Design of Low Cost Water Level Control System: Based on Novel Flip-Flop Design

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ABSTRACT

Water tanks were introduced to us since past centuries ,it has an important and increasing role in our daily life for saving and keeping water resources especially in rural areas. It has been developed and improved across time , and an automated water tanks started to be manufactured . This paper presents a design of a low cost automatic water level control system based on using few , small , and low cost electronic components ; it composed from single Application Specified Integrated Circuit (ASIC) based on Flip-Flop technology to perform required control tasks , and a simple discrete level sensors. This design is presenting a unique and effective novel automation model of level control systems ,and it can easily be upgraded to perform more sophisticated tasks ,and also can be integrated with other different systems and units..

Keywords: - *level control ,low cost ,S-R Flip-Flop ,IS-R FF ,level sensor, tank.*

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1. INTRODUCTION:

Now a days, a very crucial and important problem is the management of the water resources around the whole world. Water is commonly used in agriculture, industry and in our homes for multiple purposes. In practice there are known many types of level control that can be done. But the most common ones are those with overflow control used to prevent exceeding the maximum level that a storage tank can hold and those with fully drain for preventing the pump to work without liquid. There are cases where these two methods are combined for a maximum use of pumps capacity, for reducing the frequently starts and to reduce working for a short period of time.[1].

In a lot of industrial processes, control of liquid level is very important issue. It was been recorded that approximately 25% of emergency shutdowns in the nuclear power plant are caused by poor control of the steam generator water level. Such shutdowns greatly decrease the plant availability and must be minimized. A need for efficiency and performance enhancement in existing level controllers is therefore required.[2].

This paper introduces a simple , low cost , and efficient design of an automatic liquids level control system , it can be used effectively either in house-held water tanks or in oil and other liquids tanks in the industrial sector. The main function of this system is to automate the on/off control process of the flow pumps to control the refilling process for the liquids tanks. This system design is built on the idea of using a single inverted Set input NOR S-R flip-flop to perform the required level control tasks with an aid of a suitable driving element , and a two simple discrete level sensors to sense and detect the liquid level in the tank.

2. RELATED WORK:

There are many designs of automatic level control systems based on a group of different control techniques. Most of the suggested designs are based on Microcontrollers; as the authors in [1] ,and [3] used a microcontroller to automate the process of water pumping in an over-head , and undergrounded tanks storage systems and has the ability to detect the level of water in a tank, switch on/off the pump accordingly and display the status on an LCD screen. The researchers in [4] also used microcontroller to manage the process using wireless level sensors instead of wired sensors. Also there are another controlling devices and techniques were presented as Cosmina Illes and his colleagues in [5] suggested a Programmable Logic Controller (PLC) based level control system design. Also a FUZZY logic control based designs have been introduced by the authors in [6],[7]. A more cost-aware designs using a combination of a simple electronic components and ICs were also introduced . Ishwar C. Murmu Laloo K. Yadav in [8] used a group of NAND gates , 555 Timer ,and a NOT gate to perform level controlling functions, while the researchers in [9] used a group of OR gates , Capacitors , Resistors ,and a Transistor to construct their control circuit.

Here in this paper we're going to present an innovative design of a liquids control system which will treat and enhance all of the considerations in the other suggested designs as : reliability , complexity , power consumption , and cost-effectiveness. The system is composed from four main units as shown in the block diagram at figure 1 :

A. power unit.
B. sensors unit.
C. Control unit.
D. Driving unit.

A. power unit :

Power unit is responsible from supplying required power to the control and sensors units. it provides 0 and 5 DC voltages which are required for the operation of the corresponding digital ICs, and the level sensors.

B. sensors unit :

Sensors unit is responsible from sensing the level of liquids in the tank , it consists of two discrete level sensors ; the first sensor is on the bottom of the tank to sense when tank goes empty , while the other sensor is on the top of the tank to sense when the tank goes full of liquids.

The sensors were designed to work as follow :

- give an output at logic level 0 or (0 – 2) DC volts when there is no liquids on the determined level to sense.
- give an output at logic level 1 or (2.5 – 5) DC volts when liquids reach the level required to sense.

The sensors outputs will represent the inputs for the control unit which will execute the required control task depending on the sensors outputs values.

C. Control unit :

Control unit is the most important unit in the system. To implement an efficient control unit we should know how the system is working . the system operation can be described as follow :

- If the tank is empty , then the sensors outputs will be low (0) ; so the pump should turns on to start filling of the tank.
- When the pump starts filling, the liquids will flow to the tank and the bottom sensor status will change to high (1) : the pump should continue filling.
- When the tank becomes full of liquids, the top sensor status will change to high (1) : The pump should stop filling.
- When the tank is full of , the pump will turns off . the liquid level will start decreasing and the top sensor status will change back to low (0) : the pump should keep turning off and never turns back on again unless the tanks goes empty . (the operation process will be repeated). table I summarizes the operation of the system.

TABLE I. SYSTEM'S OPERATION

Bottom sensor output	Top sensor output	Pump status
0	0	on
1	0	No change from previous status
1	1	off

To perform these control tasks a NOR S-R Flip-Flop with an inverted set input has been implemented and used . table II shows the operation of the S-R Flip-Flop and table III shows the operation of the inverted set input S-R Flip-Flop (IS-R FF).

TABLE II. S-R FLIP-FLOP OPERATION

Set input	Reset Input	Output
0	0	No change from previous status
0	1	0
1	0	1
1	1	0 (Invalid)

TABLE III. INVERTED SET INPUT S-R FLIP-FLOP OPERATION.

Inverted set input	Reset Input	Output
0	0	1
0	1	0 (Invalid)
1	0	No change from previous status
1	1	0

As shown in table I and table III the inverted set input S-R Flip-Flop performs all of the control tasks exactly as system's operation requires. The bottom sensor output will be the input of the inverted set input ,and the top sensor output will be the input of the reset input in the S-R Flip-Flop. The output of the IS-R Flip-Flop is used to drive the flow pump using a suitable driving unit.

D. Driving unit :

The driving unit is responsible from driving the flow pump depending on the change in the IS-R Flip-Flop logic status , in this design a simple relay device is used to drive the operation of the flow pump.

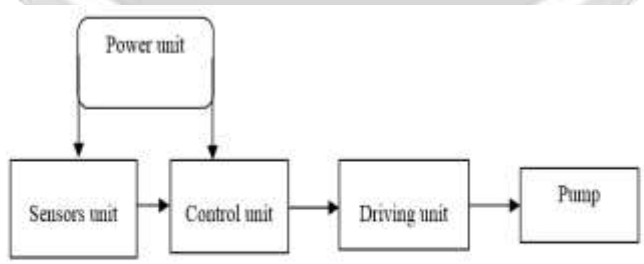

Fig. 1: Block diagram of the system.

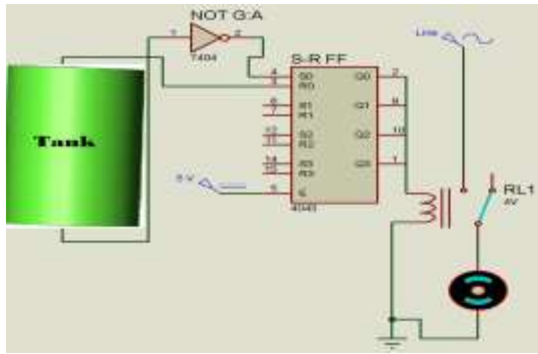

Fig. 2: Circuit diagram of the system using SR-FF and NOT gate.

3. HARDWARE IMPLEMENTATION:

The system has been successfully tested experimentally in lab where we used an IC 7404 TTL NOT gate , IC 4043 CMOS NOR S-R Flip-Flop , and a Simple 5 Volts relay device. For further work we designed a single ASIC model named as IS-R FF instead of using the two ICs separately to reduce the cost and the power consumption. Figure 3 shows the CMOS architecture of the IS-R FF ; it is constructed from a CMOS S-R FF and CMOS Inverter . Also figure 4 represents the Equivalent Logic Circuit for the IS-R FF .The operation of the IS-R FF is illustrated in Fig. 5 which shows that the output response is identical to the required response of the level control system in tables I ,and III.

This design has many advantages in comparison with other level control designs ; it's more simpler , and less in size and power consumption . another strong advantage in this design that it's cost effectiveness which makes it applicable for consumer's uses in house-held water tanks. The initial cost of this design is about (30 – 40) SDG, (≈ 4 – 5) USD.

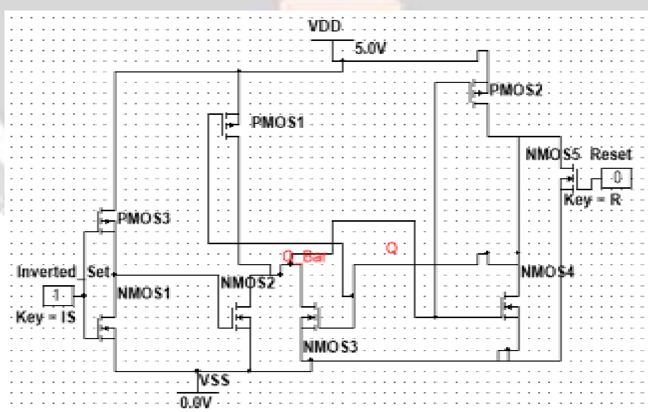

Fig. 3: IS-R FF CMOS Architecture.

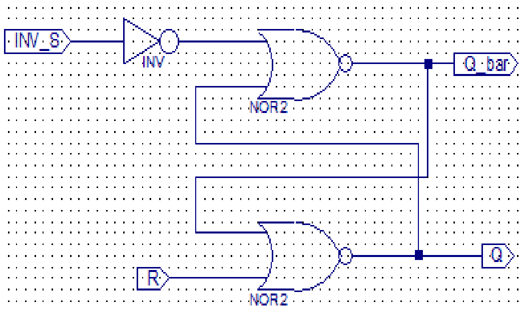

Fig. 4: IS-R FF Equivalent Logic Circuit.

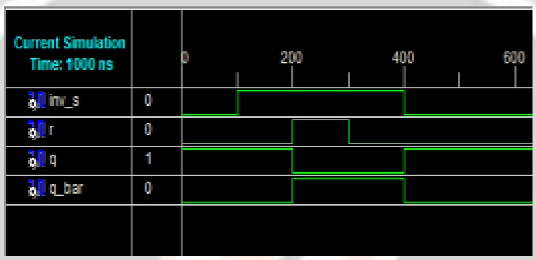

Fig. 5: IS-R FF cycle operation.

4. CONCLUSIONS:

This paper presents a new simple and efficient design of level control systems , this design is based on using a single inverted set input S-R Flip-Flop integrated circuit to perform required level control tasks. This system has many advantages in comparing with other level control systems :
design simplicity ,small size , low power consumption ,and moreover it's cost effectiveness .

Proteus 8.1 electronic circuits simulation software was used to simulate the system operation.[12]. Multisim 13.0, and Xilinx 9.2i VLSI and Electronic Devices Automation (EDA) softwares were used to design and test the operation of the IS-R FF integrated circuit.[13],[14].

5. REFERENCES:

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