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Local Fabrication of Digital Logic Trainer for Laboratory Demonstration

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Abstract – **To understand the operation of digital systems, it is important that the student grasp the basic concepts of digital logic elements. However, the cost associated with purchasing logic training equipment to enable students gain practical experience can be significant. This paper therefore, discuses prototype fabrication of a logic training module and highlights the use as an aid to enhance teaching and learning of digital computer fundamentals. It describes the development of the training kit working through the components of its parts. The practical demonstration of the module for determination of the behaviour of some logic circuit devices is then presented. The result of implementing logic expression using our prototype module is demonstrated and the results show that the module works well as improvising for declining availability of imported version due to their high cost. The performances reported from the module are in encouraging agreement as deployed in standard practice.**

Keywords – **Digital System, Demonstration Kit, Electronics, Local Fabrication.**

I. Introduction

Digital training equipment has become increasingly popular in a wide range of applications. Teaching digital hardware theories and concepts in a practical way to undergraduate students requires both a teaching and learning modality with a laboratory infrastructure. It is a general knowledge that laboratory based activities form a critical component of the overall support for teaching and learning. Digital system is involved in all aspects of modern technology, such as data processing, industrial control, and instrumentation for many fields of science and engineering. Digital electronic circuits and systems are becoming increasingly more complex, yet analysis of such systems will reveal that they are all combinations of simple and basic building blocks.

We believe that students learn computer hardware and organization better if they are given practical learning activities that illustrate the theoretical concepts. However, only a limited range of material designed specifically to supplement the teaching of computer hardware concepts is readily available in our local market for purchase. In relation to vocational education and training (VET), while the need to keep course relevant and up-to-date with the industrial developments might be the ultimate aim, proximate factors such as lack of funds to purchase equipment may interfere.

II. Objectives of the Project

This paper presents a prototype digital training system based on a cheap, readily available IC component. It focused on fabricating a relatively simple, inexpensive, and reliable digital demonstration kit that can be used to support the teaching of computer hardware and organization. It is also intended to facilitate an interactive, hands-on introduction to traditional computer hardware concepts which can be used either in the classroom as a demonstration kit to enhance the traditional lecture environment or in the laboratory to provide practical hands-on experience during digital electronic practical.

III. Motivation of the Project

The polytechnic education is undergoing intensive curricula revision to accommodate the contents and practice required by the standards for technology literacy. The motivation of this project came from the philosophy of engineering curriculum design of the National Board for Technical Education. Most of the course incorporates project and/or laboratory activities as the curriculum has a stronger emphasis on engineering design practice. This approach is intended to help the students to express their thoughts and try out their ideas; to learn the subject matter more deeply, to retain more information of the subject and more importantly their interpersonal skills grow.

IV. Basic Theory of the Project

Digital logic circuits form the basis of all digital hardware which plays a prominent role in most electronic devices used in industrial and domestic application. They are used to build computer hardware, as well as many other types of products which are broadly classified as digital hardware (Rizzoni, 2004). For most digital hardware products it is necessary to design and build some logic circuit from the scratch. Early (Pre-von Neuman) computer systems were often “hardwired” into the circuitry and this computer wiring technique determines what problem the computer would solve (Bywater, 1981).

Computer hardware concepts are described in many references (Englander, 2000; Shelly, Cashman. & Vermaat, 2003; Tanenbaum, 1999), and the logic elements are discussed extensively in the computer hardware literature (Mano, 1979; Kimber, 1997; Ajao & Onawola, 2003; Brown & Vranesic, 2005). A digital logic circuit comprises a network of logic gates. Each logic gate performs a very simple function and more complex

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operations are realized by connecting gates together (Mano, 1979). A number of sophisticated modules exist for building a variety of digital logic circuit. However, these powerful tools are usually very expensive due to Nigeria economy.

In order to use logic circuit to build subsystems, some knowledge of their operation is required together with an awareness of variety of complex functions integrated-circuit (ICs) available. Almost all the introductory textbooks for digital system and design used in most of the undergraduate engineering courses have focused on construction rules and properties of digital devices (Adeife-Osemeikhian, 1996; Ajao & Onawola, 2003; Brown & Vranesic, 2005; Mano, 1979; Rizzoni, 2004). The technology used to build digital hardware has evolved dramatically over the past four decades (Brown & Vranesic, 2005). Despite the advance in computer architecture, the approach to teaching the fundamentals of digital logic remain almost the same as that which was used in the 70's and 80's. The educational benefits of digital trainer kit are promising most especially for undergraduate electrical, electronic and computer engineering as well as computer science disciplines. Many commercial digital trainer kits are available. Unfortunately, most of the training kits hitherto used to conduct digital experiment are usually imported and also very expensive due to exchange rate of our currency during importation.

V. Materials and Method

Materials

The materials used for the digital trainer consist of a patch panel equipped with plug connectors for the purpose of constructing electronic circuits without the need for soldering the components. The device can be used and reused for several configuration of digital electronic circuit. The required integrated circuit (IC) chips for the module where carefully selected using the TTL logic data book (Texas Instruments, 1988). The IC names, identification number, and description available in "packages" are summarized in

Table 1. A list of other devices used on the module includes transformer, switches, capacitors, resistors, transistors, diodes, segment display, probe and PCB cards. The ICs containers provide input and output pins or connections which are interconnected by plated strips on circuit board, wires or other means to form complete devices. The inputs and outputs are numbered, and each number refers to as an external pin on the IC container. A ground connection and a positive power voltage are both required from each container.

Table 1: Parts list of IC components used

S.No.	Description of Components	Device No	Quantity Used
1.	2-input OR gate	74LS32	5
2.	2-input AND gate	4002	5
3.	2-input NAND gate	74LS00	5
4.	2-input NOR gate	74LS20	5
5.	2-input XOR gate	74LS86	5
6.	3-input OR gate	74S04	6
7.	3-input AND gate	7476	6
8.	3-input NAND gate	4082	6
9.	3-input NOR gate	74L05	6
10.	Dual 4-input NAND gates	7420	10
11.	Dual J-K FFs	7476	10

Methods

The components were assembled on a printed-circuit-board (PCB). A template for the printed-circuit board (PCB) that house and connect the chips were designed as shown in

Figure 1. Note that it not to scale. The PCB illustrated in the *Figure 1* accommodates one "AND" chip and the corresponding AND chip pin configuration is illustrated in *Figure 2*. Other components such as transistor, diodes etc were used to form the interface between the ICs and the rest of the module. The placement of the chips and the actual wire connection on the PCB is shown in *Figure 3*.

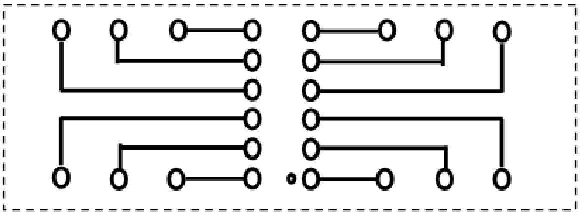

Fig.1. Template PCB Design for an IC Gate

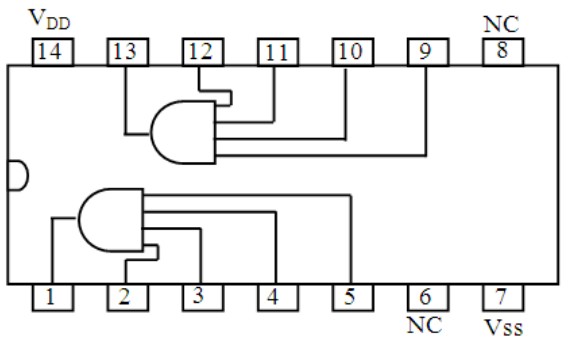

Fig.2. Example of 4082 Dual 4-input AND Gate, V_{DD}=3V to 15 V

The pull-up resistor outputs of some of the ICs require external pull-up resistors for proper logical operation. The value of the pull-up resistor was determined using equations (1) and (2).

$$R_{max} = \frac{V_{CC(min)} - V_{OH}}{N_1(I_{OH}) - N_2(I_{IH})} \quad (1)$$

$$R_{min} = \frac{V_{CC(max)} - V_{OL}}{N_1(I_{OL}) - N_3(I_{IL})} \quad (2)$$

Where

V_{OH} = logic 1 output voltage; V_{OL} = level 0 output voltage

V_{IH} = logic level I input voltage; V_{IL} = logic level 0 input voltage

I_{OH}, I_{OL}, I_{IH}, I_{IL} – similarly

There are many different types of LED lights in the market for emitting red, green, white, or yellow colours. For

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instance, standard red LEDS require about 5 to 10 mA to emit visible bright light. There are also low-current small LEDs operating from as low as 1mA. The required value of the current resistors can be calculated from equation (3) as follows:

$$R = \frac{V_S - V_f}{I_f} \qquad (3)$$

Where Vs is the supply voltage, V_f is the LED forward voltage drop and I_f is the forward current.

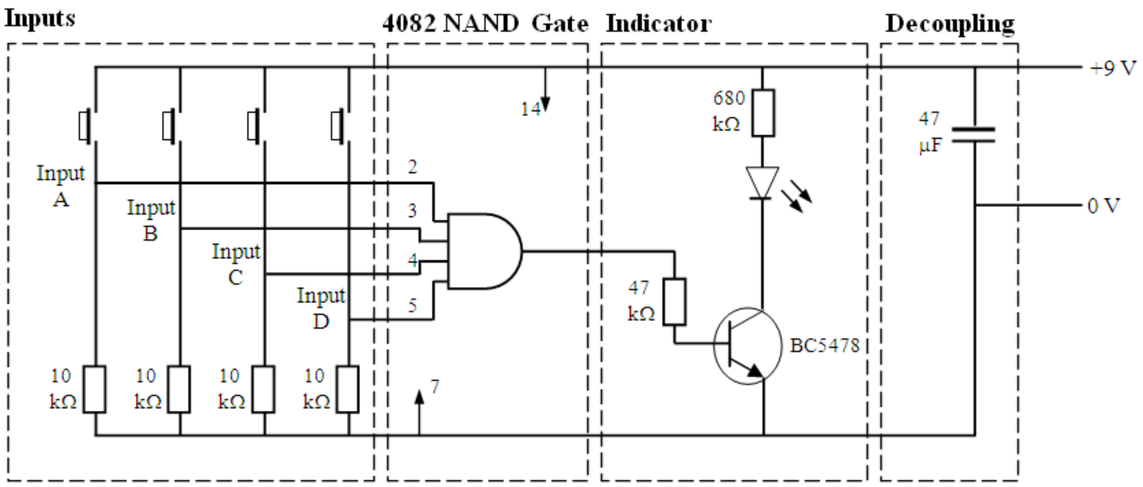

Fig.3. Placement of the IC components and interfacing on the module

VI. Implementation and Results

The diagram of the sectional part of the equipment (*Figure 4*) consists of a patch panel which highlights its important feature. The patch panel consists of a set of sockets connecting a variety of combinational logic element such as AND, NOT, NOR NAND.

Each logic circuit represents one operation during the execution of logic expression. A user could select one of several instructions by plugging a wire into the particular socket for the desired instruction. To build a logic circuit, the user choose the symbol representing the logic element needed and then defines how these elements should be interconnected to realize a larger logic circuit.

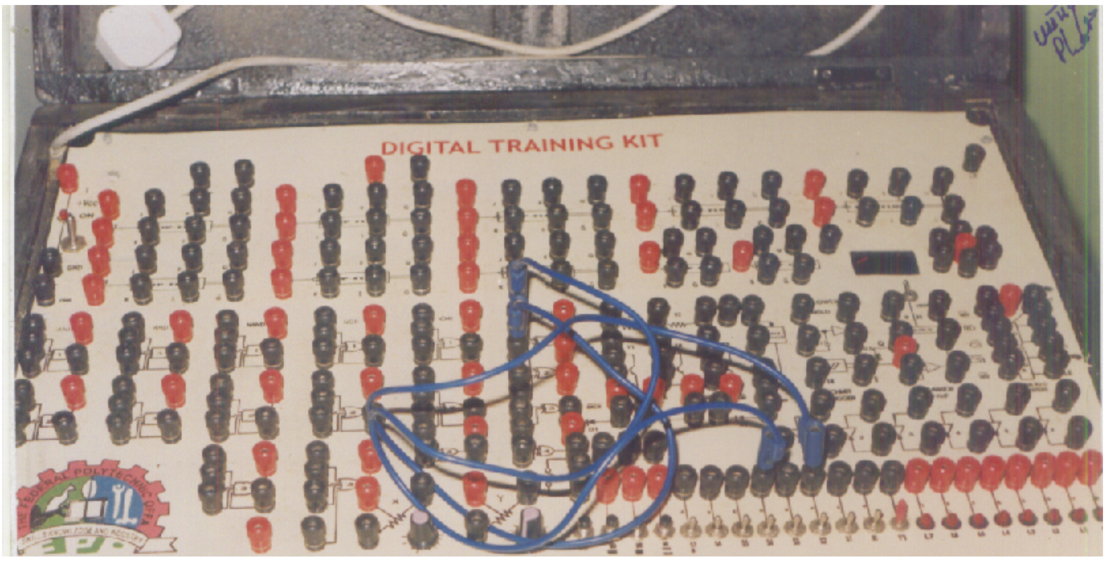

Fig.4. The finished assembly digital circuit demonstration kit

VII. Equipment Testing and Discussion

The effectiveness of the trainer was demonstrated by a couple of practical exercise. The outputs of the experiments were functionally verified against the output of the imported kit. The performance of the imported type and locally made type are favorably comparable. The result indicate that various composition of digital devices: combinational and sequential circuit could be demonstrated experimentally. Here, we describe some experimental results that have been obtained using our digital trainer module. The results are mainly on the digital circuit implementation exercise.

For example, assuming the circuit is to be used to implement the function of equation (4) using combination of NOT, AND, OR gate.

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$f(a,b,c) = \sum m(2,3,4,6,7)$ (4)

First, we derive the sum of product expression of (4) as shown in equation (5).

$$f(a,b,c) = b + a.\bar{c} \quad (5)$$

The circuit that corresponds to this expression is obtained as in *Figure 5*. The circuit diagram is therefore implemented on the patch panel of the demonstration kit as in *Figure 6*. The output of the logic elements are connected to the LED while the inputs are connected to the switches. The LED will output a voltage corresponding to the incoming value (0 or 1) from the switches in the connection which yields a corresponding Truth Table of equation (4 or 5).

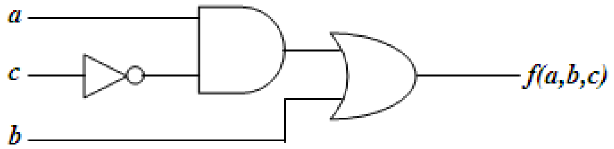

Fig.5. Circuit diagram for equation (5)

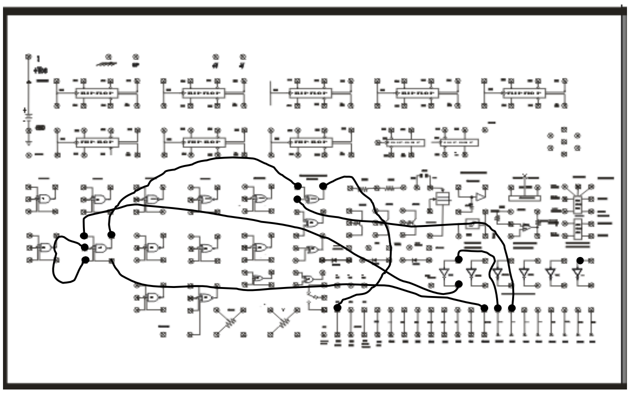

Fig.6. Implementation of Figure 5 on the patch panel

VIII. Conclusion

In this paper, we developed and demonstrated a low-cost and improvised digital electronic training module fabricated using locally available raw materials. The module is tested to be useful for experiment in an introductory course in digital logic design, which is a basic course in most electrical and computer engineering programmes offered in our tertiary institution. Guided by a series of experiment implemented on the module the performances reported are in encouraging agreement as deployed in standard practice.

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