PHILBRICK
ELECTRONIC ANALOG COMPUTING EQUIPMENT
for
MODELLING MEASURING MANIPULATING
and
MUCH ELSE

PHILBRICK RESEARCHES, INC.

IS SOLID;

We incorporated in 1946 after a decade of computational research, being the first company to offer component devices for assembling analog apparatus. Growth since then has been sustained and substantial. Our D & B rating is AaA1. Our position in the amplifier market is enviable indeed.

IS INNOVATIVE;

We have pioneered a good many of the analog techniques which are now standard. Never imitative, we have nonetheless not stooped to retaliate against imitators. The fact is we have been too busy with the next surprise, and value most of all our freedom to follow the proprietary directions of development which we believe in.

IS APPLICATIONS-CONSCIOUS;

Our customers, whether humble or grand, in whatever field of endeavor, know that we can understand their precepts and problems. We are able to explain analog methods clearly in terms of their numerous applications. It is a passion with us to assure that our products are applied where most appropriate.

IS SCIENTIFIC BUT SENSIBLE;

We do indeed nurture the scientific method, in a proprietary democracy of engineer-scientists. Empirical data, however, are given due respect here along with hypothesis and conjecture. Measurement and computation and control, at laboratory precision; these constitute part of what we sell. With such commodities in abundance, we naturally apply them in our own machinations.

IS OFTEN INCLINED TO BOAST

ANALOG OPERATIONS & INSTRUMENTS

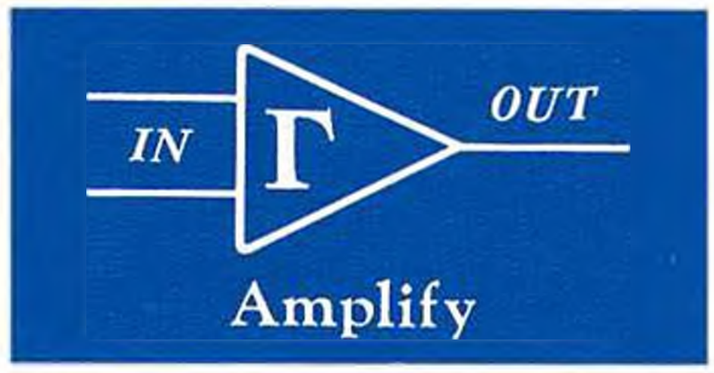
Although the Analog philosophy is readily understood by practical men, yet you will find that the most sophisticated experimentalists take delight in applying it. The operational analog technique, implementing the analog philosophy, is extremely powerful and broad in the mathematical processing of voltage-borne data, and is gaining rapidly in popularity.

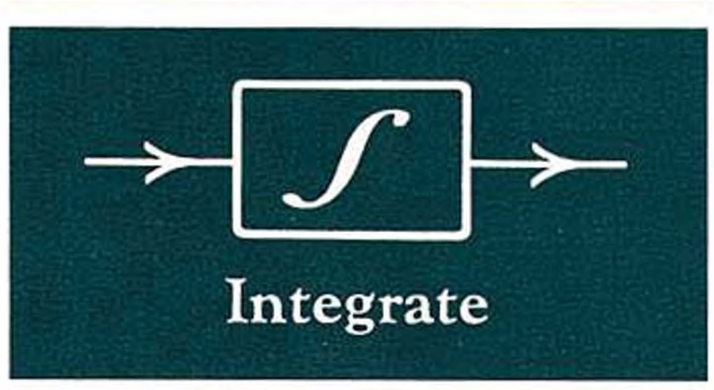
Central to this analog technique is *feedback* in forms both magical and devastating, generally accomplished by operational amplifiers boasting voltage gains from 10^4 to 10^9. The subtleties of analog feedback networks are explained by the electric or electronic initiate in a variety of specialized terms. It really doesn't matter what set of concepts is applied. Signal-flow graphs, block diagrams, or multi-port theory all can lead to the same results. So also may common sense.

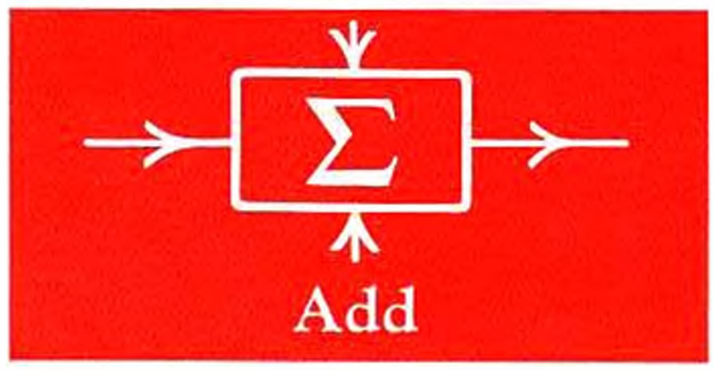
As an isolated and useful special case of analog instruments, we may cite the operational follower. For such a case no external circuit elements whatever need be used, merely a differential operational amplifier. With this instrument one may produce an accurate and "unbending" version of any voltage in a passive circuit, with substantially no interference to that circuit. Try it; understand it; let it grow into an analog machine.

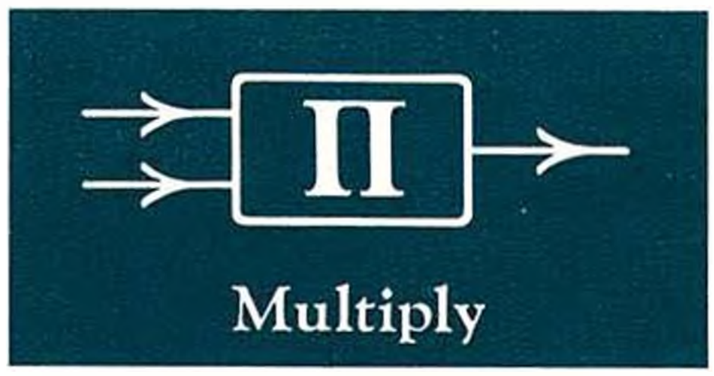
The more conventional basic analog instruments apply amplifiers with one input grounded, the other input then serving as a virtual ground. In a real sense such instruments are current followers rather than voltage followers, even when performing mathematically.

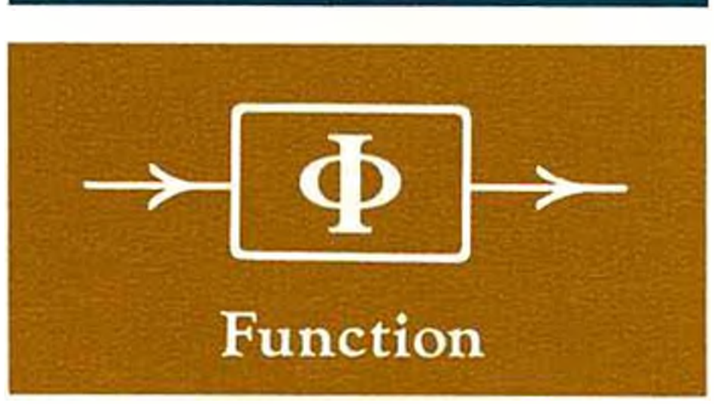
In general, amplifiers plus imagination will give you an almost unlimited array of useful instruments: for testing, regulating, experimenting, or computing. Naturally we produce more complicated instruments, but in these we employ the best available operational amplifiers.

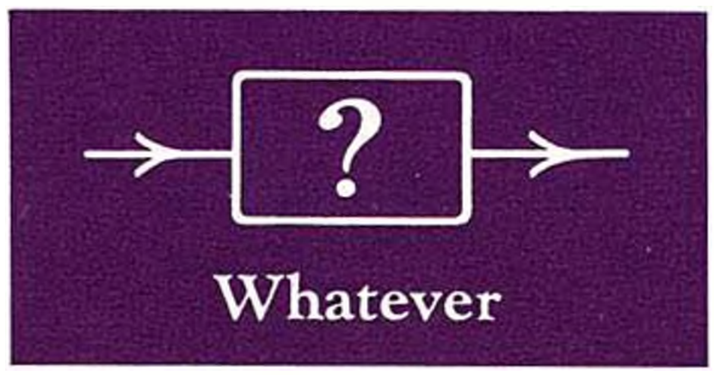




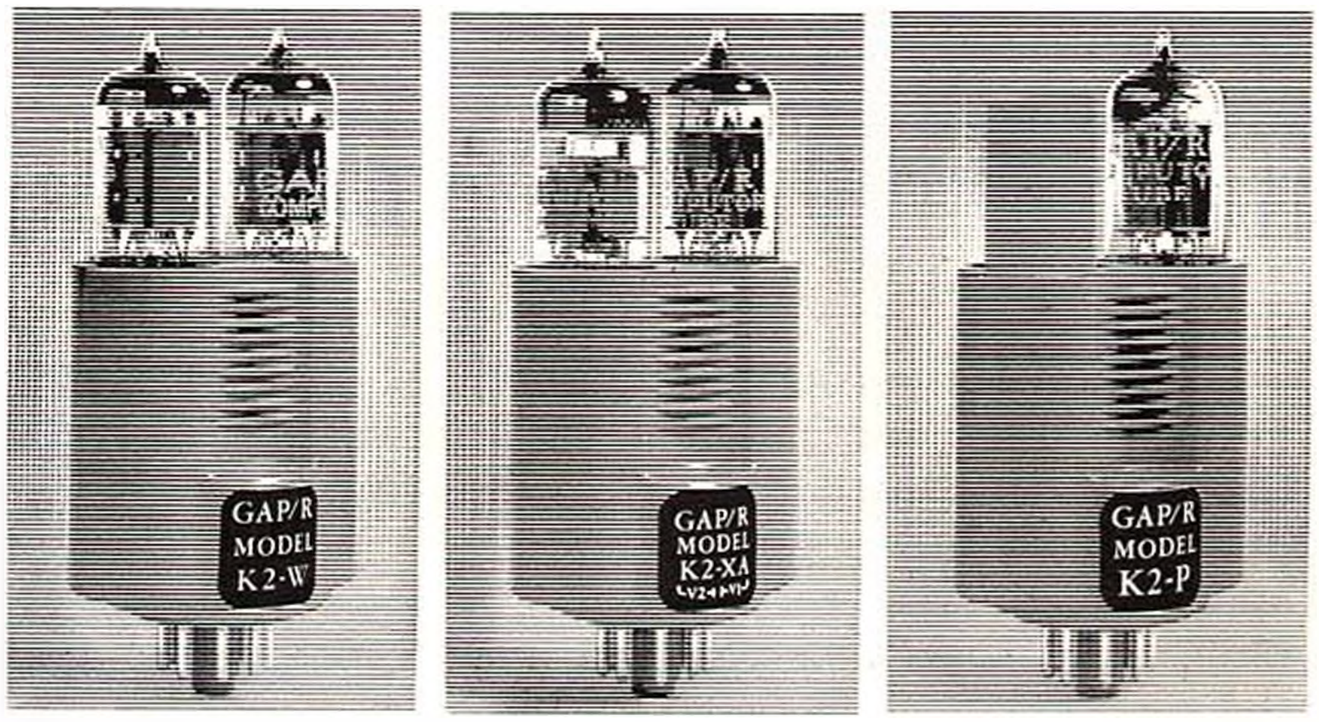








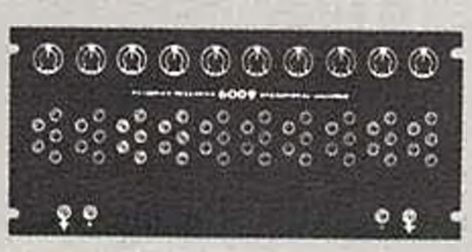
THE K2 AMPLIFIER SERIES



These familiar operational amplifiers, in production for over a decade, are used as much today as ever. We have provided literally millions of dollars worth of K2's to universities and research laboratories in every field of endeavor.

Each type is sealed in a stable plastic shell, and features a diallyl phthalate octal base plug. Each is powered by +300 and −300 VDC.

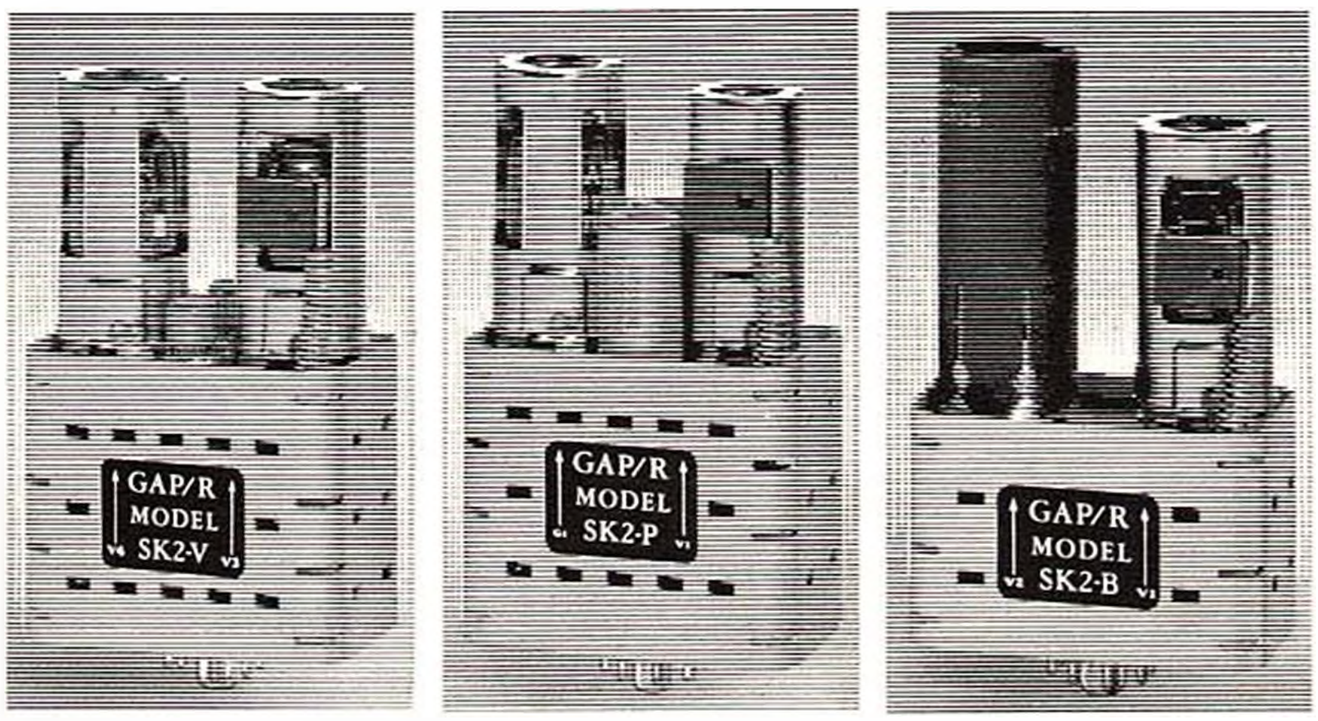
Model K2-W offers a voltage gain of 15,000 from differential inputs; output can range well in excess of its nominal ±50 volts rating at 1 ma. Model K2-XA has a gain of 20,000 and its output is rated at ±100 volts at up to 3 ma. Model K2-P is a slow chopper amplifier, with a gain of 1000, for stabilization of the K2-W or the K2-XA. For greater output current, use these amplifiers to drive the SK2-B described below.



Model 6009
Operational Manifold

This is the successor to our earlier but informal Model HK manifold comprising ten K2 amplifiers in a general-purpose mounting. For special purposes, standard octal sockets are satisfactory, anywhere on your chassis.

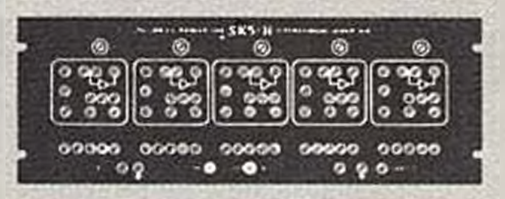
THE SK2 AMPLIFIER SERIES



This recent series extends the performance and reliability inherent in the more modest K2 series. The SK2 series is housed in all-metal ventilated cases, providing 100 per cent shielding plus spring clip hold-down hardware, internally mounted. The octal base plugs are unusually sturdy, each pin is completely shielded, being fused into an individual glass bead in the metal header.

The SK2-V features low drift, offers a voltage gain of better than 100,000 from differential inputs. Output range is from −120 to +180 volts. Its output current can be boosted to 20 ma by the SK2-B booster amplifier over a voltage range of ±100 volts. Offset and drift can be practically eliminated by using the SK2-P to stabilize the SK2-V.

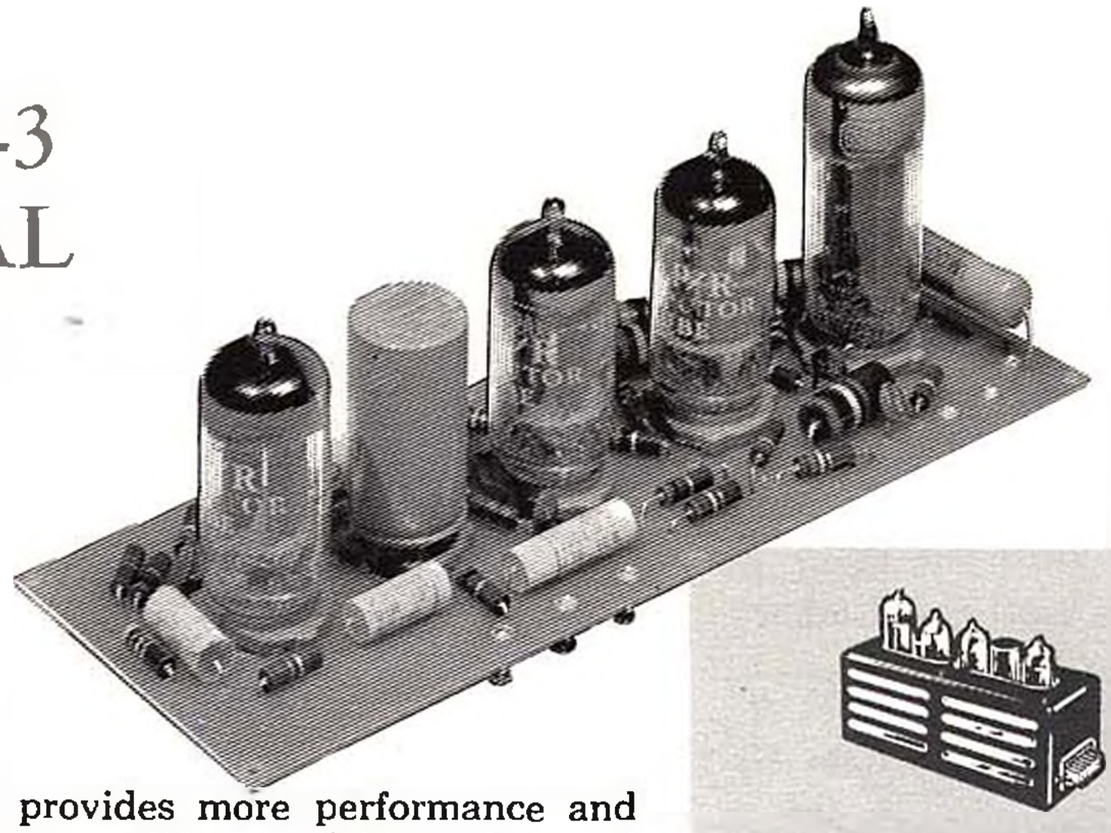
Use the SK2 series where higher performance and reliability are the first considerations.



Model SK5-H
Operational Manifold

Analogous to the 6009 above, and described on p. 5, this more conservative structure, which comprises single-ended, chopper-stabilized, and boosted operational units, includes a set of SK2 amplifiers for general-purpose applications.

MODEL USA-3 OPERATIONAL AMPLIFIER

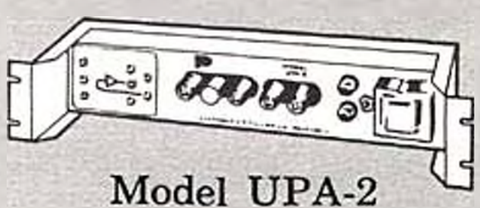


This familiar workhorse still provides more performance and reliability per dollar than any other amplifier available today, and every year its volume of sales has increased in spite of solid-state product advances.

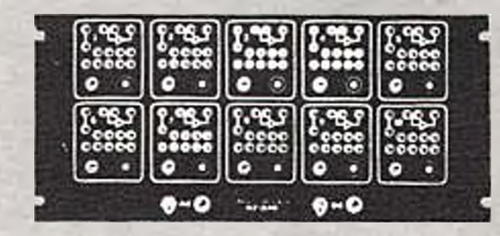
The etched circuit board is a glass-epoxy laminate; reliability is further enhanced by restricting circuitry to the bottom side only while using the foil on the component (top) side of the board for thermal shielding. It is available also in plug-in form (USA-3-M3) or in universal forms such as the UPA-2 and K7-A10. The former is a single amplifier, the latter is a manifold of 10 amplifiers; both include heater transformers. The UPA-2 is designed as a bench top unit, but is provided also with a rack adaptor.

The USA-3 provides an output voltage range from minus to plus 100 volts at currents up to 8 ma. Chopper stabilization keeps the offset and drift well under 100 microvolts, and the steady state input current under 10^{-10} amperes.

Model USA-3-M3

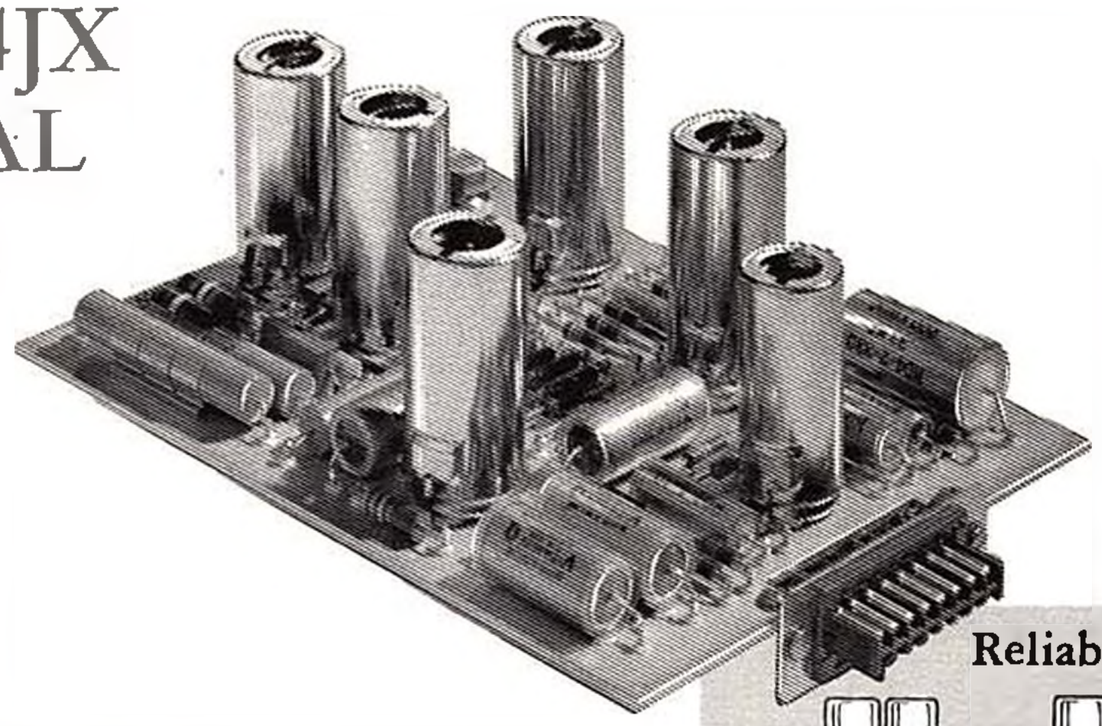


Model UPA-2



Model K7-A10

MODEL USA-4JX OPERATIONAL AMPLIFIER



The USA-4JX was designed specifically for ultimate performance and long life in military applications. All MIL parts are used, mounted on teflon-insulated stand-off terminals inserted into a heavy aluminum plate. It has lower dissipation and draws less power than any other stabilized vacuum tube amplifier available today. It is available also without the connector as Model USA-4JT.

Gain approaches a billion, gain-bandwidth product is over 2 megacycles, chopper stabilization practically eliminates drift and offset, output swings well in excess of ±100 volts, and current capability is 7 ma at ±100 volts.

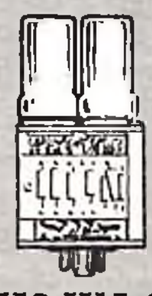
High reliability, full militarized versions of the K2 series are available also, and require no additional mounting space: the K2-WJ, K2-YJ, and K2-PJ. These use "Blue Ribbon" connectors and provision is made for securing them to the user's chassis. Octal bases are available on special order.

Reliable K2s

K2-WJ

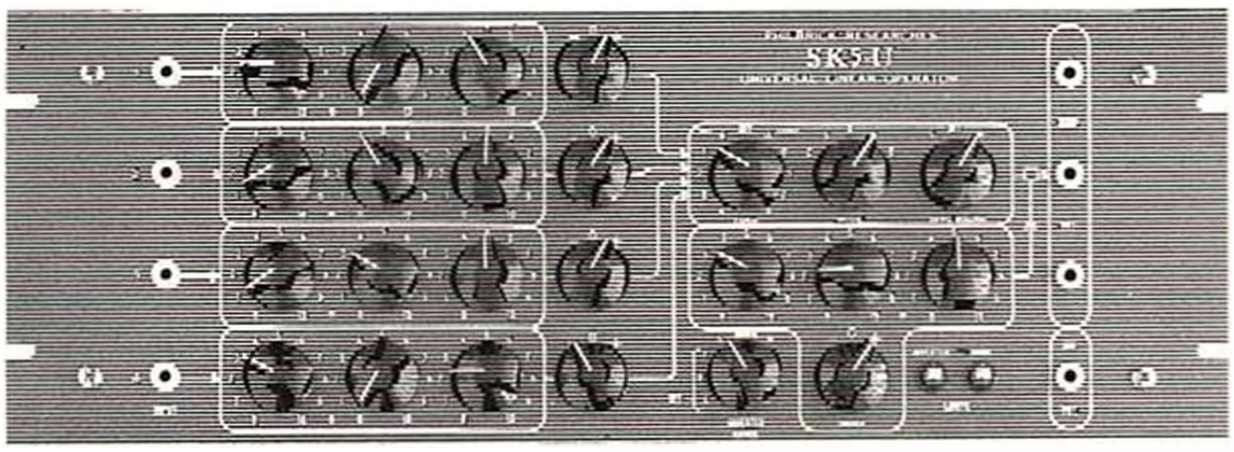
K2-YJ

K2-PJ



K2-WJ-O

MODEL SK5-U UNIVERSAL LINEAR OPERATOR



A fundamental linear building block of a Philbrick SK5 Computor, the SK5-U features a conceptual framework which is mathematical, rather than electronic. It is designed for continuous computation as well as for repetitive and single-shot operation for intervals of 0.05 to 50 seconds; outputs may be read on "Electronic Graph Paper", a large-screen electronically calibrated display.

The SK5-U normally accepts up to four variables in the form of signal voltages, multiplies them by individual coefficients, applies a sign, either plus or minus, then either integrates the sum of these products, or multiplies the sum by a constant. Any arbitrary choice of constant may then be added to form the output, whose range is from −100 volts to +100 volts.

All the above programming plus bounding, plus inverting, plus integrator clamping, plus setting of initial conditions, etc. are accomplished by front panel switch positioning. Coefficients are set numerically by decade switches, eliminating the need for calibrating and nulling of potentiometers, likewise eliminating the need for patch boards and digital voltmeters.

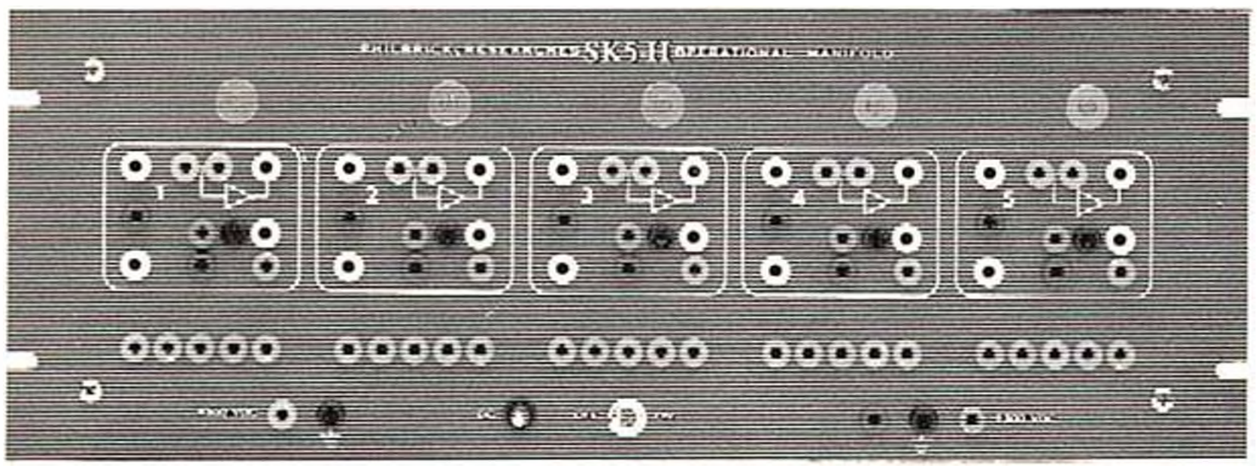
MODEL SK5-M MULTIPLIER-DIVIDER

A fundamental non-linear building block of the Philbrick SK5 Computor, the SK5-M, like the SK5-U, has a conceptual framework which is mathematical rather than electronic and is entirely switch-programmed. Output is a smooth, continuous, completely non-segmental function of the inputs. Accuracy is comparable to the best available today; nominal bandwidth is 7.5 kilocycles.

The SK5-M accepts three input variables, in the form of signal voltages, from which an output voltage, ranging from −100 volts to +100 volts, is derived as the product of two of the inputs divided by the third. The "full scale" constant, 100 volts, may be switched in to replace either a numerator input or a denominator input when only two inputs are used. Also on the front panel is a 3-dial-decade switch and movable decimal point for the purpose of scaling one of the numerator inputs.

When the output is used also as the denominator, then the output becomes the square root of the input product, precisely scaled by the above decade, or of just one input alone if the constant, 100 volts, is switched in to replace the other.

MODEL SK5-H FIVE AMPLIFIER MANIFOLD



This unit houses five uncommitted operational amplifiers, each comprising an SK2-P to stabilize an SK2-V plus booster amplifier. The SK5-H enhances the capability of an SK5 computor substantially. By plugging in simple networks of resistors, capacitors, diodes, etc., many operations too simple to tax the larger capability of the SK5-U, M, or F can be performed at a fraction of the cost for these large units, and often at comparable accuracy. Recovery from overload is instantaneous, in that saturation is prevented by an internal electronic "bound" circuit.

Uncommitted U2 plug-in boxes provide neat packaging for special operational circuitry put together by the user, making true do-it-yourself operations economical. Committed U2 boxes are available also, complete, ready-to-go, providing such operations as:

differentiation	function generation	sample-hold
integration	sine and cosine	selection
summation	squaring-rooting	precise scaling

Typical U2 plug-ins

Model U2-C Coefficient

Model U2-J Integrator

MODEL SK5-F ARBITRARY FUNCTION GENERATOR

Another fundamental non-linear building block, the SK5-F gives most unusual flexibility to function fitting in the SK5 Computor. The output voltage, whose range is −100 volts to +100 volts, is an arbitrary function of the input voltage, built up from ten straight line segments, each segment adjustable precisely in both horizontal and vertical position as well as slope. Each intersection of these segments is modified by an adjustable degree of rounding. This rounding is accomplished by fitting a true and exact parabola, whose *latus rectum* is adjustable. The parabolic section takes over from the straight line segment at the exact points of tangency, eliminating abrupt slope changes in the function generated.

The SK5-F provides extremely smooth, precise fitting of functions encountered in analog computing. It is particularly well suited to generation of functions having a steep slope, e.g., magnetic amplifier characteristics from cut-off through saturation. It is quite surprising how few segments are required for accurate fitting when precise rounding can be switched in and adjusted at each intersection.

MODEL R-100B DUAL POWER SUPPLY

Over the years a cardinal point in the Philbrick philosophy of instrument system design has been the use of low-noise, fixed-voltage power supplies sufficiently precise to provide the system reference voltage as well as the system power. This is a distinct advantage to the systems builder, simplifying his life, especially where there is no price penalty. Another cardinal point is that reliability, particularly in terms of freedom from maintenance, must be compatible with that of the amplifiers being powered.

The R-100B is designed to furnish +300 and −300 vdc, each at 100 ma. It mounts in a standard 19 inch relay rack; panel height is only 3½". It has lower internal dissipation than any other 100 ma dual 300 volt VT supply available; free air cooling is entirely adequate, so no blower is provided.

Regulation is so tight that the effective output impedance is usually determined by the cabling between the R-100B and its load. Hum and noise is typically under 1 part per million. Speed of response is extremely fast: recovery from a 50 ma step change in current to within 0.001% of steady state requires only 6 microseconds.

MODEL R-300 DUAL POWER SUPPLY

The Philbrick philosophy of using precise, fixed-voltage power supplies to serve as both reference and power source for high accuracy instrument systems has been extended in the design of the R-300. The most remarkable attribute of the R-300 (R-600, too) has been the reliability and freedom from maintenance demonstrated over the years.

This reliability is particularly significant considering the complexity required by its performance — e.g., hum and noise less than 1 part-per-million, or recovery following a step change of 50 ma load current to within 0.001% of steady-state inside of 2 microseconds. There are two main reasons for this reliability: extremely low internal dissipation, and severe derating of components; e.g., at 50% overload, the plate dissipation in the series tubes is less than 70% of rated.

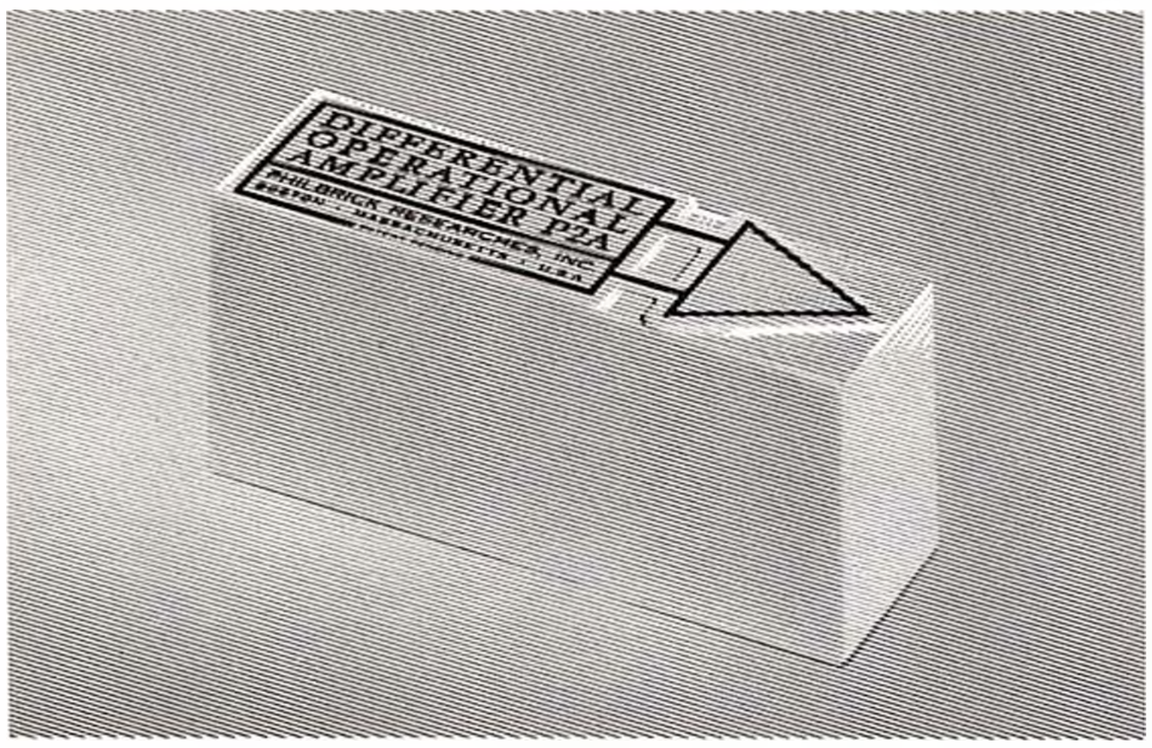
The R-300 is designed to furnish +300 and −300 volts, each at 300 ma nominal load. It is totally enclosed except for air intakes and exhaust (rear, center) of its blower. Also available is the R-600, a 600 ma version of the above; both models have the same size front panel, 19w x 7h.

SOLID STATE EQUIPMENT

Have semiconductor devices finished off vacuum tubes? Not at all. The sale of vacuum tube equipment is increasing, though eclipsed now by that of transistor equipment.

Under the impact of the Semiconductor Revolution, we sometimes feel nostalgia for the simplicity of electrons *in vacuo*, the test points available at every socket, and connections breakable by removing the tube or even turning off the power. But we find real gratification in the solid circuit virtues of semiconductors. We can do tricks that were out of the question with tube circuits; for example, a postage-stamp sized operational amplifier with a gain-bandwidth product of 100 megacycles, or a differential amplifier connected as a sampling integrator with less than 10^{-13} amperes spurious input current.

Real joy stems from watching a miniature amplifier repeat its readings day after day, temperature cycle after temperature cycle, demonstrating apparent immunity to aging. Joyfully, one forgets about blowers, heater supplies, scheduled adjustments, 10,000-hour tube replacements, and turns to contemplating the solidity of this season's systems.



MODEL P2A (STABILIZED) DIFFERENTIAL OPERATIONAL AMPLIFIER

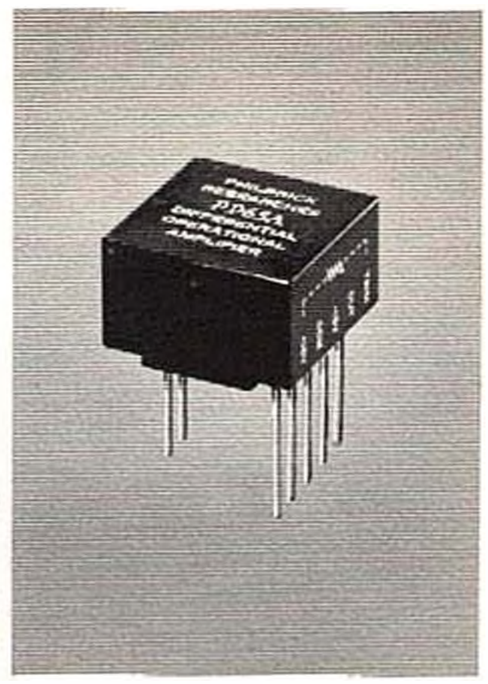
Probably the most unusual Philbrick product is the P2A, an all silicon solid-state, high gain, differential operational amplifier, whose input is fully floating in respect to the rest of the amplifier and ground. There is no inherent common mode error.

However, what makes the P2A so very unusual is that it can be used as an electrometer to measure currents as low as 10^{-12} amperes routinely, and 10^{-13} amperes or less under certain conditions; yet it exhibits unusual voltage stability.

Unlike the P2, its predecessor, the P2A can be operated indefinitely at any temperature from $-25C^{\circ}$ to $+85°C$. Its input current is extremely low even at $+85°C$, where it is still typically capable of about 10^{-10} amperes. Drift has been greatly reduced, so also has noise, particularly in the low frequency and "$1/f$" noise region. Output power has been doubled, yet the power supply drain has been reduced to about 8 ma at $\pm$ 15 vdc. Output current is rated at 2 ma at $\pm$ 10 v.

Use the P2A wherever extremely high impedance circuitry, extremely low currents, or extraordinary common mode signals must be dealt with precisely.

MODELS P65A and PP65A DIFFERENTIAL OPERATIONAL AMPLIFIERS

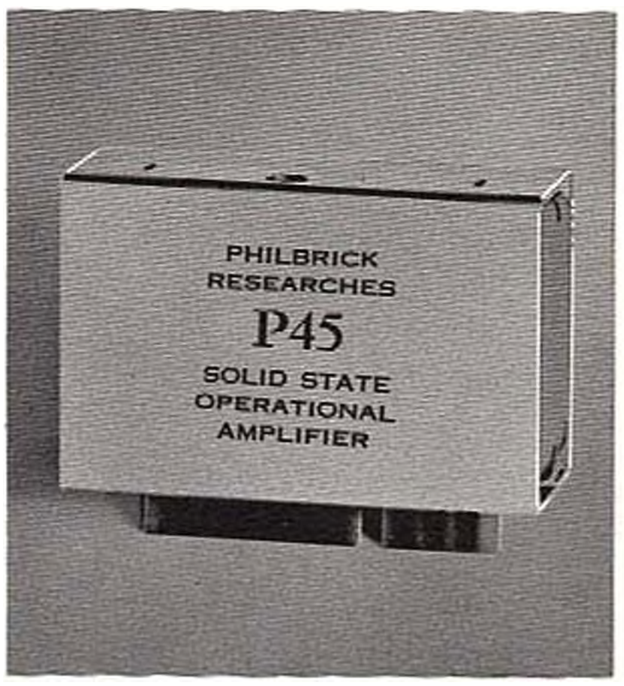


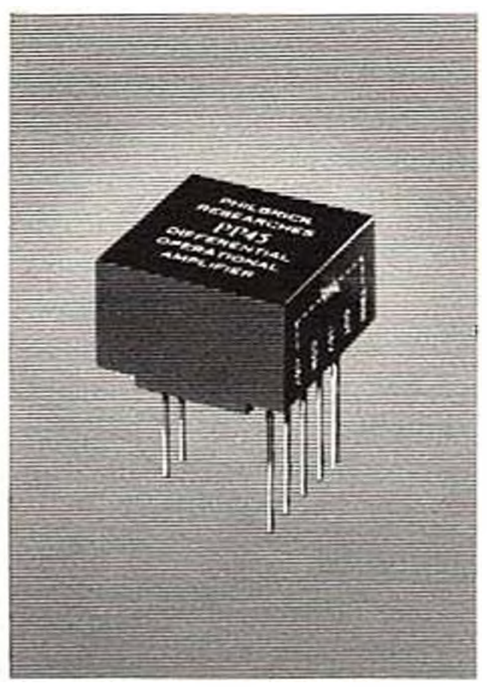
Simple, reliable, economical, the P65A is the standard workhorse of the solid-state era. Differential inputs, accessible zero balance (screwdriver) adjustment, indifference to capacitive loads, plus a sturdy edge connector plug-in arrangement combine to give it outstanding flexibility as a general purpose operational amplifier. All P style cases are 2.25 w x 1.5 h x .75 d exclusive of edge connector.

In keeping with this objective its small-signal gain-bandwidth product is over 2 megacycles; full output signal capability is over 20 kilocycles. The PP65A is a miniature version electrically identical except that there is no internal provision for trims and zero balance. A specialized version, suitable for a narrower range of applications, is available. Designated P65AH, its gain-bandwidth product is about ten times greater. All PP style cases are 1.125" square x .625" high, weigh .75 oz. installed.

Output rating of these is 2.2 ma at ±11 v; the quiescent current drain of the power supply is under 5 ma. This, plus immunity to power supply variations make them ideal for battery powered instruments. Noise is extremely low, so also is drift. Under optimum conditions, less than 30 microvolts per day drift has been demonstrated. Still more specialized versions with reduced output capability are available for battery powered applications. These, the P65Q and PP65Q feature a quiescent current drain of less than 900 microamps.

MODELS P45 and PP45 DIFFERENTIAL OPERATIONAL AMPLIFIER

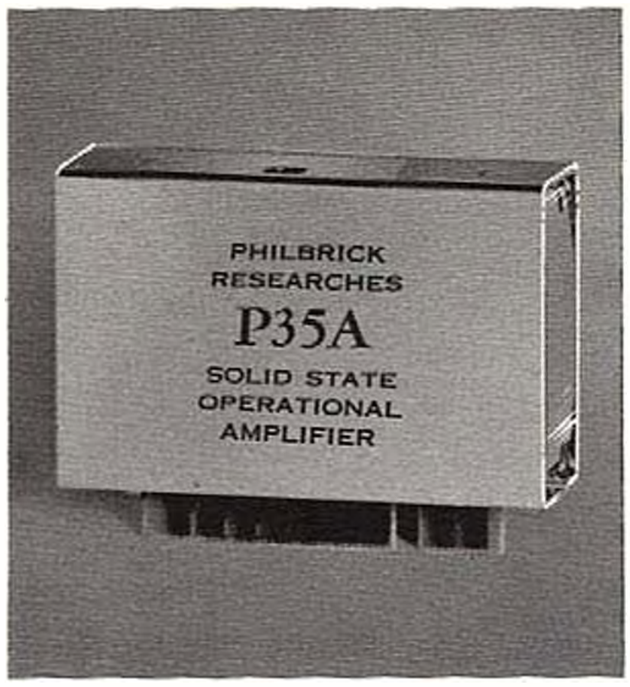


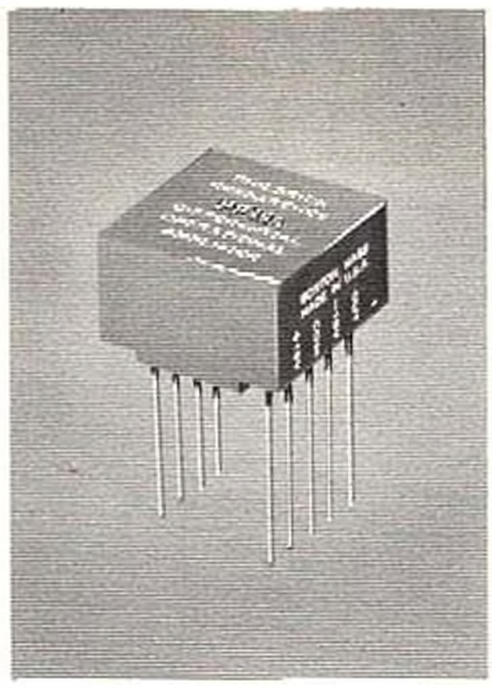


A gain-bandwidth product of 100 megacycles is featured by these little all-silicon, solid-state plug-in operational amplifiers. They are designed to operate from a ±15 volt power supply, and to provide up to 20 ma output current at ±10 v, this in spite of the extremely low quiescent current drain of 4 ma. Physical dimensions, housing, and weight are identical to those of Models P65A and PP65A, but neither has an internal adjustment in its normal form. About 30 times more bandwidth and ten times more output current capability are available.

The P45 and the PP45 make possible phenomenal speed of response in practical computing circuits, e.g., as inverters they show a small-signal rise time of 20 nanoseconds, and can also swing a 2 K load 15 volts peak-to-peak at well above 1 megacycle. Their tolerance of changes in supply voltage plus their low quiescent current drain make them ideal for battery powered instruments, particularly when large output currents are demanded occasionally.

The P45 and PP45 have full differential inputs with single ended output, giving them great flexibility in dc and low frequency circuitry. Noise is extremely low, so also is drift. Under optimum conditions, less than 30 microvolts drift per day has been demonstrated.



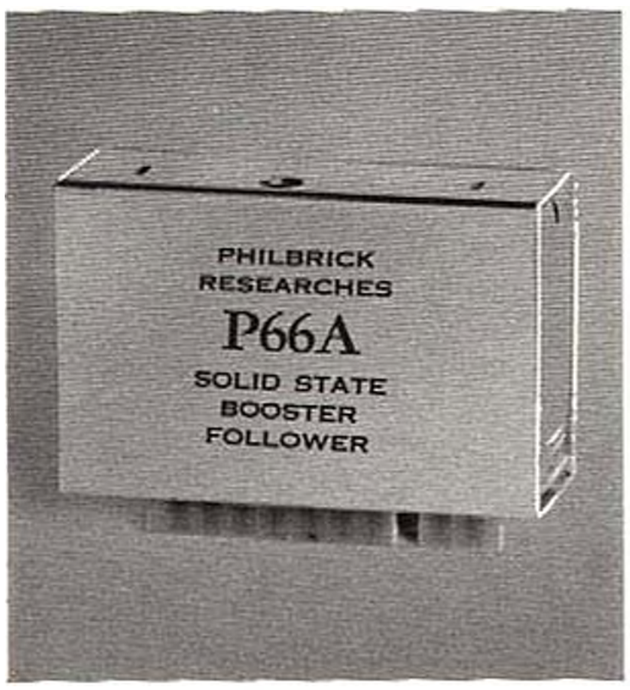


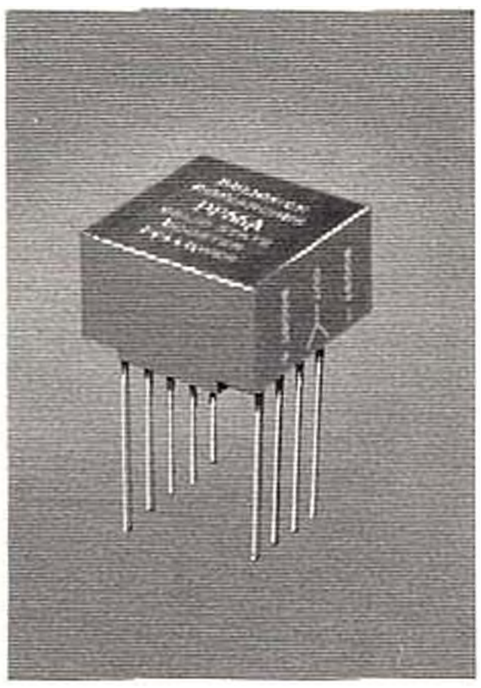
MODELS P35A and PP35A DIFFERENTIAL OPERATIONAL AMPLIFIERS

The P35A and its diminutive version, the PP35A, combine high impedance fully balanced differential inputs with an 8 megacycle gain-bandwidth product. The high input impedance and extremely low error currents are accomplished with conventional transistors. Noise, drift, and other errors are believed to be lower than for any other compact type of amplifier, particularly at elevated temperatures. Common mode errors, especially those due to input current, are extremely low, making the P35A ideally suited to full differential circuitry.

Interestingly enough, the input error currents are smallest at +85C, 6×10^{-9} amps. being typical at each input terminal. Furthermore, these error currents track each other to about $\pm 5 \times 10^{-9}$ amps. over the entire temperature range of $-25°C$ to $+85°C$, a 110°C change! Over this same range the error voltage shift is typically less than 2 millivolts. Gain exceeds 100,000; rated output current is 2 ma at ± 11 volts; a dc common mode rejection ratio of 100,000 can often be achieved in practical circuits.

Also available at lower cost are the P85A and PP85A, in these same P and PP housings. These amplifiers have similar electrical characteristics except that gain and bandwidth are reduced; so also is voltage noise, but errors due to input current are greater.



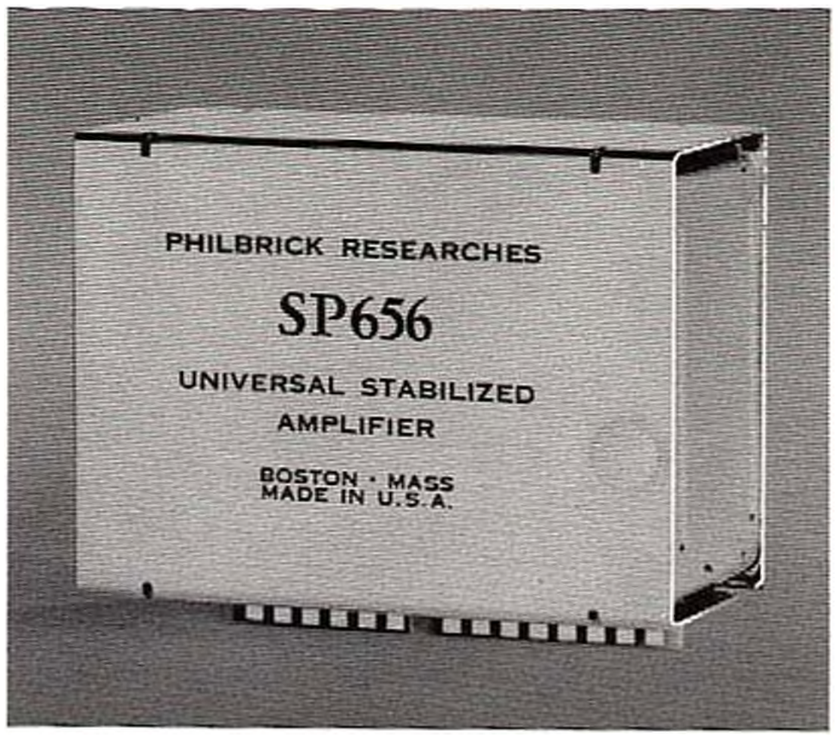


MODELS P66A and PP66A BOOSTER AMPLIFIERS

The P66A is used wherever it is necessary to boost the available output current from a P65A or similar ± 10 v amplifier up to as much as 100 ma, or to lower its apparent output impedance. Its gain is unity and so does not increase the amplifier's output voltage capability; however, a variety of other boosters are available which do, even up to ± 100 volts. Boosters do not contribute appreciable error in the amplified output signal, because they are used *inside* the feedback loop around the amplifier. Two other boosters similar in circuits and ratings to the P66A are the PP66A (in the same housing as the PP65A) and the P5 (in the same housing as the P2 amplifier).

These packaged boosters are vastly superior to ordinary emitter-followers, because they have negligible quiescent current drain; current drain is essentially that of the load current only. In contrast, operating from ± 15 vdc supplies, an ordinary emitter follower capable of delivering 100 ma at ± 10 volts output would necessarily have a quiescent current drain of well over 300 ma and a max dc drain of well over 600 ma! By comparison, even the tiny PP66A has a quiescent drain of only 1 ma and a max drain of essentially 100 ma — and that from only the one side of the dual supply dictated by the polarity of the load current. (Use these also for large capacitive loads).

MODEL SP656 CHOPPER STABILIZED OPERATIONAL AMPLIFIER

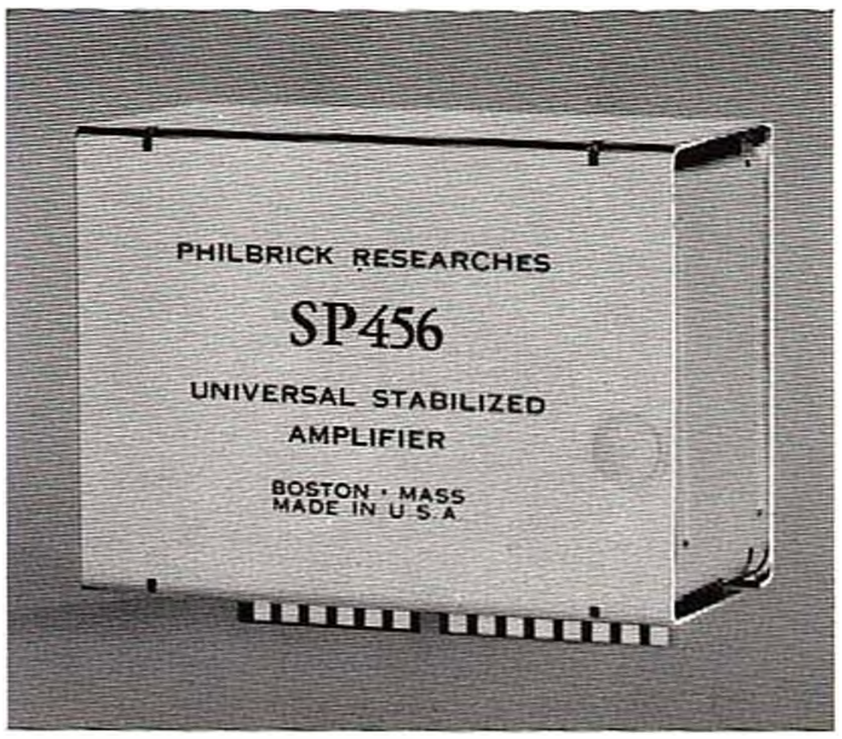


Extremely low drift and low noise are the outstanding qualities of the SP656, an all-silicon solid-state plug-in amplifier, designed to operate from plus and minus 15 vdc power supplies. Chopper stabilization keeps the long-term drift under 1 microvolt; gain-bandwidth product is over 2 megacycles; output current capability is 20 ma minimum at ±10 volts, or up to 40 ma at slightly lower output voltages. Other virtues of importance in large systems include its low dissipation, its immunity to damage from grounding the output, its rf and thermal shielding.

All power line and low frequency noise, flicker, etc., right down to "dc" drift, have been demonstrated repeatedly to be under 3 microvolts RMS, referred to the summing point; actual "dc" or long term voltage drift is less than 1 microvolt, varying generally less than 0.1 microvolt per degree C. Current drift is typically well under 10^{-12} amps. Just as in the vacuum tube era, use 1 megohm as the standard input resistor for summing, integration, etc., and obtain even better dc accuracy.

The SPR30 is an ideal individual floating power supply for the SP656. Cost is low, and it permits such circuits as a chopper stabilized follower with input resistance above a million megohms.

MODEL SP456 CHOPPER STABILIZED (WIDEBAND) OPERATIONAL AMPLIFIER

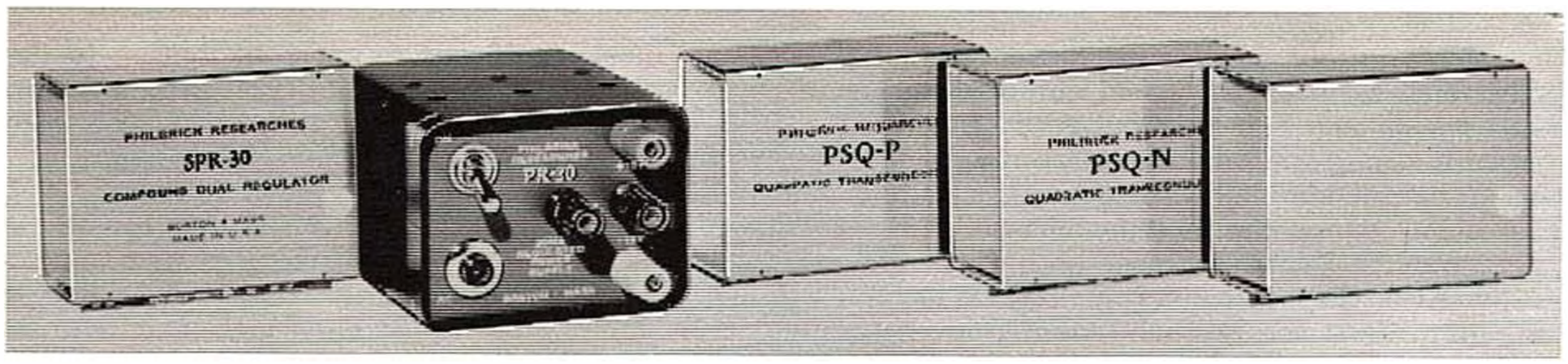


A gain-bandwidth product of 100 megacycles coupled with extremely low noise and low drift make the SP456 one of the most unusual amplifiers available in the world today. It is physically identical and electrically similar to the SP656 except for its very fast response. Long term drift at 25°C averages well under 1 microvolt; power line and lower frequency noise of less than 3 microvolts RMS has been repeatedly demonstrated. Other virtues of importance in large systems include its low dissipation, its immunity to damage from grounding the output, its rf and thermal shielding.

The SP456 is entirely at home in high impedance analog circuitry. However, stray capacitance and RF losses, even in resistors themselves, frustrate accuracy at high frequency in megohm level circuits; e.g. consider that the reactance of only 1 pf is 159,000 ohms at 1 mc. Accuracy in high frequency circuits demands the use of relatively low impedances.

Using an individual fully-floating power supply, such as the SPR30 or PR30, the SP456 can be connected as a follower of spectacular performance: apparent "dc" input resistance is well over a million megohms; large-signal output capability exceeds a megacycle!

ACCESSORY DEVICES



The availability of various accessory devices greatly simplifies the task of applying amplifiers to analog systems. For example, the SPR-30 dual 30 ma power supply is built in the standard SP plug-in package, identical to that of the SP656 and SP456 amplifiers. This precision ±15 v supply comes complete with a separate transformer. Since several amplifiers can run on one SPR-30 this arrangement makes possible an extremely neat system layout and keeps the transformer away from the input circuits. The same supply is also available as the PR-30C, complete in one slightly larger plug-in package containing the transformer. Another version, the PR-30, is designed for bench-top use and comes complete with line switch and pilot light. All versions provide a current-limiting-circuit feature and so are short-circuit proof.

A variety of other accessory devices, both active and passive, are available. As another isolated example of this classification, consider the PSQ-N and PSQ-P, which are temperature compensated non-linear circuits. These devices convert an input voltage to a current (into a summing point) proportional to the square of this input voltage, properly scaled and biased for use with operational amplifiers in the ±10 volt range. In fact, these devices are the heart of the Philbrick all-silicon multiplier, Model Q3-M1P. Still another example is an SPDT high speed electronic switch.

MODEL PR-300 PRECISION REGULATED SOLID STATE DUAL POWER SUPPLY

A strong point in Philbrick philosophy of system design has traditionally been the application of power supplies sufficiently precise to provide the system reference voltage as well as system power. When such a supply comes with its outputs precisely set to ±15 v and no adjustments provided, this becomes a great advantage to the systems builder. Current is limited to a little more than its rated value, making these supplies short-circuit proof.

The PR-300 all-silicon supply contains a regulating amplifier and internal reference capable of holding its output to better than 0.01 per cent day after day, no load to full load (300 ma), low AC line voltage to high, if temperature changes are generally less than 5°C. It will also operate satisfactorily over a temperature range from −25°C to +85°C, but over this wide range the output will typically vary ±0.1 per cent. Noise and ripple are typically under 10 parts per million.

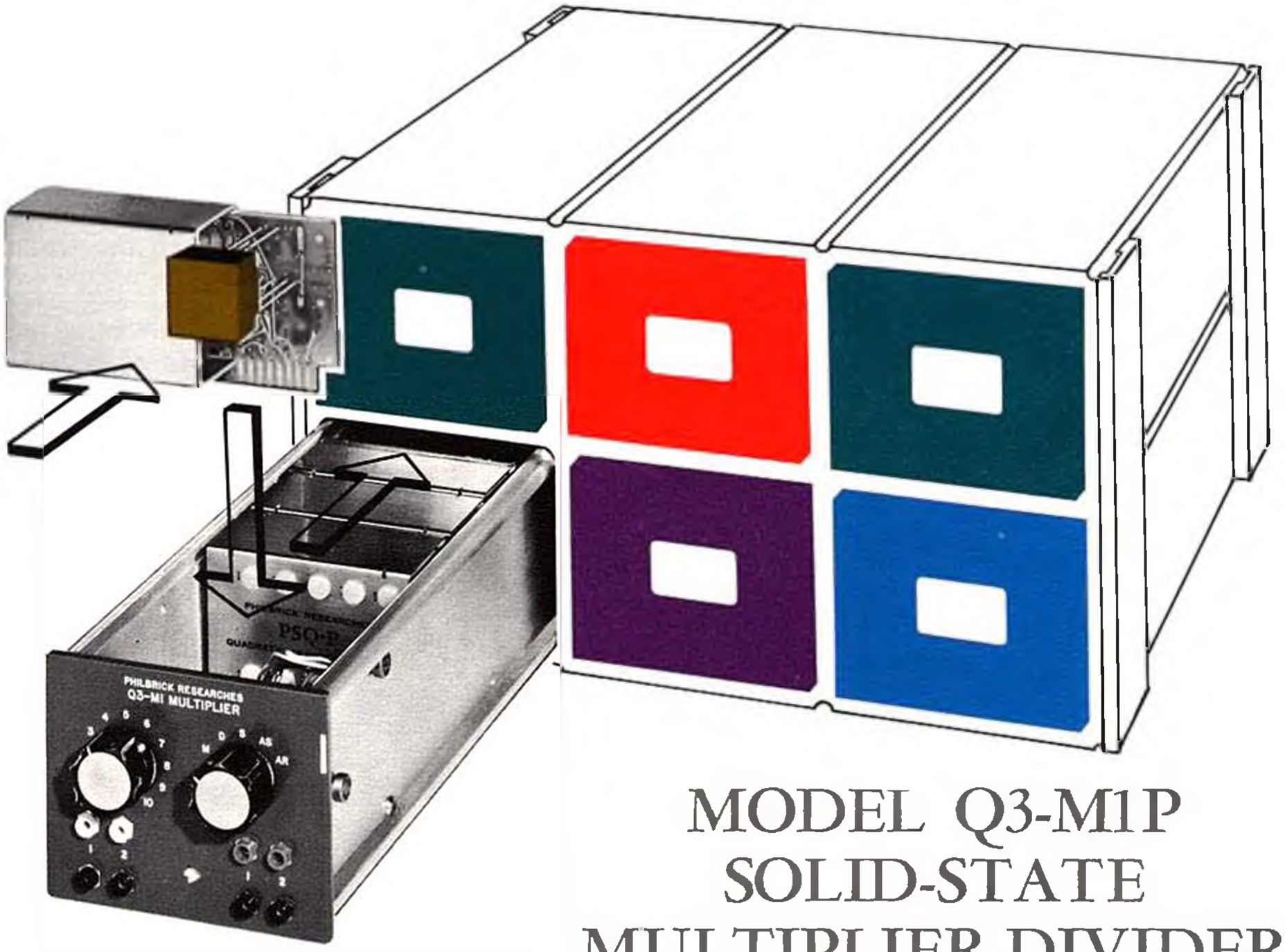
Two models are available, both all-silicon; the PR-300 is the bench model, and the PR-300C is a plug-in component designed for incorporation into the user's chassis. This latter is provided with a blue ribbon connector only and contains no pilot lights, switches or other controls.

The Q3 PACKAGING SYSTEM for ANALOG INSTRUMENTATION

This purely mechanical development has been our most significant recent contribution to the electronic art. Granting good circuit design, nothing so enhances system reliability as does mechanical design and construction. And certainly the same can be said for the flexibility. The idea is to make it strong and modular, yet through mass production keep it economical.

The outside shell of a Q3 basic module is a 13 inch length of special extruded tubing 4.2 w x 3.5 h into which the modular chassis slides on its 4 rails. These shells may be used individually or permanently joined together both vertically and horizontally to form a honeycomb of rectangular cells. Also, they will stack in locking fashion without being fastened together. If the honeycomb is 4 cells wide it can be rack mounted, even if only 1 layer high. A concealed latch locks each chassis automatically as it is inserted. Excellent thermal and electrical shielding is inherent.

Two 24-pin hermaphroditic connectors on the rear mate with two on the back plate of the shell. A number of standard front panels, modular chassis, adaptors, and accessories are available.



MODEL Q3-M1P SOLID-STATE MULTIPLIER-DIVIDER

The design of this all-silicon solid-state multiplier-divider is an example of the use of Q3 modular hardware in the packaging of systems. The Q3-M1P will multiply, divide, square, and square root, among other things. DC accuracy is of the order of 0.1%; bandwidth is well over 100kc. This 4 quadrant multiplier comprises 6 operational amplifiers, a power supply, 2 regulating amplifiers, 2 packaged non-linear subsystems, bound and limit indicator circuits, etc. Instrument systems of today may treat such a multiplier merely as a component: a "building block".

While a number of other computational Q3 modules are available, including uncommitted amplifying systems and a major power supply, these are treated separately. It is evident for example, that the SP modular packages herein described will plug nicely into the Q3 module, as many as 6 of them. Further, these standard sized SP packages include one which houses 4 of the PP style amplifiers. This gives rise to some spectacular possibilities, such as a subsystem utilizing 24 separate operational amplifiers along with their associated resistors and capacitors housed in a single Q3 module! Yet this, in turn, might constitute merely one building block.

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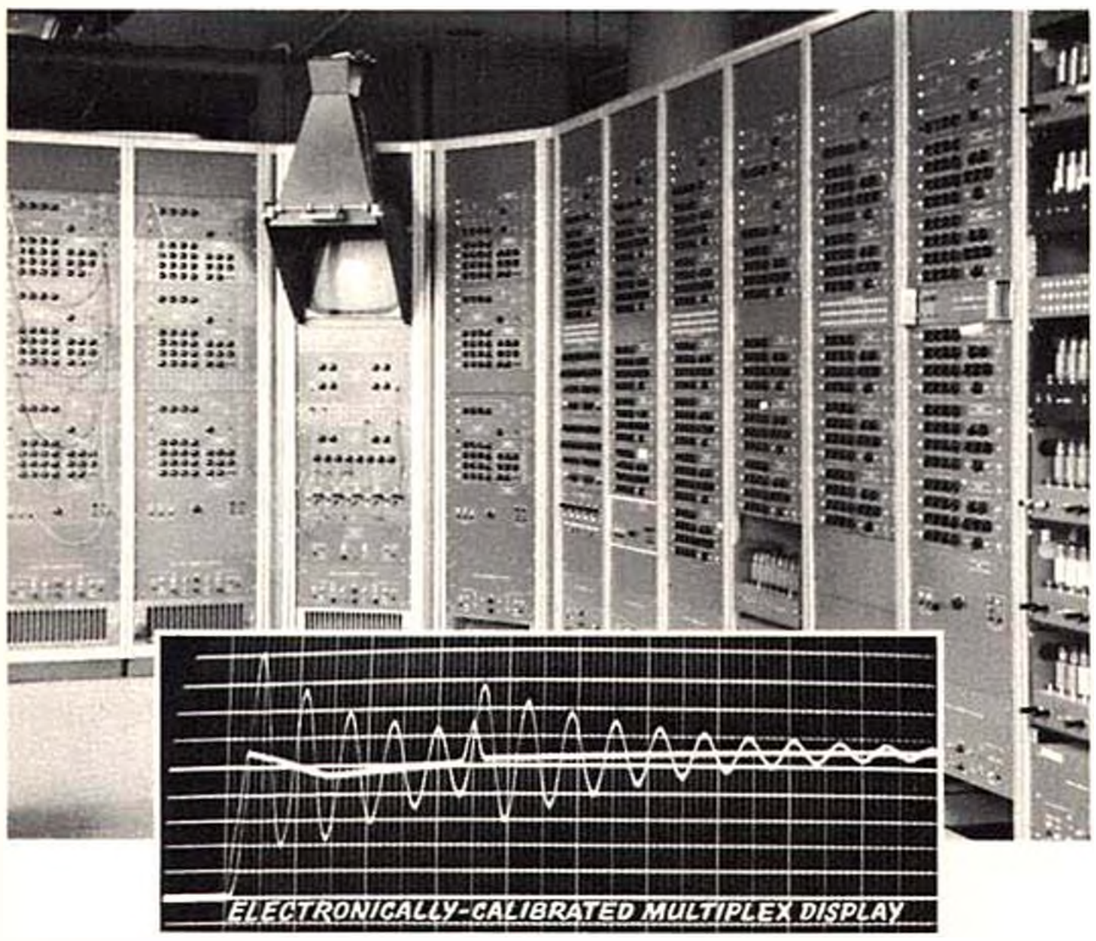
FACILITIES AND SERVICES



Our goal remains unchanged over the years: to marry operational concepts with electronic technology in pioneering the instruments and computing systems you will be using tomorrow.

Providing assistance to the user is fundamental to this goal. Toward this end we solicit and welcome the opportunity to consult with you *gratis* on circuit applications of analog components and also on the design of instruments and systems. Engineering representatives are located in most principal cities and our home office is as near as your telephone.

Consulting services at a more formal level are available at our analog computation center in Boston, greatly increasing our capability of technical assistance to the user. This well-equipped facility also serves our own engineering needs on a continuing basis.

LITERATURE

A large and increasing volume of expository data is available to customers of Philbrick Researches. Each product (and there are many more than this catalog contains) naturally has a counterpart in documentation which describes its nature and function, and which guides the user in typical applications.

Reprints from the technical journals are on hand in considerable quantity, giving details of a great variety of applications of our products and the instrumental details which these embody. Of mainly historical interest is the bound and annotated volume called A Palimpsest on the Electronic Analog Art, which includes an assortment of early papers on operational methods and on how they are applied. Reprints of more recent papers, in relevant categories, will be cheerfully supplied to any prospective user who will disclose his intentions or aspirations. Alternatively, a fairly complete list of available reprints may be readily had, offering a brief description of each paper.

The Lightning Empiricist is a house organ, published quarterly and dedicated to electronic models and allied lore. Announcements of new or improved products will be noted there by the attentive peruser, admixed with editorial matter of somewhat more general interest.

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AN ALPHABET of ANALOGICAL APPLICATIONS

A is for Amplifying, accurately and articulately, according to algebraic or analytic authority, automatically to achieve aspirations. *B* is for Balancing bridges and other networks, nonlinear as well as linear, in order to compute or test or control something. *C* is for Computing, controlling, causally reversing, closing of many categories of loops, in cosmology, communications, chemistry, et cetera. *D* is for Differentiating of variables, for example with respect to time; also dividing one by another; also dynamically transforming them. *E* is for Educating one's self or others, using electronic models of the objects in point: quick to assemble, to operate, and to alter. *F* is for Finding the finest set of design parameters for, say, a feedback system, giving maximum performance and reliability. *G* is for Generating functions in great variety, whether of time or of other variables, giving glorious graphical generality. *H* is for Hybridizing of logical and analogical apparatus, thus harmonizing the continuous and the discrete by natural procedures. *I* is for Inversion in the sense of sign-reversal, but more broadly too; also integrating; also isolation of influences; also inciting intuitions. *J* is for Judging and judicating, perhaps automatically, in the course of evaluating results against justifiable criteria. *K* is for Keeping a physical state intact or predictable, in spite of disturbances, and thus assuring some static or dynamic outcome (desirable). *L* is for Linearizing the nonlinear, if desired; conversely, for example, limiting or otherwise liberalizing the linear realm. *M* is for Modelling, measuring, and manipulating, as on the front cover, but also multiplying, memorizing, and maximizing or minimizing. *N* is for Neutralizing or nullifying of nuisances or unwanted effects in an experiment or on-line process; also normalizing. *O* is for Operating and organising systems, including self-organising ones; also optimizing by parameter search; also oscillating. *P* is for Perceiving physical states, or patterns; also predicting and prolonging desired conditions; also pedagogy on dynamical theory and practice. *Q* is for Questioning Nature, sometimes obliquely, always diplomatically, flattering her through imitation; also quickening of responses. *R* is for Realizing in the routine sense, and also in the sense of making real, as when making mathematics come to life. *S* is for Simulating or synthesizing of systems, whether already on hand or simply on the dwg. boards; also statistics and stochastics. *T* is for Testing of machines and components, as well as of brainwaves and brainstorms; also training of technologists; also trying out of tolerances. *U* is for Unilateralizing, or restricting causality to a single direction when this is required, between subsystems; also, unlearning the untrue. *V* is for Varying experimental conditions automatically, according to space-filling excursions, regular or random; also vibrating. *W* is for Weighting of averages, generalizing the simple summation of functions of time; also waveform development and analysis. *X* is for X-ray instrumentation in experimental physics, as for the velocity regulator of the Mössbauer apparatus. *Y* is for Yield-estimation for planned or existing production processes, in which intricate or implicit inter-relationships obtain. *Z* is for Zero-seeking, both in the sense of nulling and in the finding of the roots of a function. & itself is for all additional applications of analogical artifices.