International Journal of
Science and Engineering Investigations vol. 8, issue 86, March 2019
Received on March 8, 2019 ISSN: 2251-8843

Derivable Benefits on Use of Analog Computers in Human Endevour

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Abstract- These days the term analog computer is often regarded as a synonym for computer technology history and antiquity. Yet to fully comprehend and appreciate the modern day digital computer, a historical path of the analog computer and its evolution must be discussed. The mere story of the history of analog computer evolution only will not achieve this, but the inclusion of some of the initial scientific and engineering challenges leading to its evolution could through more light on how it lead to the realization of the fast digital computers of today. This will also highlight what the analog computer has helped man to accomplish and what it could still help man achieve in the future. There is scarcely any area of human endevour that has not been impacted by the evolution of the computer starting with the analog computer and its several applications. This paper focuses on the scientific and engineering applications of the analog computer in human endevour; it also highlights the benefits derived and derivable over the years and probably in the future respectively.

Keywords- *Analog, Computer, Digital, Evolution, Technology, Scientific, Engineering*

I. INTRODUCTION

The story of the technical evolution of man and his quest to conquer his physical environment cannot be told without reference to his progressive effort at creating machines to help him to do his work. There is almost no field of endeavour where the story of its progressive development cannot in one way or the other be linked to the assistance of the computer, be it automobile, aeronautical, marine or several other scientific and technological fields. These progressive developments are simultaneous with the development of computerized machine which drive them.

Initially man's need was focused on understanding and mastering his physical environment which is analog in nature, necessitating and facilitating the development of the analog computer. Further efforts at improving efficiency, speed, cost of production and portability in terms of size heralded the computer evolution of the 20th century that has materialized into the very complex and supper fast digital computers of today. Hence analog computers are the fundamental root upon which computers generally heralded.

Singh et al. (2016, pp. 439-40) in their work on computer applications in various fields classified computers based on their size, the employed technology in their fabrication, use, and the type of data they handle.

On the basis of data processing, they classified them into:

- Analog Computers
- Digital Computers
- Hybrid Computers

a) Analog Computers

These are computers that work on continuous varying physical quantities or data like pressure and temperature. Because of their ability to deal with physical problem variables, they are very useful in scientific and engineering applications. Due to their parallel data processing ability, they are faster than digital computers, but have less accuracy when compared to them.

b) Digital Computers

These are computers that work on discrete data like 1's and 0's, on or off, etc. They take in and process binary data. In digital computers, data is processed serially, but the processing of data is more accurate than in analog computers. Today digital computers find application in science, engineering, home, and office appliances as well as in education.

c) Hybrid Computers

Hybrid computers combine the features and capabilities of both analog and digital computer. They can handle both digital and analog signals. Hybrid computers are useful in application where there is simultaneous need for digital and analog processing such as hospitals and aeronautical research among others [1].

Singh et al. (2016) in tracing the origin of the word computer stated that "Computer is a coinage from the word compute which means "to calculate", hence people usually

consider a computer to be a calculating device that can perform arithmetic operations at high speed" (p. 439) [1].

Today the computer can do much more than arithmetic calculations to the extent that they are applied in artificial intelligence technology.

Analog computer invention has a long history. From the advent of the slide rule – a hand operated analog computer for doing multiplication and addition which was invented around the 17th century shortly after the concept of logarithm was made public to the planimeter – a measuring instrument used to determine the area of an arbitrary two – dimensional shape, first invented in the 19th century. The re-invention and application of analog computer have continued with progressive improvements. In the 1930's Vannever Bush and his team at MIT created what was considered the first analog computer being discouraged by the length of time it took to do mathematical computation required to solve certain engineering problems. That first device created to solve complex mathematical equations was the differential Analyzer. Initially analog computers were mechanical in nature, but during the advent of the Second World War, it evolved into being majorly electronic and by the 1950's was almost entirely replaced by it. It was the invention of the operational Amplifier, a voltage amplifier circuit device combined with other electronic components that enabled the creation of the electronic analog computer machines which could perform addition, subtraction, multiplication by a constant, integration and in special cases differentiation [2].

A. The operational amplifier

The operational amplifier (OP-AMP) is known to be one of the basic component units of the electronic analog computer. Its flexibility and adaptability in realizing different results is key to its important role in the electronic analog computer. It is a voltage amplifying device that can work together with other circuit components like resistors and capacitors connected in different formats between the input and output terminals to provide a feedback that determines any specific circuit operation, hence the name operational amplifier. It is its application in solving differential equations that gave it its relevance in analog computer design.

B. The components of a general purpose analog computer are:

1. A console that contains a collection of operational amplifiers.
2. Computing elements such as summing networks, integrating networks, attenuators, multipliers and function generators which are all circuits derivable with the operational amplifier.
3. Logic and interface units.
4. Control circuits.
5. Power supply.
6. A patch bay and various meters and display devices. The patch bay are arranged to bring input and output terminal of all programmable devices to one location where they can be conveniently interconnected by various patch cords and plugs to meet the requirement of a given problem.

C. Some unique features of analog computers which are beneficial in scientific and technological endevours among others are;

1. Within the useful frequency bandwidth of the computational units and components, all programmed computations take place in parallel and for practical purposes instantaneous, that is, there is no finite extension of time associated with each operation as encountered with digital computer methods.
2. The analog computer has a flexible addressing system that almost every computed variable can be measured, viewed with vivid instruments and recorded at will.
3. By means of patch cords, plugs switches, adjustment knobs, the analog computer program can directly be manipulated especially during dynamic computation and resultant changes in response observed and interpreted.
4. The computer can be used for online model building i,e. a computer model can be constructed in a step by step fashion directly at the console by interconnecting computational units on the basis of one or more analog representation of the real system elements. By adjusting signal gains and attenuation parameters, dynamic behaviors can be generated that corresponds to the desired response or is recognizable as that of the real system. This method allows a skillful person to create models when no rigorous mathematical equations for a system exist.
5. For those applications to which it is well suited, analog computers operate at a relatively low cost thus affording the analyst ample opportunity to investigate, develop and experiment within a broad range of parameter functions.

II. SOME AREAS OF APPLICATIONS OF ANALOG COMPUTERS

A. Modeling and simulation

One of the underlying bedrock upon which the development of science and engineering are based, is the art of modeling and design. To design and invent, there must be some sort of art that enables the scientist to do careful study, to understand the principles that govern the behavior of the parameters which in turn define the relationships between studied scientific phenomena.

According to Science Learning Hub – Pokapū Akoranga Pūtaiao (2018):

"In Science, a model is a representation of an idea, an object, a process or a system that is used to describe and explain phenomena that cannot be experienced directly. Models are central to what scientists do both in researches as well as when communicating their explanations. Models are mental visual ways of linking theory with experiment and they guide research by simplified representation of an imagined reality that enables predictions to be tested by experiment" (para. 1) [3].

The Gale Encyclopedia of science (2018) in describing the analog computer stated thus:

An analog computer models the behavior of smoothly varying mathematical variables – usually representing physical phenomena such as temperatures, pressures and velocity – by translating these variables into (usually) voltages or gear movements. It then manipulates these physical quantities so as to solve the equations describing the original phenomenon (para. 2) [4].

The word analog finds its origin from the word analogy. Analogy can be considered in this case as a systematic relationship that relates a physical process in a computer to those of the system it looks to model. Some early inventors who employed the use of the analog computer include Bill Philips who built an analog model of an economy based on hydraulics and showed that hydraulics was analogous to monetary flow and also the Differential analyzer which was invented in the 1930's by Vannever Bush and was an analog computer which modeled a system of equations and solved differential equations using mechanical shaft and gears. Much later, the electronic version of the differential analyzer were produced and put to use.

Charles Care (2008) in lending his voice to the topic observed that:

"Many computing applications belong to a family of modeling technology and it is clear that analog computers are typically used for those applications before digital was cheap, popular or fast enough. Hence, the pioneering role of analog computers in the evolution of modeling in science and technology can be in historical perspective and appreciated" (p. 69) [5].

The electronic analog computer is a good tool for modeling and simulation in system design due to its flexibility and various applications which are practically useful in manufacturing and research. Before the digital computer domination of the computer landscape, analog computers were used to model and simulate systems under study. Simulations could be done at a;

1. Component to component level
2. Functional block or module level
3. whole system level
4. multi-prototype system level

These enable the designer to detect and isolate a faulty component or module and access and rate the final system with design specification. Also multiple system design prototypes can be simultaneously modeled and simulated to compare results, efficiency and performance. Design cost and time can thus be controlled and the best design option selected. Even after digital computer dominance, analog computer based software packages are run on digital computers to achieve the purpose of simulation.

Winsberg (2013) echoes the importance of simulation in scientific study by stating that:

"More broadly, we can think of computer simulation as a comprehensive method for studying systems. In this broader sense of the term, it refers to an entire process. This process includes choosing a model, finding a way of implementing that model in a form that can run on a computer, calculating the output of the algorithm and visualizing and studying the resultant data" (para. 8) [6].

Today, analog computer models or its equivalent are used in aeronautical, automobile, industrial control, robotics engineering research etc. for gaining better insight into research topics, to develop and test methods and equipment, to carry out the design of new systems or to predict by trial and error method the model response of system applications beyond known boundaries or to improve the behavior of systems already in operation.

1) Benefits of analog computer in scientific modeling

Some benefits of analog computers in scientific research modeling and simulation are that:

1. It saves cost because when we model, we can afford to go through the process of invention over and over again until we perfect the product. It is usually less expensive to set up and study with models than with the real physical systems. With this, more could be accomplished in a short while.
2. Models are tools for pre- studying systems and predicting real system responses.
3. Models sometimes make visualization of systems possible and aids in teaching and communicating system information.

2) Benefits of analog computer in scientific simulation

Simulation is applied as a good teaching tool as seen in aeronautical training applications, education, and other fields. Other benefits of analog computer assisted simulations are that:

1. Simulation is used for testing modeled systems.
2. Simulation is a tool for predicting the behavior and output of systems under different conditions and input variables.
3. Simulation makes it easier to re-design a faulty system in a very short time instead of waiting to modify a physical prototype of the same system and test it.

B. Use of analog computers in embedded systems

Another area of application of analog computers is in embedded systems. An embedded system is like a mini-computer system in a larger computerized system. Singh et al (2016) describes embedded systems as process control systems which enable us control, monitor or help the operation equipment (p. 440) [6]. One of such areas of application of embedded systems is in analog IP (intellectual property) cores for embedded computer needs.

Supporting the view, Allan (2012) in his article "Understanding analog IP cores for embedded computing needs" stated that

"The analog IP market has exploded in the past 10 years. Demand for ADC, DAC, phase-locked loop (PLL) and DC-DC converters IP is expected to grow at more than 17 percent through 2015" (para. 4) [7].

He argued that analog IP business models allow engineers to purchase analog IP blocks and amortize the cost over multiple projects. Current applications of embedded systems span from communication systems, industrial process control to robotics engineering among others.

C. Analog computers as part of Hybrid computers

Great qualities of the analog computer like its easy programmability, the flexibility of it operations and repeatability of results have contributed to the wide use of the general purpose electronic analog computer by making it possible for it to be augmented with interface channels to the electronic digital computer giving rise to the third type of general purpose computer- the hybrid computer. The hybrid computer combines the speed and interactive ability of an analog computer with the accuracy and programming flexibility of the digital computer to find application in fields where joint analog and digital computer implementation are required in their devices. For instance, analog based sensors can be used to monitor the speed of a vehicle or to measure the body temperature of a patient, but digital computer based circuits are used to display the values on a screen or to record it on memory device.

1) Benefits of Hybrid Computers

Asba (n.d), in his article "advantages of analog computers" discussed some benefits of hybrid computers which include that:

1. They Provide On-line data processing capability of which is employed in computer applications where real time data processing and evaluation are needed.
2. Combine the speed of the analog computer component with the precision and accuracy of the digital component to deliver better results that may not be attained if either was used alone. [8]

D. Analog computer based sensors and data acquisition systems are employed in environmental studies and ecological research

Environmental and ecological data acquisition, monitoring and management are important topics in our world today. The need to monitor and regulate environmental pollution and ensure a healthy atmosphere for human, animal and plant life is on the increase. The physical quantities being monitored like temperature, pressure, relative humidity etc. are essentially analog in nature and most of the sensor systems that are used to acquire data in these investigations are analog based sensor systems by composition.

Jean-Francois et al (2012) stated in their book on sensors and ecology that:

"Many projects in ecology make direct use of environmental variables. These encompass climate, major elements in environment (especially carbon and nitrogen), the soil, water and air chemistry and light radiation. Environmental sensors need to be deployed when these values are expected to vary at a sufficiently high frequency so as to impact ecological process" (p. 282) [9].

Though digital based sensors are popular today because of digital dominance, there are some specific instances where the nature and values of the physical quantity being monitored make analog based ones more viable options. Some environmental data acquisition systems en-cooperate analog based sensors with digital based processing and storage systems in a hybrid combination.

Real time data acquisition is achieved in industries and locations that are prone to environmental pollution by the use of analog or hybrid computer based data acquisition systems to monitor and regulate pollutant threshold and send alerts on violation. Real time data acquisition systems are also employed by researchers in ecology to study the relationship between environmental parameter variation and migration behavior of species from one habitat to the other.

III. CONCLUSIONS

Although much of the benefits derived from Analog Computers in science, technology and engineering are in the realm of the past, it is a fact that Analog Computers heralded the computer revolution of the 20th century by firstly laying a fundamental and foundational background for computer technology revolution as we now have it today and secondly by catalyzing the advancements in many fields of science, technology and engineering. Presently, the Analog Computer still provides the necessary support to the modern day digital computer especially in applications that are better modeled by the analog computers or its digital equivalent or both, while Future prospects of analog computer applications believed to deliver better results than their digital computer counterparts are being anticipated.

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How to Cite this Article:

Kamalu, U. A., & Maduagwu, I. C. (2019). Derivable Benefits on Use of Analog Computers in Human Endevour. International Journal of Science and Engineering Investigations (IJSEI), 8(86), 49-53. http://www.ijsei.com/papers/ijsei-88619-07.pdf