TRANS-SONICS

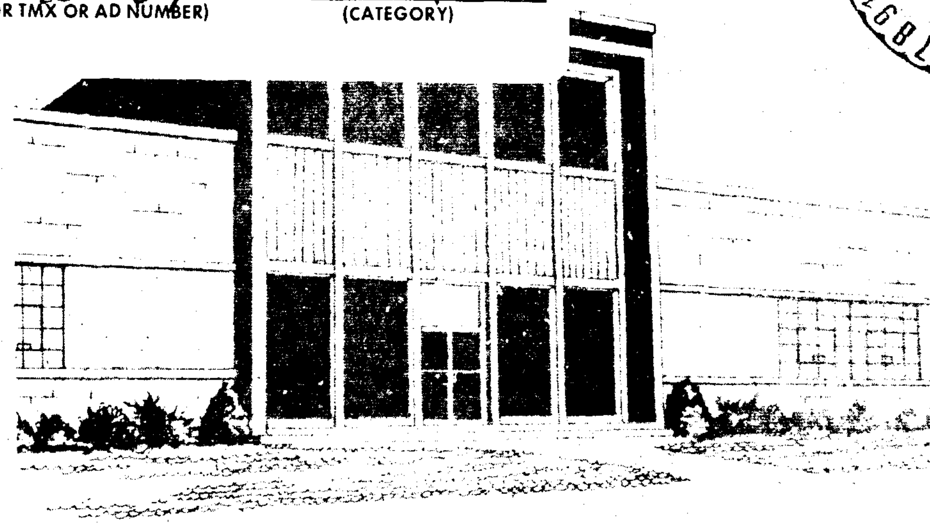
PRECISION D. C. AMPLIFIER

FINAL REPORT

Prepared For:

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION
MARSHALL SPACE FLIGHT CENTER
HUNTSVILLE, ALABAMA

CONTRACT NAS 8-5439



JUNE 1968

TRANS-SONICS, INC., BURLINGTON, MASSACHUSETTS

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ABSTRACT

This is a final report of the work performed under Phase II of Contract NAS 8-5439. Phase II provides for the development of a Precision D. C. Amplifier, using the parametric amplification techniques, and fabrication and delivery of prototype models. Phase I of this contract relative to the 12 Channel Digital Reporting System is complete and the final report has already been submitted.

TABLE OF CONTENTS

1 INTRODUCTION

This is a final report on the development of a Precision D. C. Amplifier under Contract NAS 8-5439. This amplifier was developed to exploit the properties of the Paractor Comparator which had been previously developed. Included in this report is a description of the amplifier, a history of the development, and the performance obtained in prototype evaluation.

The Paractor exhibits large gain (55 db typical) and virtually no zero shift. As a result it is particularly interesting as a device to detect the flow of direct current. The Paractor in combination with associated circuits can be used to make a linear stable dc amplifier.

A feature of the Paractor is its ability to absorb power from low voltage, low impedance dc sources. As a result the "error" voltage in a dc amplifier, having negative feedback, is used efficiently and the signal to noise ratio is favorable.

2 SUMMARY DESCRIPTION

The Precision D.C. Amplifier is a general purpose amplifier especially well suited for use with a wide variety and range of low voltage output transducers. It includes a bridge network and a floating bridge excitation power supply so that all adjustments are self-contained and installation wiring is thereby simplified. The unit is powered by 28 VDC and the output is -5, 0, +5 volts D.C. It is packaged such that 10 units may be mounted side by side in a standard 19" equipment rack. Dimensional outline drawing B122385 is enclosed.

2.1 SPECIAL FEATURES

The amplifier has the following features:

a) High input impedance.

b) High zero input voltage stability.

c) High gain.

d) High gain stability.

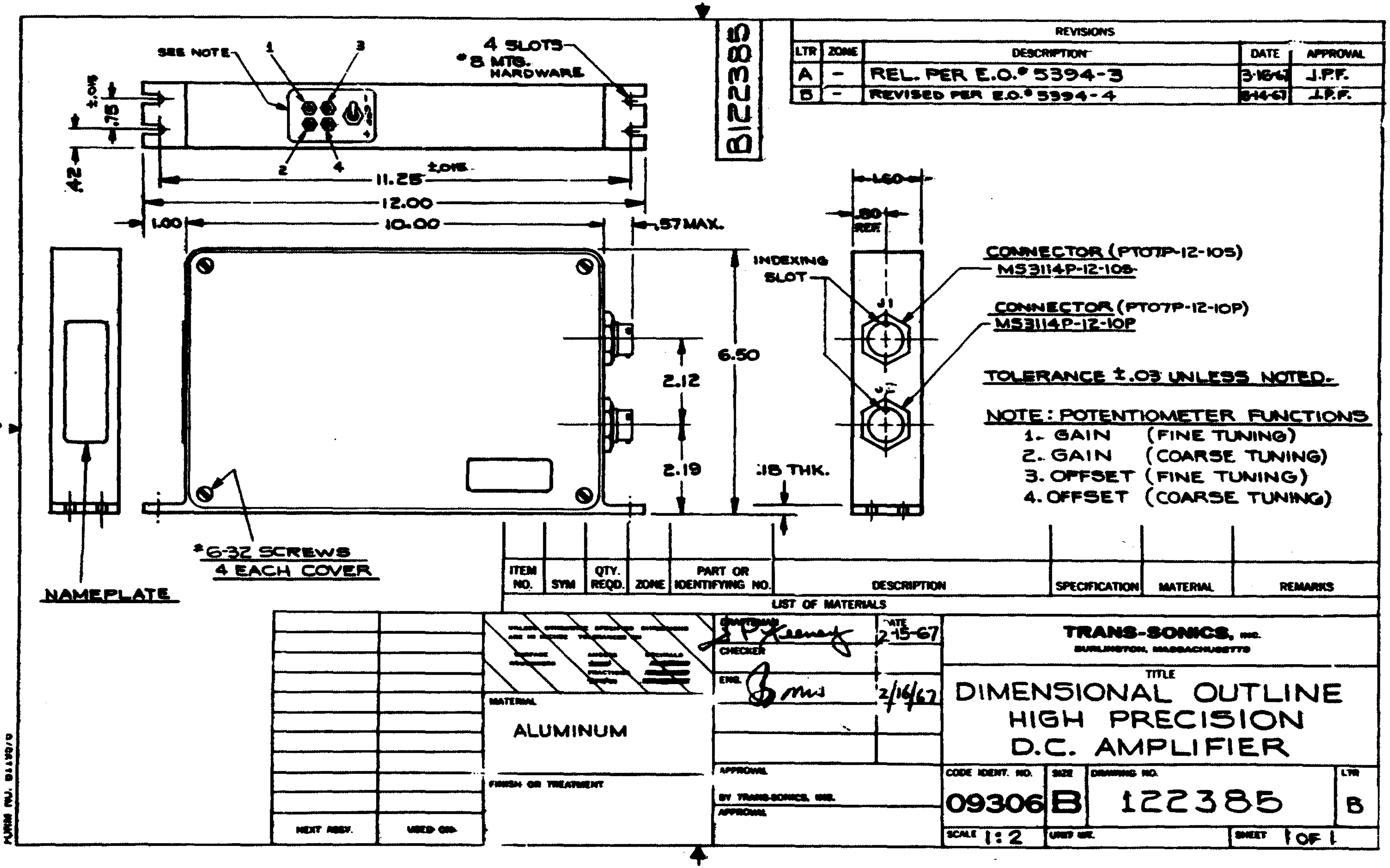
e) Fast response.

f) Complete and instantaneous overload protection.

g) Non-inverting.

2.2 PRINCIPLE OF OPERATION

The principle of operation is based upon the use of the Paractor which was developed under this contract. This Paractor detects and amplifies small error currents flowing in the potentiometric feedback network at the amplifier's input. The gain and zero stability of the amplifier is insensitive to drift typically found in transistor amplifiers. The unit developed also includes a bridge complete network, a


REVISIONS
LTR | ZONE | DESCRIPTION | DATE | APPROVAL
A | - | REL. PER E.O.# 5394-3 | 3-16-67 | J.P.F.
B | - | REVISED PER E.O.# 5394-4 | 6-14-67 | J.P.F.
B122385
SEE NOTE
4 SLOTS
#8 MTG. HARDWARE
11.25 ±.015
12.00
1.00
10.00
.57 MAX.
.42
.75
±.015
1.60
.80 REF.
INDEXING SLOT
6.50
2.12
2.19
.15 THK.
J1
J2
CONNECTOR (PT07P-12-10S)
MS3114P-12-10S
CONNECTOR (PT07P-12-10P)
MS3114P-12-10P
TOLERANCE ±.03 UNLESS NOTED.
NOTE: POTENTIOMETER FUNCTIONS
1. GAIN (FINE TUNING)
2. GAIN (COARSE TUNING)
3. OFFSET (FINE TUNING)
4. OFFSET (COARSE TUNING)
#6-32 SCREWS
4 EACH COVER
NAMEPLATE
ITEM NO. | SYM | QTY. REQD. | ZONE | PART OR IDENTIFYING NO. | DESCRIPTION | SPECIFICATION | MATERIAL | REMARKS
LIST OF MATERIALS
DRAFTSMAN
DATE 2-15-67
CHECKER
ENG. 2/16/67
MATERIAL
ALUMINUM
FINISH OR TREATMENT
APPROVAL
BY TRANS-SONICS, INC.
APPROVAL
NEXT ASSY.
USED ON
TRANS-SONICS, INC.
BURLINGTON, MASSACHUSETTS
TITLE
DIMENSIONAL OUTLINE
HIGH PRECISION
D.C. AMPLIFIER
CODE IDENT. NO. 09306
SIZE B
DRAWING NO. 122385
LTR B
SCALE 1:2
SHEET 1 OF 1

floating bridge excitation voltage source, a continuously adjustable gain control and a continuously adjustable input voltage offset control.

3 HISTORY

Before going into a detailed description of the Digital Reporting System, a brief history of the development of the Paractor will be helpful in making clear the reasons for certain choices and also to indicate the basic advantages of the system.

Several years ago, Dr. Hans Klemperer of Trans-Sonics, Inc., began investigating the possibility of controlling the phase of Paramatrons with dc current. The Paramatron, developed by Eiichi Goto at the University of Tokyo, has been used in large quantities as a basic amplifying element in Japanese digital computers. The Paramatron is capable of oscillating in either of two phases 0 or π. The two phases were used to represent 0 and 1 in binary language.

In order to control the Paramatrons, Klemperer set up a second harmonic magnetic modulator and used it to develop the necessary synchronizing signals.

During his experiments he noticed a mode of operation which seemed to involve much greater sensitivity than normally expected from a second harmonic modulator. Further investigation of the phenomenon by Klemperer, Prevot and Mott-Smith showed that parametric amplification of dc flux in the magnetic structure was occurring.

The device exhibiting this amplification was given the name Paractor from "parametric reactor". The Klemperer Paractor was driven by continuous wave, ac, and developed a large ac output in the form of a self-oscillation, the phase of which was under the control of the dc signal. Only two phases could be generated, 0 and π, and these were treated as 0 and 1 in binary language. The circuit was of the super regenerative type in that the phase could not be changed without first stopping the oscillations.

Further development indicated that this Paractor while exhibiting extraordinary gain had one property which in the case of the applications contemplated was extremely unfortunate. The Paractor "remembered" large input signals. Any overload of the control winding caused a zero shift in the Paractor which was equivalent to a dc current in the input winding.

Prevot then undertook to modify the Paractor to eliminate this undesirable property while preserving as much as possible the desirable characteristics of the original Klemperer Paractor oscillator. The new device is known as a pulsed Paractor.

3.1 THE PULSED PARACTOR

The pulsed Paractor may be best understood by considering first a second harmonic magnetic modulator.

Detection and amplification of low level dc currents can be accomplished by magnetic amplifiers. The magnetic amplifier known as a second harmonic modulator is the most sensitive of standard types. However, these modulators exhibit undesirable properties which make them unsuitable for many applications. These characteristics are primarily concerned with size, weight, slow response to an input signal and insufficient sensitivity. They arise in part because of a fundamental interplay between the requirements of high sensitivity and low memory. It can be shown that the sensitivity of a second harmonic modulator increases with excitation frequency. However, as the excitation frequency is increased, side effects occur which makes it necessary to drive the modulator with higher and higher power.

Neglecting eddy currents the number of ampere turns required to saturate a core is relatively independent of frequency. Starting with a design which is suitable for low frequency applications, it might be thought that a simple increase in frequency would increase the sensitivity. This is true up to a point.

At a certain point the natural frequency of the drive coil, resulting from self capacitance and inductance, is approached. At this point the capacitance of the coil shunts the drive current and it becomes difficult to obtain sufficient magnetic flux in the cores.

The next step that a designer might take is to reduce the number of turns on the drive coil (and usually it is necessary to reduce the number of turns on the input coil as well). This results in reduced capacitive shunting but requires higher drive current. Ultimately, copper losses in the windings and in the driving oscillator limit this approach. In addition, losses increase because of eddy currents circulating in the cores. Not only do the eddy currents waste power but they also prevent the penetration of the flux to the center of the core. These two effects taken together put a deiling on the drive frequency. In addition, the expected increase in sensitivity at the frequency limit is not fully realized because the drive coils must also be reduced in number of turns thus lowering the effect of the input current. The designer finds himself in a "box" in which he cannot realize the full potential of the core materials.

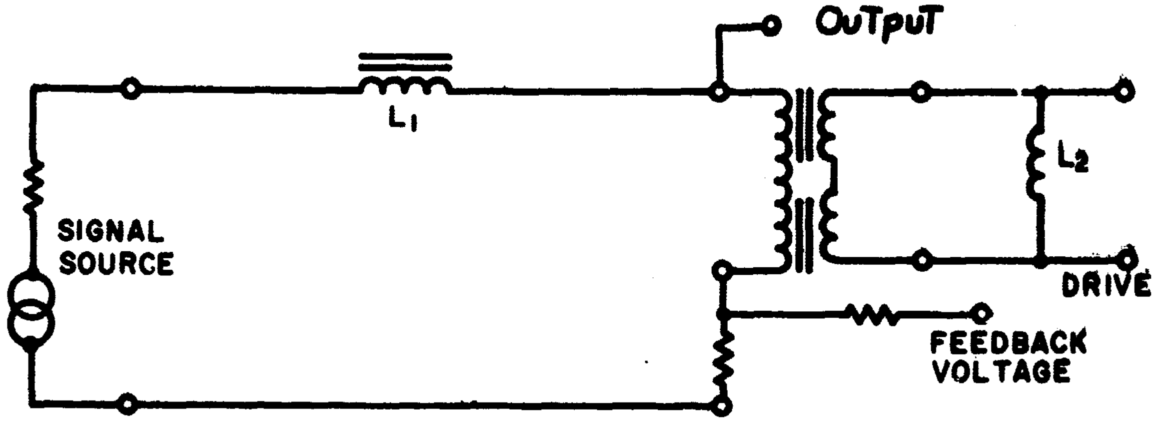
In the pase designers have attempted to solve this by pulsing the cores but it does not appear that they have understood all of the conditions necessary to obtain maximum amplification.

3.2 DESCRIPTION OF THE PARACTOR

The Paractor overcomes these problems. In view of the fact that this device employs the same coil for input control and output signal, it is important to agree on the terminology. The coil which carries the control or input signal as well as the output pulses is referred to as the flux coil, see Figures 1 and 2. The two coils through which the drive pulse is applied are called drive coils, and the circuit which includes the drive coils and the apparatus driving the coils is referred to as the drive circuit.

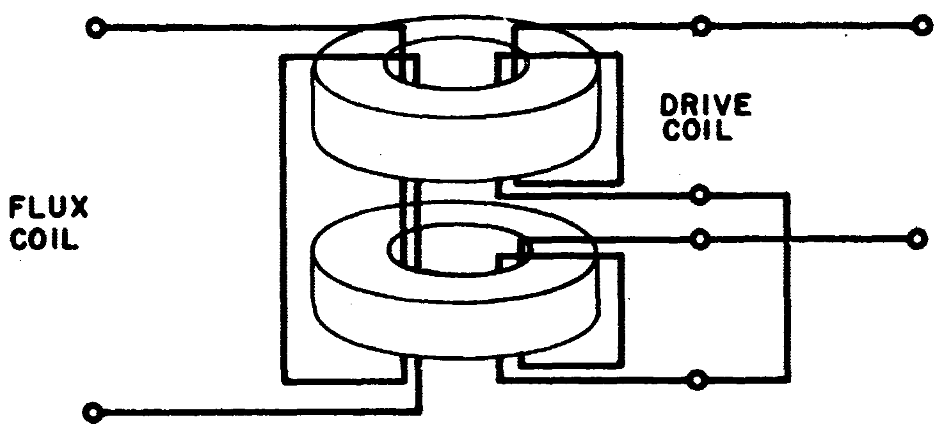
After a considerable mathematical analysis, it was realized that the pulse driven magnetic modulator might be thought of as working in the following way. The function of the drive coils is merely to establish the permeability of the cores around which the flux coil is wound. In order to prevent drive currents from being induced in the flux coil, the magnetic material is divided into two cores each of which carries a drive coil. The drive coils are connected so that the drive flux induced in each of the two cores is in opposite directions. For example, the upper core might have flux induced in the clock-wise direction while the lower core might have flux induced in the counter-clockwise direction. If these fluxes are identical, no voltage is induced in the flux coil which threads both cores. See Figure 2.

Immediately before the drive pulse is applied, the cores are in a state of high permeability. Any signal current flowing in the flux coil will result in a relatively high flux being induced in the two cores inside the flux coil. This flux is caused by the control signal operating on the high permeability of the cores.



PULSED PARACTOR

FIGURE 1



PARACTOR MAGNETIC CIRCUIT

FIGURE 2

$$\phi = K\mu H = K\mu i$$

ϕ = flux μ = permeability H = magneto-motive force

i = flux coil current K = constant

The drive pulses are of sufficient amplitude to drive the cores into saturation. As the cores saturate the instantaneous permeability of the iron decreases and approaches zero as a limit. As the permeability approaches zero, the flux induced by the control signal must disappear since the permeability is too low to support the flux. As the flux disappears a voltage is induced in the flux coil as a result of the rate of change of flux $\frac{d\phi}{dt}$. This voltage is the output signal. Obviously rapid saturation is necessary to obtain large output. This is accomplished by driving the cores with a large current as can be done with a pulse wave shape since the duty cycle is low.

This measure is not in itself sufficient to obtain all the sensitivity possible. It will be realized that if the flux coil is terminated in a low impedance, current will flow in this circuit as the cores saturate. By Lenz's law it will be seen that this current is in the direction to prevent the decay of the control flux. Thus the flux coil current prevents the gradual decay of flux in the cores. Finally, as the permeability of the cores approaches zero, the flux coil current can no longer prevent the decay of flux, and a sudden pulse appears across the flux coil. The internal inductance of the flux coil and the impedance of the output circuit determines the magnitude of this pulse. The pulse is sharp and occurs almost at the time when the permeability of the cores reach zero. The inductor L_1 is chosen to provide a high impedance to the sharp pulse. See Figure 1. It is this concentration of the output voltage in a short time which results in the large voltage gain of the device.

However, even though most of the core is driven to saturation, eddy currents might prevent the central part of each core from being completely magnitized. If any part of the core is not completely magnitized, that part will hold the dc flux induced in it by powerful control signals. This flux is equivalent to an input current and represents a zero shift. The zero shift can be sufficiently large to establish a relatively high minimum control signal level and it is important therefore that any residual dc fluxes induced by the control or flux coil are completely wiped away. Complete saturation of both cores does this. The pulse is chosen so that it is sufficiently long and intense to allow the drive flux to penetrate to the center of the cores. When this has occurred, the cores are ready to be reset to a condition of high permeability.

Resetting is accomplished by allowing a reverse current to flow in the drive circuit so as to reset the drive flux in each core to a region of maximum permeability. The amount of reset must be controlled exactly. This is accomplished by shunt inductance L_2 across the drive circuit. The back swing of this inductance is proportional to the drive amplitude. By establishing and holding the correct drive amplitude, the exact amount of reverse current can be established.

The magnetic material is chosen to obtain high permeability between pulses. However, even high permeability materials such as Permalloy can have their BH curves modified by heat treatment. It has been found that a heat treatment to give a "soft" BH curve is optimum. A hard BH curve has almost vertical sides. This makes the resetting of the flux levels extremely critical. Also the cores tend not to generate flux for weak signals. By making the BH curve less steep and narrower, as can be done by the proper heat treatment of Permalloy, a maximum flux results from the control signal.

These techniques make it possible to design a magnetic modulator which can be wound with very few turns in both the drive and control coils. Since the number of turns required is small, the cores can be made small. Aside from the desirable characteristic that the whole device is then small and light in weight, the small cores result in low reluctance. This low reluctance further enchances the sensitivity of the device. In addition, the inductance is sufficiently low to permit the rapid modulation of the core's permeability which of course is the keystone to the high sensitivity.

In addition, to the above effects, it has been found that by proper choice of the pulse repetition frequency, the back-swing of the output pulse at the flux coil (remembering that the flux coil has a relatively high inductance when the cores are not saturated), can be caused to reinforce the original control current. This has been shown to be mathematically equivalent to negative resistance in series with the flux coil. It is possible in fact to make the system regenerative so that it will lock in one extreme condition or the other. By the choice of an intermediate degree of regeneration, substantially high but controlled reinforcement of the input signal can be obtained.

The magnetic modulators designed on Contract NAS 8-5439 have the above features. They have exhibited gains as high as 60 db. Fifty-five db is considered a practical production figure. Signals in the order of 10^{-15} watts at the input circuit have been amplified successfully.

A further point to be made is that the resistance of the flux coil is extremely low so that the device can be used to amplify weak signals from low impedance sources. This means that it is suitable for amplifying extremely low voltages from high current sources such as thermocouples measuring small differential temperatures. For this reason the device is probably more suitable than any competitive electronic technique for measuring small differential temperatures as might occur in thermal survey work.

3.3 APPLICATIONS

The Paractor is well suited for use as an error detector in dc amplifiers with potentiometric voltage feedback. It is also suited as a precision current amplifier with isolated input. More than one flux coil can be employed so that several inputs may be added magnetically. The device can be used as a threshold detector where the output pulses are used to command digital cricuitry.

One of the outgrowths of the development of the Paractor has been the ability to design amplifiers and digital reporting equipment capable of efficiently handling signals from low voltage, low impedance sources. This characteristic of the Paractor along with the ability to locate the Paractor remotely, close to the source of the signal, makes it possible to record very small voltages, particularly if these voltages are available from a low impedance source. Quite generally in instrumentation systems, low voltage is accompanied by low impedance and therefore the Paractor can be used in these measurements with a minimum of difficulty.

4 AMPLIFIER DESCRIPTION

The Precision D.C. Amplifier is a new concept in precision amplifiers. In a sense the new amplifier is a complete signal conditioning system which provides several functions besides amplification.

Basically the device accepts almost any type of variable D.C. signal and almost any type of resistance sensor including strain gages. The amplifier output is a D.C. voltage at low impedance having the range -5 to +5 volts or -10 to +10 volts so that unipolar or bipolar signals may be handled.* By suitable choice of load resistor the system can be made to limit sharply at any voltage between 5 and 10 volts.

The system has provisions for several bridge completion networks so that single, two or four active strain gages can be used. In addition various configurations of bridge resistors can be set up to accommodate a variety of resistance thermometer circuits.

The amplifier also accepts thermocouple signals and permits precise measurements over small temperature spans.

A high stability internal power supply provides excitation for strain gage bridges or resistance thermometers so that no external equipment other than the sensor itself is required.

The design philosophy has been to keep all errors of the signal conditioning system so small that they contribute an insignificant error to the measurement. In this way the potential accuracy of a strain gage or resistance thermometer can be realized.

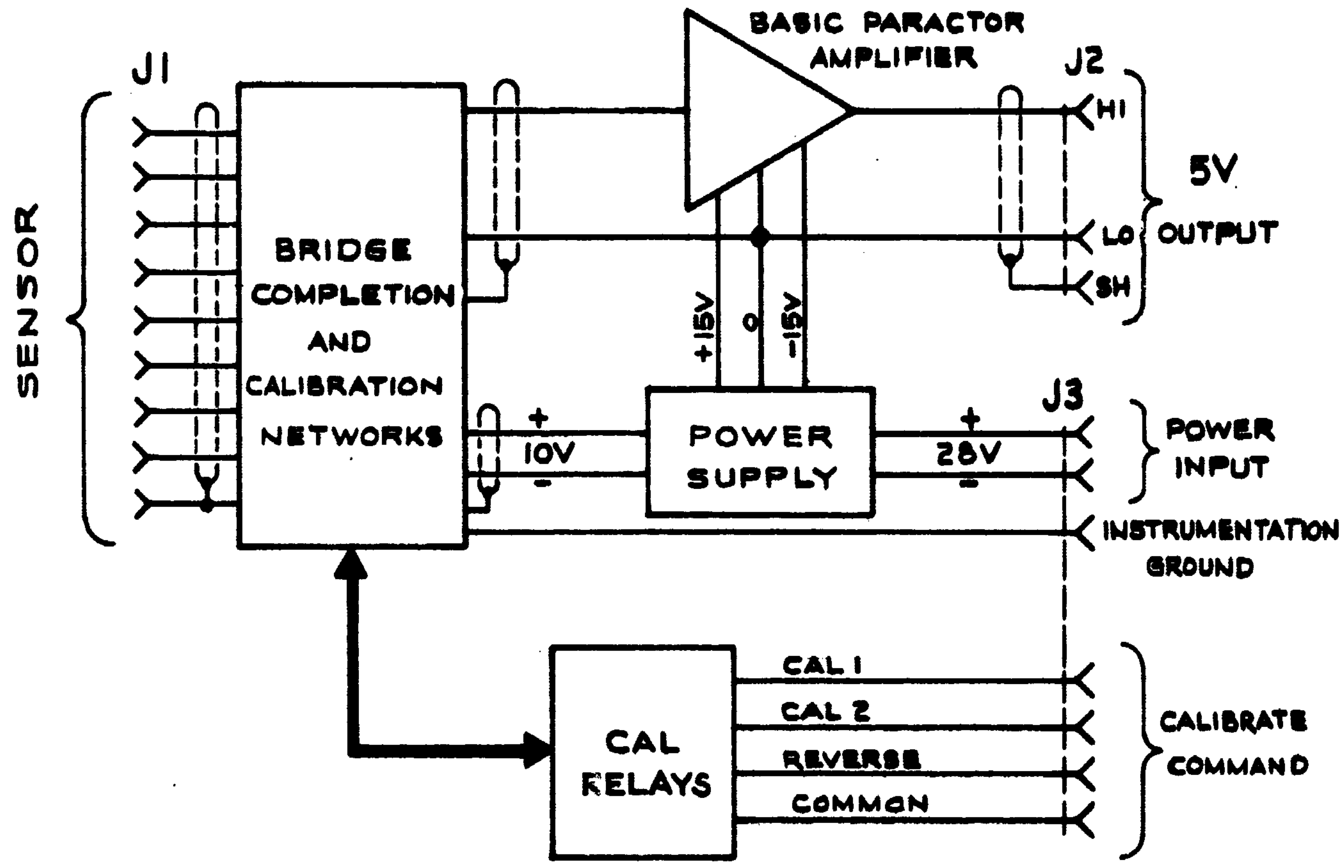
*Accuracies are stated as a percentage of 5 volts so that the accuracy applies for an unipolar signal 0-5 volts out. Percentage accuracy is better if output is used over an interval -5 to +5 volts.

Figure 3. is a simplified schematic of the amplifier. It will be noted that the system includes an instrument power supply, a bridge completion network, calibration relays and an ultra stable Paractor Amplifier.

Since the Paractor Amplifier is fundamental to the system, we will describe it first. Figure 4. is a simplified circuit diagram of the amplifier section. Amplification is accomplished in two steps. This method of amplification with two independent feedback loops results in greater stability, the control of the amplifier bandwidth independent of gain setting, and permits the separation of the zero offset circuit from the adjustable gain circuit.

The amplifier operates by comparing a precise fraction of the output voltage with the D.C. potential to be amplified. The difference potential appears across the flux coil (control coil) of a parametric D.C. amplifier stage named a Paractor. See Figure 5.

The Paractor includes a pair of high permeability torroidal cores which are used in a "flux pumping circuit" that generates a D.C. output. The power gain of the Paractor comparator is over 50 db, so that all of the following amplification is at a much higher level. The Paractor might be compared in function with the familiar mechanical or photo diode chopper with the exception that its gain is 55 db instead of unity. It is this fact that in large measure accounts for the extraordinary performance of the amplifier. Note that the operational amplifier marked "A" in Figure 5. is D.C. coupled. The Paractor is used as a D.C. to D.C. amplification stage.



SIMPLIFIED SCHEMATIC
PRECISION D.C. AMPLIFIER

FIG 3

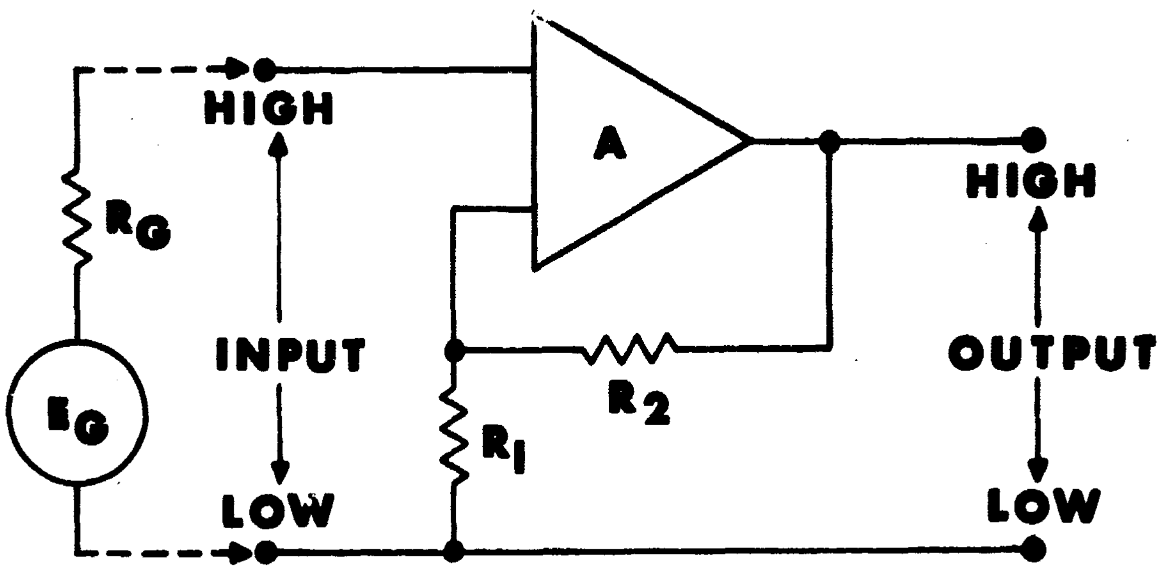
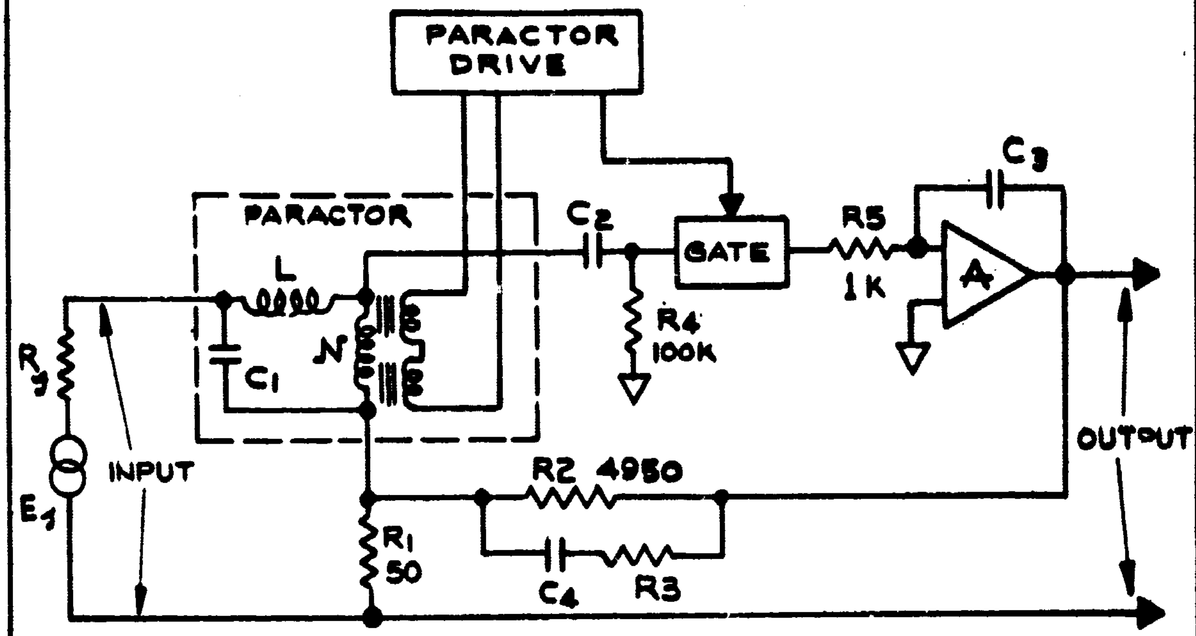


FIGURE 4



LOW LEVEL PREAMPLIFIER

L = 10 MILLIHENRY
C_1 = 0.1 MF
C_2 = 0.1 MF
C_3 = 820 PICOFARAD
C_4 = 0.05 MF
R_j = 0 TO 350 OHM

FIGURE 5

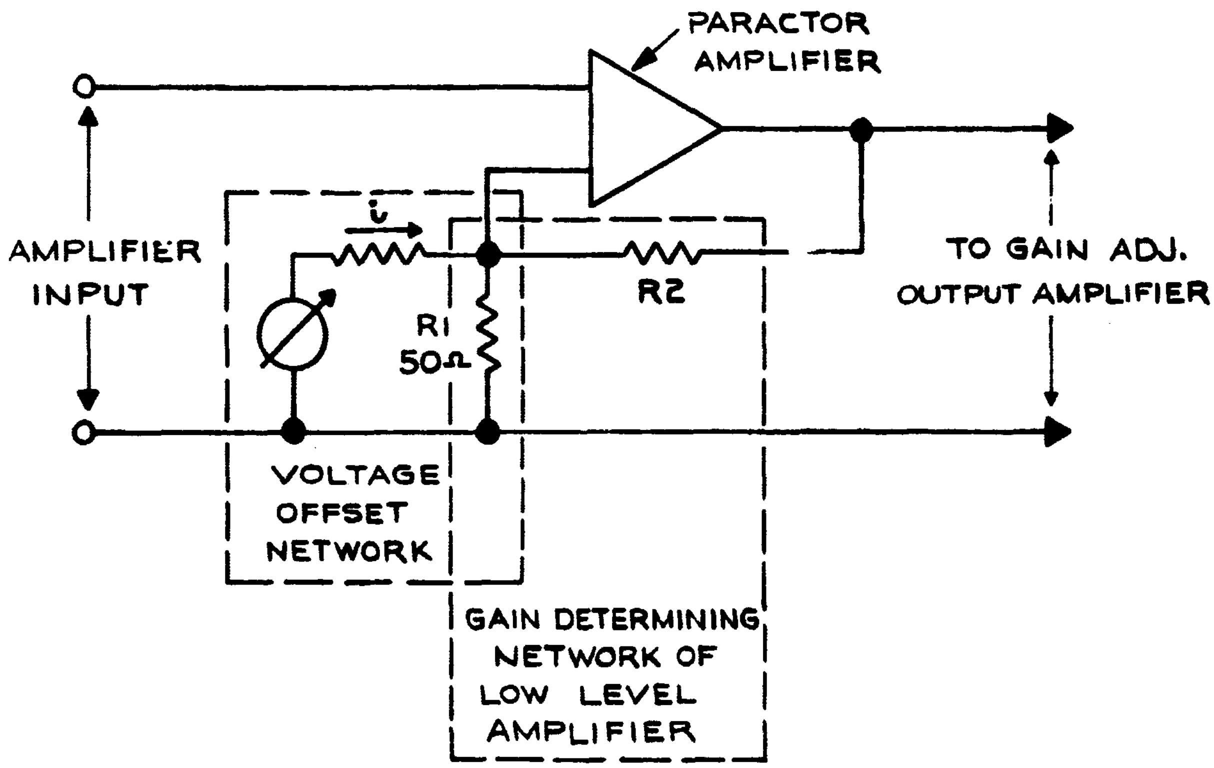
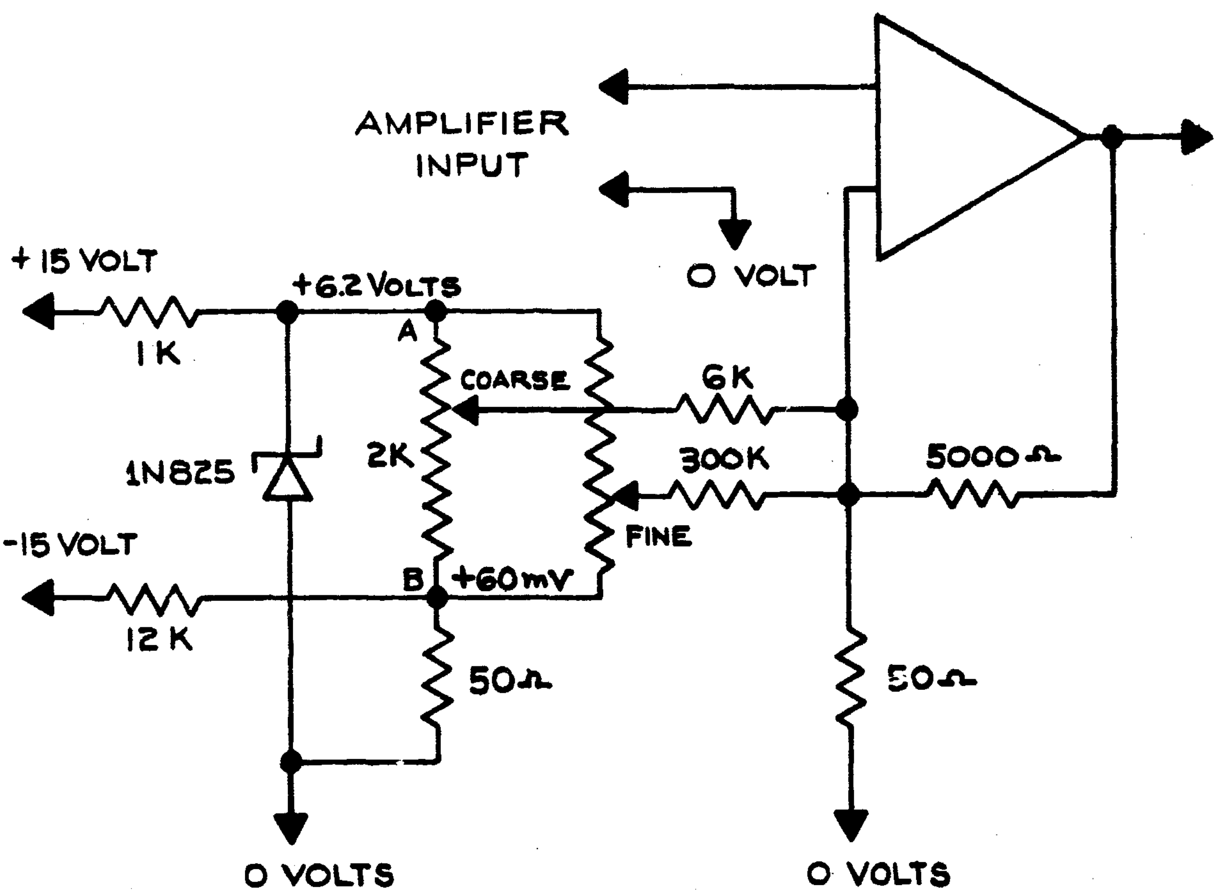
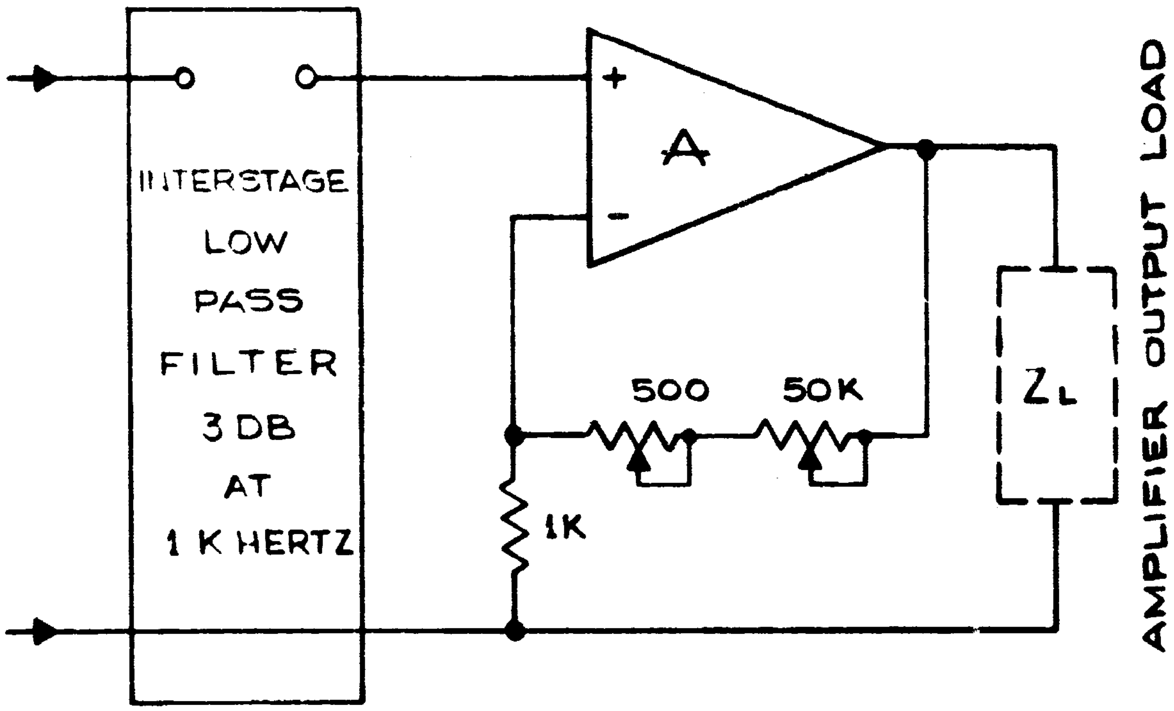

PARACTOR
AMPLIFIER
AMPLIFIER
INPUT
i
R2
R1
50Ω
TO GAIN ADJ.
OUTPUT AMPLIFIER
VOLTAGE
OFFSET
NETWORK
GAIN DETERMINING
NETWORK OF
LOW LEVEL
AMPLIFIER

FIGURE 6



OFFSET VOLTAGE NETWORK

FIGURE 7



PRECISION AMPLIFIER GAIN ADJUSTABLE OUTPUT STAGE

FIGURE 8

Referring again to Figure 4, amplification is accomplished in two stages. The first stage includes a zero offset adjustment shown in Figure 6. Offset independent of the input circuit is accomplished by passing a precisely regulated current through the feedback node resistor R1. Fine and coarse controls for this current are provided on the top panel. By the use of zero offset additional resolution and accuracy can sometimes be obtained. For example, the amplifier could be set up to amplify an input voltage from 40 to 50 millivolts generating 0 to 5 volts for this range. The zero offset can also be used to block out the initial voltage across a resistance thermometer that is excited from a constant current source. Positive or negative zero offset can be obtained. The tolerance on the adjustable offset voltage is ±0.1% of the offset.

Figure 6. also shows the fixed feedback resistor R2 which in combination with R1 determines the gain of the input amplifier. The input amplifier operates to cause the voltage across R1 to be equal to the voltage of the amplifier input terminal. As a result a very high impedance is presented to the input. For example, the D.C. input impedance is in the order of 100 megohms. Figure 7. shows the offset network in greater detail to clarify the relationship between fine and coarse adjustments. In order that the offset may be either positive or negative, a separate polarity switch is provided. Therefore, zero suppression as well as zero offset is available.

The amplifier output stage is shown in Figure 8. This stage includes a low pass filter designed to limit the bandwidth to one kHz. The gain is adjustable by means of coarse and fine rheostats in the feedback circuit. The circuit results in an extremely low output impedance

(0.1 ohm). Consequently the amplifier can drive any load requiring less than 20 milliamps. Automatic limiting at 20 milliamperes is provided so that the output stage is not harmed by a short circuit.

Additionally the current limiting feature can be used to set an output voltage limit by simply shunting the output with a resistor whose resistance value is chosen to draw 20 milliamperes at the desired limiting voltage. This feature is particularly useful when a commutator or telemetry system is being used. In this case the limiting action prevents an overloaded amplifier from delivering a signal large enough to interfere with an adjacent channel.

4.1 BRIDGE COMPLETION AND CALIBRATION CIRCUITS

The Precision Amplifier has provisions for internal bridge completion networks. For this purpose the amplifier is provided with 3 plug in bridge completion cards. Additional cards may be added.

4.2 FOR STRAIN GAGES

Figures 9, 10 and 11 represent the conventional Strain Gage Bridge Circuits with completion networks. Three relays K1, K2 and KR and two calibration resistors Rcal 1 and Rcal 2 provide a step bipolar shunt calibration. A plug in card arrangement will permit fast circuit conversions.

It will be seen that Figure 9 is for 1 external arm and 3 bridge completion resistors, included within the precision D.C. amplifier. This circuit would be used only when it is not feasible to put a second strain gage at the test object. This is because there will be no temperature compensation of the strain gage or sensor (R_x).

Figure 10 shows the preferred circuits for single strain gage measurements but with two external arms or gages. The two gages will be exposed to the same temperature environment and hence a degree of compensation for temperature errors is achieved.

Figure 11 shows the circuit for use with a typical strain gage pressure transducer or load cell, all 4 bridge arms see essentially the same temperature and environment.

4.3 FOR RESISTANCE THERMOMETERS

Figures 12, 13 and 14 describe different resistance thermometer configurations. They differ in complexity to realize differing degrees of lead wire error compensation. In Figure 12 the simplest 2 wire connection is shown. Any change in lead wire resistance is indistinguishable for changes in sensor resistance. This would be most suitable for use with high resistance sensors, where lead lengths are at a minimum. Figure 13 shows the Siemens three wire circuit where equal variations in the lead wires on opposite sides of the bridge cancel each other. Inaccuracy results if the leads become unbalanced to each other, for example, at a connector interface.

A still further degree of compensation is attained in the circuit as shown in Figure 14. This circuit is a classical Kelvin double bridge which for small unbalances closely approximate a true 4 terminal resistance measurements.

It should be noted in both Figures 13 and 14 that the calibration relay contacts are so arranged that contact resistance causes only very small errors because in each case excitation current flows through one pair of relay contacts while voltage is sensed through another relay contact.

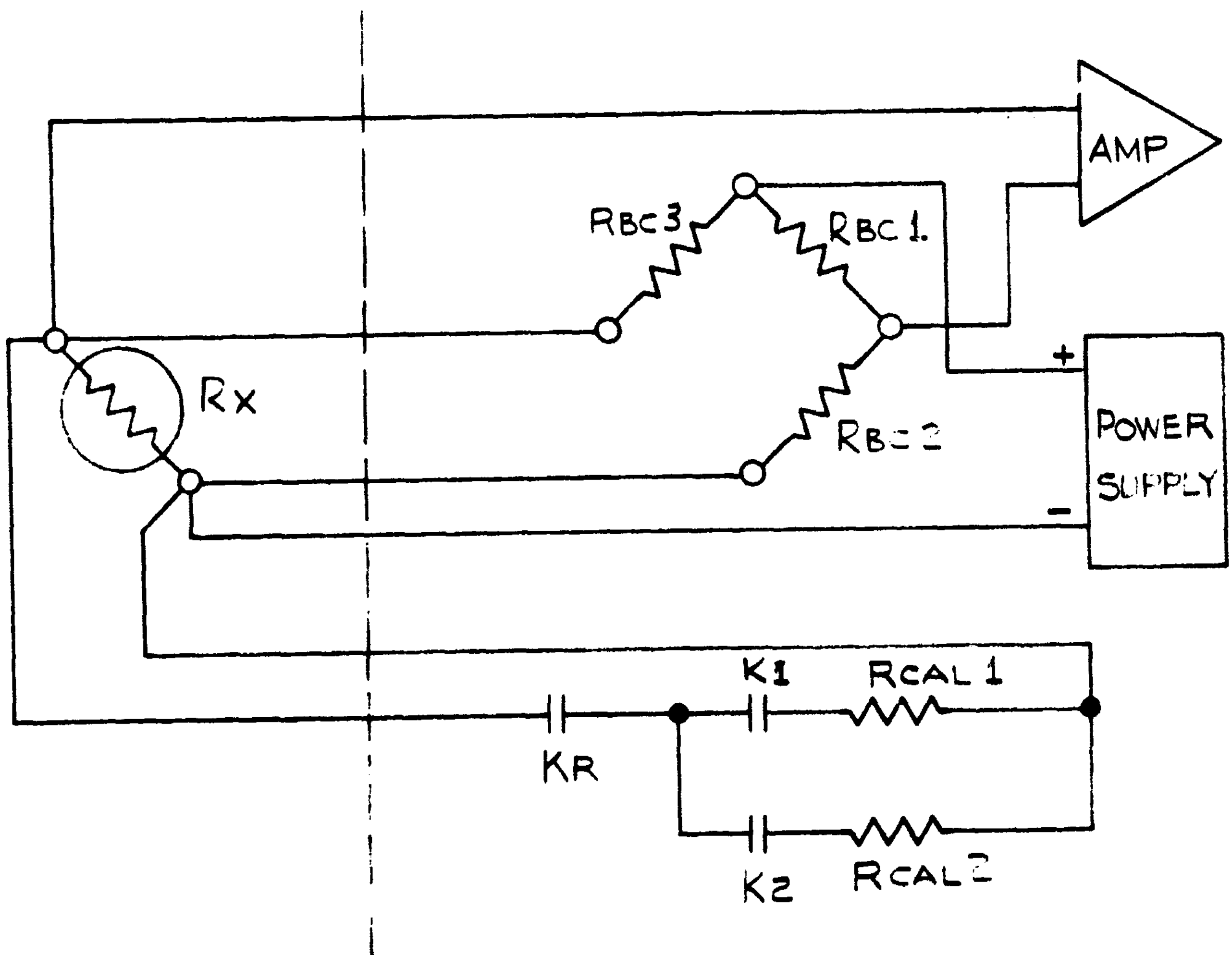


FIG. 9

STRAIN GAGE - 1 EXTERNAL ARM

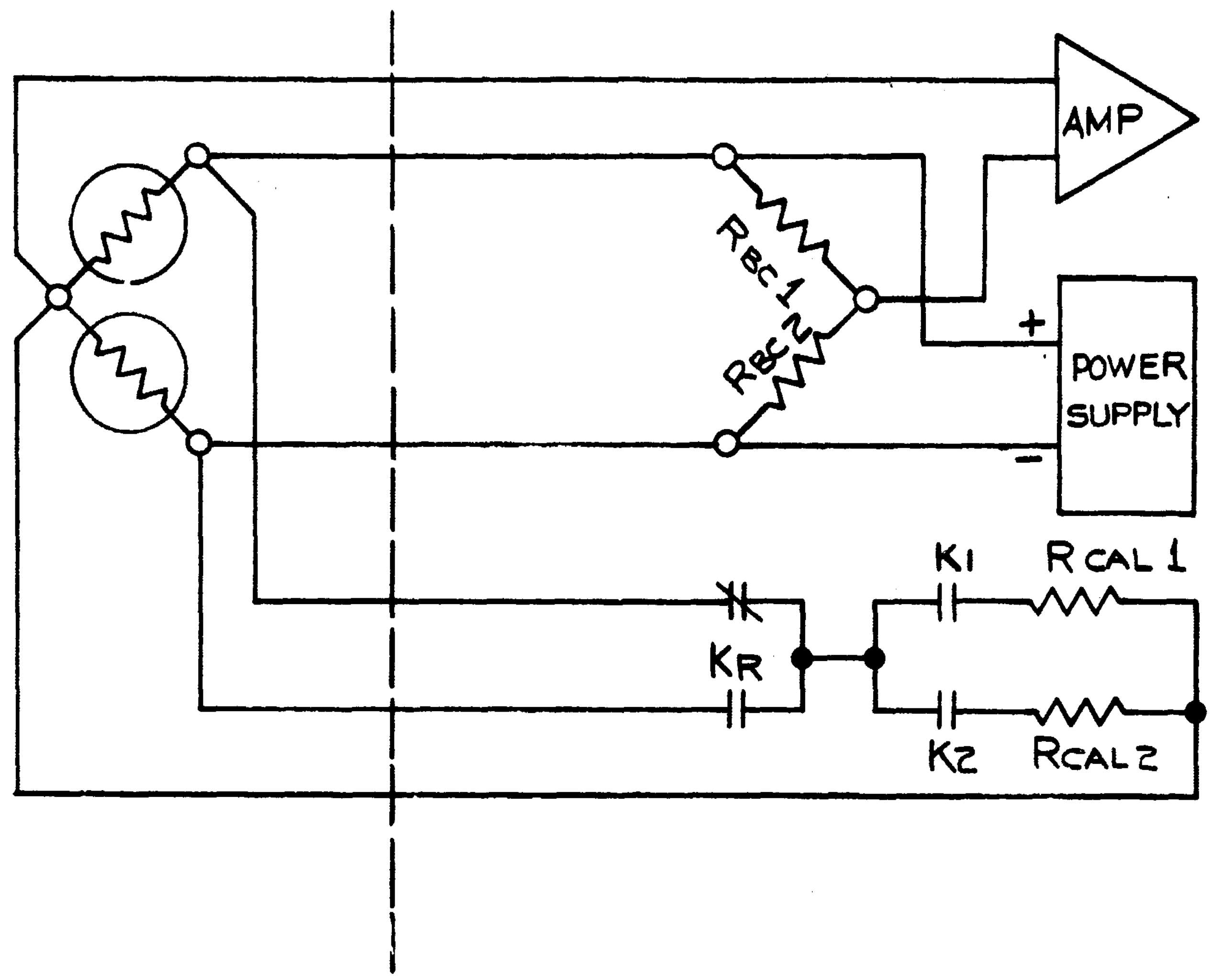


FIG. 10

STRAIN GAGE - 2 EXTERNAL ARM

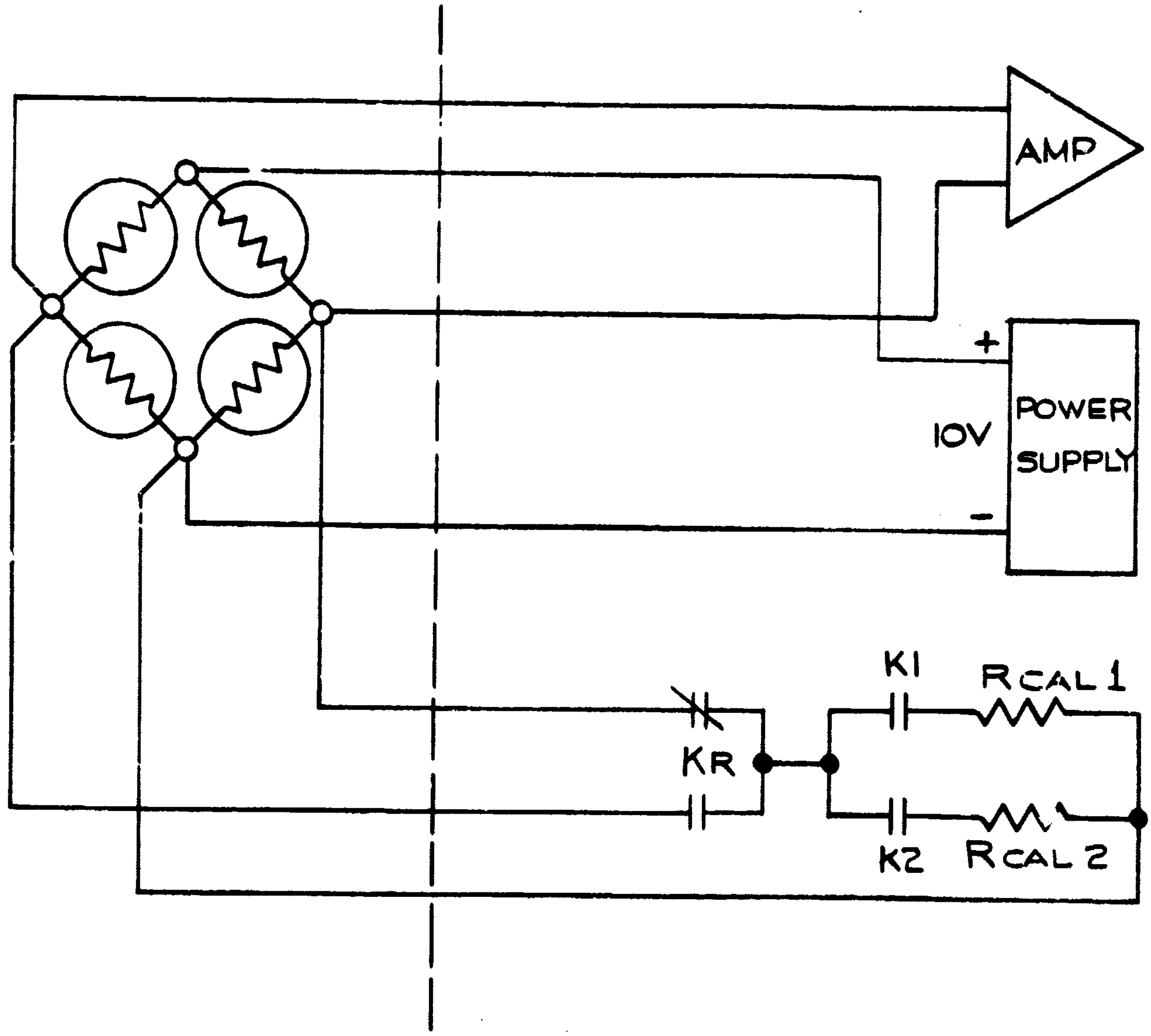


FIG. 11

STRAIN GAGE – 4 EXTERNAL ARM

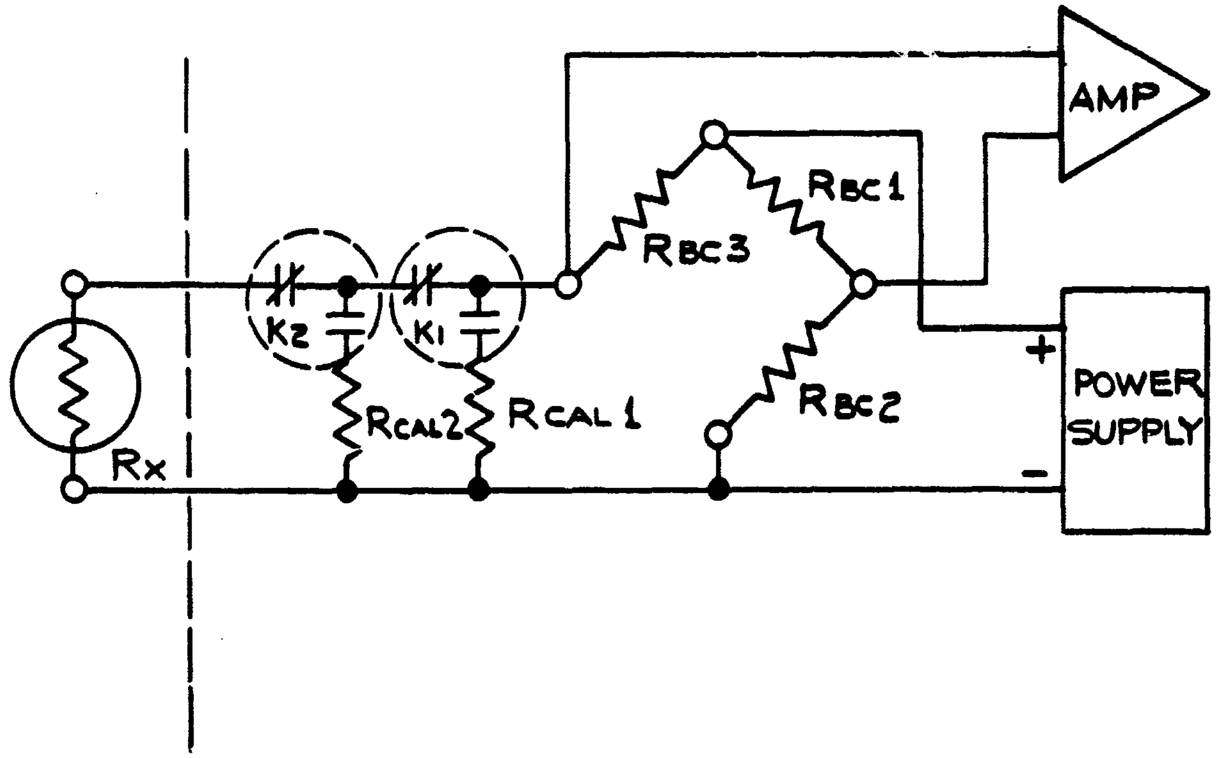


FIG. 12

RESISTANCE THERMOMETER
2 WIRE CONNECTION

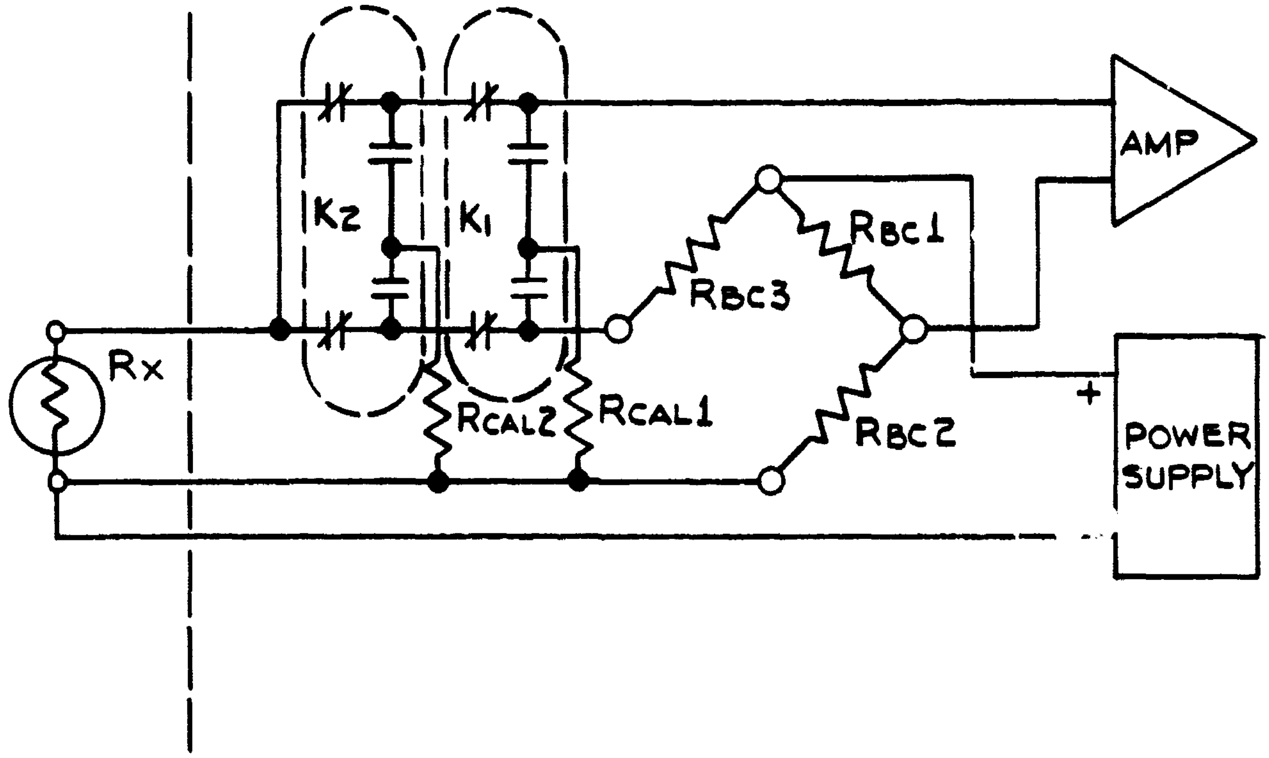


FIG. 13

RESISTANCE THERMOMETER – 3 WIRE CONNECTION

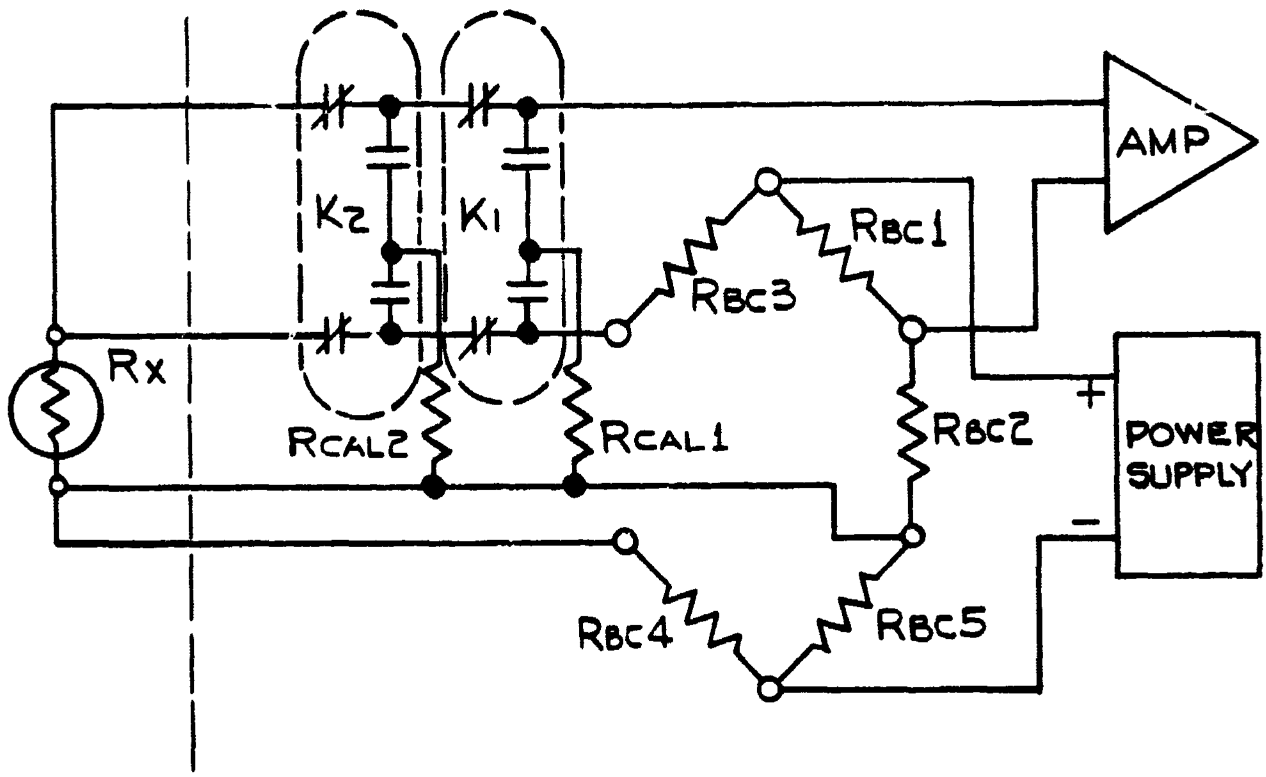


FIG. 14

RESISTANCE THERMOMETER—4 WIRE CONNECTION

4.4 SHIELDING AND ISOLATION

The entire amplifier is shielded, the shield being insulated from the outside case so that it will not be shorted to the mounting. The 28 VDC input power and the calibration relay coil circuits are shielded from the signal circuits so that they do not inject spurious noise into the signal path.

The 28V input supply is shielded and isolated by the use of a D.C. to D.C. Converter using a special transformer with double electrostatic shielding.

Special precautions will be taken to ensure minimum capacitance between the calibration sets and the calibration relay coil circuits.

4.5 POWER SUPPLY

In addition to the internal power supply the Precision Amplifier provides 10 volts bridge or resistor excitation capable of delivering up to 35 milliamps. The regulation is 0.025 percent (0.00025) for input voltage and load variations over the temperature range 32 degrees F to 150 degrees F.

4.6 FREQUENCY RESPONSE

The precision amplifier was designed to have a flat frequency response from D.C. to 1 Kilohertz, with 3 DB or less of attenuation at 1 Kilohertz. The design insures this frequency response for gain setting from 40 to 54 Decibels (50 to 10 mV input signal for full output). At higher gain setting from 54 to 74 Decibels (10 to 1 mV for full output) the bandwidth is gradually reduced from 1 Kilohertz to 100 hertz per second with a consequent improvement of signal to noise ratio.

Figure 15 shows the frequency response at three gain settings. The bandwidth is deliverately reduced for the higher gain settings in order to maintain a high signal to noise ratio. Since most potentials in the neighborhood of 1 millivolt are from thermocouples which are usually slow, the reduction in bandwidth does not appear to sacrifice performance.

Figure 16 shows the response to negative and positive step voltage at two gain settings.

4.7 PACKAGING

Outline dimensions are shown in Drawing B122385. It will be seen that the case has a body size of 6.5" x 10.0" x 1.6" with provisions for base mounting using #8 screws. The width allows 10 amplifiers to fit in a standard drawer of a 19" rack.

Controls are provided on the top surface of the amplifier for the adjustment of zero (coarse and fine) and gain (coarse and fine). In addition there is a 3-position switch which allows the operator to select zero offset polarity or to disengage the source of offset voltage.

Two connectors are provided at the rear of the Amplifier. The connector J1-MS3114-12-10S is provided for connection to the bridge completion networks included within the Amplifier. The connector J2-MS3114-12-10P is provided for D.C. Power Input, Amplifier Output and Bridge Completion Network Relay Coil Input.

The plug-in bridge completion network cards are made accessible by removing the side cover of the Amplifier. A total of 4 different plug-in bridge completion cards are supplied with each Amplifier. With the addition of the desired bridge completion resistors to these cards, it is possible to obtain the six configurations shown in Figures 9 thru 14. Type RB55 resistors may be soldered to the terminals on the removable cards.

The main circuit board of the Amplifier is mounted directly to the case via 4 screws. The inverter and individual power supplies were designed in modular form for minimum size and such that they could be easily serviced. Test points are provided at appropriate places in the circuit to facilitate bench check out of the unit. Wherever practical modular construction has been used to economize on space and to facilitate ease of servicing should this be necessary.

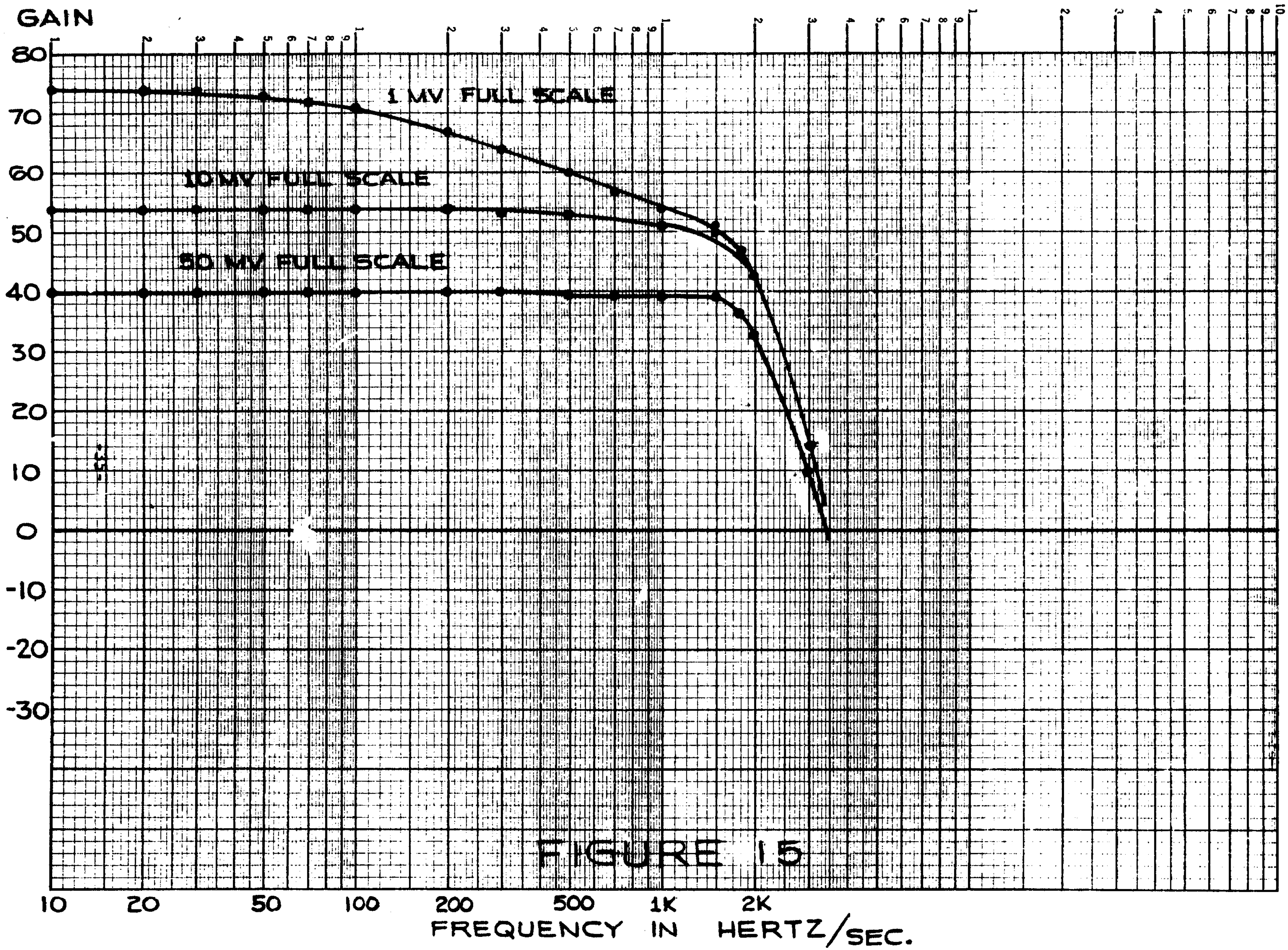
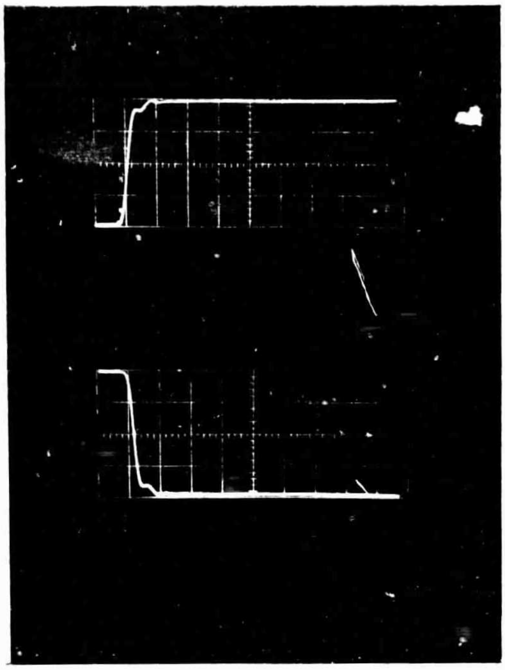

GAIN
80
70
60
50
40
30
20
10
0
-10
-20
-30
1 MV FULL SCALE
10 MV FULL SCALE
50 MV FULL SCALE
10
20
50
100
200
500
1K
2K
FREQUENCY IN HERTZ/SEC.

FIGURE 15

Vertical Scale
2V per Division

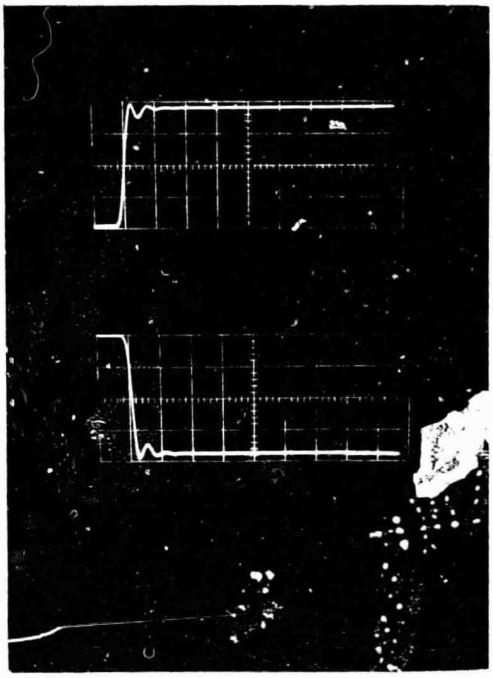
Horizontal Scale
1 millisecond
per Major Division



Gain: X 500
10 mV Input
for Full Scale

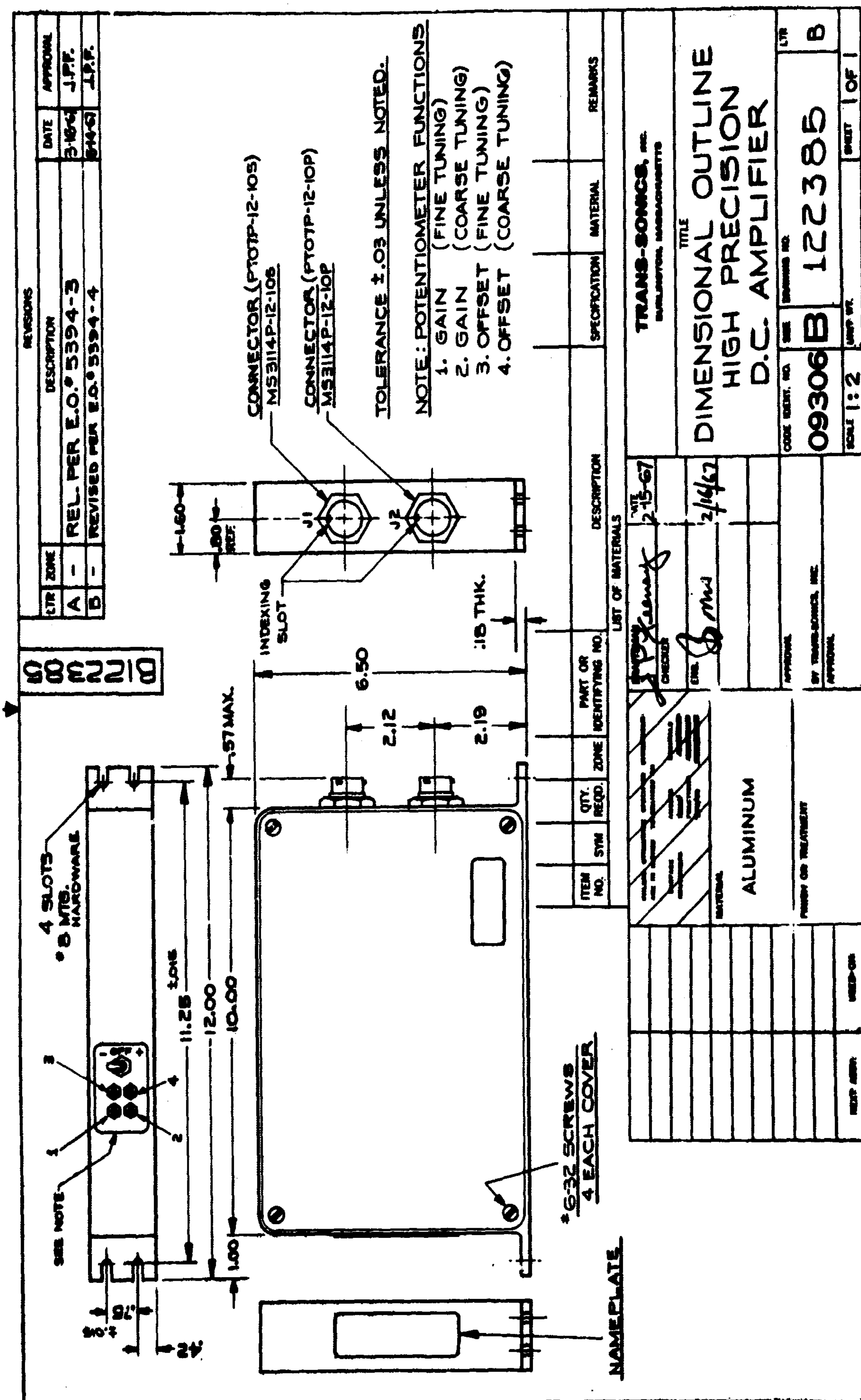
Amplifier Response to a Positive and
Negative Input Step Voltage

Scale Calibration
as above



Gain: X 100
50 mV Input
for Full Scale

FIGURE 16


DIMENSIONAL OUTLINE
HIGH PRECISION
D.C. AMPLIFIER
TRANS-SONICS, INC.
BURLINGTON, MASSACHUSETTS
CODE IDENT. NO. 09306
SIZE B
DRAWING NO. 122385
LTR B
SCALE 1:2
SHEET 1 OF 1
REVISIONS
LTR | ZONE | DESCRIPTION | DATE | APPROVAL
A | - | REL. PER E.O.# 5394-3 | 3-16-67 | J.P.F.
B | - | REVISED PER E.O.# 5394-4 | | J.P.F.
D122385
CONNECTOR (PT07P-12-10S)
MS3114P-12-10S
CONNECTOR (PT07P-12-10P)
MS3114P-12-10P
TOLERANCE ±.03 UNLESS NOTED.
NOTE: POTENTIOMETER FUNCTIONS
1. GAIN (FINE TUNING)
2. GAIN (COARSE TUNING)
3. OFFSET (FINE TUNING)
4. OFFSET (COARSE TUNING)
INDEXING SLOT
J1
J2
1.60
.80 REF.
6.50
2.12
2.19
.18 THK.
.57 MAX.
4 SLOTS
#8 MTG. HARDWARE
SEE NOTE
11.25
12.00
10.00
1.00
.75
.42
#6-32 SCREWS
4 EACH COVER
NAMEPLATE
ALUMINUM
MATERIAL
FINISH OR TREATMENT
LIST OF MATERIALS
ITEM NO. | SYM | QTY. REQD. | ZONE | PART OR IDENTIFYING NO. | DESCRIPTION | SPECIFICATION | MATERIAL | REMARKS
DRAWN
CHECKED
ENG.
APPROVAL
2-15-67
NEXT ASSY
USED ON

5 SPECIFICATION AND PERFORMANCE

Specification objectives and prototype performance is illustrated on the enclosed chart, Figure 17.

PERFORMANCE DATA

	Objective	Amplifier Spec.	Remarks
Gain	100 to 5000	100 to 5000	Gain continuously adjustable with coarse & fine controls
Gain Stability	Not specified	Better than 0.05% at Max. Gain and 0.02% at Min. Gain	Tests performed over range of temperature 30 - 120 degrees F.
Linearity	Not specified	Better than 0.02% at Max. Gain	
Frequency Response	-3DB at 1K Hz	Gain: 100 1.5K Hz (-3DB) 500 1.0K Hz (-3DB) 5000 0.1K Hz (3DB)	Continuous roll off in frequency for gain ranging from 500 to 5000 can be eliminated by removing a capacitor.
Output	-5 to +5 volts at 10 milliamps short circuit protected	-5 to +5 volts at 20 milliamps short circuit protected	Suitable as a line driver: Maximum capacitive load: 1 microfarad
Input Offset Voltage	Up to 50 millivolt stability: 0.1%	± 50 millivolt, stability: 0.1%	Stability tested over temperature range 25°F to 120°F .05% typical.
Input Voltage Drift	Not specified	The largest of ± 10 microvolts or 0.1% of F.S.	Measured with a source resistance of 360 ohms and Gain = 5000. Temperature 25°F to 120°F.
Long term input voltage drift	Not specified	The largest of ± 10 microvolt or 0.1% of F.S.	± 1 microvolt recorded over a period of 9 days.
Bridge Excitation Supply	10 volts, 10 milliamp voltage stability ±0.1%	10 volts, 30 milliamp voltage stability ± 0.05%	Over temperature range 25°F to 120°F no load and full load
Input Power	28 volts ± 10%	22 to 32 volts	Tested over the range 25°F to 120°F.

Figure 17