level of the tank. The tank has a pump based on a DC motor, so that when the motor rotates clockwise the tank tends to fill with liquid and when it rotates anticlockwise the tank tends to empty. The purpose of the pump is to maintain the tank level between the maximum and minimum levels, acting as follows:

- If the tank is **above the maximum level**, the pump is activated to evacuate liquid.
- If the tank is **below the minimum level**, the pump is activated to draw liquid into the tank.
- If the tank is **between the maximum level and the minimum level**, the engine will be stopped.

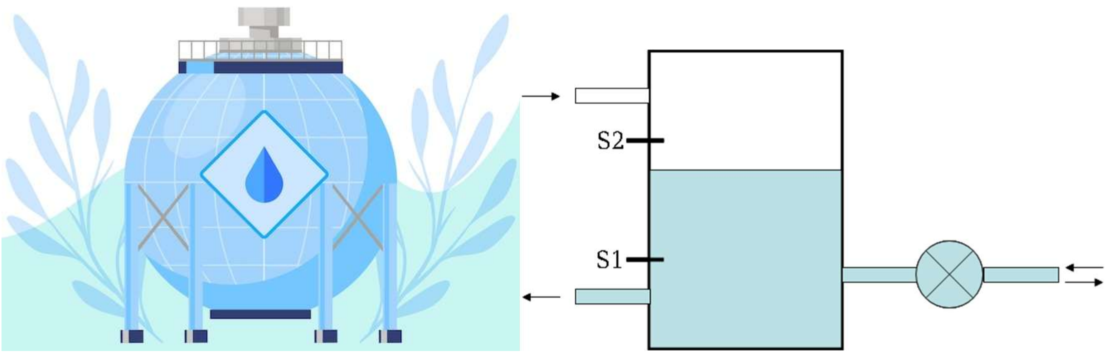


Figure 1. Water tank level control system. The tank includes two sensors (S1 for minimum level and S2 for maximum level) and a pump controlled by a combinational circuit that fills or empties the tank to keep the water level within the desired range. Source of the left image: https://www.freepik.es/vector-premium/ilustracion-conceptual-torre-agua-elegante-

hermosa_409361575.htm#fromView=keyword&page=1&position=27&uuid=46a2ab3a-2310-4821-91a1-278a12a05cea&query=Deposito+De+Agua Source of the right image: Own ellaboration

Design a combinational circuit that generates the appropriate signals to drive the pump motor by means of an H-bridge. Note: The H-bridge has two inputs, A and B, so that the following condition is met (CW: clockwise; CCW: counter clockwise).

A	B	Motor
0	0	Stop
0	1	CW
1	0	CCW
1	1	N/A

How is the efficient use of water in the tank designed?

We first identify the inputs to our system, which are the sensors S1 and S2. The value of these sensors will be 0 when the water level is below the point they set as a reference and will be 1 when the water level is above.

On the other hand, the output is the motor of the water tank pump, whose movement is described in the table above, through the signals A and B.

The objective of this problem is, therefore, to design a combinational circuit that generates the A and B signals to control the pump according to the state of the sensors in the tank:

- S1 = 1, S2 = 1 → Tank full: activate the pump to evacuate liquid (A = 0, B = 1).
- S1 = 0, S2 = 0 → Empty tank: activate pump to fill the tank (A = 1, B = 0).
- S1 = 0, S2 = 1 → Adequate level: pump remains off (A = 0, B = 0).

We must define the logical expressions and the truth table of the circuit that generates the appropriate signals for the control of the H-bridge. Let's analyse how to implement this circuit fulfilling the established criteria.

Solution

1. **Truth table:**

S1	S2	A	B

0	0	0	1	→ Water level below S1: fill tank (CW).
0	1	*	*	→ This is never the case, no matter what the engine is like.
1	0	0	0	→ Level between S1 and S2: engine stopped.
1	1	1	0	→ Level above S2: empty tank (CCW).

2. **Karnaugh maps to simplify the logic function:**

A Output:

S2 \ S1	0	1
0	0	0
1	*	1

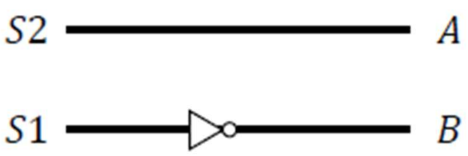
$$A = S2$$

B Output:

S2 \ S1	0	1
0	1	0
1	*	0

$$B = \overline{S1}$$

3. **Circuit:**



Conclusion

The designed system enables efficient control of water in a reservoir through a simple digital circuit. Its implementation in industry helps to optimise water use, reduce waste and improve operational efficiency, as well as encourage critical thinking and informed decision making in water resources engineering and management.

To broaden the problem, additional factors could be considered, such as:

- Use of timers to avoid rapid oscillations of the motor.
- Inclusion of a flow sensor to measure actual water consumption.

- Application of automation techniques with microcontrollers instead of pure combinational logic.