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A hybrid circuits-cloud: Development of a low-cost secure cloud-based collaborative platform for A/D circuits in virtual hardware E-lab

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ABSTRACT

The development and use of cloud based tools in virtual learning has been increasing in recent years. Electronic Design Automation (EDA) or Electronic Computer-Aided Design (ECAD) is one of the most important tools that are used for electronic circuit design and simulation. There is a number of available cloud based EDA tools that are used in industry and educational institutions.

This paper introduces a hybrid-circuits cloud-based platform that enables students to design, simulate, and model both analog and digital electronic systems. Circuits-cloud became one of the top best electronic circuit cloud tools, it is ranked as number one in Google search for the "top list of electronic circuit cloud tools". It integrates the Internet of Things (IoT) and cloud based tools by adding sensors, actuators, and interact with the physical design in the laboratory in the real time. This platform acts as a comprehensive laboratory device to capture components, draw circuits, integrate different components, apply different inputs, simulate, measure, and detect any defect or heated elements. This cloud-based platform introduces an integrated environment for digital, analog and IoT modeling. The platform has a laboratory device that can be integrated into circuits level with the cloud system to test the physical circuits in real-time remotely. This enables in-browser cloud platform for schematic capture, circuit simulation, and emulation. As a testimony of the platform of the modeling and simulation discipline, a list of about 100 types of equipment?s were included and tested. The cloud service is provided by Amazon Web Services (AWS) with high data protection service, AWS also provides encryption, key management, and threat detection that continuously monitors and protects user accounts and workloads. It is estimated to be able to serve approximately 2000 active students and tutors on a monthly average. This platform can be used in distance and blended learning as well.

1. Introduction

In this era of digital transformations and use of cloud computing, a virtual laboratory that is available anytime, anywhere is vital for supporting smart learning [1]. This enables students to easily design and simulate different digital experiments on the fly with minimum cost [2–5]. Learning can be evolved by enabling the innovative use of Internet of Things (IoT) to provide the interaction of different types of educational technologies based on the "things-to-things" concept, as a collaborative platform [6–8]. This cost-effective solution can transform education and e-learning structure. Distance learning is one of the blended tools for modern education. It is an essential tool for many universities and institutions as it offers a cost-effective solution to give on-demand learning materials [9–11]. A virtual laboratory for teaching computer and electrical engineering courses can provide students with easy access to software packages from any device, at any time [12,13]. This interactive distance learning environment, providing illustrations, simulations, and exercises, is capable of fulfilling the role of a bridge from passive learning to active learning and thus encourage deeper thinking. It is also essential to link theory with practice to enable students with developing engineering judgment and understand how to manipulate behavior that can be captured using mathematical models and Graphical User Interfaces (GUI) [14]. In

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most cases, simulation environments were shown to be powerful learning tools. They have been used in many engineering disciplines successfully. Many visual simulators are used for computer and electrical engineering courses, because of the shortage of visual simulators for the cache memory concepts simulation [15]. This illustrates their effectiveness as a supporting tool in the learning process of new multi-cache, multi-layer, multi-core processors. The IoT infrastructure provides scalability, adaptability, and open access for the distance learning paradigm. Multimedia-based IoT-centric environment is suitable to enhance the delivery of learning contents effectiveness. Students will be able to access the system via the internet at any time and place using a flexible e-learning platform. Many techniques have been introduced for remote and virtual laboratory in different areas of engineering [16,17]. A proposed e-learning model that use sensors to detect the location and temperature of students, and mobile cameras to identify their active interaction in the learning environment is introduced in [18].

In this paper, we are introducing a cloud-based remote laboratory and simulation system for a digital design that is suitable for full e-learning course in computer and electrical engineering, electronics, cybersecurity, and IoT courses. The digital service allows students and tutors to register, create a new circuit, design and test the circuit without the need of any additional resources other than an internet connection and a browser, either on the desktop, mobile devices, or tablets. IoT virtual learning requires adequate practical laboratory experiments with the simulation of different types of sensors and controllers that can be part of the IoT architecture. The introduced circuits cloud-based tool is compared to other available cloud EDA tools for testing and verification. Data and user accounts in circuits cloud are protected by the high security services provided by AWS.

The remaining of this paper is organized as following: Section 2 discusses the related works in education models of electronics and IoT courses; in Section 3 the circuits-cloud platform architecture is introduced with focusing on the layer structure, Section 4 discussing the security challenges in cloud-based and E-Learning systems; in Section 5 we are going to discuss the experimental results that have been conducted and simulated using circuits cloud platform, an emulation of a micro-controller experiment is also conducted, and a comparison of the platform with other available tools is discussed; finally the conclusions and future work will be discussed in Section 6.

2. Related work

Electronic Computer-Aided Design (ECAD) tools or Electronic Design Automation (EDA) tools are used to design and create electronic circuits, simulate, and then implement the created circuit into physical circuits [19]. EDA tools can be used for Integrated Circuits (ICs) design, starting the design from high level capture tool, synthesis tool, simulation tool, and physical layout tool as shown in Fig. 1 [20]. A framework for real time EDA tools has been introduced for IC design as shown in Fig. 2 [21].

2.1. Massive open online courses

A Massive Open Online Course (MOOC) is an online course aimed to provide an interactive course where it supports community forums, online lectures, quizzes, assignments, real-time feedback and discussions between students and teachers. MOOCs are relatively new and widely researched development in distance education which was first introduced in 2006 and emerged as a popular mode of learning in 2012. Benefits of e-learning Naji and Ibriz [22]. Understanding students' interaction with MOOCs is of great importance since it affects how their effectiveness is evaluated and how future online or distance learning courses are designed. For those students who consider MOOCs like traditional courses, which run at a standard rate over a pre-determined period of time, it would be logical to discuss their "falling behind" or "dropping out." For students who consider MOOCs as online reference materials or textbooks, however, a different set of expectations would be applicable. Here the expected interaction style can comprise of barrages of asynchronous engagement and some selected content sampling. For students who choose to use MOOCs as a tool to sharpen and even test their skills in a specific area, it would be logical to expect them to take part of the course work without even seeing the full content of the lecture [23].

2.2. Challenges of digital learning

One of the main goals of digital learning is to personalize learning. This is the ability to customize a curriculum that would be ideally matched to the skills, knowledge shortfalls and preferences of all students in the class. Moreover, evaluation is important in managing the processes involved in the use of technological tools to discover, collaborate, learn, and share knowledge [24]. It is important to comprehend student's motivation, experience perception, and disposition to use digital learning materials. We also need to prepare educative activities in virtual environments that students find comfortable and useful. However, crucial challenges are surrounding digital learning as listed below:

- **The Infrastructure**: Many universities might be lacking the appropriate IT infrastructure which supports large-scale eBooks and digital content distribution.
- **Resistance to Change**: The biggest concern in technological change is usually not the technology itself, as much as it is the people affected by this change. Instructors, administration staff and parents are all stuck in the typical fashion of teaching.
- **The challenges**: It lies here in convincing them to adopt and adapt to new digital means of teaching.
- **Content Creation**: The Content creation of digital learning is not limited to transforming current content and books to digital formats.
- **Technological Changes**: Digital curriculum is usually not a one-off investment.
- **The Curriculum**: It needs to be continuously updated along with updating the platforms when technologies change.
- **Costs of Implementation**: This updated content takes time and effort, hence, usually causing hikes in costs of implementation.
- **Value of Digital Learning**: In order to get the value out of digital learning in universities, it must be coupled with interactive and updated content.

2.3. Internet of things in education

Today's education is evolving from traditional knowledge-transfer into a self-interactive model, being influenced by technologies surrounding the education sector. This has not only mandated education institutions to revise their way of teaching but also forced the students to adapt themselves to the new era of e-learning. The new way of e-learning [25] can be seen in many real-life experiences, such as the teacher's customization of their teaching content to cater the individual students based on their learning capability, student's ability to simulate their knowledge and putting their theories into practice as well as a collaborative forums and online classes between teachers and students which ensure a high-quality outcome.

Such collaboration requires a direct interactive component, both physical and logical, to deliver such services, which is called

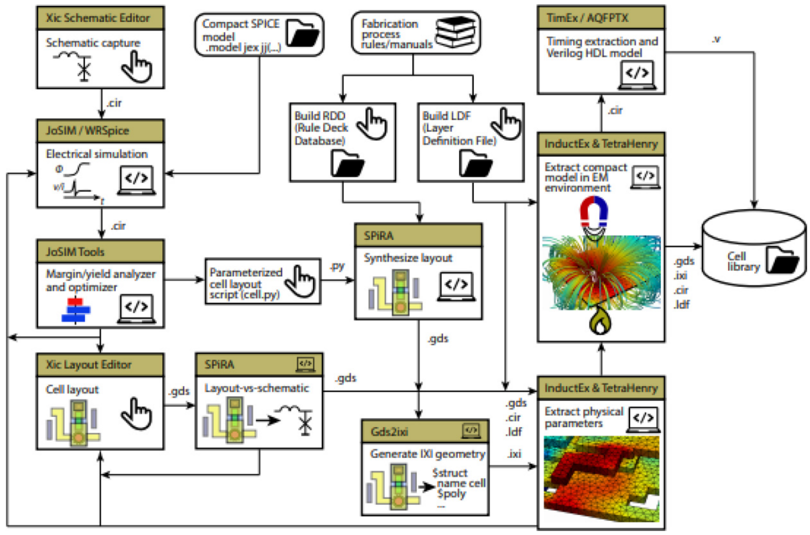

Fig. 1. EDA tools for superconducting circuits [20].

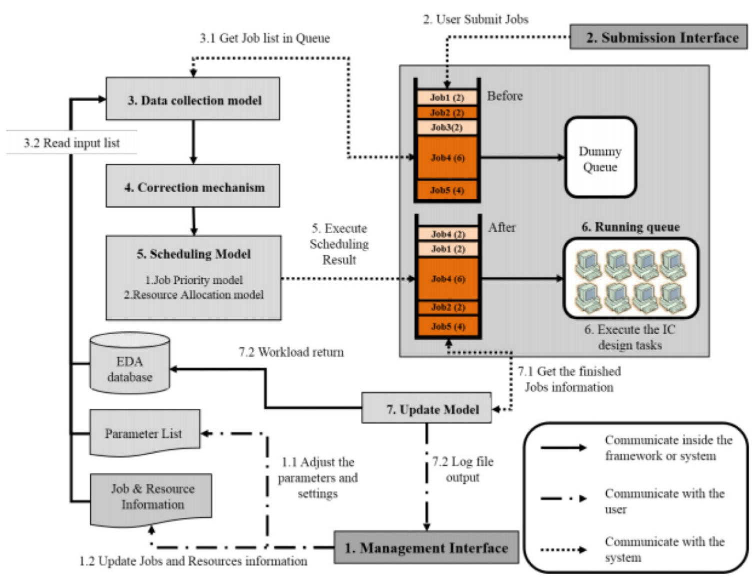

Fig. 2. Real time EDA tools for IC design [21].

IoT Solutions. With IoT, the educational institutions will be able to collect, process and store and exchange different types of data serving the e-learning techniques. The rapid growth of IoT technologies forced IoT service providers to invest in new innovations. Instead of just collecting and exchange data between the IoT devices, they started to provide data mining from the collected data that will be used later on for decision making.

2.4. Blended learning

In the current face to face (traditional) learning, teaching is done through classes that always have the same physical location, and courses are conducted at predefined times. In the blended learning process, teaching can be done at anytime, anywhere by using technology that allows online meetings with opportunities for interaction online with traditional place-based classroom methods [26]. Table 1 shows the main differences between traditional and blended teaching models.

Table 1
Comparison of the traditional and blended teaching models.

Teaching Features	Traditional Learning	Blended Learning
Location	Not flexible - predetermined classes	Flexible (anywhere)
Teaching Method	Face to face	Online, and face to face
Teaching Time	Not flexible - predetermined times	Flexible (anytime)

2.5. Traditional vs. new education models

1. **Cost**: While IoT technology will have an increase in its cost based on maintenance and engineering, it is, however, playing a major role in cutting the cost of manual processes and operations. For example, the cost of operating classrooms, books, papers, and other resources have been replaced by automation and e-learning model.

2. **Time**: Saving the time of attendance, registration, meetings, and preparations have been reduced. Also, the real-time monitoring of students, place, and staff is tracked and managed in a shorter time. This gave both students and teachers comfort in managing their time and utilizes it for better quality and outcome.
3. **Safety**: Instead of using dedicated physical security and guards, a centralized logical access control on the educational campus replaced the need for securing the students and the physical campus.
4. **Customized Learning**: The new IoT education model allows the students to personalize their Learning techniques by selecting the right approach of learning, their best way of understanding, self-assessment of their learning capability as well as an overview picture on their learning roadmap. This has shown a real outcome that prepared students to prepare for their future journey in this career sector, create a high-quality generation who can deliver in the market and their ability to create their opportunities in their real life.
5. **Virtualization**: With the new way of learning, IoT has created a virtualized world through the usage of mobile applications and web-based channels. Such online collaboration will make the traditional learning model obsolete as students and teachers will only have one way of interaction, the virtual channels.

2.6. Green IoT in engineering education

Traditionally, engineering education was a content-based, where students and teachers should physically attend the classes, carrying their physical equipment that is required for classes and labs and maintain the university facilities and peripherals. The e-learning model was not fully efficient at this stage instead, difficult to apply due to the need for the physical resources in such classes. Therefore, it was crucial to reshuffle the education model and through re-engineering, starting from the students and the physical resources in the educational institutions to achieve the objective from the e-learning model [27]. In contrast to IoT, the G-IoT at education ensures sustainable technologies that support green society, this goes through the following tasks:

- **Resource Optimization**: This means an efficient utilization of resources such as switching off the electronic resources when not needed, replacing desktops with virtual clients, using the cloud-based services and the usage of collaborative solutions for communication.
- **Recycling**: This means reusing the old IoT solutions for other purposes, repairing or recycling them in a green manner.
- **G-IoT Awareness**: The Green Engineering awareness approach should start from top management. If education institution management, board, and teachers practice this, it becomes easy for students to apply green behavior. Distribute the understanding of saving resources and automation, the cost and consumption of resources will reduce dramatically.

3. Circuits-cloud architecture

This paper introduces a novel approach for integrating the on-lab experiment built on a breadboard with the cloud-based system. It can integrate the signals received into a single scene to simulate results or run the integrated circuit using the signals received from on-lab as input for the cloud-based circuit. The platform works like an IoT integrated development platform. The platform is low-cost and requires minimal laboratory preparations since you need only to attach your laboratory device using tokens provided to send the signals generated or collected at your laboratory to the cloud-based system within your associated account. It is a simple platform and allows students and tutors to easily integrate other circuits. Re-use circuits scale the experiments and support different sensors or controllers within the same circuit design. The learner will be able to build a complete IoT ecosystem. The learner needs to configure a few cloud platform components to build an IoT project. This work introduces a cloud-based platform for teaching IoT discipline which will be an enabler for different components integration. The work will also bring the attention to the physical educational components proposed to be part of the IoT simulation and architecture, taking into consideration the main advantages of IoT on e-Learning such as collaboration, connectivity, and scalability and prove the efficiency of such integration. In areas where distance is a major obstacle hindering students from reaching or having access to well- equipped labs, distance or blended learning might be the only cost-effective way to provide education or training. The main contribution of this paper is the development of a cloud-based platform for educating analog and digital electronics courses. Circuits cloud is the only available cloud-based tools that can be integrated with the real time in-class or laboratories experiments. The initial version of circuits cloud was available online since June 2014, Fig. 3 shows the logo for circuits cloud.

3.1. Four layer architecture of circuits cloud

The circuits cloud E-lab consists of 3 layers: the circuits cloud layer, the the media server layer, the signals server layer, and the lab device layer as shown in Fig. 4. The device that integrates the system with labs experiment can send various inputs along with capturing the environments and integrating multiple sensors with the cloud system.

3.2. Applications using the cloud-based system

The cloud-based system has the potential to support many experiments and can be used as a framework for many applications. The following illustrate some ideas:

3.2.1. Smart city services and devices

IoT can provide a common middle-ware for forward-thinking smart city services. Collecting information from various heterogeneous infrastructure sensors, having access to various geo-location and IoT technologies and geo-tagging), and conveying information in a standard mean. Some recently proposed solutions recommend using cloud architectures for enabling the discovery, connection, and integration of sensors and actuators, which builds platforms capable of provisioning and supporting ubiquitous connectivity and real-time systems for smart cities. A framework may consist of sensors with Application Programming Interfaces (APIs) for sensing and actuating, and a cloud platform for the real-time management, analysis, and control of the acquired data.

Fig. 3. Circuits cloud logo.

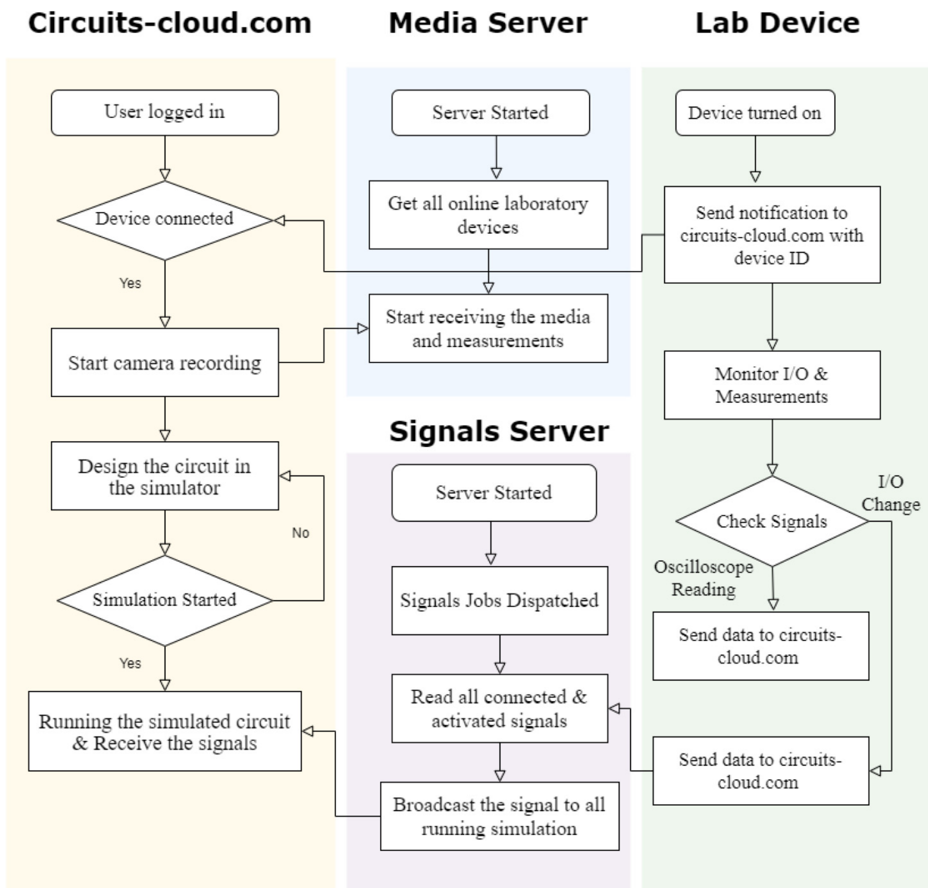

Fig. 4. Four layers circuits-cloud architecture.

3.2.2. Cloud capabilities

Security related to networked environments is a major concern for cloud IoT. Both of the IoT and cloud are vulnerable to various attacks. For the IoT, encryption can ensure data confidentiality, integrity, and authenticity. It cannot, however, deal with attacks by insiders, and it is difficult to implement on IoT devices having limited computation power. The sensor is the most vulnerable component since no additional intelligent controls can be configured on it. Also, cloud's security features require special consideration since the cloud handles the economical value, in addition to the data and tools. Fig. 5 shows the cloud Based architecture for Supporting IoT technology.

Additionally, cloud platforms require improvements to enable them to support and adapt to the fast pace of applications creation. This can be done by making domain-specific programming tools and environments readily available along with the seamless execution of applications. This can be achieved by using various dynamic and heterogeneous resources, to meet the quality of service requirements of users. Scheduling algorithms have to cater for task duplication needed for failure management, to deliver services in a reliable way [28].

3.3. Engineers garage

In this section, we are going to discuss the cloud-based system architecture. The Circuits Cloud [29] provides an in-browser cloud system for schematic capture and circuit simulation and emulation along with comprehensive laboratory device that captures, measures, and detects any defect or heated elements. Furthermore, The lab device can be integrated into circuits level with the cloud system to run real circuits simultaneously with the simulation. These tools allow students, hobbyists, and professional engineers to design and analyze digital systems. The design of the laboratory device will combine different technologies and boards into one product that increases the features and simplifies the functionality and reduces the total cost and space when buying separate products. Fig. 6 shows the main components of the cloud system.

The cloud-system expands horizontally to support many active students at the same time, using the elastic features offered by Amazon Web Services (AWS) which hosts the service. The student can add any available equipment into the editor and start building the circuit, the system automatically allocates required resources for compiling and running the simulation, and emulation. The cloud-system is cross-platform. It can be run on handheld devices, tablets, PCs and Macs. It features:

- Digital Circuits Schematic
- Digital Interactive Simulation
- Digital SPICE Simulation
- Analog Circuits Schematic
- Microchip PIC Emulation
- Arduino Boards Emulation
- External Signal integration with circuits
- Laboratory Devices

The cloud-based system is utilizing API with security tokens to allow users (Student or tutor) to send the on-lab experiment signals and data to the associated account on the system, and thus, to use these data as input to any circuit design for simulation and testing the circuit components with other parts easily and effi-

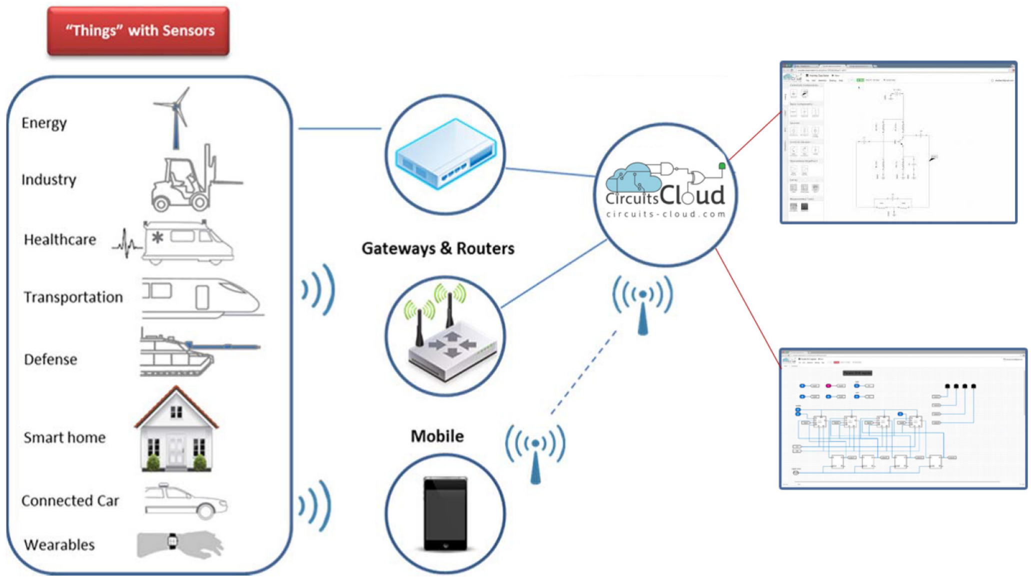

Fig. 5. Cloud IoT architecture technology.

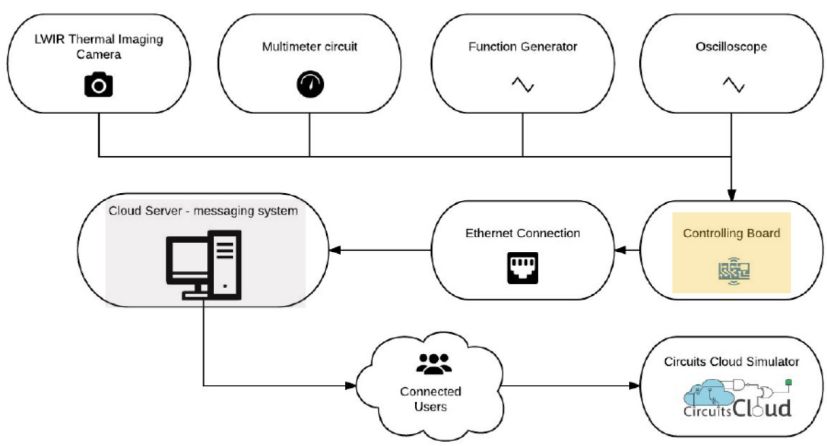

Fig. 6. Cloud-system architecture.

ciently. The graphical interface is mobile friendly and features collaboration and sharing options where the user can fork a public circuit and modify the copied, share his own design either privately or publicly. The tutor can administer and audit the classroom committed designs.

4. Security challenges in cloud-based and E-learning systems

Being exposed to the internet means that the e-learning environment will also be exposed to its security and risks and, in turn, cyber-attacks. The e-learning institutions are competing to transform from a traditional learning model to the online environment without taking into consideration the security aspects behind it. Cloud-based e-learning is one of the online methods that aim to reduce the cost of education as well as the complexity of management by transferring such factors to a third party or service provider. Although the traditional e-learning models are integrated with cloud computing methodology, most of these models overlook the security aspects of cloud computing. The main security concerns behind the cloud-based e-learning are the data availability, integrity, and privacy which requires robust security layers and using the concept of defense-in-depth. Cloud Service Providers provide three types of services based on the requirements, namely Platform as a Service (PaaS), Software as a Service (SaaS) and Infrastructure as a Service (IaaS). Each type of services has its own security risk.

4.1. Security issues in PAAS

In this model, the service provider provides the platform and the software as a service.

4.1.1. Data location

While the educational institution takes advantage of such service, they might not know where their data is stored and how it is processed. Therefore, for an instant, European Union have implemented the General Data Protection Regulation (GDPR) that mandate any country dealing with EU personal data to follow this regulation to ensure such data is properly managed and secure.

4.1.2. Privileges access

Confidentiality is a major concern in cloud services. It is also difficult to provide the assurance of this aspect. One way to maintain this is to sign a non-disclosure agreement which makes the cloud service provider legally responsible for any data leakage or breach occurs in the cloud. Another method is to implement a robust access control policy which instructs a periodic audit and review over the unauthorized data access and practicing the security principles like the segregation of duties, least privileges and needs to know. Also, implementing strong encryption mechanisms while securing the keys in dual custody.

4.2. Security issues in SAAS

In SaaS, the service provider takes care of the security countermeasures and controls. This includes the assurance of access control and confidentiality to student's data, the integrity and availability of data in a continuous manner.

4.2.1. Data security

Data is the main resource in cloud systems. The service provider tries their best to provide a level of comfort to the client, the education institution, about how and what data are being manipulated in the cloud, and whether the data is secure? Where is it stored? Is it shared with any parties? What if data get corrupted? The educational institution should have a transparent view, as the owner of data, about the process of data being manipulated in the cloud. Also, the data owner should have a clear picture of the security countermeasures taken by the service provider in case of any breaches that might impact their data. Cloud service providers should give some authority to the data owner such as decision making on unauthorized access found, taking a periodic backup of their data and provide the authorization prior to any data retention or disposal including the migration of the cloud environment.

4.2.2. Network security

Network security is the main channel of communication and service provider should ensure proper controls and monitoring are in place. This includes but not limited to a periodic network scanning for vulnerabilities, security flows, web-based misconfiguration and deployment of strong encryption algorithms.

4.2.3. Data integrity

Integrity of data means the reliability and consistency of data. The service provider should ensure that data are protected from unauthorized modifications. Based on the fact that cloud-based e-learning environment is sharing resources with other clients, the service providers should implement a robust security control mechanism like digital signature, hashing algorithms, and message authentication algorithms.

4.2.4. Data segregation

Cloud is a shared environment where multiple clients are sharing the same cloud resources which make the data segregation a complex approach. As a data owner, educational institutions should do some homework by assessing the service provider architecture to ensure their data is properly segregated and secure.

4.3. Security issues in IAAS

Infrastructure as a service provides full control to the data owner over the resources such as the network and storage resources. The cloud service provider will only be responsible for implementing the security controls and configurations on this infrastructure. Some of the different attacks in this type of cloud services are Web service attack, Service Level Agreement (SLA) attack, Distributed Denial-of-Service (DDoS), Man-in-the-Middle (MitM) attack, and Domain Name System (DNS) attack as shown in Table 2.

4.4. E-Learning security concerns

E-learning technology will always be in question when it comes to security. In comparison with the traditional learning approaches, the following security concerns will a raise:

4.4.1. User authentication

Traditionally, it is known that students get authenticated to their courses and classes on time only, during the registration. There is no frequent validation and authentication mechanism to allow students to enter classes they are not intended to attend. With e-learning, students will be required to authenticate, such as through credentials to attend the online sessions, labs and collaborative forums. Students might see this overwhelming the education process and inflexible. Also, the educational institutions should consider robust access control to mitigate the risk of sharing of identities and credentials between students.

4.4.2. Non-repudiation

Tracking accountability is a major concern in e-learning. Any unauthorized access or modifications should be detected and monitored in real-time as well as audited. This will help to track those who deny their attempted actions.

4.5. Security benefits in cloud-based and E-learning systems

Although cloud-based and e-learning systems have security concerns based on their nature, they also enhance the security from different angles.

1. **Improbability**: Cloud systems make it hard for intruders to determine the location of sensitive data such as exams questions and results or finding out the digital assets and components that store such data.
2. **Virtualization**: Portability is a major key benefit. With virtual infrastructure, it is easy to manage and contain any security breaches on the systems with minimal cost and downtime. The replacement of the infected virtual environment can be replaced in a silent and sustainable manner.
3. **Centralization**: Data stolen or losing the storage is no longer a major concern with cloud systems. Data are backed up and clustered in shared/ centralized resources which provide assurance on data availability and integrity. This is compared to the traditional learning models where data are stored in a physical location and the possibility of losing data is more likely.
4. **Monitoring**: Real-time monitoring of data and access became easier and more managed. This gives an insight on data modification and ensures the integrity of data is met.

5. Experimental results

The system can support many experiments and can be used as a framework for many applications. In the following we are discussing some of the conducted experiments, and then we will compare the circuits cloud to other available EDA cloud based tools.

5.1. Supported components

The cloud-system has been developed with around 100 different components. To start building a circuit, the system is showing a drag-and-drop list of available components, categories by type; digital, analog, and micro-controllers. The circuits cloud architecture user interface shows the top-level design of the circuit and allows the user to configure the inputs and outputs of the circuit as shown in Fig. 7. The 3D model of circuits-cloud trainer is shown in Fig. 7 All components are having the snap feature that enables

Table 2
Service level, type of users, security necessities, threats & security challenges in a cloud environment.

Service Level	Type of users	Security Necessities	Threats	Security Challenges
Software as a Service (Zoho planning, Google, Salesforce, Enterprise resource planning, Human Resource, customer Relationship applications)	Who are in need of Application Services offered by cloud vendors	• Multi-tenant deployment • Data Consistency • Information defense • Application protection • Availability of Services	• Data Breaching • Data Correctness • Modification of stored data • Session Hijacking • Network traffic investigation	• Governance and Corporate Risk Management • Legal Issues: Contracts and Electronic findings • Auditing compliance • Information organizations and secure data • Portability and exchangeability • Conventional protection, Business Continuity and Disaster Recovery
Platform as a Service (Java, Runtime, Middleware, DB)	Application Developers can develop their programs using PaaS Cloud Platform Service	Secure the Data in data transfer, data in idle Secure Images Hypervisor based Security Virtual Machine based security	Defects in set of coding Coding Modification Application Programming Deletion Imitate the relevant programs	• Data Center Procedures • Confrontation Response, Notification and Remediation • Programming Security • Encryption and Key Management
Infrastructure as a Service (Network, Storage, CPU)	User needs to obtain Physical (Infrastructure resources for their usage from Cloud Service)		Flooding request to sever Configuration mismatch in traffic route Distributed Denial of Service Breaking up the communication	• Identity and Access Management • Virtualization • Security as a Service

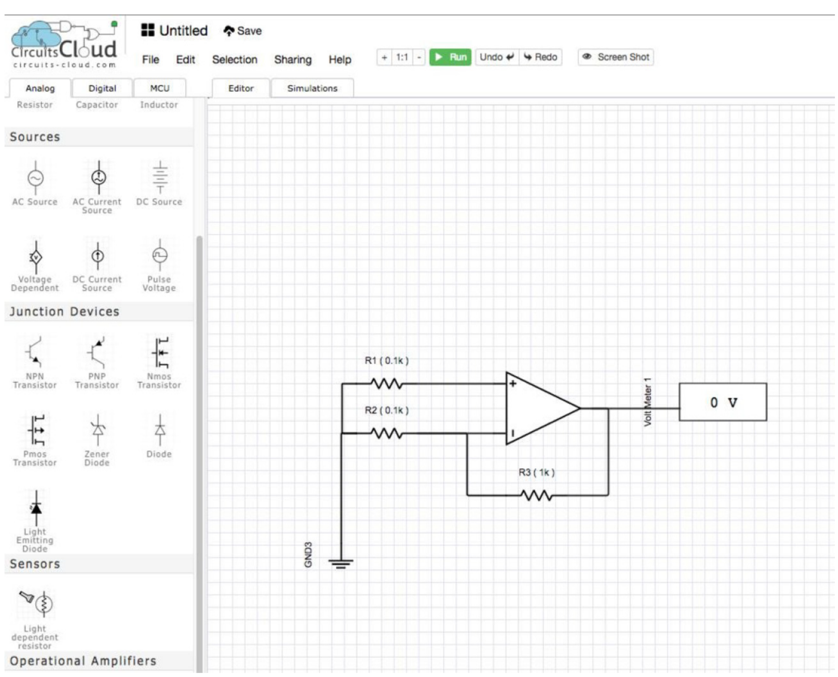

Fig. 7. Circuits-cloud architecture interface.

the connectivity of between any two components. The circuits cloud system enables running a simulation concurrently with a real time physical circuits built in the laboratory, this feature can be implemented by selecting the option of connection and it's converted on-the-fly as an interfacing system. The user is able to integrate different components in the same circuit, in the following we are listing the main components used in IoT circuits cloud:

5.1.1. Arduino

The used Arduino platform comprises a shielded components, developed in-house, for good integration with analog audio signals, user provided inputs and a standard Arduino Due which executes students' DSP program. Such a combination allows direct use of the Arduino integrated development environment (IDE), which has a low barrier to entry for students, low maintenance need and cross-platform interoperability. Discussed later are hardware and software features of the platform and design options are taken to cater to the learning goals, and the expected utilization of the platform in the DSP module [30] (see Fig. 8).

5.1.2. Micro-controllers

E-learning system consists of a virtual-circuit-making function for building circuits with a versatile Arduino micro-controller and an educational system capable of simulating robots' behaviors.

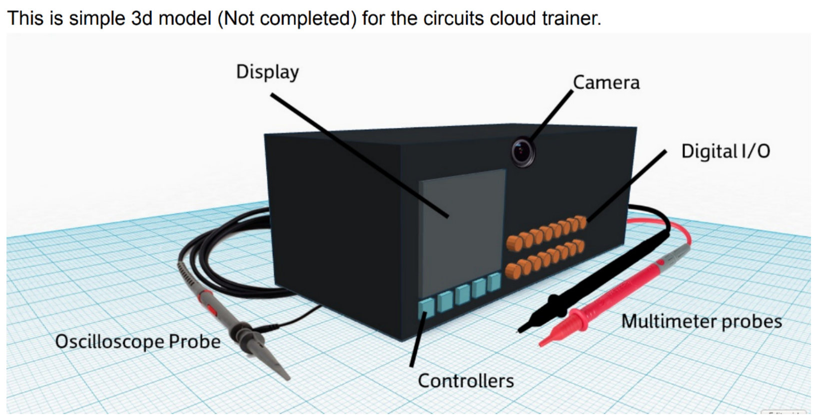

Fig. 8. 3D Model of circuits-cloud trainer.

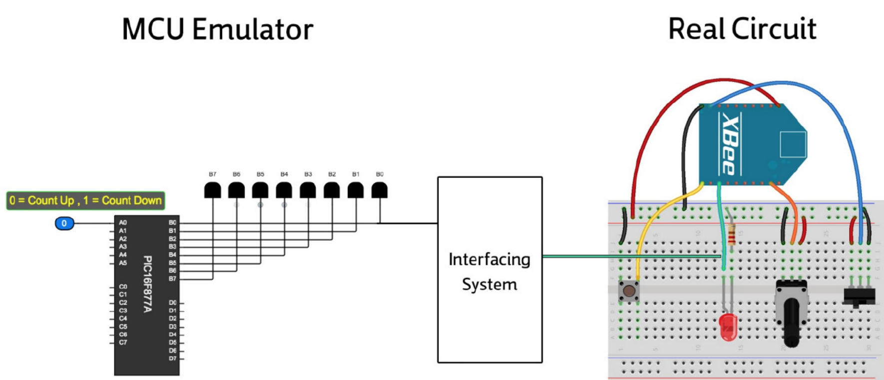

Fig. 9. Connecting real circuits with a cloud system.

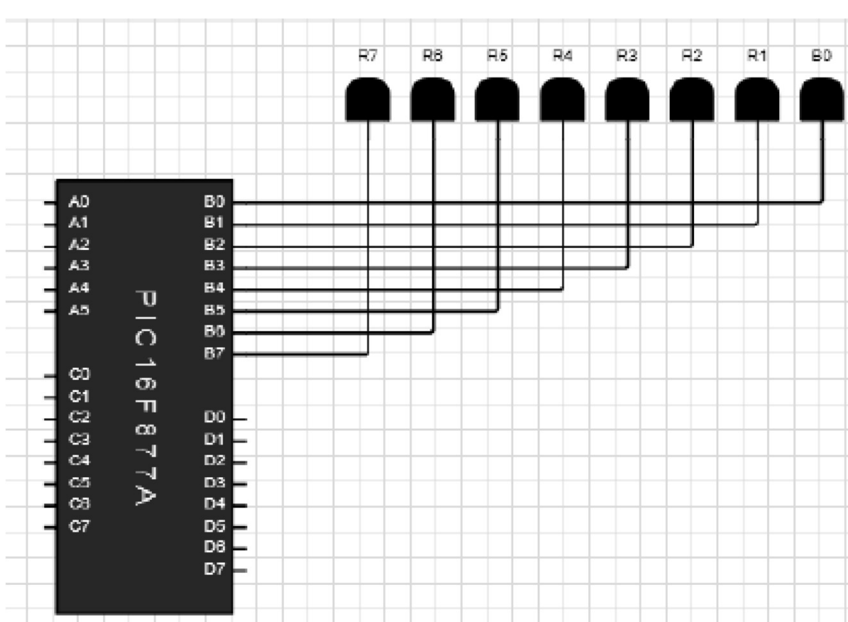

Fig. 10. The micro-controller circuit top-level design.

The proposed system consists of a system learning the construction of electronic circuits in a line-tracer robot with the general-use Arduino micro-controller and a simulation system to learn robotics behavior [31].

5.1.3. Electronic parts

Micro-controller systems and programming are ideal for learning about electronic systems, digital electronics, and for rapid prototyping. The modular nature of the sets makes them highly

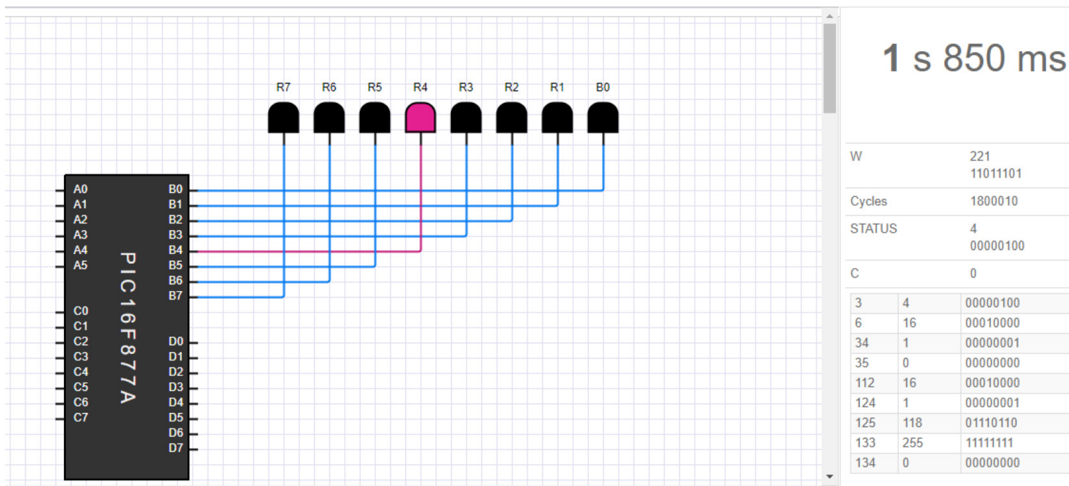

Fig. 11. The digital lab simulation.

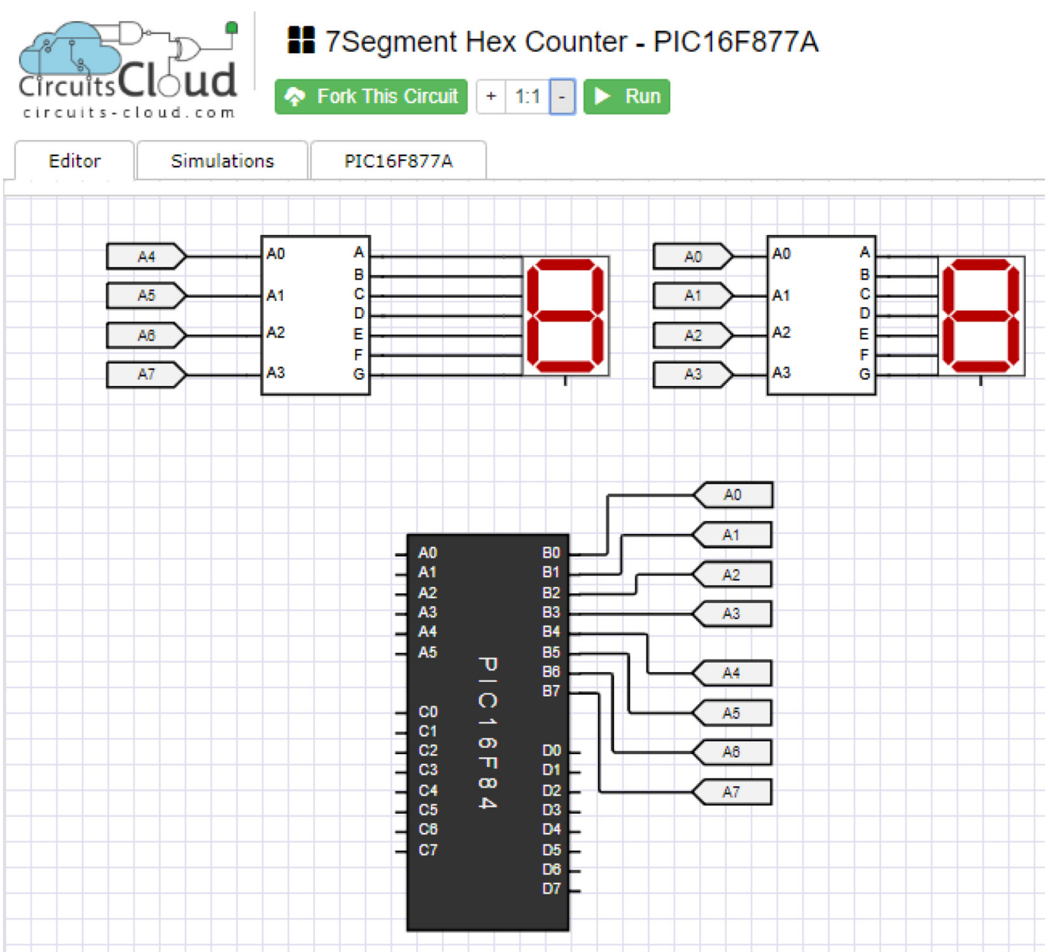

Fig. 12. Schematic of 7 segment counter.

flexible. Each set consists of a mounting panel, with a choice of upstream programmer board technology – PIC or Arduino – and a standard downstream board. Optional downstream boards allow the creation of a wide variety of electronic systems. The sets can be used by students in educational environments, up to engineers in the industrial world. The technology is real, up-to-date, and provides a great base for training the next generation of engineers and technicians. An electronic circuit is a structure that directs and controls electric current to perform various functions including signal amplification, data transfer, and computation. It consists of several different components such as transistors, capacitors, resistors, inductors, and diodes. Interactive digital circuit simulation contains various type of micro-controllers' real-time emulation, Including Microchip (PIC, Atmel AVR) Families, Real-time emulation for Arduino boards. Analog Circuits SPICE Simulation, Interactive digital simulation, Analog and Digital signals broadcasting over IP, Real sensors built in with real environments effects, Integrated oscilloscope hardware with a cloud system and Integrated multi-meter hardware with the cloud system.

5.2. Micro-controller emulation experiment

In the following, we are going to set up a quick experiment to run a counter using PIC16F877A and display the output on attached LEDs as shown in Fig. 9. The circuit top-level design is shown in Fig. 10.

The system allows the user to debug the code, and run it step by step with the ability to monitor flags, show the number of cycles required to execute the step. Fig. 11 shows how the simulation works and showing the expected results on the LEDs.

The cloud system has great flexibility by allowing the student to test the same concept on 7 Segment instead of LEDs as shown in Fig. 12. The student does not need to redesign everything, but he can make a fork to copy the design to a new project and try the new amendments to the design without losing the previous results.

The following graph shows the modification to the schematic:

The cloud system is able to integrate the analog parts also easily. Fig. 13 shows the schematic of a push power follower which

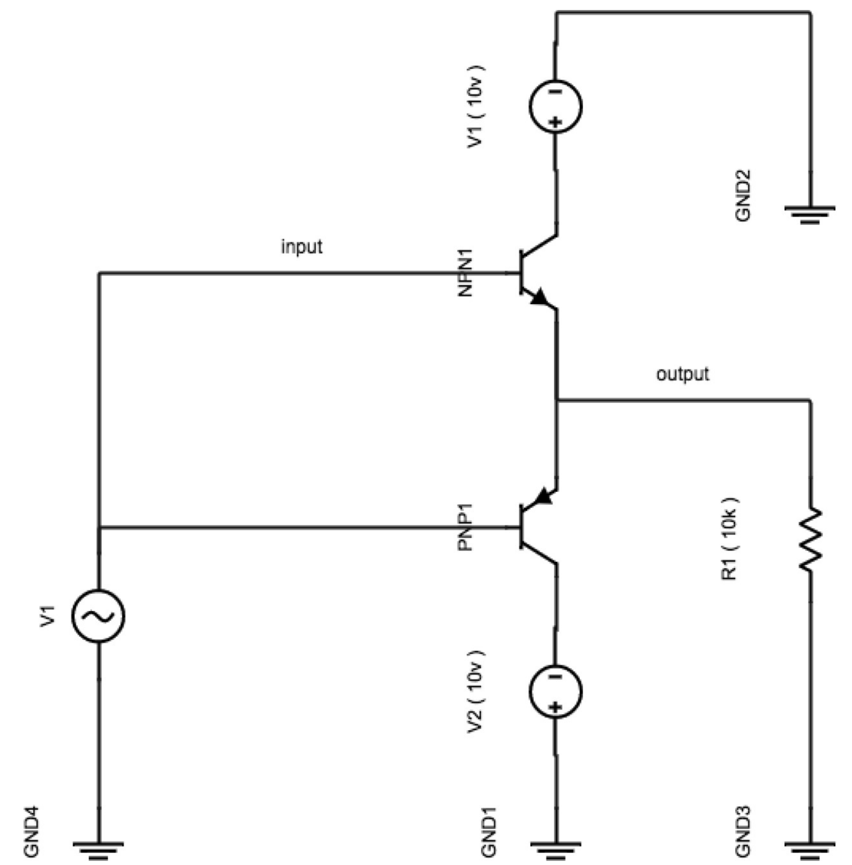

Fig. 13. Schematic of the push–pull follower circuit.

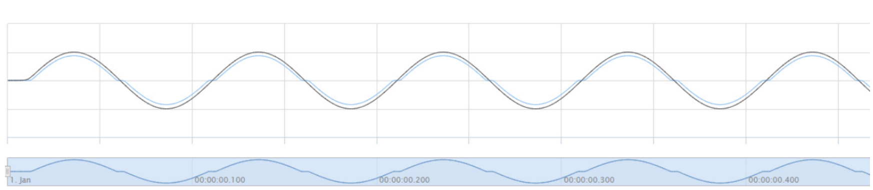

Fig. 14. Simulation of push–pull.

Table 3
Comparison of circuits-cloud platform and other available cloud based simulation tools.

Feature	Multisim	Circuits IO	Circuits Lab	Every circuits	Circuits Cloud
Digital Circuits Schematic	Y	Y	Y	Y	Y
Digital Interactive Simulation	Y	Y	N	Y	Y
Digital SPICE Simulation	Y	N	Y	N	Y
Analog Circuits Schematic	Y	Y	Y	Y	Y
Analog Interactive Simulation	Y	N	N	Y	Y
Microchip PIC Emulation	N	N	N	N	Y
Analog Interactive Simulation	N	N	N	Y	Y
Arduino Boards Emulation	N	Y	N	N	Y
Arduino Boards Emulation	N	Y	N	N	Y
External Signal integration with circuits	N	N	N	N	Y
Laboratory Device	N	N	N	N	Y
Cross Platforms	N	Y	Y	Y	Y

contains transistors and resistors, and the simulation is shown in Fig. 14.

5.3. Comparison with other tools

There are many cloud based EDA tools available online as the cloud-based services become essentials in this era, a comparative study shows that the only tools that combine the cloud-based system with the real in-class experimental study are our implemented design. Table 3 shows the comparison of the introduced circuits-cloud platform that has the full features with other available EDA cloud based tools.

6. Conclusions and future work

Cloud computing provides the full-fledged service and delivery to the e-learning institutions, however, it brings as much security risks as its benefit. While cloud systems reduce the cost of infrastructure deployment and maintenance as well as the complexity behind the management, it is a matter of risk taking to run your institution software on someone else's hardware who stores all your data in a shared environment. Unauthorized access and modification, data loss, DDoS attacks, and MitM attacks are some of the serious security challenges threating the e-learning models in the cloud. However, cloud-based and e-learning models have enhanced the security from other angels. Compared to the traditional approaches, Cloud Computing improved data security through improbability, virtualization, centralization, and real-time monitoring.

In this paper we have introduced a novel approach for integrating the on-lab experiment built on a breadboard with the cloud-based system that can integrate the signals received into a single scene to simulate results or run the integrated circuit using the signals received from on-lab as input for the cloud-based circuit. The system works like an IoT integrated development suite, which has the features of low-cost, requires minimal laboratory preparations. This research is developed with simple functions of electronics using basic components and micro-controller. The introduced circuits cloud uses AWS for providing the cloud services that help in protecting data, user accounts, and workloads from unauthorized access.

The cloud system can be enhanced by adding the Field Programmable Gate Array (FPGA) because the use of Hardware Description Languages (HDL) is vital to IoT field and will be valuable for the students to get complete on-demand laboratory with full-fledged electronics components and development boards. Furthermore, the simulation process can be improved by reducing the memory and processors utilization. A hardware or training kit should be developed to provide the students with cloud-based simulation and real time applications. While security feature provided by the cloud come in handy in protecting the system for students and teachers, further work can be done to secure the code behind this system, so that it cannot be taken or amended by unauthorized personnel yet make it easily available for usage.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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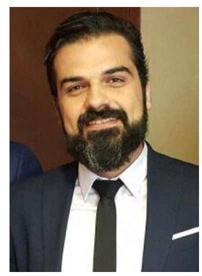

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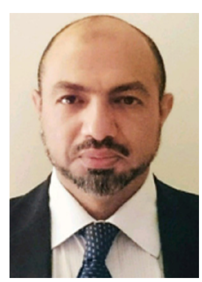

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