Two Reasons Why a Controls Laboratory Needs an Analog Computer*

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Science and technology advance neither steadily nor continuously. Concepts deemed obsolete and confined to oblivion find their niche in new developments. Discarded old methods revive as the key ingredients to new designs

Analog computing was the birthplace of two important technologies. Computer simulation, as applied to system design, was founded. The operational amplifier, to become the basis for modern linear circuitry, was perfected..

Valuable as it was, analog simulation's quasi-hardware approach to analysis aggravated users as much as it aided them. As digital simulation languages arrived, simulation engineers readily adopted them.

When the microprocessor transformed digital computers into inexpensive circuit components (more like gates, flip-flops, amplifiers, etc. than computers,) there arose unlimited prospects for digital control. But, the discrete digital and continuous analog worlds are not compatible. Timing discontinuities and variable resolution limitations create problems

Control system designs, especially microprocessor based ones, need laboratory development. For hands-on testing, the analog computer is as handy an instrument as a controls engineer could have. Its two unique and valuable functions are:

Simulator of Systems to be Controlled ... The electrical analogs of physical models, analog computer simulations offer predictable yet realistic representations of mechanisms and processes to be controlled.

Programmable Linear Circuits Manifold... The terminal points for high quality, linear circuit devices, analog computer patch panels offer the only formal means of programing linear signal processing, interface and control circuits.

This paper offers a discussion of these two analog computing uses.

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ANALOG COMPUTER REVIEW

Analog computing owes its existance to the development of the operaational amplifier. In the late 1930's the operational amplifier was refined to a point of becoming a functional circuit component. Its usefulness was demonstrated during World War II where active circuits computed anti-aircraft fire control projectile trajectories. Soon after the war ended the tech- nology was applied to general applications. By the early 1950's, the patch panel was adopted and analog computer simulation was being used enthusiastically by aircraft and other dynamic system design engineers.

As the operational amplifier was vital to the analog computer's existance, the analog computer was to the operational amplifier. The builders and users of analog computers were the driving forces that led to the amplifier's role in today's linear circuit technology. Analog simulation brought to focus its versatility. Analog computer designs struggled with its difficult stabilty problems. Analog programmers demonstrated its usefulness.

The operational amplifier's unique function was then, as it is now, to force virtual ground points throughout a circuit so that its components can be isolated and treated simply as an input/ output transfer function. By selecting amplifier networks (resistors, capacitors, transconductors) a variety of transfer function devices (summers, integrtors, multipliers, etc.) become available for circuit use

ANALOG COMPUTERS IN THE LABORATORY

A controls laboratory will likely support one of the following:

Project Development...where laboratory apparatus is dedicated to a specific project, remaining intact until the its completion.

General Development...where the apparatus is selected and organized for general engineering use.

Education...where workstations are structured for expreriments to support lecture presentations.

As a general purpose research, development and education workstation, the basic configuration of figure 1 is suggested.

TYPICAL CONTROL DESIGN WORKSTATION

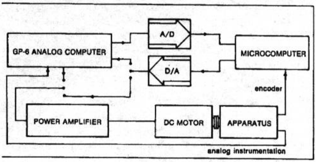

Figure 1.

In such a configuration, the user may work easily and interchangeably in the following media:

Analog Simulation... Both the controller and mechanism to be controlled are simulated on the analog computer.

Analog Control of the Hardware... The controller is patched and run from the analog computer.

Digital Control of the Simulator... The digital computer controls the analog simulator.

Digital Control of Hardware... The digital computer controls the hardware.

Analog/Digital Control of A Combined Apparatus/Analog Simulator... By adding simulated poles and zeros, simple hardware is made to function as a more complex mechanism.

SIMULATOR OF THE MECHANISM TO BE CONTROLLED

Natural systems are fundamentally continuous. It may or may nor be realistic to simulate continuous systems with discrete data. It may or may not be workable to sample a natural system as discrete data and control it with discrete commands. Digital computer simulations and control designs ultimately demand near zero sampling periods and near infinite resolution of system variables.

At some point a digital method will fail becaue of excessive sampling time or inadequate data resolution.

As the electrical analogs of real systems, analog computer simulations produce the same continuous, infinite resolution variables as those found in natural evironments.

Analog simulations synthesize continuous variables with a realism that is unattainable by digital methods.

Simulations in general enable a design to be tested for theoretical validity before being exposed to real world difficulties.

In testing a design, analog simulators are direct replacements for actual hardware.

While analog simulations are useful for both analog and digital control design, they are especially valuable for testing digital controllers:

First, a simulation of the total system will likely consider only the theoretical validity of the equivalent analog controller. Numerical simulation techniques not be well suited for simulating hybrid analog/digital systems. Mixing discrete and continuous operations adds programming difficulties that are avoided when using an analog simulator.

Second, testing the controller hardware is more complex and, thereby, more critical to the digital design. Where analog controllers are circuits of operational amplifiers, directly compatible with system analog instrumentation, digital controllers are not. They introduce discontinuities that, at times, exert unpredictable nonlinear effects.

Analog simulators offer ideal testing grounds for digital controllers, superior to real systems in the following two ways:

They behave like real mechanisms, respond to and produce the same continuous voltages

but, their behavior is predictable, the exact response of analytical models or transfer functions, and they can be altered to suit test conditions--where parameters may be changed, non-linearities, noise, etc. added, and models reprogrammed.

Second, the designer can evaluate easily all key variables,

where displacements, velocities, errors, etc. are programmed as operational amplifier outputs.

THE PROGRAMMABLE LINEAR CIRCUITS MANIFOLD

Stumbling blocks to digital/analog de-signs are, more often than not, analog circuits. No matter how important the digital processor is, no matter how much of the ap-application is handled by digital software, if the program is interfaced to an analog system there will be analog circuits.

To connect the discrete digital and continuous analog worlds, bridges need be built: Instrumentation signals need to be amplified. Variables need be to scaled. Noise needs to be filtered.

Analog computers offer the only means to build the bridges as patch panel programs rather than breadboard circuits.

Some advantages of the general purpose patch panel over dedicated breadboard circuits are:

Speed...A patched program can be up and running in a fraction of the time needed to design and test a dedicated circuit.

Reliablity... Developed for general purpose use, analog computing devices operate stabily under both resistive and capacitive loading.

Accuracy... Precision amplifier networks and high resolution parameter settings are inherent analog computer features.

Versatility... Unlike a dedicated circuit, a program is easily changed to meet unanticipated demands.

Cost... Savings are realized both from eliminating the custom design cost and by spreading the purchase costs over multiple uses.

CONCLUSION

To best meet hardware testing and developpment requirements, a controls laboratory needs to be equipped with a small general purpose analog computer.