INTERNATIONAL JOURNAL OF RESEARCH AND INNOVATION IN APPLIED SCIENCE (IJRIAS)
ISSN No. 2454-6194 | DOI: 10.51584/IJRIAS | Volume VIII Issue V May 2023

Design and Construction of a Digital Logic Training Module for Laboratory Experimentation

B. N. Ben-Festus[1], M. O. Osinowo[2], and Ben Festus[1]

[1]*Department of Physics with Electronics, Federal Polytechnic Ede, Osun State, Nigeria*

[2]*Department of Physical Sciences, Redeemer's University Ede, Osun State, Nigeria.*

DOI: **https://doi.org/10.51584/IJRIAS.2023.8511**

Received: 12 April 2023; Accepted: 28 April 2023; Published: 18 June 2023

Abstract: A Digital Logic Trainer is used to train students on experimental verification and implementation of basic logic gates. This research work describes a digital logic training (DLT) module designed and constructed using semiconductor components such as diodes, transistors, and integrated circuits. The DLT module can be used to verify logic gate theorems including Boolean expressions, combinational logic designs and Karnaugh's reduction techniques for a given logic circuit. The front panel of the DLT module comprises of different Boolean symbols for easy logic gates identification and operates effectively on a 5 V DC rectified from a 220 V AC power supply. The DLT module performs favourably well when compared with commercially available types and comes at a lower production cost.

Index Terms: Logic Trainer, Training Kit, Boolean Algebra, Semiconductor, Logic gates

I. Introduction

The Polytechnic education in Nigeria is designed to fill the technical manpower gap of the country, a factor which is largely responsible for the large unemployment statistics witnessed in Nigeria presently (Okwelle and Wordu, 2016; Ibrahim, 2021). Quality technical education requires a good mastery and replication of basic experimental designs as opposed to theoretical knowledge only. However, for a developing country like Nigeria with poor education funding, access to scientific equipment to facilitate learning in line with the Technical Education Vocational Training (TVET) objectives will only be a mirage (Ajao *et al*., 2014). One way to address this wide gap in the Nigerian Education System is for Scientists and Technologist to develop science training equipment using basic science theories with the aim of improving assimilation, mastery and good understanding of the subjects being taught. One of such approach is what this study aims at.

Digital logic can be described as the building block on which digital systems functions be it in computing, or electronics are founded (Richard *et al*., 2004; Sparkfun, 2018). A good understanding of sequential and combinational circuits, gates, decoders, counters, amongst others requires a thorough understanding of the digital logic concept. Digital logics are best understood using experimentation techniques as it is difficult for most students to grasp the importance of digital zeros and ones in real life applications. Module is one of the most used scientific tools to aid understanding of digital logic concepts by students (Alasdoon, 2013; Rizzoni, 2004).

Substantial efforts geared at fabricating digital logic training modules has been reported in literature (Hacker, 2009; Godwin *et al*., 2013; Tao *et al*., 2012; Manfrini *et al*., 2014; Ajao *et al*., 2014; Ajao *et al*., 2015; Mallikarjun *et al*., 2017). This clearly shows the global acceptability that the use of modules is very important science teaching aids in understanding digital electronic circuits. However, with digital technologies evolving over the years (Brown & Vranesic, 2005) driven by advancement in computing, the cost of obtaining digital logic trainers continues to rise out of reach of Nigerian educational institutions, thus creating a dire need within the educational system. In this study, a digital logic trainer is fabricated for the purpose of giving students an opportunity to understand basic concepts of logic gates, and semiconductor technology most especially the use of diode for rectification.

II. Materials and Methods

The digital logic training module fabricated in this study made use of different categories of electronic components such as semiconductors, resistors, capacitors, transformer, switches, probe connectors, and potentiometers. The casing of the training module was made of wooden material with a dimension of 550 mm x 425 mm. Pyrex glass material with marking diagram was used as the top cover of the training module for easy identification of electronic components by the trainees. Other subsections of the training module are discussed below.

a. Power supply unit

ISSN No. 2454-6194 | DOI: 10.51584/IJRIAS | Volume VIII Issue V May 2023

Figure 1 shows the circuit diagram of the power supply unit designed in this study. Electronic components including 12 V 900 mA transformer, rectifier, fuse, voltage regulator, and capacitor was used to convert 220 V AC mains voltage to rectified DC supply voltage used by the training module. Rectification which involves the conversion of the step-down AC voltage to the corresponding root mean square (RMS) DC value was performed with the aid of four 1N4001 diodes arranged in a full-bridge mode. 1000uF electrolytic capacitor was used to filter the power supply to give a clean and stable DC voltage while LM7805 and LM7808 voltage regulator was used to supply a steady 5 V and 8 V DC voltages to the appropriate circuits.

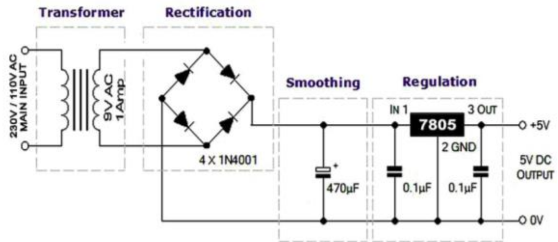

Figure 1: Schematic diagram of the power supply section

b. Logic circuit

CD4081BE, MC14069UB, and CD4070BD integrated circuits were used to design the OR, AND, NOT, NOR, NAND, and XOR combinational logic gate circuit as depicted in the functional diagrams shown in Figures 2, 3 and 4 respectively. Two probe sockets were used at the input end of each logic gate with one probe socket connected to the output of the gates.

CD4511BCN and CD4518BD integrated circuits were used to design the counter and decoder sections respectively for implementing the seven-segment display section with each IC section having four probe sockets each while sharing the same probe socket for the clock pulse input triggered by a frequency selection knob powered by the NE555 timer integrated circuit shown in Figure 5. Input signals for all the gates used are supplied through electrical signals from the manually toggled switches located on the module.

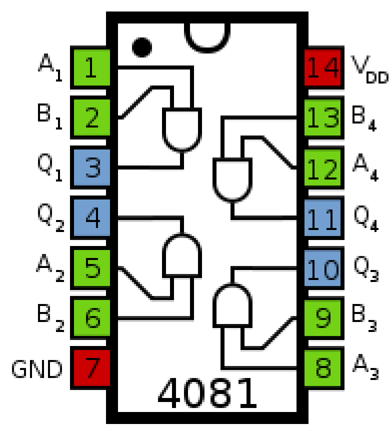

Figure 2: Functional diagram for implementing basic logic gates using 4081 IC

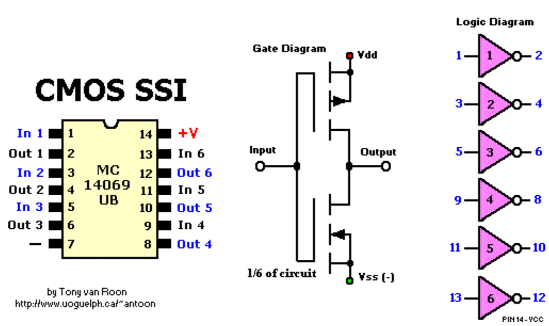

Figure 3: Functional diagram for implementing NOT gate using 4069 IC

ISSN No. 2454-6194 | DOI: 10.51584/IJRIAS | Volume VIII Issue V May 2023

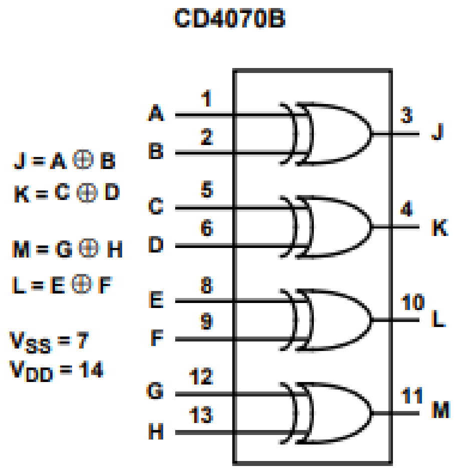

Figure 4: Functional diagram of CD4077 for implementing XOR logic gates

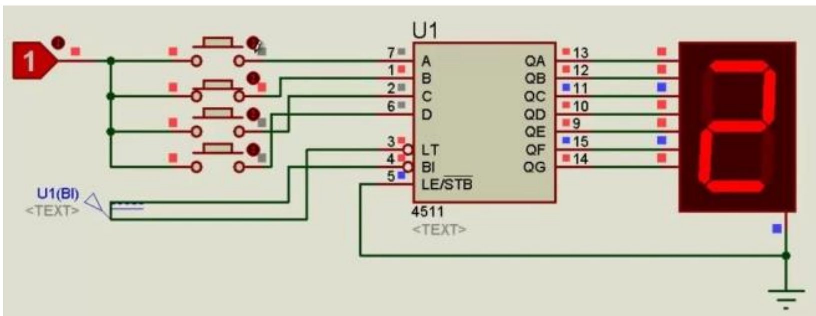

Figure 5: CD4511 BCD Seven-Segment Display Circuit Diagram

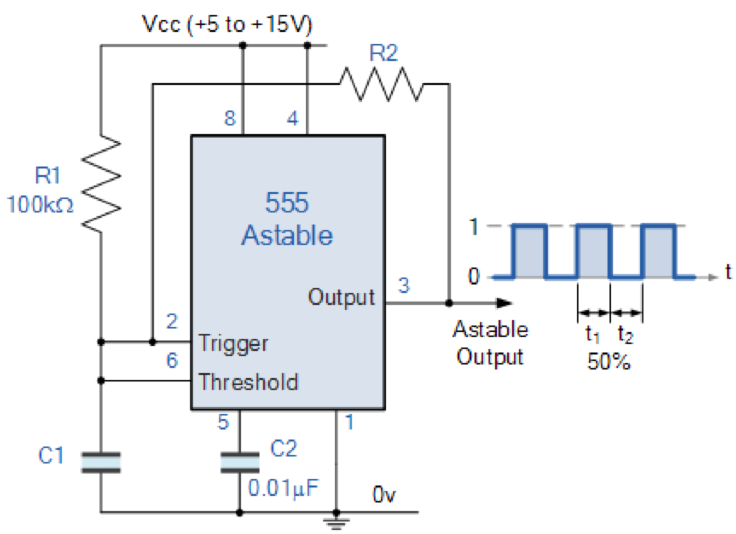

Figure 6: NE555 timer signal generating circuit diagram

c. Transistor circuit

To demonstrate the difference between PNP and NPN transistor types on the logic training module, eight (8) 2N2222A signal transistors were used. Common collector, common emitter and common base transistor amplification circuits were equally implemented on the logic training module using three BC547 transistors, 22uF capacitors, 330R and100R resistors as shown in Figures 7, 8 and 9.

ISSN No. 2454-6194 | DOI: 10.51584/IJRIAS | Volume VIII Issue V May 2023

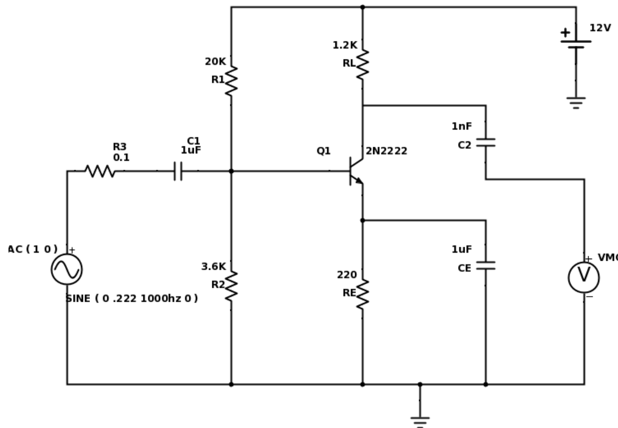

Figure 7: Schematic diagram for common emitter transistor configuration

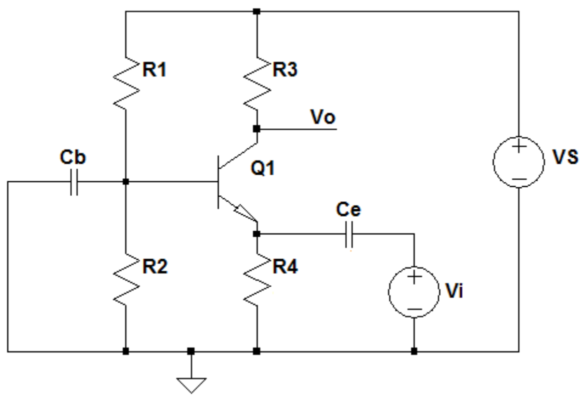

Figure 8: Schematic diagram for common base transistor configuration

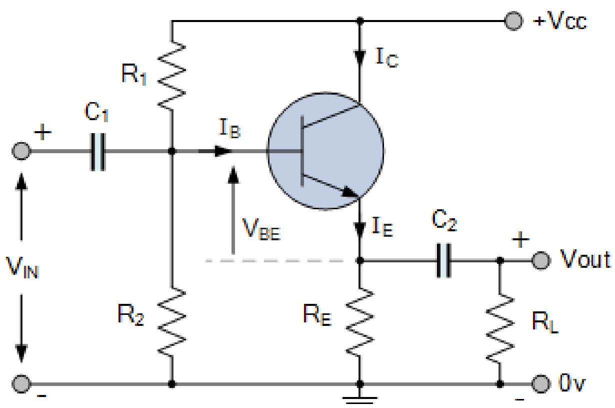

Figure 9: Schematic diagram for common collector transistor configuration

d. Diode and Rectification Circuit

Diodes are known as semiconductor components that allow electrons to flow in one direction only known as forward bias while preventing electron flow in the opposite direction known as reverse bias. In this study, four IN4004 diodes were implemented in the training module. Additional four 1N4004 diodes were also implemented to demonstrate the rectifying properties of a diode in full-bridge mode as shown in figure 10.

ISSN No. 2454-6194 | DOI: 10.51584/IJRIAS | Volume VIII Issue V May 2023

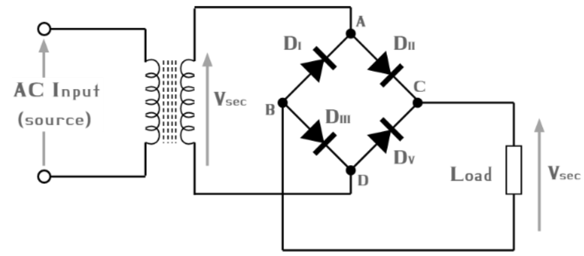

Figure 10: Schematic diagram of a Full-bridge Rectifier using Diodes

e. Voltage Regulator and Operational Amplifier

The training logic module also has a voltage regulator training section as well as an operational amplifying section. LM7805, LM7808, and LM7809 voltage regulators transistor were used to implement voltage regulation from 12 V to 5 V, 8 V, and 9 V respectively. Four probe sockets at the input allows the user to connect rectified DC voltage ranging from 9 V to 48 V at the transistor input while a probe socket is connected at the output to which probes of appropriate voltage loads can be connected. LM358 integrated circuit on the other hand was used to demonstrate the inverting and non-inverting characteristics of an operational amplifier (Op-amp) with two probe sockets available at the inverting and non-inverting end of the Op-amp and one probe socket at the output end.

III. Results and Discussion

Figure 11 shows the fabricated logic training module having different demonstrating sections namely, the logic gate training section, transistor amplification section, decoder and counter section, diode and rectification section, voltage regulation and operational amplifier demonstrators. The entire board is powered by a 5 V DC rectified AC mains power supply. Light emitting diodes are used as indicators for the verification of the truth table of each logic gate being studied. The digital logic trainer presented in this study is an improvement over the works of Myo and Zaw (2014) which uses 74HC IC series for experimental verification of the logic gates.

Figure 11: The Fabricated Digital Logic Training Module

The use of probe sockets is such that trainees can plug in probe connectors both at the input and output for experimental verification, connection to an external supply as well as connection of an electronic component directly. For example, when demonstrating rectification, trainees can connect external power supply through a step-down transformer to the training module while also connecting probe sockets to the four different terminals of the full bridge rectifier diodes. Output from the bridge rectifier diodes can subsequently be connected to an oscilloscope to view the output signal or to power a DC load.

In demonstrating the functionality of the fabricated logic trainer, different experimental procedures ranging from verification of truth table for different logic gates, conversion of alternating current to direct current using diodes, forward and reverse bias action of diodes, to transistor amplifications was performed. Performance output of the digital logic training module fabricated in this study agreed with results obtained using both theoretical expectations and commercial logic training modules. The module works

ISSN No. 2454-6194 | DOI: 10.51584/IJRIAS | Volume VIII Issue V May 2023

with low voltages of 5 V, 8 V and 9 V therefore, no internal heat due to excess current is generated and performs very well under environmental temperatures below 85 o C.

IV. Conclusion

In this research work, a digital logic training module has been fabricated using basic electronic semiconductor components. The fabricated device allows science teachers to explain theoretical concepts related to logic gates, transistors, diodes, and operational amplifiers using easy to demonstrate practical kit. The digital logic trainer is also easy to use and comes at a low-cost compared to commercially available types while performing efficiently as the commercial variants. This logic training module will no doubt help students gain better practical knowledge of the use and application of basic semiconductor components and enhance their understanding of basic electronics and digital electronics courses offered in Science Laboratory Technology Departments at various Nigerian Polytechnics including but not limited to Physics Departments and Electrical Electronics Engineering Departments in Universities and Colleges of Education.

References

1. Alasdoon A. (2013). A Recent Survey of Circuit Design Tools for Teaching, Proceedings of WCECS, Vol 1. 23-25, San Francisco, USA.
2. Ajao L. A., Olaniyi O. M., Kolo J. G., Ajao A. O. (2015). Project-Based Microcontroller System Laboratory Using Bk300 Development Board with PIC16F887 Chip, International Journal of Embedded Systems and Applications, 5(3): 15-28
3. Ajao A. O., Kadiri K. O., Bamgboye O. O. (2014); Local Fabrication of Digital Logic Trainer for Laboratory Demonstration. International Journal of Innovation in Science and Mathematics, Volume 2(1), pp. 43 - 46
4. Brown, S. and Vranesic Z. (2005); Fundamentals of Digital Logic with VHDL Design, (2nd Edition) New York: Mcgraw-HillCompanies.
5. Godwin U. O., Inyiama H. C., Chidiebele U. C., Ekene M. S. (2013). Microcontroller Based Real-Time Emulator for Logic Gate and Structured Logic Devices, International Journal of Science and Technology, 2(8).
6. Hacker C. (2009); A Low-Cost Student Constructed Digital Trainer. Conference Proceedings, AaeE, Adelaide.
7. Ibrahim W. (2021); NBTE, Polytechnics to address unemployment by creating vocational skills training. Accessed on July 1, 2022 from https://www.vanguardngr.com/2021/07/nbte-polytechnics-to-address-unemployment-by-creating-vocational-skills-training/
8. Mallikarjun. G. H., Swati I. K., Sneha S. G., Basamma B., Vivek M. N. (2017); Digital Logic Gate Simulation using Arduino Microcontroller. Journal of Control System and Control Instrumentation, Volume 3(1), pp.1-6
9. Manfrini F., Helio J. C., Bernardino H. S. (2014). Optimization of Combinational Logic Circuits Through Decomposition of Truth Table and Evolution of Sub-Circuits, IEEE Congresson Evolutionary Computation (CEC).
10. Myo S. S. T., Zaw M. T. (2014); Development of Digital Logic Trainer for Student's Experimentation. International Journal of Scientific Engineering and Technology Research, Vol. 3(10), Pages: 1912-1916
11. Okwelle P. C., Wordu C.C. R (2016); Challenges of Unemployment among Technology Graduates of Polytechnic Educationin Nigeria.Journal of Scientific and Engineering Research, 3(6):405-409
12. Richard C., Michael B. G., Haldun H., Lubomir I. (2004); The Role of Digital Logic in the Computer Science Curriculum. Panel Discussion. https://www.researchgate.net/publication/240687297
13. Rizzoni G. (2004); Principle and Application of Electrical Engineering (Revised Fourth Edition). New York: Mcgraw-hill Companies, Inc.
14. Sparkfun (2018); Digital Logic. Accessed on July 1st, 2022 from https://learn.sparkfun.com/tutorials/digital-logic/all
15. Tao Y., Cao J., Zhang Y., Lin J., Li M. (2012); Using Module-level Evolvable Hardware Approach in Design of Sequential Logic Circuits, World Congress on Computational Intelligence (WCCI).