Design and Construction of an AC to DC Converter for Charging Electronic Devices That can be Used as Instructional Material in a Physics Classroom Setting: A case of A Physics Classroom

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ABSTRACT

This project focused on the design and construction of a functional cell phone charger that converts alternating current (AC) from the mains supply into regulated direct current (DC) suitable for charging mobile phones. The project was motivated by the need to develop a simple, affordable, and locally constructed instructional material that can be used to demonstrate practical applications of electricity and electronics in the physics classroom (Bano et al., 2024). The charger was designed using basic electronic components, including a step-down transformer, rectifier circuit, filter capacitor, voltage regulator, and output charging interface. The AC voltage is stepped down to a lower voltage, converted from AC to DC through rectification, filtered to reduce fluctuations, and regulated to provide a relatively stable DC output suitable for a mobile phone charging circuit. The completed device was tested to determine its functionality, output voltage stability, and suitability for instructional purposes (Low et al., 2018). The project demonstrates important physics concepts such as alternating and direct current, electromagnetic induction, voltage transformation, rectification, filtering, regulation, electrical energy conversion and basic electronic circuit operation. The constructed charger can therefore serve as a practical instructional material that enables learners to connect theoretical concepts with real-life applications through observation, experimentation, and hands-on learning (Van Cutsem et al., 2020). The project recommends the use of locally designed electrical devices in physics classrooms to enhance learners' conceptual understanding, practical skills, problem-solving abilities, and interest in physics and electronics.

INTRODUCTION

For a long time, learners have found it hard to appreciate that the physics they are taught in secondary schools is technically practical and applicable in their daily life (Jamil & Muhammad, 2019). This has been due to the fact that most physics teachers focus on teaching students solely to pass exams instead of equipping them with basic technical skills and knowledge to exploit the physical environment as well as national development and capability for continued learning. The main focal point on the project work is on rectification of A.C voltage to D.C voltage. Much emphasis has been laid on the details for electronic component devices and circuits in the above-mentioned subject which most physics teachers tend to leave out yet it is very crucial in the practical world of the teachers (Wang et al., 2019).

Statement on the Problem

Enabling students to acquire and develop knowledge in physics and use it to understand and solve the emerging needs of society has not been emphasized because of knowledge in the theoretical and practical aspects in semi-conductor electronics (Wu et al., 2026). This has been manifested by our student's failure to apply the subject so named in small scale industries and social economic development of Uganda. What does the Ugandan physics teacher have to do about this? The answers to this question will be realized after this project work is completed and reported (Tukamuhabwa et al., 2024). The persistent challenge of inadequate practical teaching resources in Ugandan physics education is acutely manifested in the disconnect between theoretical instruction and hands-on application, a gap that directly undermines student performance and interest in science, technology, engineering, and mathematics (STEM) fields. In Kampala and across Uganda, physics instruction often relies on teacher-centered methods, such as lectures and textbook diagrams, due to a critical shortage of functional laboratory equipment and instructional materials (Aidoo, 2025).

This scarcity was recently highlighted by widespread panic among schools struggling to source specific focal lenses for practical exams, a situation that places students at an immediate disadvantage (Yu & Xie, 2026). While universities like Gulu have invested heavily in modern lab equipment, and initiatives like the Rotary Club's donation of science apparatus to schools such as Mackay Memorial College in Nateete provide essential support, these resources remain unevenly distributed and are often inaccessible to the majority of students. The design and construction of a locally-relevant AC to DC converter for charging electronic devices, intended for use as instructional material in a Kampala physics classroom, directly addresses this problem (Uboh et al., 2026). It provides a tangible, low-cost, and relatable model for teaching fundamental physics principles like rectification, as outlined in the four-step process of transformation, rectification, smoothing, and regulation. Furthermore, the project resonates with Uganda's growing emphasis on homegrown technological innovation, as seen with initiatives like the Kayoola electric bus, by enabling students to build and understand a device that solves a daily problem charging devices thereby fostering both conceptual understanding and practical engineering skills (Aghimien & City, 2025). Therefore, this project is not merely about building a functional charger but about creating a sustainable pedagogical tool that bridges the gap between theory and practice, thereby enhancing student engagement and addressing the critical shortage of hands-on learning resources in Kampala's physics classrooms.

Purpose of the Project Work

This project work is meant to help students and lecturers to adequately dig deep into semi-conductor electronics compared with the vacuum tube electronics counter parts in rectification.

This design of the project work successfully emphasized the importance of teaching approaches to be used for each concept from among the general approaches given by various scientists, writers and teachers. Breakdown approaches with which learners can embrace group or individual participation.

The Objectives of the Project Work

To promote scientific and technical skills and attitudes needed to promote the use of semi-conductor electronics physics in small scale industrial development.

To contribute to the building of the integrated self-sustaining and independent national economy especially through physics.

To inculcate a sense of originality and creativity in physics students through group activities in educational institutions and the community.

To nurture the students with knowledge that can boost the socio-economical development of our nearly technologically impotent country.

To equip individuals with knowledge to develop personnel skills of problem solving, information gathered and interpretation.

The Scope of the Study

This project work and report puts one's emphasis on the bridge-rectifier which provides full wave rectification. This bridge rectification goes a long side with different electronic components. However, special attention has been put on the design and fabrication of various electronic components into a circuit.

The Significance of the Study

This project is intended to cause a wave of change in technological approach which physics lecturers and students have been using to tackle semi-conductor electronics especially as centred on rectification as a topic. This in turn will generate indispensable capability of Ugandan students to take and solve questions relating to the subject so named.

LITERATURE REVIEW

Most of electronic devices and circuits require a D.C/Voltage source for operation. Dry cells and batteries are one form of D.C source. They have advantages of being portable and ripple free. However, their voltage needs replacement and are expensive as compared to connectional D.C/Voltage power suppliers (Mohan & Raju, 2022). Since the most convenient and commercial source of power is domestic A.C/Voltage supply from UMEME, it is advantageous to convert A.C/Voltage into D.C/Voltage. For Uganda, A.C/Voltage power supply ranges (220Vrms-240Vrms). The process of converting A.C voltage into D.C voltage is called Rectification is accomplished with the help of;

(i) A rectifier (semi-conductor or vacuum diode)

(ii) Filter (capacitive, inductive or pie fliter)

(iii) Voltage regular circuit

Rectifiers are incorporated in domestic appliances like Mobile phones, chargers, laptops, radios, televisions, computers ex-ce-tra.

In "O" and "A" level physics, we put emphasis on single phase half wave rectifiers. Single phase full wave centre tapped and full half wave bridge rectifiers. In this project work, I have tried to put the use of semi-conductor diode rectifiers in the lime light due to the fact that vacuum diode has become absolute as is to be inscribed below;

(i) Semi-conductor diode is light

(ii) Their power consumption is relatively low

(iii) They are expensive

The Project Design

The semi-conductor diode

This basically refers to solid state electronics device that is made up of a P-n junction which allows unidirectional current flow of electronics current.

P-type impunity material of the diode is the Anode while n-type impunity material is the Cathode.

In its external appearance, it looks like a very small resistor where the cathode end may have a colored band to indicate that current will go at that end as illustrated below;

current

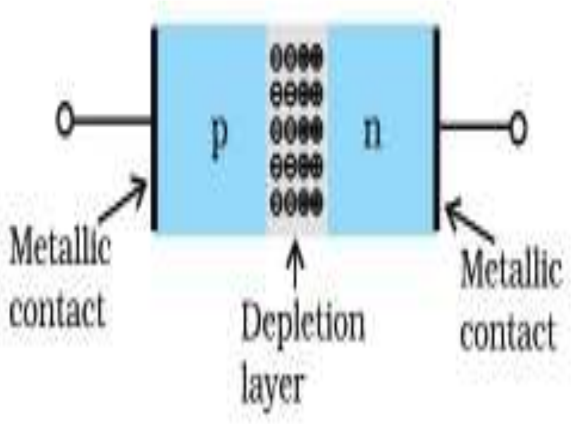

Fig. 2.1 Semi-conductor arrangement

Figure 2.2: Showing Circuit symbol

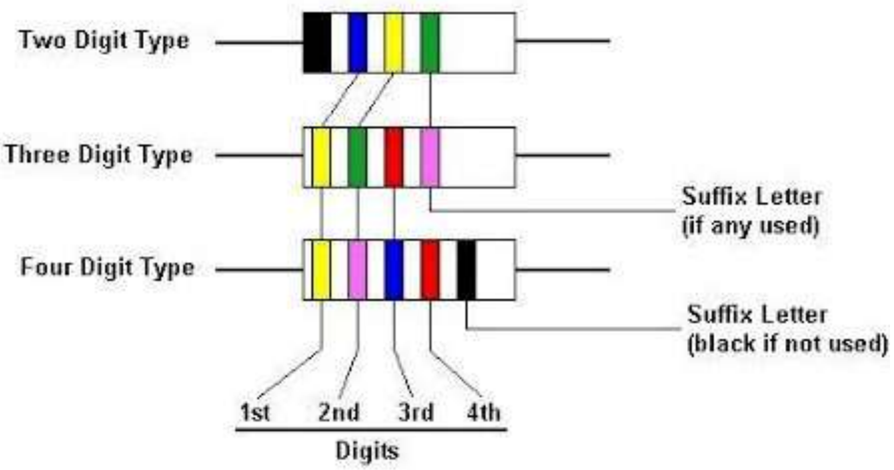

Figure 2.3: Showing Colored Band

The Bridge Rectifier (With Filter and Stabilizer)

It is the most frequently used circuit for electronics D.C/Voltage power supplies that is digital volatile disco (DVD), Television, Subwoofers, radios, Mobile phone chargers ex-ce-tra. This type requires four diodes but the transformer used is centre-tapped and has maximum voltage Vmax.

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Below is my basic circuit design for above named (it includes filter, voltage regulator)

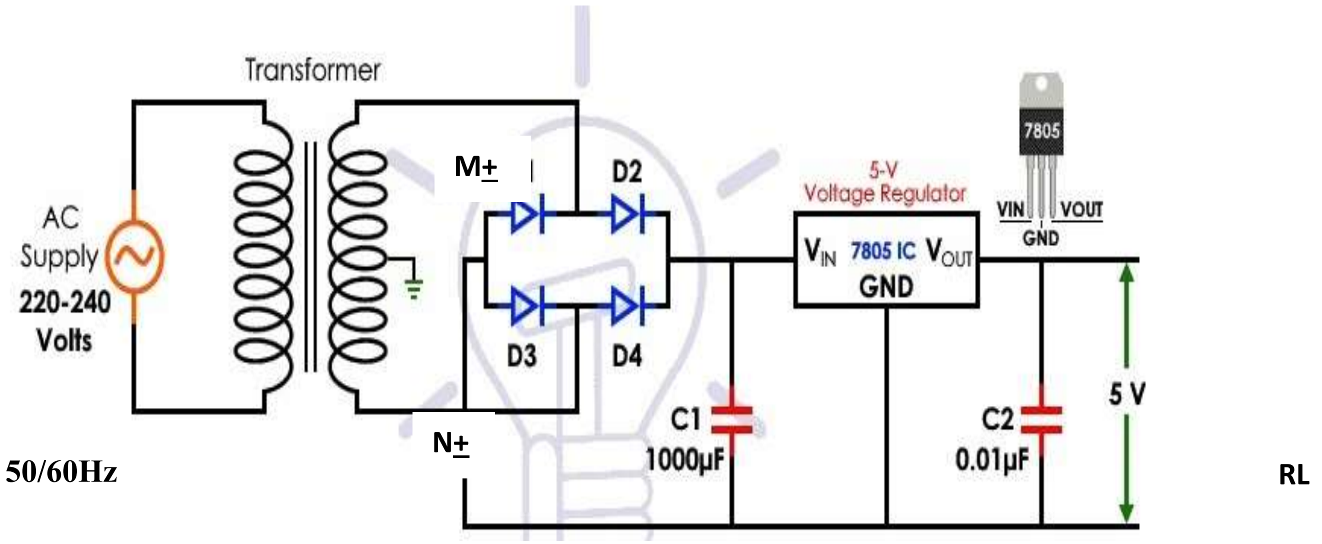

Figure 2.4: Showing basic circuit design for above nan 63V ncludes filter, voltage regulator)

During the positive half cycle, terminal M of the secondary is positive and N is negative. Diode D2 and D4 becomes forward biased (ON) whereas D1 and D3 reverse biased (OFF). Hence current flows along the whole circuit producing a drop in voltage across RL (Lod Resistor).

Some of electronic components to be assembled in the project design

Figure 2.5: Some of electronic components to be assembled in the project design

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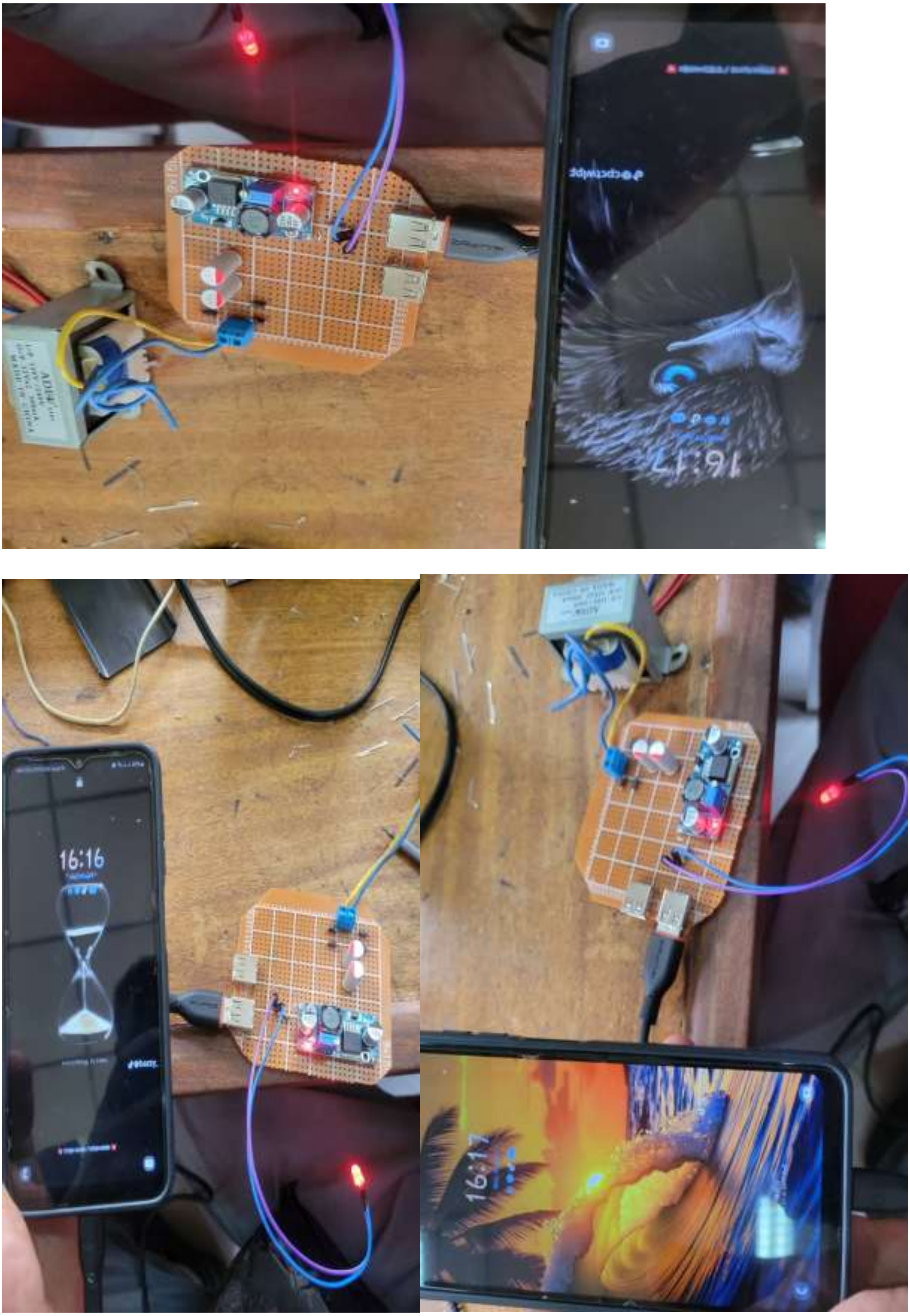

Figure 2.6: Showing physical Circuit Designing Process and testing

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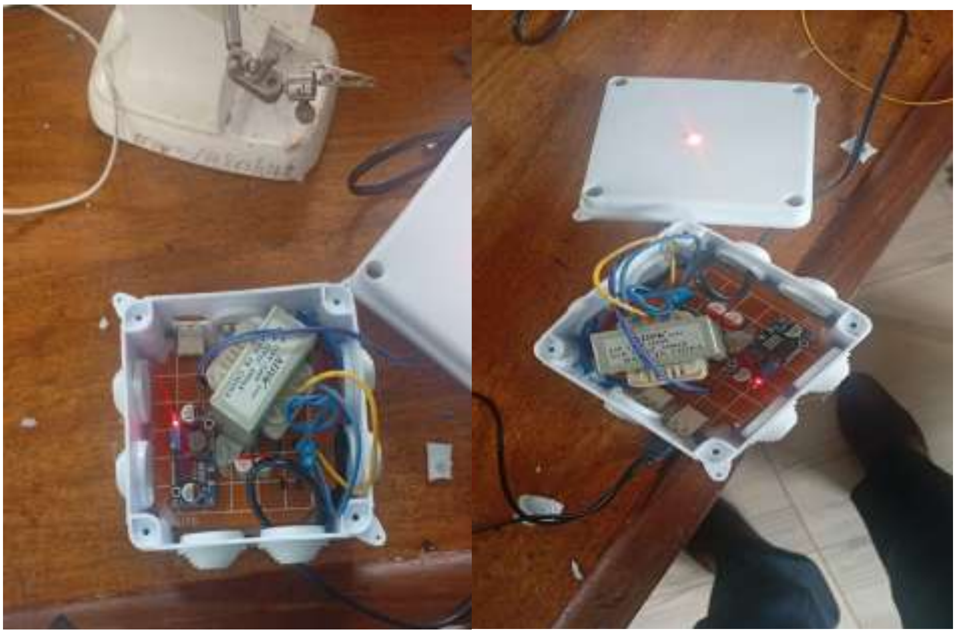

The Internal Outlook of the final Designed Project

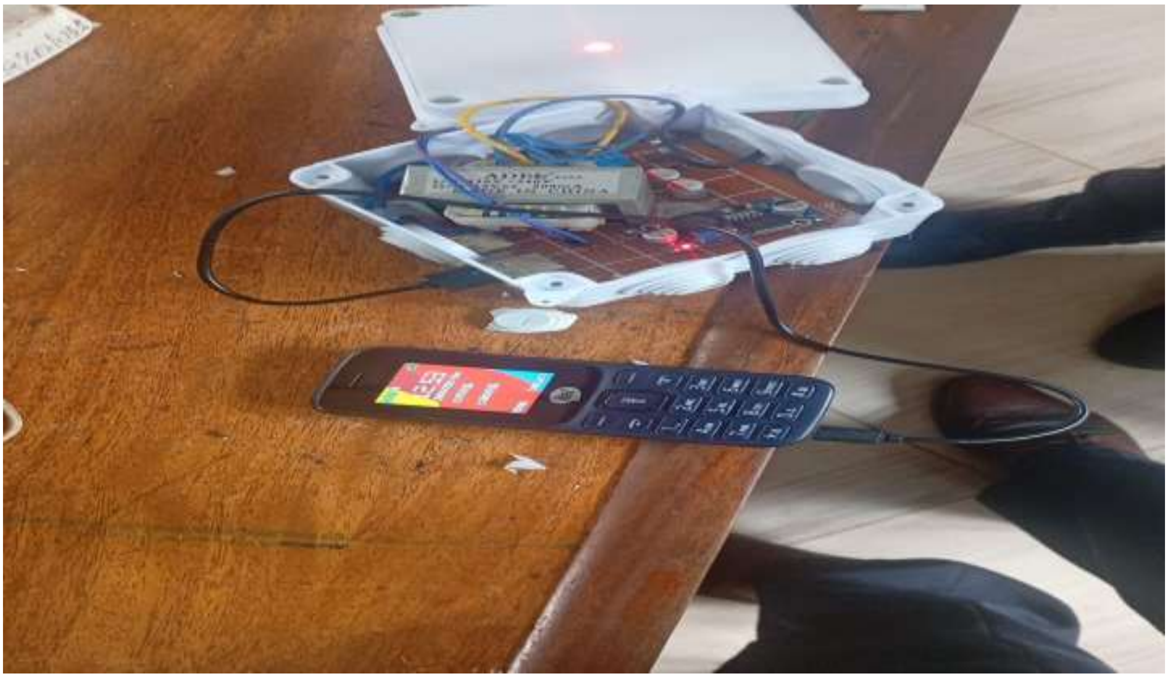

Figure 2.7: Showing the Internal Outlook of the final Designed Project

The Instrument for the Project Work and Design (Electronic Components)

The project work and design consist of the following electronic components used; 4 semi-conductor power, 1 lighting emitting diode, 1 power capacitor, 1 step down transformer, 5 phone charging pins, 1 power cable (240 Vrms), 4 RJ resistor, 2 heat sinks, 2 field effect transistor (FET 252), 1 plastic adaptable mould box, which is used in the completion of my project work and design.

Procedures for Project Design

In my design, I stepped down 240 Vrms A.C/Voltage to 3V using small transformer, whose output I rectified using three heavy duty power diodes and two light-duty power diodes that were equivalent to one duty diode. These were soldered into a bridge using a 30w soldering iron and soldering wire.

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The output of the bridge was directed to the two FET (Field Effective Transistors) to work as regulators instead of Zener-diode because I wanted to smoothen D.C/Voltage that would charge phones ranging from Motorola C113, Nokia 3310, Erickson and Samsung E1075 to Blackberry. The power code I used is that of radio and I fixed a light emitting diode to show the user that power is either ON or OFF. I incorporated all those components in plastic light duty mould box used by electricians for domestic electric installations.

The 4RJ resistors was intended to reduce on the voltage drop across the FETS (Field Effective Transistors), since the transformer was delivering 9V. the capacitor used was 1000 NF63V polarized power smoothening capacitor. On the output terminals of the regulating power supply unit. I fixed 5 large pins on which adaptable male pins of nay phone can be affixed to effect commercial charging.

DISCUSSION ON THE PROJECT WORK

In A.C Voltage main transistor receivers, diodes are used to rectify the altering mains voltage and to produce steady D.C/Voltage needed for the circuit in the receiver.

The bridge circuit is the one to produce full wave rectification whereby four diodes are used and the action is similar to the one used in measuring voltage with a moving coil meter. Using transformer, the main A.C/Voltage between M and N is supplied to the circuit. On one half of a cycle when M is positive relative to N, only the diode D1 and D3 conduct, on the other half of a cycle the diode D2 and D4 as seen in project diagram before.

The varying A.C Voltage is the rectified and rectification is said to have occurred. The large electrolytic capacitor C is used to produce a large and fairly steady D.C Voltage. C charges up to the peak value of the applied A.C Voltage and then discharges through RL when the voltage begins to decrease. If discharge takes place slowly, then C becomes recharged to the peak value of the voltage gained.

The charge-discharge takes place continuously & so the voltage across the C-RL combination is a ripple voltage. The two field transistors were used to regulate the voltage instead of Zenner-diode in order to smoothen the D.C Voltage for charging phones. The 4JR resistor was intended to control the voltage drop across FET'S since the transformer was delivering 9V.

A Graph for the Voltage Output (D.C Voltage)

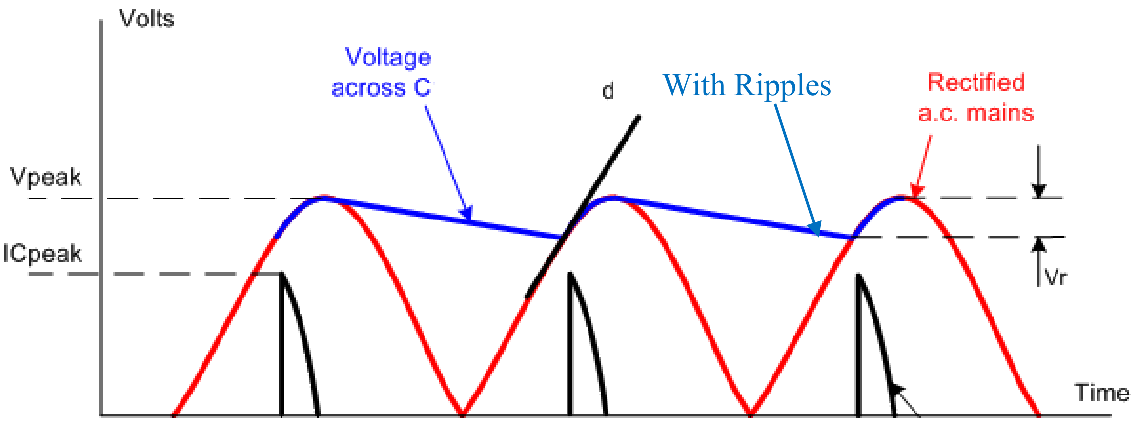

Figure 3.1: Showing A Graph for the Voltage Output (D.C Voltage)

Conclusion on Project Work

Advancement in technology being one of the main facts that can sky-rocket economic development through teaching and appreciating scientific research, I am certain that if government embraces allocations of some funds for school project work, research will take us to new horizons. Therefore, government should put more emphasis on practical subjects (disciplines) than theoretical ones in order for the country to move to the next

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level.

Recommendation of the Project Work

- To the Head teachers; these should endeavor to facilitate teachers such that they can research more on topics that are very crucial to the development of technology in Uganda
- To Physics department heads; these should always put to good use the available resources as in text books and physics equipment for research to help their teachers get to the next level.
- The Ministry of Education and Sports should endeavor to provide more science equipment and textbooks alongside computers with programs like Microsoft Encarta Students to help students research better.
- Parents or staff should embrace the concept of building young dream weaves by encouraging their children wherever they use their school knowledge to bring new ideas in science for example encouraging them to make homemade toys, other than buying them from the shops.
- The District Education Officer and District Inspectors of Institutions should ensure that qualified, registered and committed teachers are available in institutions to play their respective roles especially in the practical aspects.
- National Curriculum Development Centre; these should include in institutions curriculum more practical parts in science disciplines rather than theoretical parts. This can be made by using qualified and experienced teachers in amending the curriculum.

APPENDICES

Limitations and Delimitations

(a) Limitations

I encouraged different problems like financial constraints, power black outs when I was soldering and testing. This was accompanied by inflation which saw the prices of various electronic components rise and eventually components like student's project per-board, I ended up not using it in order to minimize some costs.

(b) DELIMITATIONS

This project work alerted me on how to use advanced facilities like internet. I also met engineers in the field of electronics and telecommunications from whom I consulted where I was astray. I learnt how to put my time to good use by balancing research and University curriculum. This enabled me to be busier than idling around the college.

REFERENCES AND BIBLIOGRAPHY

1. "A" Level Physics by Nelkon and Parker, 5th Edition Page 766 and 773
2. Aghimien J. & City, B. (2025). Inquiry-Based Learning in Enhancing Students' Performance in Physics: A Case Study of Selected Secondary Schools in Ovia North East Lga, Edo State Nigeria.
3. Aidoo, D. S. (2025). Science teachers' competencies in teaching the physics aspect of Integrated Science as seen by Junior High School pupils (Doctoral dissertation, University of Education, winneba).
4. Bano, F., Rizwan, A., Serbaya, S. H., Hasan, F., Karavas, C. S., & Fotis, G. (2024). Integrating microgrids into engineering education: Modeling and analysis for voltage stability in modern power systems. Energies, 17(19), 4865.
5. Basic Electronics for Scientists and Engineers by Dennis L. Eggleston, Cambridge
6. Electronic Device and Circuit by B.L. Theraja, Page 98 and 108

7. Jamil, M., & Muhammad, Y. (2019). Teaching Science Students to Think Critically: Understanding Secondary School Teachers' Practices. Journal of Research & Reflections in Education (JRRE), 13(2), 256.
8. Low, Q.W., Zhou, M. & Siek L. (2018). A single-stage direct-conversion AC–DC converter for inductively powered application. IEEE Transactions on Very Large-Scale Integration (VLSI) Systems, 26(5), 892-902.
9. New Complete Junior Physics by A. Atkinson, 5th Edition, Page 126 and 127
10. Tukamuhabwa, E., Kishabale, B., & Lubaale, G. (2024). SESEMAT pedagogical approaches and physics teacher effectiveness in kigezi sub-region, uganda.
11. Uboh D.E., Sunday E.S. & Utibe U.J. (2026). Effect of Blended Instructional Strategies (Cooperative, Inquiry-Based and Demonstration) on Students' Academic Achievement in Physics in Ikot Ekpene Senatorial District, Akwa Ibom State, Nigeria. Pedagogy Forward, 2(2).
12. Van Cutsem, T., Glavic, M., Rosehart, W., Canizares, C., Kanatas, M., Lima, L., ... & Vournas, C. (2020). Test systems for voltage stability studies. IEEE Transactions on Power Systems, 35(5), 4078-4087.
13. Wang, K., Zhou, B., Zhou, X., Jiang, S., & Wei, J. (2019). The output voltage control strategy for DSEG with controlled rectification based on conduction angle estimation. IEEE Transactions on Industrial Electronics, 67(5), 3350-3360.
14. Wu X., Deng W., Zhao S. & Zhou M. (2026). Course Development for "Semiconductor Device Physics" in New Engineering Education. In Exploring Innovations in Educational Technology: The ICEIT'25 Collection: Advancing Knowledge and Practice (pp. 215-223). Singapore: Springer Nature Singapore.www.google.com Microsoft Encarta Student Version 2010
15. Yu, J., & Xie, A. (2026). Reimagining the illusio of meritocracy: Affective and reflexive reconfigurations in rural students' transition to elite universities. Higher Education, 91(5), 1741-1756.