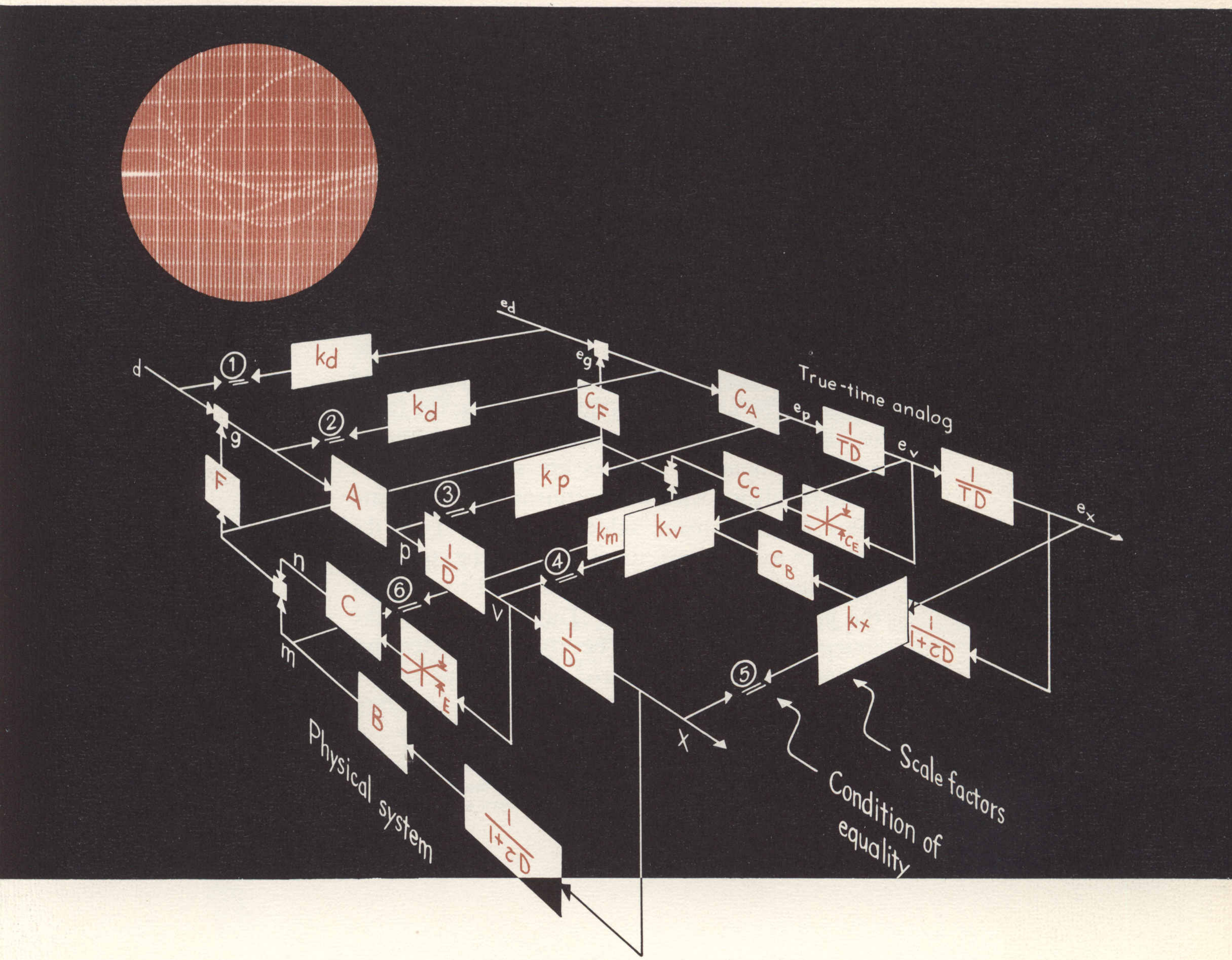
GAP/R

Electronic Analog Computors



George A.

Philbrick

Researches, Incorporated · Boston 10, Mass.

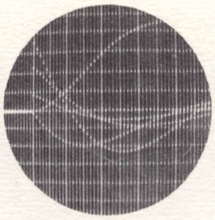
Electronic Analog Computors

Rapid advances in nuclear science, supersonic flight and automation testify to the value of computors in analysis, design and development. The two major categories of computors are *digital* and *analog*. The first deals in numbers only; the latter in continuous physical variables. In electronic analog computors, voltages are set up in direct correspondence with the pertinent physical quantities (such as mass, velocity and time) of the problem to be solved; these voltages, the computor variables, obey relationships identical to those of the problem to be solved. Time is generally the independent variable. The computing elements which establish the required relationships are d-c amplifiers, potentiometers, resistors and capacitors.

GAP/R Computors

Philbrick computors are electronic analog computors especially suited to high-speed, repetitive operation but equally useful at medium and low speeds. Philbrick alone offers computation at all speeds from the slowest simulation to the fastest repetition.

Repetitive Operation



When used repetitively, Philbrick computors automatically repeat solutions so rapidly that they can be displayed on an oscilloscope screen as a continuous picture. This allows the effect of varying parameters to be observed at once without waiting for the completion of a computor "run" as in ordinary computors. During each repetition, each computor variable varies as prescribed by the physical characteristics of the simulated system.

There are two technical problems associated with repetitive computors:

1. Oscilloscopes on which solutions are displayed may suffer from parallax and distortion.
2. The computing elements and variables must return to proper values between computing cycles.

The first problem is overcome by a Philbrick exclusive — Electronic Graph Paper. This innovation gives instantaneous and automatic calibration of both voltage and time on the oscilloscope screen itself. Further, it enables simultaneous display and precise comparison of as many variables as desired. The second problem is solved by resetting and clamping computing elements and variables at their proper values between computing cycles.

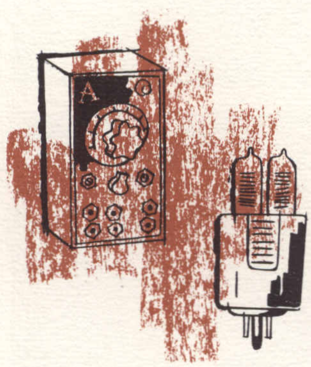
Modular Construction

Philbrick computors are assembled from modular elements. This allows the buyer to purchase a computor of whatever capacity he requires. Again, as requirements become more demanding, the computor installation may easily be expanded.

The basic elements may be selected from either the K2 or the K3 Series. The K2 Series consists of a small group of versatile operational plug-in amplifier modules, with accessory manifolds and power supplies. This series is ideal for electrical engineers who prefer to design their own circuits and who have a good idea of what goes on electrically within the components of a computor.

The K3 Series is a large group of self-contained operational units, each with its own specific function such as summing or integration. Computors assembled from this series are ideal for design engineers and others who deal with the dynamics of physical systems and processes. This series does not require familiarity with the details of computing circuitry.

GAP/R Computor Comparison Chart

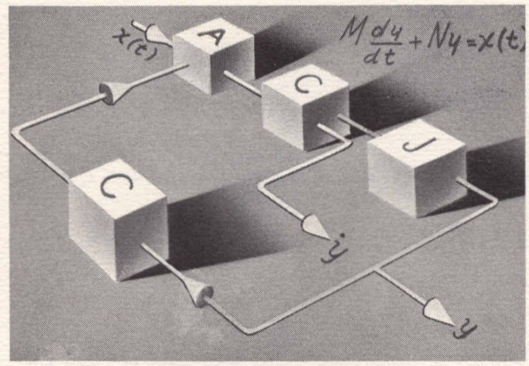


CHARACTERISTIC	K2 Standard	K2 Stabilized	K3 Standard	K3 Stabilized
Relative economy	√ √	√	√	
Suitable for special simulators	√	√ √		
Suitable for control applications	√ √	√ √		
Ease of operation	√	√	√ √	√ √
Ease of maintenance	√ √	√ √	√ √	√ √
Simplicity of interconnections	√	√	√ √	√ √
Suitable for repetitive operation	√		√ √	√
Suitable for slow or real-time operation	√	√ √	√	√ √
Easily expanded	√ √	√ √	√ √	√ √
Suitable for central programming	√	√	√	√ √
Typical mounting	Shelf	Shelf	Shelf or Console	Shelf or Console

Applications . . .

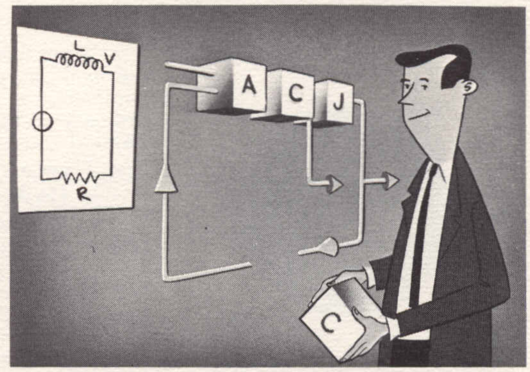
Mathematics:

Speaking very generally, the fast electronic analog is an accelerated version of the true differential analyzer. As such its mathematical realm lies chiefly in sets of total differential equations, linear and nonlinear, with time as the independent variable; yet solutions outside these sets are possible in many cases. Thus, by embodying certain conditions of similitude, systems governed by partial differential equations may often be handled. In special cases integration may be performed with respect to arbitrary signals. Normally, however, the only dependent variable is time itself.



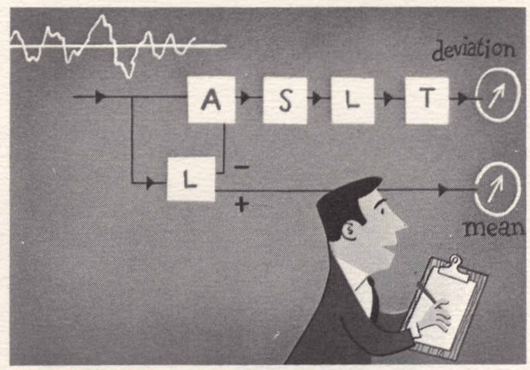
Direct Simulation:

Any branch of engineering able to utilize functional block diagrams may be served by Philbrick computors. The computor may act as an analog for an entire system, or in many cases a system may be studied by reproducing an unknown part of it by empirical means; i.e., building an experimental model from analog components, until appropriate tests show that a sound analogy obtains. By such means one may deal with analogs of objects and procedures for which mathematical formulation is not practical.



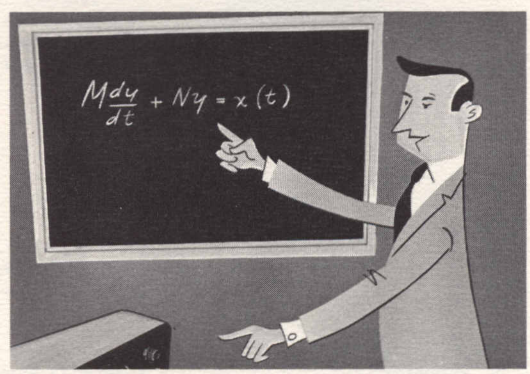
Data Reduction:

Philbrick analog computors function admirably for dynamic data reduction. In such applications data-sensing elements are connected to the computor (via transducers or directly), from the critical points of the system to be tested. The computor then instantaneously reduces the data to desired forms while the test is being conducted.



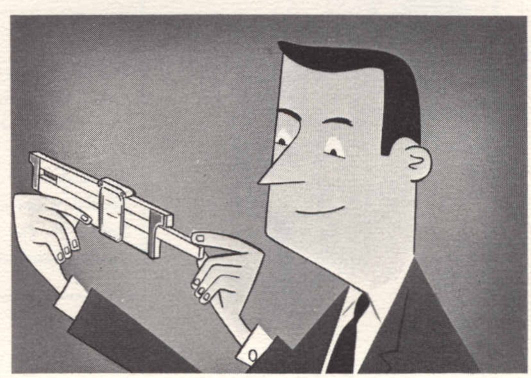
Instruction:

One highly practical application has appeared in the teaching of dynamics, instruments, controls and applied mathematics. Not only does use of an analog computor save time, and thus multiply the instructor's effectiveness, but the student obtains an inspired grasp of his subject through live demonstrations.



Slide Rule of N Variables:

As a design tool, the electronic analog computor has already proved its worth. For many problems involving linear and nonlinear variables, where slide-rule accuracy is sufficient, its ease and rapidity in obtaining answers make the repetitive Philbrick electronic analog computor an indispensable part of well-planned engineering departments and research laboratories. The repetitive nature of the display allows rapid changes in settings to be made by the engineer, who obtains thereby a feeling for and intuitive grasp of the problem which cannot be obtained in any other way.



Some Categorized GAP/R Applications . . .

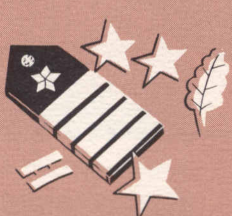
Business

Linear programming
Input-output matrices
Correlation analysis
Dynamics of economic systems

Electrical & Electronic

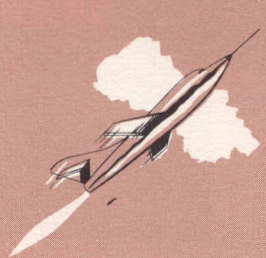
Transformer design
Voltage regulator design
Studies of transient conditions
Stability studies
Electronic system design
Circuit development
Design of servomechanisms
Load distribution control

Military & Government



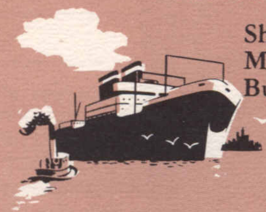
Fire- and bomb-control system design
Ballistic studies
Trainer design
Flood control and integrated river basic operations
Meteorological studies

Aircraft



Automatic pilot and stabilizer design
Control and guidance equipment design
Torsional oscillation- and vibration-damping studies
Dynamic response and stability studies
Turboprop control system design
Autopilot design
Missile dynamics

Maritime



Ship steering-gear design
Marine propeller design
Buoyancy and stability studies

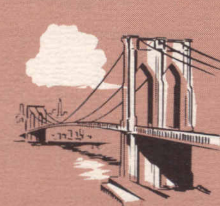
Mechanical

Suspension, spring and shock-absorber design
Governor design
Design of gas-turbine fuel systems
Stress and vibration analysis
Heat transfer studies
Shaft torque studies

Chemical & Chemical Processing

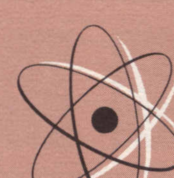
Studies of reaction kinetics
Study, design and operation of complex chemical reaction systems
Semiautomatic and automatic process control design
Oil refinery design

Structural



Bridge design
Vibration and stress studies
Analysis of indeterminate structures

Nuclear

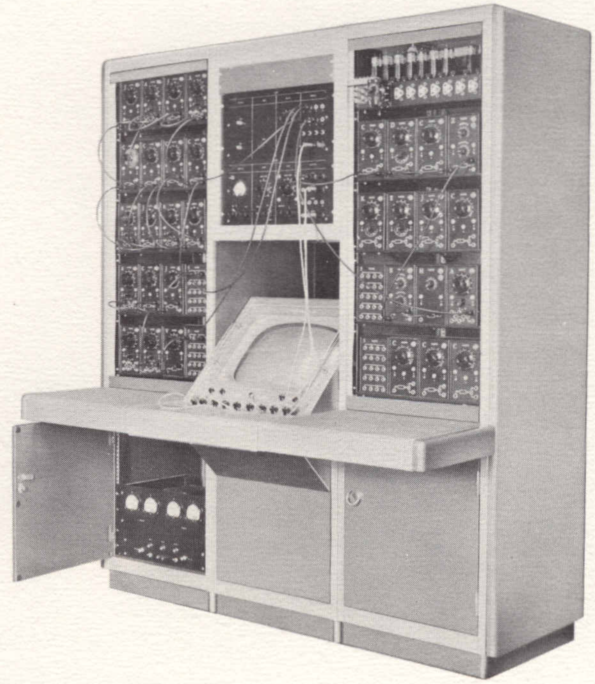


Design of reactor control systems
Atomic reactor simulation

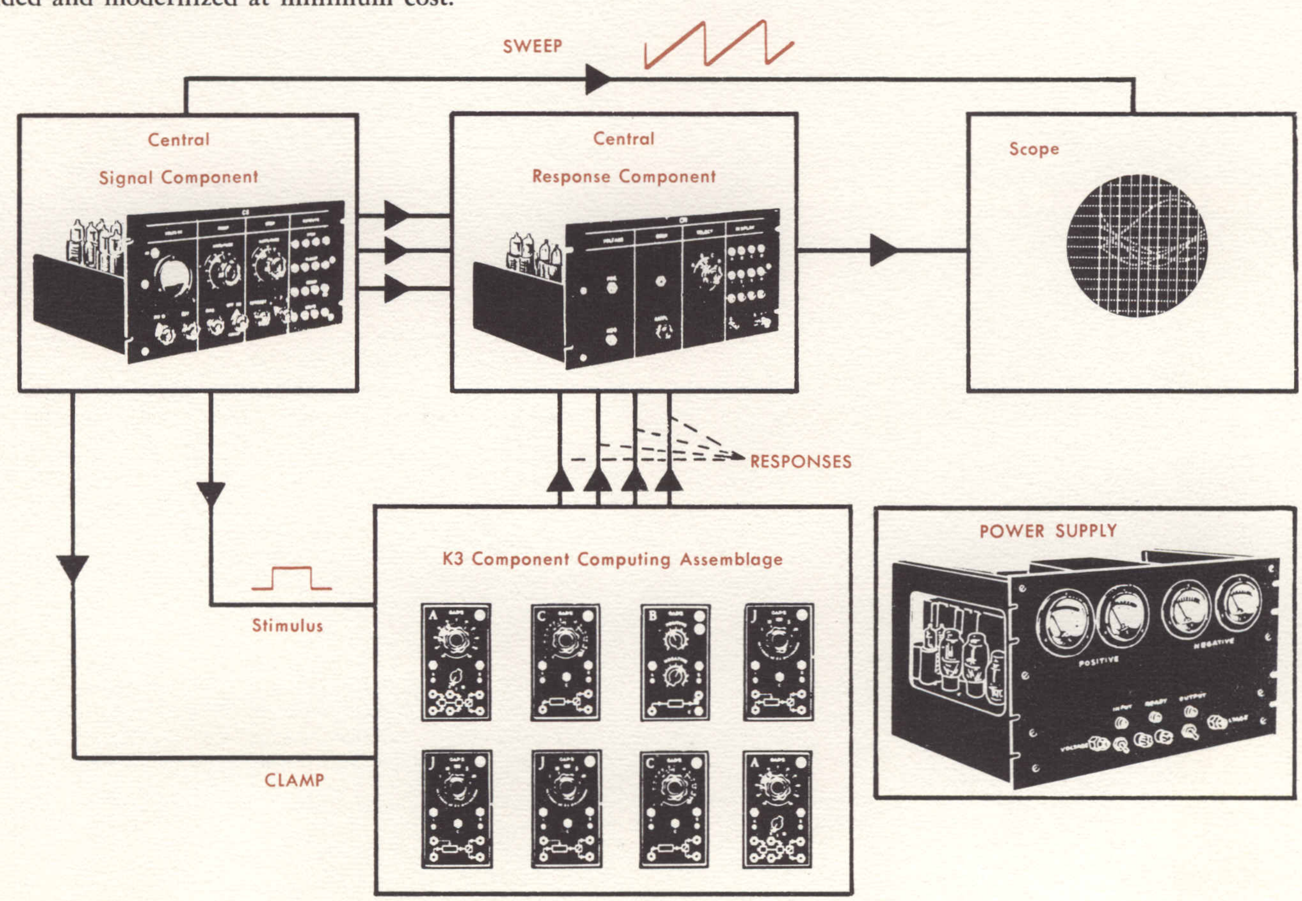
K3 Components

Typical K3 Components

The new K3 series of Analog Computing Components is a modular family of operational blocks, both linear and nonlinear, which allow rapid set-up of the problem with minimum knowledge of electronic circuitry. Each component is a self-contained operational unit, engineered for functional efficiency in a computing system. The user of a K3 installation goes directly from a block diagram of the problem-to-be-solved or system-to-be-simulated to the correct arrangement and interconnection of the computing components, to set up a dynamic analog model. Solutions may be displayed on an oscilloscope screen. Linear components (K3-A, C, D, E, J, K, and L) provide both positive and negative outputs which may be used simultaneously. Inputs and outputs may range from —50 to +50 volts. Clearly-visible lamps denote outputs in excess of 50 volts. For facility in servicing (rarely needed), all operational amplifiers are readily removable plug-ins. K3 installations are easily expanded and modernized at minimum cost.



K3 Computor Console Installation



K3 Installation Comprising a Complete High-speed Computor

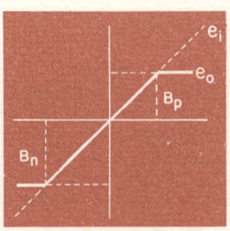
K3 Components (cont.)

Linear

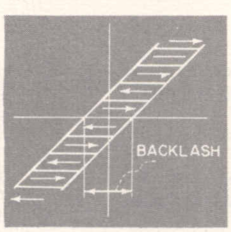
MODEL	EQUATION	DESCRIPTION
K3-A Adding Component	$\pm e_o = e_i + e_2 + e_3 + e_4 + E$	Computes the sum of one to four input signals, plus a d-c voltage E which may be varied from —50 to +50 volts. Accuracy: ±0.5%; rise time: 10 microseconds.
K3-C Coefficient Component	$\pm e_o = Ce_i$	Multiplies input by constant, but adjustable, factor set on a dial calibrated from 0 to 100 with unity at the center. Accuracy: ±0.5% with C set to 1.
K3-D Differentiating Component	$\pm e_o = aT\frac{de_i}{dt}$	Computes the first time derivative of the input. The time constant, T, may be set to 0.04, 0.4, 4.0 or 40 milliseconds. The scale factor, a, may be set continuously from 0 to 100%. Accuracy: ±0.5%.
K3-E Augmenting Differentiator	$\pm e_o = e_i + aT\frac{de_i}{dt}$	Output is the input signal directly plus the first time derivative of the input. Details of the differentiating function are the same as for the K3-D.
K3-J Integrating Component	$\pm e_o = \frac{1}{T}\int e_i dt$	Computes time integral of input. The time factor, T, is selectable at 0.4, 4.0 and 40 milliseconds and 1 second. A terminal is available for application of a clamping signal to restore outputs to zero. Accuracy: ±0.5%.
K3-K Augmenting Integrator	$\pm e_o = e_i + \frac{1}{aT}\int e_i dt$	Output is the input signal directly plus the first time integral of the input. The time factor, T, may be set to 0.04, 0.4, 4.0 or 40 milliseconds. The scale factor, a, may be set continuously from 0 to 100%. Accuracy: ±0.5%.
K3-L Unit-Lag Component	$e_o + aT\frac{de_o}{dt} = \pm e_i$	Slows rise time of input by an amount T. T is continuously adjustable from 0 to 100% of 0.04, 0.4, 4.0 and 40 milliseconds. Accuracy: ±1%.
K3-5 Connecting Jack-Box	*None*	Contains five sets of four parallel-connected jacks. Provides a means for forming multiple driving connections.

e_o=output voltage; e_i, e_1, e_2, e_3, e_4 represent input voltages.

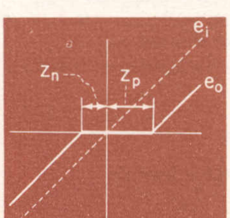
Nonlinear



K3-B OUTPUT VS. INPUT



K3-H OUTPUT VS. INPUT



K3-Z OUTPUT VS. INPUT

MODEL	EQUATION	DESCRIPTION
K3-B Bounding Component	*See graph*	The positive and negative bounds are independently adjustable. Each bound may be set linearly from 0 to 50 volts.
K3-H Backlash Component	*See graph*	Output follows input, after sufficient change, but remains behind by a prescribable amount. Upon reverse of the input, output is stationary until the input has proceeded by the prescribed amount in the reverse direction. The degree of backlash is adjustable from 0 to 50 volts.
K3-M Multiplying Component	$e_o = \frac{e_1 e_2}{25}$	Provides product of two inputs. Scale factor is 25 volts=1. All electronic, "non-quarter-square" multiplier. Error less than ±0.5% for inputs between 0 and 25 volts.
K3-S Squaring Component	$e_o = \frac{ae_i^2}{25}$	Computes the second power of the input and provides an adjustable scale factor a. With a set 100%, input equals output when input equals 25 volts. Accuracy: ±1%.
K3-σ Special Squaring Component	$e_o = \frac{ae_i\lvert e_i\rvert}{25}$	Characteristics are similar to the K3-S except that the point-symmetric or odd-function "parabola" is represented. Appropriate in hydraulic phenomena which involve both square-law resistance and bi-directional flow. Accuracy: ±2%.
K3-T Square Root Component	$e_o = 5a\sqrt{e_i}$	Computes the positive square root of positive inputs and provides an adjustable scale factor a. With a set to 100%, input equals output when input equals 25 volts. Accuracy: ±1%.
K3-τ Special Square Root Component	$e_o = \frac{5ae_i}{\sqrt{\lvert e_i\rvert}}$	Characteristics are similar to the K3-T except that a point-symmetric form is represented. Appropriate in hydraulic phenomena requiring the inverse drop-flow relation. Accuracy: ±2%.
K3-V Absolute-Value Component	$e_o = a\lvert e_i\rvert$	Computes the absolute value of the input multiplied by a continuously adjustable scale factor. Accuracy: ±0.5%.
K3-Z Inert-Zone Component	*See graph*	Suppresses a central band of variation of the input, outside of which any surplus variations are transmitted at unit sensitivity. The inert zone is continuously adjustable by two dials, for independent adjustment up to 50 volts each side of zero.

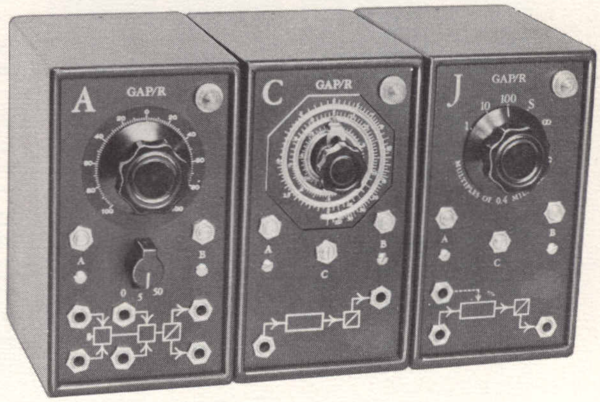
e_o=output voltage; e_i, e_1, e_2, e_3, e_4 represent input voltages.

KS3 Components

With the introduction of the KS3 components, GAP/R now offers the widest band of computing speeds available. Especially suitable for slow or real-time operation, the KS3 series of Analog Computing Components is a stabilized version of, and completely compatible with, the standard K3 series. KS3 components may be used separately or together with K3 components. A decided advantage of the KS3 (and K3) series is elimination of external computing resistors and capacitors. This results in maximum simplicity of problem set-up. The wire-wound resistors and polystyrene capacitors used in computing elements in the KS3 series allow high stability and accuracies of 0.1% or better. Features of the operational amplifiers used in this new line are:

- ±100V input and output excursion
- Automatic overload prevention to eliminate the long recovery time from overload inherent in stabilized operational amplifiers
- Gain of 3×10^7
- Long term stability equal to ±1 millivolt

The table below summarizes the characteristics for linear KS3 components. Unless otherwise indicated, only the positive version of the output is available from these components.



Typical KS3 Components

MODEL	EQUATION	DESCRIPTION
KS3-A Adding Component	$\pm e_0 = e_1 + e_2 + e_3 + e_4 + E$	Computes the sum of one to four input signals, plus a d-c voltage E which may be varied from −50 to +50 volts. Accuracy: 0.1%; rise time: 10 micro-seconds. Output is available in both plus and minus sign.
KS3-C Coefficient Component	$e_0 = Ce_i$	Multiplies input by constant, but adjustable, factor set by a three-turn dial calibrated from 0 to 100 with unity at the center. Accuracy 0.1% with C set to 1. Available with three decade 0.1% fixed step attenuation.
KS3-D Differentiating Component	$e_0 = aT \frac{de_i}{dt}$	Computes the first time derivative of the input. The time constant, T, is fixed at 1 second. The scale factor, a, may be set continuously from 0 to 100%. Accuracy: ±0.1% with a set to 100%.
KS3-E Augmenting Differentiator	$e_0 = e_i + aT \frac{de_i}{dt}$	Output is the input signal directly plus the first time derivative of the input. Details of the differentiating function are the same as for the KS3-D.
KS3-J Integrating Component	$-e_0 = \frac{1}{T}\int e_i \, dt$	Computes the time integral of the input. The time factor, T, is fixed at 1 second. Unit is relay clamped with high impedance input to clamping signal. Accuracy: ±0.1%; open-loop drift: 0.4 volt/hour.
KS3-K Augmenting Integrator	$e_0 = e_i + \frac{1}{aT}\int e_i \, dt$	Output is the input signal directly plus the first time integral of the input. The time factor, T, is fixed at 1 second. The scale factor, a, may be set continuously from 0 to 100%. Accuracy: 0.1%.
KS3-L Unit-Lag Component	$e_0 + aT \frac{de_0}{dt} = e_i$	Slows rise time of input by an amount T. T is continuously adjustable from 0 to 100% of 1 second. Accuracy: ±0.1%.

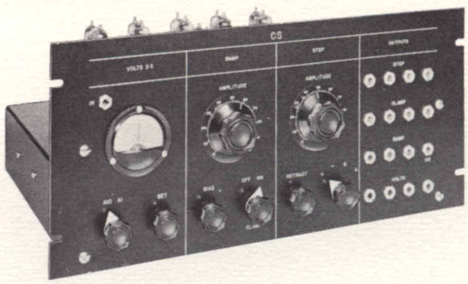
e_0=output voltage; e_i, e_1, e_2, e_3, e_4 represent input voltages.

Model CS Central Signal Component

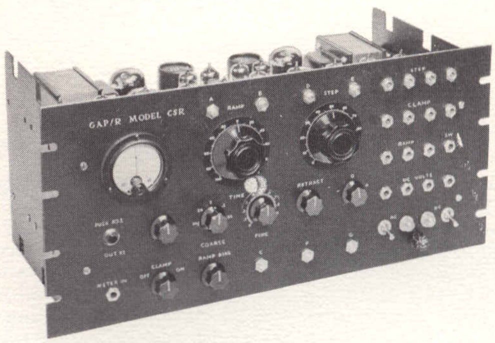
Model CS provides stimuli and programming for automatic repetitive computation. In addition to the synchronized Ramp, Clamp, and Step outputs, it offers an adjustable, accurate source of d-c voltage for checking calibrations. The D-C Level, Ramp, Clamp, and Step signals are all accessible from standard jacks (in sets of 4 each).

The RAMP is a linear 50-millisecond sawtooth, adjustable both as to amplitude and to offset. One of the 4 outputs is a fixed-amplitude sweep for oscillography. The CLAMP is a 5-millisecond pulse, positive immediately after Ramp flyback but negative for the rest of the cycle. It is generally applied to Integrators to enforce an initial equilibrium.

The STEP departs 5 milliseconds after removal of the Clamp, and returns at the Ramp flyback. It is adjustable in amplitude and sign, and may be retracted to form a square pulse of any width up to about 30 milliseconds. This wave, at any amplitude or pulse-width, may be produced in a symmetrical sequence of alternating positive and negative steps, on a 10-cps base. The normal function of the Step is the application of repeated stimuli — or initial conditions — to analog computing configurations assembled from Philbrick components.



Model CS

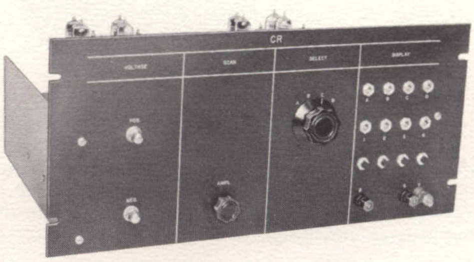


Model CSR

Model CSR Central Signal Component

Model CSR is a more versatile version of the CS plus an R-100 Power Supply. In the CSR, the Ramp duration is adjustable from 50 seconds to 50 milliseconds and may be synchronized with the 60-cps line. The Clamp is positive during the first 5% of Ramp duration, negative during the remaining 95% of Ramp duration.

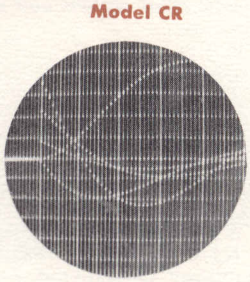
The STEP departs after the first 10% of the Ramp duration, and returns at the Ramp flyback. It is adjustable in amplitude and sign and may be retracted to form a square pulse of any width up to about 90% of Ramp duration.



Model CR

Model CR Central Response Component

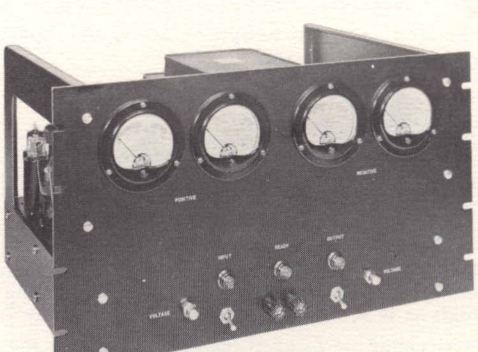
Model CR is the generator of a Philbrick exclusive — Electronic Graph Paper — which gives instantaneous and automatic calibration of both voltage and time on the oscillograph screen itself. It may be used with any standard oscilloscope. Model CR accepts eight signals for display, five of which may be displayed simultaneously. For repetitive analog solutions, this method of display permits simultaneous plotting, to high precision, of five concurrent variables.



CRO Display of Electronic Graph Paper

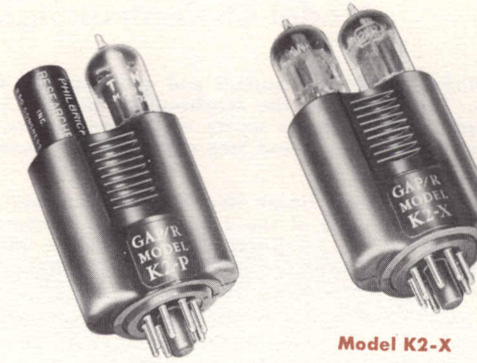
Model RS Regulated Power Supply

Ideal for K3 and KS3 installations including Model CS and Model CR components, Model RS supplies plus and minus 300 VDC regulated outputs, each at 400 milliamperes. It may be conveniently built into cabinets or quickly rack-mounted. Included are meters which indicate the output voltage and current.



Model RS

K2 Components



Model K2-P

Model K2-X

The K2 series of plug-in components offer the most computing per dollar. The cost of a K2-type installation may run as low as one-tenth the cost of other manufacturers' installations with similar computing capabilities. An Operational Manifold forms the basis for a very flexible and expandable installation. It can be equipped with K2-W, K2-X and/or K2-P amplifier units to supply either ±50 volts, ±100 volts or chopper-stabilized outputs. An amplifier remains uncommitted until a computing operational plug-in is plugged into its terminals, which are readily available at the front of the manifold. A comprehensive manual of K2 operational amplifier applications is now available upon request.

Model K2-W Operational Amplifier

Model K2-W is a high-gain d-c amplifier designed as an operational amplifier in high-speed electronic analog computors. With these plug-in units as basic sub-assemblies, computing devices may be assembled with only the simplest wiring. The versatile K2-W handles addition, subtraction, integration, differentiation, inversion, impedance-conversion and other operations. Balanced differential inputs, which will track from −50 to +50 volts, allow various combinations of such computing operations, and afford significant savings in equipment. Cathode-follower output, high gain (15,000) and low drift rate (typically less than 5 millivolts per day) combine to give high accuracy in the plus-to-minus 50-volt output range. Operating power requirements are 6.3 VAC and 300 VDC.

Model K2-X Operational Amplifier

Model K2-X features higher gain (30,000) and greater output excursion (−100 to +100 volts) than the K2-W, but is similar in other aspects. It is intended to supplement the K2-W and will serve for more demanding applications in which its higher power consumption and slightly greater cost may be justified.

This model will perform all of the functions attributed to the Model K2-W. It plugs into the same octal sockets and employs the same connections for power and for computing signals.

Model K2-P Stabilizing Amplifier

Model K2-P is a chopper amplifier designed to stabilize d-c operational amplifiers such as Model K2-W or K2-X. The combination of the K2-P and K2-W or K2-X comprises a Stabilized Operational Amplifier in which drift is reduced to a sub-millivolt level, d-c gain is increased a thousandfold, and computing accuracy is a maximum.

Such usage permits the optional inclusion of a blocking capacity in the grid circuit of the Operational Amplifier, reducing the grid current virtually to zero.

The K2-P is similar in appearance to the other K2 Plug-in Components, using the same case structure and octal base.

Model K2-B Booster Amplifier

The Model K2-B current amplifier may be used with either the K2-W or K2-X Operational Amplifiers to increase its available output current. Output currents as high as ±30 milliamperes at ±55 volts may be obtained.

Here again the form of the K2 line is used, the K2-B utilizing the familiar molded plastic case and octal base. This structure allows rapid installation into customer designed setups or into all GAP/R manifolds.

Operating Specifications

Model K2-W

Gain: 15,000 DC, open loop
Power requirements: 4.5 Milliamps. at +300 VDC
4.5 Milliamps. at −300 VDC
0.6 Amperes at 6.3V
Input impedance: Above 100 Megohms
Output impedance: Less than 1K open loop
Drift rate: 5 Millivolts/days, referred to input
Voltage range: −50 VDC to +50 VDC at output and both inputs
Response: 2-Microsecond rise time

Model K2-X

Gain: 30,000 DC, open loop
Power requirements: 7.5 Milliamps. at +300 VDC
5.2 Milliamps. at −300 VDC
0.75 Amperes at 6.3V
Output impedance: Below 300 ohms, open loop
Voltage range: −50 VDC to +50 VDC for inputs (together):
−100 VDC to +100 VDC for output
Response: 1-Microsecond rise time

Model K2-P

Gain: 1,000 DC
Chopper: Airpax Model A-175
Power requirements: 2.4 Milliamps, at 300 VDC
0.45 Amperes at 6.3V 50-60 CPS
Input impedance: 2 Megohms DC
Output impedance: 22 Megohms and 1 MF
Stability: Inherently below 0.1 MV
Response: Substantially a time lag of 22 sec.

Model K2-B

Quiescent Current Drain: 15 Milliamps. (±300V)
Output Current Maximum: ±30 Milliamps.
Output Voltage Maximum: ±55 Volts
Minimum load lumped for above maximum: 2K
Example: 600 Ω can be driven only to 18V
Output Generator Impedance: 300 Ω approx.

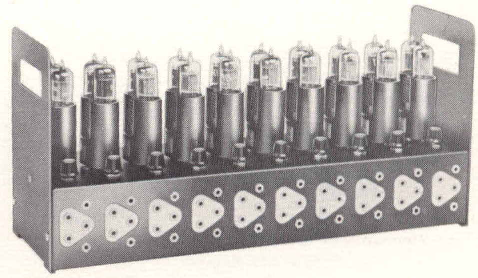
Many laboratories and computing centers have constructed instruments and computers around standard GAP/R Plug-in Amplifiers using available technicians and materials. However, for large installations (or overburdened staffs) it has proved economically advantageous to utilize many other packages manufactured by Philbrick. These include manifolds and chassis, as well as kits for rapid assembly of passive computing elements and selected lists of resistors, capacitors and diodes.

Operational Manifolds

MODEL HK. Model HK contains a manifold of 10 octal (8-pronged) sockets intended to receive units from the K2 Series. It is usually supplied with 10 K2-W Operational Amplifiers. Power requirements are ±300 VDC (regulated) and 6.3 VAC. Connections to individual amplifier inputs and outputs are accessible at the front, where a logical arrangement of jacks enables direct synthesis of computing networks in infinite variety. For each amplifier a convenient bias control is available for zeroing or for adjusting offset. Operating periods from milliseconds to minutes are feasible with this equipment, depending only on the computing capacitors employed and on the type of stimulation. Signals supplied may be sinusoidal (0.1 cps to 50 kc), stepwise, random, or in any combination. Operation may be repetitive or "single-shot."

MODEL HKR. Model HKR is an HK plus an R-100 Power Supply. Its power requirements are 115 VAC.

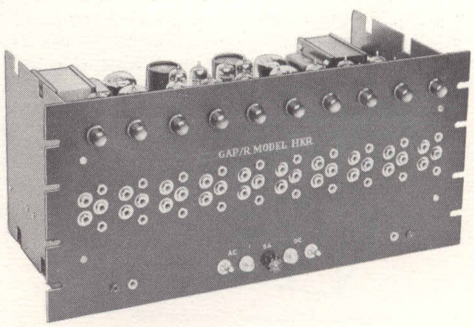
MODEL MK. Model MK is a four-socket version of the HKR. Its power requirements are 115 VAC.



Model HK

Modular Plug-Ins

Simple temporary lash-ups are always possible with a few computing elements, plus plugs and alligator clips. However, when fairly permanent circuit assemblies are found desirable it is convenient to mount the circuit components in suitable structures which will preserve form, yet permit flexible use of amplifiers.



Model HKR

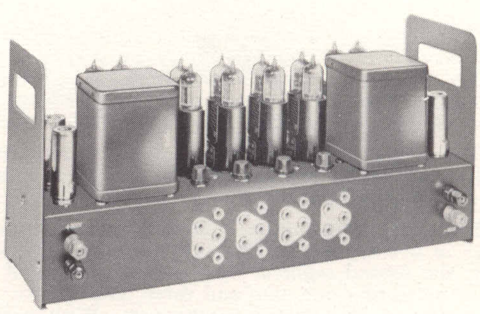
Model K-Modular Assembly Unit

The Model K-Modular Assembly Unit includes pre-drilled Bakelite panels (dimensionally accurate) that fasten together like a "Meccano" set. These panels (front, back, top and bottom) have positioned holes for the reception of jack plugs, potentiometers, switches and banana plugs. The assembly blocks are pre-tapped and designed for single and multiple assembly.

Pre-drilled, insulated plug-boards may be had in single, double and up to ten-module units.

Circuit components are also available from GAP/R. Components suggested for use with Model K-Modular Assembly Units follow:

- Resistors (Deposited Carbon);
  - 50K, 100K, 200K, 250K, 750K, 1 Meg., ½%
- Capacitors (Silver Mica);
  - 400 MMF, 4000 MMF, 1%
- Capacitors (Mylar)
  - 0.04 MF, 0.4 MF, 1.0 MF, 1%
- Variable Resistors (wire wound)
  - Clarostat Type 10, 100K (No guarantee on linearity, effective electrical rotation, or on total resistance).
  - Clarostat Type K2WX, 1% linearity, 1° effective electrical rotation and 2% total resistance.



Model MK

Model K - Passive Modular Plug-Ins

These compact devices, when plugged into the front of the Model HK Operational Manifold, Model HKR Powered Operational Manifold, Model MK Operational Fourfold, and Model DBR Portable Computor, perform operations similar to those of their K3 namesakes.

Assembled from units of the "K-kits" they are all ready to *plug-in.* Here again, where time is an important factor, these units in pre-assembled form afford rapid utilization of the computing elements. Brief descriptions of some of the standard units follow.

Model K-A *Adder* has five adding positions and sum output. All resistors are 500K, ½%.

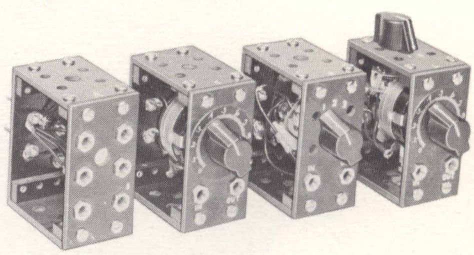
Model K-C *Coefficient* uses a 100K, wire wound potentiometer, plus input and output jacks.

Model K-D *Differentiator* has a three-position selector switch for time factors, plus input and output jacks.

Model K-J *Integrator* has the inverse action of the K-D with similar switchable internal capacitors.

Model K-L *Unit-lag* incorporates a 100K, wire wound potentiometer, a two-position capacitor selector switch and input and output jacks.

Multiplying modules and many other operations are also pre-assembled by GAP/R.

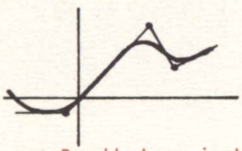


Model K-Passive Modular Plug-Ins

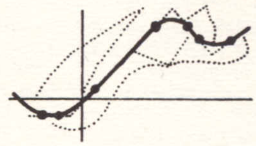
GAP/R Components

Model FFR Arbitrary Function Component

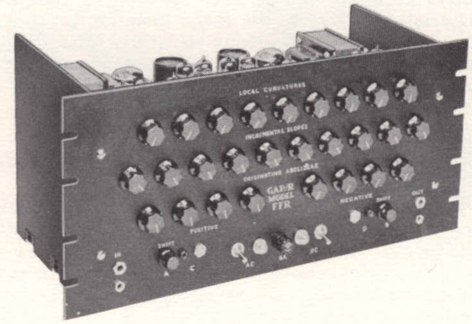
The Model FFR causes the output to follow an assignable function of the input. It utilizes an approximation based on ten connected line-segments, each of which is independently adjustable as to slope, length, and amount of curvature between segments. The FFR features quadratic rounding (interpolation) of line-segment junctions, shift controls and a self-contained power supply operating from 115 VAC.



Segments Roughly Approximated by Tangent Slopes



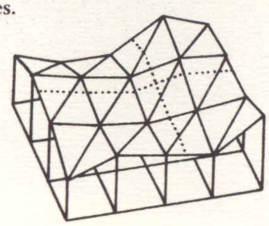
Local Curvatures Tailor Function Accurately



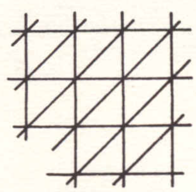
Model FFR

Model F2V Function of Two Variables Component

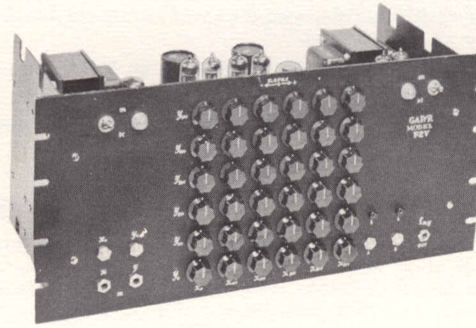
Now in production is an all-electronic generator for any function of two independent variables. This is an "electronic three-dimensional cam" producing an output voltage which is an adjustable function of the two independent input voltages. Specifically, this provides a developed surface with adjustable slopes throughout the surface and adjustable increments for each edge function. Typical applications are the simulation of compressor maps and thermodynamic states of matter. Extensions of these techniques provide for generation of function of three or more variables.



Portion of Surface Generated by Model F2V



Top View of Surface



Model F2V

Model DLS Delay Line Synthesizer

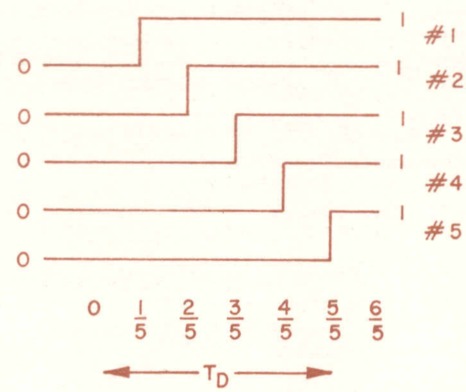
Model DLS is a five section delay line function synthesizer in which the output of each section may be delayed in time by an amount continuously adjustable from 10 milliseconds to one second. The time delay may be adjusted by a knob on the front of the control unit or by an external voltage.

Externally adjusting time delay by a voltage makes the unit extremely flexible. Model DLS has a range of total time delay continuously adjustable from 50 milliseconds to 5 seconds. The external voltage adjusts time delay under the equivalences: 50 volts equals 50 milliseconds and 0.5 volts equals 5 seconds.

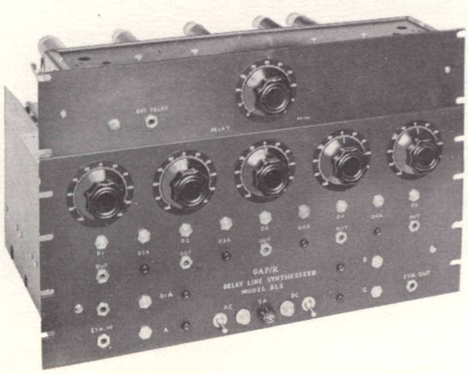
The output of each section may have an amplitude of zero to 10 times (up to 50 volts) that of the input signal and may be combined in either sign with the outputs of the other sections.

Functions of 50 milliseconds to 5 seconds duration may be synthesized by Model DLS in five segments. The first segment is approximated by the output of section one; the second segment by the combination of section one and two outputs; the third by section one, two and three outputs; etc. An input is available that permits cascading of Model DLS synthesizers. With two or more units, functions may be more closely approximated and functions of greater than 5 seconds duration may be synthesized.

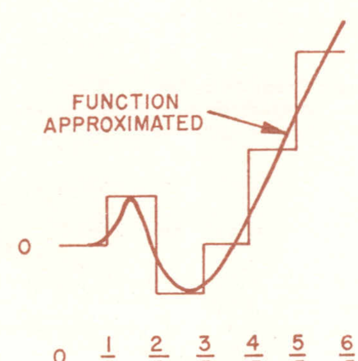
Input Signal



Unit Outputs of Each Section



Model DLS

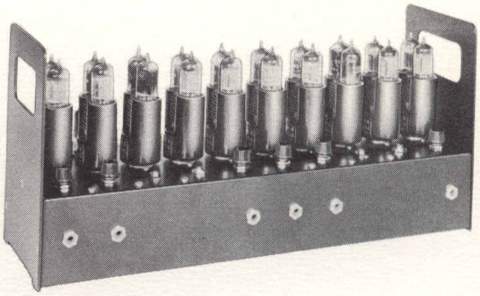


Output of Model DLS and the Function Fitted

Model MU/DV Duplex Multiplier-Divider

Model MU is a compact two-channel analog multiplier-divider in which high precision and speed of response are combined with simplicity and modest power requirements. Philbrick multipliers are the only accurate, high-speed electronic multipliers available. Total error is less than 0.25%; rise time is better than 0.1 millisecond. The calibrating adjustments are simple, permanent, and not critical.

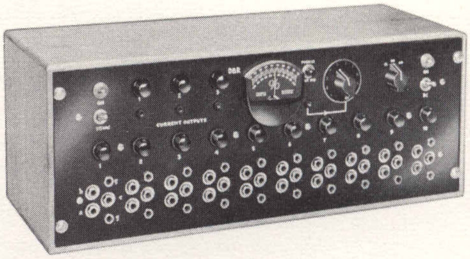
The principle of operation of Model MU/DV is based on an exact physical law, embodied without approximations which would require special tubes or segmented characteristics. The method involved in this multiplier is not "quarter-square," but an entirely new modulating technique.



Model MU/DV

Model DBR Portable Computor

Model DBR is a truly portable analog computing instrument for applications needing from one to ten operational amplifiers. It consists of the Model HK Operational Manifold, a built-in Model R-100 Power Supply, initial-condition current sources, and a "CLAMP, HOLD, OPERATE" switch, all self-contained in a single compact oak case. The DBR is ready to perform at a moment's notice a wide range of computational and simulation tasks — via standard or special GAP/R Model K-Passive Modular plug-ins or (for even faster set-ups), via banana jacks or General Radio plugs. The DBR is enjoying wide acceptance as an auxiliary and as an educational computor.



Model DBR

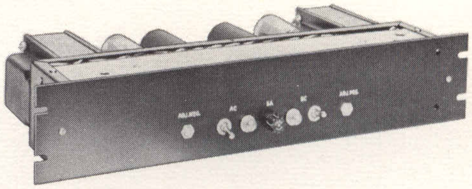
Regulated Power Supplies

GAP/R offers regulated supplies ranging from 100 to 400 milliamperes at ±300 volts output. Up to 20 K2-Ws may be driven by the lowest priced unit in this line.

MODEL R-100. Model R-100 is a new and compact power supply designed primarily for use with analog computing instruments. However, its modest cost and excellent performance has resulted in widespread general application. This supply may be conveniently built into cabinets or quickly rack-mounted. The regulated outputs are plus and minus 300 VDC, each producing a conservative 100 milliamperes.

MODEL RJ-100. Model RJ-100 is a shelf or desk mounting version of Model R-100.

MODEL RK-200. A shelf or desk mounting supply, Model RK-200 is a 200 milliampere version of the R-100. It includes meters which indicate output current and voltage.

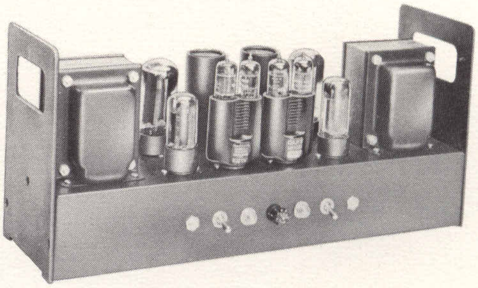


Model R-100

Console Cabinets and Mounting Racks

For installations where appearance is important, modular enclosure console cabinets are available from several manufacturers, whose names will be furnished on request. Otherwise, standard relay racks are recommended wherever economy and accessibility are essential.

Model RK-200



Model RJ-100

Origin and Development

The Keynote: Controls

GAP/R took its present form in 1946, but in effect our organization began a decade earlier when the founder first applied its basic techniques in research on automatic controls. This early work was a double success; it led to improved industrial instruments now in general use, and it made known the power of the electronic analog as a developmental tool. Since then the method has been continuously advanced, made stronger and more versatile.

From the earliest models, our analog instruments could operate repetitively, presenting computed variables on the oscilloscope screen — plotted either against time or against one another. These machines were highly successful; they compressed hours into milliseconds, days into minutes, and years of experience into a pleasant afternoon.

The Age of Modules

By 1948 a number of special Philbrick Computors had been built, each for some particular class of problems. Although all such applications succeeded, it was noted that a more generalized applicability depended on the use of modular elements from which any type of analog computing system might be speedily assembled.

Hence, there evolved the K3 Series of components, which could be treated by the practical engineer like the unitary operations in his block diagrams. He was spared electronic details, and could remain close to reality. We were enabled to supply precisely the assortment of components needed for the job at hand, to be added to later as required. Service and supply were faster and easier, and customer satisfaction proved the wisdom of our philosophy.

Elementary and Advanced Nonlinearity

By this time the Arts of linear operations and linear equation-solving were commonplace. From the outset, Philbrick Computors had included the basic nonlinear phenomena of limits, thresholds, and hysteresis, and we had lived intimately and impartially with these frequently-neglected properties of practical structures. Our Model FF was probably the first commercial embodiment of Segmented Voltage Functions. The modern forms of this component, for functions of one variable, are nearly ideal.

The Pace Quickens

To enumerate some of the signs of our steady growth: Philbrick customers spontaneously set up an annual conference to discuss applications; we start publication of *The Lightning Empiricist* to promulgate newsworthy developments; we engage Pi - Square Engineering Co. as consultants on new applications and techniques.

In fast succession the K2 Series, the Electronic Graph Paper, the new MU Multiplying Component, the FFR Function Generator, and the new K3 Series were added to our product line. Any of these recent developments may be interconnected with earlier types, thus continuing our policy of nonobsolescence.

As matters stand, the evolutionary cycle is still in process, but the fullness and variety of our collection of analog tools is attested to in our catalog pages. Philbrick policy is to pioneer in new developments, in awareness of application problems, and in maximum service to the user.

SERVICES

Applications Engineering

Through our applications engineering department, customers are assured of prompt and capable consideration of their computor needs. We welcome complex problems from potential computor users. We prefer to tailor computing installations to the specific requirements of the user, because only in this way can the computer get the most from his computor. On-the-spot field consultants are available for the design of special computors and simulators.

Computor Consulting Service

With our contracting consultants, PI - SQUARE ENGINEERING CO., INC. (400 Western Union Bldg., Boston 10, Mass.), GAP/R has continued successfully to master difficult dynamic and control problems through applications of analog art. PI - SQUARE offers the complementary experience and abilities of the two principals, Henry M. Paynter and George A. Philbrick; the dominant activity of this organization is concerned with the application of computing aids of all types to rational engineering analysis and design. With available computing facilities ample to tackle most problems, PI - SQUARE is on call separately or through GAP/R.

Component Services

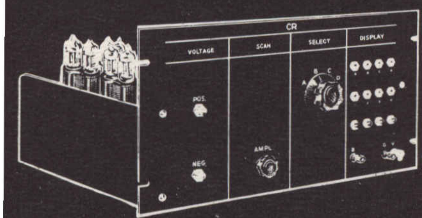
For handling overhaul and repair with economy and dispatch, GAP/R is amply equipped. On the rare occasions when it becomes necessary, components are repaired or replaced within an average interval of one week. Every component is guaranteed for 90 days against failure due to faulty parts or manufacture. After this period a nominal service charge may be made if equipment is returned to the laboratory for replacement or overhaul.

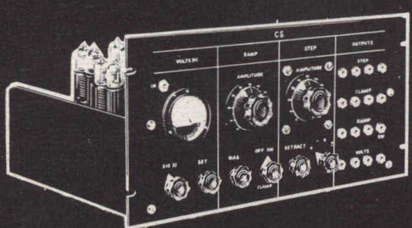
Further Information

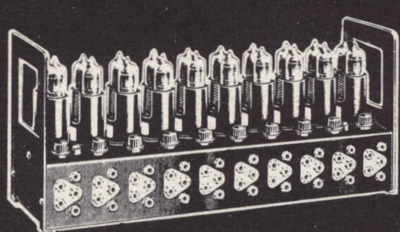
For further information or a demonstration, contact your GAP/R area representative. For free consultation on your applications and computor requirements, contact:

Director of Sales and Applications Engineering
George A. Philbrick Researches, Inc.
230 Congress St.
Boston 10, Mass.

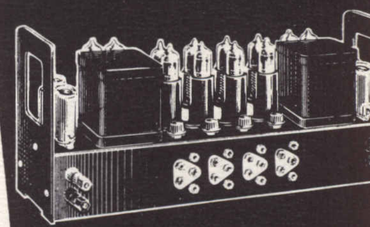
Some Representative GAP/R *Customers*

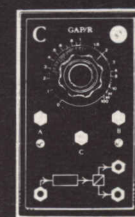


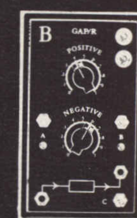


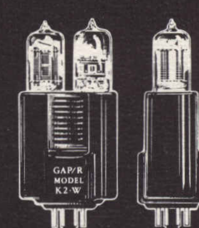


Allis-Chalmers Mfg. Company
Allison Division General Motors Corp.
Askania Regulator Company
Bendix Products Division
Convair Division of General Dynamics
Defence Research Establishment, Sweden
E. I. du Pont de Nemours
General Electric Company
Grumman Aircraft Engineering Company
Hamilton Standard Division
Massachusetts Institute of Technology
Etablissement Neyrpic, France
Pullman Standard Car Mfg. Company
Radio Corporation of America
Royal Aircraft Establishment, England
Shell Development Company
United Shoe Machinery Company
University of Bologna, Italy
University of Wisconsin
Vickers, Incorporated
Westinghouse Electric Company
Woodward Governor Company
Wright Aeronautical Division









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