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TABLE OF CONTENTS

1. Abstract

Control of water level is a function that finds use in many areas. It is essential to create a stable, efficient and easy to build mechanism for detecting and controlling water levels in containers of various sizes as the applications for this technology is massive. It is a cornerstone in hydrometry, irrigation logistics (to name a few largescale applications), and in general day-to-day life usages where knowledge of fluid level adds to the comfort factor of everyday life, such as bottles that tell you the level of water in them, or having the right amount of water to be heated in a water heater. Needless to say, innovation and reinvention in this sector is a very in-demand area which we are trying to break ground on.

The basic principle behind water level control is the use of a control circuit to divert current from the motor when the water level reaches the limit and to supply current to the motor pump when the level reaches below a certain minimum threshold. This requires a water level sensor, a motor pump and the use of the Bipolar Junction Transistor to facilitate the control circuit. By effecting the circuit using the abovementioned elements, the motor is turned on and pumps water into the required container whenever the water level subsides below a minimum level and stopping pumping whenever it goes above the maximum level. In this way, the water level is maintained within a certain range.

An Automatic Water Lever Indicator and Controller is used in RO Water Purifiers to maintain the water level of the container from which purified water is filled by the user, by pumping the water from the purifier whenever needed. This concept is also used on a large scale in Water Reservoirs and Dams where control of water level is crucial to mitigating floods, and to properly enable irrigation. These are a few direct applications of the concept. Our model is relatively cheap and simple to make with the circuit design we have implemented and can be widely adapted and used for any application involving water level control. It has scope of improvement and upgrade in its design to suit more efficient usage requirements or more large-scale usage requirements.

2. INTRODUCTION

We can build an automatic water level indicator and controller relatively easily. The circuit required will increase in complexity as we increase the functions required to be performed. It will require a few Bipolar Junction Transistors along with LEDs to indicate thresholds. It can be built in a quickly and easily. In this circuit we've incorporated BJT with specification of BC 547. We use BJT for its well-known property of amplification and switching characteristics.

The control circuit consists of multiple BJTs linked to switches (water level sensors) in their base circuit branches. When the water level reaches the level of the sensor, it conducts current and acts as a closed switch, thereby turning on the transistor and powering an indicator LED. When the water level reaches the maximum threshold level and completes the final switch, the power from the control circuit is diverted into the ground and the relay switch is opened, closing the motor circuit and turning off the motor pump. Likewise, when the water level is drained below the minimum level, a tertiary circuit diverts current back into the motor circuit and turns on the motor pump. This is done with the help of a latch configuration which will be discussed later in the report. This is the basic working of the device, which will be summarised in this report.

The rest of the report is divided into a Literature review, a Methodology comprising the problem statement, components used, hardware and software implementation of the circuit, conclusion, and scope for future development. In the literature review, we have shown a few past attempts in applying the concept of water level control and what we learnt and incorporated into our project from each of these attempts. In our methodology, we have described in detail our attempt at creating and designing this technology with a software implementation, a hardware implementation and the workings of its main component, the Bipolar Junction Transistor. We have also included our thoughts on the future scope and development of this project with which this technology can be taken to greater heights.

3. LITERATURE REVIEW

Automatic Water Level Indicator by Abhishek Singh (Hackatronic)

This is a simple water level indicator made using BJTs (BC547), LEDS, resistors and a buzzer. Powered by a 9v battery, when water level reaches each indicator level, the Base circuit is completed for the transistor on that level, which powers an LED indicating that the level has been reached. When the water level reaches the indicator at the highest level, the final transistor circuit also powers a buzzer which goes off and indicates that water is overflowing. The water level indicator circuit from our design was based on the design given here. It is a 4 sensor setup with depth sensors at 4 levels in the container with the Transistor going into saturation when the circuit is complete and lighting uo LEDs.

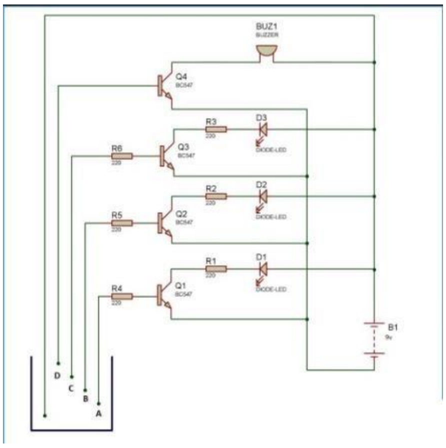

Fig 2.1.1 Circuit Design

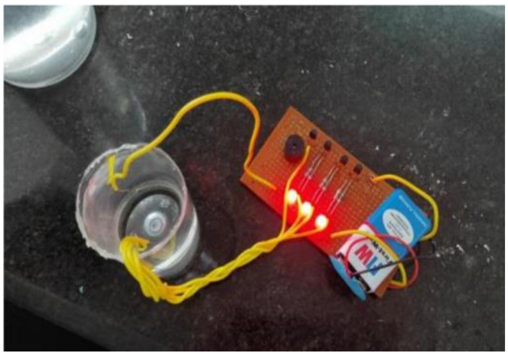

Fig 2.1.2 Physical model

Automatic water level controller using BJT and Relay – (Electronics Area)

This is one of the simplest designs for a water level controller, with 3 sensors to indicate water level and the use of a relay to actuate the motor. When the water level reaches the lowest level for the first time, the circuit becomes active. After activation, if the level rises past the higher sensor, the transistor goes into saturation opening the NC relay contact, which deactivates the motor. The transistor is then locked in place due to the closing of the NO relay contact. Similarly, when the water level is drained down to the lowest level sensor, the transistor goes into cutoff, the NC relay contact closes and turns on the starter, thereby activating the motor. Effectively, this circuit stops motor action at the highest water level and starts it in the lowest level. However, it involves the usage of AC and requires a bridge rectifier, a starter and an electrolytic capacitor. Since we preferred our project to be used with DC current, we used the idea of relay actuation from this design.

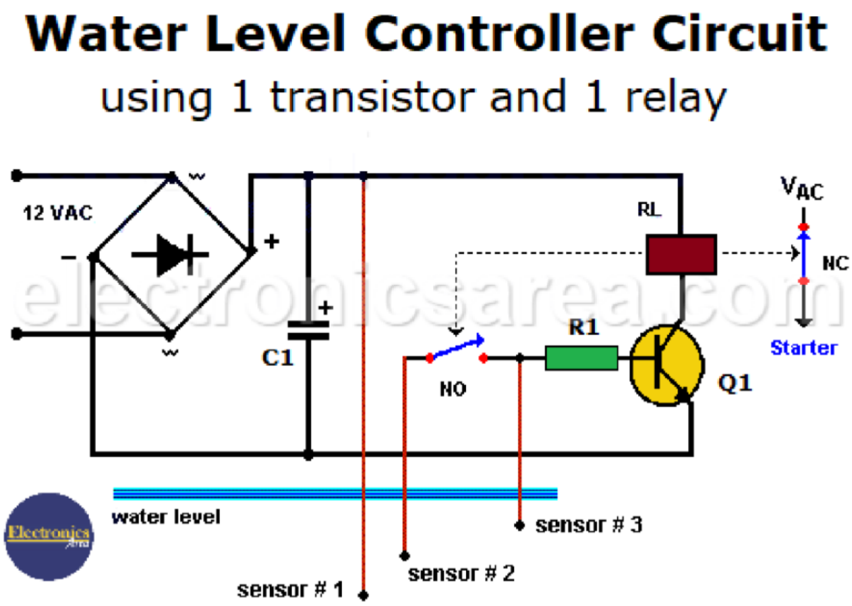

Fig 2.2.1 Circuit Design

Automatic water level controller circuit using IC555 and BJT – (Electronics for you)

The workings of this circuit are similar to the circuit shown in section 2.2, however with one key difference. The Indicator input, source voltage, ground, output connection to the transistor and relay circuit are all centrally connected to the 555 IC, which serves as the brain of the circuit, controlling current flow to the various parts of the circuit with change in the water level. While this design helped us further understand the use of relays in a controller circuit and the use of ICs, it involves the use of AC current along with an issue in cost effectiveness (price of the IC shoots the cost up).

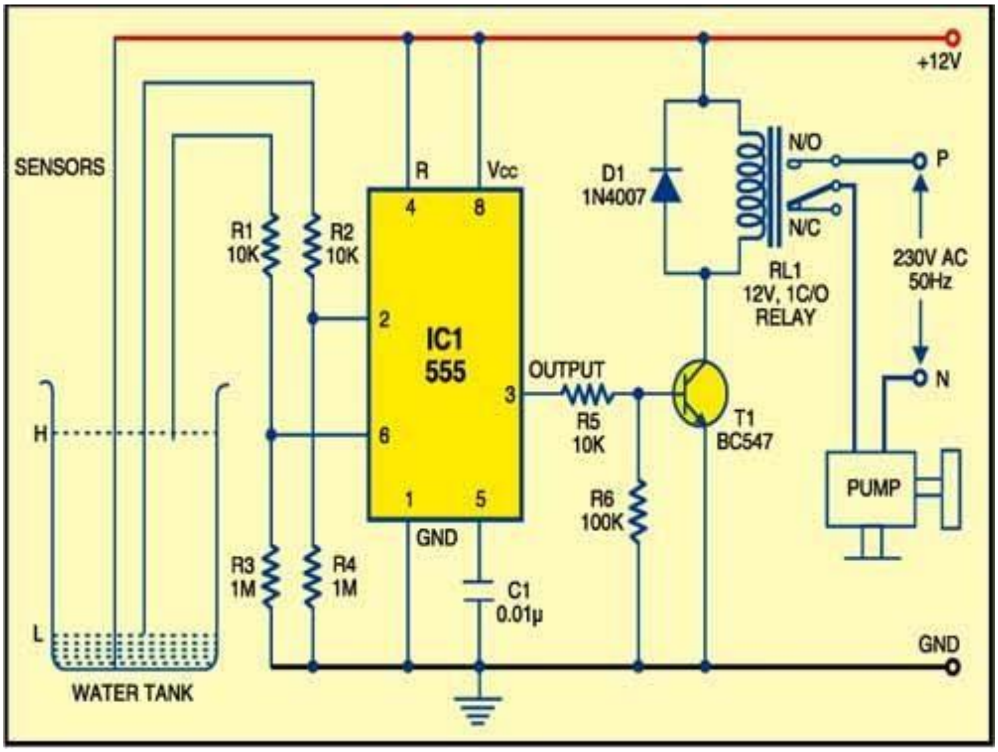

Fig 2.3.1 Circuit Design

4. METHODOLOGY

4.1 THEORY ON PROBLEM STATEMENT

Measure of water flow, also known as Hydrometry, is an established science, dating back many centuries. Ancient Greek Mathematicians measured the flow of rivers. Several other instances of measurement of water levels and river flows can be seen across the ages. In 1831, Henry Palmer designed the first continuous water level recorder (with recording on his paper graph). In the modern age, several methods exist today to measure the level of water in a container and to control it by means of a pump.

The principle behind the concept is simple. Set certain discreet water levels in a container, and if the level of water Is below the lowest level, then pump water into the container and let the level rise. As the level of water reaches the maximum level, stop the pumping action so that the level of water is maintained. Now drain the water slowly. When the water level reaches the lowest level, start the pumping action so that the water level is always maintained between the minimum and maximum levels.

In the project performed here, a control circuit with BJTs determines the pumping action of the motor based on the level of water in the container. The current controlled characteristics of the BJT is used to cut off power supply to the motor circuit when the water level reaches the threshold level, and to deliver current to the motor circuit when water level falls below the minimum threshold. The basic workings of such a circuit, was explained in the introduction.

We pair multiple such transistors in a common emitter configuration to create an indication of multiple set levels in a container which can be indicated using LEDs. This indication circuit is paired with the motor circuit in such a way that LED indication and control of motor action takes place simultaneously. Thus, an automatic water level indicator and controller is created.

4.2 COMPONENTS AND THEIR DESCRIPTION:

Materials Used:

- PCB
- BC547 (NPN)
- BC557 (PNP)
- Resistors (1k ohm, 22k ohm, 100 ohm)
- Relay Module (5v)
- LEDs (Green, Yellow and Red)
- Battery Packs (9v)
- Connecting Wires
- DC Motor (5v)
- Cardboard Cover
- Jumper Cables
- Probe (a stick)

4.2.1 BIPOLAR JUNCTION TRANSISTOR (BC547 and BC107):

A bipolar junction transistor (BJT) is a three-layer semiconductor device that serves as an electronic switch or amplifier in electronic circuits. It is composed of two junctions, hence the name "bipolar," and can be of two types: NPN (negative-positive-negative) or PNP (positive-negative-positive). The three layers of a BJT are doped to create two p-n junctions. The middle layer, called the base, is lightly doped and is sandwiched between the heavily doped emitter and collector layers. The emitter region is either n-type for an NPN transistor or p-type for a PNP transistor, while the collector region is the opposite type. The behaviour of a BJT is controlled by the flow of charge carriers (electrons or holes) through the different regions.

BJTS can be used as an amplifier, filter, rectifier, oscillator, or even a switch**.** The transistor will operate as an amplifier or other linear circuit if the transistor is biased into the linear region. The transistor can be used as a switch, if biased in the saturation and cut-off regions. This allows current to flow or not flow in other parts of the circuit. Because a transistor's collector current is proportionally limited by its base current, it can be used as a sort of **currentcontrolled switch**. A relatively small flow of electrons sent through the base of the transistor can exert control over a much larger flow of electrons through the collector.

Here, in our circuit, BJT is used as a current control device. Why use a

Transistor to Control Current? Two points to note here. First, the fact that when BJT is used in this manner, the switch contacts need to only handle what little base current is necessary to turn the transistor on; the transistor itself handles most of the circuit's current. This may be an important advantage if the switch has a low current rating: a small switch may be used to control a relatively highcurrent load. Second, the current controlling behaviour of the transistor enables us to use something completely different to turn the lamp on or off. Consider the alarm system working using a buzzer, where a battery provides 9 V to overcome the 0.7 V base-emitter voltage of the transistor to cause base current flow, which in turn controls the buzzer.

In our circuit, we use the NPN (BC547) transistors as part of the indicator circuit and in controlling the relay. We use PNP (BC557) transistors as part of the latch circuit used to control the motor by effecting a NOT pulse.

Fig 4.2.1.1 - BJT (BC547) NPN

Fig 4.2.1.2 – BJT (BC557) PNP

3.2.2 RELAY (5V):

A relay is an electrically operated switch. It consists of a set of input terminals for a single or multiple control signals, and a set of operating contact terminals. The switch may have any number of contacts in multiple contact forms, such as make contacts, break contacts, or combinations thereof. Relays are used where it is necessary to control a circuit by an independent low-power signal, or where several circuits must be controlled by one signal.

Relays were first used in long-distance telegraph circuits as signal repeaters: they refresh the signal coming in from one circuit by transmitting it on another circuit. Relays were used extensively in telephone exchanges and early computers to perform logical operations. The Relay has 2 contacts which control its operation, the NO (Normally Open) and NC (Normally Closed) contacts.

Fig 4.2.2.1 - 5V Relay

4.2.3 LIGHT EMITTING DIODE (LED):

It is a semiconductor device that emits light when an electric current passes through it in the forward direction. The basic structure of an LED consists of a semiconductor material, typically composed of gallium arsenide (GaAs), gallium phosphide (Ga P), or gallium nitride (Ga N), with specific impurities added to create either p-type or n-type regions. The interface between these regions forms a p-n junction. When a forward voltage is applied to the LED, electrons from the n-type region and holes from the p-type region recombine at the junction. This recombination process releases energy in the form of photons, producing light. The colour of the emitted light depends on the bandgap energy of the semiconductor material, which is determined by its composition. We use red, green and yellow LEDs in our circuit design.

Fig 4.2.3.1 - LED

4.2.4 RESISTOR:

A resistor is a passive electronic component that restricts the flow of electric current in a circuit. It is designed to have a specific resistance value, measured in ohms (Ω), and is typically represented by a zigzag line symbol in circuit diagrams. The primary function of a resistor is to create a voltage drop or to limit the amount of current flowing through a circuit. When an electric current passes through a resistor, it experiences resistance, which causes a reduction in the current flow. The resistance value of a resistor is indicated by color-coded bands or alphanumeric codes printed on its body. The color bands or codes provide information about the resistor's resistance, tolerance, and sometimes its temperature coefficient.

Fig 4.2.4.1 - 1k ohm resistor

Fig 4.2.4.2 - 22k ohm Resistor

Fig 4.2.4.3 – 100 ohm resistor

4.2.5 MOTOR (DC - 5V):

A DC motor is any of a class of rotary electrical motors that converts direct current (DC) electrical energy into mechanical energy. The most common types rely on the forces produced by induced magnetic fields due to flowing current in the coil. The flow of current in the armature coil in the presence of a magnetic field causes the armature and the shaft to rotate and produce a torque. This torque can be used to give a mechanical output. In our circuit, the motor is used to simulate pumping action of water into the required container.

Fig 4.2.5.1 - 5V DC Motor

4.2.6 BATTERY (9V):

A battery can be defined as an electrochemical device (consisting of one or more electrochemical cells) that can be charged with an electric current and discharged whenever required. Batteries are usually devices that are made up of multiple electrochemical cells that are connected to external inputs and outputs. Depending on the source voltage, the size of the battery may vary. We use a battery here to give source voltage to our circuit design in order to push the transistors into saturation when needed.

Fig 4.2.6.1 - 9V Battery

4.2.7 CONNECTING WIRES:

Connecting wires, also known as electrical wires or conductors, are essential components in electrical and electronic systems that enable the flow of electric current between various components, devices, and circuits. They serve as pathways for the transmission of electrical signals and power. They are used throughout our circuit design.

Fig 4.2.7.1 - Connecting Wires

4.3 SOFTWARE IMPLEMENTATION:

The circuit was simulated using the software, Falstad. This is a digital circuit simulator applet. It a free to use web applet that can simulate most widely used circuit components, and displays the signal outputs across each element in any circuit that is created in it. One can use it to create circuits ranging from the most simple to the most complex circuits.

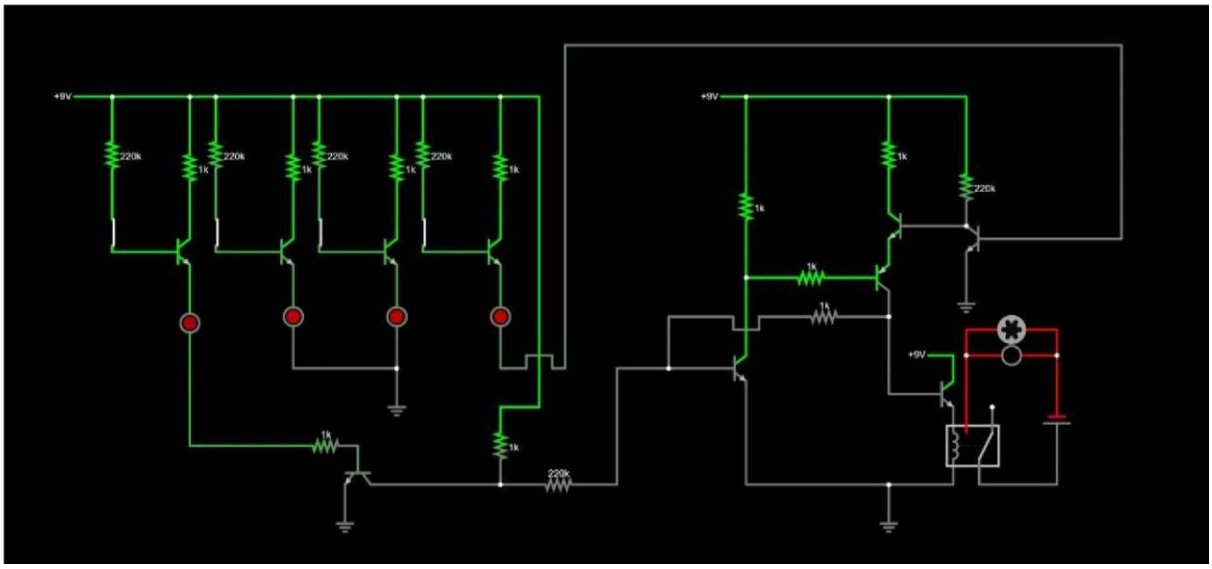

Fig 4.3.1 - Proposed Software simulation of the circuit

Parts of the Circuit:

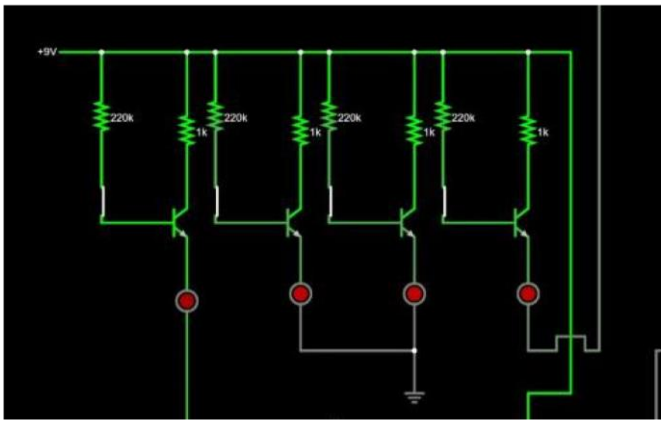

Fig 4.3.2 - The Indicator circuit / Control Circuit

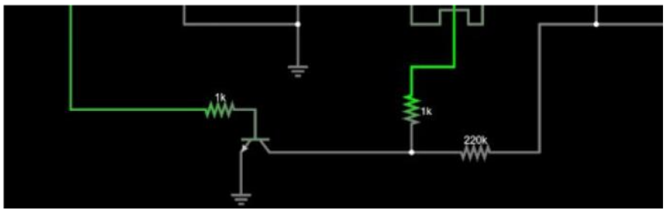

Fig 4.3.3 – The Motor Start circuit

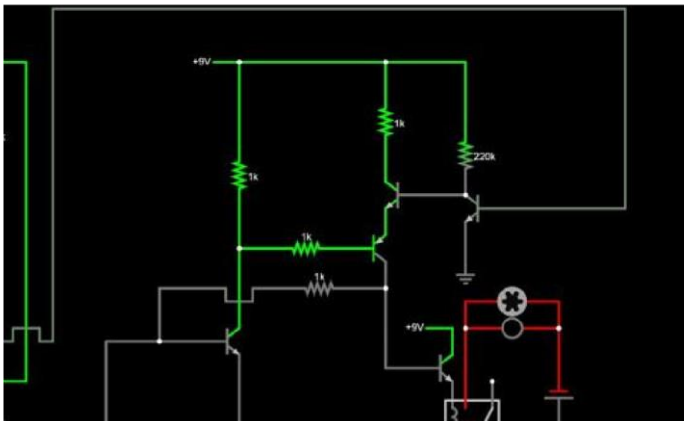

Fig 4.3.4 – The Motor Stop Circuit

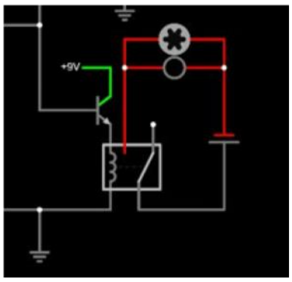

Fig 4.3.5 – The Motor Circuit

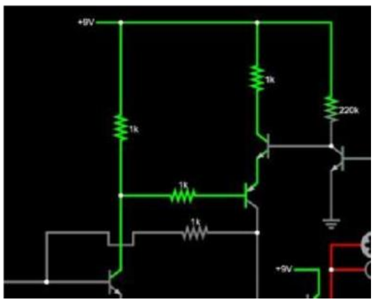

Fig 4.3.6 – Latch Configuration using NOT gate **Working:**

The above circuit is the most accurate simulation of our working circuit. It consists of 4 main sub-circuits, the transistor circuit which detects water levels and indicates it using LEDS, the motor start and stop circuits connected to the first emitter output and the last emitter output which enact the working of the motor. The Motor start and stop circuits are governed by a latch configuration which effects a NOT pulse to the motor circuit when it is required to be deactivated.

When the water level is at the lowest level, the motor is running due to relay action and the water level keeps rising. When it rises past the second and third level, the indicator LEDs turn on showing that these respective levels have been reached. When the water level reaches the final indicator level, the LED turns on and current flows through the motor stop circuit. The Motor Stop circuit which is actuated by the latch circuit shown, which upon activation by flow of current, reduces the amount of current flowing to the relay from the transistor circuit and stops relay and motor action. Thus, the water level remains at the highest level until drained.

Upon draining, the water level reduces past the 3rd and 2nd indicator levels respectively and the LEDs turn off. When water reaches the lower threshold level, the first LED turns off and current stops flowing into the Motor Start circuit, which in turn causes the latch configuration to send sufficient current into the relay and start motor action and begin pumping water into the container.

So, effectively, the water level will always be between the lowest and highest indicator level in the container. Thus, the working of the circuit is simulated and the hardware model can be implemented.

4.4 HARDWARE IMPLEMENTATION OF THE GIVEN CIRCUIT:

4.4.1 First Implementation:

The circuit was first created and tested using a bread board using 2-way switches as indicators. When the switches turned on, it was the equivalent of the water level reaching that corresponding indicator level. This way, we could simulate a container filling up or being drained. The required output was obtained using an earlier iteration of the designed circuit.

4.4.2 Final Implementation:

The circuit was created as per the simulation shown above (after simplifying the latch configuration and the motor start and stop circuits – this could not be done in the simulation due to software limitations) and displayed the required output. A temporary cardboard cover was used to shield the circuit and a probe, made using jumper cables and a stick or rod, was used as a water level indicator unit that can be inserted in any water container, to simulate rise and fall of water level. When it was dipped slowly into the water in the container, it effectively meant that the water level was rising in the container and the LEDs turned on in succession. When the probe was raised slowly, it effectively meant that the water level was falling and the LEDs turned off in succession. When the highest level in the probe was reached while dipping, the motor turned off, and when the lowest level was reached while raising, the motor turned on, thus giving the required output.

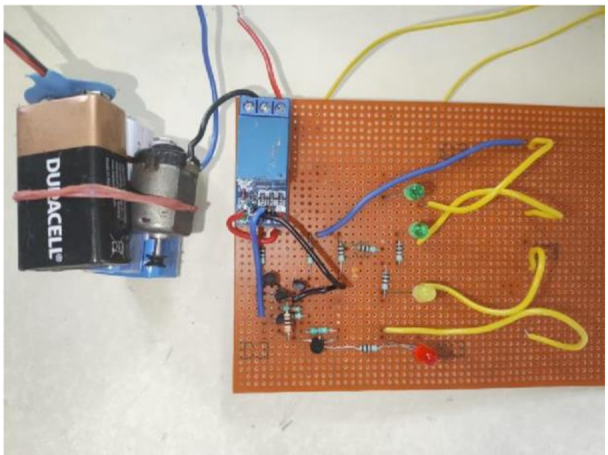

Fig 4.4.2.1 – Circuit with battery connected

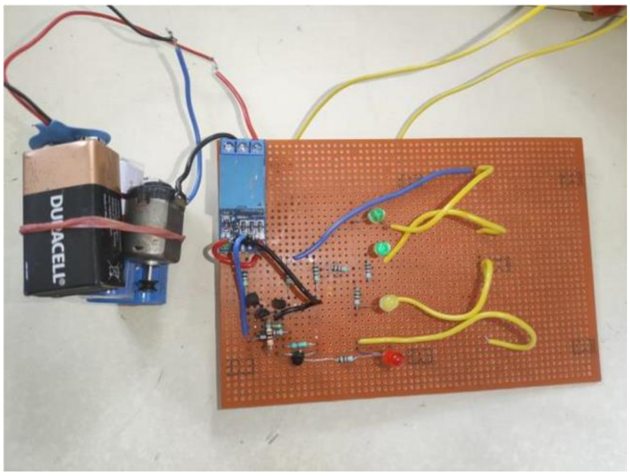

Fig 4.4.2.2 – Circuit with source wiring

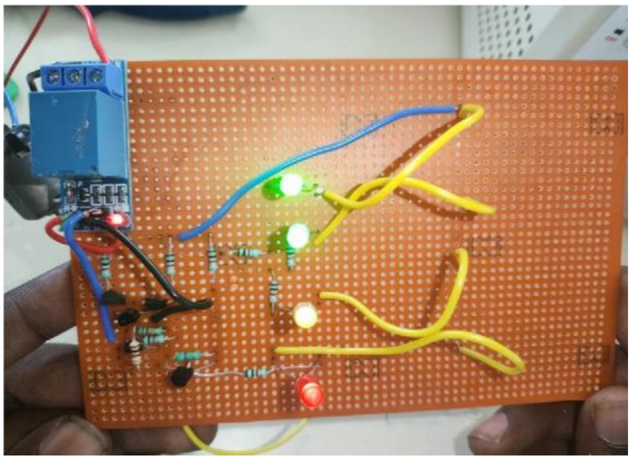

Fig 4.4.2.3 – LED Indication

4.4.3 Working Circuit:

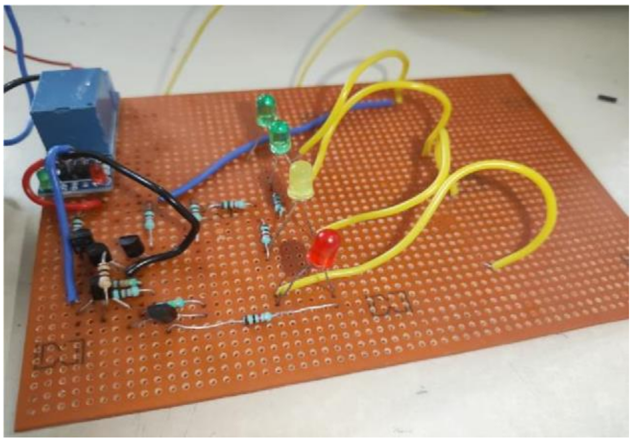

Fig 4.4.3.1 – The complete circuit

4.4.4 Working principle of the proposed circuit (BJT):

A Bipolar Junction Transistor (BJT) can be used as an electronic switch in digital circuits. It can operate in two distinct modes: cutoff and saturation. Let's explore the working principle of a BJT switch in both these modes:

1. Cutoff Mode:

In cutoff mode, the transistor is effectively turned off, and no current flows between the collector and emitter terminals. The base-emitter junction is reverse-biased, preventing the flow of current. To achieve cutoff mode, the voltage at the base terminal (Vbe) must be below the threshold voltage (Vth).

2. Saturation Mode:

In saturation mode, the transistor is fully turned on, and current can flow freely between the collector and emitter terminals. The base-emitter junction is forward-biased, allowing current to flow from the base terminal to the emitter terminal.

To achieve saturation mode, the voltage at the base terminal (Vbe) must be above the threshold voltage (Vth).

To use a BJT as a switch, we typically employ a common-emitter configuration. Here's a step-by-step explanation of how it works:

1. Cutoff State:

- Initially, no current flows through the transistor.
- The base-emitter junction is reverse-biased (Vbe < Vth), and the transistor is in the cutoff region.
- The collector-emitter path acts as an open circuit.

2. Saturation State:

- To turn the transistor on, we apply a sufficient voltage across the baseemitter junction (Vbe > Vth).
- This forward-biases the base-emitter junction, allowing current to flow from the base terminal to the emitter terminal.
- The flowing base current triggers a larger current flow between the collector and emitter terminals.
- The collector-emitter path acts as a closed circuit with a low resistance.
- The transistor is now in the saturation region, and a high output voltage can be observed across the collector-emitter terminals.

To summarize, when the base-emitter voltage exceeds the threshold voltage, the BJT turns on, allowing a current to flow through the collector-emitter path. This behaviour is analogous to closing a switch, allowing current to pass through.

5. RESULT

S.NO	CONDITION	RESULT	OBSERVATION
1	Water level is kept at minimum level	1st LED starts glowing, Motor Starts	Controller is activated Pumping Action Starts
2	Water level reaches 2nd level	2nd LED starts glowing	Water level has risen
3	Water level reaches 3 rd level	3rd LED starts glowing	Water level has risen further
4	Water level reaches maximum level	4th LED starts glowing, Motor Stops	Water level has reached limit, Pumping Action stops
5	Water level starts to be drained	4th LED stops glowing	Water level is falling
6	Water level falls to 3 rd level	3rd LED stops glowing	Water level has fallen
7	Water level falls to 2 nd level	2nd LED stops glowing	Water level has fallen further
8	Water level falls to minimum level	1st LED stops glowing, Motor Starts, LED starts glowing again	Water level has fallen to minimum level

6. CONCLUSION

Hence, a cheap, effective and efficient circuit has been created which can be easily replicated with the implemented circuit and design and can be adapted to a wide range of containers for effective use. The advantages of this circuit are its cheap to create with a production cost of less than Rs 350 per unit, and very straightforward to operate. The circuit has many applications in RO water purifiers and larger scale applications which can be realised by further working on the circuit and instituting upgrades. This project was completed in 2 months as part of the course work, with the first implementation taking 3 weeks to configure, and the final model and report created throughout the rest of the duration of the project. The final model was tested and produced the desired output as predicted by the software simulation. Finally, the model and the report were verified by the faculty-in-charge, and the project was recognised.

This project helped us learn the fundamentals of using BJT as a current controlled switch and in using common emitter configuration to detect inputs. We also learnt how to use relays in a circuit and learnt the Latch configuration which helped in controlling motor action in the circuit. Overall, we learnt how to build a product from idea to final implementation and document it in a proper manner. These learning outcomes have helped us further our skills in the field and will enable us to become better engineers.

7. FUTURE WORK AND DEVELOPMENT

Future of BJT:

The future of BJT is influenced by advancements in semiconductor technology and the increasing dominance of other transistor technologies, such as MOSFETs (Metal-Oxide Semiconductor Field-Effect Transistors). At Research and Development: Research efforts continue to explore new materials, device structures, and fabrication techniques to enhance the performance and characteristics of BJTs. These efforts aim to improve parameters like speed, power efficiency, and reliability.

Future work and Development of circuit proposed:

The probe made of jumper cables and the rod can be upgraded and expanded to fit a container of any size instead of one size only. The motor and circuit can be upgraded for operation on a larger scale. The number of indicators and transistors can be increased or decreased according to need. This circuit can be used in RO water purifiers, water heaters, swimming pools (using detectors instead of wire endings for safety) and even in reservoirs as mentioned in the scope by switching to power electronics and implementing proper hydro engineering. We can further involve the use of AC circuits and components to make simpler and more effective circuits performing the same functionality. Components like bridge rectifiers, capacitors, voltage regulators etc can be used to enhance the circuit for related usage scenarios.

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