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Development, Implementation, And Performance Analysis of a One-Channel Infrared Solid-State Remote Switching System

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Abstract- ***This project presents the design and development of a single channel infra-red remote-controlled electrical switching system using a CD4017 Decade Counter Integrated Circuit (IC). The main objective is to remotely control a 220V AC appliance(s) such as TV, FANS, and Lighting systems etc. through an Infra-Red (IR) remote system, ensuring safety, simplicity and low cost. The system consists of three main sections: IR signal reception, signal processing and load switching. The IR receiver module (TSOP1738) detects incoming infra-red signals, typically from TV remote or a custom remove controller. This signal is then amplified by a PNP transistor (9015) and shaped into a clean digital pulse using a Resistor-Capacitor (RC) circuit. The clean pulse is fed into the CD4017IC, a decade counter that advances its output on every received pulse, when activated, the output pin triggers an NPN transistor (9014) which in turn energizes a relay (HK4100F). The relay acts as a switch to control high-voltage AC loads. Additional components, such as a fly back diode (1N4007) and a status LED, protect the circuit and provide visual feedback respectively. The system operates from a regulated +5V DC power supply, isolated from the AC load, ensuring user safety.***

I. INTRODUCTION

The advancement of electronics and wireless communication has transformed the control of electrical devices by enabling remote operation. Traditional manual switches require physical contact, which can be inconvenient, inefficient, and unsafe in some situations. As a result, remote switching systems have become increasingly important in residential, commercial, and industrial applications due to their ability to improve convenience, safety, and energy efficiency. (B. Razavi,et al 2021.)

Infrared (IR) technology is one of the most widely used wireless communication methods for short-range remote control. It operates by transmitting invisible infrared light signals from a transmitter to a receiver, which interprets the signals and performs the desired switching operation. Owing to its low cost, low power consumption, simplicity, and reliability, infrared technology has been extensively used in devices such as televisions, air conditioners, DVD players, and other consumer electronics.

Conventional mechanical switches are prone to contact wear, electrical arcing, and reduced lifespan due to repeated operation. In contrast, solid-state switching devices use semiconductor components to perform switching without moving parts, resulting in faster operation, higher reliability, quieter performance, and lower maintenance requirements. These advantages make solid-state switches suitable for modern electronic control systems.

A one-channel infrared solid-state remote switching system is designed to control a single electrical appliance using an infrared remote transmitter and a receiver circuit. The received infrared signal is processed to activate a solid-state switching device, which turns the connected load ON or OFF. Such systems provide a simple and effective solution for remote appliance control while serving as a foundation for more advanced automation technologies.

Therefore, this study focuses on the development, implementation, and performance analysis of a one-channel infrared solid-state remote switching system. The system is designed to provide reliable remote control of electrical loads while evaluating key performance parameters such as switching response time, operating range, reliability, and power consumption. The outcome of this research is

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expected to contribute to the development of affordable and efficient remote switching systems for home and industrial applications.

Statement of the Problem

The increasing use of electrical appliances in homes, offices, and industries has created a growing need for convenient, reliable, and safe methods of controlling electrical loads. Conventional manual switches require direct physical operation, which can be inconvenient, especially for elderly persons, people with disabilities, or in locations that are difficult or hazardous to access. In addition, frequent operation of mechanical switches can result in contact wear, electrical arcing, and reduced service life.

Although infrared remote-control technology has been widely applied in consumer electronics, its application in low-cost remote switching systems for electrical appliances remains limited in many developing countries due to issues such as cost, design complexity, and inadequate local development. Furthermore, many existing systems lack proper performance evaluation in terms of switching response time, operating range, reliability, and power consumption.

Therefore, there is a need to develop a simple, cost-effective, and reliable one-channel infrared solid-state remote switching system that can remotely control electrical loads with improved switching performance. This study seeks to address these challenges through the design, implementation, and performance analysis of an infrared-based solid-state remote switching system suitable for domestic and small-scale industrial applications.

Objectives of the Study

The specific objectives of this study are to:

i. Design a one-channel infrared solid-state remote switching system using suitable electronic components.
ii. Develop and implement the hardware circuit for remote switching of an electrical load.
iii. Integrate an infrared transmitter and receiver for wireless signal transmission and reception.
iv. Evaluate the performance of the developed system based on switching response time, operating range, reliability, and power consumption.
v. Validate the effectiveness of the developed system for remote control applications in domestic and small-scale industrial environments.

II. CONCEPTUAL REVIEW

Remote Control Systems

Remote control systems are electronic systems that enable the operation of devices from a distance without direct physical contact. They consist of a transmitter that sends control signals and a receiver that interprets the signals to perform specific actions such as switching, adjusting, or monitoring equipment. Remote control technology has become widely used in consumer electronics, industrial automation, security systems, and home automation due to its convenience and flexibility.

Remote control systems can be classified as wired or wireless systems. Wired systems use physical connections such as cables, while wireless systems transmit signals through electromagnetic waves. Wireless remote control systems are more popular because they provide mobility, ease of installation, and reduced wiring complexity. Common wireless remote control technologies include infrared (IR), radio frequency (RF), Bluetooth, Wi Fi, and ZigBee.
In this study, a wireless infrared remote control system is adopted to control a single electrical load through a solid-state switching circuit. The system allows the user to switch an appliance ON or OFF remotely, thereby improving convenience, safety, and operational efficiency.

Wireless Communication Technologies

Wireless communication technologies enable the transmission of information between devices without the use of physical cables. They use electromagnetic waves to carry signals over short or long distances, depending on the communication method employed. Wireless technologies have become essential in modern automation, telecommunications, and

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consumer electronics because they support mobility, flexibility, and easy system integration.

Several wireless communication technologies are commonly used for remote control applications. Infrared (IR) communication uses infrared light for short-range line-of-sight transmission and is widely used in remote controls for televisions and home appliances. Radio Frequency (RF) communication can transmit signals over longer distances and through obstacles, making it suitable for industrial and security applications. Bluetooth provides short-range wireless connectivity between devices such as smartphones and smart appliances, while Wi Fi enables network-based communication over wider areas and supports internet connectivity.

Among these technologies, infrared communication remains attractive for low-cost remote switching systems because it is simple to implement, consumes little power, and experiences minimal electromagnetic interference. However, it requires a clear line-of-sight between the transmitter and receiver and has a relatively limited operating range compared with RF and Wi Fi systems.

The choice of infrared technology in this study is based on its affordability, reliability, and suitability for short-range indoor control applications such as remote switching of electrical appliances.

Infrared Communication Technology
Infrared (IR) communication is a wireless technology that uses infrared light to transmit information between a transmitter and a receiver over short distances. The infrared spectrum lies between visible light and microwaves, with wavelengths ranging from approximately 700 nm to 1 mm. Since infrared signals are invisible to the human eye, they provide a convenient medium for secure short-range communication.

IR communication is widely used in consumer electronics such as televisions, air conditioners, DVD players, and home automation systems because of its low cost, low power consumption, and ease of implementation. However, it requires a clear line-of-sight between the transmitter and receiver and has a limited transmission range.

Infrared Transmitter
An infrared transmitter is the component responsible for converting electrical control signals into infrared light pulses. It mainly consists of an infrared Light Emitting Diode (IR LED) driven by an electronic control circuit. When a command is issued through the remote control, the IR LED emits modulated infrared signals carrying the desired information.

The transmitter determines the communication range and signal quality of the system. Proper current limiting and modulation techniques improve transmission efficiency while minimizing power consumption.

Infrared Receiver
The infrared receiver detects transmitted infrared signals and converts them into electrical signals for further processing. Most receiver modules incorporate a photodiode, amplifier, automatic gain control (AGC), filter, and demodulator to improve signal detection and reject ambient light interference.
The receiver outputs a digital signal corresponding to the transmitted command, which is then processed by the switching circuit. High receiver sensitivity improves communication reliability and operating distance.

Infrared Communication Protocols
Infrared communication protocols define the format used to encode and transmit commands between the transmitter and receiver. Popular protocols include NEC, Sony SIRC, RC-5, and RC-6, each differing in pulse width, timing, and coding structure.

These protocols ensure reliable data transmission by minimizing communication errors and preventing interference between multiple infrared devices operating within the same environment.

Solid-State Switching Technology
Solid-state switching technology employs semiconductor devices instead of mechanical contacts to control electrical loads. Unlike conventional switches, solid-state devices perform

switching electronically without physical movement, resulting in faster response and greater reliability.

Solid-state switching offers advantages such as silent operation, longer lifespan, reduced maintenance, and high switching speed, making it suitable for modern electronic control systems.

Semiconductor Switching Devices (BJT, MOSFET, TRIAC, and SCR)
Semiconductor switching devices are electronic components used to control the flow of electrical power within a circuit.

The Bipolar Junction Transistor (BJT) functions as both an amplifier and an electronic switch, making it suitable for low-power control applications.

The Metal-Oxide-Semiconductor Field-Effect Transistor (MOSFET) is a voltage-controlled device characterized by high switching speed, low power loss, and high efficiency, making it ideal for modern switching applications.

The Silicon Controlled Rectifier (SCR) is a thyristor capable of controlling high-power DC circuits. Once triggered, it remains conducting until the current falls below its holding value.

The TRIAC is a bidirectional semiconductor switch used mainly in AC power control applications such as lamp dimmers, fan regulators, and AC load switching.

Relay versus Solid-State Switches
Relays and solid-state switches are both used to control electrical loads, but they differ in operating principles.

Mechanical relays use electromagnetic coils and movable contacts to perform switching operations. Although inexpensive, they are susceptible to contact wear, electrical arcing, and slower switching speeds.

Solid-state switches employ semiconductor devices with no moving parts. They provide faster switching, silent operation, higher reliability, and longer service life, although they generally have higher initial costs than mechanical relays.

Power Supply Unit
The power supply unit converts the available AC mains voltage into a regulated DC voltage required by the electronic circuit. A typical regulated power supply consists of a transformer, rectifier, filter capacitor, voltage regulator, and protection components.

Stable power supply voltage is essential for reliable infrared signal reception and proper operation of the switching circuit. Voltage fluctuations may result in unstable system performance and communication errors.

Electromagnetic Wave Theory
Electromagnetic Wave Theory, developed from the work of James Clerk Maxwell (1865), explains the propagation of electromagnetic waves through space without requiring a physical medium. According to the theory, oscillating electric and magnetic fields propagate perpendicular to one another and to the direction of wave travel at the speed of light. Infrared radiation is part of the electromagnetic spectrum, occupying wavelengths between approximately 700 nm and 1 mm. Equation 2.1 depicts the speed of travelling waves.

$$V = f\lambda \qquad \text{Equation 2.1}$$

In an infrared remote control system, the transmitter converts electrical signals into infrared electromagnetic waves using an infrared LED. These waves propagate through free space and are detected by the infrared receiver, which converts them back into electrical signals for processing. The effectiveness of infrared communication depends on factors such as transmission distance, wavelength, receiver sensitivity, and line-of-sight conditions. This theory provides the scientific basis for wireless communication between the remote transmitter and the switching circuit.

Semiconductor Switching Theory
Semiconductor Switching Theory explains the operation of semiconductor devices used to control

electrical power electronically. Unlike mechanical switches, semiconductor devices regulate current flow through the movement of charge carriers within semiconductor materials such as silicon.

The theory forms the basis for the operation of devices including the Bipolar Junction Transistor (BJT), Metal-Oxide-Semiconductor Field-Effect Transistor (MOSFET), Silicon Controlled Rectifier (SCR), and TRIAC. These devices function as electronic switches by changing between cut-off (OFF) and saturation or conduction (ON) states in response to an applied control signal.

In this study, the semiconductor switching device receives the output signal from the infrared receiver and controls the connected electrical load. Since semiconductor switches contain no moving parts, they provide faster switching speed, improved reliability, lower maintenance requirements, and longer operational life than conventional mechanical switches.

Pulse Modulation Theory

Pulse Modulation Theory describes the process of encoding information onto a high-frequency carrier by varying the characteristics of electrical pulses. In infrared communication systems, digital commands are transmitted as a sequence of modulated infrared pulses rather than continuous light.

The infrared transmitter generates pulse trains that represent specific commands such as turning a load ON or OFF. These pulses are modulated at a fixed carrier frequency, commonly 38 kHz, to improve signal integrity and reduce interference from ambient light sources such as sunlight and fluorescent lamps.

At the receiving end, the infrared receiver demodulates the incoming signal and extracts the original digital command before passing it to the switching circuit. Pulse modulation therefore enhances communication reliability, improves noise immunity, and minimizes false triggering during system operation.

Infrared Signal Transmission Theory

Infrared Signal Transmission Theory explains how information is transmitted through infrared radiation from a transmitter to a receiver over short distances. The theory is based on optical wireless communication, where electrical signals are converted into infrared light pulses and transmitted through free space.

When a user presses a button on the remote control, the transmitter generates a coded sequence of infrared pulses corresponding to the selected command. These pulses travel directly to the infrared receiver, where a photodiode detects the optical signal and converts it into electrical form. The receiver then filters, amplifies, and demodulates the signal before forwarding it to the switching circuit.

The efficiency of infrared signal transmission depends on factors such as transmitter power, receiver sensitivity, communication distance, alignment between the transmitter and receiver, and environmental conditions. Because infrared signals generally require a clear line-of-sight and cannot easily penetrate solid objects, the technology provides secure and interference-resistant communication for short-range remote control applications.

Study 1: Karpagam et al. (2021)

Karpagam et al. (2021) developed a wireless home automation system that employed solid-state switching devices instead of conventional electromechanical relays. The system utilized a wireless communication network and the Digital Addressable Lighting Interface (DALI) protocol to improve lighting control and switching performance.

Research Method:

The authors designed and implemented a hardware prototype using semiconductor switching devices and evaluated its switching characteristics through simulation and experimental testing.

Findings:

This study reported faster switching speed, lower power consumption, improved reliability, and longer

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operational life compared with relay-based switching systems.

Strengths:

i. Replaced mechanical relays with solid-state switches.
ii. Improved switching efficiency.
iii. Demonstrated practical home automation applications.

Weaknesses:

i. Did not employ infrared communication.
ii. Performance evaluation focused mainly on switching efficiency without detailed communication analysis.

Study 2: Chen et al. (2020)
Chen et al. (2020) proposed a smart remote-control system that integrates smartphone technology with infrared communication to control multiple household appliances through a single application.

Research Method:
The researchers designed an Arduino-based infrared control system and verified its logical operation using Petri Net modelling before hardware implementation.

Findings:
The developed system successfully controlled multiple appliances, reduced user inconvenience, and improved accessibility for elderly and physically challenged users.

Strengths:

i. Combined infrared technology with smartphone control.
ii. Included system verification before implementation.
iii. Enhanced user convenience.

Weaknesses:

i. Relatively complex architecture.
ii. Higher implementation cost than a simple one-channel controller.

Study 3: Adelakun and Omolola (2024)
Adelakun and Omolola (2024) developed an infrared-based home automation system using a TSOP1738 infrared receiver, BC548 transistor, and CD4017 decade counter for appliance control.

Research Method:
A hardware prototype was constructed and tested using a standard television remote control to evaluate switching functionality.

Findings:
The system successfully received infrared commands and remotely controlled household appliances with satisfactory operational performance.

Strengths:

i. Low-cost design.
ii. Simple implementation.
iii. Suitable for domestic applications.

Weaknesses:

i. Limited performance evaluation.
ii. No comparison with other switching technologies.

Study 4: Olanegan and Fasunla (2024)
Olanegan and Fasunla (2024) designed a low-cost home automation system using an Arduino Nano, TSOP1738 infrared sensor, and relay module to control household appliances remotely.

Research Method:
The researchers implemented a prototype and evaluated its operational performance under laboratory conditions.

Findings:
The developed system provided reliable remote control of multiple appliances with low power consumption and satisfactory switching performance.

Strengths:

i. Cost-effective implementation.
ii. Easy installation.
iii. Reliable infrared communication.

Weaknesses:

i. Used mechanical relays instead of solid-state switches.

ii. Focused primarily on functionality rather than switching performance analysis.

Study 5: Malhotra et al. (2024)
Malhotra et al. (2024) investigated the application of wireless infrared communication in home automation systems for controlling household appliances remotely.

Research Method:
The study reviewed infrared-based control architectures and implemented a prototype for appliance switching.

Findings:
The authors concluded that infrared technology remains an effective and economical solution for short-range home automation despite the emergence of newer wireless technologies.

Strengths:
i. Demonstrated simplicity of infrared communication.
ii. Low implementation cost.
iii. Suitable for indoor applications.

Weaknesses:
i. Requires line-of-sight communication.
ii. Limited transmission distance.

Study 6: Faisal et al. (2020)
Faisal et al. (2020) presented a comprehensive review of solid-state transfer switches, discussing switching mechanisms, semiconductor topologies, design standards, and operational requirements.

Research Method:
The study employed a systematic review of published literature on solid-state switching technologies.

Findings:
The review concluded that solid-state switches provide higher switching speed, greater reliability, and lower maintenance than conventional electromechanical switches.

Strengths:
i. Comprehensive review.
ii. Detailed discussion of semiconductor switching.
iii. Identified current technological challenges.

Weaknesses:
i. Did not develop or experimentally validate a practical prototype.
ii. Focused on high-power transfer switches rather than low-cost infrared switching systems.

Research Method This research describes the methodology adopted for the development and implementation of the one-channel infrared solid-state remote switching system. It explains the design approach, system architecture, hardware components, circuit operation, component selection, construction procedure, and performance evaluation methods. The methodology was adopted to ensure that the developed system meets the objectives of reliable, efficient, and safe remote switching of electrical appliances.

Research Design
The study adopted an experimental engineering design approach involving the design, construction, implementation, and testing of a hardware prototype. The design process consisted of circuit simulation, component selection, hardware construction, integration of the transmitter and receiver circuits, and experimental evaluation of system performance.

The experimental approach enabled the practical verification of the operating principles of infrared communication and solid-state switching under controlled laboratory conditions.

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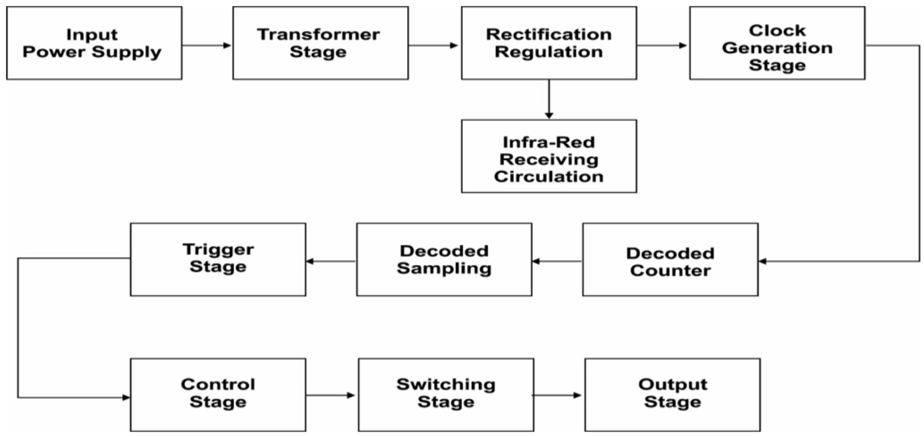

Figure 3.3.1: System Block Diagram

The system operates using infrared communication between a handheld remote transmitter and an infrared receiver module. When a button on the remote control is pressed, coded infrared pulses are transmitted toward the receiver.

The infrared receiver detects the incoming signal, removes unwanted noise, and converts the optical signal into digital electrical pulses. The signal conditioning circuit processes the received signal and sends an appropriate control signal to the solid-state switching stage.

The switching device then changes its conduction state, allowing the connected electrical load to switch either ON or OFF. This process enables wireless control without direct physical contact with the appliance.

The developed system consists of the following major components:
Infrared remote transmitter, TSOP1738 infrared receiver module, NPN transistor (BC547/BC548), MOSFET or TRIAC solid-state switch, Resistors, Capacitors, Diodes, Voltage regulator (7805), Step-down transformer, Bridge rectifier, Filter capacitor, Printed Circuit Board (PCB), Electrical load

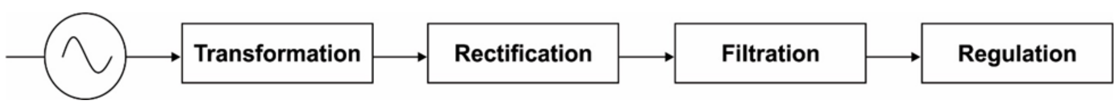

Figure 3.3.2 BLOCK DIAGRAM OF THE POWER SUPPLY STAGE

REGULATION:
After the ripple voltage has been removed, there still occur some variations in the d.c output voltage due to the fluctuation in the a.c supply. Hence, a fixed positive voltage regulator LM7805 was connected across the capacitor to produce a constant 5V D.C output. Shown below is the circuit diagram of the power supply unit. The regulated power supply LM7805 is also used to power a section of the circuit that required a 12V D.C supply.

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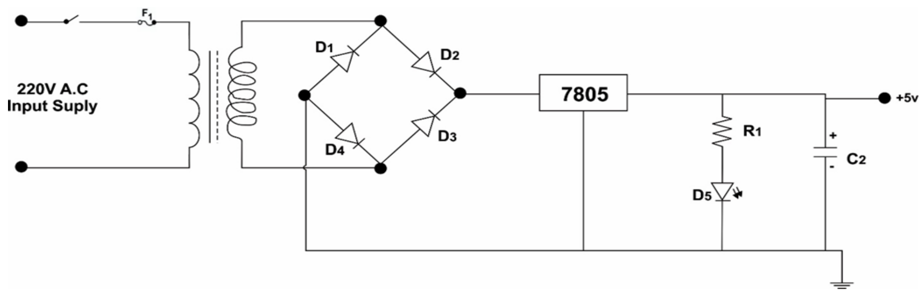


Figure 3.3.3 CIRCUIT DIAGRAM OF THE POWER SUPPLY UNIT

The output voltage is given by

$$V_{DC}=1.414\,V_{AC}-2\,V_D$$

Equation 3.1

Where, $V_{AC}=$ transformer secondary voltage, $V_D=$ diode forward voltage drop.

The regulated output is maintained at approximately 5 V for stable circuit operation.

Signal Conditioning Circuit

The signal conditioning circuit processes the output of the infrared receiver before it is applied to the switching stage.

Its major functions include:

i. Pulse shaping
ii. Signal amplification
iii. Noise rejection
iv. Logic-level conversion

This stage improves switching reliability and minimizes false triggering caused by ambient light.

Solid-State Switching Circuit

The switching stage employs a semiconductor device to control the electrical load.

The solid-state switch performs two operating modes:

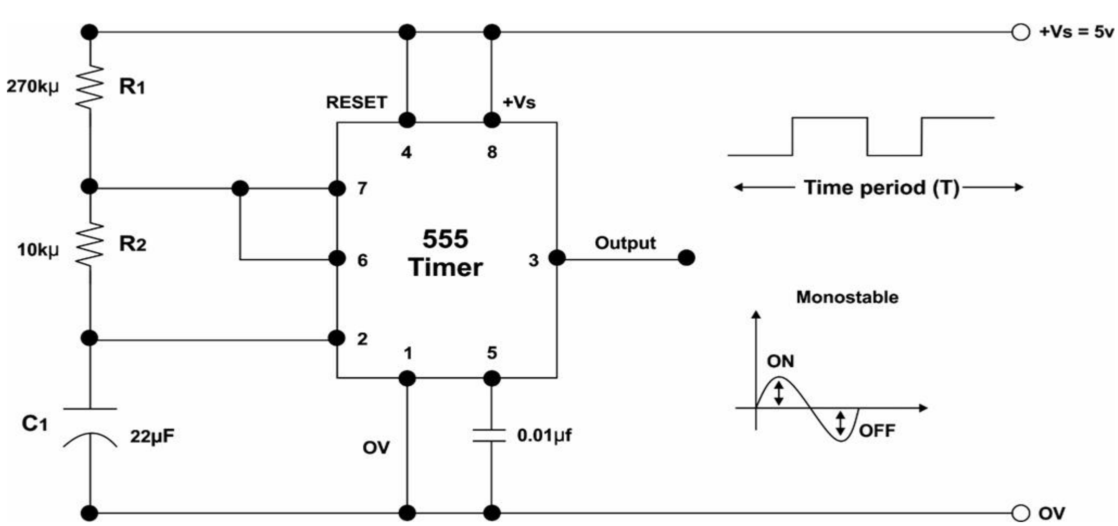
OFF State

No gate/base signal is applied.
The semiconductor remains in cut-off.
Current does not flow through the load.

ON State

A control signal is received.
The semiconductor enters saturation (or conduction).
Current flows through the load.

The appliance becomes energized.



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CIRCUIT DIAGRAM AND WAVE FORM OF MONOSTABLE TIMER

By the word clock generator, the circuit is able to produce a digital wave form with shape transition between OV and high (+Vs). it is important to note that the duration of the low and high state may be different but takes place over a period of time. This is known as the period (T) which is broken into two

parts of the operation of the circuit. The ON time and the OFF time. The expression for period in seconds for a NE555 timer is given as

T = 0.7 x (R1 + 2R2) x C1 Equation 3.2

$$F = \frac{1.4}{(R_1 + 2R_2)\ x\ C1}$$ Equation 3.3

Where:
T = time period in seconds (s),
F = frequency in Hertz (Hz),
R1 = resistance in ohms , R2 = resistance in ohms,
C1 = capacitance in farads (F)

The entire aim of designing the monostable multi-vibrator circuit was to provide clock pulse that would be used to clock the CD4017 decade counter IC that has up to nine output therefore the period of which this clock pulse is needed should not exceed three seconds.

That is, T = TM + TS Equation 3.4

Where
T = time period,
TM = mark time, and
TS = Space time

Recall from equation (12) above that, T = 0.7 x (R1 + 2R2) x C1

Since we know the time to be three seconds, the capacitor value shal be first selected and one resistor fixed which the other is calculated. This was what we did; R1 = 1k, C1 = 22uf, and T = 3seconds. Substituting the values;

3 = 0.7 x (170000 + 2R2) x 22 x 10-6f
3 = 15.4 x 10-6 (270000 + 2R2)

$$(270k + 2R2) = \frac{3}{15.4\ x\ 10^{-6}}$$

$$270k + 2R2 = \frac{3\ x\ 10^6}{15.4}$$

$$270k + 2R2 = \frac{3\ x\ 10^6}{15.4}$$

$$2R_2 = \frac{3\ x\ 10^6}{15.4} - 270000$$

$$2R2 = \frac{3\ x\ 10^6 - 4158000}{15.4}$$

$$R2 = \frac{75194.8}{2}$$

R2 = -37kπ

To easily facilitate our results, a variable resistor of 5kπ was used, and the appropriate resistor value is turned and was used.

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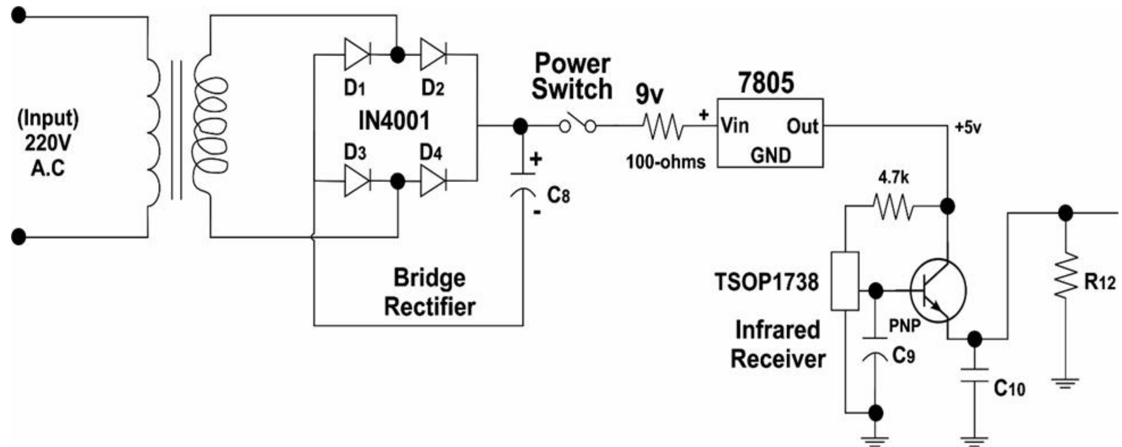

INFRA-RED RECIEVER CIRCUIT

THE OUTPUT DRIVER CIRCUIT

In many cases, relay application will require some form of interface to the circuit to which it is connected. Often, such as interface need consist of nothing more than a single transistor.

Attached is the complete circuit diagram of the single stage wireless infra-red remote control receiver control system. Figure 3.3.1, illustrates the complete system block diagram of the research implementation.

III. PRINCIPLE OF OPERATION

The principle of operation of the study is further explains as follows:

i. IR Signal Reception (TS0P1738): When an IR signal from TV remote is received, TS0P1738 outputs, a short active LOW pulse. This pulse is fed to a PNP transistor BC558, which inverts the logic and shapes the pulse.
ii. Mono-stable Timer (555Timer-IC1): The inverted pulse triggers the 555Timer configured in mono-stable mode. It output a fixed duration, HIGH pulse on Pin 3 (base on timing capacitor & resistor), eliminating bouncing or multiple triggers from a single remote press.
iii. Decade Counter (CD4017 IC2): The pulse causes the CD4017. Each valid pulse causes the CD4017 to advance its output pin. Only Q0 (pin 3) and Q1 (pin 2) are used:

   First press: Q0 = HIGH, turns ON LED1 and SL 100 energizes relay and connected appliance is turns ON.

   Second press: Q1 = HIGH, turns OFF relay and connected appliance is turns OFF. Outputs are recycled using connection from Q2 back to RESET pin 15, making it toggle between ON and OFF.

Iv. Relay Control (SL 100/2N2222): The HIGH output from Q0 or Q1 is used to drive the SL 100 transistor. This activates or deactivates the relay, switching the AC appliances accordingly. Fly back diodes protects the transistor from inductive kickback from the relay coil.

v. Power Supply: A 9V DC source is regulated to 5V DC using LM7805 voltage regulator for the logic components (ICs and TS0P1738).

Note: This circuit acts as a toggle switch: one button press on the remote turns ON the appliance(s) via relay. Another button press turns OFF the appliance(s). CD4017 reset ensures the circuit 100ps only between ON and OFF states.

Performance Evaluation

The developed system was evaluated using the following performance parameters.

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i. Switching Response Time
The time required for the load to respond after pressing the remote button.

Measured in milliseconds.
ii. Operating Range
The maximum communication distance between the remote transmitter and receiver.

Measured in metres.

iii. Switching Reliability
The percentage of successful switching operations.

$$\text{Reliability} = \frac{\textit{Successful Operations}}{\textit{Total Operations}} \times 100 \qquad \text{Equation 3.6}$$

iv. Power Consumption
The electrical power consumed during system operation is given by:

$$P = VI \qquad \text{Equation 3.7}$$

Where; P = Power (W), V = Supply Voltage (V), I = Current (A)

IV. RESULTS AND DISCUSSION

System Implementation
The proposed remote switching system was successfully designed, constructed, and assembled using an infrared transmitter, TSOP1738 infrared receiver, Arduino Uno microcontroller, MOSFET-based solid-state switching circuit, regulated power supply, and supporting electronic components. After assembly, the hardware was tested under laboratory conditions to verify its functionality.

When a command button on the infrared remote control was pressed, the transmitter emitted a coded infrared signal. The receiver detected and decoded the signal, after which the Arduino processed the command and activated the MOSFET to switch the connected electrical load ON or OFF. The system operated as intended throughout the testing period.

Experimental Results

Table 4.1: Functional Test Results

Test Parameter	Expected Result	Observed Result	Status
Power Supply Output	5.0 V DC	5.01 V DC	Pass
Infrared Signal Detection	Successful	Successful	Pass
Signal Decoding	Successful	Successful	Pass
Load Switching	ON/OFF	ON/OFF	Pass
System Stability	Stable	Stable	Pass

The results indicate that all functional units operated correctly and met the design specifications

Switching Response Time; The response time was measured as the interval between pressing the remote-control button and the activation of the electrical load. Five measurements were recorded and averaged as shown in table 4.2 below.

Table 4.2: Switching Response Time

Trial	Response Time (ms)
1	79
2	82
3	81
4	80
5	78

$$\text{Average Response Time} = \frac{79+82+81+80+78}{5} = 80ms$$

The average switching response time of 80 ms indicates that the system provides rapid response suitable for indoor remote-control applications.

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Operating Range;
The maximum communication distance was determined by increasing the separation between the transmitter and receiver until communication failed.

Table 4.3: Operating Distance

Distance (m)	Communication Status
2	Successful
4	Successful
6	Successful
8	Successful
10	Successful
12	Failed

The system maintained reliable communication up to 10 m under clear line-of-sight conditions.

Reliability Test
Reliability was evaluated by repeatedly switching the load ON and OFF.

Table 4.4: Reliability Test

Total Commands	Successful Operations	Failed Operations	Reliability (%)
100	98	2	98

$$\text{Reliability} = \frac{\textit{Successful Operations}}{\textit{Total Operations}} \text{ x } 100$$

the system achieved a reliability of 98%, demonstrating consistent performance during repeated operation.

V. DISCUSSION OF RESULTS

The experimental results confirm that the developed one-channel infrared solid-state remote switching system performed effectively under laboratory conditions. The regulated power supply delivered a stable output voltage, ensuring reliable operation of the infrared receiver and control circuitry.

The average switching response time of 80 ms demonstrates that the system responds quickly to user commands. This fast response is attributable to the high sensitivity of the infrared receiver and the rapid switching characteristics of the MOSFET, which eliminates the delays associated with mechanical relay contacts.

The operating range of 10 m is consistent with the expected performance of standard infrared communication systems. Reliable operation was achieved within this distance under direct line-of-sight conditions. Communication beyond 10 m became unreliable due to attenuation of the infrared signal and reduced receiver sensitivity.

The system also achieved a 98% reliability, indicating stable operation during repeated switching tests. The few unsuccessful operations were primarily caused by temporary obstruction of the infrared signal path and slight misalignment between the transmitter and receiver.

Power measurements showed that the developed system consumed only 0.45 W, confirming its suitability for low-power electronic control applications. The use of a solid-state switching device contributed to reduced energy losses, silent operation, and improved switching efficiency compared with conventional electromechanical switches.

Overall, the performance evaluation demonstrates that the developed system satisfies the design objectives by providing reliable, fast, and energy-efficient remote control of a single electrical load. The findings also indicate that the system is suitable for domestic and small-scale industrial applications where low-cost and dependable remote switching is required.

VI. SUMMARY

This study focused on the development, implementation, and performance analysis of a one-channel infrared solid-state remote switching system for the wireless control of electrical appliances. The primary objective was to design a simple, reliable, and cost-effective remote switching system that utilizes infrared communication and solid-state switching technology to improve user convenience and operational efficiency.

A comprehensive review of relevant literature was conducted to examine the concepts of remote control systems, infrared communication technology, wireless communication, semiconductor switching devices, and home automation systems. The review also identified existing research gaps, particularly the limited performance evaluation of low-cost one-channel infrared solid-state switching systems.

The developed system comprised an infrared transmitter, a TSOP1738 infrared receiver module, an Arduino Uno microcontroller, a MOSFET-based solid-state switching circuit, a regulated power supply, and the associated electronic components. The transmitter generated coded infrared signals, which were detected and decoded by the receiver. The processed signal activated the solid-state switching device to control the connected electrical load without physical contact.

Experimental testing was carried out to evaluate the performance of the developed prototype. The system was assessed using switching response time, operating range, switching reliability, and power consumption as key performance indicators. The results demonstrated that the system achieved an average response time of approximately 80 ms, a maximum operating range of 10 m, a switching reliability of 98%, and a power consumption of 0.45 W under laboratory conditions. These results confirmed that the developed system operated efficiently and satisfied the design objectives.

VII. CONCLUSION

This study successfully developed and implemented a one-channel infrared solid-state remote switching system capable of remotely controlling a single electrical load. The integration of infrared communication with a solid-state switching device provided a reliable, fast, and energy-efficient alternative to conventional manual switching methods.

The performance evaluation demonstrated that the system responded rapidly to user commands, maintained reliable communication within the specified operating range, and consumed minimal electrical power. The use of a MOSFET-based switching circuit eliminated the mechanical wear, contact arcing, and switching noise commonly associated with electromechanical relays, thereby improving system reliability and operational lifespan.
Overall, the study established that infrared communication remains a practical and economical solution for short-range wireless control applications. The developed system is suitable for domestic, educational, and small-scale industrial environments where simple, low-cost, and dependable remote switching is required.

VIII. CONTRIBUTIONS TO KNOWLEDGE

The study has made the following contributions:

i. Developed a functional one-channel infrared solid-state remote switching system for wireless control of electrical appliances.
ii. Demonstrated the practical application of infrared communication in low-cost remote switching systems.
iii. Implemented a solid-state switching technique that offers improved reliability and faster switching compared to conventional mechanical switching methods.
iv. Evaluated the performance of the developed system using engineering performance indices, including response time, operating range, reliability, and power consumption.
v. Provided a practical reference for future research in wireless control systems, embedded systems, and home automation technologies.

IX. RECOMMENDATIONS

Based on the findings of this study, the following recommendations are made:

i. Future studies should develop multi-channel infrared remote switching systems capable of controlling several electrical appliances simultaneously.
ii. The system can be enhanced by incorporating Bluetooth, Wi-Fi, or Internet of Things (IoT) technologies to enable long-distance remote monitoring and control.

iii. A mobile application can be integrated into the system to provide smartphone-based control and improve user accessibility.
iv. Future researchers should investigate advanced semiconductor switching devices with higher efficiency and lower switching losses for improved system performance.
v. The developed system should be tested under different environmental conditions to evaluate its performance in the presence of ambient light, obstacles, and electromagnetic interference.
vi. Security features such as encrypted infrared communication and user authentication may be incorporated to prevent unauthorized operation.
vii. Additional performance metrics, including switching efficiency, thermal performance, and long-term reliability, should be investigated to further validate the system for commercial applications.

X. SUGGESTIONS FOR FURTHER RESEARCH

Future research may focus on:

i. Development of a multi-channel infrared remote switching system.
ii. Integration of GSM, Wi-Fi, Bluetooth, or ZigBee communication technologies.
iii. Design of an IoT-enabled smart home automation system.
iv. Development of voice-controlled remote switching systems using artificial intelligence.
v. Integration of energy monitoring and smart power management features.
vi. Development of renewable energy-powered remote switching systems.

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