OPERATIONAL PRINCIPLE OF WATER LEVEL DETECTOR FOR AGRICULTURAL AND DOMESTIC USE

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Abstract
This paper proposes a design to automatically detect the level of water in a reservoir (storage tank) at a preset level and initializes an information to the users in case of low water level. The functionality of this sensor depends basically on the electrical conductivity of water (probes) which varies, depending on the level of its impurity. It is of this note that the electrical conductivity of saline (35g/kg at 25^{o}C) is 4.8S.m^{-1}, while the electrical conductivity of high quality drinking water ranges between 0.0005 – 0.05 S.m^{-1}, and that of deionized water is 5.5 x 10^{-6} S.m^{-1}. In this sensor system, an actuator that operates on the basic principle of an astable multivibrator, operating with a duty cycle of 50.25% with an output frequency of 3.256Hz is required to operate on the water level detection. Hence, a continuous train of rectangular pulses whose band width is 0.154s at a period of 0.306s was designed and developed for the system. The device is powered by a dual power source for redundancy sake, reliability and maximum efficiency.
Keywords: *Astable multivibrator, duty cycle, charging and discharging time, bandwidth and electrical conductivity.* **http://dx.doi.org/10.4314/jafs.v9i2.2**

Introduction

The quest to tackle the negative consequences that water could pose if not properly monitored and controlled in domestic and agricultural use, has aided and propelled the research and construction of this water level detecting device, which can be used to determine water level and its usage in this area (i.e. domestic and agricultural). The development of an astable multivibrator circuit is to produce oscillation when the probe senses water at a preset (lower) level. The NE555 timer IC was introduced by synergetic corporation to act as a booster in multiple vibration/probe detection values (www.circuitstoday.com).

The water level alarm detector is very simple and basic, but not without its shortcomings, one of which is the source of its power. The circuit operates on a 3V dc (battery), which could not adequately power the circuit and produce the required audible sound from the buzzer since the minimum recommended operating voltage for the 555 timer is 45v **(Duncan 1983; Malvino 1984)**. To annul this problem and to also reduce the cost of power supply, a dual power supply source is adopted – 9V dc battery source and a 220V – 240V ac source. Also introduced in the modified circuit is the power indicator light emitting diode (LED) **(Powersupply www.kpsec.free.uk.com/powersup.htm)**

Design and Analysis of the Circuit

Design

The initial circuit: The circuit is classified into three parts as shown in Figure 1;

(i) The actuator part: This consists of the astable multivibrator, working dependently with the capacitor C1, resistor R1, R2 and the resistance across the probes.

(ii) The output transducer: In this case is the buzzer. It translates the oscillatory signals from the astable multivibrator in the actuator part of the circuit to an audio signal.

(iii) The power supply part, which inputs into the device a 3V dc source

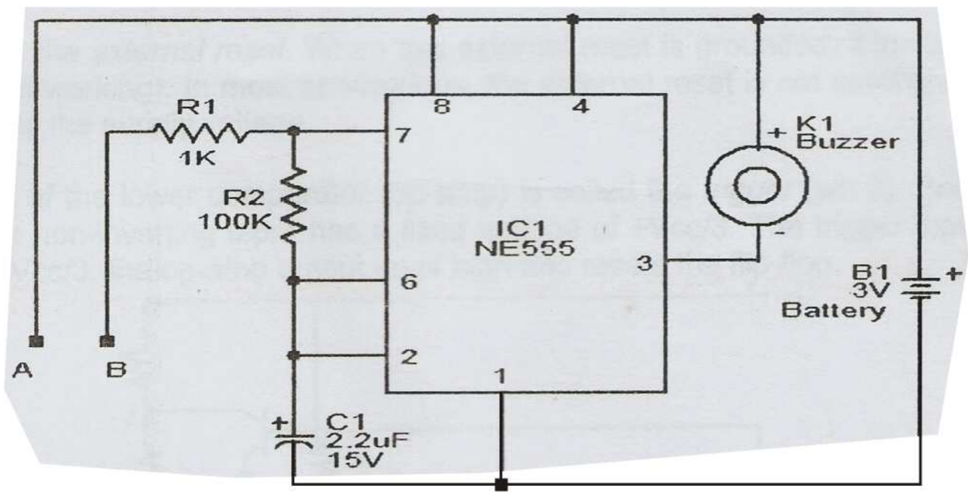


Figure 1: Water level alarm circuit power supply (www.circuitstoday.com)

The circuit operation is based on an astable multivibrator wired around IC1 (NE555). The operating frequency of the astable multivibrator here will depend on capacitor C1, resistance R1, R2 and the resistance across the probes A & B in the water when probes are out of water, the circuit would open, the multivibrator would not produce oscillations and the buzzer would not beep. As soon as there is water up to the level of probes, current would relatively pass through the water, and a closed circuit would be formed. At this instant, the IC would start producing oscillations of frequency proportional to the value of C1, R1 R2 and the resistance of water across the probes. The buzzer which acts as an audio transducer would then start to beep continuously to indicate the presence of water at the level of the sensing probes.

Astable Multivibrator: An astable multivibrator is a two stage switching circuit in which the output of the first stage is fed to the input of the second stage and vice versa **(Sybil 1985)**. The outputs of both the stages are complimentary. This free running multivibrator generates a square wave without external triggering pulse. The NE555 IC is the main component of the circuit, having 8-pin, as indicated in Figure 2. The upper comparator has two pins – the *threshold input* (pin 6) and the *control input* (pin 5). The control i.e. pin 5 is not used in most applications so that the control voltage equals +2Vcc/3. Whenever the threshold voltage exceeds the control voltage, the high output of the comparator sets the flip flop.

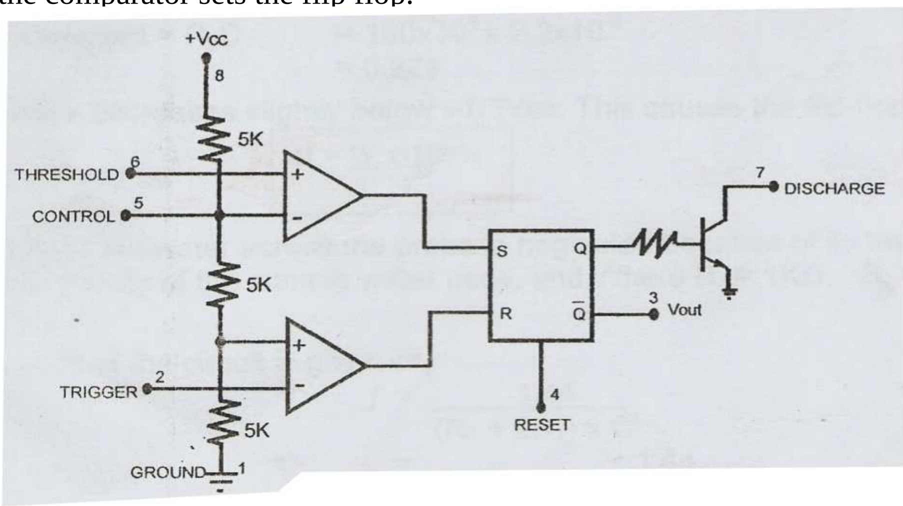


Figure 2: The Block Diagram of 555 Timer

Courtesy: (William 1978)

The collector of the discharge transistor is attached to pin 2, when pin 7 is connected to an external timing capacitor C1 as shown in figure1, a high Q output from the flip flop would saturate the transistor and discharge the capacitor. However, when Q is low, the transistor opens and the capacitor charges. The *complementary signal* out of the flip-flop is attached to pin 3, the output. Pin 4 is attached to the external reset. When this external reset is grounded, it inhibits the device (i.e. prevents it from working). In most applications, the external reset is not used and the pin 4 is directly connected to the supply voltage. The inverting input of the lower comparator (op-amp) is called the *trigger* (pin 2). Because of the voltage divider, the non-inverting input has a fixed voltage of +Vcc/3. The trigger input voltage is slightly less than +Vcc/3, the op-amp output goes high and resets the flip-flop. The timer as shown in Figure 3 serves as astable multivibrator for the inverting input process.

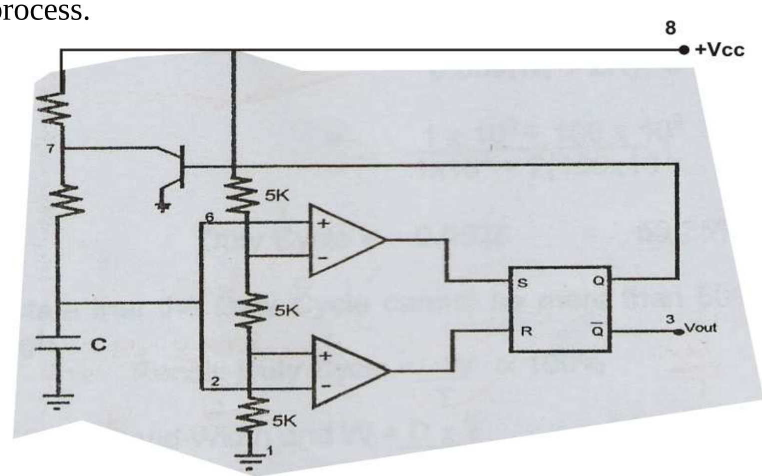


Figure 3: 555 Timer Connected as Astable Multivibrator

Extracted from Udomisiri (2008) and William (1991).

Analysis Of The Circuit

Pin 1 is the ground of the chip, while pin 8 is the positive supply pin. The NE555 IC will work with any supply voltage between 4.5 and 16V.

The charging (high output) time constant is given by

$$Charging\ Time\ Constant = (R_1 + R_2)C \tag{1}$$

$$= (1x10^3 + 100x10^3)2.2x10^{-6}$$

$$= 0.2222s$$

Capacitor charges and threshold voltage increases until it exceeds +2/3Vcc

$$Discharging\ Time\ Constant = R_2C = 100x10^3x\,2.2\,x10^{-6}$$

$$= 0.22s$$

The threshold voltage decreases slightly below +1/3Vcc. This causes the flip-flop to reset.

$$The\ percentage\ Duty\ Cycle\ is\ defined\ as\ D = \frac{W}{T}\,x\,100\% \tag{2}$$

Where; W = bandwidth; T = total time

where the resistance of the water across the probe is neglected because of its trivial value which is due to the high conductivity of the sample water used, and where R_1 = 1K Ω and C = 2.2µ*f*, therefore,

The output frequency of the circuit is given as,

$$f = \frac{1.44}{(R_1 + 2R_2)x\,C} \tag{3}$$

$$f = \frac{1.44}{(1x10^3 + 2(100x10^3)2.2x10^{-6})}$$

$$= 3.256Hz$$

The discharging time (output low) is

$$T_L = 0.693\,x\,R_2\,x\,C \tag{4}$$

$$= 0.693\,x\,100\,x\,10^3\,x\,2.2\,x\,10^{-6}$$

$$= 0.15246s \approx 0.153s$$

The charging time (output high) is

$$T_H = 0.693\ x\ (R_1 + R_2)C \tag{5}$$

$$= 0.693\ x\ (1\ x\ 10^3 + 100\ x\ 10^3)\ 2.2\ x\ 10^{-6}$$

$$= 0.15399s \approx 0.154s$$

The total time is given by

$$T = T_L + T_H \tag{6}$$

$$= 0.693\ (R_1 + 2R_2)C$$

$$= 0.152 + 0.154 = 0.306s$$

The duty cycle is the ratio of time when output is low to the total period.

$$Here\ it\ is\ defined\ as\ \frac{Discharge\ time}{Total\ time\ (T)} \tag{7}$$

$$= \frac{0.693R_2C}{0.639\ C(R_2 + R_1 + R_2)} \tag{8}$$

$$= \frac{R_2}{2R_2 + R_1}$$

$$Substituting\ the\ values, Duty\ cycle = \frac{1\ x\ 10^3 + 100\ x\ 10^3}{1\ x\ 10^3 + 2(100\ x\ 10^3)}$$

$$Duty\ cycle = 0.5025 = 50.25\%$$

It is imperative to state that the duty cycle cannot be less than 50% and output low must be less than output high.

Recall that from Eq. 2, $duty\ cycle = \frac{W}{T}\ x\ 100\%$

where W is the bandwidth and $equals = \frac{D\ x\ T}{100} = \frac{50.25\ x\ 0.306}{100} = 0.154s$

Figure 4 below shows a bandwidth and conductivity waveforms for farmstead or domestic water volume signal.

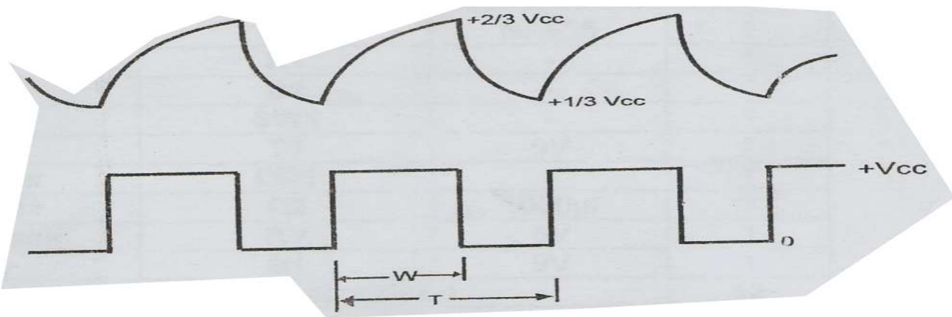


Figure 4: Output Waveforms

Construction, Assembly and Testing

Construction:

The modified circuit: The final circuit is also classified into three. The third part *(Power supply part)* is introduced basically to improve its performance. In the power source part, a dual power supply is adopted for this project for redundancy sake; a 9V dc supply and a 220/240V ac supply are used alternatively as convenience demands. The ac Power Supply Unit (PSU) is composed of a step-down 9V transformer, a bridge rectifier, filter capacitor and a 5V (7805C) voltage regulator. The PSU rectifies the 220-240V source to a 4.5-9V dc input voltage for the device as shown in Figure 5. The package and the equipment testing device are shown in stages (1 – 4).

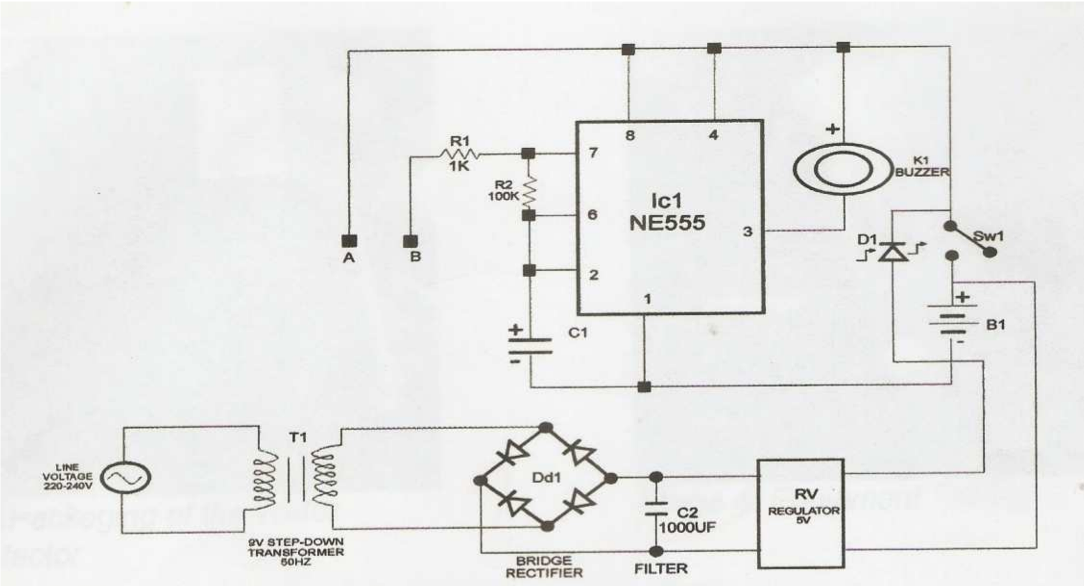


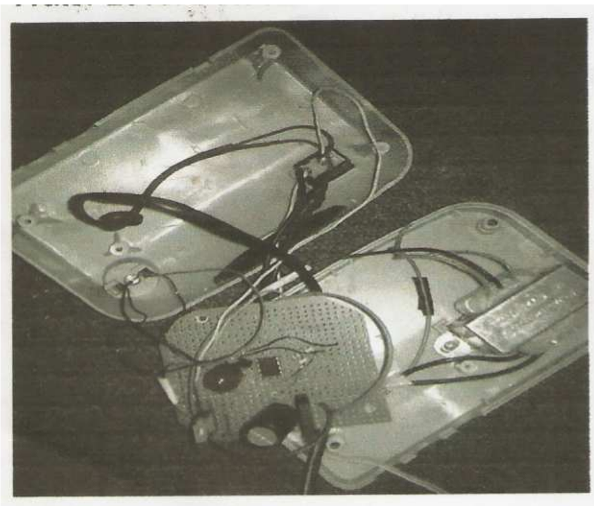
Figure 5: Modified Water Level Alarm Circuit

Table 1: List of components

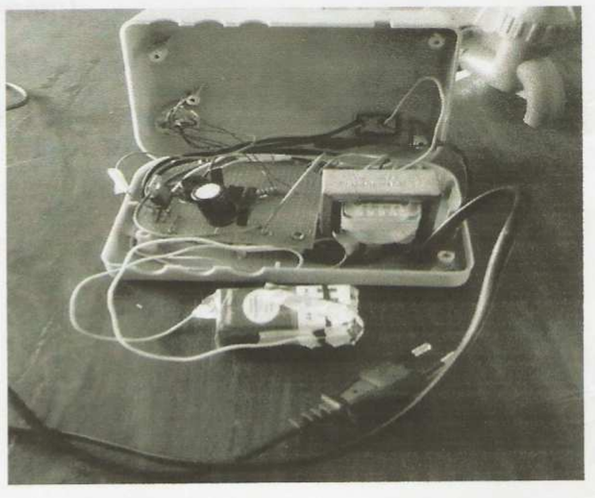
Components	Description	Values	No.
Resistor	R1	1KΩ	1
Resistor	R2	100KΩ	1
Capacitor	C1	2.2µf	1
Astable Multivibrator	IC1	NE555	1
Buzzer	K1	-	1
LED Indicator	D1	-	1
Switch	SW1	-	1
Transformer	T1	9V	1
Bridge Rectifier	DD1	-	1
Filter Capacitor	C2	1000µf	1
Voltage Regulator	RV	5V	1
DC Battery	B1	9V	1
Total number of components used			**12**

Assembly and Testing

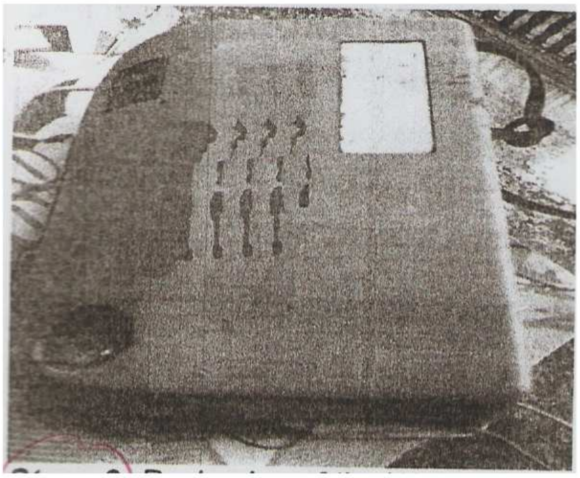
The pictures shown below are the various stages in the construction, assembly and testing of the water level detector device.



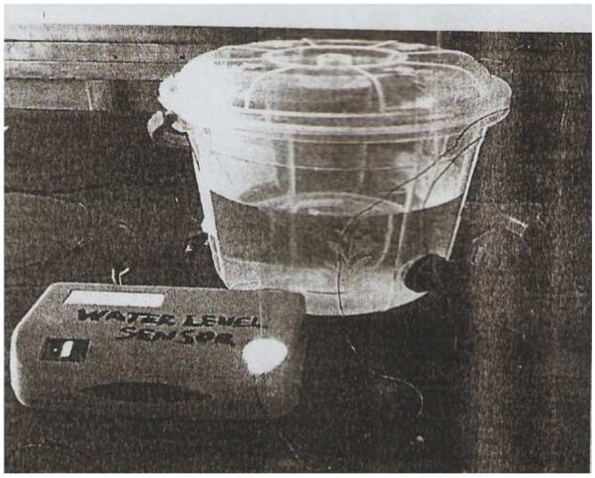
Stage 1: *Construction 1*



Stage 2: *Circuit being fixed inside the casing*



Stage 3: *Packaging of the water level detector*



Stage 4: *Equipment testing*

Conclusion/Recommendation

The water level detector design could be improved such that when the alarm is triggered as a result of detecting water at a predefined level, it will also automatically switch OFF the water pumping machine, as in the case of pumping water into a reservoir/container. It could also be improved such that it switches the pumping machine ON and OFF intermittently with respect to a given level at the reservoir/container – this will ensure the ever presence of water in the reservoir/container. It can also be used to detect water in water sensitive areas, where water is not needed – like power stations, laboratories and also in some electric device, to mention but a few, to trigger alarm when the presence of water is sensed.

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