THE LIGHTNING EMPIRICIST

Advocating electronic models, at least until livelier instrumentalities emerge

Volume 12, Number 2 April 1, 1964

CUSTOMERS, APPLICATIONS & REPRINTS

Editorial

It has been remarked of the computing industry generally that one of its sources of strength lies in its having attracted "from an amazing variety of disciplines a wild assortment of bright, interesting, creative people". Count us as confirming this, but also as qualifying it.

This power, namely that of the interdisciplinary collaboration and competition which infuses this business, has two interacting manifestations. One is in the technology of computing devices as such; the other is in the application of these devices and techniques to a very broad scope of engineering and scientific studies. The needs in fact tend to precede the solutions, which begin in a few fields and diffuse to others: with feedback and turbulence providing for evolution.

Now from our standpoint, admittedly prejudicial, we find the apparatus and practitioners of what T. C. Fry calls *reckoning* to be of somewhat less interest. This predominantly numerical pursuit, important for example in the daily life of Business, is however in good hands. Our concern is with model building or *simulation,* dynamic measurement plus manipulation, feedback controls, and analog data processing. Decision-making implements are indeed included, although we consider them a branch of continuous instrumentalities.

Our analogical and instrumental products find their way to an especially desirable class of users. This is because most such products are applied by our customers in the assembly of special-purpose equipment having great diversity of nature and applicability. Our point is that the type of engineers and experimentalists who are capable of thus exploiting feedback (for instance) are a lot more fun to deal with than are those who merely can learn how to run a calculating machine* from an instruction manual. Furthermore it is from those former fellows that the doctrines and preferences tend to flow out to the rest of society.

Thus not only are we internally, as a corporate group, prolific producers of literature, on products, techniques and philosophy, but externally the periodical literature has increasingly described applications of our wares in new and useful embodiments. One could not ask for better advertising; certainly it is superior to the conventional, and more costly, magazine-page variety. Of course we do buy advertising space, and exhibit at expositions. Direct mailing to a very large list is also permitted by our budget, especially whenever a new device or method is afoot.

With a project in progress to modernize and augment our proprietary literature, we wish to devote this issue of The Lightning Empiricist to a review of what is currently available to users in the way of documentary data. In particular, the following pages contain a list of reprints from the technical literature, in which an assortment of experts show how they have applied our products. In each case the formalities of copyrights and so on have been scrupulously observed. If you have a problem of instrumentation, possibly someone has already treated a parallel case and has written it up.

Conversely, if you have broken through in a new and useful endeavor with our apparatus, and your application is not under wraps, perhaps you could provide an article for this journal. In either case, we maintain a knowledgeable and sympathetic staff which is pleased to share your dilemmas or enthusiasms.

*Philbrick also makes complete machines, has for decades, and shall into the foreseeable future.

Philbrick Literature, Old & New

Roughly ten years ago, when we were one half as old and one tenth as large as we are now, our own literature was prophetic but rudimentary. It survives only in the museum or nostalgia category. Correspondingly, the analog literature of the technical periodicals was relatively sparse. In 1955 there was compiled, under our stewardship, *A Palimpsest on the Electronic Analog Art,* arranged and annotated by Prof. H. M. Paynter of M.I.T. This bound volume, compiled largely of published papers of pioneers, was widely sold and distributed by us. It has been used as a textbook and a reference by institutions and laboratories everywhere.

Since then the literature of the subject has grown explosively. Today's Palimpsest would be ten inches thick. There are furthermore ten good books on the analog art. Even handbooks recognize the fundamental nature of analog instrumentation. Do you recall the conventional technical handbooks? They began with basic mathematics, then formulas: things considered applicable to all of technology. Look at the new Second Edition of the American Institute of Physics Handbook, for a lump-in-the-throat of vindication. The first section, following a bibliography, is on Analog Computing in Physics Research. Moreover the first cut shows a venerated Philbrick K2 Plug-in Operational Amplifier. How times have changed!

Look now from Physics to Chemistry. Listed subsequently herein, among the available reprints, is an Operational Amplifiers Symposium held last year by the American Chemical Society. This charming item consists of ten papers from the November issue of Analytical Chemistry. All but one of these papers show applications of our own computing products.

Locally, our own Applications Manual for Philbrick Computing Amplifiers is in its tenth printing. Although a major revision and expansion is in process and overdue, this pamphlet is still relevant and applicable to the latest equipment.

Each of our products, of course, has associated documentation intended to advise the user, in varying degrees of detail and refinement. Here much of the philosophy and reconditeness is offered for the operational intentions of the discriminating purchaser.

There is also naturally this journal itself, issued currently every three months. We decline the opportunity further to describe it here. Another publication, not regularly issued and much less formal, which we distribute, is that called Application Briefs. Excluding earlier issues now considered obsolete, and future issues which are hard to predict even with an analog extrapolator, the following Briefs are available on request:

Application Brief D4 — 1 February, 1961
Closed loop stability of operational amplifiers
The precepts and procedures whereby in marginal or difficult cases the cooperation between an amplifier and its external network may be freed from the dangers of oscillation.

Application Brief D5 — 3 April, 1963
P65 as amplifier with high input impedance
Techniques applicable for this or similar direct-coupled operational amplifiers to afford positive gain in unloading service with high performance. In spite of the title, low impedance applications are viable also: even to thermocouples!

Application Brief D6 — 9 May, 1963
Operational amplifier as direct-reading precision resistance comparator
This amounts to the implementation, or indeed the automation, of a DC bridge. Actually, AC operation is equally practical. Accuracies on the order of one part per million are feasible.

Application Brief D7 — 17 May, 1963
Operational amplifier as constant current source
Showing how extremely accurate currents may be established in loads having a "virtual" ground. These currents may also follow a variable program. Compare the 1 January, 1964 issue of The Lightning Empiricist.

Application Brief D8 — 15 August, 1963
"Single-ended" inverting amplifiers
Although the most accurate stabilized amplifiers are normally single-ended, they are not ruled out as followers or current-pumps to grounded loads. This Brief shows how a floated power supply enables such performance.

Application Brief D9 — 3 September, 1963
P65A's used to form a low-noise differential instrument amplifier
How three such amplifiers may afford a symmetrical pair of inputs, with negligible loading of sources below 10 kilohms, and with 80 db common mode rejection; also how to adjust the dynamic response for biophysical and other uses.

THE LIGHTNING EMPIRICIST

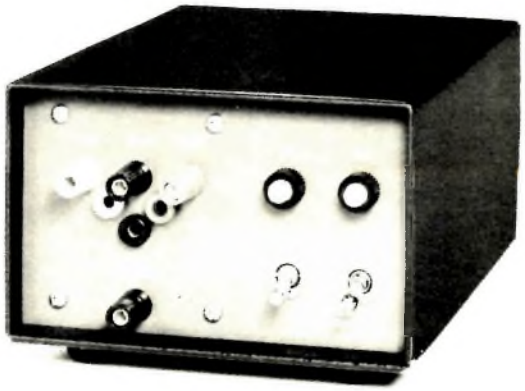
The LIGHTNING EMPIRICIST is published at quarterly intervals by Philbrick Researches, Inc., at 127 Clarendon Street, Boston, Massachusetts 02116 and printed in the U.S.A. Comments and contributions are always welcome and should be directed to the Editor, LIGHTNING EMPIRICIST.

Analogical Quotation

We have commented recently on the use of models by physicists, and chemists come in for praise elsewhere in these very pages. To pass from chemistry to organic chemistry, and from there to quantum chemistry, we should like to cite Streitweiser, as quoted by Prof. Louis P. Hammet; interviewed in the January ussue of *International Science and Technology*.

"For organic chemists, the importance of quantum mechanics lies not at all in exact calculations from first principles, but rather in providing heuristic concepts and insights in establishing qualitative and quantitative semi-empirical data and, especially, in facilitating the application of what has long been the organic chemists most important tool: reasoning by analogy".

We are grateful for this choice bit of Lightning Empiricism.



MODEL PR-300
PRECISION REGULATED SOLID STATE
DUAL POWER SUPPLY

The importance of the philosophy behind the design of the PR-300 demands extension of a previous article (Vol. 11, No. 4). A cardinal point is the advantage to the systems builder of using one supply sufficiently precise to provide the system reference voltage as well as system power, preset at the factory with no provision for adjustments since none are needed.

With this in mind the PR-300, a ± 15 v all-silicon supply, contains a regulating amplifier and internal reference capable of holding its output to better than 0.01% 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 from -25°C to $+85$°C, but over this wide range the output will typically vary $\pm 0.1\%$.

Two models are available, both all-silicon. The PR-300 is the bench model, and the PR-300C is a plug-in unit designed for fastening to the user's chassis as a component. This latter is provided with a blue ribbon connector only, and contains no switches, pilot lights, or other controls. Before the supply is shipped, its voltage is trimmed to 15 v $\pm 0.1\%$ and no external trims or adjustments are provided. Isolated windings provide ac outputs for driving choppers, one for 115 vac and one for 6.3 vac.

In case of sustained overload or short circuit, output current is limited to a little over its 300 ma rating, and the output voltage collapses. When the fault is removed, the output voltage returns to 15 volts.

COMPENDIUM OF REPRINTS CURRENTLY AVAILABLE

from Philbrick Researches, Inc., Application Department

Reprint No. 1 — June, 1957
ISA Journal

Dynamic analysis of heat exchanger control, by B. D. Hainsworth, V. V. Tivy, and H. M. Paynter.

Simulation of plant dynamics for a shell-and-tube exchanger, and of its control with a proportional-derivative-integral controller. Includes the effect of thermal and pneumatic delays, and of the parametric influence of load change. Older Philbrick apparatus was employed.

Reprint No. 2 — September, 1958
Communications and Electronics (AIEE)

Matrix programming of electronic analog computers, by R. E. Horn and P. M. Honnell.

Arrangement of an analog machine into a matrix pattern, giving examples, and emphasizing the conceptual advantages for differential equations, which are, as indicated later by Honnell, not limited to linear examples. Reprint includes discussions by Pipes, Rideout, Paynter and Sheingold.

Reprint No. 3 — October, 1958
Transactions of the ASME

Contributions to the stability theory of systems of surge tanks, by C. Jaeger.

A study by differential equations of the two surge tank problem for hydro stations. Includes a discussion by Prof. H. M. Paynter which introduces a valid simplification and illustrates the use of analog computation. Analog computations would actually have enabled the handling of complexities greater than originally assumed.

Reprint No. 5 — 1960
Regelungstechnik

Analogy between stochastic processes and monotone dynamic systems, by H. M. Paynter.

Paper presented by Dr. Paynter at the 1960 International Control Conference in Moscow. The analogy is mathematically and physically rigorous, showing in particular how a large class of systems, including distributed cases, may be contained within a two-parameter classification. Internationally flavored discussion, and closure, are included.

Reprint No. 6 — 29 December, 1958
AAAS Session on Gen. System Theory

Ordering and selection processes and ultra-reliable systems, by H. M. Paynter.

This is an esoteric item, having no text, but the dozen figures are partly self-explanatory. Beginning with Philbrick's selection concepts (see Palimpsest) a comparison with binary logic is delineated, and the broader ideas of *stratification* are explained, along with the *middle-of-the-road* analog decision operator.

Reprint No. 8 — July, 1959
Journal of the Boston
Society of Civil Engineers

Hydraulics by *analog*, Part 1, by H. M. Paynter.

Described an electronic model of a pumping plant, the latter involving a centrifugal pump with its motor, an air chamber, a conduit, and a stand pipe, all independently simulated. Nonlinear characteristics are represented — even the pump's check valve. High speed analog embodiment is shown, as applied to storm drainage and sewage disposal in Metropolitan Boston, giving local color.

Reprint No. 12 — November, 1957
Transactions of the ASME

Computer representations of engineering systems involving fluid transients, by F. D. Ezekiel and H. M. Paynter.

A treatise on the lumped representation of hydraulic equipment, mostly for analog computation, and illustrating an unfamiliar but powerful vectorial approach. Pairs of variables are considered together (as *effort* and *flux*), the products of which are *power*. Block diagrams with generalized symbols are employed, yet the treatment is specific and clear.

Reprint No. 11 — August, 1958
Transactions of IRE,
Nuclear Science
Professional Grp.: New York

Fast time scale simulation of a reactor control system, by G. Friedensohn and D. H. Sheingold.

Simulation on a 100:1 time scale of the reactor kinetics and servo system. Represented are six delayed neutron groups, nonlinear rod effectiveness, 4-quadrant torque-speed characteristics, rod limiting, and temperature coefficient of reactivity. Results include transition from manual to automatic control during start-up.

Reprint No. 13 — 7 September, 1955
G. E. Computer Seminar, New York City

Modern analog computing machines, their precepts and purposes, by G. A. Philbrick.

This talk by our founder is earthy and subjective. Note the date before considering the first adjective of the title too seriously. One or

two passages have some humorous value, especially in the light of subsequent developments. The arguments are relatively simple and non-mathematical, the (captive) audience having been largely made up of engineering managers.

Reprint No. 14 — November, 1957
Review of Scientific Instruments

New integrating circuit and electrical analog for transient diffusion and flow, by J. R. MacDonald.

Part of a Texas Instruments study supported by the U. S. Public Health Service. An operational circuit is discussed for the simulation of transient diffusion and flow of material between two storage spaces or volumes. The method is applicable in the general case when flows in the two directions are unequal. Non-linear behavior and time-varying parameters are admissible in the method.

Reprint No. 16 — December, 1958
Automatic Control

Missile rate simulator provides sinusoidal motion for guidance systems, by J. K. Nelson.

This article describes an approach to the simulative evaluation, at a subsystem level, of motion sensing elements as used in large missiles. Part of the apparatus resembles the actual operating equipment, as a *direct* model. The remainder is simulated operationally.

Reprint No. 17 — April, 1959
Review of Scientific Instruments

Recording optical pyrometer, by N. A. Blum.

A single operational amplifier serves in an instrument for measuring brightness temperature (at 0.65 mu) in the range from 1300°C to above 3000°C, with a lag of a few milliseconds. Reliable to ±20°C, intended for electric arc plasma jet studies, it reduces hazard of standard optical pyrometers in measuring transient fluctuations.

Reprint No. 18 — 16 January, 1958
Joint IRE-PGED Meeting, New York City

Analog computor techniques applied to industrial instrumentation and control, by B. Seddon.

Notes on operational amplifiers, covering basic usages, complementing the Philbrick Application Manual for Computing Amplifiers. Covers internal design considerations, classes of noise and pickup, special problems with chopper stabilization, integrator and differentiator considerations, and adjustable laboratory references.

Reprint No. 20 — April, 1959
Analytical Chemistry

Electronic controlled-potential coulometric titrator, by M. T. Kelley, H. C. Jones, and D. J. Fisher.

An Oak Ridge National Laboratory study on instrumenting redox titration at controlled potential. *Differential* amplifiers are applied, along with an operational integrator, so that coulombs are read out in terms of voltage, bringing Faraday's law to life either manually or automatically.

Reprint No. 21 — Date missing
Electronic Design

Analog computer reference supply, by C. E. Foiles, J. P. Hartmann, and H. Koerner.

This is a one-page job showing a simple but effective way to get plus and minus 100 volts at minimum cost. From the University of Arizona, where Prof. G. A. Korn maintains a Mecca for analog computation.

Reprint No. 22 — May, 1959
Review of Scientific Instruments

Use of operational amplifiers in precision current regulators; & use of operational amplifiers in accelerator beam current control, by K. Eklund.

Two papers, showing simplifications in design afforded by such means. In the first, these little amplifiers drive 15 power tubes supplying up to 3 amperes to the field winding *of a generator*, which in turn supplies 200 KW to a nuclear spectrometer. In the second an operational difference amplifier is used to detect beam position and consequently to control same in a Van de Graaff generator.

Reprint No. 23 — 19 December, 1957
Private Communication

Stabilized follower amplifier, by D. Deford.

Prof. Deford, at Northwestern, early showed us how a single-ended chopper-stabilized amplifier may be applied as though, in some respects, it were a differential amplifier. The gain in this case is unity; input impedance is over 10 to the 10th ohms.

Reprint No. 24 — 7 September, 1957
ISA Computer Clinic, Cleveland, Ohio

A report to engineers and management, by staff of Philbrick Researches.

Built around a demonstration of our analog equipment, these are essentially notes on a sample system of which study is enabled by a repetitive analog. The system is a typical temperature-controlled plant, along with the necessary controls. Optimization and the evils of criticality are illustrated.

Reprint No. 25 — September, 1959
Analytical Chemistry

Controlled-potential and derivative polarograph, by M. T. Kelley, D. J. Fisher, and H. C. Jones.

September, 1960
Analytical Chemistry

Controlled-potential polarographic polarizing unit with electronic scan and linear residual current compensation, by the same authors.

The two papers are bound together in the reprint. In the first, regular and derivative polarograms are developed and presented, illustrating the advantages of controlled-potential over conventional polarography. Special testing and filtering techniques are described. The second paper describes an electronic scanning circuit having superior performance to that of the conventional motor driven potentiometer scanner. A Czechoslovakian reference, on a current compensation technique, lends an exotic note in this paper.

Reprint No. 26 — October, 1959
Science

Respiratory carbon dioxide response curve computer, by J. W. Bellville and J. C. Seed.

This machine plots alveolar ventilation, in volume per unit time, against alveolar per cent carbon dioxide. Details of the apparatus and its operation are given, involving analog equipment plus a rapid gas analyzer and a pneumotachograph. More precise response curves are observed than heretofore. See also Reprint No. 41.

Reprint No. 27 — 5 April, 1960
ISA Symposium,
Computers in the Process Industry

Analog methods, by B. Seddon.

A development of standard computing operations, starting with the operational amplifier itself. Alternative viewpoints are given, and more detail than is usual on noise and error. Linear and nonlinear mathematical operations, and sampling, are included.

Reprint No. 28 — June, 1960
IRE Transactions
on Electronic Computers

A precision amplitude-distribution amplifier, by W. F. Caldwell, G. A. Korn, V. R. Latorre, and G. R. Peterson.

Describes a system designed for the study of random processes in conjunction with analog computing equipment, and of compatible accuracy. Pulses from a "slicer" gate a counter, producing a digital readout of the estimated first-order probability density of the input signal.

Reprint No. 29 — 6 November, 1956
Electronics

Subaudio tunable amplifier, by J. M. Reece.

A Naval Research Laboratory development of a narrow-band such amplifier, for frequencies from 0.5 to 100cps. A twin-tee feedback circuit is involved, and one operational amplifier. The arrangement picks out single frequency content from random inputs. Future possibilities are outlined. One page.

Reprint No. 30 — September, 1960
Review of Scientific Instruments

Vacuum tube electrometers using operational amplifiers, by G. F. Vanderschmidt.

Operational amplifiers are shown to save time in design, construction, and maintenance over orthodox electrometers. Offered as ideal for built-in such instruments with special characteristics. Two general types are illustrated.

Reprint No. 31 — January, 1961
Proceedings of the IRE

A new active-passive network simulator for transient field problems, by W. J. Karplus.

An intimately hybridized form of computation, derived from a method of the late G. Liebmann, whereby the space and time dimensions are both made discrete, but the dependent variables are continuous. No capacitors are employed, but storage is introduced by potentiometer settings. The concept of negative resistance is introduced.

Reprint No. 32 — March, 1960
Review of Scientific Instruments

High precision large current regulator, by K. C. Brog and F. J. Milford.

Applied by Case Institute physicists for magnet currents to 50 amperes, as measured by 40 milliohms. Series regulator is solid-state, as the control amplifiers could indeed also be. Drifts in field at 5000 gauss were 0.008 gauss per hour.

Reprint No. 33 — April, 1961
Analytical Chemistry

Second harmonic alternating current polarography with a reversible electrode process, by D. E. Smith and W. H. Reinmuth.

The AC method simplifies instrument problems, but DC operational amplifiers are still applicable. Frequencies used were from 19.2 to 77 cps. It is argued that the higher harmonics are more sensitive to variations in the solution kinetics.

Reprint No. 34 — August, 1961
Review of Scientific Instruments

Electronic determination of the I, G, and I/G parameters of a tunnel diode, by C. R. Gneiting.

A Johns Hopkins Radiation Laboratory study. Aside from the tunnel diode interest, this paper illustrates a number of operational testing techniques, including generation of a linearly swept independent variable, division of one variable by another, and cross plotting. Nine stabilized amplifiers are used, with no attempt made to reduce this number.

Reprint No. 35 — October, 1961
Research/Development

Electronic analog instruments as tools of research and development, by G. A. Philbrick.

This is a somewhat philosophical dissertation on the controversies and concepts revolving about analog instruments and their applications. Operational amplifiers are related to other apparatus as found in feedback measurements, computations, and manipulations. Characteristically, the first person singular occurs; but the tone is modest.

Reprint No. 36 — September, 1961
Electronics

Precision analog memory has extended frequency response, by T. A. Brubaker.

This is an account in detail of a sampling and storage device from Prof. Korn's stamping ground at the University of Arizona. It can track a 30 volt sine wave with less than 2 degrees phase shift at 20 Kcps, and holds within 20 millivolts for 100 milliseconds.

Reprint No. 37 — August, 1960
Electroencephalography and Clinical Neurophysiology Journal

A new instrument for the summation of evoked responses from the nervous system, by B. S. Rosner, T. Allison, E. Swanson, and W. R. Goff.

Averaging of repetitive transients by means of tape-loop and analog circuitry. Up to 125 neuroelectric responses may be evaluated. Frequency modulation to 1000 cps is possible with a 27 Kcps carrier frequency.

Reprint No. 38 — October, 1961
Analytical Chemistry

Incremental approach to derivative polarography by C. Auerbach, H. L. Finston, G. Kissell, and J. Glickstein.

This paper describes a new and relatively simple technique involving an approximation to the derivative of an instantaneous voltage-current curve, by automatic sequencing. Simultaneous or separate readouts of current increments and the currents themselves are afforded.

Stationary electrode polarography with a staircase voltage sweep.

A second paper, related incidentally to the above and bound as one reprint therewith. In this case, presentation is on a CRO screen, the result being called a "voltammogram". Comparison is made to linear sweep methods.

Reprint No. 39 — Date missing
Private Report

A particular application of FM tape used with an analogue computer, by D. J. Cholley.

This is a Hercules Powder Company document, offered by ourselves through their kindness. Recordings being made of transducer deflections during rocket firings, the actual thrust as a time function was computed by an analog assemblage which involved a simulation of the dynamics of the rocket plus the mechanical testing structure.

Reprint No. 40 — January, 1963
IEEE Conference Paper

Capabilities of some nonlinear instrument circuits for low level transients, by B. Seddon.

Beginning with operational amplifier fundamentals, this paper passes to an exposition on *comparators*, their circuitry and philosophy. Feedback networks for comparators are treated, and the benefits of bounding and hysteresis. Based on detailed properties of diodes, some practical design criteria are finally developed.

Reprint No. 41 — May, 1962
Review of Scientific Instruments

Analog computation of respiratory response curve, by T. W. Murphy and R. Crane.

Standard chopper-stabilized amplifiers and associated instrumentation are applied in a study of the normal human ventilatory response to increasing concentrations of carbon dioxide. Concern arises owing to the latter as a toxic side effect of analgesic therapy. Compare Reprint No. 26.

Reprint No. 42 — November, 1962
Journal of Chemical Education

Instrumentation based on operational amplifiers, parts I and II, by C. N. Reilley

Treatment beginning with fundamentals of feedback, and proceeding to chemical laboratory applications, which include conductivity measurements, photometric circuits, control of electrolytic circuits, and mathematical operations. Seond part includes further mathematical modelling and data processing, chemical applications thereof, and practical advice on equipment itself.

Reprint No. 43 — November, 1963
Analytical Chemistry

Operational amplifiers symposium.

Sixty-three pages of papers given under the auspices of the Division of Analytical Chemistry, California, April, 1963. Ten papers in all, and twenty-six authors.

Generalized circuits for electroanalytical instrumentation, by W. M. Schwarz and I. Shain.

A classification of operational feedback circuits intended as guidance in the choice of configurations for particular applications. Concepts of *potentiostatic* and *galvanostatic* structures are developed and explained. Circuits with one amplifier, and those with more than one, are considered.

A multipurpose operational amplifier instrument for electroanalytical studies, by W. L. Underkofler and I. Shain.

This paper extends the previous one in part, giving practical data on a laboratory device applicable to polarography, stationary-electrode polarography, several kinds of electrolysis, voltammetry, coulometry and chronopotentiometry. Step functions and cyclic triangular waves are applied.

Power of time and exponential current chronopotentiometry, by R. W. Murray.

Operational instrumentation for generating currents which vary as a power of time or exponentially with time. Advance electrode potential

control is involved. Theory and application is offered for diffusion processes in single and multiple component systems. Experiment data are given for thallium and oxygen reduction.

A multipurpose electrochemical instrument for control of potential or current, by G. Lauer, H. Schlein, and R. A. Osteryoung.

This describes a system for current and potential control, with operational amplifiers, in electrochemical studies. Switching circuits are described for voltage detection, affording measurements between fixed levels.

Electroanalytical controlled-potential instrumentation, by G. L. Booman and W. B. Holbrook.

This relatively long and detailed paper gives principles of feedback control, as applied in terms of operational amplifiers to the construction of coulometric equipment. Special cell designs are described, and their electrodynamic properties are treated.

A digital readout device for analog integrators, by E. C. Toren, Jr. and C. P. Driscoll.

Describes circuitry for counting the full excursions of operational integrators, and resetting them. Accuracies to 0.1 per cent are attained, and programming is possible to read equivalents directly.

AC polarography employing operational amplifier instrumentation, by D. E. Smith.

Subtitle is: Evaluation of instrument performance and application to some new AC polarographic techniques. Stable oscillators and tuned amplifiers are used, with accurate measurement of fundamental-harmonic current amplitudes and phase angles. Trace analysis, and possible improvements, are discussed.

A practical instrument synthesizer, by C. F. Morrison.

Describes a generalized analog device on which 40 analytical techniques have been tested. Examples given are: an automatic bimodal potentiometric titrator, and a recording linear conductance bridge. Synthesizer serves also as a design prototype for specific instruments.

The Heath analog computer as a versatile analytical tool, by G. W. Ewing and T. H. Brayden, Jr.

The purpose of this paper is primarily instructional, where 1 per cent precision is adequate. Applications to conductometry, polarography, and colorimetry are described.

Instrumentation for cyclic and step-function voltammetry using operational amplifier switching modules, by R. P. Buck and R. W. Eldridge.

Here amplifiers serve as control units for potentiostats and amperostats. Multiple sweeps are featured as extending the usefulness of voltammetry. Design details of generators, voltage references, and comparators are given.

Reprint No. 44 — October, 1963
ISA Journal

Solid state pH meter, by F. R. Zimmerli.

Attacks the problem encountered in process stream measurements, where high resistance must be maintained between a reference probe and the glass electrode sample probe. The application of our high input impedance solid state P2 amplifier is described, to on-line as well as to laboratory equipment.

Reprint No. 45 — March, 1963
Proprietary Document

Operational amplifier techniques in process control, by P. D. Hansen.

A collection of figures, largely self-explanatory, prepared for lectures by Dr. Hansen, and considered useful separately. Input and feedback precepts are given for convenient analysis, then typical applications to measurement, manipulation, and control.

Reprint No. 46 — December, 1963
Review of Scientific Instruments

Multiplication and logarithmic conversion by operational amplifier-transistor circuits, by W. L. Patterson.

The advantages of a transistor over a diode are discussed as a passive circuit element to be employed with operational amplifiers in the production of exponential and logarithmic characteristics. A multiplier based on the direct and inverse logarithmic conversion is described. A paper on the same subject, and apparently independent, was presented at the 1963 Solid State Circuits Conference by J. F. Gibbons and H. S. Horn of Stanford University Medical Center. It was entitled "A circuit with logarithmic transfer response over 9 decades", and we do not as yet have it available as a reprint.

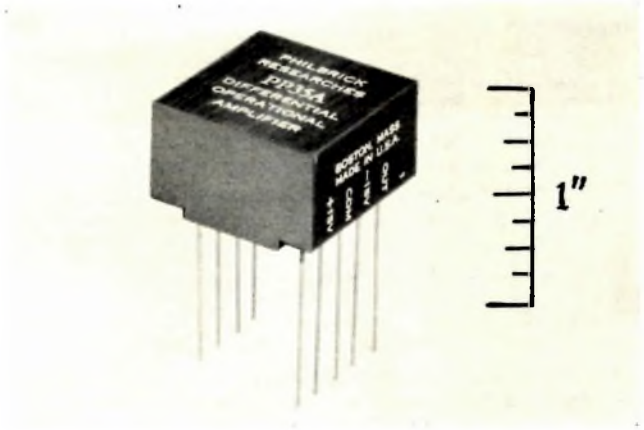
Reprint No. 47 — January, 1964
ISA Transactions

Automatic digital setup and scaling of analog computers, by H. M. Paynter and J. Suez.

An MIT study, partly supported by us, in which it is shown how the choice of transformed parameters in an analog machine may be automatically accomplished, for optimum resolution, etc., by a digital facility. The question of why not an entirely digital solution is discussed and answered.

Note on Grouping of Reprints

The numbering of the above reprints *is roughly* chronological. Groups of papers having some cohesive relationship may be cited as follows: General and introductory, Nos. 13, 18, 27, and 35; Extended but conceptually related, Nos. 5, 6, and 47; Applications to automatic controls, Nos. 1, 11, 39, and 45; Applications to medicine, Nos. 26 and 41; Applications to matrices and networks, Nos. 2 and 31; Chemical and biological instrumentation, Nos. 20, 25, 33, 37, 38, 42, 43 and 44; Specific circuital techniques, Nos. 17, 21, 23, 28, 29, 31, 36, 40 and 46; Current regulation, Nos. 22 and 32; Dynamic simulation and measurement, Nos. 16, 34, 45.



MODEL PP35A DIFFERENTIAL SOLID STATE OPERATIONAL AMPLIFIER

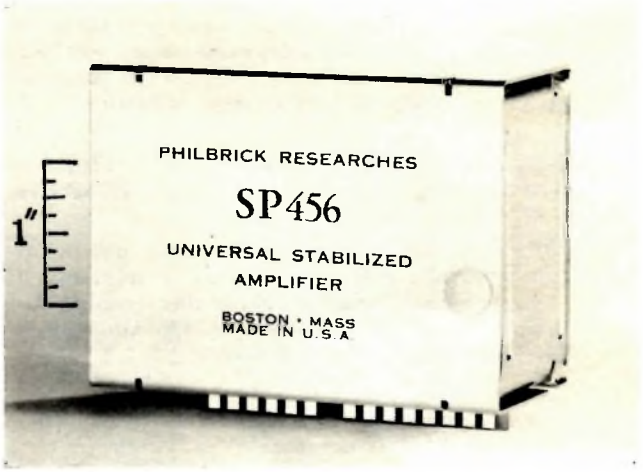
The tiny all-silicon PP35A is particularly well suited as a simple general purpose amplifier in those applications demanding full differential input operation over wide bandwith. Although it has high input impedance and is not chopper stabilized, its drift and noise are extremely low, especially in regard to current, referred to either input terminal.

The PP35A occupies 0.9 cu. in., weighs ⅔ oz. installed, and operates from ±15 volt power supplies. Gain-bandwidth product is about 8 megacycles and current output capability exceeds 2 ma at ± 10 volts. Apparent resistance between the two input terminals is over 2 megohms. Common mode rejection ratio exceeds 20,000:1, dc voltage gain is 100,000.

At room temperature an input current of about 20 nanoamperes flows toward the amplifier into each of the differential inputs. The shift in this current due to a change in temperature amounts to about 0.15 nanoamps per degree C. Similarly, the shift in voltage error between the two differential inputs amounts typically to 20 microvolts per degree C.

Use this tiny general purpose amplifier as a:

- ±.01% follower, input resistance 100 megs.
- compact, low-drift integrator
- fast, high impedance, full differential amplifier
- fast, high impedance, precise comparator

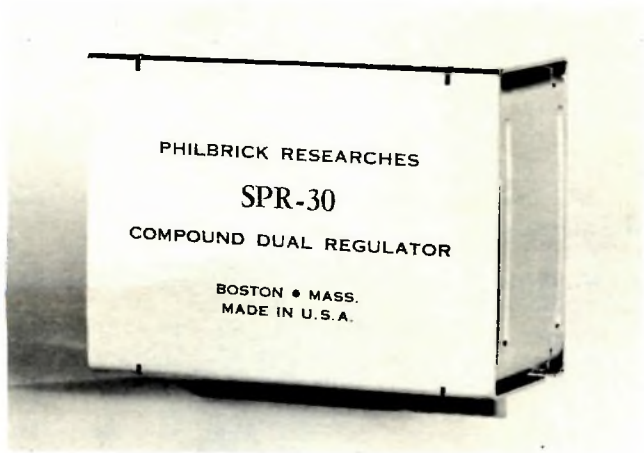


MODEL SP456 CHOPPER STABILIZED WIDEBAND OPERATIONAL AMPLIFIER

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 an all silicon unit operating from ±15 v power supplies, 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. T. C. drift is about 0.1 μV/degree C.

Output current capability exceeds 20 ma at ±10 volts. It has low quiescent drain, 6 ma, from its power supply, the output can be short circuited without damage, and it has extremely low internal dissipation.

The SP456 is quite at home in the high impedance analog circuitry generally associated only with vacuum tube amplifiers, for example, the use of 1 megohm as the standard input resistor for summing, integration, etc. The average "dc" error or "drift" current is so low, typically under 10^{-12} amperes, that high dc accuracy is possible even with 1000 megohm computing circuitry. Please note, however, that resistors themselves frustrate accuracy at high frequency in megohm level circuits; accuracy in high frequency circuits demands use of relatively low impedances.



MODEL SPR30 PLUG-IN REGULATED POWER SUPPLY

The SPR30 all-silicon Power Supply offers new flexibility to the instrument designer by providing a compact ±15 volt dual power supply (except for the transformer) in a plug-in package identical to that of the SP456. Because the transformer is available separately, it may be installed away from the area of summing points and computing circuitry. The advantage of a plug-in power supply housed in a package identical to that of the amplifiers makes practical more compact, self-powered instruments, at the same time providing an accurate reference voltage. By allowing an independent "floating" supply for one amplifier, a whole new class of circuits are possible at low cost.

The SPR30 is stable day-in-day-out to better than 0.03% against line and load, outputs are set at the factory to 15 vdc ±0.5%. Over its design range of −25°C to +85°C the output shifts less than 40 millivolts typically, and temperature variations cause the output to change less than 0.01% per degree C, less than half this much being typical.