# A Novel Laboratory Experimental Platform Using LabVIEW and Multisim Environments


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***Abstract*—The role of engineering laboratories during undergraduate studies, especially in the disciplines of electrical and computer engineering, is extremely important. Due to the spread of COVID-19, the conduction of laboratory work is becoming a challenging task. To transfer the engineering knowledge and problem solving skills, hardware equipment and components are used in the laboratories. Similarly, software simulators are also used due to the budget and space constraints. In this context, a separate simulator is required for each kind of laboratory experiment which not only increases the cost but also requires long learning time. Therefore, there is a need for a platform that can be used in both situations, i.e., real and virtual environments. A real environment implies that the experiments are performed physically inside the laboratory. On the other hand, a virtual environment advocates the use of the proposed platform remotely. Consequently, a LabVIEW and Multisim based experimental setup is proposed in this paper that is useful in various types of engineering laboratory experiments. The proposed platform allows to perform algorithmic level exploration as well as component level implementation. For algorithmic level exploration, a LabVIEW programming environment is employed while the circuit level implementation is supported with a Multisim. It has been observed that the proposed system is user friendly, requires less learning time and can be easily implemented in real and virtual environments.**



***Keywords*—*GUI, laboratory experiment, LabVIEW, learning management system, Multisim, simulation, virtual experiment***


## I. Introduction

Due to the pandemic that started in the year 2020, many departments in various universities started offering classes using different online learning management systems (LMS). The examples of these LMS are the proprietary virtual environment such as Blackboard Learn [1], the cloud based web service like Google Classroom [2] and open-source LMS such as Moodle [3] etc. The e-learning approach using different LMS works well in delivering the contents and knowledge development for theory classes, however, the conduction of laboratory experiments is always a challenging situation under these circumstances.

Conventionally the laboratory experiments are designed on a customized hardware trainer which is useful to a particular type of experiments but cannot be used in other laboratory experiments [4]. For example, the electric circuit and electronics laboratory experiments are performed using the components and basic equipment like multi-meter, oscilloscope, and function generator. The signal processing and communication systems laboratories are equipped with the signal generator, oscilloscope, spectrum analyzer, and various kinds of modules e.g., modulator, demodulator, filter, parity generator, coder, etc. Furthermore, these hardware trainers cannot be used if the experiments are required to be conducted remotely (in a virtual environment).

In order to address the limitations of hardware trainers for virtual environments (distant learning), various types of simulators are used. For example, Logisim [5] is used for designing and simulation in the digital logic design laboratory experiments. In the signal and systems laboratory, MATLAB is used [6]. Similarly, in communication systems, the Simulink environment is generally employed [7]. Each of the aforementioned simulators require some learning time. Furthermore, sufficient computational power is needed to handle various types of simulators for different laboratories. More importantly, the cost of license for each workstation (if not open-source) may hinder the widespread adoption of these simulators. Consequently, a single platform is required that can be used in different laboratories to perform experiments physically or remotely.

This article has proposed a novel platform to perform experiments, physically as well as remotely, in different electrical and computer and engineering laboratories. The proposed tool performs algorithmic and component level explorations. For algorithmic level exploration, a laboratory virtual instrument engineering workbench (LabVIEW) [8] programming environment is employed. For component level implementation, a Multisim [9] environment is used. Algorithmic level exploration is needed in laboratories like signals and systems while the component level implementation is required in laboratories like communication systems and digital logic design.

The proposed tool not only allows the remote conduction of laboratory experiments, it also decreases the overall required learning time and does not need prior programming (coding) knowledge. It has a user friendly graphical user interface (GUI), easy to use and provides in-depth knowledge of fundamental concepts to the engineering students which is difficult to manage in normal circumstances due to the costly equipment, limited laboratory timings and availability. It has also addressed the issue of high computational power by replacing various simulators with a single platform. Similarly, it provides remedy for license cost as only a single academic site license is now required instead of multiple academic licenses for different simulators.

The rest of the paper is organized as follows. Section II provides background information necessary to understand the article. Related work is explained in Section III. The proposed platform is presented in Section IV along with the algorithmic and circuit level implementations. Comparison of the proposed platform with hardware and simulators is discussed in Section V. Finally, Section VI provides the concluding remarks.

## II. BACKGROUND

This section first provides some background knowledge on the LabVIEW programming environment and Multisim environment in Section II-A and Section II-B respectively. Subsequently, an overview of laboratories in electrical and computer engineering is presented in Section II-C.

### *A. LabVIEW Environment*

LabVIEW is a graphical software environment developed by the national instruments (NI) [8]. It is used to design and develop various kinds of testing, monitoring, controlling, and automation applications with hardware interfacing. The LabVIEW programs are called virtual instruments (VIs). The three components of a VI are: (i) front panel, (ii) block diagram, (iii) connector pane. The front panel is designed using controls (inputs) and indicators (outputs). The block diagram contains the graphical code of the objects placed on the front panel. The connector pane provides connectivity between the inputs and outputs of various blocks. The main feature of LabVIEW is it's easy to use without having any programming skills and connectivity with several applications and 3rd party hardware. LabVIEW is available with different operating systems support including Windows, Mac, and Linux with Base, Full, and Professional editions.

### *B. Multisim Environment*

Multisim is a software used to design and simulate various kinds of electric and electronic circuits [9]. It provides easy-to-use circuit design environment and interactive simulations. Various components can be selected from the libraries to make a schematic diagram. In addition it is equipped with several common instruments including the multi-meter, function generator, oscilloscope, spectrum analyzer etc. Furthermore, Agilent and Tektronix instruments are also available. Multisim provides simulation facilities as well as real-hardware interface e.g., NI educational laboratory virtual instrument suite II (NI ELVIS II) [10] interface. Finally the 3D prototyping breadboard environment is also available using the same setup.

### *C. Description of Laboratories*

In electrical and computer engineering discipline, the engineering laboratories can be classified into computational laboratories and communication laboratories [11]. In the computational part, the major laboratories are digital logic design, advanced logic design, microprocessor, embedded systems and so on. The communication part consists of laboratories like signals and systems and computer communication. Due to space limitations, this article has presented the proposed platform (in Section IV) in the context of only three laboratories: signals and systems, communication systems and digital logic design.

In the signal and systems laboratory, students generally generate various types of signals and analyze the corresponding responses in time and frequency domains. Similarly, in communication systems laboratory, students are required to implement various modulation schemes such as amplitude shift keying (ASK), frequency shift keying (FSK) and phase shift keying (PSK). Finally, digital logic design laboratory allows the students to utilize various integrated circuits (ICs) for the designing of different combinational and sequential circuits. Examples of these combinational and sequential circuits are timer, counter, register file, multiplexer, finite state machines (FSM) and so on.

## III. RELATED WORK

The remote control of laboratory equipment for the course of basic electronics is presented in [12] based on LabVIEW. The authors have addressed the issue of expensive and specialized laboratory equipment by replacing the hardware and software environment with the virtual environment that can be accessed remotely.

The work in [13] focuses on teaching methodology in engineering laboratories using virtual instruments designed in the LabVIEW. The use of LabVIEW in different courses e.g., signal processing and analog communication is presented using practical examples. One of the main goals of the research is to minimize the time and efforts during the setup and conduction of the experiments.

Modeling and simulation of analog filters using LabVIEW is presented in [14]. The two main objectives of the research using virtual instrumentation are; (i) analysis and simulation of analog filters, and (ii) implementation and simulation of a passive analog filter. The mathematical model of the high-pass and low-pass filters are designed and implemented using LabVIEW.

The simulation of analog modulation is performed in the research [15] using LabVIEW. Initially the models for amplitude modulation (AM) and frequency modulation (FM) are designed and then simulated using LabVIEW. The parameters can be adjusted during simulation.

The article in [16] focuses on the use of virtual technology to implement electronic circuit experiments. The software application used in the research provides the students a 3D simulation environment with a web-based instructor. The benefits of the research have been observed as higher attendance and good students' scores.

A virtual analog modulator tool is developed using LabVIEW in [17]. It provides the basic concept of analog modulation techniques. The user can select the message and the carrier. The results are presented in both time and frequency domains. In addition channel noise can be added to the signal. The training board NI-ELVIS is used for system level implementation.

The commonly used analog and digital modulation schemes used in communication systems are analyzed in [18] using LabVIEW. The two analog modulation schemes used in the research are amplitude modulation and frequency modulation, while phase shift keying is used to explain the functionality of digital modulation techniques.

The application of LabVIEW in the course of signal processing is presented in [19]. The objective of research is to provide a virtual tool that looks like a real-environment. The proposed system encourages the students and provides the ability to analyze and problem solving skills.

The use of LabVIEW and Multisim in virtual electronic laboratory is presented in [20]. Various features of the LabVIEW and Multisim environments are explained. The methodology is useful to overcome the shortage of laboratory equipment and can be accessed remotely using a web browser.

## IV. Proposed Platform

This section describes the functionality and salient features of the proposed platform in different laboratories of electrical and computer engineering. The proposed platform provides algorithmic level exploration as well as circuit level implementation. The algorithmic level exploration is needed in laboratories like signal and systems laboratory while the circuit level implementation is required in laboratories like communication systems and digital logic design.

For algorithmic level exploration, the LabVIEW programming environment is used. For circuit level implementation, the NI Multisim environment is employed. It implies that the proposed platform in this article consists of two major components: the LabVIEW programming environment and the NI Multisim environment. In the following, the significance and working principle of the proposed platform is illustrated. First, the algorithmic level exploration is performed in Section IV-A by analyzing the signal in time and frequency domains. Subsequently, the circuit level implementation is performed in Section IV-B and Section IV-C by implementing a modulation scheme and a digital counter respectively.

### A. Signal Analysis

A typical example in a signal processing laboratory is to generate a square wave from multiple sinusoids and perform the corresponding analysis in time and frequency domains. Equation 1 shows the general representation of such a square waveform which consists of four sinusoids with different frequencies and amplitudes.

$$f = sin(angle) + sin(3 \times angle)/3 + sin\,(5 \times angle)/5 + sin\,(7 \times angle)/7 \quad (1)$$

Equation 1 shows that the fundamental frequency is 1 Hz with a voltage level of 10 V. Furthermore, the 3rd, 5th and 7th harmonics in Equation 1 use 1/3rd, 1/5th and 1/7th voltage values of the fundamental waveform. The implementation of Equation 1 in the proposed platform is shown in Fig. 1–4.

Fig. 1 shows the front panel, designed in the LabVIEW, to select four values of the frequencies and voltages of a sinusoidal waveform. The frequencies can be chosen in the range of 1–10 Hz (using circular knob) at the bottom. Similarly, the four voltage levels can be adjusted in the range of 1–10 V (using vertical slide bars) at the top.

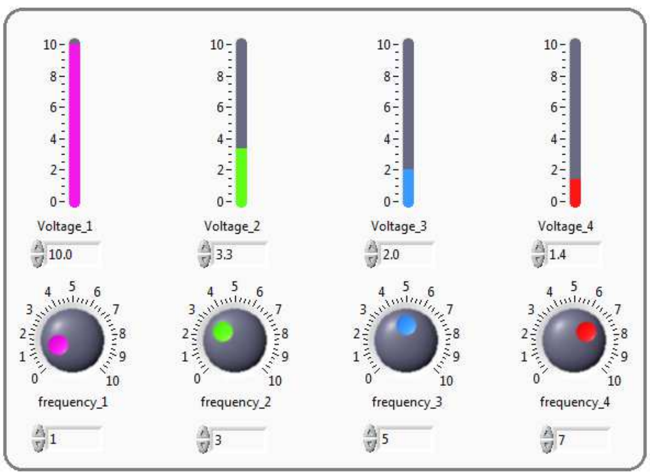


Fig. 1. Control panel for frequencies and voltages selection.

The digital indicators show the instantaneous values (for both frequency and voltage). It is important to note that the frequencies are selected as (1, 3, 5, 7) Hz while the corresponding voltage levels are chosen as (10.0, 3.3, 2.0, 1.4) V respectively.

Fig. 2 illustrates four sinusoidal waveforms based on the frequency values and voltage levels selected by the control panel (as shown in Fig. 1). Moreover, it also shows the sum of all waveforms. It implies that the proposed platform allows the user to perform a time domain analysis of any type of signal. The frequency of the fundamental sinusoidal waveform is 1 Hz and voltage level is 10 V (purple color). The second waveform has the frequency of 3 Hz and the voltage level is 3.3 V (green color). Similarly, the frequency in third waveform is 5 Hz and voltage level is 2.0 V (blue color). The fourth waveform has a frequency of 7 Hz and voltage level is 1.4 V (red color). Finally, the sum of all waveforms is shown by the white color.

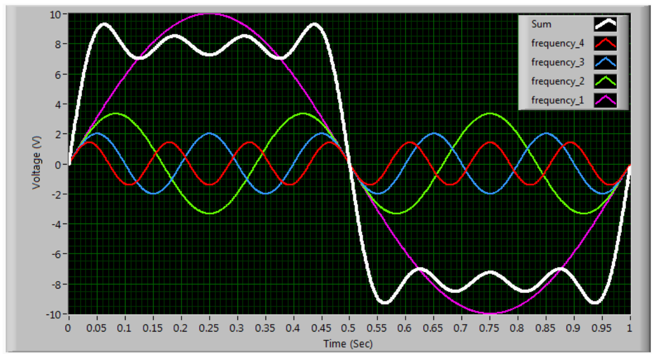


Fig. 2. Time domain analysis (LabVIEW front panel)

While Fig. 2 enables us to perform a time domain analysis, the corresponding frequency domain analysis is equally important, as shown in Fig. 3. The horizontal axis shows frequency in Hz, while the voltage levels of each component are shown on the vertical axis in volts. The values for each of the four frequency components (1, 3, 5, 7) Hz can be seen as (7.0, 2.3, 1.4, 0.9) $V_{rms}$ respectively. It is important to note that the frequency and voltage levels can be adjusted from the control panel (Fig. 1) and the corresponding response in frequency domain is updated in real-time in Fig. 3.

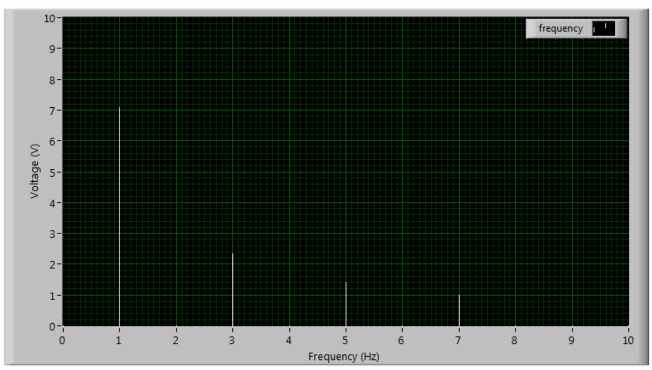


Fig. 3. Frequency domain analysis (LabVIEW front panel)

Fig. 1–3 represent the front-end (front panel) of the proposed platform. The corresponding back-end, represented as the LabVIEW block diagram, is shown in Fig. 4. From the left, the four blue icons (knobs), represented as frequency_1, frequency_2, frequency_3, and frequency_4, are used to select the frequency in Hz. Similarly, the orange icons (vertical slide bars), represented as Voltage_1, Voltage_2, Voltage_3 and Voltage_4, are used to provide voltage levels in volts. Both types of icons are connected to the sine waveform generator as an input. It is obvious from Fig. 4 that four sine waveform generators are used, as the total number of sinusoids components are 4. The output of all the sine waveform generators goes to the adder. Three adders are required for this purpose. Consequently, the effect of all four waveforms is combined using a build array function and plotted in time domain. Similarly, the amplitude and phase spectrum block is used to represent the frequency components of the waveforms.

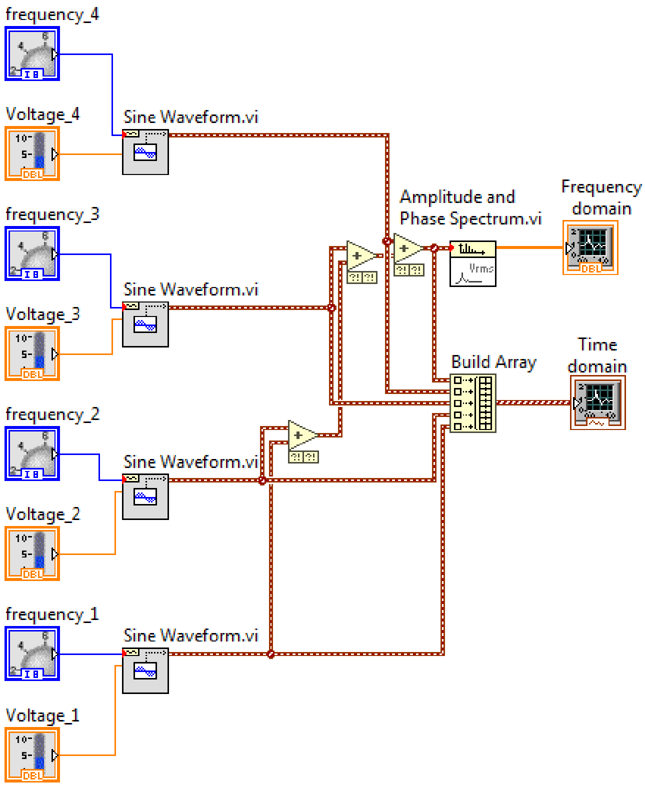


Fig. 4. LabVIEW block diagram

## B. Signal Modulation

While the time and frequency domain analysis of any signal is an important feature of signal and systems laboratory, various modulation schemes are required to be implemented in communication systems laboratory. One of the important modulation scheme is phase shift keying (PSK). The circuit level implementation of a PSK modulator, using the proposed platform is shown in Fig. 5. The NI Multisim component of the proposed platform is used for this purpose.

A general purpose operational amplifier (OPAMP) LM358N is used as a comparator with a 10 kΩ feedback resistor (shown as R2). The input signal (V2) of 1 kHz is applied at the base of an NPN transistor 3904 (that works as a switch) through a 1 kΩ resistor (R5). The modulating signal / carrier (V1) is 10 kHz, with a voltage level of 5 V. The oscilloscope channel A is connected with the carrier (V1), while channel B is connected with the input signal (V2). The output is taken using the channel D of the oscilloscope. The circuit is powered by a source of 12 $V_{DC}$.

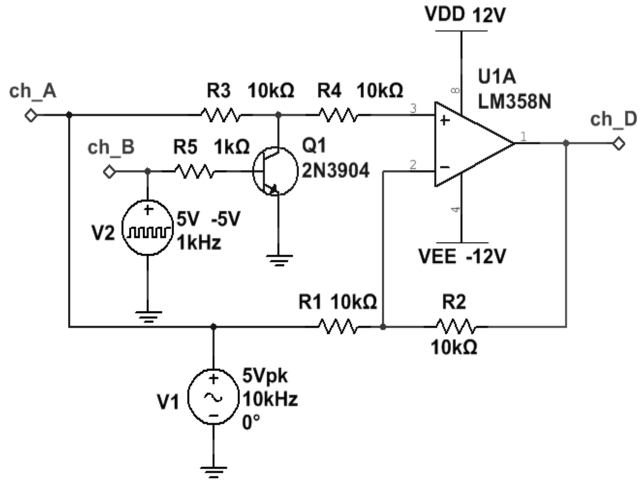


Fig. 5. PSK modulator circuit level implemnetation.

Fig. 6 shows the input and output waveforms of the PSK modulator. The input to the modulator circuit is sinusoidal waveform (blue color), while the message (information) signal i.e., the square wave is shown in red color. Finally, the output of the circuit is the PSK modulated signal (purple color). It can be seen from Fig. 6 that the first time phase change is observed when the message signal goes from high-low. Similarly, the second phase change occurs at the transition when message signal goes from low-high. Other phase shifts can be observed at each transmissions.

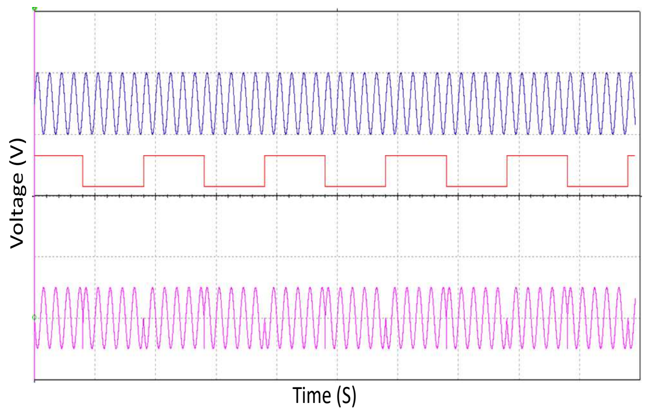


Fig. 6. PSK modulator input and output waveforms.

## C. Digital Counter

The previous subsections in this section illustrate the significance of proposed platform in the signal and systems as well as communication systems laboratories. The proposed platform is also useful in the laboratories like digital logic design. In order to validate its significance, Fig. 7 shows an up/down counter with enable, clear and direction control functions. The electronic circuit is designed using two digital integrated circuits (ICs) 74191 in cascaded mode. An IC 74165 (parallel-load 8-bit shift register) is used to control the timings of the circuit with 800 Hz clock frequency, while the shift/load operation is controlled using 100 Hz clock. The output is displayed on two digital displays. The supply voltage 5 $V_{DC}$ are applied to power-up the circuit. The up/down counting can be controlled using the direction switch, while to reset the counter, clear switch is used. The enable switch is used to enable/disable the counting.

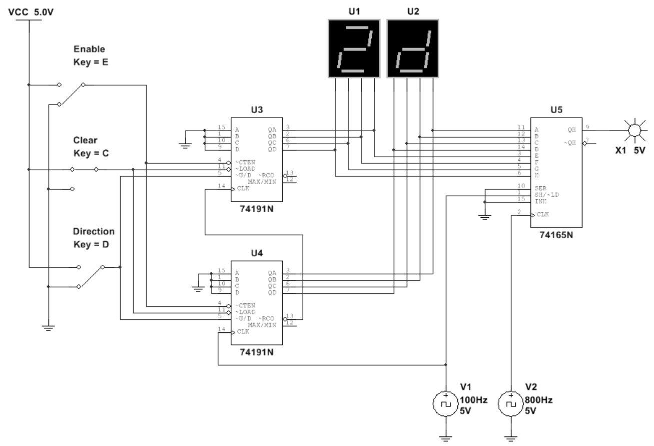


Fig. 7. Up/down counter with enable function.

## V. Discussion

This article has presented a platform environment for the conduction of experiments physically and remotely.

### *A. Comparison of Proposed Platform with Hardware Laboratory Equipment*

The hardware laboratory equipment is always the first choice for the conduction of experiments in any engineering discipline and is also recommended by well-known engineering accreditation agencies [21]. With hardware equipment and components, students are able to get hands-on experience. In addition, they are able to work in groups and develop some problem solving skills [22]. Furthermore, they also get some troubleshooting experience and learn state-of-the-art engineering tools [23]. However, due to the growing importance of e-learning, the engineering community is looking for alternatives [24]. Furthermore, due to the busy schedule of laboratories, students always face issues like the lack of practice in laboratories. On the other hand, the proposed platform aims to provide the same hands-on experience remotely. However, the troubleshooting experience on real components is not possible with the proposed platform.

### *B. Comparison of Proposed Platform with Simulators*

Simulators are generally employed to replace the requirement of hardware components and equipment. However, the current practice is to use different simulators for various courses. Authors of this paper have faced some serious issues with this approach (different simulators for different laboratories). For example, some simulators like Multisim has two versions. The Multisim Live (free version) does not require license but the simulation of relatively circuits with more than 25 components per circuit is not possible [25]. On the other hand, each remote user is required to obtain a licensed version. In this context, the proposed tool is using a single academic site license that can be used for multiple students irrespective of their numbers and duration.

Another issue, related to the use of different simulators reported by various students, is the computational power and memory requirements. For example, MATLAB requires several gigabytes of memory and consumes a handsome amount of processor resources. In the proposed approach, students are required to install only one platform which relatively requires less computational power and memory.

At the end, authors have noticed that students really feel difficulty whenever they come across a new simulation environment. A comprehensive amount of time is consumed for the learning of simulation environment. The proposed tools is easy to learn due to LabVIEW environment as no prior programming skills are required. Furthermore, students learn a single environment and use the same environment for multiple laboratories.

To summarize, with the proposed platform, the students are not able to perform any group activity as well as hands-on experience with the real hardware, but each student can be involved individually and able to perform experiments successfully. In addition, the students are able to learn more deeply while staying at home during the university campus closure due to lockdown.

## VI. Conclusions

In this paper, we have proposed a novel platform for laboratory experiments in the electrical and computer engineering department. The proposed tool is based on LabVIEW and Multisim for the exploration of algorithms and circuits respectively. It has been observed that the learning time of students with the proposed tool is much lower as compared to the conventional simulator approach. Furthermore, the proposed platform requires less computational power and memory.

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