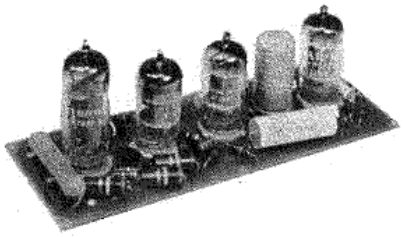
The Lightning Empiricist

A journal for devotees of high-speed analog computation, those enthusiasts for the new doctrine of Lightning Empiricism, publishable aperiodically and distributed without charge by Geo. A. Philbrick Researches, Inc., 285 Columbus Avenue, Boston 16, Mass. and offering items of interest and value on such computational topics as applications, techniques, and new or improved components.

ISSUE NO. 6 GAP/R OCTOBER 1958

USA-3 NOW IN ORBIT

MODEL USA-3 UNIVERSAL STABILIZED AMPLIFIER



One of the outstanding recent developments in the galaxy of Philbrick computor components is the Model USA-3 Universal Stabilized Amplifier. This Amplifier is a high capacity, precision instrument. Its reliability is such that performance under various conditions can be predicted with assurance.

What this Amplifier can do for you, dear reader, and its numerous virtues are indicated briefly in these columns, and described at length in literature available upon request.

Electronic precision and mechanical sturdiness are gained through the use of:

1. A carefully designed printed circuit mounted on a glass-epoxy board;
2. Selected JAN type resistors.
3. Chopper stabilization;
4. Cathode follower output.

In its naked state, the USA-3 is 7 inches long, $2\frac{1}{2}$ inches wide (board dimensions) and 3 inches overall height. It can be mounted horizontally, vertically, or in any other orientation. Inclusion in assemblies is rendered very easy by its construction. Just allow enough room for access to the tubes and for proper ventilation.

See pages 2 and 4 for modular packaging of the USA-3.

Low cost is another virtue. Reliability and performance per dollar is greater with the USA-3 than with any other amplifier available today.

ADVENTURES IN AMPLIFIER APPLICATIONS

In these columns, we will describe various useful and often requested applications of Philbrick amplifiers. These applications will include unconventional operations as well as the conventional ones of summing, scale changing, inverting, and integration. Some will be self-evident to the sophisticated reader. All, however, will display the versatility possessed by Philbrick amplifiers.

The applications that follow include both the familiar K2-W (with or without the K2-P stabilizer) and the USA-3, each placed in its proper niche. Fig. references that appear under the K2-W circuits are to circuits described in the Applications Manual for Philbrick Octal Plug-in Computing Amplifiers (available upon request). Note that these circuits utilize two features of the K2-W that are exclusive to it among operational amplifiers:

1. The input is differential (matched to $\frac{1}{3}$ of 1 %). Each terminal is available for action in applications that require no chopper stabilization.
2. The amplifier can be driven into limits or to ground for long periods without damage or excessive recovery time.

In figure 1 (See page 3.) the guiding principle is that within its ratings, amplifier A will supply whatever gain and offset are necessary to "servo" the output of the booster B so that the latter, within its ratings, can satisfy the power demands of the operational configuration and the load, as well as preserve the null at amplifier A. B may exist in any form, of which the following are typical:

1. A powerful cathode follower ---

ADVENTURES (Cont. on Page 3)

REAL TIME, PRESENT TENSE

From the hearty response to the questionnaire distributed with the last issue of The Lightning Empiricist, it is evident that many of our readers favor our policy of giving the maximum possible space to new computing components, methodology and applications. Manifestly, there are other services we can render toward furthering communication between interested readers and knowledgable authors. This column will be devoted to news of exceptional opportunities for such intercourse, including Philbrick's participation in shows, announcements of the availability of reprints, and information about new activities.

NEW ADDRESS. The headquarters of George A. Philbrick Researches, Inc. are now at 285 Columbus Avenue in Boston's Back Bay area, within a few blocks of major hotels and transportation facilities. You can reach us conveniently by telephone (COmmonwealth 6-5375) and by wire (FAX Boston). A map showing our location is available on request.

COMPUTING SERVICES. Pi Square Engineering Company and its computing facility, the American Center for Analog Computing (AC/AC) are now divisions of GAP/R under the direction of Dr. Henry M. Paynter. They offer the complete gamut of consulting services from the leasing of time on their extensive "all-analog" computor installation to the complete solution of any problem amenable to rational analysis. Write or telephone their headquarters at 127 Clarendon Street, Boston 16, Mass. (COmmonwealth 6-5376), for understanding and sympathy with regard to your dilemmas and enigmas.

EJCC. Visit the Philbrick exhibit at the Eastern Joint Computor Conference and Exhibit at Philadelphia's

REAL TIME (Cont. on Page 4)

GAP/R ALL-SPEED ELECTRONIC ANALOG COMPUTORS

The Lightning Empiricist

PROLOGUE

Philbrick listens to and appreciates the murmurs of approval that have greeted its contributions to the art and science of analog computation. Convinced of the soundness of modular construction, Philbrick has pioneered and presented to its public an impressive array of computor modules. From these, a wide variety of ad hoc, general purpose, and special purpose computors, and instrumentation and control arrays are constantly being constructed and reconstructed.

But these murmurs also impart demands for better and better tools. Four such "better and better's" are mentioned herein: the Model USA-3 Universal Stabilized Amplifier, the Model K5-U Universal Linear Operator, the Model SR-400 Super-Regulated, Tracking Type, Dual Power Supply, and the Model UPS-2 Regulated, Tracking Type, Dual Power Supply.

What these can do and some of their many virtues are herein presented with the restraint imposed by limited space. Upon request, we will wax more eloquent.

Philbrick also has listened to other rumblings about the content and frequency of this aperiodical. To satisfy these, two steps are in process:

1. In this, and in most all succeeding issues, we will continue the inclusion of articles on applications and methodology. Block diagrams, solutions to generalized problems, ex cathedra pronouncements of principles will be the primary vehicles.
2. We are implementing plans for publishing our aperiodical more frequently. Who knows! It might even become a periodical!

Read hearty. Send for amplified literature. And please write to us your questions and suggestions.

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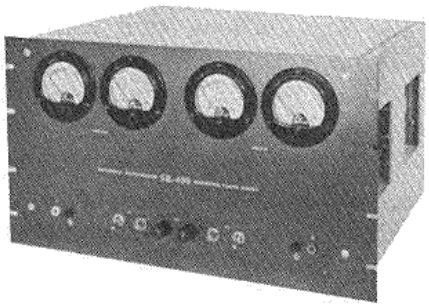
Is our record of your address correct? If not, won't you please feed back the correction signal.

POWER SUPPLY NEWS

Three excellent rack mounted, regulated, tracking type, dual power supplies are now available. Each has been designed to meet the exacting demands of electronic analog computor operation. These are the 400 ma Model SR-400, the 100 ma Model R-100A, and the 45 ma Model UPS-2.

Each of these power supplies provides +300/0/-300 vdc and heater power at line voltage-and-frequency via one or more standard 5-pin RETMA socket connectors. Each also has the negative supply referenced to an 85A2 gas tube and the positive supply cross referenced to the negative supply. The long term stability of each is about 0.1 %. In the SR-400 and the R-100A, this can be materially improved by the use of a mercury battery reference. A few specifications follow.



Model SR-400

The short term tracking error is less than 0.01 %. The long term tracking drift is less than 100 mv.

Hum and noise are of the order of 300 μvac average.

Dc regulation from no load to full load is typically less than 0.003 %.

Dc regulation caused by swings in input voltage (105 to 125 vac) is not observable except as minor drifts of the order of 0.003 %.

Output is via four paralleled RETMA connectors. The construction is such as to minimize cross talk between the four outputs.

Model R100-A

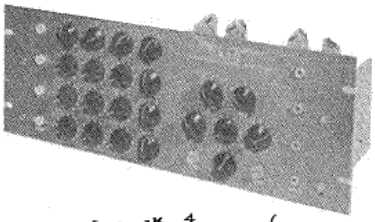
With the 85A2 reference provided, the 24-hour stability is about 300 mv.

Hum, noise, and jitter collectively is about 2 mvrms.

Dc regulation on account of load swings is about 0.02 %. Dc regulation on account of swings in input voltage (108 to 125 vac) is about 0.1 %.

POWER (Cont. on Page 3)

MODEL K5-U UNIVERSAL LINEAR OPERATOR



$$e = e_0 + 10^m \left[\int dt\right]^n \sum_{i=1}^{4} a_i e_i \quad \begin{cases} m = 0,1,2,3 \\ n = 0,1 \end{cases}$$

Upon reflection, you will recognize this equation as a canonical form for a wide variety of linear problems in the pure and applied sciences. Closed form analytical solutions for systems of such linear equations exist only for low orders. Stability and other relative performance criteria are almost never simply or obviously related to allowable parameter changes. The addition of essential nonlinearities further confounds classical attacks.

But the versatile K5-U at once comes to the rescue of the harassed explorer. Its virtues are many, not the least of which are release from tedium and savings in time.

The characteristics and utility of the K5-U and its companions will be discussed in forthcoming issues of The Lightning Empiricist. Meanwhile, literature is available.

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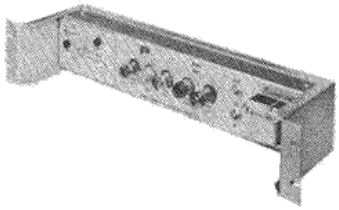
MODEL UPA-2 UTILITY PACKAGED AMPLIFIER



The UPA-2 is a USA-3, equipped with a heater transformer and a bias adjustment, contained in a rack mounting adaptor 3½ inches high. The removal of two thumb screws releases the adaptor and converts the amplifier into a bench top unit.

Computor connections are made via five banana jacks arranged with standard ¾-inch spacing. Thus, passive circuitry can be mounted on double (GR) banana plugs. The inputs can be completely shielded by the use of a plug-in shielded component box, available as an accessory.

The performance characteristics, of course, are those of the USA-3.

Literature on this versatile Amplifier is available upon request.

ADVENTURES IN AMPLIFIER APPLICATIONS (Continued)

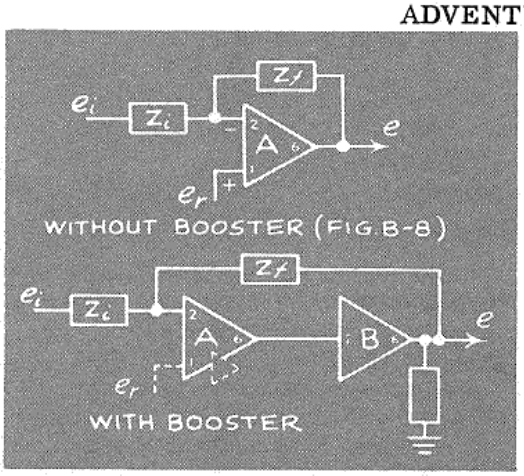


FIGURE 1. LOADING OF A GENERAL OPERATIONAL CONFIGURATION

applicable to requirements for moderately high voltage and current.

2. A transistor follower --- for supplying very large current at very low voltage, as for driving galvos.

3. A triode amplifier stage --- for supplying much more ramified output voltage ranges and levels than the amplifier itself can supply.

It may be necessary to invert the open-loop amplifier polarity in boosters 2 and 3, but this is easily accomplished with all Philbrick operational amplifiers.

For all the above cases, it may be desirable to operate the booster from a separate power supply which is better "matched" to the load than the ±300-volt supply. The regulation of this power supply can be at least an order of magnitude worse than that of the operational amplifier power supply.

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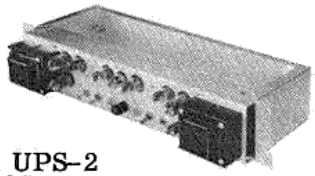
POWER (Continued)

Input and output connections are made via cords and plugs.



Model UPS-2

The UPS-2 has been especially designed to drive the UPA-2 amplifier and is compatible with it in structure and appearance. Its 3½ in. rack adaptor can be removed to convert the unit into a bench model.

Dc regulation on account of input voltage swings (110 to 120 vac) is about 0.1 %. Dc regulation on account of load swings (0-45 ma) is about 0.01 %. Output is via one RETMA connector.

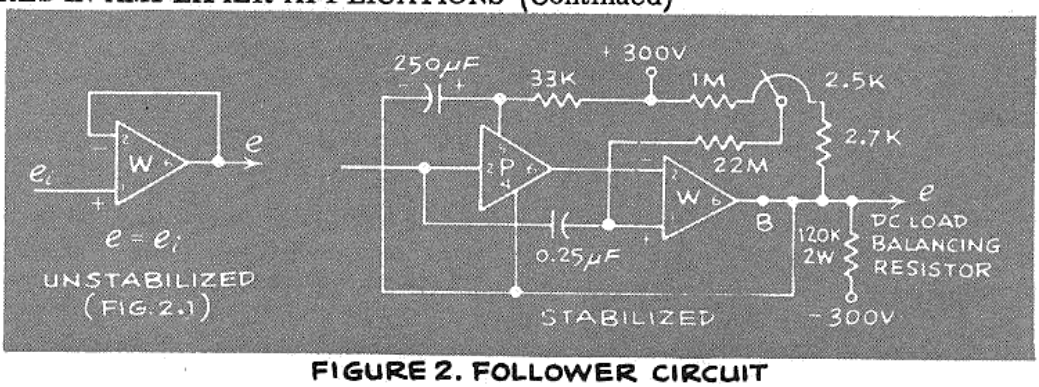


FIGURE 2. FOLLOWER CIRCUIT

The follower circuit isolates e_i from e without changing the value or the sign. Stabilization and offset correction improve the drift, input impedance, and differential accuracy by factors of 10 to 100 or more.

It is often advantageous to use an insulated guard around the input circuit and to tie the guard to the output. The guard is thus operated at a low impedance level and may or may not be protected by a grounded shield at the discretion of the user.

A booster may be inserted at B.

The decoupling filter reduces the ability of signals at chopper frequency to "fool" the stabilizer by modulating the plate supply voltage of the chopper amplifier. It is not necessary for following slowly varying signals.

This circuit is a modification of the circuit suggested by Professor Donald Deford of Northwestern University and incorporated in many of the chemical instruments he has designed, using Philbrick Operational Amplifiers.

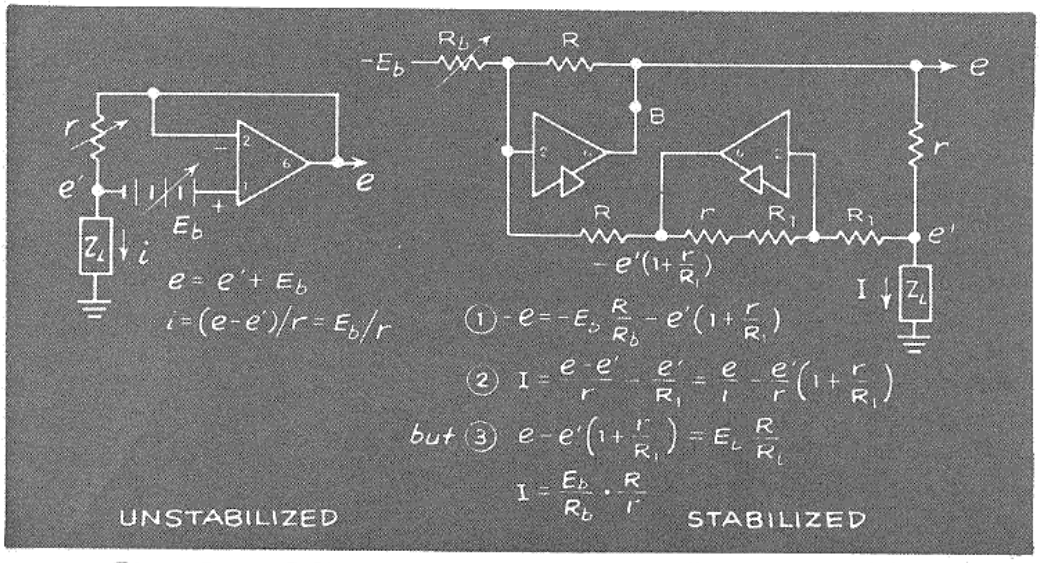


FIGURE 3. DRIVING CURRENT TO A GROUNDED LOAD

The two-amplifier configuration is more general than the single-amplifier circuit because both the load and the reference can be grounded. A booster may be inserted at B.

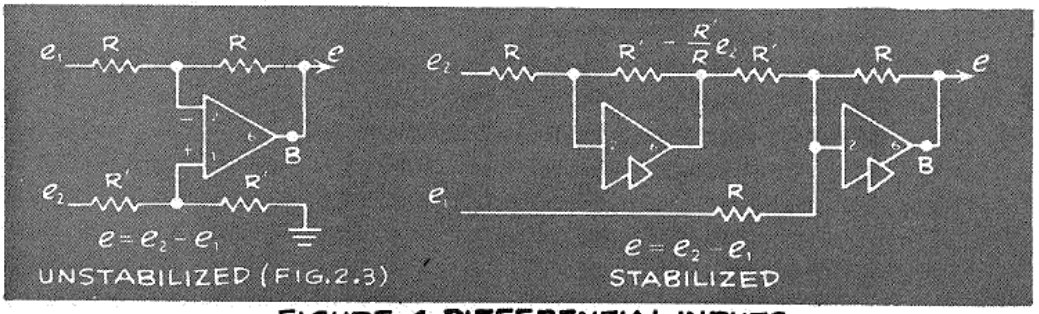


FIGURE 4. DIFFERENTIAL INPUTS

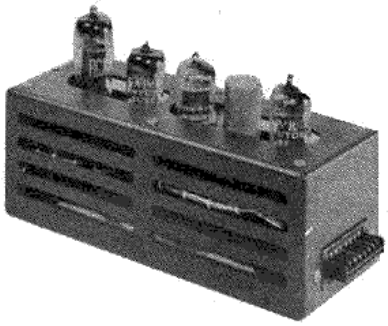
Stabilization enables the differential amplification of small signals.

Inclusion of a current booster at B enables very low single-ended or differential inputs to control large power outputs.

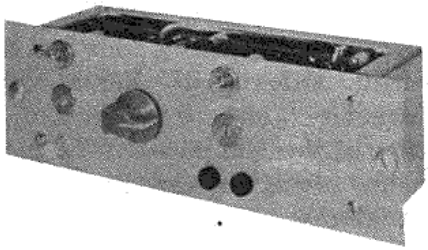
ADVENTURES (Cont. on Page 4)

PACKAGED USA-3'S

To meet specific conditions, the USA-3 has been packaged in various guises. Why not write for pertinent literature?



The USA-3-M3 is shown above. It features a ventilated aluminum housing and a 16 pin Blue Ribbon male connector.



Another package, custom designed for an instrumentation circuit, is illustrated above.

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REAL TIME (Continued)

Bellevue-Stratford Hotel, Booth 35, December 3, 4, and 5. This annual event, sponsored jointly by AIEE, IRE, and ACM, is the largest and most comprehensive exposition devoted solely to computors and their applications. Philbrick engineers and expert consultants will be on hand to greet you and show you what's really new in analog computation.

REPRINTS. Have you seen a copy of the "Notes on Operational Amplifiers" from a talk given before the IRE-PGEC in New York in January, 1958? Although quite informal, it is useful as a supplement to the "Applications Manual for Philbrick Octal Plug-In Computing Amplifiers," and the UPA-2 Technical Data. Among its contents are a discussion in some detail of the sources of noise in operational amplifier circuits, a description of an improved stabilized follower circuit, and notes on sources of error in integration and differentiation. A copy will be sent you on request.

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Smith, O. J. M.: Posicast Control of Damped Oscillatory Systems. Proc. IRE, Vol. 45, pp 1249-1255, Sept. 1957. (A method, previously known to us, for producing dead-beat response in a lightly-damped oscillatory feedback system.)

Smith, O. J. M.: Mixed Distributed and Lumped Parameter Systems. 1957 WESCON Convention Record, Part 2, Vol. 1, pp 122-132. (A thorough mathematical analysis of the subject.)

Tallman, G. H. and Smith, O. J. M.: Analog Study of Dead-Beat Posicast Control. IRE Transactions on Automatic Control, PGAC-4, March 1958. (Elimination of oscillations and overshoot in a lightly damped servomechanism within considerably less than one cycle of the uncompensated oscillation.)

*Refers to Philbrick products.

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ADVENTURES (Continued)

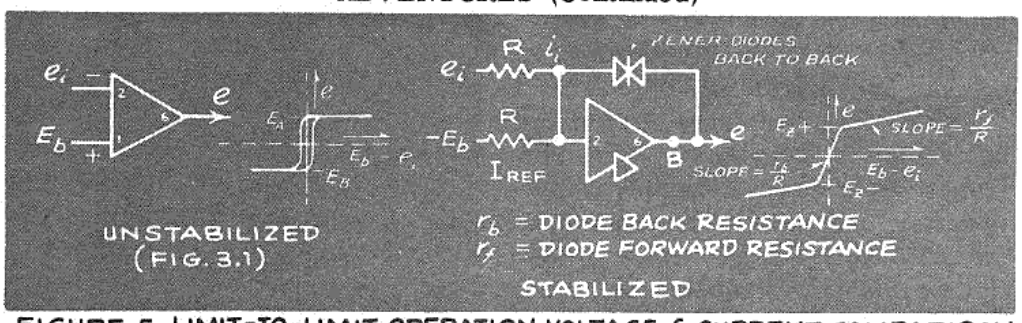

FIGURE 5. LIMIT-TO-LIMIT OPERATION, VOLTAGE & CURRENT COMPARISON

The Zener diodes insure that the stabilized amplifier --- within its load ratings --- will not be driven out of balance, even though the gain maybe quite high in the transition region. Typical applications of this circuit are null amplification, differential relay drive, and amplifier protection. As an accurate and rapid comparator, its applications in automation circuitry are legion. A booster may be inserted at point B.

A glow lamp, such as NE-2 or NE-81, can be substituted for the Zener diodes with a considerable increase in transition slope, but it may require especial attention to circuit stability. A thyrite has certain advantages, such as a graded limit with very high gain at null.

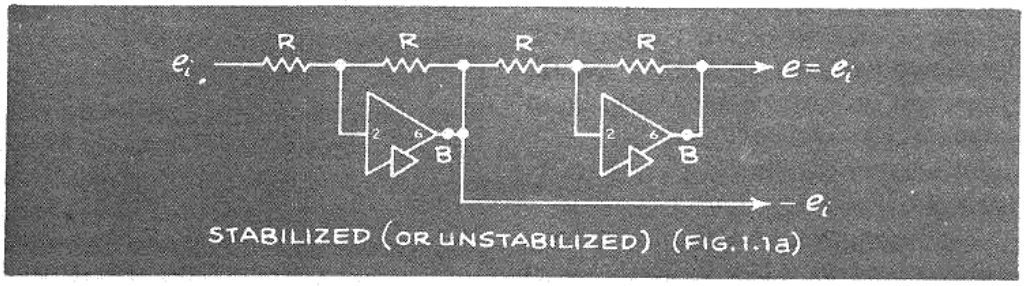

FIGURE 6. PUSH-PULL OUTPUTS

Precision inverting makes push-pull outputs feasible. Inclusion of boosters at B extends the usefulness of this circuit to the driving of transducers that require powerful balanced inputs.