Westinghouse

The Operation And Maintenance Of TCA (Transistor Computer Amplifier)

GENERAL

The term "Operational Amplifier" is generally applied to a high gain d-c amplifier used to perform mathematical operations by means of passive input and feedback networks. Analog computers employ a number of operational amplifiers to provide the functional relationships needed to accurately represent systems of various types for study. In a similar manner, operational amplifiers are used in industrial control systems to provide the functional relationships needed to obtain prescribed system performance.

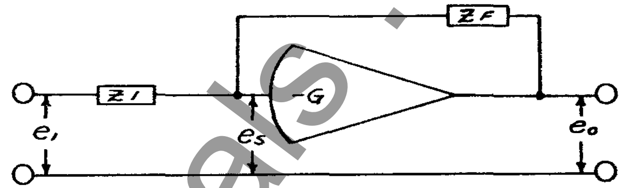

FIG. 1 - OPERATIONAL AMPLIFIER

EQUATION 1 - $\frac{e_o}{e_1} = \frac{-Z_F}{Z_1}$

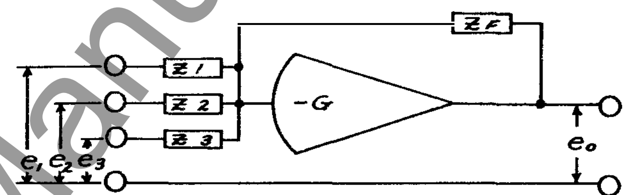

FIG. 2 - SUMMING AMPLIFIER

EQ. 2 - $e_o = -e_1 \frac{Z_F}{Z_1} - e_2 \frac{Z_F}{Z_2} - e_3 \frac{Z_F}{Z_3}$

EQ. 3 - $\frac{e_o}{e_1} = -\frac{1}{RCp}$

EQ 4 - $\frac{e_o}{e_1} = -\frac{R_F}{R_1}$

TCA, the abbreviation for Transistor Computer Amplifier, is used as a name for a Westinghouse operational amplifier. The TCA is built to be used in industrial control systems where durability and reliability are of great importance. The TCA provides precision performance and allows greater use of series stabilization methods, non-linear techniques, and analogue computer circuitry.

FUNCTIONAL CONSIDERATIONS

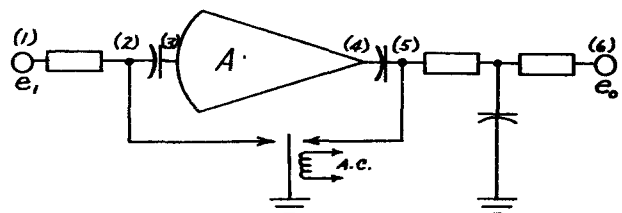

FIG. 3 - CHOPPER AMPLIFIER

Figure 1 shows the diagram for an operational amplifier and it can be shown that when G is very large the overall amplifier gain is dependent only on the passive impedances, Z_1 and Z_f.

Figure 2 shows a summing amplifier and in a similar manner, if G is very large, e_0 is the sum of the inputs e_1, e_2 and e_3 with gains dependent only on the passive impedances Z_1, Z_2, Z_3 and Z_f.

If Z_f is a capacitor C and Z_1 is a resistor R, the amplifier in Figure 1, becomes an integrator and equation 3 applies. Similarily if Z_f is a resistor R_f and Z_1 is a resistor R_1 the amplifier in Figure 1, provides an accurate gain (equation 4). Many other operations are possible including differentiation, time delays and function generation.

The foregoing relationships are obtained by making the amplifier gain G very high. This requirement is met by using a high gain d-c amplifier.

Drift Free Amplification

Three methods are utilized for reducing drift in the d-c amplifiers of the TCA. These are push-pull circuitry, feedback and chopper stabilization.

1. Push Pull Circuits

Push-pull circuitry relies on cancelation of drift by common mode rejection and is dependent upon circuit symmetry.

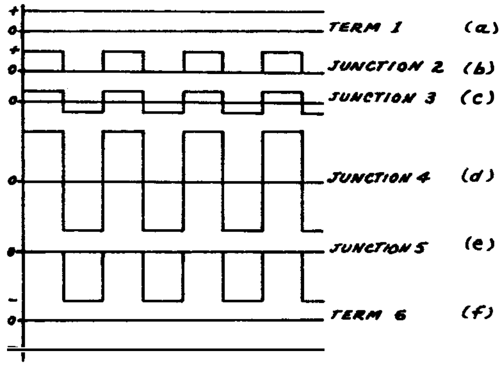

FIG.4 - CHOPPER MODULATION & DEMODULATION

2. Feedback Circuits

Both current and voltage feedback are used in the d-c and a-c amplifiers for the TCA. Feedback improves bias stability and also reduces amplifier drift.

3. Chopper Stabilization

If sufficient drift free gain can be obtained at the early stages of a d-c amplifier, effective and satisfactory drift reduction is possible. Chopper stabilization is a method for obtaining early stage driftless gain. Chopper stabilization is accomplished in the TCA by means of an a-c amplifier and chopper as shown in Figure 3. Input and output capacitors block d-c to provide drift-free gain in the a-c amplifier. Through the use of a chopper, a d-c signal may be modulated, amplified as a-c and demodulated back into d-c thus achieving driftless d-c amplification.

Figure 4 illustrates chopper modulation and demodulation. Signal attenuation is neglected in these diagrams in order to simplify the description.

The chopper coil is energized from an a-c source causing alternate grounding of the input and output circuits of the a-c amplifier. Referring to both Figures 3 and 4, a constant d-c voltage at terminal (1) is chopped at junction (2) into a square wave as shown in curve (b). This square wave will pass through the input capacitor as shown in curve (c) to be amplifier as shown in curve (d). During the time the input chopper contacts are open the output contacts are closed so that only negative portions of the square wave appear at junction (5), curve (e). The output signal is next filtered leaving only the d-c component in the output as shown in curve (f). The a-c amplifier-chopper combination thus becomes a driftless d-c amplifier capable of amplifying either polarity of input. The frequency response of this amplifier is, however, limited because of the output filter.

Complete Drift Stabilized Operation Amplifier

Figure 5 shows a complete drift stabilized TCA operational amplifier.

It will be noted from this circuit that the a-c amplifier precedes the d-c amplifier thus providing early stage driftless amplification. Slow drift originating in the d-c amplifier is thus regulated out by the gain of the a-c amplifier. A second input is provided to the d-c amplifier, through capacitor 1-C. This input by-passes the a-c amplifier utilizing the high frequency response capabilities of the d-c amplifier. This combination of amplifying channels provides an open loop response characteristic as shown in Figure 6.

The closed loop response of the drift stabilized amplifier connected for a gain of one (by using a 100 K feedback resistor and 100 K input resistor) is typical as shown in Figure 7.

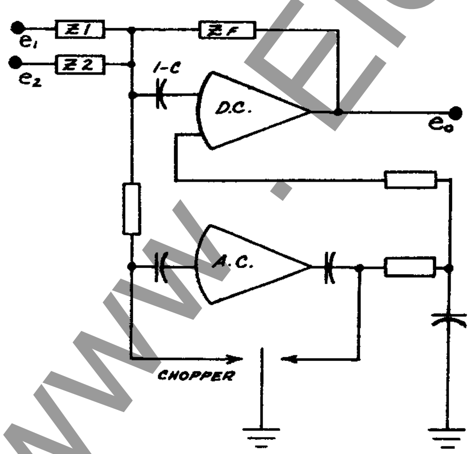

FIG. 5 - COMPLETE DRIFT STABILIZED OPERATIONAL AMPLIFIER

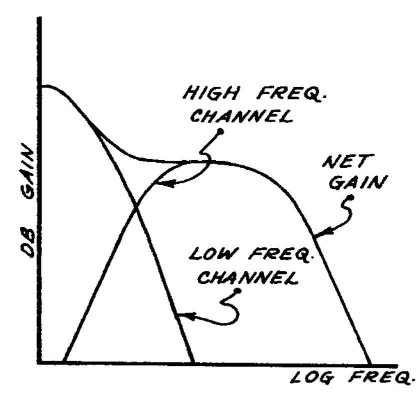

FIG. 6 - OPEN LOOP RESPONSE

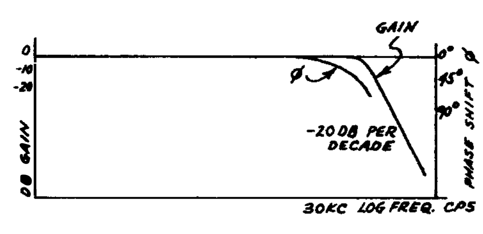

FIG. 7 - CLOSED FREQUENCY RESPONSE

DESCRIPTION OF THE TCA MODULE

The TCA is designed to allow flexibility in application permitting the system designer to take advantage of analog computer techniques and apply these to industrial control systems.

The design provides a standard basic TCA module. Provisions are made for adding to the basic module a wide variety of input and feedback impedance devices such as resistors and capacitors to obtain specific TCA characteristics as required in control systems.

Figures 8, 9, and 10 show the assembly of parts that make up a TCA. The d-c amplifier panel fastens in the module frame as shown in Figure 8. External connections are made through a connector in the d-c amplifier panel. The a-c amplifier panel fastens to the d-c amplifier panel by means of stand-off studs which serve as mechanical support as well as electrical connections between panels. Refer to Figure 9. The basic module does not include input and feedback impedances. The d-c amplifier panel, however, provides terminals to which input and feedback resistors can be soldered as required. When capacitors or more complex computing networks are required to obtain desired TCA functions, a Function Panel can be attached to the d-c amplifier panel in the same manner as the a-c amplifier panel. Refer to Figure 10.

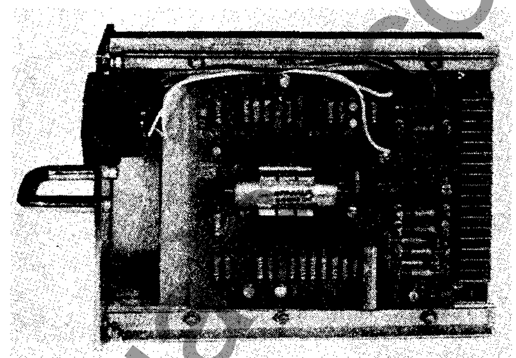

Fig. 8 - TCA Module Showing the D.C. Amplifier Panel

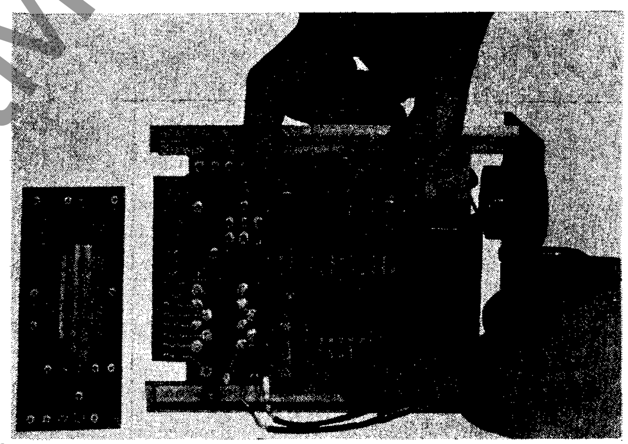

Fig. 9 - Addition of A.C. Amplifier Panel

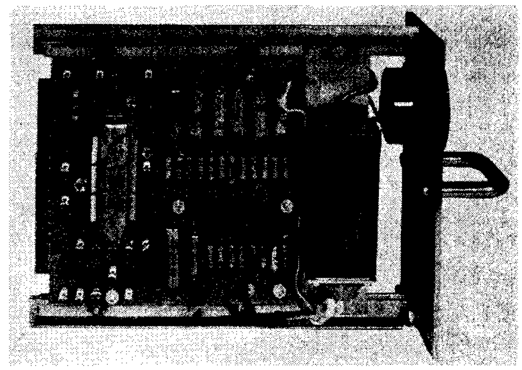

Fig. 10 - Function Panel Added to the TCA Module

A. Mechanical Parts

A TCA Module is designed as a plug-in unit to fit into a PRODAC type cage for interconnection with other parts of a system. The plug-in unit consists of a front plate and side covers enclosing the amplifiers and associated parts. This enclosure provides circuit shielding and mechanical protection. The side covers and front plate are attached by brackets to rails at the top and bottom of the enclosure. These rails guide the module into position in a cage. A handle fastens to the front plate to provide easy removal of the module from the cage.

B. Output Meter

A zero-center meter mounts in the front plate of each TCA module to display the output voltage of the TCA. This meter provides quick information about the TCA performance and the system in which the TCA is used.

C. Chopper

The electromechanical chopper mounts on a bracket inside the module enclosure. A frequency-doubler type chopper is sometimes used and is identified as Cat. No. BA-12D. This chopper operates from a 6.3 volt 60 cps supply only. The frequency must be held to 60 ± 1/2 cps. The voltage should be held to ± 5% although ± 10% can generally be tolerated if the frequency stability is good. More generally, chopper cat. no. BA-50/60 is used. This chopper will operate with frequencies of 47 to 63 cps at 6.3 volts ± 10%.

D. A-C Amplifier

The a-c amplifier functions together with the mechanical chopper to provide for d-c gain as well as drift stabilization in the TCA. This amplifier consists of four stages of amplification as shown in Figure 12. The first and second stages are basically the same as the third and fourth stages. Each of these pairs of stages uses both current and voltage direct feedback to achieve a high degree of bias stability. In addition, direct and capacitive feedback from the amplifier output to the input transistor emitter provides a wide bandpass of uniform gain. Capacitive coupling eliminates amplifier drift. The chopper modulates input signals to the amplifier and demodulates output signals. Capacitor 9C prevents chopper action from appearing on the TCA summing junction, capacitor 8C filters the demodulated signal from the amplifier and provides a low frequency cut-off for signals passing through the a-c amplifier to the d-c amplifier.

E. D-C Amplifier

The d-c amplifier provides the high gain and wide bandpass necessary for accurate operational amplifier performance. The amplifier consists of five stages, as shown in Figure 13, the first two being push-pull. Three feedback circuits are used for shaping the amplifier response characteristics.

Output Limiters

The maximum output voltage is limited to approximately ± 9-1/2 volts by Zener diodes 4D and 5D operating in conjunction with biased diodes 6D and 7D. By limiting the output voltage, amplifier saturation is avoided and therefore, amplifier "hang-up" is prevented.

When testing these units, care should be exercised to insure that the input signal, input resistance

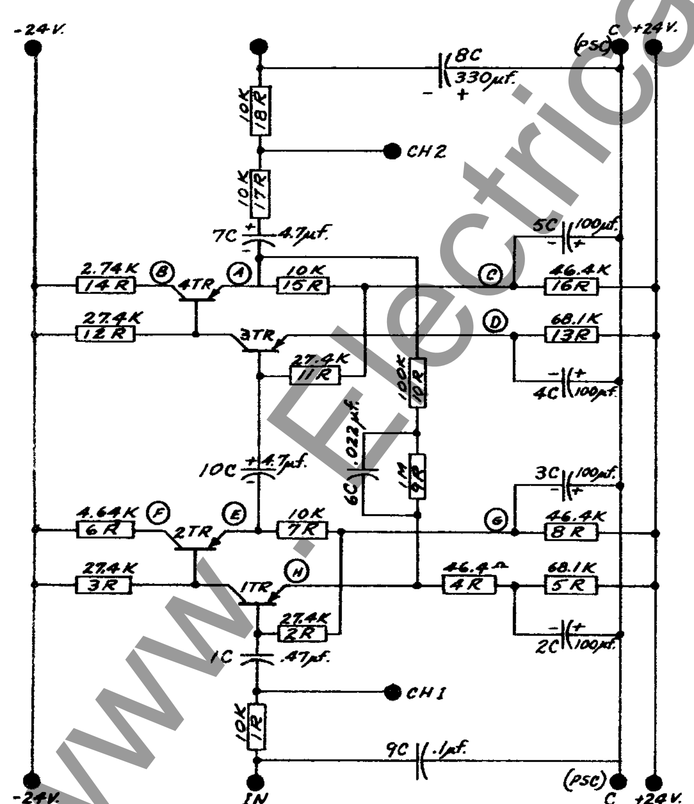

FIG. 12 - SCHEMATIC DIAGRAM, A.C. AMPLIFIER

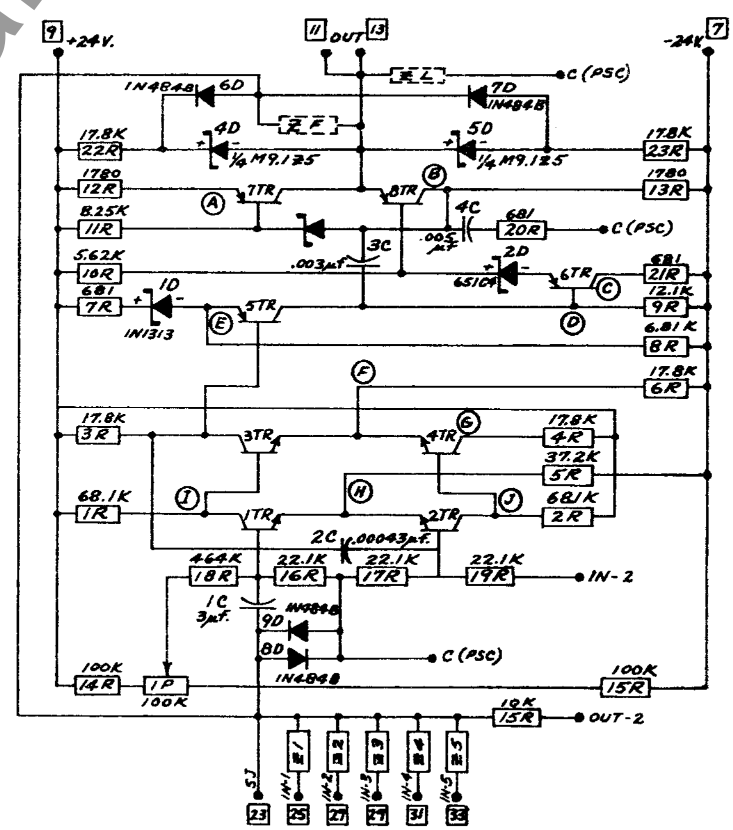

FIG. 13 - SCHEMATIC DIAGRAM, D.C. AMPLIFIER

and output load all duplicate the system application as closely as possible to prevent over-driving the amplifier.

Input Limiters

Diodes 8D and 9D limit the input voltage at the summing junction to the forward-drop voltage of the diodes (about 0.7 volts). These diodes present high impedance at the low voltages that normally occur at the summing junction and therefore, do not effect the amplifier performance, but protect the summing junction when excess voltages occur at any of the input resistors. The base-emitter junction of the input transistor is also protected from excess transient voltages which could otherwise damage this junction.

Balance Potentiometer 1-P

Potentiometer 1-P provides for balancing the input of the TCA. This operation is accomplished by adjusting 1-P to obtain zero output from the stabilizing amplifier as measured at 1N-2 on the d-c amplifier panel. For integrators, this adjustment can also be made by adjusting the minimum integrator drift with zero input to the TCA.

Loading Impedance

The d-c amplifier panel provides a space (ZL) for mounting an output loading impedance. A capacitor or resistor is infrequently used in this position. More generally, this space is left blank. When a 0.001 mfd capacitor is used in this position, it provides decoupling (at very high frequencies) between the TCA and the output circuitry.

Input and Feedback Resistors

The d-c amplifier panel provides spaces for mounting five input and one feedback computing resistors as required for the function to be performed by the operational amplifier.

F. Function Panel

When additional space is needed for computing impedances over and above that available on the d-c amplifier panel a function panel is used. The function panel provides for mounting resistors and capacitors in a variety of circuit configurations. This panel connects electrically and mechanically to the d-c amplifier panel by means of stand-off stud connectors.

TROUBLE SHOOTING AND MAINTENANCE

The best guidance in trouble shooting, repair and maintenance of TCA modules is a good understanding of the principles of operation of the modules and functions to be performed in the control system. Unfortunately, in linear feedback control systems it is sometimes difficult to differentiate between cause and effect so that locating a malfunctioning element of the regulating loop while the loop is closed may not be readily achieved. The following information should help however, in trouble shooting.

A. Locating Defective TCA Modules in a Control System

TCA modules have a voltmeter in the output of each operational amplifier to aid in trouble shooting. The output voltage range of a TCA is approximately ± 10 volts. Because of the high gains used in operational amplifier, it is likely that a defective amplifier will go to output limit of ± 9 to 10 volts or output saturation of ± 10 volts or more and can be located by the output voltmeter. Output limit, however, is more likely caused by excessive input signals to the TCA. Output saturation may be caused by a power supply or chopper failure. Since modular plug-in construction is used for TCA's, an effective trouble shooting practice is to replace a suspected module with a spare. If replacement clears up the system trouble the replaced modules can then be tested and repaired without interfering with production. It is important however, that a thorough check for poor connections be made at this time to eliminate this possible cause for the trouble.

In repairing TCA modules, the first step is generally that of locating which sub-assembly is defective. The complete sub-assembly can then be replaced. Limiting repair to the replacement of sub-assemblies may prove the most practical although sub-assemblies can be repaired if testing facilities and personnel are available.

B. Locating A Defective Module Sub-Assembly

1. Remove the module side covers and apply d-c and a-c power to the proper module terminals as shown in Figure 14.

2. With all the inputs open the output meter should read zero if a feedback resistor is used in position Z_f on the d-c amplifier board. If the module is an integrator a 100 K resistor can be temporarily connected in this position. If a small d-c signal is applied to one of the inputs the output should control with a d-c gain equal to the ratio of the feedback resistance to the input resistance. If this control is not obtained the d-c amplifier panel probably needs to be replaced.

3. If in step 2 above, with open inputs the output meter goes to + or − about 10 volts, jumper capacitor 1-C on the d-c amplifier panel. If this brings the output voltage back near zero and allows control from an input, the a-c amplifier or the chopper is probably defective. By replacing one of these at a time (first the a-c amplifier) the trouble may be located.

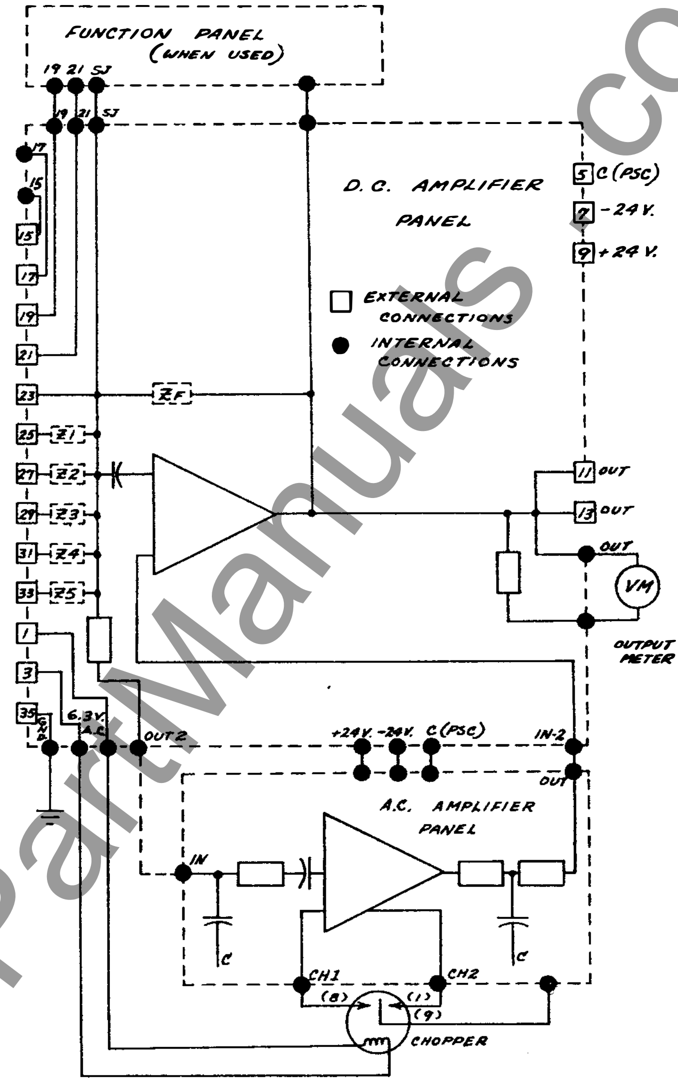

FIGURE 14 - MODULE INTERCONNECTIONS

4. In trouble shooting, the connectings should be carefully inspected for shorts or open circuits. Be sure shielded leads do not have shields shorting to terminals. Be sure all push-on connectors are tight.

C. Repairing Amplifiers

The repair of amplifier panels requires proper test equipment and an understanding of how the amplifiers operate. Typical d. c. test point voltages are shown in Figures 15 and 16.

Since all TCA printed circuit boards are sprayed with a varnish to seal surfaces against moisture and dirt, this varnish must be penetrated at test points in order to measure voltages. After test, the boards can be re-sealed with a clear plastic spray such as Krylon. Do not spray the connectors. Printed boards are extremely reliable but will tolerate only a small amount of soldering and resoldering. Use a small, low wattage soldering iron to avoid damage. Transistors are usually the most reliable components and should not be removed unless indicated to be defective by circuit test results. When a transistor is replaced, be careful to avoid damaging the transistor by excessive heating.

As shown in Figure 13, an external voltage applied to the amplifier output will be shorted to the power supply common through the diodes and the resulting excess currents may burn out several of the diodes. If the limiter circuit Zener diodes are damaged the associated diodes always should be checked also.

BIAS VOLTAGES

A +17V.
B -17V.
C -21V.
D -4.9V.
E +10V.
F +2.8V.
G +12.5V.
H -0.15V.
I +2.7V.
J +2.7V.

VOLTAGES TO COMMON (C)

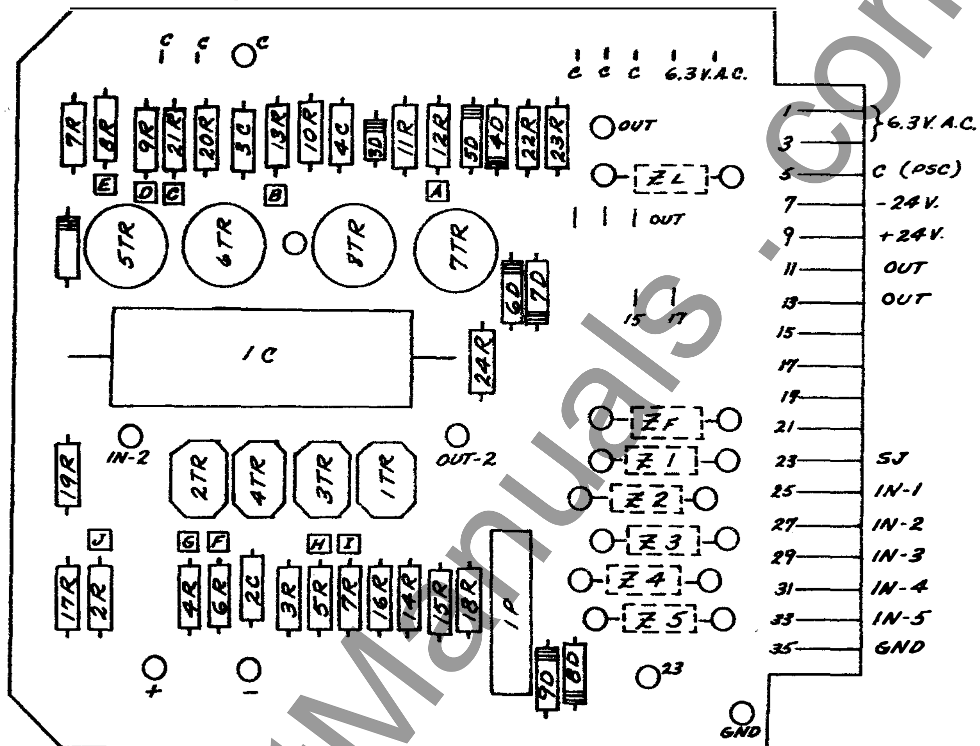

FIGURE 15 - D.C. AMPLIFIER VOLTAGE TEST POINTS

BIAS VOLTAGES

A -11V.
B -22V.
C -5.4V.
D -5V.
E -11V.
F -21V.
G -5.4V.
H -5V.

VOLTAGES TO COMMON (C)

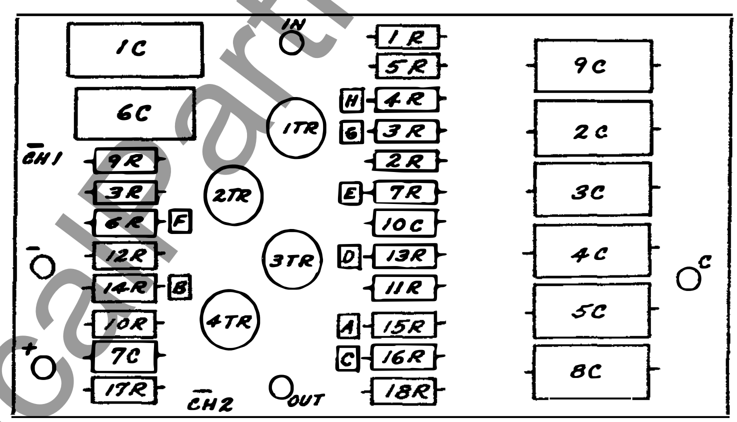

FIGURE 16

A.C. AMPLIFIER VOLTAGE TEST POINTS

GENERAL DATA			
Module L1Z is the basic TCA module complete except for input and feedback impedances.			
Output	Chopper Supply	D.C. Supplies	
± 9-1/2 volts typical as limited by Zener limiters. ±5mA maximum	6.3 volts ± 5%, 75 mA 60 cps ± 1/2 cps or 47-63 cps when 50/60 cps chopper is used.	Regulated: 24 V. ±50 mV., 20 mA -24 V. ±50 mV., 20 mA Ripple: 1mV RMS maximum	Non-Regulated: (when performance Permits) 24 to 26 V., 20 mA -24 to -26 V., 20mA Ripple: less than 25 mV. RMS

Ambient Temperature: 0-55° C

Style Numbers - 427A478G02 (heart shaped meter)
- 427A478G03 (square meter)

Design Reference EPM: D-490742

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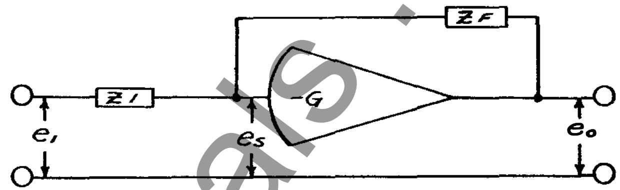

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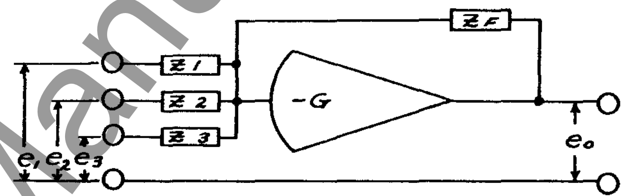

FIG. 2 - SUMMING AMPLIFIER

EQ. 2 - $e_o = -e_1 \frac{Z_F}{Z_1} - e_2 \frac{Z_F}{Z_2} - e_3 \frac{Z_F}{Z_3}$

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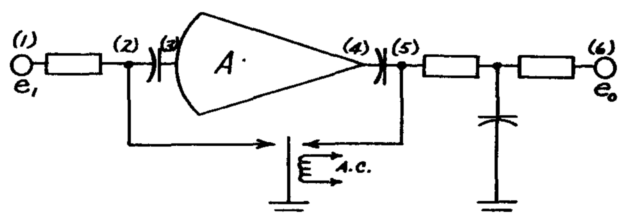

FIG. 3 - CHOPPER AMPLIFIER

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Figure 2 shows a summing amplifier and in a similar manner, if G is very large, e_0 is the sum of the inputs e_1, e_2 and e_3 with gains dependent only on the passive impedances Z_1, Z_2, Z_3 and Z_f.

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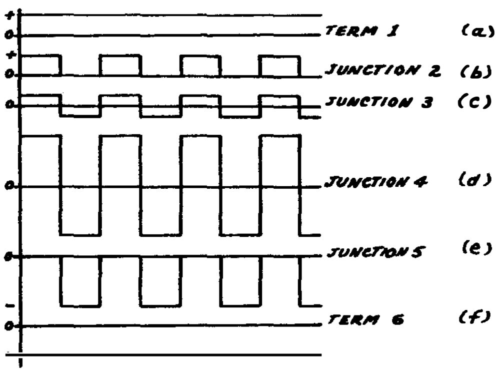

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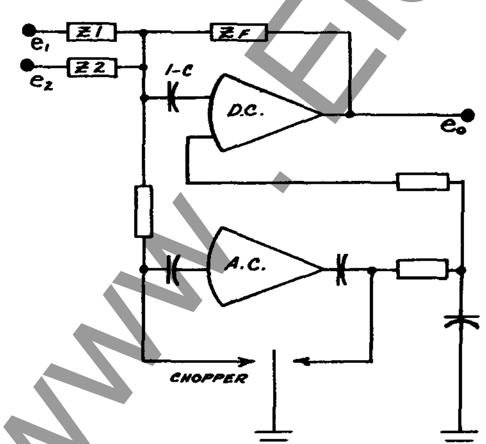

FIG. 5 - COMPLETE DRIFT STABILIZED OPERATIONAL AMPLIFIER

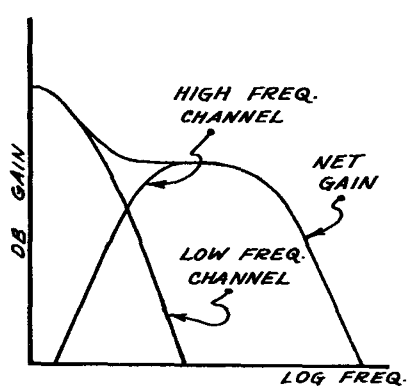

FIG. 6 - OPEN LOOP RESPONSE

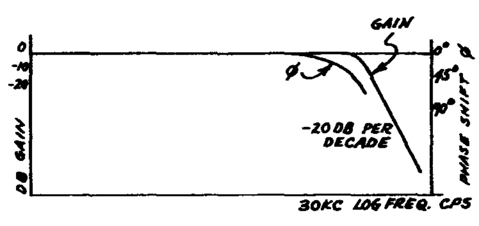

FIG. 7 - CLOSED FREQUENCY RESPONSE

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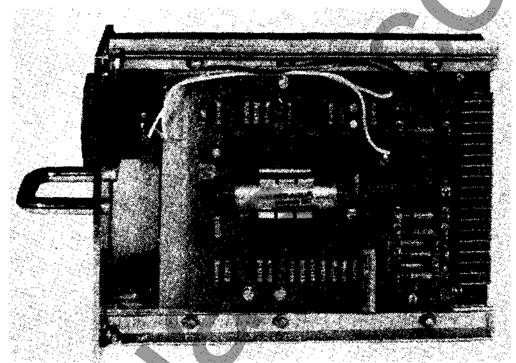

Fig. 8 - TCA Module Showing the D.C. Amplifier Panel

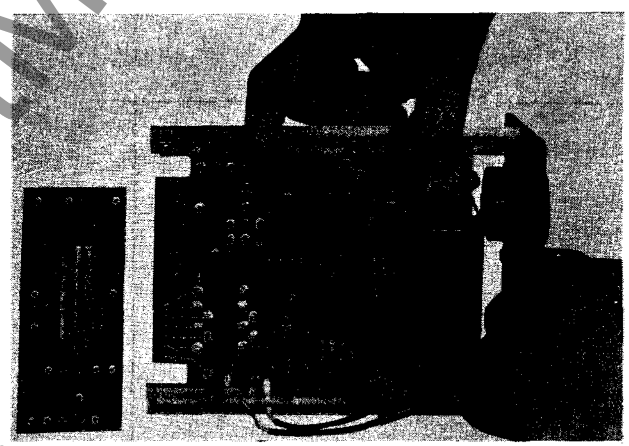

Fig. 9 - Addition of A.C. Amplifier Panel

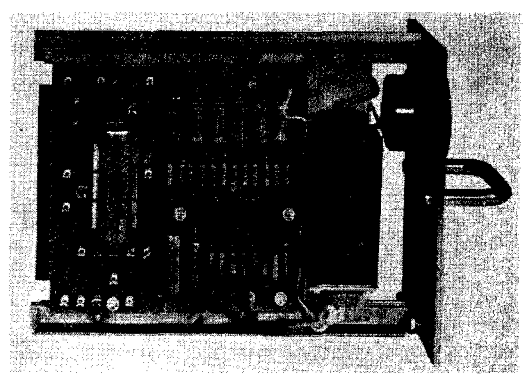

Fig. 10 - Function Panel Added to the TCA Module

A. Mechanical Parts

A TCA Module is designed as a plug-in unit to fit into a PRODAC type cage for interconnection with other parts of a system. The plug-in unit consists of a front plate and side covers enclosing the amplifiers and associated parts. This enclosure provides circuit shielding and mechanical protection. The side covers and front plate are attached by brackets to rails at the top and bottom of the enclosure. These rails guide the module into position in a cage. A handle fastens to the front plate to provide easy removal of the module from the cage.

B. Output Meter

A zero-center meter mounts in the front plate of each TCA module to display the output voltage of the TCA. This meter provides quick information about the TCA performance and the system in which the TCA is used.

C. Chopper

The electromechanical chopper mounts on a bracket inside the module enclosure. A frequency-doubler type chopper is sometimes used and is identified as Cat.No. BA-12D. This chopper operates from a 6.3 volt 60 cps supply only. The frequency must be held to 60 ± 1/2 cps. The voltage should be held to ± 5% although ± 10% can generally be tolerated if the frequency stability is good. More generally, chopper cat. no. BA-50/60 is used. This chopper will operate with frequencies of 47 to 63 cps at 6.3 volts ± 10%.

D. A-C Amplifier

The a-c amplifier functions together with the mechanical chopper to provide for d-c gain as well as drift stabilization in the TCA. This amplifier consists of four stages of amplification as shown in Figure 12. The first and second stages are basically the same as the third and fourth stages. Each of these pairs of stages uses both current and voltage direct feedback to achieve a high degree of bias stability. In addition, direct and capacitive feedback from the amplifier output to the input transistor emitter provides a wide bandpass of uniform gain. Capacitive coupling eliminates amplifier drift. The chopper modulates input signals to the amplifier and demodulates output signals. Capacitor 9C prevents chopper action from appearing on the TCA summing junction, capacitor 8C filters the demodulated signal from the amplifier and provides a low frequency cut-off for signals passing through the a-c amplifier to the d-c amplifier.

E. D-C Amplifier

The d-c amplifier provides the high gain and wide bandpass necessary for accurate operational amplifier performance. The amplifier consists of five stages, as shown in Figure 13, the first two being push-pull. Three feedback circuits are used for shaping the amplifier response characteristics.

Output Limiters

The maximum output voltage is limited to approximately ± 9-1/2 volts by Zener diodes 4D and 5D operating in conjunction with biased diodes 6D and 7D. By limiting the output voltage, amplifier saturation is avoided and therefore, amplifier "hang-up" is prevented.

When testing these units, care should be exercised to insure that the input signal, input resistance

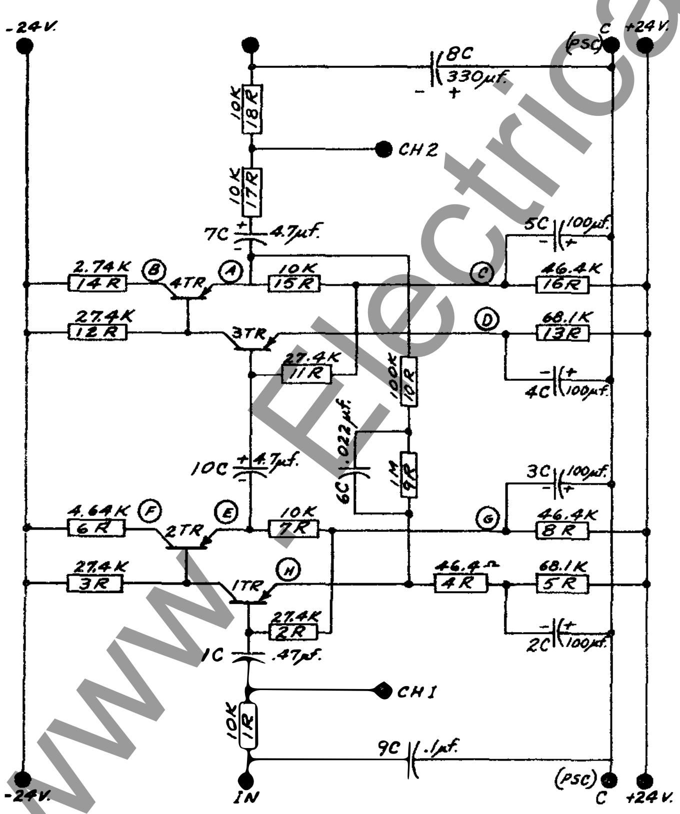

FIG. 12 - SCHEMATIC DIAGRAM, A.C. AMPLIFIER

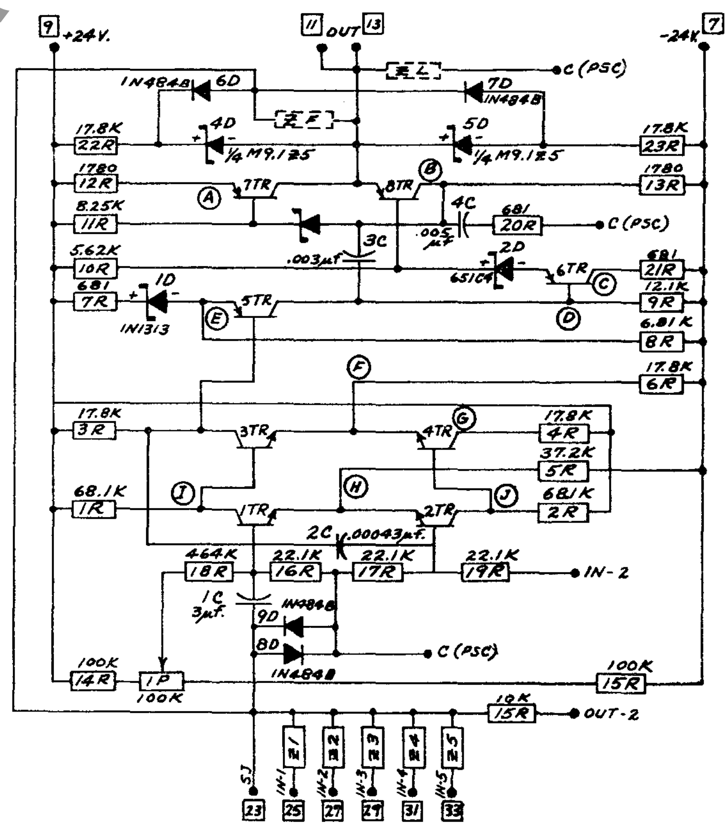

FIG. 13 - SCHEMATIC DIAGRAM, D.C. AMPLIFIER

and output load all duplicate the system application as closely as possible to prevent overdriving the amplifier.

Input Limiters

Diodes 8D and 9D limit the input voltage at the summing junction to the forward-drop voltage of the diodes (about 0.7 volts). These diodes present high impedance at the low voltages that normally occur at the summing junction and therefore, do not effect the amplifier performance, but protect the summing junction when excess voltages occur at any of the input resistors. The base-emitter junction of the input transistor is also protected from excess transient voltages which could otherwise damage this junction.

Balance Potentiometer 1-P

Potentiometer 1-P provides for balancing the input of the TCA. This operation is accomplished by adjusting 1-P to obtain zero output from the stabilizing amplifier as measured at 1N-2 on the d-c amplifier panel. For integrators, this adjustment can also be made by adjusting the minimum integrator drift with zero input to the TCA.

Loading Impedance

The d-c amplifier panel provides a space (Z_L) for mounting an output loading impedance. A capacitor or resistor is infrequently used in this position. More generally, this space is left blank. When a 0.001 mfd capacitor is used in this position, it provides decoupling (at very high frequencies) between the TCA and the output circuitry.

Input and Feedback Resistors

The d-c amplifier panel provides spaces for mounting five input and one feedback computing resistors as required for the function to be performed by the operational amplifier.

F. Function Panel

When additional space is needed for computing impedances over and above that available on the d-c amplifier panel a function panel is used. The function panel provides for mounting resistors and capacitors in a variety of circuit configurations. This panel connects electrically and mechanically to the d-c amplifier panel by means of stand-off stud connectors.

TROUBLE SHOOTING AND MAINTENANCE

The best guidance in trouble shooting, repair and maintenance of TCA modules is a good understanding of the principles of operation of the modules and functions to be performed in the control system. Unfortunately, in linear feedback control systems it is sometimes difficult to differentiate between cause and effect so that locating a malfunctioning element of the regulating loop while the loop is closed may not be readily achieved. The following information should help however, in trouble shooting.

A. Locating Defective TCA Modules in a Control System

TCA modules have a voltmeter in the output of each operational amplifier to aid in trouble shooting. The output voltage range of a TCA is approximately ± 10 volts. Because of the high gains used in operational amplifier, it is likely that a defective amplifier will go to output limit of ± 9 to 10 volts or output saturation of ± 10 volts or more and can be located by the output voltmeter. Output limit, however, is more likely caused by excessive input signals to the TCA. Output saturation may be caused by a power supply or chopper failure. Since modular plug-in construction is used for TCA's, an effective trouble shooting practice is to replace a suspected module with a spare. If replacement clears up the system trouble the replaced modules can then be tested and repaired without interfering with production. It is important however, that a thorough check for poor connections be made at this time to eliminate this possible cause for the trouble.

In repairing TCA modules, the first step is generally that of locating which sub-assembly is defective. The complete sub-assembly can then be replaced. Limiting repair to the replacement of sub-assemblies may prove the most practical although sub-assemblies can be repaired if testing facilities and personnel are available.

B. Locating A Defective Module Sub-Assembly

1. Remove the module side covers and apply d-c and a-c power to the proper module terminals as shown in Figure 14.

2. With all the inputs open the output meter should read zero if a feedback resistor is used in position Z_f on the d-c amplifier board. If the module is an integrator a 100 K resistor can be temporarily connected in this position. If a small d-c signal is applied to one of the inputs the output should control with a d-c gain equal to the ratio of the feedback resistance to the input resistance. If this control is not obtained the d-c amplifier panel probably needs to be replaced.

3. If in step 2 above, with open inputs the output meter goes to + or - about 10 volts, jumper capacitor 1-C on the d-c amplifier panel. If this brings the output voltage back near zero and allows control from an input, the a-c amplifier or the chopper is probably defective. By replacing one of these at a time (first the a-c amplifier) the trouble may be located.

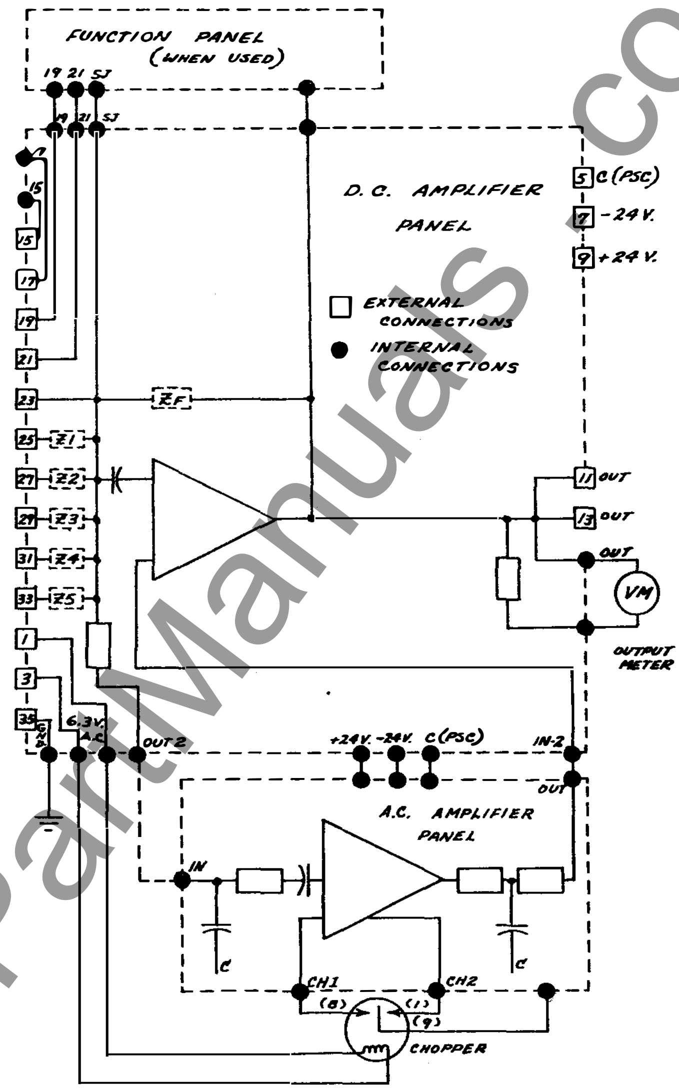

FIGURE 14 - MODULE INTERCONNECTIONS

4. In trouble shooting, the connectings should be carefully inspected for shorts or open circuits. Be sure shielded leads do not have shields shorting to terminals. Be sure all push-on connectors are tight.

C. Repairing Amplifiers

The repair of amplifier panels requires proper test equipment and an understanding of how the amplifiers operate. Typical d. c. test point voltages are shown in Figures 15 and 16.

Since all TCA printed circuit boards are sprayed with a varnish to seal surfaces against moisture and dirt, this varnish must be penetrated at test points in order to measure voltages. After test, the boards can be re-sealed with a clear plastic spray such as Krylon. Do not spray the connectors. Printed boards are extremely reliable but will tolerate only a small amount of soldering and resoldering. Use a small, low wattage soldering iron to avoid damage. Transistors are usually the most reliable components and should not be removed unless indicated to be defective by circuit test results. When a transistor is replaced, be careful to avoid damaging the transistor by excessive heating.

As shown in Figure 13, an external voltage applied to the amplifier output will be shorted to the power supply common through the diodes and the resulting excess currents may burn out several of the diodes. If the limiter circuit Zener diodes are damaged the associated diodes always should be checked also.

BIAS VOLTAGES

- A +17V.
- B -17V.
- C -21V.
- D -4.9V.
- E +10V.
- F +2.8V.
- G +12.5V.
- H -0.15V.
- I +2.7V.
- J +2.7V.

VOLTAGES TO COMMON (C)

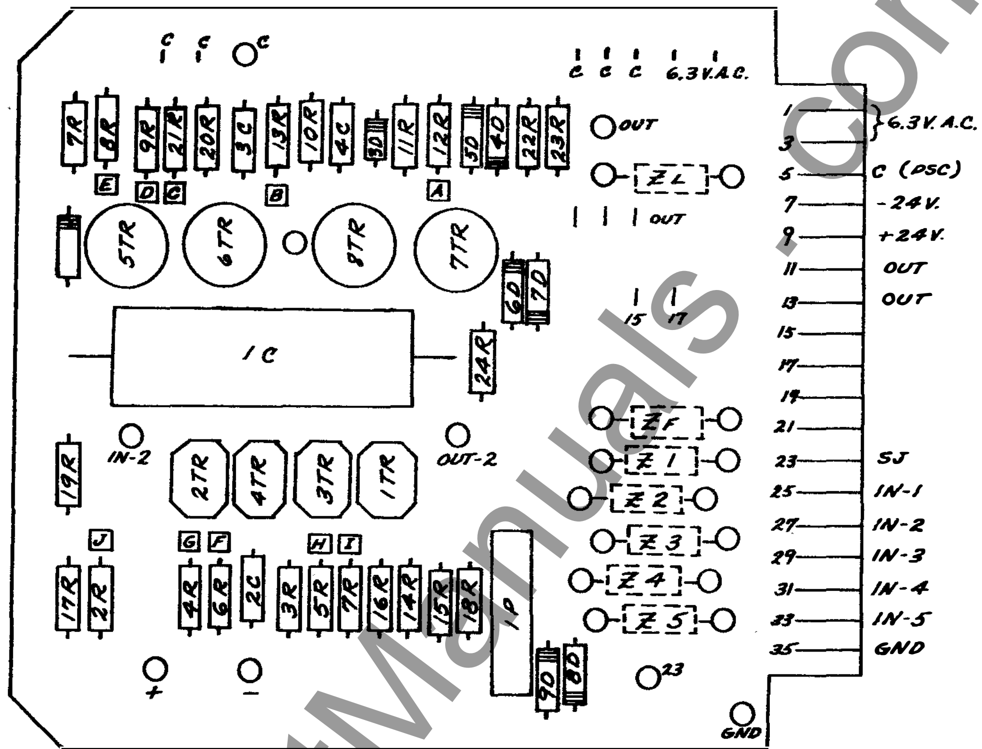

FIGURE 15 - D.C. AMPLIFIER VOLTAGE TEST POINTS

BIAS VOLTAGES

- A -11V.
- B -22V.
- C -5.4V.
- D -5V.
- E -11V.
- F -21V.
- G -5.4V.
- H -5V.

VOLTAGES TO COMMON (C)

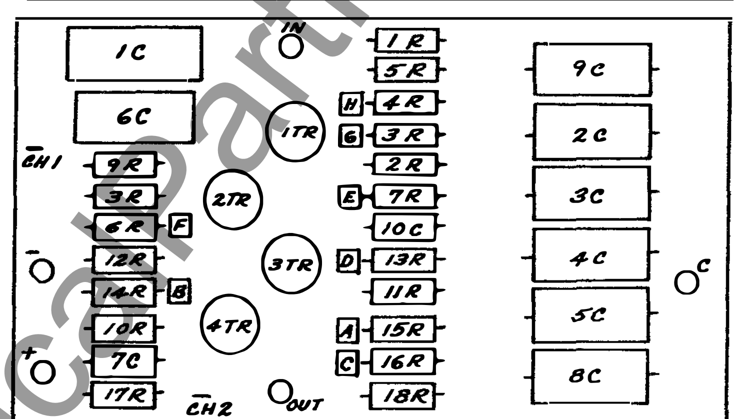

FIGURE 16 A.C. AMPLIFIER VOLTAGE TEST POINTS

GENERAL DATA			
Module L1Z is the basic TCA module complete except for input and feedback impedances.			
Output	Chopper Supply	D.C. Supplies	
± 9-1/2 volts typical as limited by Zener limiters. ±5mA maximum	6.3 volts ± 5%, 75 mA 60 cps ± 1/2 cps or 47-63 cps when 50/60 cps chopper is used.	Regulated: 24 V. ±50 mV., 20 mA -24 V. ±50 mV., 20 mA Ripple: 1mV RMS maximum	Non-Regulated: (when performance Permits) 24 to 26 V., 20 mA -24 to -26 V., 20 mA Ripple: less than 25 mV. RMS

Ambient Temperature: 0-55° C

Style Numbers - 427A478G02 (heart shaped meter)
- 427A478G03 (square meter)

Design Reference EPM: D-490742

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BUFFALO DIVISION BUFFALO 5, N. Y.