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DESIGN AND DEVELOPMENT OF A PORTABLE SOLAR MOBILE CHARGER.

BY

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DECLARATION

I Soita Jonathan hereby declare that this project work entitled "Design and Development of a Portable Solar Mobile Charger" is my work and has never been submitted for any academic award.

Signature…………………………… Date… 4/06/2026 ……

APPROVAL

This project entitled "Design and development of a portable solar mobile charger" was done under my supervision and submitted with my approval.

Signature……………………………………………

Date……4/6/2026……………

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DEDICATION

To my father Mr. Soita John, mothers Mrs. Kituyi Sylvia and Mrs. Namae Edith, my siblings; Soita Joel, Soita James, Soita Elizabeth, Soita Mary Immaculate, Soita Mary, Soita Joseph, Soita Martha, And Soita Eddy my cousin brother Mr. Wanakyeli Charles, my aunties; Mrs. Nabalayo Esther, Mrs. Bisikwa Annet, Soita Jacob and Mrs. Mutonyi Hasifa and my grandmother Mrs. Namakoye Agata.

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ABREVIATIONS

C - Capacitance

DC - Direct Current

E - Energy

LED - Light Emitting Diode

LM - Linear Monolithic

PCB - Printed Circuit Board

PV - Photovoltaic

R - Resistance

USB - Universal Serial Bus

V - Voltage

ABSTRACT

The increasing dependence on mobile phones for communication, education, and business has created a growing demand for reliable charging solutions, especially in areas with limited or unreliable electricity supply. This study focused on the design and development of a simple and cost-effective battery-less solar mobile charger powered by solar energy. The system was developed using a 7 V solar panel, an LM7805 voltage regulator, capacitors, resistors, a diode, and a USB charging interface to provide a regulated output suitable for mobile phone charging. The performance of the system was evaluated under varying sunlight conditions by measuring the input voltage, output voltage, and output current at different times of the day. The results showed that the charger performance depended strongly on solar radiation intensity, with output voltage and current increasing toward midday. The maximum output voltage and current obtained were 4.89 V and 117.7 mA, respectively, recorded at 2:00 PM. Although the system successfully converted solar energy into electrical energy, the output current was lower than the charging requirements of most modern smartphones, resulting in slow charging. Nevertheless, the study demonstrated the potential of solar energy as a sustainable and environmentally friendly source of power for low-power electronic devices in off-grid areas. The study recommends the use of larger solar panels, improved voltage regulation methods, and energy storage systems to enhance charging efficiency and system reliability.

CHAPTER ONE: INTRODUCTION

The growing dependence on mobile phones and portable electronic devices has created a need for reliable power sources. However, in many developing regions, access to grid electricity remains limited or unreliable. Solar energy, a clean and renewable resource, provides an alternative for powering small electronic devices. This project aims to design and develop a portable, affordable, and efficient solar mobile charger capable of operating in various sunlight conditions.

1.1 Background of the Study

The rapid increase in mobile phone usage across the world has created a continuous demand for reliable and convenient charging systems. In today's world, mobile phones have become more than just communication tools—they are lifelines. People use them for banking, studying, accessing health information, running small businesses, staying in touch with family, and even navigating daily tasks. Mobile phones are no longer limited to communication alone; they are now essential tools for education, online business, banking services, healthcare communication, and access to digital information. As dependence on these devices grows, ensuring consistent access to charging power becomes increasingly important (Chowdhury & Kaiser, 2021).

Yet for many individuals, especially those living in rural communities, something as simple as charging a phone remains a constant struggle. In many rural and semi-urban areas, electricity supply remains unreliable or completely unavailable. As technology becomes increasingly central to everyday life, the need to keep these devices powered has been vital, but electricity access challenges persist (Chowdhury & Kaiser, 2021).

This challenge has motivated researchers and engineers to explore alternative energy solutions, particularly renewable sources. The need for alternative charging systems is clear: without reliable power, the benefits of mobile technology remain out of reach for millions. Solar energy is widely recognized as one of the most accessible and sustainable energy sources available. It is clean, renewable, and environmentally friendly. Solar-powered charging systems offer a practical solution for portable electronics, especially in off-grid locations, and there is growing interest in compact and portable solar charging units that can serve both personal and community energy needs(Chowdhury & Kaiser, 2021).

Existing solar charger technologies vary in design and complexity. The design of a solar mobile charger is based on photovoltaic (PV) technology, where solar panels convert sunlight into direct current (DC) electricity. This generated power must then be regulated to match the charging requirements of mobile devices. Proper sizing of solar panels and integration of voltage regulation circuits are critical to achieving stable and efficient charging performance, since fluctuations in solar intensity can affect output voltage and potentially damage mobile devices (Yogyakarta, 2015). Integrating charge controllers and voltage stabilizers into solar charger designs significantly improves energy efficiency and protects both the storage battery and the mobile device. Successful solar charger development therefore depends not only on the solar panel itself but also on proper power electronics design (Moje et al., 2023). Wireless solar charging systems have also been explored to improve convenience and user experience. A prototype integrating photovoltaic generation with wireless charging technology demonstrated that combining solar energy with wireless power transfer increases portability and eliminates cable dependency, although efficiency optimization remains a key technical challenge (Imtiyaz et al., 2021). Comparative analysis of wired and wireless charging approaches identifies cost, efficiency, portability, and reliability as key performance factors in solar charger design (Singh & Jaiswal, 2022). Portability and multi-functionality are also important considerations; a solar charging system that combines mobile charging with LED lighting demonstrates that solar charging units can serve multiple purposes, especially in areas where access to electricity is limited, thereby enhancing their practicality and value in rural environments (*Solar Panel Based Mobile Charger and Small Led Lamp*, 2015).

Despite these advancements, limitations of current systems remain. While wireless systems improve convenience, wired solar chargers currently offer higher energy efficiency and lower implementation costs (Singh & Jaiswal, 2022). Recent developments have focused on low-cost and user-friendly solutions, and the feasibility of developing affordable solar chargers using locally available materials has been demonstrated, showing that effective power regulation and battery integration can be achieved without significantly increasing system cost (Shakya, n.d.). However, performance optimization through improved converter design and energy management techniques has been emphasized as a key factor in enhancing efficiency (Igbologe & Chiejine, 2024). Modern designs further focus on compact system architecture and improved conversion efficiency, reflecting the ongoing evolution of portable solar charging technology toward higher reliability and reduced size (*Design and Construct of a Portable Solar Mobile*, 2024).

Environmental sustainability is another major advantage of solar-powered charging systems; a comparative life cycle assessment between a solar charger and a conventional power bank indicates that solar chargers have lower long-term environmental impacts, particularly when used over extended periods, thereby contributing to reduced carbon emissions and sustainable energy consumption (Rieder et al., 2025). Nevertheless, challenges related to efficiency fluctuation, weather dependency, and cost-effectiveness continue to limit widespread adoption, underscoring the need for further design improvements in portable solar mobile chargers.

1.2 Problem Statement

Despite the increasing use of mobile phones for communication, education, business, and access to digital services, many people in rural and off-grid areas still face challenges in charging their devices due to unreliable electricity supply and limited access to the national power grid. Existing charging alternatives such as commercial solar chargers and power banks are often expensive, less portable, or unable to provide stable charging performance under varying sunlight conditions. In addition, some low-quality charging devices available on the market produce unstable voltage and insufficient current, which may result in slow charging, poor efficiency, or damage to mobile devices.

As a result, there remains a need for a low-cost, portable, and reliable solar-powered mobile charging system capable of providing stable output voltage suitable for charging mobile phones in electricity-constrained environments. Therefore, this study seeks to design and develop a simple and affordable solar mobile charger that can provide an alternative source of charging power for users with limited access to grid electricity.

1.3 Aim and Objectives of the Study

1.3.1 Aim of the Study

This study aimed at designing and developing a cost-effective solar-powered mobile charger for use in areas with limited access to grid electricity.

1.3.2 Objectives

The study was guided by the following objectives:

1. To design a solar-powered charging system capable of converting solar energy into electrical energy for mobile phone charging.

2. To integrate a voltage regulation circuit capable of providing a stable 5 V output suitable for mobile phone charging.
3. To evaluate the performance of the developed system by measuring output voltage and current under varying sunlight conditions.

1.4 Scope of the Study

This study focused on the design and development of a solar-powered mobile charger capable of charging mobile phones and other low-power electronic devices. The study covered solar energy harvesting, solar panel selection, voltage regulation, circuit implementation, and performance evaluation of the developed system under varying sunlight conditions.

The project was limited to a small-scale portable charging system and did not include large-scale solar power generation systems, wireless charging technologies, or advanced battery storage systems.

1.5 Significance of the Study

The study promotes the use of solar energy as an alternative and sustainable source of power for charging mobile phones in off-grid and electricity-constrained areas. The developed system provides a low-cost and environmentally friendly charging solution that may help reduce dependence on conventional electricity sources and fossil-fuel-based energy.

The project also contributes toward environmental conservation and supports Sustainable Development Goal 7, which emphasizes access to affordable and clean energy for all. In addition, the study demonstrates the practical application of photovoltaic technology and voltage regulation in small-scale electronic systems.

Furthermore, the project serves as a practical learning resource for students, researchers, and communities interested in renewable energy technologies and sustainable engineering solutions.

1.6 Report organistion

The remainder of this report is organized into four chapters

1.6.1 Chapter Two: Literature Review

This chapter reviews previous research related to solar powered mobile chargers, photovoltaic systems, voltage regulation techniques, and electronic components used in solar charging circuits.

1.6.2 Chapter Three: Materials and Methods

This chapter describes the methods used in the design and development of the solar mobile charger. It includes the system design, materials used, circuit development, circuit diagram, and testing procedures.

1.6.3 Chapter Four: Results and Discussion

This chapter gives a clear report on results, interpretation, analysis and discussion of the data which was obtained on the research work and how the data was used to arrive at the stated objectives of the study.

1.6.4 Chapter Five: Conclusion and Recommendations.

This chapter highlights the main findings of the study, the conclusion drawn from the research, and the recommendations intended to address the problems identified during the study and improve future practice in the area of study.

CHAPTER TWO: LITERATURE REVIEW

2.1 Solar Energy and Photovoltaic Technology

The performance of a solar mobile charger depends largely on the selection of electronic components used in the circuit design.

Solar energy is a renewable energy source obtained from the sun and converted into electrical energy using photovoltaic cells. Photovoltaic cells generate direct current (DC) electricity when sunlight strikes semiconductor materials such as silicon. Solar panels consist of multiple photovoltaic cells connected in series or parallel to increase voltage and current output(Chowdhury & Kaiser, 2021).

Solar energy is widely used because it is clean, abundant, and environmentally friendly. Many portable devices can utilize solar energy through compact solar panels integrated into charging circuits. The use of solar technology in mobile charging systems reduces dependence on fossil fuels and grid electricity(Gayitri et al., 2023).

2.1.1 Fundamental Principles and Construction of Solar Panels

A solar panel also known as a photovoltaic module is an assembly of interconnected solar cells that convert sunlight directly into electricity through the photovoltaic effect (Bhatia, n.d.). This process is purely light-based, not heat-based, meaning panels generate electricity even on cloudy days, though at reduced efficiency(Bhatia, n.d.). Solar photovoltaic technology has come a long way since Alexandre-Edmond Becquerel first discovered the photovoltaic effect in 1839(Series, 2021). What began as a scientific curiosity has evolved into a sophisticated energy solution that is reshaping how we power our world. The journey from those early experiments to today's high-efficiency solar panels reflects decades of material science breakthroughs, manufacturing innovations, and a growing global commitment to renewable energy. This review examines the different types of solar panels across generations, their unique characteristics, and how they fit into various applications from powering a simple pocket calculator to running an entire commercial building.

2.1.1.1 Types of solar panels (PV systems)

Solar technology begins with first-generation solar cells, which are fundamentally built on crystalline silicon wafers. These panels have dominated the market for decades and continue to do so today and, approximately 80% of the solar cell market is still based on crystalline silicon technology (Series, 2021).

2.1.1.1.1 Monocrystalline Solar Panels

Monocrystalline panels are the purists of the solar world. They are created from a single, continuous crystal structure using the Czochralski method, where a seed crystal is slowly pulled from molten silicon to form a large ingot(Kaur, 2023). This meticulous process results in exceptionally high-purity silicon, which translates directly into performance.

What makes monocrystalline panels stand out is their efficiency. With rates reaching above 20%, they convert more sunlight into electricity per square foot than any other traditional panel type(Panels, n.d.). They are also remarkably durable, with a lifespan extending to 50 years(Kaur, 2023). However, this performance comes at a cost both financial and material. The manufacturing process is energy-intensive and expensive, making these panels the premium option in the market.

Visually, monocrystalline panels are distinctive. They have a uniform dark black or dark blue appearance with rounded edges, which many homeowners find aesthetically pleasing (Panels, n.d.). For someone with limited roof space who wants maximum power generation, these panels are typically the go to choose.

2.1.1.1.2 Polycrystalline Solar Panels

Polycrystalline panels take a different approach. Instead of growing a single crystal, manufacturers melt multiple silicon fragments and pour them into square molds(Kaur, 2023). The result is a panel made up of many smaller silicon crystals, which gives it a characteristic blue, speckled appearance.

The trade-off here is straightforward: lower cost for lower efficiency. Polycrystalline panels typically operate at around 12-15% efficiency, which is noticeably less than their monocrystalline counterparts(Bhatia, n.d.). However, they are significantly cheaper to produce because the manufacturing process is simpler and faster. For homeowners with ample roof space who are working within a budget, polycrystalline panels offer a practical balance of cost and performance.

Polycrystalline cells are less efficient than monocrystalline cells primarily due to grain boundaries within the material, which impede the flow of electrons (Series, 2021). Nevertheless, they have carved out a substantial market share, particularly in large-scale installations where space is abundant.

2.1.1.1.3 Thin-Film Revolution

The high cost of crystalline silicon drove researchers to explore alternatives, leading to the development of second-generation thin-film solar cells. These panels are created by depositing extremely thin layers of photovoltaic material onto substrates like glass, metal, or plastic(Kaur, 2023). The absorbing layer in thin-film cells is about 1 micron thick, compared to 350 microns for traditional silicon wafers a dramatic reduction in material usage.

2.1.1.1.4 Amorphous Silicon (a-Si) Panels

Amorphous silicon represents the most established thin-film technology. Unlike crystalline silicon, which has an ordered atomic structure, amorphous silicon atoms are arranged randomly. This disordered structure gives a-Si unique properties, including exceptional light absorption over 40 times higher than crystalline silicon(Bhatia, n.d.).

These panels are the ones you have likely seen in pocket calculators. They are affordable, lightweight, and can be deposited on flexible substrates, opening up creative applications like curved surfaces or building-integrated designs. However, their efficiency is modest, typically ranging from 4-8%(Kaur, 2023). What they lack in efficiency, they make up for in low-light performance amorphous silicon panels actually perform relatively well in cloudy or diffuse light conditions, making them suitable for regions with less intense sunlight.

2.1.1.1.5 Cadmium Telluride (CdTe) Panels

Cadmium telluride has emerged as one of the most commercially successful thin-film technologies. With a band gap of 1.45 eV, CdTe is nearly perfectly matched to the solar spectrum, meaning it can absorb sunlight very efficiently(Series, 2021). The material also boasts a high absorption coefficient, so only a very thin layer is needed.

The efficiency of CdTe panels has improved significantly, with laboratory efficiencies reaching about 21% according to First Solar's published results(Series, 2021). Commercially, they typically operate in the 9-11% range, which is respectable for thin-film technology(Kaur, 2023).

However, CdTe faces a significant hurdle: environmental concerns. Cadmium is a toxic heavy metal that can accumulate in living organisms(Kaur, 2023). While the panels themselves are sealed and safe during operation, manufacturing and disposal require careful handling, and recycling processes remain expensive. In Europe particularly, public concern about cadmium has limited the adoption of this otherwise promising technology(Panels, n.d.).

2.2 Solar Powered Mobile Phone Charging Systems

A solar powered mobile charger is a device that converts solar energy into electrical energy for charging mobile phones. It typically consists of a solar panel, voltage regulator, energy storage element (battery or capacitor), and an output interface such as a USB port(Solar Panel Based Mobile Charger and Small Led Lamp, 2015).

Studies have shown that solar mobile chargers are particularly useful in off-grid environments where electricity supply is unreliable. A portable solar-powered charger designed for off-grid regions demonstrated the ability to deliver approximately 5 V output with sufficient current for mobile charging using a buck converter and optimized circuit design(Sanvi et al., n.d.).

Other research projects have explored systems where solar panels directly charge mobile devices through voltage regulation circuits to maintain stable output voltage. These systems are designed to improve efficiency and portability(Al-mashhadany & Attia, n.d.).

2.3 Voltage Regulation in Solar Charging Circuits

Voltage regulation is an essential component of solar mobile chargers because solar panels produce fluctuating voltage depending on sunlight intensity. Mobile phones typically require a stable 5 V DC input, which is commonly delivered through USB charging ports(Solar Panel Based Mobile Charger and Small Led Lamp, 2015).

To achieve this stable output, voltage regulators such as linear regulators or DC-DC converters are used. Linear voltage regulators like the L7805 are commonly applied in small solar charger circuits due to their simplicity and reliability. They regulate the output voltage by adjusting the resistance in the feedback circuit.

Additionally, buck converters are widely used to step down the solar panel voltage to the required charging voltage while maintaining efficiency(Sanvi et al., n.d.).

A voltage regulator is defined as a device that maintains a constant output voltage regardless of variations in input voltage or load conditions(Does et al., 2022).

The operation of a voltage regulator is based on a feedback control system consisting of a reference voltage, feedback network, and pass element. The feedback circuit continuously monitors the output voltage and compares it with a reference value. Any deviation generates an error signal, which adjusts the conduction of the pass element to restore the desired output(Figure 5.2.1 Voltage Regulator Diagram Source Elprocus.Com, n.d.).

This closed-loop mechanism ensures high accuracy and stability, making voltage regulators indispensable in sensitive electronic applications.

2.3.1 Classification of Voltage Regulators

2.3.1.1 Linear Voltage Regulators

Linear voltage regulators operate by varying the resistance of a pass element (such as a transistor) to maintain a constant output voltage. These regulators are simple, reliable, and produce low noise, making them suitable for low-power applications(Does et al., 2022).

However, their efficiency is relatively low because excess energy is dissipated as heat, especially when there is a large difference between input and output voltage(Figure 5.2.1 Voltage Regulator Diagram Source Elprocus.Com, n.d.).

Linear regulators can be further categorized into fixed, adjustable, s eries, and shunt regulators.

2.3.1.2 Switching Voltage Regulators

Switching voltage regulators operate by rapidly switching a transistor on and off and controlling the duty cycle to regulate the output voltage. This method significantly improves efficiency, as less power is lost as heat(Power et al., n.d.).

They are capable of performing step-up (boost), step-down (buck), and voltage inversion operations, making them more versatile than linear regulators.(Does et al., 2022)

Despite their advantages, switching regulators are more complex, can generate noise, and require careful design considerations.

2.3.1.3 IC-Based Voltage Regulators

Integrated Circuit (IC) voltage regulators are widely used due to their compact size, reliability, and ease of implementation. These regulators are designed to convert an unregulated input voltage into a stable output voltage within a specified range(Power et al., n.d.).

IC regulators are commonly classified as:

- ✓ Three-terminal regulators
- ✓ Fixed and adjustable regulators
- ✓ Positive and negative regulators

These categories simplify the selection process for designers depending on application requirements.

2.3.1.3.1 The LM7805 Voltage Regulator

The LM7805 is a widely used fixed linear voltage regulator that provides a constant output of +5V. It belongs to the 78XX series, where the last two digits indicate the output voltage (e.g., $7805 = 5$V)(Power et al., n.d.).

This regulator is particularly suitable for powering digital circuits, including microcontrollers and embedded systems, where a stable 5V supply is essential.

2.3.1.3.1.1 Working Principle

The LM7805 operates as a linear series regulator with an internal reference voltage, error amplifier, and pass transistor. The output voltage is continuously compared with the reference voltage, and any difference is corrected by adjusting the conduction of the pass transistor(Power et al., n.d.).

Additionally, the regulator requires an input voltage that is typically 2–3V higher than the output voltage to maintain proper regulation.

The LM7805 includes several protective features that enhance its reliability:

- ❖ Thermal shutdown protection
- ❖ Current limiting
- ❖ Safe operating area protection

These features ensure that the device can withstand adverse operating conditions and prevent damage(Power et al., n.d.).

This is the voltage regulator capable of providing stable output voltage for electronic circuits. It is commonly used in solar charger circuits to regulate the voltage supplied to mobile devices.

2.4 Resistors

Resistors control current flow within the circuit and determine voltage levels in voltage divider networks used with regulators such as LM7805.

2.5 Capacitors

Capacitors are fundamental passive components found in nearly every electronic device, from camera flashes and radio tuners to power supply filters and timing circuits. This literature review synthesizes three instructional documents to present a cohesive understanding of capacitors: their basic definition, geometric determination of capacitance, energy storage, charging and discharging behavior in resistor-capacitor (RC) circuits, and the role of dielectrics.

A capacitor consists of two conductors (plates) separated by an insulator such as air, paper, or a dielectric material(Chelaru & Aileni, n.d.). When connected to a battery, the plates store equal and opposite charges. The key experimental finding is that the charge Q stored on the plates is directly proportional to the potential difference V between them:

$$\mathrm{Q}\ \alpha\ \mathrm{V} \text{ or } \mathrm{Q} = \mathrm{C.V}$$

where the constant of proportionality C is called the capacitance(Chelaru & Aileni, n.d.). Capacitance is therefore defined as the ratio of charge to potential difference: $\mathrm{C} = \frac{\mathrm{Q}}{V}$ (Chelaru & Aileni, n.d.).

2.5.1 Energy Stored in a Capacitor

The energy stored in a capacitor is a function of two measurable quantities: its capacitance and the voltage across it. The standard equation, $\mathrm{E} = \frac{1}{2}\mathrm{CV}^2 = \frac{1}{2}\mathrm{QV} = \frac{1}{2}\frac{\mathrm{Q}^2}{\mathrm{C}}$, where E is energy in joules, C capacitance in farads, Q is the charge in coulombs and V voltage in volts, reveals something important: energy scales with the square of voltage. This is why high-voltage capacitors can store substantial energy even with modest capacitance values, and why capacitor banks in power systems are often charged to thousands of volts(Torki et al., 2023).

This energy equation guides capacitor selection. Storing 10 joules at 5 volts requires a capacitance of $C = \frac{2E}{V^2} = \frac{2\times10}{5^2} = 0.8F$—a supercapacitor. The same 10 joules at 500 volts needs only $\frac{2\times10}{V500^2} = 80\mu F$ which is a modest film or ceramic capacitor. This explains why high-voltage systems can use small, inexpensive capacitors while low-voltage energy storage demands physically large supercapacitor banks(Letsie & Nthako, 2025).

2.5.2 Charging Process

When you connect a capacitor to a voltage source through a resistor, the capacitor does not charge instantly. Instead, its voltage rises along an exponential curve. This behavior is governed by Kirchhoff's voltage law; the source voltageV_S equals the voltage across the resistor V_R plus the voltage across the capacitorV_C

$$V_S = V_R + V_C$$

The resulting differential equation, $V_s = R\frac{dQ}{dt} + \frac{Q}{C}$, has a solution that gives voltage as a function of time:

$$V_C(t) = V_S\left(1 - e^{-\frac{t}{\tau}}\right)$$

where $\tau = RC$ is the time constant, measured in seconds when resistance is in ohms and capacitance in farads(Letsie & Nthako, 2025).

What does this curve look like in practical terms? After one time constant, the capacitor reaches about 63.2% of the source voltage. After two time constants, about 86.5%. After three, 95.0%. After five time constants, the capacitor is considered fully charged at 99.3% of the source voltage. A capacitor is effectively charged after five time constants(Torki et al., 2023).

2.5.3 Discharging Process

Discharging a capacitor through a resistor follows a similar but opposite pattern. If a capacitor initially charged to voltage V_0 is connected across a resistor, the stored energy dissipates as heat in the resistor. The voltage across the capacitor decays as:

$$V_C(t) = V_0\left(e^{-\frac{t}{\tau}}\right)$$

Again, $\tau = RC$. After 1 time constant, voltage drops to 36.8% of its initial value. After 3 time constants, to 4.98%. After 5, to 0.67% effectively zero(Letsie & Nthako, 2025).

The current during discharge is $I(t) = \frac{V_0}{R} e^{-\frac{t}{\tau}}$, flowing in the opposite direction to the charging current. This exponential discharge is exploited in countless applications: timing circuits where a capacitor discharging through a resistor triggers a comparator at a specific threshold, flash tubes where the rapid dump of energy produces intense light, and defibrillators where precisely shaped pulses deliver life-saving shocks to the heart(Torki et al., 2023).

The discharge current at $t = 0$ is $\frac{V_0}{R}$. If the resistor is very small say, a short circuit the current becomes theoretically infinite, though in reality it is limited by the capacitor's internal resistance (ESR) and the inductance of the loop. Shorting a charged capacitor is dangerous not only because of the spark but also because the sudden current surge can weld contacts or damage components.

2.5.4 The Time Constant, τ

The time constant $\tau = RC$ is the single most important parameter describing a capacitor's dynamic behavior. It tells you how fast the capacitor responds to changes. A small time constant means fast charging and discharging; a large time constant means slow.

The time constant has a beautiful physical interpretation, it is the time required for the capacitor to charge to 63.2% of the final voltage or to discharge to 36.8% of the initial voltage. But beyond this numerical definition, the time constant represents the rate at which the stored energy can be transferred in or out of the capacitor. For a given capacitance, smaller resistance yields faster charge/discharge but higher currents. For a given resistance, smaller capacitance yields faster response but less stored energy(Letsie & Nthako, 2025).

2.5.5 Energy Efficiency and Practical Considerations

Capacitors are remarkably efficient energy storage devices. A well-designed capacitor loses only a small fraction of stored energy as heat during charge and discharge cycles. The round-trip efficiency (energy returned divided by energy supplied) exceeds 95% for most capacitor types and can approach 99% for high-quality film capacitors(Chelaru & Aileni, n.d.).

However, real capacitors have losses. The primary loss mechanism is due to ESR: during both charging and discharging, the current flowing through ESR generates heat (I^2R losses). For a capacitor charged and then discharged through the same resistance, the energy dissipated in the resistor during charging equals the stored energy, and the same amount dissipates during discharging. If you charge a capacitor through a resistor and then discharge it through the same resistor, exactly half the energy supplied by the source ends up stored in the capacitor; the other half is lost as heat in the resistor during charging. Then during discharging, that stored energy is entirely dissipated as heat in the discharge resistor. This inherent 50% efficiency when charging through a fixed resistor is why energy recovery systems use switched-mode converters rather than simple resistive charging.

2.6 USB Port

The USB port provides the interface through which the regulated voltage is delivered to the mobile phone.

These components collectively ensure stable power conversion, voltage regulation, and safe charging of mobile devices.

The above show that solar mobile chargers are feasible and effective for providing sustainable power solutions for portable electronic devices.

CHAPTER THREE: MATERIALS AND METHODS

3.1 Materials and Components

The following materials was used in the development of the solar mobile charger:

1. 9V Solar panel to convert sunlight into electrical energy.
2. L7805 voltage regulator to regulate output voltage.
3. White LED to show continuity of current.
4. Resistors 220Ω shall control current and voltage levels towards the LED.
5. Capacitors (100𝓜F and 10𝓜F) to filter and stabilize voltage.
6. USB port to provide charging interface.
7. Diode to prevent reverse current flow.
8. Connecting wires for Electrical connections.
9. Multimeter for measuring voltage current, and for testing continuity in the circuit.

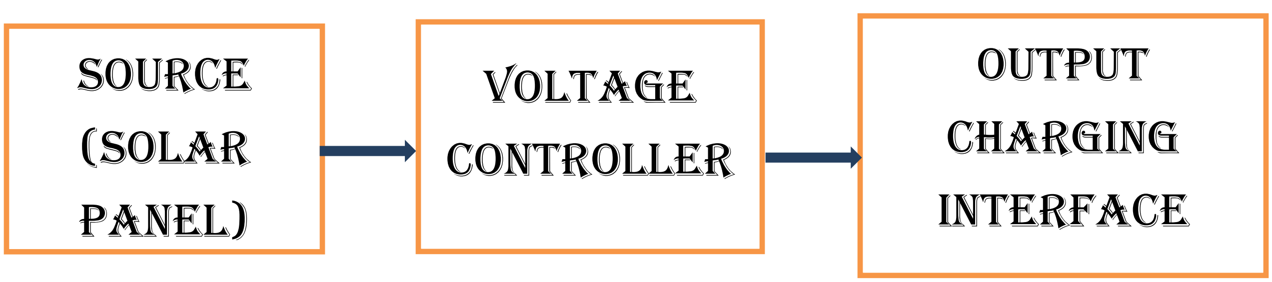
3.2 Methods

3.2.1 System Design

The solar mobile charger system consisted of the following main stages:

1. Solar energy harvesting stage
2. Voltage regulation stage
3. Energy filtering and stabilization stage
4. Output charging interface

3.2.1.1 Block Diagram



The system converted sunlight into electrical energy using a solar panel and regulated the voltage to the required level for mobile phone charging.

3.2.1.2 Construction Procedure

The construction process involved the following steps:

a) The L7805 voltage regulator was fixed on the PCB to control the output voltage to a maximum of 5V.

b) The diode was connected to the input of L7805 then the input capacitor(100μF) was also soldered on the input and the ground of the regulator to filter fluctuations from the source.

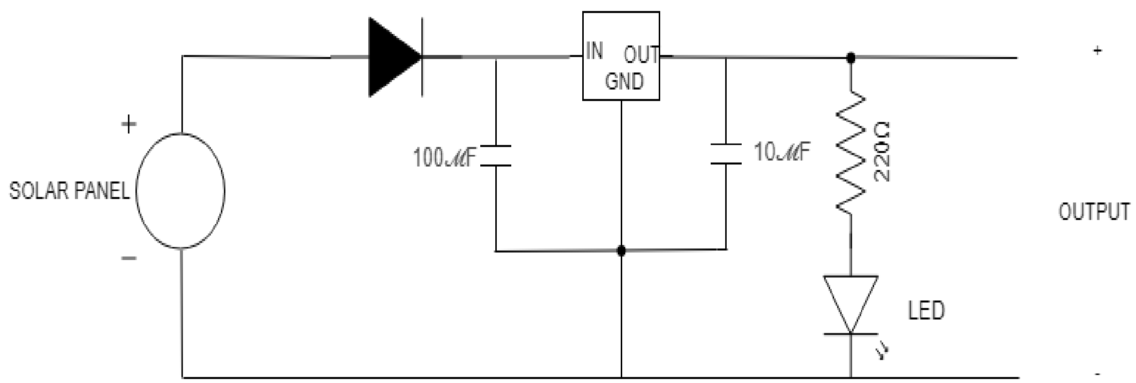
c) The second capacitor (10μF) was connected on the output of the L7805 and the ground line to reduce on the ripples in the output.

d) A resistor was added on the output terminal of the regulator to minimize on the current reaching the LED. The anode of the white LED was connected on the other part of the resistor.

e) The cathode of the LED was connected to the ground which became the ground for the output voltage.

f) The positive of the USB port was connected on the output of the regulator while its negative terminal was connected at the cathode of the LED.

3.2.2 Circuit Diagram



3.2.3 Testing and Evaluation

The performance of the solar charger was evaluated by:

- Measuring the output voltage using a multimeter.
- Measuring current output under different sunlight conditions.
- Charging a mobile phone through the USB port.
- Comparing the output voltage with standard USB charging voltage (5V).

CHAPTER FOUR: RESULTS AND DISCUSSION

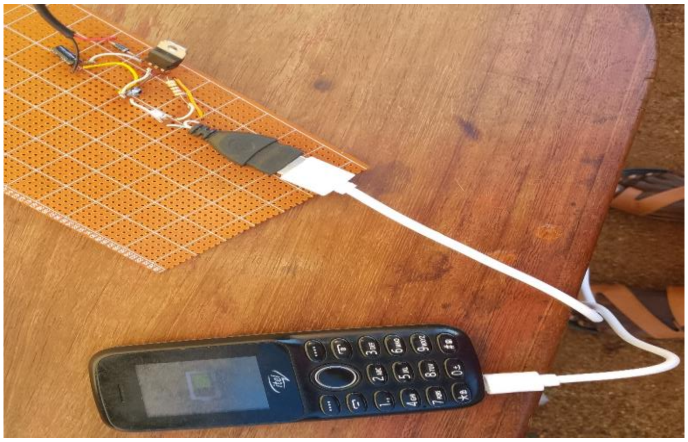


Figure 4. 1 Phone charging

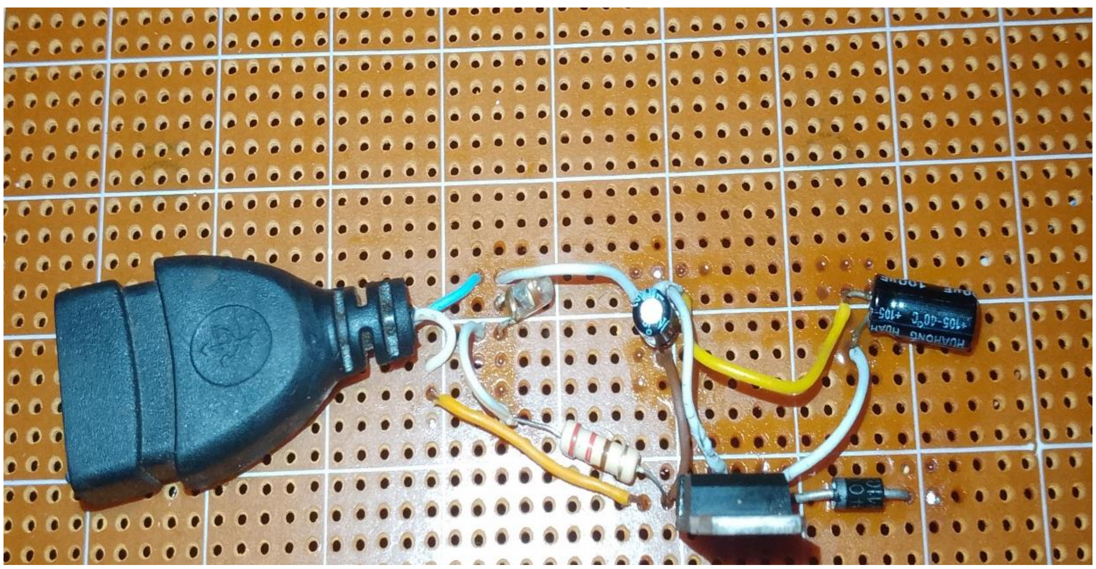


Figure 4. 2 Developed control circuit and output system

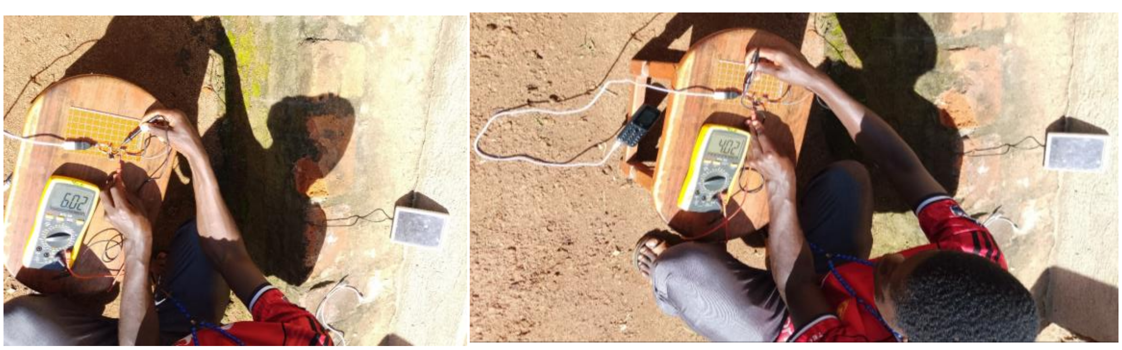


Figure 4. 3: First data values obtained at 10:00am.

Table 4. 1 : Data obtained for 9 hours on a sunny day at Nagongera trading center.

Hour in a day	Input voltage (V)	Output voltage (V)	Output current(mA)
10:00AM	6.02	4.02	63.7
11:00AM	6.12	4.06	83.7
12:00PM	6.14	4.23	95.3
1:00PM	6.17	4.75	110.2
2:00PM	6.20	4.89	117.7
3:00PM	6.20	4.63	100.6
4:00PM	6.05	4.54	93.9
5:00PM	5.68	3.73	62.5
6:00PM	5.32	3.22	30.2

4.1 Interpretation of the results

From Table 4.1 above the results show how strongly the performance of the system depended on the intensity of sunlight available throughout the day. As the sunlight increased from morning toward midday, both the output voltage and output current also increased steadily. The highest performance was observed around 2:00pm, which corresponded to the period when solar radiation was strongest. After this time, the output values gradually decreased as the intensity of sunlight reduced toward the evening hours.

At peak operation, the system produced an output voltage of 4.89 V. This value was very close to the standard USB charging voltage of 5 V required by most mobile phones. This indicated that the solar panel and voltage regulation circuit were able to generate a nearly suitable charging voltage under strong sunlight conditions. However, although the voltage approached the required level, it did not remain constant throughout the day. In the early morning and late evening, the output voltage dropped significantly, reaching values that were too low to support effective phone charging. This meant that the charger performed best only during periods of high solar irradiance.

The output current followed a similar trend. The current increased gradually with increasing sunlight intensity and reached a maximum value of 117.7 mA during peak sunshine hours. Even though this confirmed that the system successfully converted solar energy into electrical energy, the current produced was still much lower than the charging current commonly required by modern smartphones. Most smartphones typically require at least 500 mA for normal charging, while fast charging systems require even higher currents. Because of this low current output, the charging process using the prototype was very slow, and some phones did not detect the charger at all.

The low charging current may have been caused by several factors. One possible reason was the limited power rating or surface area of the solar panel used in the design. A smaller panel captured less sunlight and therefore produced lower electrical power. In addition, energy losses within the voltage regulator and connecting components may also have reduced the amount of current reaching the output terminal. Environmental conditions such as cloud cover, panel orientation, and temperature variations could further have affected the system performance during testing.

CHAPTER FIVE: CONCLUSION AND RECOMMENDATIONS

5.1 Conclusion

The study successfully showed that solar energy could be used directly to charge mobile phones without the use of a storage battery. The developed battery-less portable solar mobile charger responded directly to changes in sunlight intensity, with the best performance being observed during the afternoon hours when solar radiation was highest.

Both the output voltage and current increased to their maximum values, confirming that the system was capable of converting solar energy into usable electrical energy for mobile phone charging.

The results also revealed that the charger produced lower voltage and current levels than those required by most modern smartphones, which resulted in slow and sometimes unstable charging.

The absence of a battery storage system further caused the output to fluctuate whenever sunlight conditions changed.

However, the project successfully demonstrated the potential of solar energy as a clean, affordable, and environmentally friendly source of power for small electronic devices, especially in areas where access to electricity is limited or unreliable.

5.2 Recommendations

The ability of direct solar energy to charge mobile devices without relying on conventional electricity or battery storage, makes this project environmentally friendly, simple, and cost-effective. However, to improve the performance of the prototype, future designs should;

1. Incorporate larger and more efficient solar panels capable of generating higher current and more stable voltage outputs suitable for modern smartphones.
2. Included A DC-to-DC boost converter to maintain a constant 5 V USB output even when sunlight intensity changes throughout the day.
3. Incorporate an energy storage component such as a rechargeable battery or supercapacitor to stabilize the charging process during cloudy weather or temporary shading.
4. Optimize the circuit design to minimize energy losses within the regulator and connecting components so as to improve overall system efficiency.

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Figure 5.2.1 Voltage Regulator Diagram Source elprocus.com. (n.d.).

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