American Journal of Engineering Research (AJER)
e-ISSN: 2320-0847 p-ISSN : 2320-0936
Volume-12, Issue-8, pp-26-34
www.ajer.org
Research Paper Open Access

Influence of Electronic Science and Technology

Remzi YILDIRIM[1], Abubaker A. GUTTAR[2], Ousama A.SHAABAN[2], Ahmed SALIHY[2], Abdurrahman HAZER[2]
[1] *RY Photonics, Ankara, Turkey*
[2] *Graduate School of Natural and Applied Sciences, Department of Computer Engineering, Ankara YıldırımBeyazıt University, 06760 Ankara, Turkey*

ABSTRACT : *In this study, a brief analysis of the semiconductor era, the development of science and technology, made of semiconductor germanium, silicon and other materials was made. It is seen that analog electronics, which is used as a basic technology, contributes greatly to the development of other fields of science. In other technologies developed depending on this basic area, the pyramid structure is given according to the signal processing techniques and the order of development. Design techniques have been added to this pyramid depending on the signs used by the systems. The designs of the systems are generally determined according to the signal processing techniques, and the processes for modeling; simulation and standard production are also determined. In this, system design techniques, signal processing techniques, testing, durability and stages until the production stage are defined together*
KEYWORD: *Semiconductor, Diode, Transistor, Chip, Technology*

Date of Submission: 24-07-2023 Date of acceptance: 06-08-2023

I. INTRODUCTION

There have been many important developments and inventions in science over the last century. However, no invention of the semiconductor has been as influential as the diode and transistor. The diode and transistor did not radically change electronics and other related sciences and technologies. The transistor, the active part of electronic circuits, was invented in 1947 by John Bardeen and Walter Brattain of the William Shockley team at the Bell Telephone Research Laboratories [1]. The team received the Nobel Prize in 1956 for their work.

Jack Kilby and Robert Noyce produced the microchip, the next stage of the transistor, from semiconductor for the first time in 1959 [1]. Thus, the packaging of semiconductor transistors entered a new stage. This stage is the placement of a large number of transistors in a small volume and also a new breakthrough in the field of circuit systems. The development of this microchip technology has led to a very significant technological change in the field of circuits and systems. This very significant development accelerated the development of electronics and then computers and all other electronic systems. This technological change has forced some of the other fields of science to change and has influenced some other fields of science.

The first application of the semiconductor transistor was in 1953 when Texas Instruments produced radios [1]. Thus began the semiconductor world or the Ge-Si era. The production of Ge-Si Microchips led to a revolutionary development in the electronics industry. The main ones are the production of computers using semiconductor chips, the production of semiconductor logic gates and the digital electronics era. The production of many different memories such as RAM and ROM designed by these logic gates and then the production of microprocessors as chips can only be counted as the main ones. This new digital technology and computer technology has affected and continues to affect all kinds of business areas. This semiconductor technology and science has entered every field of industry. Chips continue to spread rapidly in our daily lives. Today, they are being further developed and used for different purposes, even in humans or people consisting of biological structures. It is estimated that they will be used much more widely in bio-hybrid systems in the coming years. Perhaps the materials from which the chips are made are nowadays obtained not only from Ge-Si but also from many other elements. But the end goal is the same. In the future, the Ge-Si era will soon be replaced by quantumchips. Because, it is given in many open sources that they are working intensively in these areas. The quantum era will close an era in technology and science and start a new era. Therefore, we think that quantum systems or chips are very important.

2. TECHNOLOGY LEVEL

In this study, it has been tried to determine the current state of use and the trend of the technology as a forecast for the future, which is basically produced from electronic science and technology. For this purpose, the systems were evaluated according to their signaling characteristics in general. While making this evaluation, only very basic features were taken into account. These include the signal used by the system, the basic structure of the system and the design technique. On the other hand, the marking used in the design, model check and testing for mass production, and then certification procedures to obtain a production permit were taken into account. Whichever product is produced, it must obtain a production certificate and a certificate of availability for users in order to document its compliance with the legislative rules. For these, it is mandatory to have passed the standard tests of reliability and resilience engineering standard tests. Before these tests are performed, we think it is necessary to perform model pull tests to test the operability of the system. For this, it is necessary to have extensive knowledge in advance for the selection of the technology to be used. The choice of technology and then the management and production of this technology should be decided. Of course, the biggest problem for new technologies is the lack of standards and the need to learn how to test them. Then the certification process is completed. Abbreviations and their meanings and short and brief characteristics are explained below.

Analog Technology (AT): Analog systems or technologies form the basis of today's technologies. The general meaning of this is that all systems that do not use digital signals are called analog systems. The area where it is very commonly used is more commonly used as analog electronics. However, if it is evaluated as the signal it produces or uses, it would not be wrong to use it as the name given to large and small systems that produce or process analog signals. The biggest negative aspect of these analog systems is that the signal used is the use of the same signal continuously from one end to the other. As a result, continuous amplification and filtering noise is very effective [2].

Digital Technology (DT): It is used as the name given to systems that process or generates digital signals. In these systems, while the digital signal leaves a system or unit, the signal itself is regenerated. The signal produced in analog systems, or the signal itself entering the system is used without being renewed or reproduced as the original. In this respect, digital systems have advantages over analog systems. However, the negative aspects of these systems are the delay time delays are very high. Working at very high frequencies creates problems or work. With analog systems, they operate at higher frequencies [2-3].

Hybrid Systems Technology (HS): Hybrid systems are dynamic systems consisting of the combination of many different systems. There are many examples such as automobiles, electric-gasoline, gasoline-LPG, gasoline-LPG-electric [4].

Process Control (PC): Process control systems are systems built to meet the needs of industry. These systems are based on classical logic and analog electronics [5].

Operation Control Technology (OT): Operation control technologies are systems developed for the needs of the industry. While the beginning of these systems consisted of analog electronics and classical logic systems, today all kinds of technologies suitable for the purpose are used [6].

Information Technology (IT): Information systems are systems that developed after the invention of computing systems. Today, they are widely used in every field [7]. It represents the development of software-based systems, especially those that developed after operational technology.

Internet of Things (IoT): It is known as the Internet of Things or "Industry 4.00". The purpose of these systems is to minimize the human resources working in the sectors and to increase productivity to the highest level and to reduce costs to the lowest level [8].
Industrial Internet of Things (IIoT): The Internet of Things is the name of a system consisting of a large network structure whose bandwidth is very large or meets the need. While IoT requires limited bandwidth, IIoT requires very wide bandwidth [9].

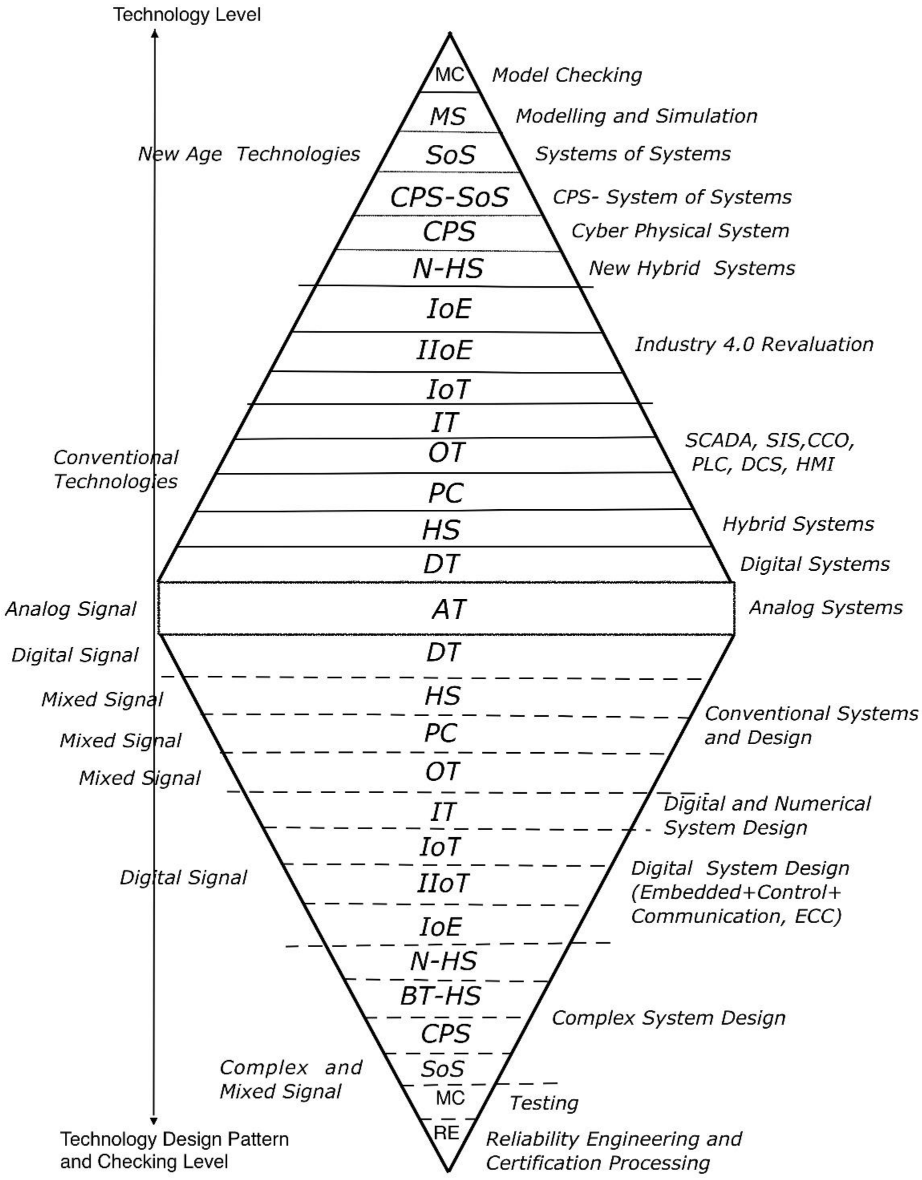

Figure 1. Analog electronics based systems, signals and classification

Internet of Everything (IoE): IoE is the technology that covers the fact that everything in the future will be controlled via the Internet or communication systems [10].

New Generation Hybrid Systems (N-HS): New generation hybrid systems, on the other hand, are systems that enable the transplantation of organs taken from very different organisms to organisms that are not of their own species, and that do not industrially produce organs and similar particles biologically. For example, the implantation of artificial non-biological eyes in humans.

Biotechnology and Hybrid Systems (BT-HS): These systems aim to adapt products from biotechnology to hybrid systems. For example, the use of biological ears in seismic systems for listening to sound. Artificial ears can also be used in acoustic systems. Today, microphones are used here.

Cyber Physical Systems (CPS): Cyber physical systems are a combination of many systems. Europeans refer to a sub-section of CPS as IoT. However, the US does not set any limits for CPS. Therefore, it can consist of many different systems, large and small. Robots working in a group in a factory and all robots working in the factory are good examples of these. Again, more than 2000 systems used in passenger airplanes and all electronic systems in automobiles are current examples of this field [11-13].

Systems of Systems (SoS): SoS is systems that are composed of many independent systems. They can operate both independently and in concert with other systems, or they can operate as a single system. An example is the control of intercontinental missiles with nuclear warheads. Where the missile passes over land, it is controlled by radar systems on land; at sea it is controlled by ship radars, in the air it is sometimes controlled by aircraft radars, and again by applications. Each system operates independently. Each system is controlled independently and receives feedback. All systems in the system of systems are combined and controlled in a single system structure [14]

Cyber Physical System of Systems (CPS-SoS):CPS-SoS systems are large systems consisting of both systems combined. For example, it includes all the systems on an aircraft carrier. Each system can operate independently or as a single system [15].

Modelling and Simulation (MS): Modeling is the definition of mathematical system equations of a system or the definition of mathematical ratios for the work to be used appropriately. Simulation is the operation of these mathematical relations, time base, frequency plane or ratio equations by computer in the appropriate plane to be used. The more realistic the ratio equations are organized, the more accurate the results are. In other words, simulation results are obtained depending on the success of the mathematical equations [16-17].

Model Checking (MC): It is the testing of the finished product or model with a large number of variables using model logic techniques. This testing process consists of a structure depending on the variables used in the product. For example, testing a passenger airplane is very different from testing a smartphone. Their variables are also different [18-19].

Reliability Engineering and Testing Certification Process (RE):RE engineering is the final testing process performed by manufacturing organizations before a finished product is tested for conformity to standards. This is the stage before official corporate production authorization is obtained [20].

3. SIGNAL TYPES AND SIGNAL PROCESSING TECHNIQUES USED BY SYSTEMS

Signal techniques use optical and electrical signals as sources and analog, digital and digital systems as signal types. These systems are the ones that use the same type of profit from one end to the output and the ones that use a different signal. These are analog signal input is converted to digital signal; the output signal can be analog or digital. The other is the optical signal. This signal also has analog and digital variants. Generally, systems that use mixed signal types consist of hybrid, CPS and complex systems. These systems are a combination of more than one system with different structures. For example, a passenger aircraft may have analog and digital communications for communication, satellite and GPS receivers, hydraulic, pneumatic, mechanical, or multiple different systems working together for the electronic and mechanical systems of the aircraft, the outputs of many sensors are analog, and there are other subsystems to make these signals meaningful. Today, it is very difficult to find simple or pure technology systems. The reasons for this are that very large electronic hardware and short computational systems can be produced in very small physical sizes. For this reason, it is often preferred due to cost. A simple example is children's toys. These toys are both cheap and have very good capabilities.

Another type of signal is the Bio-signal type. This signal is the type of signal received from living things or measured from living things. These signals are especially used in measurements in medical electronics. Instead of classifying this signal as analog or digital, it is more appropriate to call it a bio signal. There are two types of this signal. One is a complex signal in the form of special packages delivered by blood; the other is signals sent from the nervous system and signals obtained from the sub-sections of the bio system. For example, the heart cardiograph signal. Another type of signal is the optical signal. This is the type of signal used by the biological system, especially in the eye and vision process in children. Acoustic signals and systems are used for hearing. These are the types of signals that can be seen and physically measured. We think that there are many other types of bio signals. These are the types of signals that are known today. But it is also known that many subsystems such as forces, transducers, sensors, actuators, etc. produce signals. The most obvious example of this is, is gravity a force? Or is gravity an energy? If it is energy, what kind of energy or force is it? We are still discussing this.

3.1. TECHNOLOGY LEVEL

These systems are generally technologies developed on the basis of analog electronic technology. For this reason, developments in analog electronics technology directly affect all other technologies that follow, and other technologies develop and grow accordingly and are offered to people as products. Electronics technology is also dependent on semiconductor science and technology. If semiconductor technology develops, electronic circuits and systems chip technology also develops. Semiconductor science and technology is also dependent on materials science and technology. If materials science develops, so does semiconductor science and semiconductor technology. Therefore, development must take place in all fields of science and technology so that other fields can also develop. Every field of science and technology should be seen as a whole and should develop as a whole. Sectoral, this is true.

In the figure 1, all fields of science and engineering have developed and are developing completely dependent on the development of analog electronics. "Digital Logic" parts are designed by taking advantage of the characteristics of the analog electronic parts in different operating areas, as a result of the design of the characteristic operating points in different areas. From these simple "inverter and logic gates" flip-flops, counters, ADC, DAC converters, encoders, decoders, RAM, ROM and ALU and other subsystems are produced. Many different products are obtained from these subsystems. Many examples can be given such as analog-digital converters, digital analog converters, memories. Circuits and systems engineering has emerged from the combination of these sub-parts and systems. Circuits and systems engineers produce new electronic components by combining many subsystems. For example, the PIC is the most prominent example of these. PICs are the control unit produced by General Electric for microprocessors. Over time, the PICs themselves have become a part due to the needs of the industry.

Microprocessors are systems that are used for general purposes and are peripherals inside the chip. However, due to the needs of the industry, systems such as micro-controllers, microcomputers, COPs, PICs and VHDL and many processor systems are produced today. The development of these many different systems in the same chip circuits are made by system engineers. Examples that come to mind are single-chip calculators, modem receivers and transmitters for credit card withdrawals, and postal machines with digital communication systems and printers.

Hybrid systems are new types of systems consisting of electronic, digital logic and mechanical systems. The most prominent hybrid system is the hybrid automobile. Hybrid automobiles have many different applications such as mechanical, electronic, LPG, NLG and electric. In addition to these, printers, photocopiers, offset printing machines have both electronic, electro-mechanical and software. Today, such hybrid systems are becoming widespread.

Process control technologies, on the other hand, are the industrial application of analog and digital systems used in the widely used process control. In these systems, there are also measurement systems for process control. These measurement systems can use different sensors. Measurement systems are made with electronic sensors or electronic systems. Depending on this measurement process, process control is performed. It is still in use today.

Operation technologies are again the technology group used in all kinds of control processes in the industry. In this technology group, all kinds of technologies needed are used together. These are generally the technology segment used for large systems. For example, we can count the system formed by factories that make mass production with full automation.

Information technologies are systems whose core system consists of technology and digital system control. These technologies are systems that process and produce digital data based on software. It is a set of digital systems that are much better than other systems thanks to the flexible capabilities of the system. In previous systems, software-dependent systems may be limited. The most obvious difference of these systems from others is that the core system is digital. Therefore, the arrangements in the core system directly affect the whole system. These systems can record the data of the operations performed. In other systems, data can be recorded when requested. By analyzing all the data in the past, all kinds of information about the system can be accessed and it also gives the opportunity to work on the system for the future. In these systems, all kinds of feedback are possible. A few exceptions to this are that all systems in mass production work with new data after shutdown. This can be partial shutdown or general shutdown. It depends on the desired data change. Again, mass production facilitates the tracking of faulty products and provides the opportunity to analyze big data.

Examples of these include all kinds of data banks of governments, institutions and organizations, digital communication systems, Internet network.

IoT is a new type of application that combines two technologies, Information and Opration Technologies (IoT). IoT is never a new type of technology. It should be considered as the name given to the combination of different technologies and their use in different fields. No new technology is produced. However, it is the application of existing technologies by combining them in many different areas. For example, a tractor plowing a field unmanned with GPS connected. All air, sea and land vehicles used unmanned can be counted.

IoT technology called Industry 4.00 or the Internet of Things. IoT systems are a combination of communication, physical system, and control and computation systems. These subsystems are independently operating and controlled systems. There is no feedback in the whole system. The most important problem in the communication system is the bandwidth in real-time systems and the technical time delays caused by digital communication techniques. If digital communication is used in the system, there is never a definite solution to the data time delay. However, if the data is increased to very high frequencies, the time delay effect can be reduced. Or technically, if the data time delay is provided at very small times from the response of the system, the time delay is neutralized. However, this problem has not been solved today.

The IoT system uses mixed signals. These can be analog, optical and digital signals. Optical signals can be used in optical networks used for communication; electrical analog or digital signals can be used in control systems. All semiconductor sensors in the control system generate analog signals. Therefore, the conversion of these signals to ADC and then to DAC signals causes real-time physical time delays. All sub-layers or base layer outputs of the system are the sum of the real-time delays generated by the underlying systems. As each system operates independently, time delays are also generated independently. Most of these time delays are due to physical causes. Therefore, the data processing time delay problem is not easy to solve. Real-time data processing time delay can be reduced to acceptable reasonable times, but it can never be zero due to physical reasons.

IIoT, Industrial Internet of Things, can be considered as a more comprehensive version of IoT. It is theoretically accepted that the bandwidth needed for communication is infinite. However, there are bandwidth limit values in practical applications and technologically. If the bandwidth problem is technologically solved or if very broadband technology develops, the rate of widespread realization of IIoT is very high if sufficient bandwidth for users is met at very low cost. Otherwise, it has a chance to be used in limited countries and areas.

The next stage of IIoT is the Internet of Everything (IoE) or the Internet of Everything or the control of all kinds of objects through internet/communication systems. This concept theoretically exists today. However, it is not practically possible with today's technology. However, if science and technology change and new fields of science and communication technology develop, there is no limit to its application. This limit is only valid for today.

Next-generation hybrid systems (N-HS) will be more of a combination of living and non-living structures. By making inanimate, it can be counted as artificial inanimate organs replacing the missing organs of humans or humans. The main ones will be artificial legs, artificial hands, artificial fingers, artificial fingers, artificial hearts and many other organs. The most advanced of these systems is that the organs are artificially biologically or organically produced and best suited to the body structure to be used. Today, organ transplants are used to try to find a cure for people's non-functioning organs. But there is still no 100% compatible or problem-free organ transplantation. In the future, this problem will be seriously tried to be solved. In addition, the commercial dimension of the field of study is quite high. The signal-processing feature of these systems will use mixed signal processing techniques.

Biotechnology and Hybrid Systems (BT-HS) are systems consisting of more than one different bio or more than one bio system and non-bio systems. The signal processing of these systems consists of complex and mixed signals. Because the system is a combination of different systems, different signal processing techniques are used. In other words, the man-made parts use either analog or digital signals, while the bio system part uses the type of signal it produces.

The basic philosophy of these systems is to combine very different systems and sell them commercially. For example, artificial eyes and biological ears made for living things can be used in seismic systems for listening to sound. Today, sensors or microphones are used here. Despite this, there is still no pre-warning system for earthquakes.

Cyber physical systems (CPS) consist of systems that process mixed signals. Analog signals can be used in some parts of these systems, digital signals in some parts, and optical signals in some parts. This depends entirely on the systems that are created in the CPS design. Today, it is at the high end of the technology for now.

CPS-SoS is composed of more systems than CPS systems. Many SoS systems combine to form a CPS system. Therefore, the signal processing techniques they use are mixed signal. Optical, analog and digital signals can all be used in these systems. Because there are no limitations or restrictions for purpose-designed CPS-SoS systems.

Systems of Systems (SoS) are a structure consisting of more than one independent system, where each system operates independently, can be controlled independently and receives feedback. For this reason, such systems are not only very large, but they are also an aggregation of independent systems. The most obvious examples of this are the control of an intercontinental missile by its own electronic system, the control of a missile by systems on ships at sea, and the control of a missile by satellites where these are not available. Here, each system is an independent system. But each system is used as part of the whole. Another example is military aircraft carriers. These ships have all kinds of systems needed. These systems operate both independently and as part of a larger system. There is no limit to the level of technology and signal processing in these systems. These systems are mixed signal-processing systems. Modeling and simulation (MS) is a widely used method in engineering design. The success of simulation depends entirely on the success of the model. For this reason, modeling and simulation are extremely important for design at any time and in any period, and to see the state of the designed systems before the first sample is produced. The success of simulation depends on modeling. The more accurate and realistic the modeling is, the more the error between it and the real system is negligible. If the modeling equations are inadequate, there are huge differences between simulation and real results. This situation is not preferred and does not inspire confidence.

Model Checking (MC) is the technique of testing a prototype product with a real model using "Model Logic" techniques. It has application for every product manufactured. However, it is a very valid fault finding technique for very complex and large systems. After the design errors are found, they are corrected and the new product is tested under the same conditions. Thus, design and production errors are minimized. This technique started to develop after 1981. Especially in VLS chips, the presence of billions of transistors and many subsystems makes it impossible to test by human hands. Instead, computers do this work with software. It is also the highest level of technology. Depending on the structure of the system, any kind of sign can be used as a signal. There is no limit to this. However, the core must be suitable for the "modal logic" signal or the output signals must be suitable for the system.

4. SYSTEM DESIGN TECHNIQUES

Three types of design techniques are used in engineering applications [21]. These are;

1. Model base engineering,
2. Software base engineering,
3. Component base engineering.

In model-based engineering, first of all, the details of the need are determined before starting the design. The systems, subsystems and software that will respond to this need are also determined. Characteristic details of the systems and subsystems are determined. Then, the modeling and design of these systems are started [22]. If the simulation results of the modeled system are successful, the next steps are taken. The next process is to study how these systems will be combined and whether the combined system will meet the need. The combined and completed system is tested for its suitability for the purpose. If the desired result is obtained, it means that the design was done correctly. If the system is problematic, the source of these problems is found and solved. After the problem is solved, the whole system is tested again in accordance with the purpose. If the test results are suitable for the desired purpose, the next stage is passed. This stage is to test the product, which has been designed in accordance with the purpose, by playing or running it in the real environment. Problems arising at this stage are seen. Then the sources of these problems are identified and solved again. Thus, these processes are repeated until the newly designed system is suitable for the desired purpose.

In software base engineering, a brand new software design is made due to the need in this field. It is written and realized. But there may or may not be other systems to run the software. For this, all other systems and subsystems that are needed at this time are designed in accordance with the software. Then the software made in the combined system is run. Errors in the system are eliminated until it is suitable for the purpose. Then it is implemented in real systems. Eliminating the errors that will occur here perfects the system. Thus, the new design product is realized.

Finally, in component engineering, a new component system is produced. The software suitable for this part system is the design of other subsystems.

While performing these operations, analog and digital systems, in general, classical system design techniques are applied. If the systems are composed of different systems and different subsystems, they also differ in terms of transportation. The most obvious examples of this are CPS, SoS and complex systems. Cyber physical systems and CPS (digital system+control, system+communication, system+physical system). More than one technique is used in the design of these systems and more than one system stability technique is applied.

Finally, there are complex systems. These are large systems consisting of a large number of different systems that work both independently and as a single system by combining systems. These systems are realized using very different design techniques. Complex prompts, on the other hand, can be multi-signal processing and are composed of a large number of different systems. Therefore, signal processing techniques are also com

5.CONCLUSION

In this study, the contribution and development of semiconductor analog electronics to other fields of science is given in historical order. While making this ranking, other fields of science and technology produced from analog electronics, which is the basic technology, are also given. The basis of analog electronics is Semiconductor science. In the development of this science, semiconductor electronic components (diodes, transistors, FETs, etc.) and chips are produced from the combination of physics, materials, chemistry, machinery and many other fields. Developments in the packaging technology of semiconductor electronic components have first developed other fields of science and then appropriate technological products have been produced. The simplest example of these is digital logic gates. Scientific and technological developments in this field have brought about changes in other fields.

Radical changes and technological developments in one field of science have led to radical changes in other fields of science and, depending on this change, it is also seen how other scientific and technological fields have developed. In these newly developing fields, especially signal processing techniques and design techniques have changed. In particular, while there was no signal processing in the field of mechanical design, it has indirectly entered the system design. Thus, a brief historical evaluation of the development of science and technology in the silicon era has also been made.

In the next 25 years, we expect very serious developments in quantum science and quantum technologies. This will lead to the commercialization of quantum computers, quantum computing systems, quantum communication systems, quantum electronics and quantum chips. This will open up new horizons in science and technology and usher in a new era. The next industry will be called the "quantum era" or industry 6.00. The next developments will be in the field of quantum biology and artificial synthetic biology in the field of biology. In this period, everything will be produced in organic form. This period will be called the "biology era".

REFERENCES

[1]. R.C Jaeger, T.N. Blalock, Microelectronic Circuit Design, MCGraw Hill, 2015, [https://www.devirpatent.com]. [https://www.elprocus.com/know-about-brief-history-of-electronics-and-their-generations/].March-2022
[2]. MIT Open courseware, 6.004: computation Structures.-2022
[3]. R. L. Grossman, A. Nerode, A.P. Ravn, H.Rischel (Ede), Hybrid Systems, Sprinder-Verlag, 1993
[4]. Myke King, Process Control: A Practical Approach, 2th Ed. Wiley 2016
[5]. [https://internetofthingsagenda.techtarget.com/ feature/Dell-IoT-Division-focuses-on-partnerships-OT-IT-convergence], March, 2022
[6]. Richard Fox, Information Technology: An Introduction for Today's Digital World, CRC Press, 2013
[7]. B.K. Tripathy, J. Anuradha, Edited by, "Internet of Things (IoT)", CRP Press 2019
[8]. Sabina Jeschke, Christian Brecher Houbing Song, Danda B. Rawat Editors, "Industrial Internet of Things Cybermanufacturing Systems" Springer International Publishing Switzerland 2017.
[9]. Beniamino Di Martino, Kuan-Ching Li Laurence T. Yang, Antonio Esposito Editors,
[10]. "Internet of Everything Algorithms, Methodologies, Technologies and Perspectives", Springer Nature Singapore Pte Ltd. 2018.

[11]. E. A. Lee and S. A. Seshia,"Introduction to Embedded Systems - A Cyber-Physical Systems Approach", Second Edition, MIT Press, 2017.
[12]. Rajeev Alur, "Principles of Cyber-physical Systems", MIT Press. 2017.
[13]. E.A.Lee, Past, Present, Future of Cyber Physical Systems: A Focus on Model, Sensors, 2015, 15, 4837-4869.
[14]. Mo Jamshidi, "Systems of Systems Engineering: innovations for the 21st century", J. Wiley and Sons, 2009.
[15]. Andrea Bondavalli. Sara Bouchenak, Hermann Kopetz (Eds.) "Cyber-Physical Systems of Systems Foundations – A Conceptual Model and Some Derivations: The AMADEOS Legacy" –Springer Open-2016.
[16]. L. G. Birta, G. Arbez, "Modelling and Simulation", Springer, 2007
[17]. Jason Kinser, "Modeling and Simulation in Python", Green Tea Press. 2022
[18]. Edmund M. Clarke, Thomas A. Henzinger,Helmund Veith, Roderick bloem Editors, "Handbook of model Checking", Springer, 2018
[19]. Christal Baier and Joost- Pieter Katoen, "Principle of Model Checking", The MIT Press. 2008
[20]. Kailash C. Kapur, Michael Pecht, "Reliability Engineering" , John Wiley & Sons, Inc. 2014
[21]. A . Wayne Whymore, "Model-Based Systems Engineering", CRC Press.1993
[22]. W.L.Chapman, A.T.Bahill, A.W. Wymore "Engineering Modeling and Design" CRC Press.1992