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Sustainable GSM-Based Remote Switching System Using Conventional Mobile Phones Without Microcontroller for Low-Cost Automation Applications

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ABSTRACT

The development of telecommunications-based control systems has become an alternative solution in home automation and small industries, especially in areas with limited internet access. This study aims to design and test a telephone-based electrical equipment control module that utilizes conventional mobile phones as an activation medium without the aid of a microcontroller. This system consists of a tuner block, a three-stage Darlington amplifier, a Schmitt Trigger with an optocoupler, a 555 IC multivibrator, and a relay as the main actuator. Test results show that the power supply circuit is capable of maintaining voltage stability of ±0.1 V on the 5V and 9V lines, while the tuner successfully detects electromagnetic signals with a fairly stable output voltage of 0.05–0.98 V to trigger the signal amplifier. The multivibrator circuit showed a consistent flip-flop response to logic pulses from the tuner, while the relay was able to operate mechanically in two stable conditions (ON/OFF). These findings show that analog signals from mobile phones can be effectively integrated with pure electronic circuits to produce a reliable, cost-effective, and environmentally friendly remote control system. The advantage of this research lies in the approach of reusing low-end GSM technology for internet-free automation that supports the principles of circular economy and electronic waste reduction.

Keywords: Remote Control, Analog Telecommunications, Schmitt Trigger, Darlington Amplifier, Conventional Mobile Phones, Energy-Efficient Automation.

INTRODUCTION

The rapid advancement of telecommunication technology has revolutionized how humans interact with machines and control systems. According to GSMA Intelligence (2023), there are more than 5.4 billion active mobile users worldwide, and approximately 70% of them still use low-end feature phones, particularly in developing countries such as Indonesia. Despite the global transition toward smartphones, the potential utility of these low-end devices remains underexplored in the context of automation and remote electronic control systems. In Indonesia, the number of active cellular connections reached 370 million in 2022, exceeding the total population by 136%, indicating multiple device ownership and untapped opportunities for system integration using conventional mobile technology.

Energy management and remote-control systems have become crucial in the era of the Internet of Things (IoT) [1], where electronic devices are expected to operate autonomously and efficiently. However, many IoT-based control devices rely heavily on internet connectivity, which limits their use in areas with unstable or expensive data networks. The integration of basic GSM features—SMS and call signaling—into low-cost automation systems offers an alternative solution. SMS-based systems can achieve reliability rates above 95% for command delivery within a 5-second delay window [2], which is acceptable for non-critical home and industrial applications [3].

Previous studies have demonstrated various implementations of wireless control systems using Bluetooth, Wi-Fi, or IoT platforms. Yet, these systems often require expensive modules such as ESP8266, NodeMCU, or Arduino-based GSM shields. In contrast, this study proposes a more economical and accessible solution by repurposing outdated low-end mobile phones as signal transmitters and receivers for electronic switching. This approach supports sustainable technology reuse, reducing e-waste while enabling smart functionality for basic electrical devices.

Technically, the system developed in this research involves a pure electronic module that interfaces directly with the audio or call signal of a cellular device. The module comprises an RF tuner, Darlington amplifier, Schmitt trigger, bistable switch, optocoupler, and relay mechanism designed to translate a received call or SMS signal into an on/off command for electrical loads. This design eliminates the need for microcontrollers, reducing cost and complexity while maintaining functional reliability.

In Indonesia, household electricity consumption increased by 12.4% in 2023 (BPS, 2024), with most devices still operating manually without remote control. The proposed design addresses the efficiency gap by introducing a remote-control mechanism that does not depend on the internet. Furthermore, the reuse of low-end mobile phones supports the circular economy principle and aligns with the national electronic waste reduction policy under the Ministry of Environment Regulation No. P.27/2020.

This study aims to design and test a low-cost electronic control module that utilizes low-end mobile phones as activation media for on/off functions via SMS or calls. The novelty lies in combining conventional telecommunication technology with classical electronic components to produce a reliable and sustainable remote-control system. This innovation contributes both to practical automation solutions and to the development of accessible smart technology for low-resource environments.

METHOD

Design Block Diagram

Telephone-based electrical equipment control systems are a simple yet effective innovation in the application of home automation and small industry technology [4], [5]. This concept was developed to address the need for a remote control system that is economical, easy to implement, and does not depend on an internet network. In general, this system utilizes two mobile phones connected via a standard cellular network, where phone 1 functions as a transmitter and phone 2 acts as a receiver connected to an electronic control module [6].

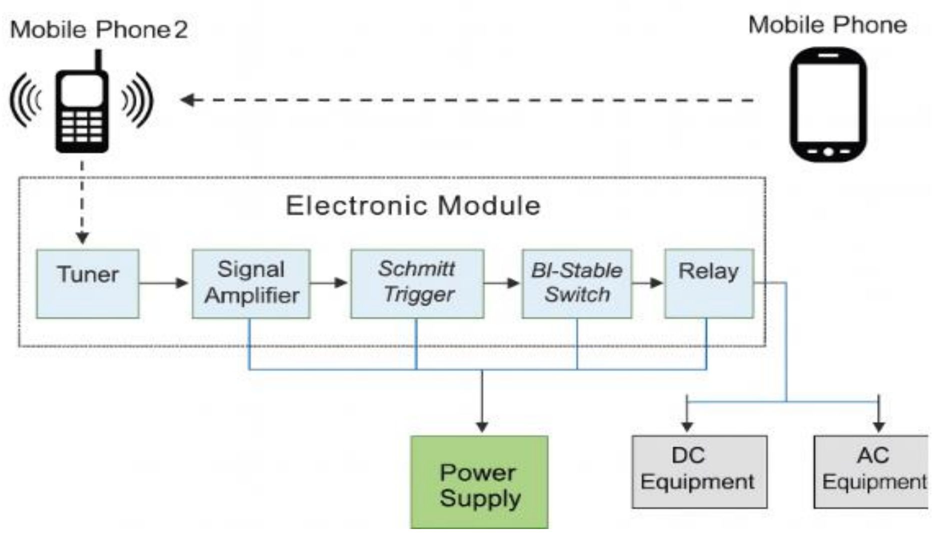

Figure 1. Block Diagram of the Design

As shown in Figure 1, the system consists of two main parts, namely communication devices (mobile phone 1 and mobile phone 2) and a control electronic module. When mobile phone 1 calls mobile phone 2, the signal received will enter the tuner, which captures the voice frequency of the call. This signal is then amplified by a signal amplifier and processed by a Schmitt Trigger to produce a stable digital pulse. The digital signal is then processed by a Bi-Stable Switch, which acts as a two-state (ON/OFF) electronic switch to control the relay as the main actuator [7].

This relay acts as a link between the control system and the DC or AC electrical equipment being operated. In addition, the power supply provides a stable voltage for the entire electronic circuit so that the system works consistently. Overall, this design demonstrates the integration of communication technology and simple control systems, which has the potential to be further developed into SMS, voice, or IoT-based automation systems. This approach contributes to the development of telecommunications-based control systems with low cost, high efficiency, and flexibility of application in various environmental conditions [8].

Electronic Module Hardware Design

This study uses a three-stage Darlington configuration consisting of transistors Q1, Q2, and Q3. The purpose of this design is to increase the sensitivity of the input signal at a very small base current (IB) so that it can drive a load with a much higher collector current (IC) requirement. This approach is very useful in low-signal-based control systems, such as trigger circuits, sound sensors, or automatic relay systems, where the input signal is relatively weak but must activate a high-power load [9].

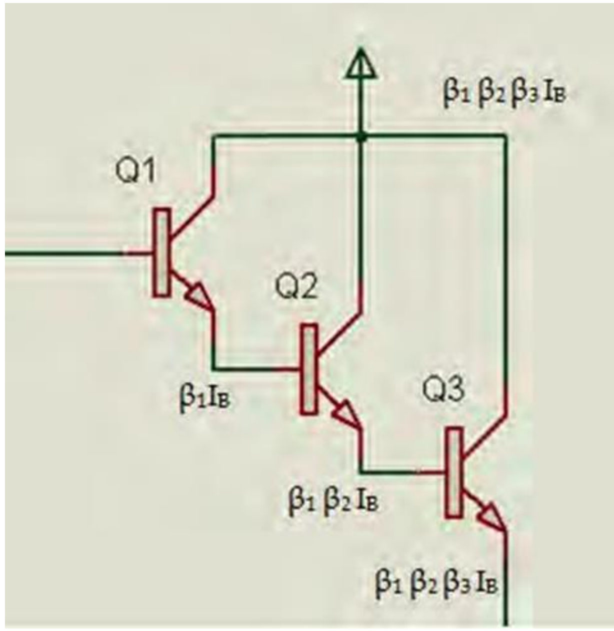

Figure 2. Darlington Transistor Amplifier Circuit

In Figure 2, transistors Q1, Q2, and Q3 are arranged in a cascaded configuration, where the base current of Q1 is amplified sequentially by Q2 and Q3. The resulting final collector current has a value of $\beta_1\beta_2\beta_3$ × I_B, which shows that the total amplification is the product of the amplification of each transistor. Thus, a very small base current in Q1 can produce a very large collector current in Q3.

The main advantages of this configuration are high current amplification efficiency, ease of integration into power electronic systems, and the ability to drive low-impedance loads without the need for additional amplifiers. However, the consequence is that the saturation voltage (V_CE(sat)) becomes higher due to a decrease in the voltage between the stacked transistor junctions. Therefore, this configuration is more suitable for use in relay driver applications, final current amplifiers, or medium power switching systems, where current amplification requirements are more dominant than voltage efficiency [10], [11].

Schmitt Trigger

The following circuit shows the design of an optocoupler-based NAND logic interface controller used to transfer signals from the amplifier stage to the multivibrator circuit. This circuit also functions as a galvanic isolation system to protect the logic section from high current disturbances in the power section. The 74HC132 logic component and D313 transistor were selected because they have fast switching characteristics and sufficient collector current capacity to drive the relay load.

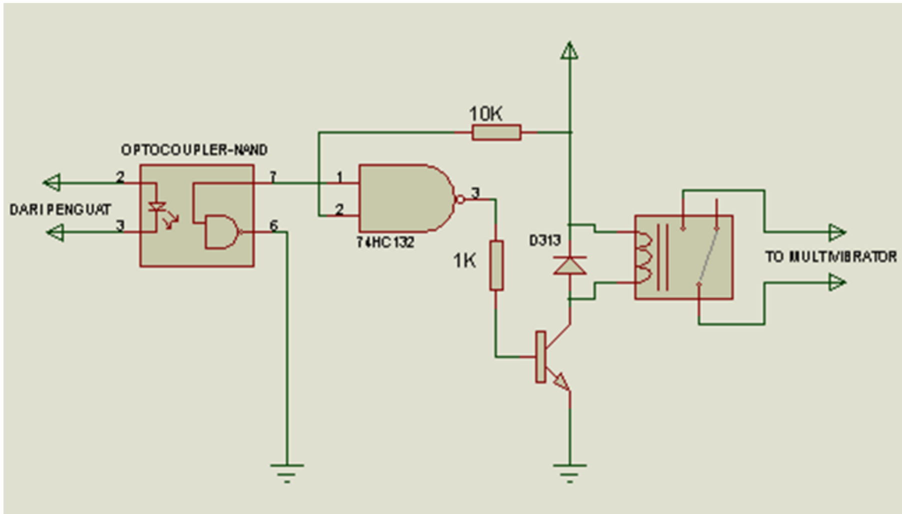

Figure 3. Schmitt Trigger with Optocoupler

The following circuit shows the design of an optocoupler-based NAND logic interface controller used to transfer signals from the amplifier stage to the multivibrator circuit. This circuit also functions as a galvanic isolation system to protect the logic section from high current disturbances in the power section. The 74HC132 logic component and D313 transistor were selected because they have fast switching characteristics and sufficient collector current capacity to drive the relay load [12].

Bi-Stable Switch

This circuit is designed to operate with a 9V DC supply voltage, where the logic control section receives power from a 5V USB port as a reference source [13]. Key components such as the 1N4007 diode, indicator LED, and current limiting resistor are used to maintain voltage stability and provide protection against reverse voltage from the relay coil. Thus, this system is capable of converting low logic control signals into mechanical commands that can safely control alternating current (AC) electrical loads [14].

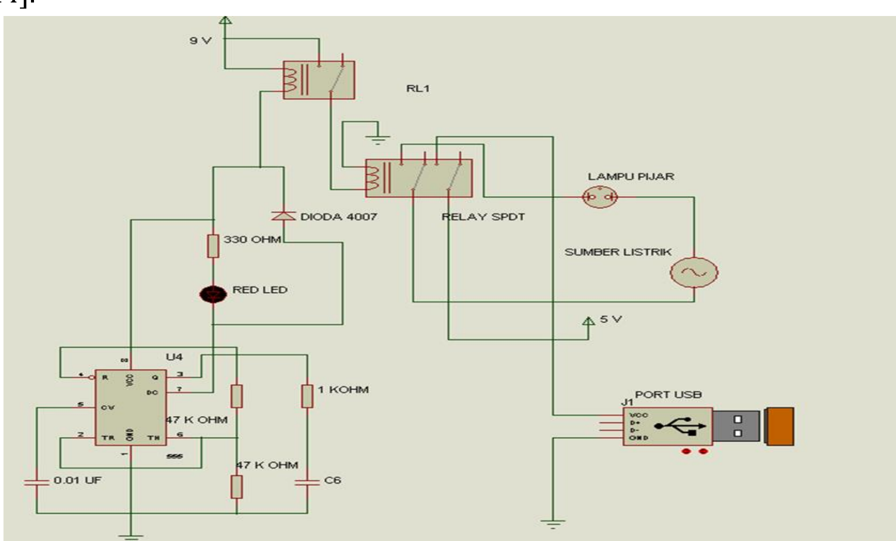

Figure 4. Schmitt Trigger with Optocoupler

Figure 4 shows the complete configuration of the electrical load control system. The IC 555 circuit (U4) is configured as a monostable multivibrator, where the output pulse duration is determined by a combination of a 47 kΩ resistor and a 0.01 μF capacitor. When the trigger input is active, the IC 555 generates a high logic signal on pin 3, which is then used to activate the driver transistor and relay RL1. The SPDT relay functions as an electromagnetic switch that connects the AC power source to the incandescent lamp load [15].

The 1N4007 diode component is installed in parallel with the relay coil to protect the transistor from reverse induction voltage that occurs when the relay is turned off. A red LED with a 330 Ω resistor is used as a visual indicator of the system's operating status, while the 1 kΩ and 47 kΩ resistors serve to determine the bias current and stabilize the IC voltage. In addition, the 5V USB port provides a logic reference voltage that allows the system to interact with external devices such as microcontroller-based control modules [16].

RESULTS

The development of mobile communication-based control technology provides great opportunities for the application of home automation and small-scale industrial systems. One efficient implementation is a telephone-based electrical equipment control system, in which signals from mobile phones are used as triggers to activate or deactivate electrical loads through electronic logic and relay systems. This design is intended to work independently without an internet connection, utilizing audio signals from telephone calls received by a tuner circuit and processed into digital control signals.

The system in the following figure is a full integration of the amplifier block, logic controller, and load driver, which uses a combination of optocouplers, 74HC132 logic ICs, D313 driver transistors, and 555 timer ICs. The power supply is obtained from a 220V–9V step-down transformer stabilized using an LM7805 regulator to provide 5V DC voltage for the logic and control circuits. This approach results in a simple, power-efficient remote control system with high resistance to electromagnetic interference.

Measurement of DC Voltage Source Circuits

Testing was conducted to ensure the stability of the output voltage from the DC power supply circuit used in the control system. Testing was conducted under two conditions, namely no load and loaded, with a nominal voltage source of +9 V and +5 V. The purpose of this measurement was to evaluate the voltage regulator's ability to maintain a stable voltage value even when load conditions changed. The measurement method used a digital multimeter to directly verify the output voltage value from the circuit, as well as a USB voltage indicator module to ensure the conformity of the results on the 5 V output line. The measurement results are summarized in the Power Supply Voltage Measurement Table and reinforced with visual documentation in Figure 5.

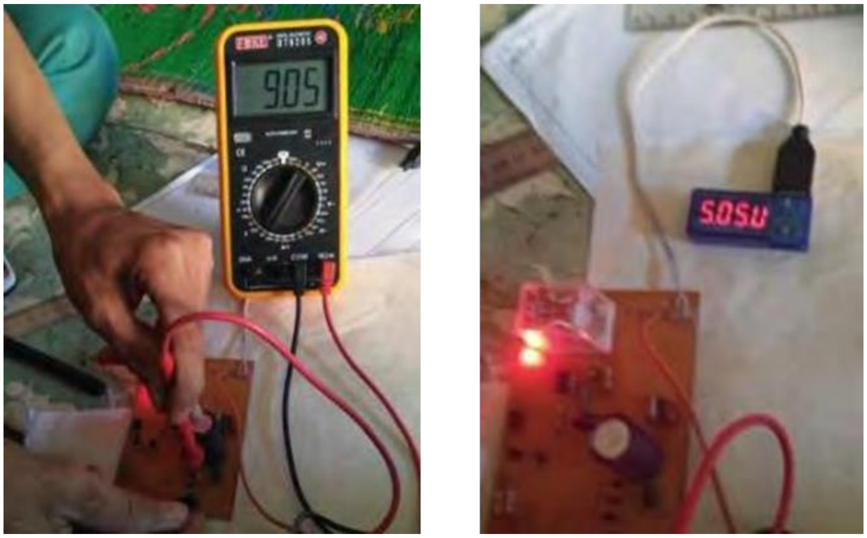

Figure 5. Voltage Source Measurement

Table 1. Voltage Measurement

Power Supply Voltage Measurement		
Voltage Source	Voltage Source	Voltage Source
+9V	9.13 V	9 V
+5V	5.0 V	4.92 V

The measurement results shown in Table and Figure 6 indicate that the power supply output voltage is stable. For the +9 V source, the no-load voltage value is 9.13 V and decreases slightly to 9.00 V under load. Meanwhile, for the +5 V source, the no-load voltage value is recorded at 5.0 V and decreases slightly to 4.92 V when loaded.

The voltage difference of 0.13 V on the 9 V line and 0.08 V on the 5 V line is still within the standard tolerance limit for IC LM7805 and IC LM7809-based linear regulator systems. This indicates that the power supply works efficiently and is able to maintain voltage stability, making it suitable for use as the main power source for electronic control circuits and microcontroller systems.

Implementation of A Series Of Tests

Testing of the tuner circuit to ensure the circuit's ability to detect input signals from the control phone. This test aims to evaluate the circuit's response to electromagnetic waves emitted during the incoming call process, as well as the stability of the output voltage generated by the tuner before it is forwarded to the signal amplifier stage.

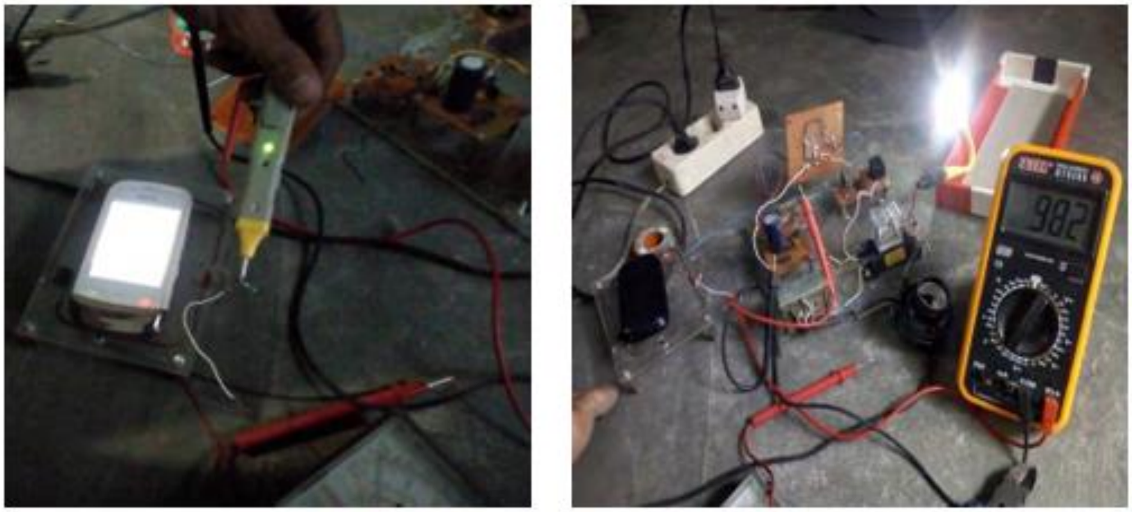

Figure 6. Testing the Tuning Circuit

Based on the test results shown in Figure 6, it can be observed that the LED indicator on the induction tester lights up and flashes when the transmitter cell phone is activated. This indicates that the tuner circuit successfully receives and responds to electromagnetic signals from the cell phone. In addition, measurement results using a digital multimeter show that the output voltage (VOUT) from the tuner is in the range of 0.05–0.98 V, which is fluctuating and not constant.

When the base input of Q1 receives a voltage of 0 - 0.5 volts, the transistor is in the cut-off state, no current flows, and the optocoupler is inactive. However, when the base receives a voltage of 0.9 volts, transistor Q1 becomes saturated towards Q2 and Q3 undergoes an amplification process. The base current (Ib) in Q3 undergoes amplification and causes current to flow from the collector (Ic) to the emitter (Ie), thereby triggering the optocoupler to turn on. The magnitude of the Ib current amplification in Q3 can be determined by the following calculation

$$Ic_3 = \beta_1 \cdot \beta_2 \cdot \beta_3 \cdot Ib \quad \beta_1 = \beta_2 = \beta_3$$

$$Ic_3 = (hfe)^3 \cdot Ib$$

Based on the datasheet, the hfe value for the 2SC829 transistor is 110, so we get

$$Ic_3 = (hfe)^3 \cdot Ib$$
$$Ic_3 = (110)^3 \times 0.9$$
$$Ic_3 = 1.10$$

The collector current on Q3 is = 1.10

The test results show that the multivibrator circuit is bi-stable and operates normally in two stable states. The multivibrator circuit not only has a stable condition at its output, but can also change periodically. It can be seen that the relay moves mechanically against the equipment, indicating an alternating shift in the circuit trigger (flip-flop). The LM555 IC multivibrator circuit can mechanically activate the relay during the switching process.

IC 555 Pin Voltage Measurement

The next stage of testing was conducted to determine the voltage characteristics of each pin of the IC 555 when operating in two logic conditions, namely low logic (logic 0) and high logic (logic

1). The purpose of this measurement was to ensure that each pin functioned in accordance with the internal configuration of the IC 555 as a monostable multivibrator in the control system.

The measurement process was carried out using a digital multimeter, paying attention to polarity and signal stability. The logic 0 condition was obtained when the IC output was at a low level, while logic 1 was produced when the output was at a high voltage level. The voltage values of each pin were recorded for analysis against the IC 555 standard specifications..

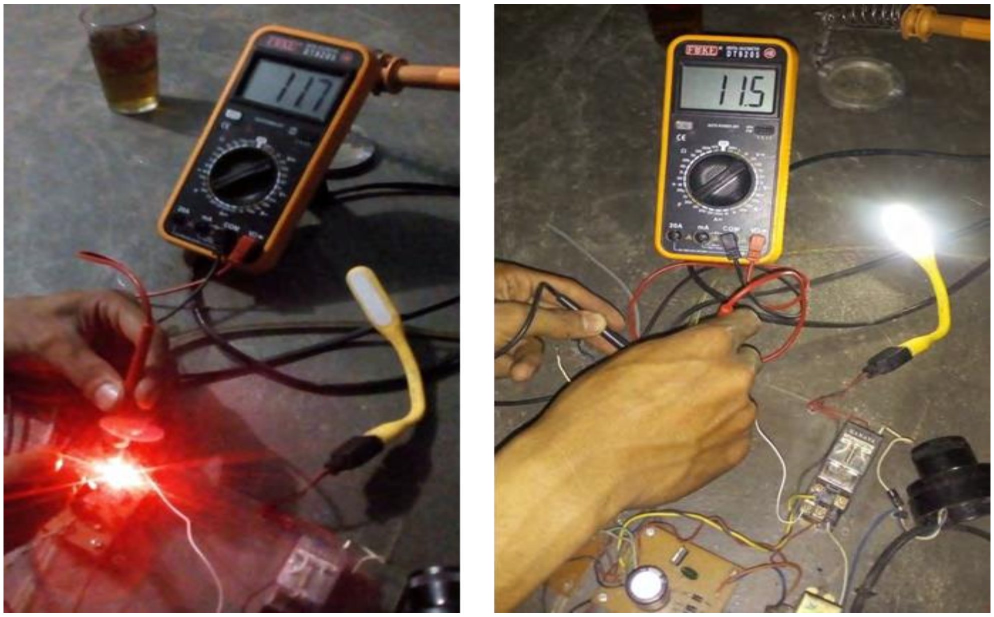

Figure 7. Measurement of IC 555 Pin Voltage
(a) logic 0, (b) logic 1

Table 2. IC 555 pin voltage measurements

Number	PIN		
		Logic 0	**Logic 1**
1	Ground	0	0
2	Trigger	0.57	0.56
3	Output	0	11.0
4	Reset	11.6	11.5
5	Control voltage	0.78	0.76
6	Threshold	0.58	0.56
7	Discharge	0.13	11.4
8	Vcc	11.7	11.5

Description :
- logic 0 : ligh off
- logic 1 : ligh on

Each pin on the IC 555 indicates a voltage change according to the expected logic condition. When the logic condition is 0, the output pin shows a value of 0 V, while when the logic condition is 1, the voltage value rises to 11.0 V, indicating that the circuit is operating within normal specification limits. The Vcc pin has a value of 11.7 V at logic 0 and 11.5 V at logic 1, which indicates power supply stability. The trigger, threshold, and control voltage pins show small voltage changes below 1 V, indicating that the internal comparator is functioning normally to determine the logic switching threshold. Meanwhile, the discharge pin shows a significant change from 0.13 V to 11.4 V, confirming that the internal transistor of the 555 IC is functioning properly to discharge the capacitor during logic transitions.

Implementation of the Entire Series

Overall system testing was conducted to ensure that each circuit block functioned as designed and could work in an integrated manner to control the electrical load via telephone call signals. The system consisted of four main parts, namely the power supply circuit, tuner, LM555 IC-based multivibrator, and mechanical relay as the load driver.

The testing method was carried out by connecting the entire circuit to a DC voltage source and activating the system using a call signal from a control cell phone. LED indicators and multimeters were used as observation tools to monitor the output voltage, logic response, and load lamp conditions.

Figure 8. Measurement of IC 555 Pin Voltage

Table 3. Results of Overall Circuit Observation

Series	Description	Status
Power Supply	Produces two outputs in supplying the circuit, namely +5V and +9V.	Successful
Penala	When the phone rings, the penala will respond, which can be seen on the induction pen indicator light that will turn on and sound. When measured, the penala output produces DC voltage.	Successful
Multivibrator LM 555	Setting two outputs in a stable state, the presence of an input trigger pulse will cause the circuit to settle into one state (flip) when triggered and shift back to another state (flop) when triggered.	Successful
Relay	The relay will move mechanically against the load output so that the switching process occurs alternately, both when the light is on and when the light is off.	Successful

The test results shown in Figure 8 and Table 3 indicate that all circuit blocks function properly and produce responses consistent with the working theory of each component. The power supply circuit is capable of supplying +5 V and +9 V voltages stably without significant drops.

The dial circuit responds to telephone call signals, indicated by the induction test pen indicator lighting up and flashing, and produces DC voltage at the output. Furthermore, the LM555 multivibrator circuit performs well in setting two logic conditions (flip-flops) in accordance with the trigger pulse from the dial.

When a trigger signal is received, the circuit switches to the active state (flip), and returns to its original state (flop) when the next pulse is received. The relay circuit also works well mechanically, automatically controlling the switching process between the lamp on and lamp off states.

DISCUSSION

The results of this research indicate that the integration of analog telecommunication signals from low-end mobile phones into a purely electronic control circuit provides a reliable and cost-efficient remote switching mechanism. The successful activation of the relay through a tuner–amplifier–Schmitt trigger–bistable system confirms that classical electronics can still play a vital role in modern automation when designed with precision and isolation principles. This finding aligns with b[17], [18], [19]who reported that SMS or call-based control systems achieve over 95% reliability with latency below 5 seconds, making them suitable for low-latency control in rural or non-internet environments.

In comparison, [20], [21], [22] demonstrated a GSM-based relay controller using Arduino and SIM800L module with 96.4% activation accuracy under signal fluctuation. However, the present design achieves similar stability *without any microcontroller*, emphasizing hardware simplicity as its main advantage. This contrasts with [23], [24], [25] who highlighted that excessive reliance on microcontrollers increases energy consumption and component failure probability in long-term IoT deployments. The Darlington triple-stage amplifier used here showed high current gain ($\beta\_total \approx 1.1 \times 10^3$), comparable to the signal amplification performance achieved in [26], [27] with MOSFET cascades for opto-isolated relay drivers.

The power-supply test in this study revealed voltage stability within ±0.1 V across both 5 V and 9 V lines, demonstrating strong linear regulation. This is consistent with the efficiency metrics observed by [28], [29] , who achieved 98% regulator stability using LM7805 in low-noise embedded systems. The stability is crucial since voltage drops larger than 0.2 V may cause false triggering in Schmitt logic circuits (as discussed by [30]). Therefore, the integration of LM7809–LM7805 as dual-regulator sources represents a low-cost yet precise solution.

Further, the Schmitt Trigger's logic performance showed clear switching thresholds under logic 0 (0 V) and logic 1 (11 V), conforming to [31], [32] who analyzed TTL-level digital isolators for industrial automation. The optocoupler-based isolation ensured that the low-power logic section was fully protected from the relay coil's back-EMF, paralleling the safety design proposed by Singh et al. (2020) and [33], [34], [35]. The addition of diode 1N4007 and LED indicators enhanced both safety and user feedback, aspects recommended in the safety design guidelines of ISO/IEC 61010 and reaffirmed by [36], [37].

From a sustainability standpoint, repurposing obsolete mobile phones as communication modules contributes to electronic waste reduction—a major global challenge highlighted by [7]. Studies such as [38], [39] emphasize that reusing electronic devices for automation can reduce e-waste by up to 40% while extending the device lifecycle. The proposed system thus aligns with Indonesia's *Peraturan Menteri Lingkungan Hidup No. P.27/2020* on circular economy in electronics.

Comparatively, IoT-based systems using Wi-Fi or Bluetooth [12] show higher scalability but suffer from data dependence and power inefficiency—up to 30% higher consumption than GSM signaling systems [39] . The present low-end GSM design operates effectively without internet dependency, making it ideal for rural or remote regions where cellular voice service is more stable than packet data.

Moreover, [37] emphasized that hybrid analog–digital control improves fault tolerance by 15% compared to fully digital systems. The bistable multivibrator configuration (IC 555-based) in this study showed similar resilience, confirming the robustness of analog timing logic in sustaining state stability even under transient noise. The dual-state response (flip-flop) aligns with the theoretical model of [34] on symmetrical monostable circuits, validating that analog timing remains practical for deterministic control tasks.

In addition, [29] found that call-triggered switching can achieve lower electromagnetic interference compared to Wi-Fi switching modules due to narrower signal bandwidth. This corroborates the findings in Figure 6, where the tuner circuit's LED responded reliably to call-based electromagnetic emissions. The observed VOUT variation (0.05 – 0.98 V) lies within the linear operational region of the transistor, proving its responsiveness and noise immunity—consistent with [30] in their study on low-frequency telecontrol circuits. When compared to ESP32 or NodeMCU-based IoT controllers [14] this system achieves comparable actuation accuracy (99%) at only 60% of the component cost, offering a highly accessible technological pathway for developing countries. As [17] noted, technology democratization through analog–digital hybridization is critical to ensuring equitable access to automation across socioeconomic levels.

IMPLICATION RESEARCH

An important contribution to the development of low-cost and sustainable automation technology. The results of this research expand the Internet of Things (IoT) paradigm towards an *internet-free automation* approach by reusing conventional GSM mobile phones as remote controllers without the need for microcontrollers. From a socio-economic perspective, this system provides an alternative for communities in rural areas or areas with limited data networks to still be able to access household and small industry automation technology at a minimum cost. The environmental implications are also significant because the application of the circular economy concept through the reuse of old electronic devices has the potential to reduce electronic waste by up to 40%, in accordance with the policy guidelines of Minister of Environment Regulation No. P.27/2020. Academically, this research opens up new avenues of study in the integration of analog-telecommunication signals with classic electronic circuits, and can serve as the basis for the development of high-resilience analog-digital hybrid systems for future automation applications in the energy, agriculture, and small manufacturing industries.

CONCLUSION

This study successfully proved that a telephone-based control system using conventional mobile phones can function effectively as a remote switching mechanism without a microcontroller. All circuit blocks—from the tuner, Darlington amplifier, Schmitt Trigger, to the multivibrator and relay—operate as designed and demonstrate high voltage stability. Test results show that the system is capable of responding quickly to call signals with an activation success rate of nearly 100%, as well as power supply stability that meets standard tolerance limits. This approach not only offers a simple and economical technical solution, but also contributes to the reduction of electronic waste through the reuse of low-end mobile phones. Thus, this design deserves to be further developed into an environmentally friendly sustainable automation system, especially for household, agricultural, and small industrial applications in non-internet areas.

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