The Future of Engineering Education
2024 Annual Conference & Exposition
Oregon Convention Center
Portland, OR . June 23 - 26, 2024
ASEE
Paper ID #44552

An Innovative Approach for Teaching Some Concepts of Digital Design Laboratory Course in 2+2 Program Using a Portable Laboratory Instrumentation

Dr. Neda Bazyar Shourabi, Pennsylvania State University, York

Dr. Bazyar Shourabi is an Assistant Professor of Electrical Engineering at the Pennsylvania State University/York Campus. Her current research is focusing on Smart cities and engineering education.

Dr. Oludare Adegbola Owolabi P.E., Morgan State University

An Innovative Approach for Teaching Some Concepts of Digital Design Laboratory Course in 2+2 Program Using a Portable Laboratory Instrumentation

Abstract

Experimental-centric instructional pedagogy (ECP) with portable laboratory instrumentation offers a practical, hands-on experience for understanding concepts at a low cost. This paper outlines the adaptation of ECP to introduce the commercial ADALM1000 Active Learning Module (referred to as M1K) to students in the 2+2 program during a Digital Design Laboratory course in fall 2023, marking the first implementation of such an approach in an engineering department at Pennslvania State University-York campus . The paper presents a novel approach to implementing a subtractor using full adders and the ADALM1000 Active Learning Module. Prior to this experiment, students were introduced to concepts such as subtractors, half adders, and full adders in the Introduction to Digital Systems course. The implementation of a subtractor using full adders and the ADALM1000 consolidates and reinforces these concepts. To facilitate the project, students worked with full adder ICs, breadboards for circuit connections, and the ADALM1000 Active Learning Module.

Keywords: Experiment-centered pedagogy, Digital design laboratory, Motivate and increase learning, Engineering education.

Introduction

The usual way teachers use blackboards in our classrooms isn't great for getting today's students interested and curious. Instead of just talking to them, educators can make learning more fun by using different teaching methods and making the classroom more interactive. This helps students see right away if they're doing things right or wrong so they can fix mistakes as they go.

In the early 1900s, a researcher named Jean Piaget found that kids understand things better when they do hands-on activities instead of just hearing facts [1]. And other experts like Meyers and Jones agree that learning is more effective when students are actively involved, like reading, writing, talking, solving problems, or answering questions in a thoughtful way [2].

Also, many studies have shown that technology and hands-on activities can help students understand how theory connects to real-life situations in engineering projects. This kind of learning, called experimental-centric-based instructional pedagogy (ECP), mixes problem-solving with teaching methods that encourage students to figure things out on their own. With new portable lab equipment, students can practice their skills with friends and independently, even outside of class [3-9].

Course Curriculum

The Digital Design Laboratory, CMPEN 275, is a required one-credit laboratory course for students majoring in the 2+2 program. Under this program, more than half of all first-year students commence their studies at a campus other than the main campus and then transfer to complete their degree at the main campus or another affiliated campus. This transfer process is known as the 2+2 plan.

Students are expected to take CMPEN 275 in their sophomore year before transferring to the main campus. The course builds upon the concepts covered in CMPEN 271, allowing students to further develop their understanding and practical skills through hands-on application of these topics.

CMPEN 271 serves as the lecture course for CMPEN 275, comprising 3 credit units, and students typically enroll in both courses concurrently in a single semester. Passing CMPEN 271 is a prerequisite for CMPEN 275. The primary objective of CMPEN 271 is to instruct students in numerical values across various number systems, conduct number conversions, and introduce basic logic operations such as AND, OR, and NOT. Additionally, students learn about combinational logic circuits, Boolean expressions, DeMorgan's theorems, and timing diagram analysis. The course also covers the implementation of circuits represented by Boolean expressions, design, and analysis of sequential logic digital systems using state diagrams and tables, operation of flip-flops, registers, counters, decoders, encoders, multiplexers, and demultiplexers, as well as an understanding of digital-to-analog converters and analog-to-digital conversion.

Experiment Overview

Basic arithmetic operations in digital computing include addition and subtraction. When these operations are effectively implemented, multiplication and division become simpler, as multiplication is essentially repeated addition, and division is repeated subtraction.

Parallel subtractors are utilized to subtract binary numbers with more than one bit. These subtractors can be constructed in various ways, including combinations of half and full subtractors, all full subtractors, or full adders with subtrahend complement input. For this experiment, the last method was chosen.

Binary adder circuits are designed to add two binary numbers. They are categorized based on how they handle the output of the '1+1' addition:

- Half Adder
- Full Adder

A full adder is a combinational logic circuit that adds three bits and produces two outputs: a sum and a carry. Since a half adder cannot handle three inputs, the full adder is used to add three digits simultaneously. It comprises three inputs, two representing the significant bits to be added, while the third is the carry from the previous addition. The outputs are labeled as sum ($\sum$) and carry out

(COUT). The block diagram of a full adder typically includes input labels A, B, and CIN, and output labels Sum and COUT.

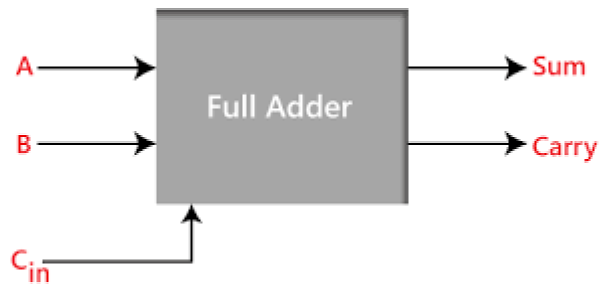

Figure 1. Full adder

The following table shows the truth table of a Full Adder:

Input			Output	
A	B	CIN	SUM	Cout
0	0	0	0	0
0	0	1	1	0
0	1	0	1	0
0	1	1	0	1
1	0	0	1	0
1	0	1	0	1
1	1	0	0	1
1	1	1	1	1

Table 1. Truth Table of a Full Adder

A 4-bit parallel subtractor can be devised using four full adders, as depicted in the diagram below. This configuration executes the subtraction operation based on the principle that adding the minuend and the complement of the subtrahend yields the same result as subtraction.

To subtract A from B, we derive the 2's complement of B by taking the 1's complement and adding 1 to the least significant pair of bits. In this circuit, the 1's complement of B is obtained using inverters (NOT gates), and a 1 can be added to the sum via the input carry.

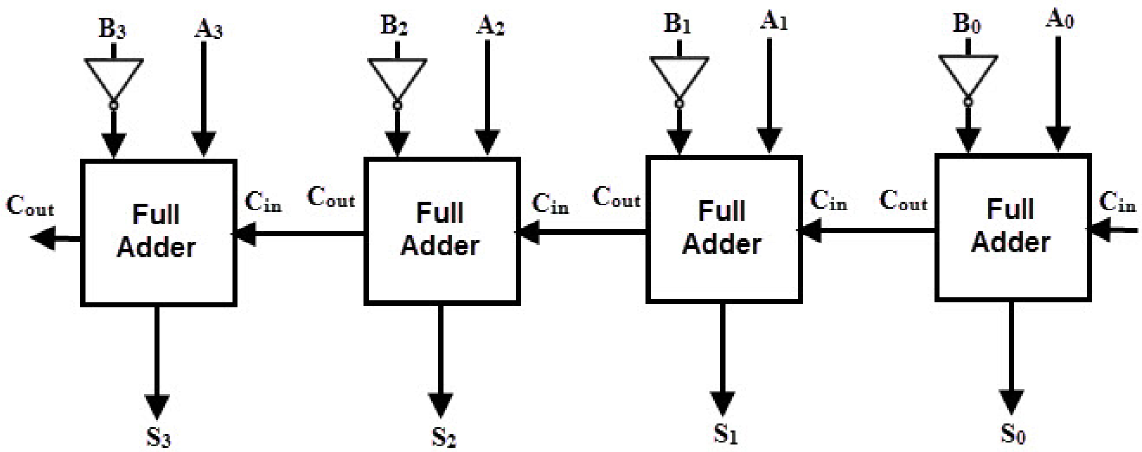

Figure 2. Subtractor

In this experiment, A represents the decimal integer 13, and B represents the decimal integer 7. In binary, 13 is represented as 1101, and 7 is represented as 0111. Table 2 displays the status of input bits for the subtractor, as shown in Figure 2.

A_3	A_2	A_1	A_0	B_3	B_2	B_1	B_0	Cin
1	1	0	1	0	1	1	1	1

Table 2. Inputs of the subtractor

Based on Figure 2, the output in the binary system is = 0110, which is 6 in the decimal system.

Hardware Implementation and Cost Analysis

Description	Product Number	Quantity	Price	Total
Breadboard	------	1	$7	$7
Jumper Wires	------	-------	$5	$7
ADALM1000/M1K	-------	1	$70	$70
NOT/Invertor gate	SN54LS04	1	$2	$2
Full adder IC	SN74LS83	1	$2	$2
LED	-------	4	$1	$4
Laptop	---------	1	0	0
Total:	$92			

Table 3. Component and Cost Analysis for the Subtractor

Hardware implementation provided comprehensive details about each component. A sample of these components and their description follows: Product Number SN54LS04, a NOT gate, contains multiple independent gates, each performing the logic NOT function. For this experiment, four NOT gates were required. The output of each of these four gates is connected to the Full adder IC, and each input of these four NOT gates is considered a bit of the number 7. The chip has fourteen pin inputs, with pin number 7 serving as the ground connection and pin number 14 as the voltage (power supply) connection.

Product Number SN74LS83, a Full Adder gate, consists of four independent gates, each performing the Full Adder logic function. The chip has sixteen pins, with pin number 12 serving as the ground connection and pin number 5 as the voltage connection. Pin 13 functions as the carry-in, and pin 14 indicates carry-out. Pins 1, 3, 8, 10, and 16 are designated for number 13, while pins 4, 7, 11, and 16 are designated for number 7; these pins receive the outputs of NOT gates. The outputs of this chip, including pin numbers 9, 6, 2, and 15, are connected to LEDs for displaying number 6. Figure 3 shows the IC.

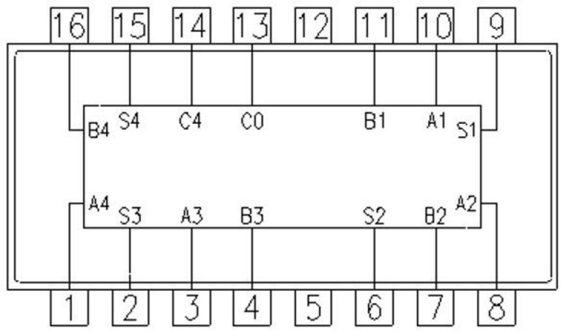

Figure 3. Full adder IC

Portable lab kits like ADALM1000, ADALM2000, and Arduino are handy tools for simulating complex physical systems, especially circuits. They're also great for distance learning since students can use them remotely. The ADALM 1000 module (shown in Fig. 4) was used in this project. It's a fantastic device for students and enthusiasts because it combines several useful tools like an oscilloscope, function generator, logic analyzer, digital pattern generator, and power supply. It works with different operating systems like Linux, Android, Windows, and Mac, making it easy to use. This device is crucial for connecting circuit components and analyzing voltage, current, and impedance (like resistance, inductance, and capacitance) in our circuits. Overall, in this research project, ADALM1000 was introduced to the students so that they could utilize the other features of this device in their career paths or in other future research projects. Subsequently, another research project was conducted in this course using the M1K to test the functionality of a 4x1 multiplexer, and the students also utilized other features of the M1K.

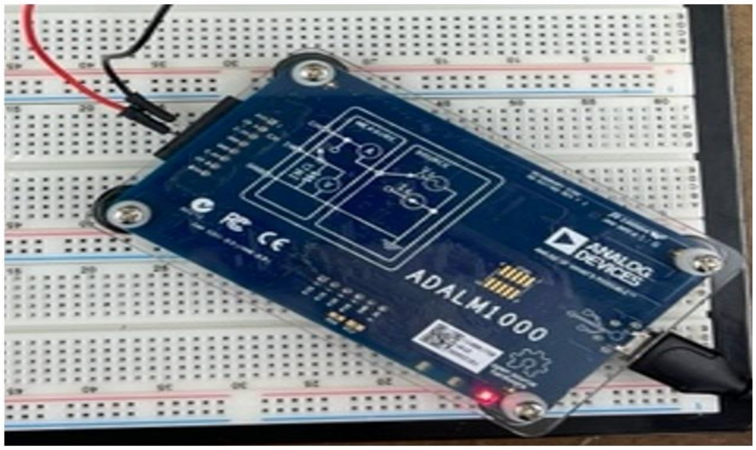

Figure 4. ADALM1000

Methodology

The goal of this hands-on laboratory experiment is to introduce students to the concepts of subtractors and full adders and to familiarize them with their functions. The experimental logic pedagogy was implemented in person as part of an undergraduate 2+2-degree program course, CMPEN 275: Digital Design Laboratory, during the Fall 2023 semester. Before conducting the experiment, lectures on the half adder, full adder, and subtractor gates were delivered to the students in CMPEN 271 several weeks in advance. An overview of the experiment, along with the materials required and detailed procedural instructions, was provided on Canvas before the experiment's implementation.

Experimental Procedures

1. Convert decimal numbers (13 and 7) to binary numbers.
2. Put the ICs on the breadboard.
3. Attach the LED to the output pins (Connect the long leg of the LED to the positive terminal and the short leg to the pin).
4. Establish a connection between VCC and the breadboard.
5. Establish a connection between GND and the breadboard.
6. Energize your breadboard using your M1K.
7. Alternate the input pins to achieve the desired outputs.

Performance Results

Figure 5 displays a photograph of one of the group's results. However, one group forgot to take a picture of their circuit after showing the result, so only four circuits were available.

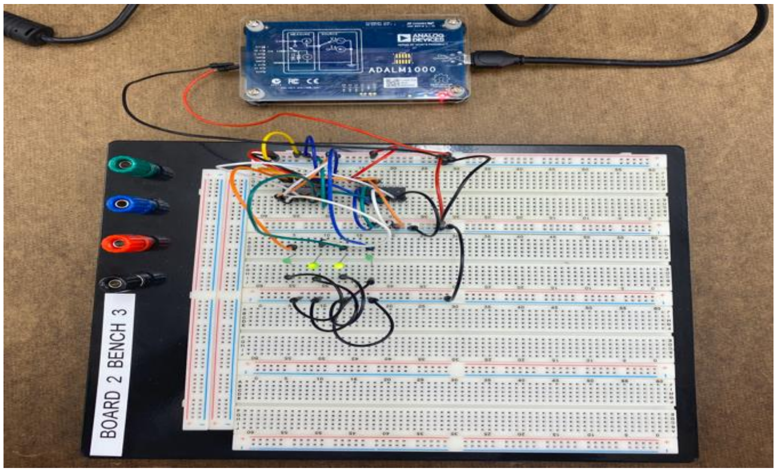

Figure 5. Student circuit group number 1

Outcomes and Conclusions

After the experiment, students were informally interviewed. Ten students were involved in this project. All of them were enrolled in the 2+2 program degree major during Fall 2023. Four of them will continue their education in electrical engineering, two in Computer Engineering, three in Computer Science, and one in Electro-Mechanical Engineering Technology. None of them had prior experience with the M1K device; this was their first exposure. They expressed great enthusiasm about conducting more experiments using the M1K. As a result, another experiment utilizing the M1K was considered. Two students wanted to expand their knowledge beyond basic concepts and explore different aspects of the M1K, potentially incorporating it into their future senior projects. One student even expressed interest in purchasing one M1K device to continue experimenting at home. The students found using the M1K easier than other devices, such as power supplies, and noted that they could complete experiments more efficiently than usual. Working in groups of two, all team members were actively engaged, and each of the five groups successfully achieved the project objectives. Overall, the experiment provided students with valuable exposure to various experiments associated with the M1K, enhancing their understanding and skills.

References

[1] J. Piaget, "The Origins of Intelligence in Children," *M. Cook, trans., New York: International Universities Press, 1952.*

[2] C. Meyers, and T. B. Jones, "Promoting Active Learning: Strategies for the College Classroom". *Jossey Bass Pub; San Francisco, 1993.*

[3] C. Bonwell, and J. Eison, "Active Learning: Creating Excitement in the Classroom". *ASHE-ERIC Higher Education Report No. 1. Washington, D.C., 1991.*

[4] K. Conner, Y. Astatke, “Simultaneous Implementation of Experimental Centric Pedagogy in 13 ECE Programs,” *Proceedings of 2015 American Society for Engineering Education (ASEE) 2015 Annual Conference, Seattle, WA June 14-17, 2015.*

[5] Y. Astatke, K. A. Connor, D. Newman,J. O. Attia, and O. E. Nare. , “Growing experimental centric learning: The role of setting and instructional use in building student outcomes’” *ASEE Annual Conference & Exposition, New Orleans, Louisiana, 2016. 10.18260/p.25427 (2016).*

[6] Y. Astatke, J. Ladeji-Osias, P. James, F. Moazzami, C. Scott, K. A. Connor, and A., Saka, “Improving and expanding engineering education in the Middle East and Africa using mobile learning technology and innovative pedagogy”. *In Abdulwahed, M., Sasna M., Freud J. (eds), Advances in engineering education in the Middle East and North Africa (pp 235-260) Springer, (2016).*

[7] K. A. Connor, D. Newman, M. Morris Deyoe, J., Craig, M. Chouikha, & Y. Astatke, “Mobile studio pedagogy: Overcoming the barriers that impede adoption. American Society of Engineering Education, 2012”. *Retrieved from* [https://peer.asee.org/mobile-studio-pedagogy-part-1-overcoming-the-barriers-that-impede-adoption,](https://peer.asee.org/mobile-studio-pedagogy-part-1-overcoming-the-barriers-that-impede-adoption) 2012.

[8] O. Adeniran, M. Rahman, O. Owolabi, N. Bazyar Shourabi, E. Sakk, “Preliminary Experience and Impact of Experiment-focused Teaching Approach in a Computer Architecture Course in Computer Science”. *ASEE Annual Conference & Exposition, Baltimore,* 2023.

[9] M. Rahman,O. Adeniran, N. Bazyar Shourabi, O. Owolabi, “Initial Impact of Evidence-Based and Experiment-Focused Teaching Approach in a Computer Architecture Course in Computer Science”, *International Conference on Computational Science and Computational Intelligence, 2022 .*