Automatic Water Level Sensor and Controller System

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Abstract— **In this paper, we investigate the design of a water level sensor device that is able to detect and control the level of water in a certain water tank or a similar water storage system. The system firstly senses the amount of water available in the tank by the level detector part and then adjusts the state of the water pump in accordance to the water level information. This electronic design achieves automation through sequential logic implemented using a flip flop. A seven segment display and a relay-based motor pump driving circuit are part of this integrated design. The water pump automatically turns on and starts filling the tank when the water level is empty or level ONE and turned-off and stop filling the tank when water level reaches maximum-level NINE; furthermore, the water pump will remain in its standstill state from level EIGHT down to TWO when the level is decreasing due to water consumption.**

Keywords— water level, sensor, seven segment display, priority encoder, water pump, relay, JK flip-flop, motor driving circuit.

I. INTRODUCTION

Our world and community is facing excessive water usage either for domestic or commercial purposes and it is a serious issue, which affects the sustainability of our environment. Water shortages or scarcity may be caused by the current climate change, such as altered weather-patterns (including droughts or floods), increased pollution, and increased human demand and overuse of water. As water is one of the scarce natural resources, it is important to properly use and manage our usage in different sectors. Especially in those places who are known for low-drinking water supplies like Middle East and North African (MENA) countries, there is a need to monitor the water usage across the different sectors such as the residential, agricultural, commercial and industrial areas. In recent years, there is a lot of study to conserve our natural resources such as energy and water. Water and energy conservation techniques and technological interventions are important to attain sustainable solutions to our environment that is currently at risk due to excessive use of such natural resources as a result of increase in population, human demand and economic growth. According to United Nations (UN) report, almost half of the world's workers work in water-related sectors showing most of the jobs dependent on water [1]. Therefore, investments that enable proper water usage mechanisms or technologies will have significant impact on sustainable development. Several researches are undergoing in order to conserve our precious resources such as water and energy. One of the factors that diminishes the accessibility of enough water is climate change that also arises due to the excessive use of non-renewable energy sources such as fossil fuels. As water is needed for energy production, energy is also needed for production, transportation and distribution of water. Therefore, energy and water are directly or indirectly related sustainability issues that may not be seen separately. An efficient use of one of the resources will contribute to the efficient use of the other resource and vice versa. In [2], [3] an electricity consumption campus audit was performed and mechanisms on reducing energy consumption were suggested. In [4]-[7] an electronic system were designed for automatic controlling of water pumps that are used for agricultural fields or plant watering and light intensity controller for energy saving. The speed of water pumps can be controlled by specially designed electronic power circuits [8], [9]. Especially, the work in [4] considers watering of agricultural fields based on the level of soil moisture sensing in order to avoid unnecessary wastage of water due to improper irrigation management system such as unawareness of farmers about sufficient supply of water in the manual watering.

Among others, we can monitor our daily consumption of water by measuring the quantity through an appropriate device such as water level measuring devices installed in a water tank or a similar storage container whether it is in private or commercial applications. In this paper, we propose a water-level monitoring system, which can sense the water movement in the upward or downward direction and then indicate the proper water level inside the container. The device will have ten sensors merged in the container; the purpose is to give the user an accurate reading of the height of water in the tank through a numbered display from zero to nine. The device also contains an automated part where it can control a water pump by switching it on when the tank is empty level zero or level one and then turn it back off when the tank is full at level nine. We believe that the installation of such a system will enhance proper management and usage of water in domestic houses, agricultural or industrial areas through monitoring and control of the quantity of usage. Such systems contribute towards the aim to conserve our natural resources and maintain the sustainability of the environment as through monitoring, water usage patterns and inefficiencies can be identified and reduction targets can be planned.

II. SYSTEM OVERVIEW

The proposed system comprises a water level sensor (with voltage output readings), a digital logic processing circuit or an integrated circuit (IC) which processes the sensor input

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signals, a 7-segment display unit, a JK flip flop sequential circuit, a motor drive circuit controlled by relay based driver. The proposed system includes water level sensors which can be assumed electrode resistive sensors that depend on the water's conductivity where at the desired points of level detection, it will conduct electricity between two fixed probe locations or between a probe and the tank wall [10], [11]. The water will complete the circuit and the sensor output can be used in different ways, such as opening or closing an electronic switch or turning on or off a water pump. Fig. 1 shows the general block diagram showing the different parts of the system. In the first sensor block, the level detector sensors provide appropriate signals either HIGH or LOW depending whether the electrode probes have contact with the liquid water or not. The water level sensor signals will be processed by a specially designed digital logic circuit or a priority encoder circuit that takes the ten sensor input signals and provides four encoded output signals. The encoder output will pass to the seven segment display unit that shows the appropriate water level in decimal number. On the other hand, the encoder output is also being an input to a specially designed sequential circuit that controls the motor pump driving circuit.

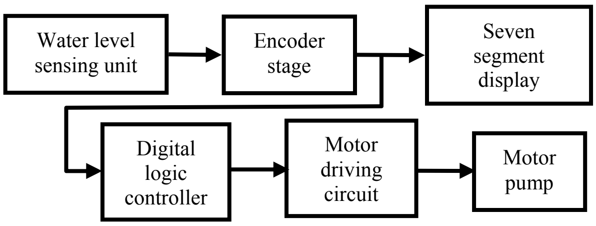

Fig. 1. Automatic water level monitoring system

III. WATER LEVEL SENSOR AND ENCODER STAGE

The sensors are assumed metallic electrode probes from P0 to P9 as shown in Fig. 2. These electrodes are inserted inside the water tank or reservoir with its water level to be monitored. Since the electrodes are basically depending on the conductivity of water to present a resistor and close the circuit, the use of electrodes will meet the efficiency and accuracy required with very low cost. The outputs D0 to D9 depend whether the electrodes are in contact with the water or not. For instance when, the probe P9 is not in contact with the water the output D9 will simply be the supply voltage Vcc or HIGH and when the probe is in contact with the water the output D9 can be adjusted to be LOW by selecting appropriate values for the resistors R1 and R2. Depending on the resistance of the water and the supply voltage Vcc, R1 and R2 can be selected to satisfy the threshold voltages levels that will be considered LOW or HIGH levels at the inputs of the digital encoder circuit. The required power supply voltage Vcc for the digital encoder circuit can be supplied using appropriately designed voltage regulator circuit. The digital encoder circuit can be designed using the input-output relations shown in Table I or alternatively an already designed 10 to 4 priority encoder IC can be used from the market. As it is known, a priority encoder operates by selecting the highest priority input among several inputs; the input with highest priority will take precedence [12]. The sensor inputs to the encoder circuit are also carefully designed by noting whether the encoder operates in active-LOW or active HIGH digital conditions. A simple inverter digital logic can change the sensor input signals to either LOW or HIGH depending on the required conditions. The water levels in decimal digits from 0 through 9 are displayed in the seven segment display stage. The working of a seven segment display can be achieved through the use of a decoder. An example of a seven segment display along with its decoder, which is referred to as BCD-to-seven segment decoder (7447) and seven segment display (7730) can be found in [12]. The BCD to seven-segment decoder changes the 4 inputs (outputs of the digital encoder stage: A. B, C, D) into 7 outputs, and these are connected to the inputs of the seven segment display.

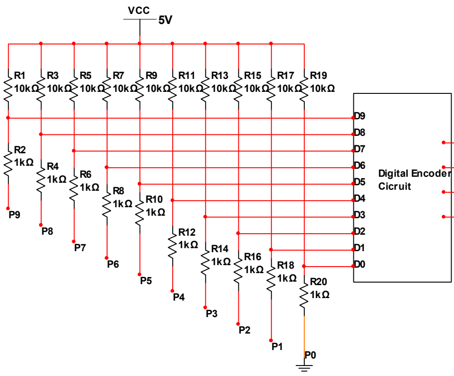

Fig. 2. Water level sensor and Digital Encoder

TABLE I. DIGITAL ENCODER TRUTH TABLE

Water Level	Digital Encoder Inputs										Encoder Ouputs			
	D0	D1	D2	D3	D4	D5	D6	D7	D8	D9	A	B	C	D
0	1	0	0	0	0	0	0	0	0	0	0	0	0	0
1	1	1	0	0	0	0	0	0	0	0	0	0	0	1
2	1	1	1	0	0	0	0	0	0	0	0	0	1	0
3	1	1	1	1	0	0	0	0	0	0	0	0	1	1
4	1	1	1	1	1	0	0	0	0	0	0	1	0	0
5	1	1	1	1	1	1	0	0	0	0	0	1	0	1
6	1	1	1	1	1	1	1	0	0	0	0	1	1	0
7	1	1	1	1	1	1	1	1	0	0	0	1	1	1
8	1	1	1	1	1	1	1	1	1	0	1	0	0	0
9	1	1	1	1	1	1	1	1	1	1	1	0	0	1

IV. DIGITAL LOGIC CONTRLOLLER AND MOTOR DRIVING CIRCUIT

The digital logic controller circuit is the one responsible for the automation of the system that sends signals and performs the switching ON and OFF the motor water pump. When water in the tank or a similar container is empty or at level ONE, the water pump will be triggered and be in SWITCHED ON condition and therefore pumps water into the tank. While the water flows through the levels upwards, the water pump state will remain ON until the level NINE is reached, where at this level a signal is sent to trigger the water pump OFF. While in the SWICHED OFF condition, the level of water decreases due to consumption for the purpose it is serving. As with upward flow of water, it is of a high priority that the downward flow in water will also maintain its water pump state until reaching level ONE, which is considered the minimum level before the tank being empty or ZERO level. Thus, by this design specification, the controller system maintains its main purpose of automatically controlling the level of the water inside the container.

A sequential circuit using the J-K flip flop or other flip-flop types can be used to control the driving circuit for the motor water pump. The change of motor SWITCHED OFF to SWITHCED ON conditions and vice versa can be easily tracked by designing a logic controller whose outputs will be the inputs to the J-K flip flop. Let Q_n and Q_{n+1} are the present and the next state of the J-K flip flop. It is known that when J=0 and K=0, there is no change in state of the flip flop ($Q_{n+1}=Q_n$); J=0 and K=1 is a reset condition for the J-K flip flop ($Q_{n+1}=0$); J=1 and K=0 is a set condition for the J-K flip flop ($Q_{n+1}=1$) and lastly J=1 and K=1 is toggle in state of the J-K flip flop, $Q_{n+1}=\overline{Q_n}$, Assuming that the initial state of the J-K flip flop is logic 0, when the digital encoder output ABCD is either 0000 (water tank level ZERO) or 0001 (water tank level ONE), the next state of the J-K flip flop is set to be one ($Q_{n+1}=1$) so that the water motor pump starts filling the container. The motor remains in switched ON condition during the levels from ONE to EIGHT (no change in the J-K flip flop output). When the level of the water tank is FULL or alternatively the level reaches NINE (ABCD=1001), the J-K flip flop is reset to change to the state of zero ($Q_{n+1}=0$) in order the motor is SWITCHED OFF and stops pumping to the tank or the container.

Using the above specifications and following the procedure for the digital logic design, one can find the truth table shown in Table II showing the change in state of the J-K flip flop with respect to the change in the encoder outputs (A,B,C,D) or alternatively the change in the level of the water tank. At level 0, one may note that if the current state of the flip flop Q_n is 0, that would mean the water pump is Switched off, so when J is 1 and K is in don't care state, that condition will turn on the water pump ($Q_{n+1}=1$). If however, at level 0, with the condition that the current state of the flip flop, $Q_n=1$ (motor ON condition), if the values are K=0 and J is in don't cares state, this means the water pump is running and hence it will remain running ($Q_{n+1}=1$). This case also applies to level 1 as we specify to fill the tank in the conditions of either tank level is empty or level one. In the water level conditions, two to eight, if the current state of the flip-flop is $Q_n=0$, this means the motor pump is in SWITCHED OFF condition, which means the water level is decreasing from the FULL tank down to level one and if the current state is $Q_n=1$, the motor is in Switched ON condition and hence water level is increasing from its lowest level until the tank is FULL. In the design, at level 9 the water filling process for the tank needs to stop since the tank or the container is in FULL condition. This means the value of Q_n (present state of the flip flop) needs to change from 1 to 0. This is achieved by ensuring K=1 and do not caring about the values of J, and thus Q_n becomes 0 regardless of the values of J. From studying Table II and using K-map, we can find simplified Boolean functions for the J and K inputs in terms of the variables A, B, C, D as given in (1) and (2)

$$J=(\overline{A+B+C}) \tag{1}$$

$$K=A\overline{B}\overline{C}D=A(\overline{B+C})D \tag{2}$$

TABLE II. TRUTH TABLE FOR THE LOGIC CONTROLLER CIRCUIT

Water Levels	**Digital Encoder Outputs**				**JK-flip flop state**		**JK-flip flop inputs**	
	A	**B**	**C**	**D**	**Q_n (Present state)**	**Q_{n+1} (Next state)**	**J**	**K**
0	0	0	0	0	0	1	1	x
0	0	0	0	0	1	1	x	0
1	0	0	0	1	0	1	1	x
1	0	0	0	1	1	1	x	0
2	0	0	1	0	0	0	0	x
2	0	0	1	0	1	1	x	0
3	0	0	1	1	0	0	0	x
3	0	0	1	1	1	1	x	0
4	0	1	0	0	0	0	0	x
4	0	1	0	0	1	1	x	0
5	0	1	0	1	0	0	0	x
5	0	1	0	1	1	1	x	0
6	0	1	1	0	0	0	0	x
6	0	1	1	0	1	1	x	0
7	0	1	1	1	0	0	0	x
7	0	1	1	1	1	1	x	0
8	1	0	0	0	0	0	0	x
8	1	0	0	0	1	1	x	0
9	1	0	0	1	0	0	0	x
9	1	0	0	1	1	0	x	1

The relation in (1) shows a NOR gate implementation of the J input and the relation in (2) shows a combination of AND gate and INVERTER implementation or AND gate and NOR implementation. Fig, 3 shows the logic controller circuit for the motor and the motor driving circuit. The overall work of the system can be explained by assuming the initial condition of empty tank. In this case, only the electrode probe P0 is active, which means the water tank level is zero (ABCD=0000). Using the logic equations (1) and (2), J=1, K=0 and hence the water motor pump is activated and start pumping water and fills the tank. When level one is reached, electrode probes P0 and P1 are active and hence (ABCD=0001) again in this situation the pump continue filling the tank as J=1 and K=0. When level two is reached, P0, P1 and P2 are active (ABCD=0010). In this case, J=0 and K=0 and from the sequential behaviour of the JK flip flop, the present state will be the same as the previous sate ($Q_{n+1}=Q_n=1$), which means the motor continues to be in SWITCHED ON condition and continues pumping to fill the tank. This situation will continue until level nine. When level NINE is reached ABCD=1001, J=0 and K=1, the JK flip will be reset to zero (Q=0) and hence the motor is switched OFF and stops pumping since the tank is FULL. When the collected water is getting consumed for its application, the tank level starts to drop and motor remains in switched off condition until level one is reached where it again starts to pump. This procedure continues in this designed automatic system. Table III shows the truth table for the JK flip flop when the motor pump is filling the tank with water and a similar table can be derived when the water level is decreasing due to consumption of water.

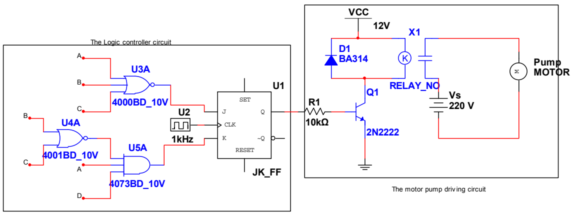

Fig. 3. Logic controller and motor pump driving circuit

TABLE III. TRUTH TABLE FOR JK-FLIP FLOP WHEN THE WATER PUMP IS FILLING THE TANK

Water Levels	**Digital Encoder Outputs**				**JK-flip flop state**		**JK-flip flop inputs**	
	A	**B**	**C**	**D**	**Q_n (Present state)**	**Q_{n+1} (Next state)**	**J**	**K**
0	0	0	0	0	0	1	1	0
1	0	0	0	1	1	1	1	0
2	0	0	1	0	1	1	0	0
3	0	0	1	1	1	1	0	0
4	0	1	0	0	1	1	0	0
5	0	1	0	1	1	1	0	0
6	0	1	1	0	1	1	0	0
7	0	1	1	1	1	1	0	0
8	1	0	0	0	1	1	0	0
9	1	0	0	1	1	0	0	1

V. DISCUSSIONS

From this study, we can see that automatic water level and monitoring and control system can be designed and implemented for a number of levels that is required for the application. As part of the requirement for senior design project and using the techniques discussed in the above sections, an eight level water level detector was designed, built and tested in the laboratory and it was found that the system works properly. Such system is to be considered smart, as it does not only sense and indicate the level of water but also controls the water level in the tank not to be empty and not to be over full. It also acknowledges the direction of water flow, whether or not the water level rises or falls; thus it maintains the water pump state accordingly. The sequential circuit plays the main roles in the automation as the JK flip flop controls the relay switch, which in turn was responsible for activating the motor that pumps the water. The use of such systems in the relevant applications helps to monitor the quantity of water consumed and identify the usage patterns. Usage monitoring is also the first step to implement water conservation programs. Water is a scarce resource and the proper use and conservation of water is very crucial in the 21st century and beyond especially in the Gulf Cooperation Council (GCC) countries like the United Arab Emirates (UAE) as they are known for the low drinking water reservoirs and mainly dependent on desalinating the sea water. Water is a key element for the human survival but unsustainable patterns of water consumption and usage are still evident in our practical life [13] and hence there is a strong need to change this pattern or behavior to sustainability as the world would indeed cease to exist without the availability of water.

VI. CONCLUSIONS

In this paper, an electronic system is designed to control and monitor the level of water in a tank or a similar reservoir based on the water detector sensor information. The different stages of the proposed system are designed using easily available discrete components. The electronic system is designed to automatically control and display water levels from zero to nine. The methodology of the design can be extended to design a system for controlling any other required number of water levels. The proposed system eliminates manual monitoring and controlling for home, agricultural or industrial users. The system achieves proper water management and enhances productivity from automation.

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