Automatic Water Level Control System Using Discretized Components

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ABSTRACT: This study is based on the design of a portable automatic water level control switch that is capable of switching on the pump when the water level in the overhead tank goes low and switches it off as soon as the water level reaches a pre-determined level to prevent dry-run of the pump in case the level in the underground tank goes below the suction level. The water in the tank is measured by the conductive probes and displaced via the LED indicators. At maximum-set capacity the pump is de-energized to automatically switch off, thereby stopping the inflow of water into the tank. The design approach involves three major stages which are: the power supply unit, the sensing unit, and the motoring and relay unit. The uniqueness of this work is the use of discrete components such as transistors to achieve water level control. This approach is more economical, simpler and easier to implement than the sophisticated programmable logic controllers and computerized microprocessors.

In recent years automatic control systems have gained an increasing importance in the development and advancement of the modern civilization and technology. There are two major methods of water level control: manual method and automatic method. The manual method involves the switching ON and OFF of the power supply to the pump motor manually by an operator when the tank is either empty or full. This method is common with domestic water supply systems where water is pumped from a well to an overhead tank e.g. borehole water supply. The limitation of this method is that it is prone to overflows and cavitation and hence wastage of resources. This is as a result of human error due to time wasted in opening and closing valves. So there is a need of an automatic or "human less" system to increase efficiency. The automatic water level controls are of various designs. Some of these designs are discussed in the following literatures. Band and Anyasi (2014) in their paper presented the design of an automatic water level controller. The design system uses the mercury flow switch. The system incorporates two contactors which are energized to provide a direct online start of the motor. An over load relay senses the presence of excess current and disconnects the supply while the mercury flow switch uses the Archimedes principle of flotation to provide electrical contact to switch ON and OFF supply to the motor when the tank is empty or full respectively. This system is relatively cheap,

affordable and durable. The major drawback of this system is the use of the mercury switch. Mercury switches have a relatively slow operating rate due to the inertia of mercury drop; they are also highly toxic and accumulate in any food chain. A water level sensor with voltage output readings was designed using a digital logic processing circuit or integrated circuit, a 7-segment display unit, a JK flip flop sequential circuit, and a motor drive circuit controlled by relay based driver (Getu and Attia, 2016). The water level sensors were electrode resistive sensors that depended on the water's conductivity. At the desired points of level detection, it will conduct electricity between two fixed probe locations or between a probe and the tank wall. 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.

An Electric Water Pump Controller and Level Indicator has been designed making use of metallic conductors or probes sensors, each positioned at different levels along the height of the tank height to act as sensors. Similarly to the aforementioned literature, (Getu and Attia, 2016). The electrical conductivity of water is exploited. The additional components used are the comparators to monitor the presence of water at the probes and microcontrollers, to drive digital outputs which turn on visual display

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LEDs that indicate various water levels in the tank (Das et al, 2017). The automatic water level control has been applied practically in the water-replenishing tank of central air conditioning (Zhang, 2013), and computerized water level control system for system generator of Qinshan nuclear power plant (Lang et al, 1997).

The objective of this study is to design and construct a portable automatic water level control switch capable of switching on the pump when the water level in the overhead tank goes low and switches it off as soon as the water level reaches a pre-determined level to prevent dry-run of the pump in case the level in the underground tank goes below the suction level.

MATERIALS AND METHOD
The block diagram of the water level control system described in this paper is shown in Fig 1.
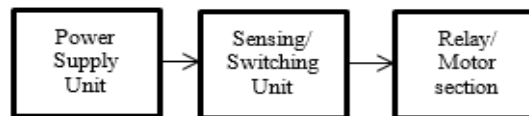

Fig 1: Simplified block diagram of water level control system

The Power supply: Power supply is important because it supplies electric power to the other units such as the sensing unit and relays and motor. The power supply comprises of Transformers, rectifiers, and Filtering capacitors.

Transformer: The *transformer* is a static electrical device that transfers electrical energy between two or more circuits through electromagnetic induction. Transformers with I/O rating of 240V/12V, 2A types were used in this work. The transformer ratings are shown in Table 1.

Table 1: Calculated Values and Ratings of the Transformers

S/N	Description Of Parameter	Formula	Rated Value	Calculated Value
1	Input current	$I_{(I/P)}$	2A	2A
2	Max input current	$I_{(I/P)}\sqrt{2}$		2.8A
3	Input voltage	$V_{(O/P)}$	220V	220V
4	Max input voltage	$V_{(I/P)}\sqrt{2}$	310.2	310.2
5	Output current	$I_{(O/P)}\sqrt{2}$	2A	2A
6	Max output current	$I_{(O/P)}\sqrt{2}$	2.8A	2.8A
7	Output voltage	$V_{(O/P)}$	15V	15V
8	Max output voltage	$V_{O/P)X}\sqrt{2}$	21.21V	21.21V

Rectifier: The rectifier module of the type 50V / 4A and two single diodes of the type IN 4007 are employed for the rectification. These rectifiers were used to bring about direct power (Hughes, 1995) to the entire system and also control the switching *on* and *off* of the indicator LED via relays. It is important to state that the choice of both the full-wave rectifier module and the individual diodes were chosen to withstand the secondary output voltage and current from the transformer. So it can be seen that the ratings are well known from the following calculations.

Given that, Output current = 2A
Taking input voltage of the rectifier module to be the maximum output voltage from secondary terminals of transformer

$$V_{\max(I/P)} = 15 \times \sqrt{2} = 21.21\,V \qquad (1)$$

Peak output voltage from the full-wave rectifier, V_{dcm} is given by

$$V_{dcm} = V_m - (0.7 \times 2) = V_m - 1.4 = 19.81\text{ V} \quad (2)$$

The value, 1.4 V is the value of the forward voltage drop across the two diodes.

Calculation for the value of the rectifier module: Rectifier module input voltage is taken as the maximum output voltage from secondary terminals of transformer

$$V_{i/p} = V_{max} \times \sqrt{2} = 15 \times \sqrt{2} = 21.21\,V \qquad (3)$$

Using FOS of 1.5
$$WVDC \leq 1.5 \times 21.21V = 31.815\,V \qquad (4)$$

A rectifier module rating of 50 V/4 A, was chosen since it falls within a very safe margin as revealed from the calculation.

Filtering Capacitors: The voltage impressed on the parallel filtering capacitors are same and is exactly V_{dcm} = 21.21V. Choosing an exact value for the filter capacitors will not show any safety in the design. So a higher voltage rating is estimated using 1.5 F.O.S. Therefore,

$$WVDC \geq 1.5 \text{ X Vdcm} = 1.5 \times 19.81V$$
$$= 29.71V \qquad (5)$$

Therefore a 35V WVDC was chosen since it falls within a safe margin revealed from this calculation. This value is commercially available.

Capacitance Calculation (Ripple Factor): Capacitors can be defined as a passive two terminal electrical component that stores potential energy in an electric field. Ripple factor is given by the relation:

$$R = \left[\left(\frac{V_{rms}}{V_{dc}}\right)^2 - 1\right]^{1/2} = \left[\left(\frac{15}{13.6}\right)^2 - 1\right]^{1/2} = 0.484 \quad (6)$$

The design values for these capacitors can be gotten from the formula

$$C = \frac{1}{4\sqrt{3} \times R_L \times R \times F} \quad (7)$$

Where f = frequency of operation = 50Hz, R = ripple factor = 0.484, R_L = load =10.5KΩ,

$$C = 4.13 \; x \; 10500 \; x \; 0.484 \; x \; 50$$
$$= 596\mu F, 35V \quad (8)$$

Choosing a safety margin of 1.5 working capacitance,

$$C_w \geq 1.5C = 1.5 \times 596$$
$$= 894\mu F \quad (9)$$

A 1000μF, 35 V capacitor value which is readily available and is safe enough as revealed in the calculations, was chosen.

Transistor and Sensing Section: The transistor types used are C945 and A1015. Their applications are in op-amp and in high frequency switching. Operating voltage is 12V dc. The switching transistors T1, T3 and T5 are connected in common emitter configuration. Calculating Values for the Resistors and Current

RB1 = RB3 = RB5 = 50,000KΩ

This is the value of underground water resistance

The base current, Ib for T1, T3 and T5, using Ohm's law will be

$$I_b = \frac{V_{cc}}{R} \quad (10)$$

Where Vcc = collector voltage = 12V

$$R = RB1 = RB3 = RB5 = 50K\Omega$$

Putting the values in Ohm's law equation above, we have

$$I_b = \frac{12}{50,000} = 0.24mA \quad (11)$$

This current is enough to bias the transistors to function as closed switches.
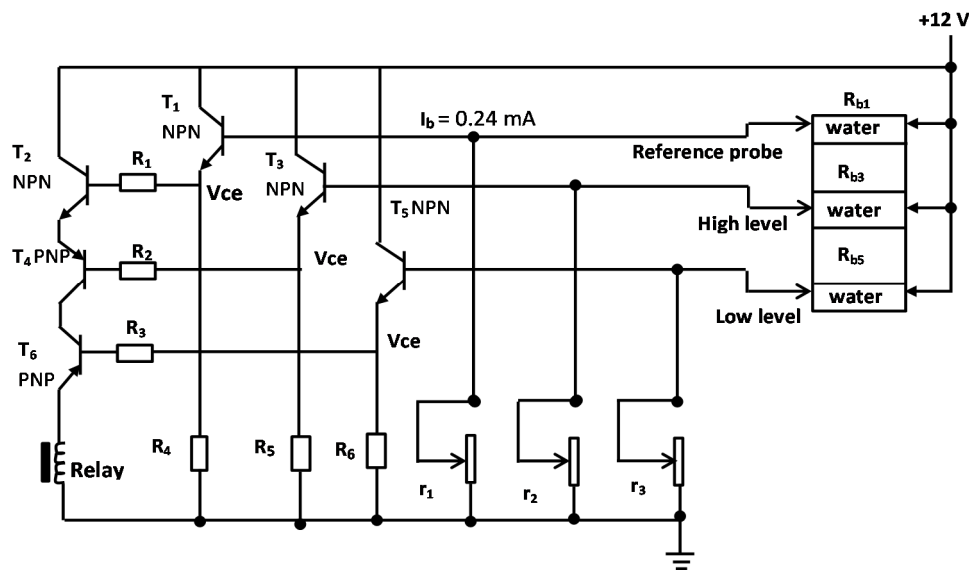

Fig 2: Sensor unit design of the water level control

Electrical sensors are devices that detect and respond to some type of input from the physical environment. The specific input could be light, heat, motion, moisture, pressure or anyone of a great number of other environmental phenomena. In this case the sensor detects voltage. Figure 2 presents the sensing unit design of the water level control.

Relay/Motor Section: The relay is an electrically operated switch, relays are used as an electromagnet to mechanically operate a switch but other operating principles are also used such as solid state relay, since relays are switches the terminology applied to switches is also applied to relays. A relay switches one or more poles each of whose contact can be thrown by energizing the coil. The Motor section comprises of an electrical machine that converts electrical energy into mechanical energy. Most electric motors operate through the interaction between the motors magnetic field and winding currents to generate force in the form of rotation

RESULTS AND DISCUSSION
The power unit delivers +12V to the control system as well as to the tank. As control unit maintains contacts with water in the tank via 4 probes; reference probe, Vcc probe, Low probe and High probe. With the availability of little water in the tank the reference probe starts conducting to the base of T1 which switches on T2. T4 and T6 are forward biased through R4 and R5 as a result current flows to energize RELAY 1 which switches on the PUMP. As water level rises T5 conducts to reverse bias T6. The T6 is bypassed through the upper set of contacts of relay 1 so the pump continues to run. When T3 senses water it conducts to reverse bias T4 to de-energize the relay and the sumo stops pumping.

Preliminary Test: Two preliminary tests were performed; in the first test, an energy bulb is used as shown in Fig 3. When the connections are completed and water is manually poured into the tank, a certain pre-determined level is reached and the bulb light which was originally ON now goes OFF. When the tap is open and water level receded in the tank, at a certain fixed level the bulb light comes ON. This clearly shows that by replacing the bulb with pump similar ON and OFF actions will be initiated. This led to the final design shown in Fig 4.
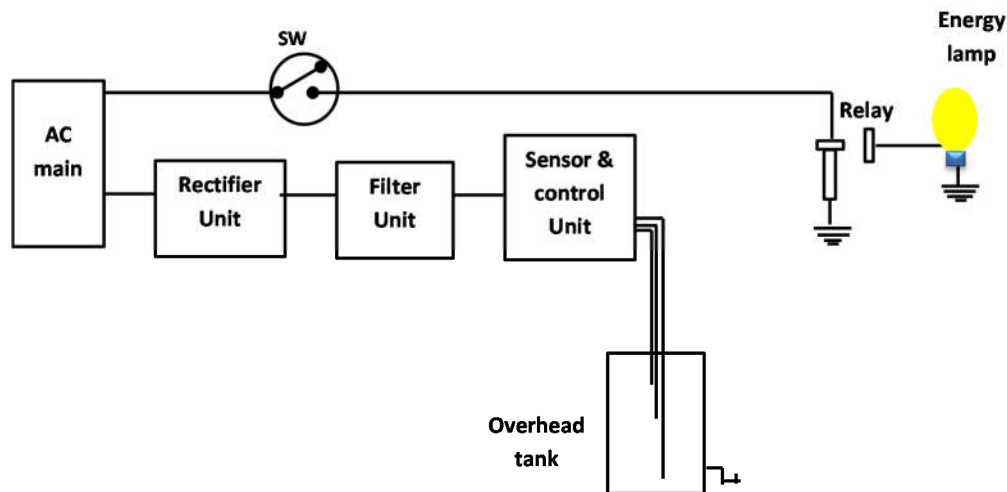

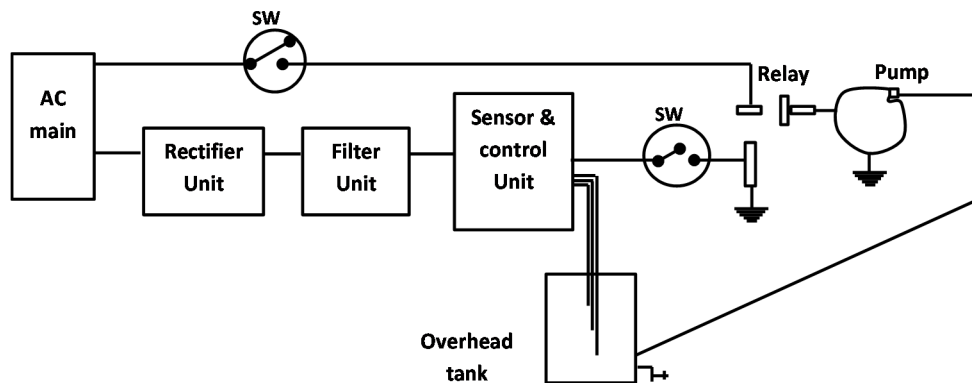**Fig 3**: Block diagram of the test circuit with energy lamp

Fig 4: Block diagram of the test circuit with electric Pump.

Conclusion: This study presents the implementation of discrete components such as transistors to automatically switch OFF the electric pump, when the water tank is filled up and switch ON when the water falls below the low level probe in the tank. The significance of this engineering design is to achieve a simple, cheap, efficient and reliable means of water level monitoring so that continuous and regular transfer of water in a tank system will be guaranteed. This design can find useful applications in volumetric measurements and mixing chemical processes.

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