



Construction of an Automatic Water Level Controller with Pump Automation

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Abstract – Manual switching of domestic water pumps routinely leads to tank overflow, wasted water and electricity, and pumps left running dry. This study presents the design and construction of a low-cost automatic water level controller that starts a pump when an overhead tank reaches its low level and stops it when the tank is full, without human intervention. The system is built from five functional blocks: a linear power supply, a water level sensing unit, a control unit, an LED level display, and a relay-based pump drive. The power supply steps 240 V AC down through a center-tapped transformer, rectifies it with a 1N4007 bridge, smooths it with a 1000 μ F capacitor, and regulates it with LM78xx regulators; a 6 V battery and change-over relay provide backup. Conductive probes placed at low, middle, and high levels in the tank switch BC547 transistors, whose outputs set and reset an NE555 timer operated in bistable (flip-flop) mode. The NE555 output drives a BD139 transistor and a 12 V relay that switches the pump, while LEDs show the current water level. The circuit was simulated, tested on a breadboard, soldered on a Vero board, cased, and tested with a simulated overhead tank (bucket) and provision for a well-level indicator. The prototype switched the pump on at the low level and off at the full level as designed and was built for a total component cost of ₦47,850. The design is suitable for residential tanks driven by small pumps and can be extended with a microcontroller, ultrasonic, and IoT-based monitoring.

Keywords: Level Sensing, NE555 Bistable Multivibrator, Pump Automation, Relay, Water Conservation, Water Level Controller.

1. Introduction

The sustainability of available water resources is a dominant issue in many parts of the world. This problem is closely linked to poor water allocation, inefficient use, and the lack of adequate integrated water management (Sreeja & Rajamanickam, 2015). Water is used for agriculture, industry, and domestic consumption; therefore, efficient use and monitoring are important constraints on home and office water systems. The common method of level control in homes is to start the feed pump at a low level and let it run until a higher level is reached in the tank. This is done manually and depends on someone remembering to switch off the pump. If they forget, the tank overflows, water and electricity are wasted, and the pump is overworked; when the source runs dry, the pump may run without water and be damaged.

An automatic water-level controller eliminates this dependence on the user. It monitors the level in the overhead tank, refills it when the level reaches a lower threshold, and switches off the pump at the upper threshold. This ensures that water is available around the clock, while saving time, energy, and water, and extending pump life. The same principle is used to monitor the liquid levels in reservoirs and silos.

1.1 Problem statement

Users often forget to switch off the pump when the tank is full, resulting in water wastage through overflow. Users may also fail to notice when the tank is empty. A system that monitors the level and automatically switches the pump addresses both of these problems. This study asks: Can a low-cost

discrete-component controller eliminate manual switching while maintaining reliability over repeated fill cycles, and how does its cost and complexity compare to microcontroller-based alternatives?

1.2 Aim and objectives

This study aimed to construct an automatic water level controller with pump automation. The objectives questions are to:

1. Can a discrete NE555-based controller reliably switch a domestic pump on at a low threshold and off at a high threshold without the use of software?
2. Does the conductive probe approach provide sufficient hysteresis to prevent relay chattering?
3. The component cost of the discrete design was lower than that of an equivalent Arduino-based system, and a water level controller that automatically switches a pump on and off was constructed.

1.3 Significance and scope

Automatic control saves energy by turning off the pump when the tank is full and saves water by preventing overflow. The scope was kept deliberately simple to keep the device affordable and easy to maintain: it controls a single pump from three-level probes and shows the level on LEDs, without printers or other complex peripherals. The design is limited to small domestic pumps switched through a 12 V relay and is not intended for industrial pumps.

2. Literature review

Prior automatic water level controllers differ mainly in how they sense the level (conductive probes, float switches, or ultrasonic sensors), what makes the switching decision (discrete logic, a microcontroller, or a PLC), and how they report status (LEDs, buzzers, LCDs, or a phone app).

2.1 Conductive-probe systems

The EWPCLI uses the electrical conductivity of water: metallic probes in the tank feed a microcontroller, which lights LEDs and switches the pump at preset levels, removing the need for manual supervision and extending pump life (Das et al., 2015). Keshinro and Kazeem (2014) built an audible controller that monitors low, medium, and high levels, with LEDs for the first two and a buzzer for a full tank, running on a 9 V battery with NPN transistor switching. Abdullahi et al. (2017) reviewed low-cost conductive indicators for residential, commercial, and laboratory tanks, noting that dissolved minerals make water conductive enough to close sensing circuits.

2.2 Ultrasonic and microcontroller systems

Okhaifoh et al. (2015) used an ultrasonic sensor that converts echo time to a digital level, with a microcontroller lighting LEDs and switching the pump to extend its lifetime. Kehinde et al. (2017) used ultrasonic detection and DC power to eliminate the risk of electrocution, driving pumps of up to 1 HP at a maximum output current of 20 A. Sunmonu et al. (2020) combined a 20 kHz ultrasonic sensor with an Arduino UNO and LCD, and Olabisi et al. (2019) noted that a non-contact sensor avoids contamination from probes and wires. Refni et al. (2018) switched the pump on at 20 % and off at 100 % of the reservoir level using an Arduino Uno and LM016L LCD. Garba (2020) built a contactless ultrasonic controller as a teaching project, and Nigussie and Seid (2019) tested an embedded prototype at the Debre Berhan University for farm use. Similar microprocessor-based designs with LCD or LED status displays were reported by Ejiofor and Onaolapo (2016) and Lambe and Patil (2018), respectively.

2.3 Wireless, IoT and PLC systems

Esiobi and Obiora-Dimson (2019) separated a solar-powered Arduino monitoring unit with an RF transmitter from the pump control unit. Onyan and Okhaifoh (2020) linked an HC-SR04 sensor and Arduino Uno through an ESP8266 Wi-Fi module to a smartphone app, with pump thresholds of 0.09 m and 0.29 m. Al-Rabayah et al. (2016) used a wireless sensor network, Mamun and Hossain (2017) a solar-powered irrigation pump, and Oyediran et al. (2022) a Mitsubishi FX1N-32MR PLC reading float switches through ladder logic. Mane et al. (2021) identified IoT integration, real-time analytics, and solar-powered rural deployment as future directions.

2.4 Summary of related work

Study	Level sensing	Controller	Status display	Note
Oyediran et al. (2022)	Float switches	Mitsubishi FX1N-32MR PLC	LEDs	Industrial ladder-logic control
Mane et al. (2021)	Level sensors	Microcontroller	—	Proposes IoT and solar extensions
Sunmonu et al. (2020)	20 kHz ultrasonic	Arduino UNO	LCD	Household, farm and business use
Onyan & Okhaifoh (2020)	HC-SR04 ultrasonic	Arduino Uno + ESP8266	Android app	Remote control; 0.09 m / 0.29 m thresholds
Garba (2020)	Ultrasonic	Microcontroller	—	Contactless; teaching project
Olabisi et al. (2019)	Ultrasonic	Microcontroller	LCD	Avoids probe contamination
Nigussie & Seid (2019)	Level sensors	Embedded controller	LCD	Tested for farm use
Esiobi & Obiora-Dimson (2019)	Ultrasonic + RF link	Arduino	LCD	Solar-powered monitor
Refni et al. (2018)	Ultrasonic	Arduino Uno	LM016L LCD	Pump on at 20 %, off at 100 %
Kehinde et al. (2017)	Ultrasonic	Microcontroller	LCD / 7-segment	DC drive up to 1 HP, 20 A
Das et al. (2015)	Conductive probes	Microcontroller	LEDs	EWPLCI
Okhaifoh et al. (2015)	Ultrasonic	Microcontroller	LEDs	Controls on/off timing
Keshinro & Kazeem (2014)	Conductive probes	NPN transistors	LEDs + buzzer	9 V battery; three levels
This work	Conductive probes (3 levels)	NE555 bistable + relay	LEDs	Mains with 6 V battery backup

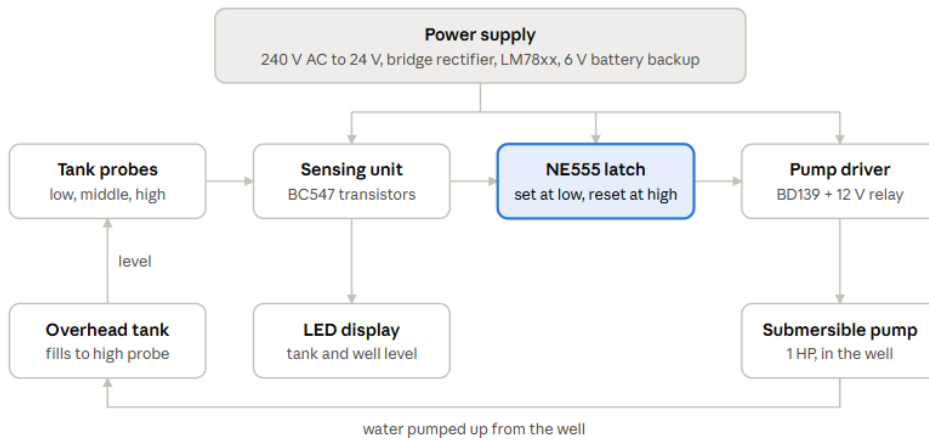
Recent designs rely on microcontrollers for state logic and ultrasonic sensors for contactless measurement, both of which increase cost and complexity. This study returns to conductive probes for simplicity and uses an NE555 bistable multivibrator to provide hysteresis in hardware, eliminating the need for firmware while retaining reliable two-point control. Unlike recent microcontroller-based designs, this study demonstrates that the same binary on/off control can be achieved with a discrete NE555 latch, reducing the cost and eliminating the need for programming, which may lower the barrier to local fabrication and repair. The most recent designs rely on a microcontroller and ultrasonic sensing, which add cost and programming effort. Instead, this study uses discrete, readily available parts — conductive probes, transistors, and an NE555 timer — to deliver the same on/off control at a low cost without firmware.

1. 3. Materials and methods

2. The design hypothesis is that a bistable NE555 timer triggered by conductive probes can provide the same binary on/off control as a microcontroller-based system at a fraction of the cost and without firmware.

3.1 System overview

A modular design approach was used: the system was divided into functional blocks, each a section of the circuit with one job. The blocks are the power supply, level sensing unit, control unit (NE555 timer), display unit (LEDs), and pump drive (transistor and relay). Probes in the overhead tank report the water level, and a separate indicator monitors the underground (well) reservoir so that the pump does not run when the source is empty.



The probes report the level to the sensing unit, which sets or resets the NE555 latch; the latch drives the relay that runs the pump until the tank reaches the high-level probe.

3.2 Power supply unit

The linear power supply steps down 240 V AC to 24 V AC with a center-tapped transformer protected by a 1 A fuse. Four 1N4007 diodes in a bridge rectify this to pulsating DC, which a 1000 μF electrolytic capacitor smooths to a nearly constant voltage. LM78xx three-terminal regulators (input, ground, and output pins) then provide the fixed rails: a 12 V rail for the relay coils and a 9 V rail for the NE555 timer and sensing transistors, with 47 μF capacitors across the regulator outputs to suppress slow variations. A 6 V DC battery, fed through a blocking diode and a change-over relay (RL1), keeps the controller running during mains failure.

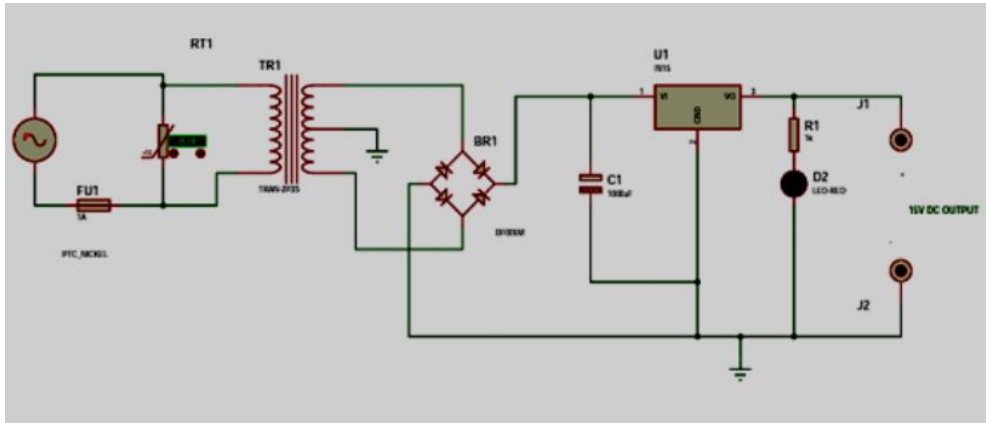


Figure 2. Circuit diagram of power supply unit.

3.3 Level sensing unit

Three conductive probes were fixed at the low, middle, and high levels of the overhead tank, with a common probe at the base. Because dissolved minerals make water conductive, water bridges a probe and the common electrode switches on a BC547 NPN transistor. The transistor outputs drive the level LEDs and pull the NE555 trigger and reset inputs low at the appropriate levels.

3.4 Control unit: NE555 in bistable mode

The NE555 timer was used as a set-reset flip-flop (bistable multivibrator). In this mode, both output states are stable, and no RC timing network is required; thus, the output remains HIGH or LOW until an external signal changes it. This prevents relay chattering as the water surface moves near a probe.

Pin	Name	Function in this design
1	Ground	Connected to 0 V
2	Trigger	Held HIGH by a pull-up resistor; pulled below $V_{cc}/3$ by the low-level sensor, which SETS the flip-flop (output HIGH, pump on)
3	Output	Drives the pump relay through a transistor; sources or sinks up to 200 mA
4	Reset	Held HIGH by a pull-up; pulled LOW by the high-level sensor, which RESETS the flip-flop (output LOW, pump off)
5	Control	Decoupled to ground with a 0.01 μF capacitor against noise
6	Threshold	Tied to ground so the flip-flop can only be reset through pin 4
7	Discharge	Not used in bistable mode
8	Vcc	Connected to the regulated supply

The control logic directly follows these two inputs. When the water level falls below the low probe, the trigger input decreases, the flip-flop sets, and the pump starts. As the tank fills past the middle probe, neither input changes the stored state; therefore, the pump continues to run. When the water reaches the high probe, the reset input decreases, the flip-flop resets, and the pump stops. The pump remains off as the level falls through the middle band until the low probe is uncovered again, which provides hysteresis to the controller.

3.5 Pump drive unit

The NE555 output switches a BD139 transistor that energizes a 12 V single-pole double-throw (SPDT) relay (RL2). The pump is wired to the normally open (NO) and common (COM) contacts, so it runs only while the relay coil is energized. A 1N4007 diode and 100 μ F capacitor were connected across the coil to absorb the reverse voltage produced when its magnetic field collapses, which would otherwise arc and eventually destroy the switching contact. Relays rated at 10 A (change-over) and 40 A (pump outlet) were used.

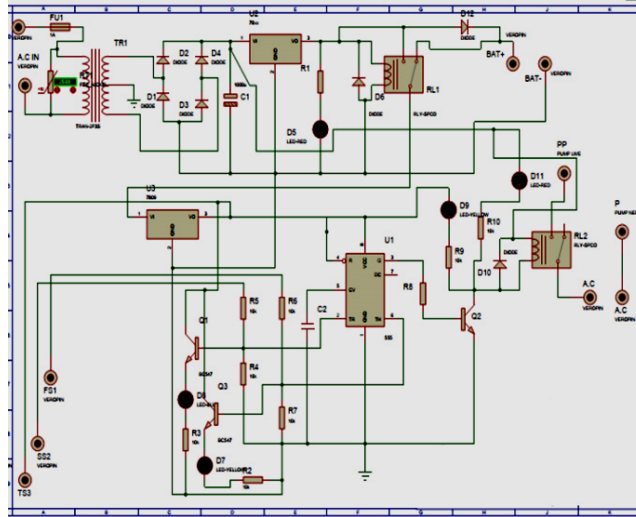


Figure 3. Complete circuit diagram: power supply and change-over relay RL1 (top), probe inputs FS1, SS2, and TS3 with BC547 sensing transistors (left), NE555 latch U1 (center), and pump relay RL2 (right).

3.6 Pumping power

The hydraulic power delivered by the pump to the water is

$$P_0 = \rho g H Q$$

where P_0 is the pump output power (W), ρ is the fluid density (kg/m^3), g is the gravitational acceleration (9.81 m/s^2), H is the head added to the flow (m), and Q is the flow rate (m^3/s). The shaft power required to drive the pump is P_0 divided by the pump efficiency, and pipe-work losses are added to the head that the pump must supply. A 1 HP submersible pump was used in this study.

3.7 Construction procedure

1. The circuit was designed and simulated using a laptop computer.
2. Each component and sub-unit (power supply, NE555 stage, relays) was tested using a digital multimeter before assembly.
3. The circuit was prototyped on a breadboard to confirm its correct operation.

4. The components were transferred to the Vero board and soldered with a 60 W / 220 V soldering iron, taking care not to overheat heat-sensitive parts.
5. The board was screwed to the base of a ventilated casing, with the level indicators visible through its transparent cover, and coupled to the pump, probes, and plumbing.

Tools used were a digital multimeter, laptop computer, precision screwdrivers, a temperature-controlled soldering station, and a bench power supply.

4. Results and discussion

The completed controller switched the pump on when the overhead tank fell to the low probe and off when it reached the high probe, with each sub-unit passing its bench test. Components were first tested individually, then the circuit was proven on a breadboard (Figure 4) before being soldered on a Vero board (Figure 5) and cased (Figure 6).



Figure 4. Prototype testing on breadboard before soldering

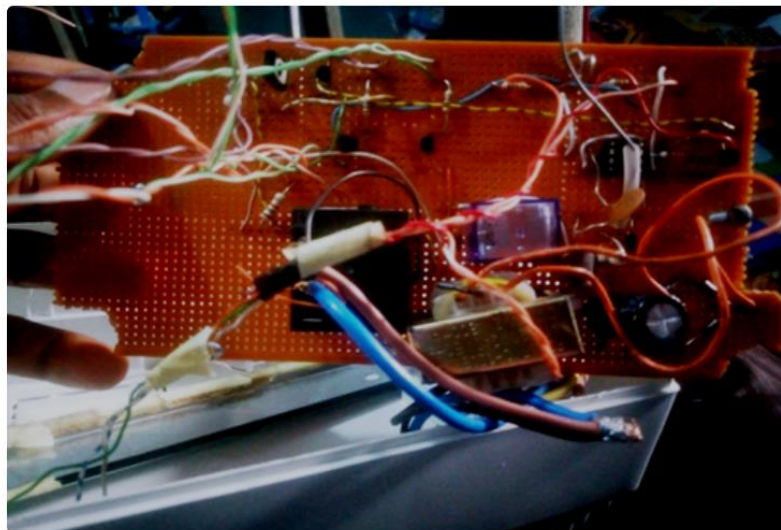


Figure 5. Components soldered on the Vero board.



Figure 6. The controller was completed in its casing, with the level indicators visible through the transparent cover.

4.1 Unit tests

Unit	Test performed	Outcome
Power supply	Component values verified; output rails measured with the DC voltage range of a digital multimeter	Output within the range required by the circuit
Change-over and pump relays (10 A, 40 A)	Switching checked after assembly	Relays switched as designed
NE555 control stage	Supply voltage checked; output at pin 3 measured while operating the trigger and reset inputs	Output latched HIGH on trigger and LOW on reset
Plumbing	Overhead (bucket) tank checked for leaks; hose from lower to upper tank checked for breaks	No leakage found

4.2 System operation

In the full-system test, the probes in the overhead tank detected the changing water level and drove the NE555 inputs. With the tank below the low probe, the latch set, the relay energized, and the pump filled the tank from the well. When the water reached the high probe, the latch reset, and the pump stopped. The system was cycled 20 times over a 48-hour period. All 20 cycles completed without false triggers or relay chatter. Long-term reliability (months of continuous use) was not assessed because the NE555 held its state between the two probes, and the pump did not cycle on and off as the water rose past the middle probe. The LEDs indicated the current level throughout.

4.3 Cost of construction

The prototype cost ₦47,850 in components and transport, of which the 1 HP submersible pump accounted for ₦33,000 (69 %). The controller itself (electronics, casing, and wiring, excluding the pump and transport) cost ₦12,100.

Item	Unit price (₦)	Qty	Amount (₦)
Submersible pump, 1 HP	33,000	1	33,000
Casing	4,500	1	4,500

Transportation	—	—	2,750
3-core flexible cable	350	3	1,050
Step-down transformer (240 V / 24 V)	800	1	800
LEDs	50	12	600
15 A socket	600	1	600
15 A plug	600	1	600
13 A plug	600	1	600
12 V 40 A relay	250	2	500
Soldering lead	250	2	500
6 V DC battery	400	1	400
12 V 10 A relay	150	2	300
Capacitors	50	4	200
BC547 transistors	50	4	200
Relay pin sockets	50	4	200
Vero board	200	1	200
Connecting cable	200	1	200
9 V battery	150	1	150
Voltage regulators	50	3	150
NE555 timers	50	2	100
Resistors	10	10	100
IC sockets	50	2	100
BD139 transistor	50	1	50
Total			47,850

Buckets used as overhead and well tanks, plumbing materials, and miscellaneous items were not priced.

4.4 Discussion

An Arduino Uno retails for approximately ₦10,000 in Nigeria, whereas the NE555 and supporting transistors cost ₦6,500, a 30% reduction. The discrete design also eliminates the need for a USB programmer and IDE software, which may be barriers in resource-limited settings. The results confirm that a discrete NE555 latch provides the same on/off control as the microcontroller-based designs reviewed in Section 2 (Okhaifoh et al., 2015; Sunmonu et al., 2020) without firmware or programming tools. The bistable latch provides hysteresis in hardware, which addresses the repeated switching problem noted in float-type systems (Refni et al., 2018). The battery-backed changeover relay keeps the controller alive during mains failure, which is a drawback of automatic systems identified in the literature.

This design has some limitations. The prototype was tested under controlled laboratory conditions with clean water in buckets. Field deployment may introduce additional failure modes (e.g., probe fouling from algae or sediment, relay contact wear from voltage transients) that were not evaluated in this study. Conductive probes come into contact with the water and can corrode or foul over time, which ultrasonic sensing avoids (Olabisi et al., 2019). The controller shows the level only on LEDs and offers no remote monitoring, unlike Wi-Fi and app-based systems (Onyan & Okhaifoh, 2020). It is sized for domestic pumps and is not suitable for industrial installations.

5. Conclusion and recommendations

An automatic water-level controller with pump automation was designed, built, and tested. It starts the pump when the overhead tank reaches a low level and stops it when the tank is full, eliminating the

need for manual switching and preventing overflow. The design uses conductive probes, BC547 sensing transistors, an NE555 timer in bistable mode, and a relay-driven 1 HP submersible pump, with a battery backup for the controller. Commercial float-switch controllers in the local market range from ₦20,000 to ₦30,000; the discrete-component design presented here falls below this range. The prototype performed as designed and was built for ₦47,850, of which ₦12,100 was the controller itself, making it affordable for domestic use.

The following improvements are recommended for future work.

- The conductive probes were replaced with ultrasonic or stainless-steel sensors to reduce corrosion and contamination.
- Add a microcontroller with an LCD or seven-segment display to show the level as a percentage and log the pump run time.
- Dry-run protection that inhibits the pump when the well level is too low is added.
- Wi-Fi or GSM connectivity was added for remote monitoring and control.
- Power the system from a solar panel for rural sites without a reliable mains supply

More broadly, the local production of basic electronic components and practical electronics research centers in polytechnics would make projects of this kind cheaper to build and strengthen students' practical skills.

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