The Lightning Empiricist

A journal for devotees of high-speed analog computation, those enthusiasts for the new doctrine of Lightning Empiricism, publishable aperiodically and distributed without charge by Geo. A. Philbrick Researches, Inc., 230 Congress Street, Boston 10, Mass. and offering items of interest and value on such computational topics as applications, techniques, and new or improved components.

ISSUE NO. 5 GAP/R OCTOBER, 1956

GENERAL PURPOSE ANALOG COMPUTORS

Frequently, a customer will ask us to recommend an assortment of GAP/R modules for the construction of a computor to solve undefined problems. This is in contrast to the customer who has groups of problems with well defined similarities. For the latter, a specific *assortment* of *units can* be listed. For the former, a generalized assortment must be assembled.

A completely generalized assortment of computor modules — one equipped to handle any likely problem in any field — would be large and expensive. While GAP/R would admire *to* supply many such assortments, we recommend that our customers examine their problems and discover likely upper limits on which to base "starter" assortments of modules. Then as experience develops, specific needs will be felt and other modules can be added. A basic philosophy and practice of GAP/R lends weight to this process of computor expansion — all models of computor modules are compatible with all other models. Our newest models will function with our oldest models.

One criterion suggested for the size of an assortment and the variety of its content is the number of integrators. On this basis, we suggest minimum assortments for two, four, six, and nine integrators. The order of equations that can be solved with each Philbrick assortment is, of course, substantially larger than the number of integrators.

GENERALIZED ASSORTMENTS OF K3 MODULES

Model	Computing Equipment	Assortment G	A	P	R
CS	Central Signal Component	1	1	1	1
CR	Central Response Component	1	1	1	1
K3-A	Adding Component	2	4	6	9
K3-B	Bounding Component	•	1	2	3
K3-C	Coefficient Component	4	8	12	18
K3-D	Differentiating Component	•	1	1	1
K3-E	Augmenting Differentiator	•	•	1	2
K3-H	Backlash Component	•	1	1	2
K3-J	Integrating Component	2	4	6	9
K3-K	Augmenting Integrator	•	•	1	2
K3-L	Unit-lag Component	1	2	3	4
K3-S	Squaring Component	•	1	•	1
K3-T	Square Rooting Component	•	•	•	1
K3-Z	Inert-zone Component.	•	•	1	1
K3-5	5 by 4 Jack Connector Box	1	2	3	5
MU/DV	Electronic Duplex Multipier/Divider	•	•	1	1
FFR	Arbitray Function Component	•	•	1	1
RS	400 MA Power Supply (Rack Mounting) . . .	1	2	2	3
SC	Signal Cables	25	40	60	90
PC	Power Cables	15	30	45	65
HC	Rack Shelf, for Components	3	7	11	16
RR	Six Foot Relay Rack	1	2	2	3

CONTENTS

SALES AND APPLICATIONS

See you at the Exposition. Which one? The Third International Automation Exposition at the New York Trade and Show Building, 500 Eighth Avenue, New York City, 26-30 November, 1956.

In our exhibition space, Booth 142, second floor, we will have a live display including a variable process simulator, a three term electronic control, plug-in computor networks, electronic graph paper, and *precision* regulated power supplies. All these utilize the versatile K2 Operational Amplifier.

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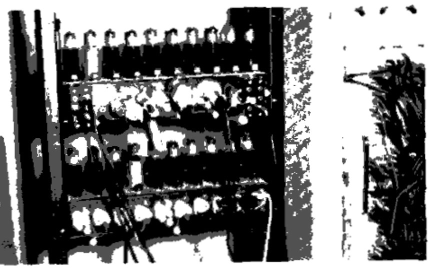
The subjoined photograph illustrates a typical use of auxiliary amplifier capacity — specifically GAP/R K2-W Operational Amplifiers, K2-P Stabilizing Amplifiers, and HK Operational Manifolds.



This photograph, given us by a customer,* also illustrates the "sociability" of GAP/R modules. Three different makes of passive plug-ins are mounted on the manifold — a compatibility made possible by our adoption of the standard banana jack with ¾ inch spacing.

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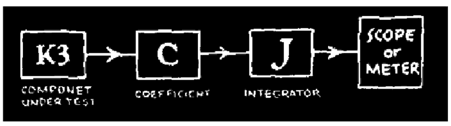
Our New England — Upstate New York representative, Technical Instruments, Inc., Waltham, Mass., has handed us a *circuit* used by some of our customers for balancing K3 components. Simple — but very *effective.*



Among the advantages (compared)

*** Name given on request.**

(Concluded on page 2)

GAP/R ALL-SPEED ELECTRONIC ANALOG COMPUTORS
The Lightning Empiricist

46 TEN YEARS OF PROGRESS '56

On October 31 GAP/R will be 10 years old. During this period we have served hundreds of satisfied customers and have pioneered many developments in the art of electronic analog computation. This date is, however, a milestone. The road to even greater activities stretches ahead of us. We accept the date as a challenge, not only to continue our pioneering efforts but also to maintain ourselves as a primary source of well engineered and manufactured analog computor components.

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We welcome:

John Hickey, Production Supervisor; Francis H. Achard, Publications. **Mr. Hickey brings to us twenty years experience in the production of electronic apparatus, from small component assemblies to extensive receiver, transmitter, and television sets. **Dr. Achard brings *to* us a broad experience in the preparation, editing, and publishing of commercial and engineering training literature. **Our mailing list has been set up on Speedaumat plates. In some cases, we have had to shorten the addresses. Won't you please let us know of any errors or omissions in your address. **Our genial consultant, Dr. H. M. Paynter attended the Conference on Control Technology at Heidelberg, West Germany.

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Sales and Applications (Concluded)

to a non-integrating method) are:

1. High accuracy — malfunctioning is accumulated, and hence exaggerated on display.
2. Easy and quick to use.
3. Broad visibility of indication.

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Our New York — Eastern Pennsylvania representative, Kee Enterprises, 97 Reade St., New York City, announces the opening of a message service in Philadelphia, Pennsylvania, preliminary to opening a full-time office there. The number to call is Pennypacker 5-3520 or 3521.

- - - Printed in the US.A. - - -

GENERAL PURPOSE PANCELERIC ANALOG COMPUTORS APPLIED TO SYSTEM ENGINEERING PROBLEMS

What Are System Engineering Problems?

An engineering system is an interconnected assemblage of inorganic and organic components designed and constructed to accomplish a specific task. Such assemblages comprise:

Storage units — tanks, pressure vessels, flywheels, and other inertias;

Transmission links — conductors, belts, gears, levers, transformers;

Transduction equipment — pumps, motors and generators, machines of all kinds, heaters;

External influences — supply and demand fluctuations, weather, noise.

Constraints — physical, economic, and human;

Control devices — governors, limiters, modulators, valves, switches;

People — as system operators and to supply supervisory control features not provided through automation.

Basically, even a single machine, such as a boiler, a pump, a machine tool, or a motor, is an engineering system. It contains all of the elements of storage, transmission, etc. From these relatively simple systems we develop extended systems of many interconnected machines, each playing a significant part in accomplishing the task of the whole system.

People constitute a vital part of a system both as operators and as limiters, A system beyond the capacity of people to understand, design, construct, and operate is a dream for the future. Ultimately, we shall grow up to it — and find others still on the horizon. The physical capacity of people to operate a system must be considered. In fact, the physical limits imposed by human operators have stimulated designers of systems to interpose built-in controls that can react more rapidly and precisely than the human operator, and to leave to the latter the things that he can do best.

The design of an engineering system is primarily a matter of synthesis. Given a task, a set of constraints, and a supply of components, the engineer's job is to create conceptually a satisfactory system.

The task must be defined explicitly, but is subject to modification and even redirection as the design develops.

The constraints, too, should be well understood at the start, and additional ones imposed as conditions demand. One of the vital duties of the design engineer is to make sure that he properly selects, evaluates, and applies all applicable constraining factors — a duty doubly important when he must extrapolate data. Well known cases in point are the Tacoma Narrows Bridge and the British *Comet aircraft.*

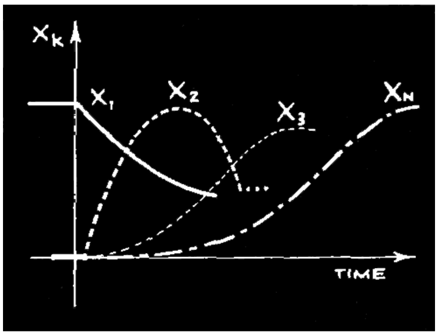
The components may be immediately available — or subject to development. In fact, many systems in the conceptual stage today require components that must be designed and developed to meet specific needs.

The role of the analog computor in design is coextensive with the design problems themselves. With the computor, the design engineer can translate his conceptual and mathematical models directly into a physical model which can be manipulated as extensively as desired — even beyond the

CHEMICAL PROCESS REACTION

Consider a succession of chemical reactions in a process plant, each governed by the equation:

$$-\frac{dX_k}{dt} = K_k X_k^{\alpha_k} - K_{k-1} X_{k-1}^{\alpha_{k-1}}$$



The analog model is set up as:

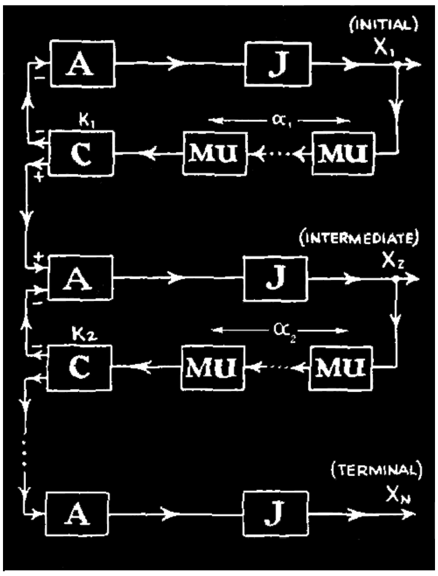


Fig. 1. Chemical Process Reaction

point where a real system would be destroyed. More of this later.

Construction of an engineering system is a matter of preparation, assembly, and installation. It has its own extensive and perplexing problems, but except as these problems involve redesign of system components, operation of parts installed, or the design and/or operation of construction facilities, these problems are outside the province of the analog computor.

Operation starts with the engineering system as installed. Given the system, the operator's job is to determine and apply optimum modes of operation.

The operating engineer has a specific engineering system at his command, including physical components, constraints and limits of all kinds, people, and a set of demands to be satisfied. Ultimately, the operator must satisfy but not exceed demand. In some cases he cannot exceed demand, as in the electric power industry. In other cases, limited storage is available, as in the manufactured gas industry.

On the other hand, the operator can fail to satisfy the demand, satisfaction being measured in terms of quantity, quality, safety, and economy.

The operator, too, finds the analog computor a powerful tool. He can use it to schedule his production and his facilities, to control operations, and to analyze his results.

The Role of the Analog Computor

Two procedures are involved in the solution of system engineering problems : empirical and rational. Not only are these procedures compatible, but both must be used in both design and operation. If the empirical procedure alone is used, excellent replicas of preceeding systems may be developed — and may be entirely unsuited to the projected task. If the rational procedure alone is attempted, a disaster can easily follow because of an assumption not based on fact.

Practically, it is inconceivable that either procedure be used exclusively, although a specific task may call for a greater proportion of one to the other. As examples, let us cite two illustrations; Suppose the problem involves an electric power system in a small community. The components of such a system are well known and have been thoroughly engineered. Such matters as choice of prime mover, fuel, voltages, and distribution facilities can readily be subjected to empirical analysis. But considerations of possible interconnections, potential growth and character of the community, and supply of operators — all matters of rational analysis supported in part by empirical data — can well modify the empirically made choices.

On the other hand, suppose the problem is to design and operate a robot to replace in all respects the traffic policeman at a busy intersection. Here many of the problems and basic data are known empirically — that is, the basic requirements can be set up — but then we must apply rational procedures because our specific experience is limited or non-existent.

The empirical and rational procedures are interactive rather than pars allel. Activity in one procedure stimulates or demands activity in the other. Both must be used in the approach to any system engineering problem. Moreover, a rational procedure that cannot be supported by empirical procedure or vice versa, is certainly suspect and can lead to a dangerous result.

The engineer concerned with the design or operation of an engineering system cannot confine his concern to the task immediately at hand. The design engineer must develop his project so that it can be constructed and operated. The construction engineer may encounter problems that demand redesign or will influence operation. Operating problems may call for redesign or new construction.

Initially, the engineer may develop a conceptual model, closely following up with a mathematical model. Finally, however, he needs a physical model to explore the ranges and possibilities of his conceptual and mathematical models and to verify operation.

The analog computor is the most powerful model that an engineer can use. Its power arises from its versatility. It supplements and enlivens the engineer's conceptual model. It enables the solution of the mathematical model without recourse to confusing transformations and approximations. And it provides a vivid model of operation. This does not mean that the analog computor can supplant the conceptual and mathematical models. In fact, it is good only as they are sound.

The analog computor is a tool — a glorified slide rule — that the engineer can use to translate his ideas into simulated action. If the engineer has available a panceleric general purpose analog computor, he can model his system at slow, real, or fast time as desired. He can impose bounds and other non-linearities, vary parameters, and explore the range of possibilities of his conceptual model. He can extract both quantitative and qualitative data on an electronic graph, and can record them photographically. As he studies the operation of his system, a little additional effort can enable him to extract the data for special purpose analog computors that will enable close control of the system.

The foregoing discussion is illustrated by three examples, all drawn from actual situations.

(Concluded on page 4)

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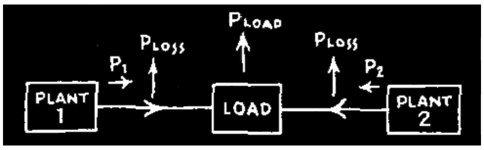
POWER LOSS FORMULA

Consider an electrical power system consisting of two generating stations and a load.



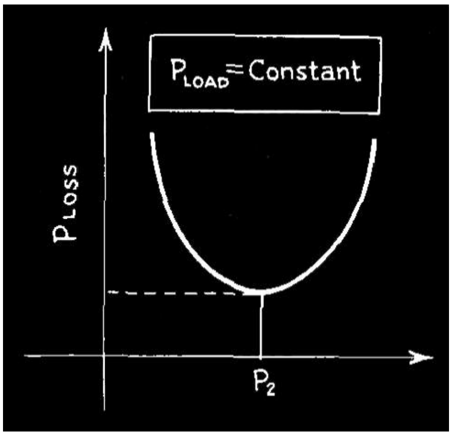
Based on the loss formula of E. E. George:

$$P_{load} + P_{loss} = \Sigma P_k$$

$$P_{loss} = \sum_{mn}\sum B_m B_n P_m P_n$$

Expanding for two stations

$$P_{loss} = B_{11} Pi_1^2 + (B_{12} + B_{21}) P_1 P_2 + B_{22} P_2^2$$



Analogically, this becomes

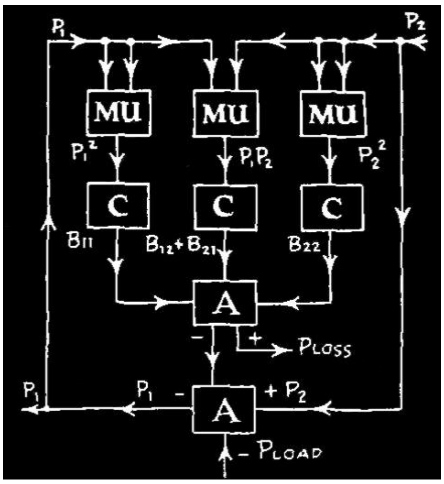
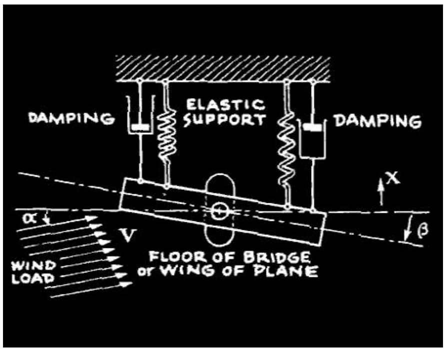


Fig. 2. *Power* Loss *in an Electric* Power System

System Problems (Concluded)

AERODYNAMIC INSTABILITY

Consider a model of the roadbed of a bridge — or the wing of an airplane in flight — suspended as illustrated and subjected to the indicated forces and constraints.



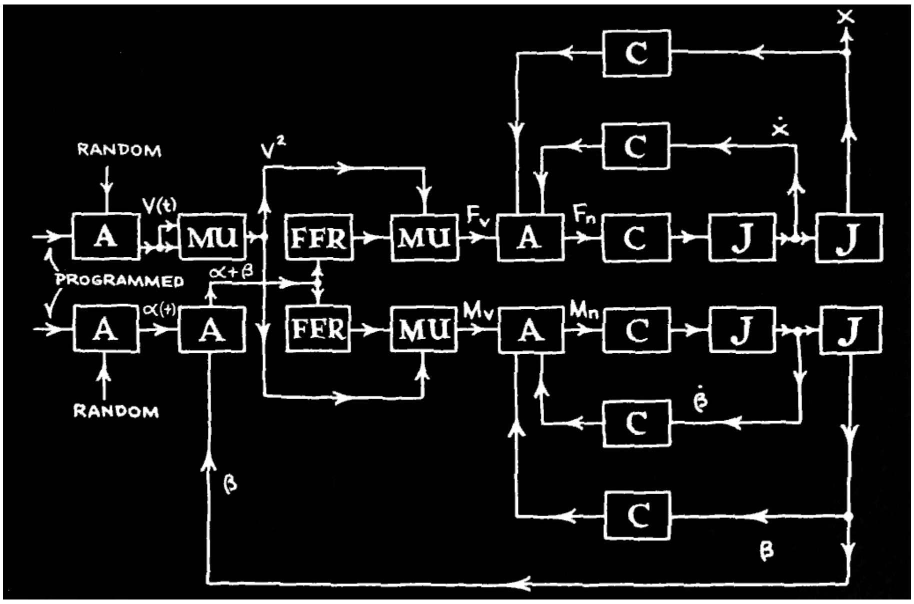


Fig. 3. Problem of Aerodynamic Instability

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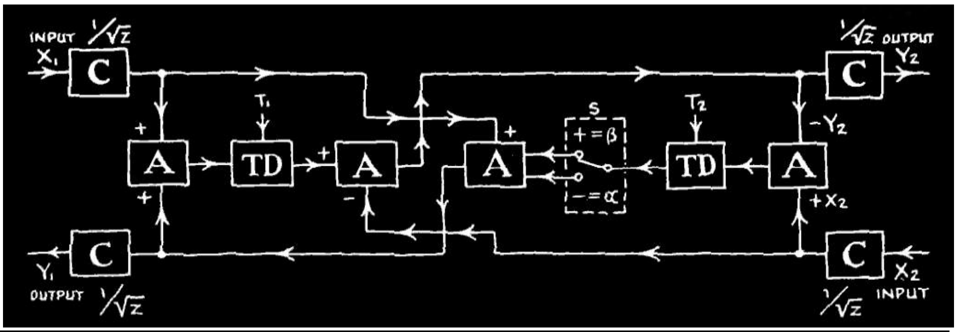
**Refers to GAP/R products.*

CIRCUITS AND BLOCK DIAGRAMS

Dissipationless Transmission System

Our good friends F. D. Ezekiel and H. M. Paynter have devised and employed a universal block diagram for a lossless transmission line for the *Row* of mechanical, electrical, and fluid energy.

A=Adder S=Switch
C=Coefficient TD=Time Delay
E=Effort (Force, Voltage, Pressure)
F=Flow (Velocity, Current, Flow)
T_1 =Downstream Propagation Velocity
T_2=Upstream Propagation Velocity
Z=Characteristic Impedance



Configuration	Form	Switch	Variables			
		S	X_1	X_2	Y_1	Y_2
I Impedance/Impedance	α	—	E_1	E_2	F_1	F_2
II Impedance/ Admittance	β	+	E_1	F_2	F_1	E_2
III Admittance/Impedance	β	+	F_1	E_2	E_1	F_2
IV Admittance/Admittance	α	—	F_1	F_2	E_1	E_2