MODEL RP

OPERATIONAL MANIFOLD

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MANUAL

of

INSTALLATION,

OPERATION,

APPLICATION

and

MAINTENANCE

PHILBRICK MODEL RP OPERATIONAL MANIFOLD

1. DESCRIPTION

1.1 GENERAL DESCRIPTION. The Model RP Operational Manifold is a "Better Breadboard" --- a self-contained, miniature console designed for fast, economical, efficient experimentation, simulation, and instruction in the practical application of the solid-state Operational Amplifier. Provided with receptacles that accept five plug-in Operational Amplifiers of the Philbrick Style P*, a color-coded jack field is associated with each of these five amplifier positions to permit convenient installation of passive circuit elements, and interconnection of elements, circuits, and amplifier stages, using standard plugs, links, components, and leads. (Several Accessory Kits, containing selected connection hardware and components for use with the Manifold, are available at reasonable cost ... see the Section 2.6 for a description.

Two additional receptacles each accommodate a larger Philbrick SP-size Plug-in, such as a Quadratic, Logarithmic, or Sinusoidal Transconductor, or even a Chopper-Stabilized high-gain amplifier. These additional sockets are intended to be used in conjunction with (or in place of) the first and fifth Operational Amplifier Positions.

An independent (free-floating) receptacle is also provided, accepting an additional 10-pin plug-in module such as a P-size Operational Amplifier, a Booster Amplifier, P-size transconductor, or any arbitrarily selected set of circuit elements pre-assembled on an OP-O Uncommitted Plug-in Unit. Numbered jacks adjacent to this independent socket facilitate connection between this module and those of the basic five Operational Amplifiers.

The instrument features a built-in Dual Regulated DC Power Supply, wired to furnish operating power to all plug-in elements at the eight different receptacles, and, within limitations, to external stages and components as well.

1.2 MECHANICAL DESCRIPTION. As Figure 1-1 shows, the Model RP is completely housed within a rectangular anodized-aluminum case having a sloping front panel, and may be used with equal facility either as a bench-mounting unit, or, by tilting the sloping panel into the vertical plane (Figure 1-2), as a rack-mounted unit. The standard walnut end-bells are replaced by aluminum adaptor brackets for rack-mounting. The complete instrument, less plug-in elements, measures 19 inches wide, 7 inches high, and 7 inches deep overall, and weighs 10 pounds.

* Model EP85AU Amplifiers are normally furnished, but any combination of units may be ordered and used.

1.2.1 OPERATIONAL AMPLIFIERS (POSITIONS 1 to 5).

Any combination of plug-in Operational Amplifiers of the Philbrick Style P can be accommodated in the five 10-pin receptacles provided at the base of the front panel. Above each receptacle is an associated jack field containing eighteen color-coded tip jacks, internally connected in the relationship shown in Figure 1-3, for Operational Amplifier Positions 2, 3, and 4.

1.2.2 DUAL RECEPTACLES (POSITIONS 1 and 5)

Operational Amplifier Positions 1 and 5 also employ the basic connection pattern of Figure 1-3, but include connections with an upper receptacle on the panel as well, as shown in Figure 1-4. This upper receptacle is equipped with two 15-pin edge connectors that enable it to accept either a Philbrick SP-size Operational Amplifier such as the SP65A or SP2A, or one of the Philbrick SP-size Operational Circuit Plug-ins, such as the Quadratic, Logarithmic, or Sinusoidal Transconductors. (See Appendix for Amplifier Chart and Transconductor Bulletin 6220.)

As the diagram indicates, the signal paths of the SP65A Amplifier and P-Series Amplifier are essentially wired in parallel. Accordingly, Amplifier Positions 1 and 5 may each be used in any of four ways:

a. With the P-Series Amplifier inserted.
(Functions same as Positions 2, 3, and 4).

b. With the P-Series Amplifier and Transconductor inserted.

c. With the SP-Size Amplifier inserted.
(Functions same as Positions 2, 3, and 4 but with the superior characteristics of a chopper-stabilized or parametric Operational Amplifier).

d. With certain SP-size Unit Operators that are complete Unit Operators, containing integral Amplifiers.

1.2.3 AUXILIARY RECEPTACLE

Centered on the panel above the jack fields is an auxiliary 10-pin receptacle, with its pins brought out to isolated tip jacks directly beneath it on the panel. This receptacle will accept an additional P-size Operational Amplifier, Current Booster, or Transconductor, or a special circuit mounted and wired on a 10-contact plug-in card, enabling convenient interconnection of that plug-in with other Manifold circuits via its panel jacks.

Dashed lines imprinted on the panel surface indicate the jumper connections required for power and ground when an Operational Amplifier or Booster occupies this receptacle. Directly to the right of the receptacle are the AC Power ON-OFF Switch, and a pair of Power Common jacks; to its left are jacks for 6.3 VAC provided for energizing the choppers of Stabilized Amplifiers inserted in the upper receptacles. When using stabilized amplifiers 1 kΩ and 470 Ω resistors must be used and connected as shown. When the 6.3 VAC circuit is not required for Chopper drive, it may be used as a convenient utility signal source of approximately 20 volts peak-to-peak.

1.2.4 DC POWER SUPPLY

Positive and negative 15 VDC operating potentials and 6.3 VAC chopper-drive voltage are furnished to the Manifold circuits by a Model OSPR-30 Dual Regulated Power Supply (Figure 1-5), mounted at the extreme rear of the chassis. AC line power is brought into the unit through a 3-wire captive line cord, and a 0.1-ampere fuse in a rear-mounted fuse holder.

1.3 FUNCTIONAL DESCRIPTION

The discussion that follows will be confined to the functional relationships made feasible by the provision of receptacles and jack fields, and by pre-wired internal connections. The (truly manifold) applications of the Model RP as an Analog breadboard will be explored in subsequent sections.

1.3.1 OPERATIONAL-AMPLIFIER POSITIONS.

Each of the five Operational-Amplifier receptacles is wired internally to the instrument power supply, grounds, and panel jacks as indicated in Figure 1-6, providing convenient access to its signal terminals. Ground-return connection points, one to HQ Ground (symbol ⏚) and one to Power Common (symbol ⏚), are provided to permit compliance with the dictates of good Grounding practices. The metal shield that surrounds some plug-ins is grounded directly to the chassis. Pin 7 is connected to a common bus that is used only when the Manifold is accommodating gated-amplifier circuits. The signal input and output connections are straightforward, and are indicated by the diagram imprinted on the panel.

1.3.1.1 A Note on Amplifier Selection. The Model EP85AU Operational Amplifier normally furnished for use in the RP Manifold is an economical, solid-state unit of proven performance, designed for general-purpose use in computing, measurement, simulation and control-system applications. It uses silicon semiconductors and features low voltage-offset drift, low noise, and excellent common mode rejection. Since all P-size Operational Amplifiers are physically interchangeable, operation of the Manifold is by no means constrained to the general-purpose arena. More sophisticated or specialized circuits may be composed by selecting other amplifiers from the broad Philbrick family, which includes, among many others:

EP25AU for extremely high input impedance and sub-nanoampere current offsets. (FET type).

EP35AU for low voltage-offset drift, low input currents, and high common-mode rejection.

EP45ALU for greater output-current capability and enhanced stability under capacitive loading.

EP65AHU for full output swing up to 80 kHz and rapid switching.

Their characteristics are listed on the chart in the Appendix.

2. PUTTING THE RP INTO SERVICE

2.1 UNPACKING AND INSPECTION.

The RP Operational Manifold is shipped in a single corrugated cardboard carton, which contains the Manifold with five P-size Operational Amplifiers and the power supply already inserted in the receptacles, a pad of Circuit Record sheets, a copy of the Philbrick Applications Manual for Computing Amplifiers, and a copy of this manual. The Manifold is ordinarily equipped with walnut end bells, for use as a bench-mounted unit; if ordered specifically for rack mounting , the end bells are replaced by brackets that are punched to permit securing the instrument in a standard 19-inch rack.

Unless otherwise specified in the purchase order, the RP is furnished with five Type EP85AU Operational Amplifiers. Additional amplifiers, components, Operational Plug-ins, or other accessories that may have been ordered in conjunction with the RP Manifold, are packed separately.

The shipment should be inspected completely, as soon as possible after receipt, for any evidence of shipping damage; perforated carton, dented or twisted chassis, loose parts, cracked or broken end bells, scratches, abrasions, should be called to the attention of the carrier at once, to substantiate any resultant claim for reimbursement.

2.2 CHECK-OUT PROCEDURES.

The user will require the use of an Oscilloscope with DC coupled vertical amplifier with a sensitivity of 10 mV/cm or better, preferably with calibrated graticule, for examining the input and output signal waveforms and levels during the test.

Make certain the DC power supply (accessible from below) is firmly seated, the 0.1-ampere fuse is in place in the fuseholder on the rear panel, and that the five Operational Amplifiers in the front panel are firmly located in their receptacles. Plug the line cord into a source of 115-volt (±10%), 50 to 400 Hz power, and press the AC pushbutton to ON.

Note: The power supply transformer, separately-mounted inside the Manifold housing, is equipped with a dual-primary winding which is normally parallel-connected, for operation on nominal 115-volt power lines. When specified, the instrument is furnished with the primary windings connected in series, for 208-250 volt line input. An appropriate line plug must be installed locally, as all units wired for 230 volts are shipped without line plug.

2.2.1 Power Supply Check

Read the following voltages on the jack field:

6.3 volts AC between the two Violet jacks.

+15 volts between any Red jack and any ground (black) jack on the Patch Panel.

-15 volts between any Yellow jack and ground jack.

The presence of correct voltages will indicate that the power supply is in operating condition. If all are absent, check that AC line voltage is available at the source, and that the fuse is intact, and properly inserted in the holder. If the fuse is blown, replace it with one of the same rating; if the fuse blows a second time, do not replace it, but disconnect the unit from the power line and refer to the section on Trouble Shooting Procedures. If 6.3 VAC is present but +15 VDC and/or -15 VDC are absent, recheck the seating of the power supply plug-in and see that there is no obvious damage to the internal manifold wiring. If unsuccessful in restoring all three supply voltages, call your Philbrick Field Office for assistance.

2.3 PERFORMANCE TEST PROGRAM.

To test both the Manifold circuits and the operating condition of the five Operational Amplifiers, and to gain familiarity with the use of the new instrument, proceed as follows:

2.3.1 Amplifier Balance.

Philbrick amplifiers such as Model EP85AU have a built-in rheostat with which the voltage offset of the amplifier, an undesirable voltage appearing between its input terminals, may and should be adjusted to zero. Mount resistors of 100 Ω and 100 kΩ on twin tip plugs with 3/4 inch spacing. Program Amplifier No. 1 to amplify its own voltage offset by a factor $1 + \frac{100\text{ k}}{100} = 1001$, as shown in Figure 2.1. Using a small screwdriver, turn the rheostat through its range (10 turns); the output voltage should smoothly vary between several volts positive and several volts negative. After power has been applied for at least ten minutes, carefully adjust the rheostat for zero output; this leaves the amplifier ready for service. This procedure should be repeated each week where amplifiers are permanently committed to precision applications, or after a drastic change in temperature or when an amplifier is recommissioned after storage. Where an application requires more stability than that of which a given amplifier may be capable, it is necessary to check the balance before every reading or experiment.

SP-size amplifiers such as the parametric Model SP2A (but not SP65A or SP65AH, which do not have built-in balance controls) can and must be balanced in exactly the same fashion, though it will be found that the range of adjustment is very much smaller. Balance the other amplifiers in similar fashion after allowing them to warm up. To allow amplifiers to remain warmed up without actually programming them, leave them in their receptacles with positive input grounded and negative input connected to output, thus keeping them out of saturation.

2.3.2 Static Test

Having established that an amplifier can be balanced, it is very unlikely that it should not operate properly in circuitry within its capability. The static test will prove this and at the same time it will demonstrate the summing point constraint to the novice in the Analog Art.

Remove the 100 Ω resistor from circuit 2.1 and install two 200 kΩ resistors, as shown in circuit 2.2. Connect a lead from the free terminal of one of the 200 kΩ resistors to a (red) +15 VDC jack. Observe that the output is $-e_i\left(\frac{R_f}{R_i}\right) = -15 \times \frac{100\ k}{200\ k} = -7.5$ V.

Also measure the voltage between the amplifier's input terminals. If the meter or oscilloscope is sufficiently sensitive, a voltage of no more than 100 μV should be observed.

Next, install a lead from the free end of the second 200 kΩ resistor to a (yellow) -15 VDC jack. Observe the output voltage $e = -e_1\left(\frac{R_f}{R_1}\right) - e_2\left(\frac{R_f}{R_2}\right) = -\left(+15 \times \frac{100\ k}{200\ k}\right) - \left(-15 \times \frac{100\ k}{200\ k}\right) =$ 0, within the accuracy of the match between R_1 and R_2. The voltage between the amplifier's input terminals again will be found to approach zero.

2.4 USING THIS MANUAL.

Because the capabilities of the Operational Amplifier find employment in every discipline and every industry, and because the RP Manifold is a fundamental tool for exploration and exploitation of those capabilities, this manual must considerately address itself to an unusually diversified audience, extending not just from the beginning student in electronic engineering to the Past Master of the Electronic Analog Art, but also reaching out to embrace similar ranges of user expertise in every walk of technological life. Past Masters will require little more than the master schematic diagram herein, and a perfunctory review of the General Description of Section 1. Less-practiced users will find Section 3, the General Rules for Using the RP Manifold, of assistance in developing familiarity with the instrument, and with the principles of good housekeeping in Operational circuits. Section 5 augments this fundamental information with ten specific examples of Operational Amplifier Circuits, selected both for their general usefulness and for maximum diversity.

Students, members of the Electronics profession whose interests and activities have heretofore been applied to other segments of the technology, and incipient converts from other sciences, industries, professions, or branches of engineering, would probably find it wise to refer initially to the Background Theory exposition in the Applications Manual for Computing Amplifiers, Section 1. There they will find a reasonably complete introduction to the art.

Due to the multiple objectives assigned to this test, the reader may encounter material that he considers excessively detailed, or he may be troubled by what seems to be cursory treatment (or even omission) of some types. We trust that he will bear with any oversimplification he finds (in the interests of a broader dissemination of the Analog mystique) and that he will call upon us or the Bibliographical references, for Greater Amplification, if needed.

Practical matters concerned with sustaining the original level of performance of the Manifold --- routine maintenance, trouble-shooting, replacement parts, factory assistance in repairs and replacements, consultation in design and de-bugging problems --- are treated in Section 6, which also includes the master schematic diagram, and lists of available accessories for the RP Operational Manifold.

As a general recommendation, we suggest one quick, complete reading of this manual, regardless of the present magnitude of your expertise, or cynicism, on the subject. At worst, it may serve as a refresher, and at best it may stimulate your creative centers. The State of the Art is still open to advancement, as of this writing.

2.5 INSTALLATION OF THE RP MANIFOLD IN PERMANENT OR SEMI-PERMANENT SYSTEMS.

As normally procured, the RP is a bench-mounting unit, equipped with a pair of walnut end-bells that facilitate bench handling of the instrument, as well as provide a professionally-finished appearance. When the Manifold is to be incorporated into a larger installation, it may readily be converted to a rack-mounting instrument, merely removing four screws that hold the end-bells in place, and substituting a pair of adaptor brackets for the end bells, securing them with the same set of screws. The adaptor brackets are punched to accept rack-mounting hardware on standard spacing, and are standard accessories, that may be ordered from stock at any time.

Installed in a standard 19-inch EIA relay rack, the Manifold occupies a panel height of 7 inches, and an over-all depth of 7 inches behind the rack, exclusive of cable allowances.

2.6 RECOMMENDED ACCESSORIES.

Prolonged experience in the use of the RP Manifold in any laboratory will eventually produce a collection of "proprietary" accessories --- standard components, and component combinations, networks, complete Operational Circuit plug-ins --- that have been developed to expedite the construction and modification of Operational Amplifier systems in the user's particular field of operation. As a starting point for such a "library" of standard building blocks, and as a convenient source of basic hardware for routine circuit interconnection, Philbrick has developed a series of Accessory Kits for use with the Manifold, as well as a liberal selection of individual components (mounted or unmounted) for general network construction. In the absence of a specific program of activities for initial use of the Manifold, we recommend that the user obtain one Type MAK-2 Basic Hardware Kit, which provides the adaptors, shorting bars, and input/output leads used for direct interconnections, and a supply of uncommitted dual-tip plugs, with set-screws, for mounting individual components, and a Type CCK-U Computing Component Kit, which provides assortment of unmounted resistors, capacitors, zeners, and diodes.

In addition to the forementioned accessory kits, ocilloscope and multimeter, the discipline to which the manifold is to be applied will dictate additional instruments such as:

Stop watch for timing slow phenomena

Audio oscillator

Pulse or Function Generator

X-Y recorder or 'scope camera

Resistance and Capacity Decades

Precision Voltage Source (standard cell)

Precision Volt Meter (DVM)

and, in most cases, a wider variety of resistors, capacitors and zeners, some to 0.1% or better tolerances, more hardware, more diodes, several relays (reed relays with 6 V, 1 mA coils are fine).

For specific applications, specialized amplifiers, e.g. FET, parametric or chopper stabilized types, may be selected from the latest Amplifier Chart, and Non-Linear Transconductors from Bulletin 6220. There also are switching networks such as SPREL (for integrator set-run-hold switching), PT&H (for Track and Hold switching) and PSU and PSL (upper and lower selector, respectively). Your local Philbrick Sales Engineer or the Philbrick Applications Engineering Department will gladly advise you in the selection of accessories for your individual requirements.

3. GENERAL RULES FOR USING THE RP MANIFOLD

3.1 Impedance Levels.

There are two conflicting constraints to consider in selecting the impedance level at which a circuit will function:

(a) To minimize all kinds of noise pickup, all kinds of leakage; the effects of parasitic capacitances; and the effects of amplifier input impedance and offset currents --- the lower the impedance level, the better.

(b) To minimize loading of the signal source; loading of the amplifier; loading of bias, reference, and amplifier supplies; to minimize the effects of parasitic inductance, joint and contact resistances --- the higher the impedance level, the better.

In a majority of all applications, the first constraint dominates. In many circuits, you have no choice. Here are a few rules of thumb:

(a) 20 kΩ is the area of compromise; neither constraint operates there, in general.

(b) Circuits like Integrators, Differentiators, and Filters, in which capacitor leakage is often a problem, should be pushed downward in impedance level, until the capacitors get unmanageably large, 10 μF being close to the maximum.

(c) Circuits should always be designed for the highest operating (full scale) signal level (current or voltage) that they can handle, to minimize the importance of all stray effects --- within the amplifier ratings for voltage and current output swing.

3.2 Noise Levels and Sources.

The influence of the power line as a source of conduit for noise has been minimized by the design of the regulated DC Supply in the Manifold; however, it cannot be completely ignored, since other instrumentation used in conjunction with the Manifold may not be so guarded, and can introduce a considerable amount of power-line-originated interference. Signal generators, oscilloscopes, DC reference and bias sources (other than the supply in the Manifold), chopper-stabilized "outboard" circuitry, and other auxiliary equipment, particularly those equipped with local oscillators and sweep-generators, may also inject spurious signals.

The significance of a given type and level of noise will, of course, depend upon the particular Operational circuit, its application, and its sensitivity to interference; other things being equal, its effect will be more pronounced when introduced in earlier, lower-level stages. Shielding, guarding, by-passing, and filtering may be required --- applied either to the external equipment, or to the high-sensitivity Operational Amplifier stages, or to the entire circuit, as dictated by the requirements of the application. A quick check of the electrostatic and electromagnetic noise field, using a sensitive, wide-band oscilloscope, can forestall the need for extensive and expensive debugging in the development of a functional circuit. A loop of wire of about the same circumference as the length of the longest low-level patch-lead is a good "probe" for electromagnetic field study, and a resistor connected across the terminals of a shielded, high-impedance, low-capacitance Oscilloscope probe will serve to study electrostatic noise. (The resistor should duplicate the impedance level at the lowest-level stage in your circuit.)

It is a good idea --- even if the circuit seems to work properly --- to check the noise level of each circuit "stage" (at some point that will tolerate loading, like the Amplifier output terminal) with a sensitive, wide-band Oscilloscope. Remember that noise energy at frequencies <u>outside</u> the closed-loop bandwidth of a circuit can still overload its input stages.

Keep leads as short as possible. Avoid leakage paths through insulation other than air. Space the manifold away from other equipment, using shielded, coaxial, or "twisted" leads, properly grounded to the manifold, for interconnections between it and the other instruments in the setup. Watch out for: flourescent lamps; unshielded power transformers; high-voltage supplies of any kind; AC power cords; contacts that interrupt significant current or voltage; RF sources of any level --- even nearby radio transmitters!

3.3 <u>Dynamic Stabilization.</u>

Because Operational Amplifiers always employ feedback, the possibility of dynamic instability up to and including sustained oscillation, always exists. Whenever the gain and phase-shift conditions around the loop favor instability at some frequency, the circuit can oscillate at that frequency. This will ordinarily be the result of either a conceptual oversight in designing the feedback network, or "stray" or unsuspected circuit elements that significantly modify the network you <u>think</u> you have designed. Though the true cause is sometimes extremely elusive, remember that <u>there is always a way out</u>. Refer to the Philbrick Applications Manual, particularly Section 1.43 and 1.44, for assistance, but remember that no feed-back resistor should be used without some capacitor across it; 100 pF is typical for general purpose work.

3.4 Input Uncertainties.

If the circuit is achieving a true null --- "clean" of noise and drift, innocent of overwhelming offset voltage or current, truly negligible in signal level compared to the lowest input or output, then the battle is nearly won. If a good, true null exists, the effective open-loop gain must be reasonably high, the amplifier must be in its linear mode, and the summing point must really be obeying the ideal-case conditions. If not, the circuit will never work properly, (unless it is an intentionally non-linear circuit such as a crossing detector, multivibrator etc.)

In single-ended circuits, in which one input terminal is held near or connected to ground, it is possible to check the null condition with a single DC-coupled, sensitive Oscilloscope or electronic voltmeter. In differential circuits, it must be checked by a true-differential instrument, or the instrument used must be buffered (isolated) by a true differential amplifier.

Certain anomalies do not necessarily (or ever) show up in the null test. These include:

(a) Offset Current errors, due to the amplifier input current flowing through the external feedback impedances. In an Integrator, for example, this effect can be distinguished by observing the output increase from zero with no input voltage connected.

(b) Leakage currents of any kind, from any source, flowing into or out of the summing point.

(c) Voltage offset errors, caused by the currents that these offsets drive through external impedances.

(d) "Strays" --- resistive, reactive, or complex, unless they are coupling noise into the summing point.

All the above-listed can be ferreted out by simple detective work ... sometimes by what physicians call differential diagnosis: "... if it's not this, then it must be that." Short the input signal terminals --- what do you see? Ground the signal input terminals --- what happens? Open the signal input path --- what happens? Finally, calculate what should happen, from the characteristics of the amplifier and the components, and check the production against the facts you measure or observe. Very often the clue pops up out of the calculation itself.

3.5 Circuit Compatibility.

The rules for combining circuits are implicit in the rules for making circuits:

(a) Drive from low impedance into high.

(b) Minimize noise and uncertainties by striving for the largest full-scale levels attainable.

(c) Avoid strays by using short leads, maximum separation, and guarding of leakage paths.

(d) Avoid undesired common impedances --- in ground returns, in power-supply lines, in lines from (or to) external equipment.

(e) Read I. 28 - I. 31 of the Applications Manual for Computing Amplifiers.

3.6 Signal and Reference Sources.

When in doubt, use a battery. Batteries are generally stable, have lower noise, are isolated from the line, and are physically convenient to hook up as signal or reference sources. A good, fresh mercury cell, after a few minutes of stabilization at a current well within its rating, exhibits a stability of the order of a few PPM/hour.

If you need AC, of any waveform, the best bet, for the reasons just stated, is to build up a simple battery-operated Signal Source.

If you must use line-powered instruments --- and often you must --- be very careful to ground them intelligently (see earlier discussions) and be very suspicious of their spurious-signal content, such as:

(a) low-level ripple and hum on higher or lower frequency signals.

(b) amplitude and base-line drift, particularly in oscilloscopes and function generators.

(c) spikes and hash --- often of very high frequency, and never mentioned in the specifications.

(d) distortion ... particularly in ramps and sine-waves.

(e) ringing in pulses and square-waves.

3.7 Boosters.

When necessary to deliver more current than may be obtained from a general-purpose Operational Amplifier (designed primarily for high voltage gain and economy of power consumption), the designer can often use standard types having more power output. Often, however, he must find some way to "boost" the current capabilities of any amplifier without visibly deteriorating any of its other characteristics, notably its closed-loop voltage gain and frequency response.

Model P66A may be used in the 10-pin upper receptacle for currents up to 100 mA with external power supply or less within the ratings of the built-in power supply.

Philbrick also makes voltage boosters, which increase the output voltage range of Operational Amplifier circuits, and also offers standard higher-voltage power supplies to energize them. Information on both will be found in the Appendix.

3.8 Bounding and Clamping.

"Bounding" means restriction of the output voltage to some assigned maximum, even when the input signal exceeds its assigned full-scale value (either polarity). In practice, this is generally accomplished by use of a supplementary and non-linear feedback circuit, such as shown in Reprint 40. Note that the ideal "bound" circuit is dormant until full scale is reached, at which time it takes over the job of supplying the feedback current necessary to balance the loop, at no significant increase in e.

So far as the amplifier is concerned, the output voltage could be restrained by a non-linear load, such as a zener diode connected across the normal load, or it could be allowed to go to its own limit, without permanent damage.

However, after an amplifier "saturates", i.e., has gone off to a limit, it can require many seconds --- even minutes --- before it recovers its former zero adjustment. This is particularly true of chopper-stabilized designs, which may take 15 minutes to regain summing point control, much longer to reestablish microvolt stability. Bounding them is almost essential.

Bound circuits effectively eliminate the problem of recovery from overload by preventing both the occurrence of overload and its consequences.

The ideal bound circuit would have an infinite "dormant" impedance below the critical value of bound signal, and zero "active" impedance above that value ... in fact, it would resemble in those respects an ideal zener diode. Since, for almost all applications, both upper and lower bound limits must be established (i.e., both positive-going and negative-going signals must be limited) a pair of such ideal zener diodes would have to be used in the bound circuit. In applications requiring symmetrical bound limits, one zener diode can be made to do the job if mounted in a diode bridge circuit.

3.9 Selecting Components.

If an amplifier's open-loop gain is high enough, the circuit behavior depends only on the characteristics given it by the feedback network --- but: those characteristics are only as good, and as dependably stable, as those of the components you choose. Don't Cheat --- use accurate, stable, high-quality components!

Read Sections I.32 - I.36 in the Applications Manual for Computing Amplifiers ... and save yourself a lot of trouble, pain, and expense in the long run.

TROUBLE SHOOTING PROCEDURES

Failure to Operate. (Includes failure of Operational Circuit to perform, as well as failure of operating potentials).

a. If 6.3 VAC is not present across the two violet jacks, check the obvious possibilities: Line cord not plugged into AC line, line voltage not available at correct value, 0.1-ampere line fuse (in rear fuseholder) blown, Power Supply not fully seated in its receptacle, AC power switch on panel not in ON position.

b. If the AC power is reaching the Manifold, and the line fuse is not blown, check for positive and negative 15 volts at the red and yellow panel jacks.

   (1) If 6.3 VAC is present across the violet jacks and the positive and negative 15 volts is not present at the red and yellow jacks, proceed to remove the patched in circuitry that could be causing these voltages to be shorted. After eliminating the possibility of a short and the DC voltages are still not present, the power supply should be removed and sent to the factory for repair.

   (2) If all potentials are present and correct, check the Operational Circuit diagram for design errors, and check the circuitry for correspondence with the diagram.

   (3) Check Amplifiers by substitution, if spares are available (shut off AC power prior to insertion or removal of amplifier).

   (4) Check circuit component values.

   (5) Check voltages at receptacle connectors.

c. If the fuse is blown:

   (1) Check the Operational Circuits installed on the jack panel for inadvertent shorts or overloads. If one is discovered, remove it, install a new 0.1-ampere fuse in the holder, and check for restored operation.

   (2) If no short or overload is discovered, or if the fuse does blow a second time, disconnect all circuitry and external connections from the patch panel, and remove all Amplifiers and plug-in modules from the receptacles. Insert a new 0.1-ampere fuse in the holder, turn AC power on, and check for the correct DC potentials at the red and yellow panel jacks.

(3) If the DC potentials are restored in the previous step, monitor both potentials and insert the five P-size Operational Amplifiers successively into the receptacle at Position 1, shutting off the AC power each time before inserting or removing the Amplifier. Failure of the DC potentials when one particular Amplifier is inserted indicates a defective Amplifier. (Do not attempt to repair the Amplifier; it should be returned to the factory intact.)

Intermittent, or Sub-Standard Operation. This class of failures is one in which the Circuit functions, though unsatisfactorily, and there is no outright failure of DC power.

Satisfactory Operations, with Random Interruptions or Departures. Defects responsible for erratic operation (deviations not characterized by a detectable pattern) are often difficult to locate. In most cases, the culprit is an internal flaw in the construction of some component; less often, it is a poor contact in a jack or connector, and least often it is a defective solder joint or insulation path in the circuit wiring. Small variations in an applied voltage, internal heating effects, changes in local ambient temperature or humidity, oxidation, thermal expansion or contraction, vibration, and other influences, are collectively and individually capable of activating the flaw, to produce the momentary short or open circuit, or alteration in value, that changes the circuit parameters and thus alters the performance. Frequently, the altered conditions are prone to reverse almost instantly; the circuit thus hops from one mode to the other, in a completely arbitrary manner.

Isolation by substitution is the most effective technique for resolving intermittent defects; the plug-in construction of the RP Manifold makes the procedure reasonably convenient: If possible, isolate the "stage" (that is, the particular amplifier position and its immediately-related components) in which the intermittency occurs.

Sub-Standard Performance. Among the reasons for unsatisfactory performance, other than defective components and errors in circuit setup, the following should be given consideration:

a. The response equation may include an error, introduced during its derivation.

b. The equation may be correct, but may have lost (or gained) something in the translation to an Analog design, because of some anomaly not allowed for --- leakage, offset, pickup, noise, etc.

c. Remember that bounding, limiting, speed of response, finite-gain error, stray capacitance, and other Departures From The Ideal in practical circuitry, will restrict its performance. Scaling down, and compensation in various forms, can extend the useful range, but the presence and magnitude of these inhibiting factors must be recognized.

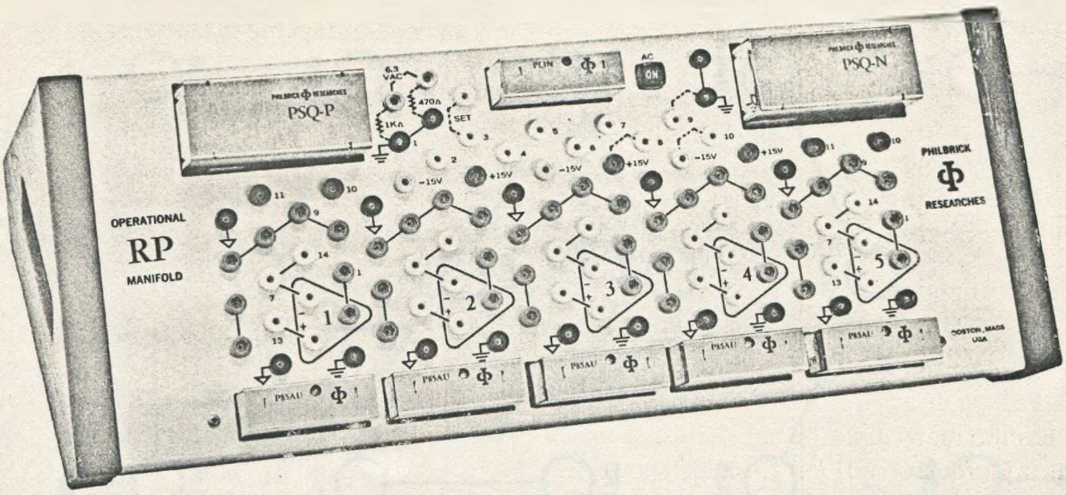

Figure 1-1. RP Manifold, Bench Model

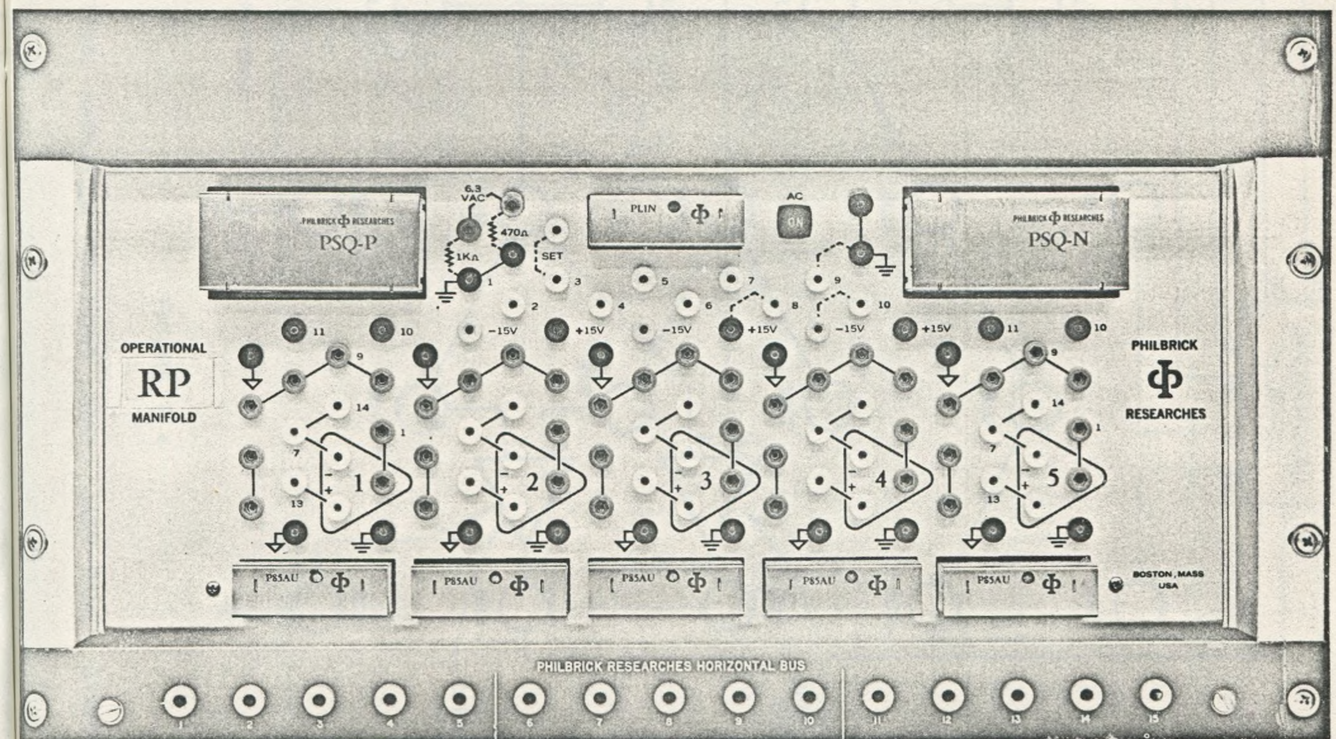

Figure 1-2. RP Manifold, Rack-Mounting Model

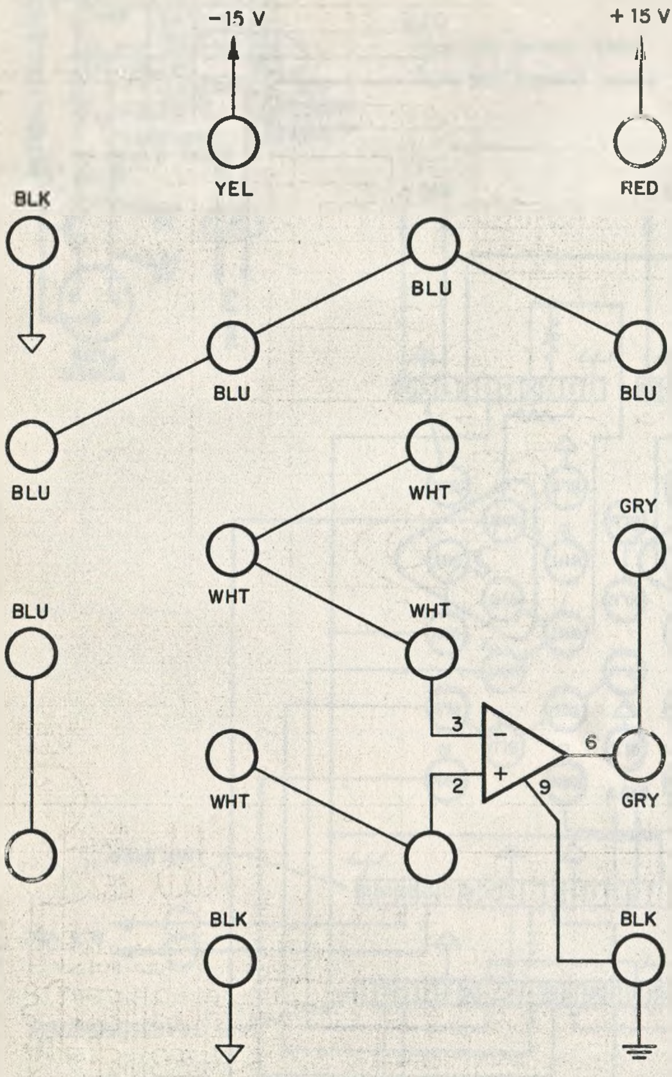

FIGURE 1-3

OPERATIONAL AMPLIFIER POSITIONS 2,3, AND 4
JACK-PANEL CONNECTIONS

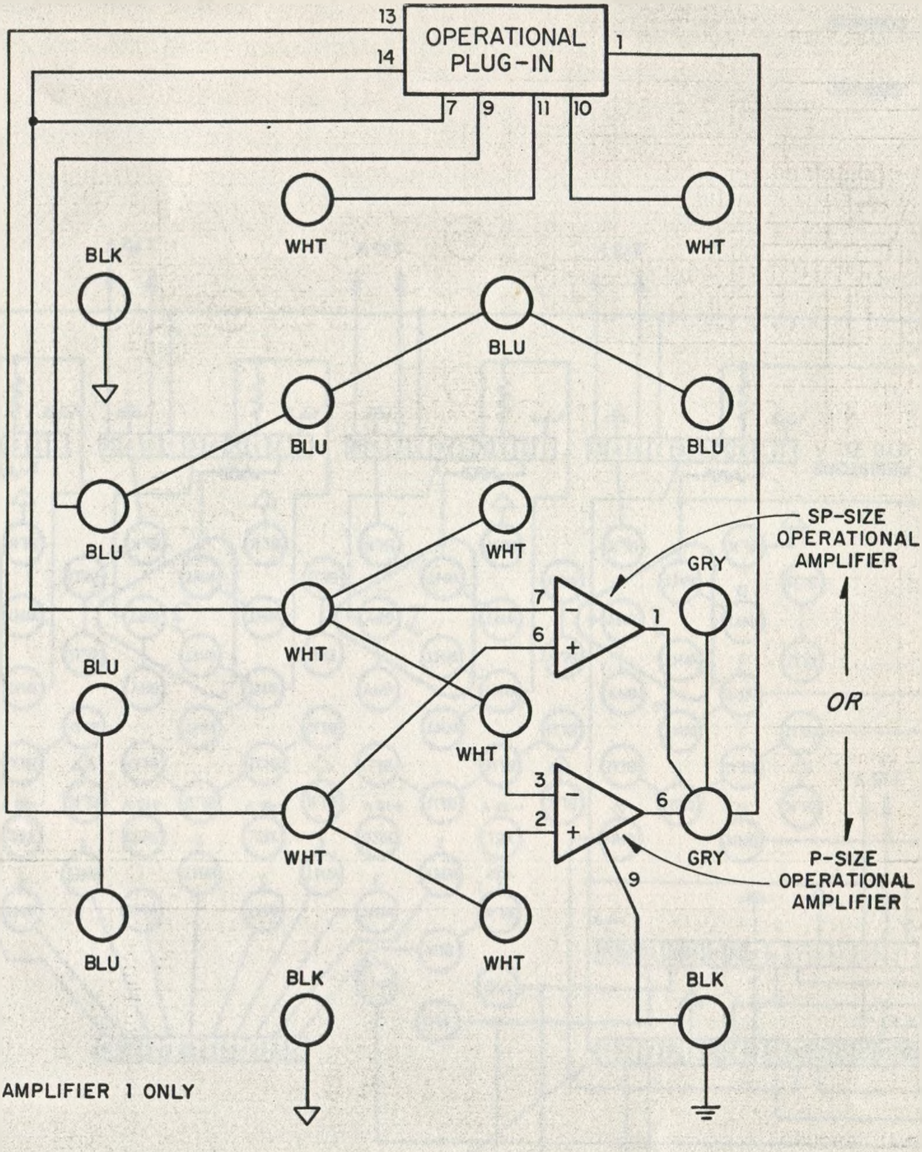

FIGURE 1-4

OPERATIONAL AMPLIFIER POSITIONS 1 AND 5 JACK-PANEL CONNECTIONS

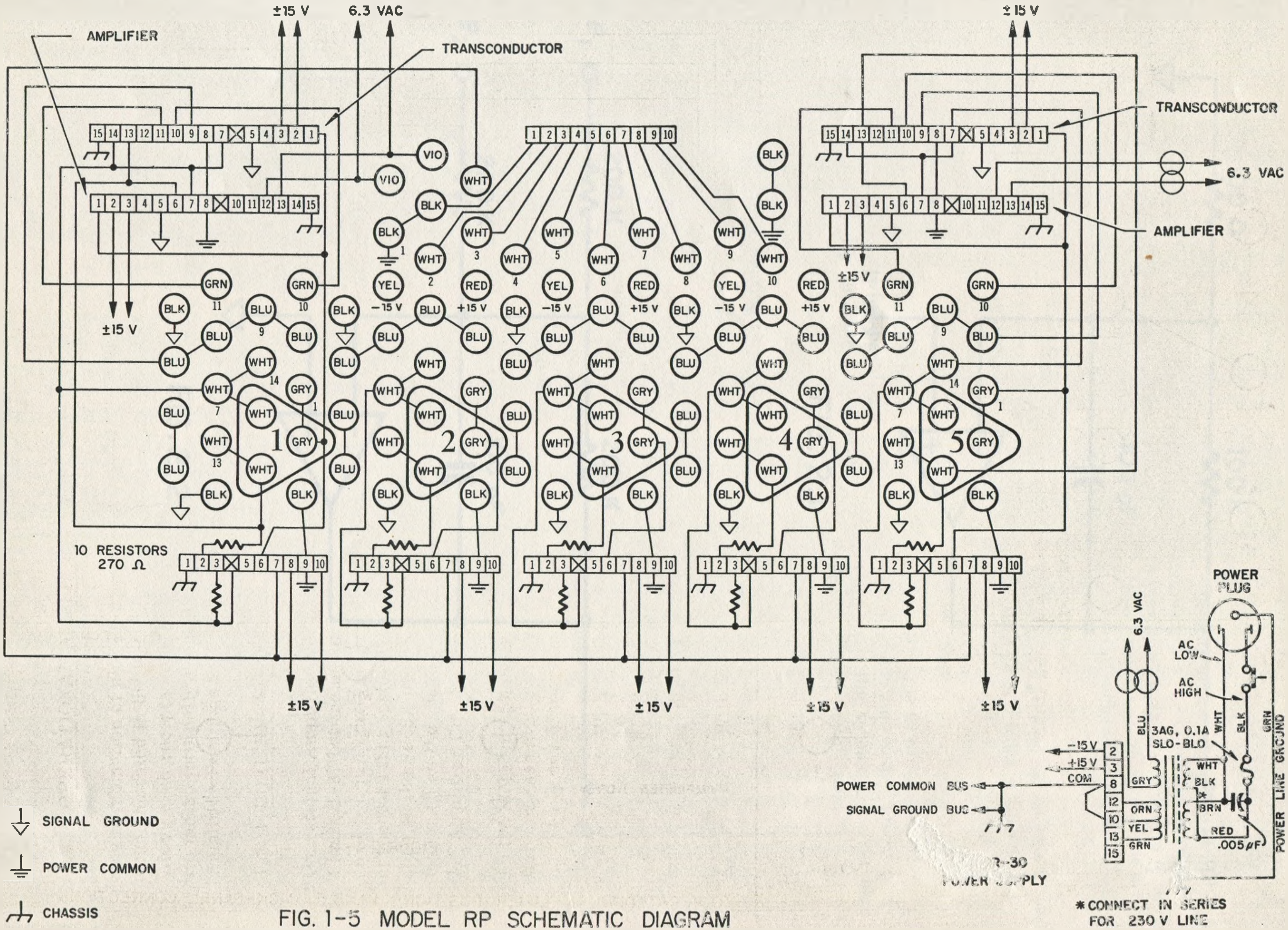

FIG. 1-5 MODEL RP SCHEMATIC DIAGRAM

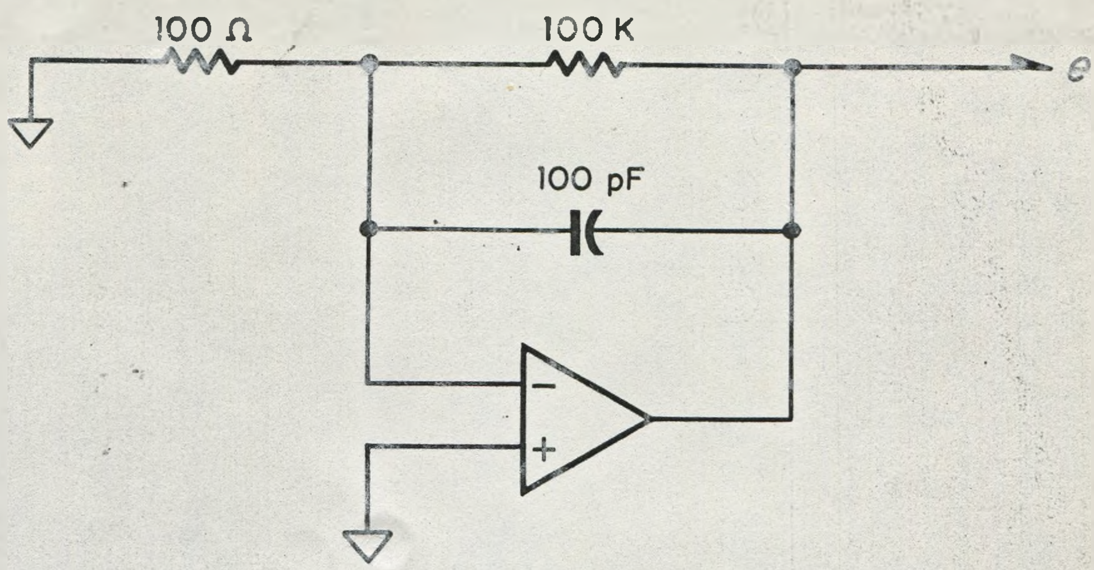

FIG. 2.1

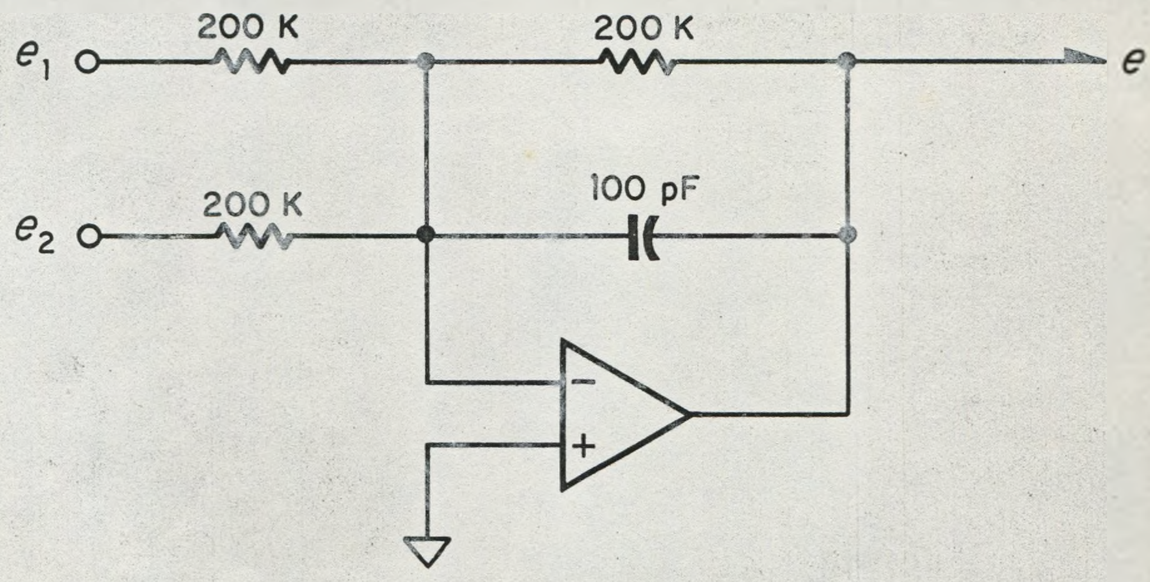

FIG. 2.2

PHILBRICK Φ RESEARCHES

ACCESSORY KITS FOR PHILBRICK SOLID STATE OPERATIONAL INSTRUMENTS

To facilitate the immediate application of Operational Instruments such as Model MP four-amplifier manifold by users who do not have extensive supplies of connection hardware and computing components on hand, Philbrick offers "starter kits" in both categories of accessories. Also available are uncommitted plug-in component boards, with or without metal cases, to fit the accessories sockets provided in these operational instruments.

Model MAK Connection Hardware Kit

Though several manufacturers of electronic hardware offer a wider selection, the kit will be found adequate to fully program four operational amplifiers and make external connections.

Model MAK contains:

2	Shielded cable, twin tips-banana plugs	24	Plug, twin tips to tip jacks, red (Component Mounting, set screws)
1	Shielded cable, twin tips-alligator clips	2	Plug, twin tips to banana jacks, black
12	Patch cord, tip-tip, assorted lengths and colors	12	Shorting bar, metal, twin tips

Model CCK-U Computing Component Kit

Computing grade resistors and capacitors are provided as well as diodes and by-pass capacitors. The tolerance of the computing components, 1% unless stated otherwise, was chosen as the most reasonable compromise between accuracy and cost. While the amplifiers to be programmed may be capable of better accuracy, 1% is adequate for most applications and certainly for the evaluation of operational circuitry. Where the requirements justify their additional cost, more accurate resistors or capacitors are available from a variety of manufacturers and, in a limited range of values, from Philbrick.

Model CCK-U, contains the following components:

4	Diode 1N914	2	Resistor 1/2W met. film 200kΩ
2	Zener Diode 9.5V, 5%	2	Resistor 1/2W met. film 499kΩ
2	Resistor 1/2W met. film 100Ω	4	Resistor 1/2W met. film 1MΩ
2	Resistor 1/2W met. film 1kΩ	2	Resistor 1W 2% comp 10MΩ
2	Resistor 1/2W met. film 2kΩ	4	Capacitor mica 20% 100V 100pF
2	Resistor 1/2W met. film 4.99kΩ	4	Capacitor mica 20% 100V 1000pF
8	Resistor 1/2W met. film 10kΩ	2	Capacitor polystyrene 100V .01µF
8	Resistor 1/2W met. film 20kΩ	2	Capacitor polystyrene 100V .1µF
2	Resistor 1/2W met. film 49.9kΩ	1	Capacitor polystyrene 100V 1µF
4	Resistor 1/2W met. film 100kΩ	4	Capacitor, cer. 50V .1µF $^{+80}_{-20}$%

Model CCK-M Computing Component Kit

The components of Model CCK-U are mounted on stackable twin-tip plugs, ready for insertion in Philbrick solid state operational instruments.

Models SP-O and OSP-O Uncommitted Plug-in Boards

15-contact uncommitted plug-in boards, providing component space of approximately 3 × 2 × 1 inches, are available with metal case (model SP-O) or without case (model OSP-O).

CCK-M B.