INSTRUCTION MANUAL

WESTAMP A520 SERIES

This is a general manual describing a whole series of amplifiers and may be used in conjunction with drawings pertaining to various specific models.

CAUTION

The maintenance procedure described herein should be attempted only by highly skilled technicians using proper test equipment. Read your warranty provisions before starting, to avoid voiding your warranty.

TABLE OF CONTENTS

FORWARD:

This manual is a general purpose manual covering the theory, application and trouble-shooting of the A520 series of transistor amplifiers. The manual does not necessarily specifically apply to any one individual amplifier. However, the information is presented in a general way so that it may be applied to specific amplifiers in conjunction with the associated drawings and parts lists.

INSTALLATION:

Each amplifier in the A520 series comes with an individual installation drawing showing where to make the various connections for power input, signal input and output to the motor or other load. While this manual may show in a general way how to make connections to amplifiers, always be certain to follow the specific instructions applicable to a specific amplifier. Always be certain to apply the correct power input voltage and frequency. Some amplifiers may have dual voltage power transformers and in such cases make certain that the jumpers are on the correct transformer terminals. On small amplifiers, the output to the motor or load may be taken from the circuit board TB1, terminals 6 & 7. On all large amplifiers the output is usually taken from separate terminals mounted on the chassis. Caution! Do not use grounded test equipment on the output circuits and do not connect either of the output circuits to ground. The signal inputs are usually applied directly to the circuit board terminals TB1 - 1, 2, 3 with respect to terminal 4. However, on a few larger amplifiers, the input circuits may be extended to an additional terminal strip mounted on the chassis. Use shielded wire for signal inputs to prevent stray pick up and noise from being introduced into the amplifier input. The amplifier may have a band width anywhere from 5 KC down to a fraction of a cycle, depending upon the specific requirements and also upon the components installed in the Compensation Board.

Shown in Figure 1 is a typical test connection for an amplifier with a matching motor-tach. This is a specific example but the connections have general application. When testing with a motor-tach, it is essential to have the Compensation Board installed and the components properly selected and adjusted, otherwise the system will be oscillatory. When a positive signal input is applied from the battery, then the voltage fed back from the tachometer must be negative. A more elementary test can be made by substitutinga fixed resistor in place of the motor-tach. For this situation a Comp. Board is not required and perhaps it will be preferred not to test with a Comp. Board installed if it has a long time constant. The Lag Network (C2 and R4) required by some systems may have a time constant of a hundred seconds which makes testing of the amplifier without the motor-tach difficult.

APPLICATION:

After the amplifier has been installed and tested in accordance with the specific installation instructions, it is then necessary to proceed with applying it to the complete system. Successful application of a new amplifier in a new system usually requires both theoretical knowledge and practical experience with servo mechanism. An adequate discussion of servo mechanisms is beyond the scope and intent of this manual. However, a brief discussion of some of the possible adjustments and procedures will be made. Figure 2 shows an A520 series circuit board with the Compensation Board installed. The location of the various adjustments and specifically selected components is shown. All of the adjustments and components shown in Figure 2 are not always present in the various versions of the amplifier. Many servo systems can be set up and stabilized using less than half of the adjustments and specially selected components shown in Figure 2.

Adjustments:

There are three gain adjustments on the main board which adjust from zero to maximum gain for each input respectively. There is a fourth gain adjustment on the main board labelled "FB"

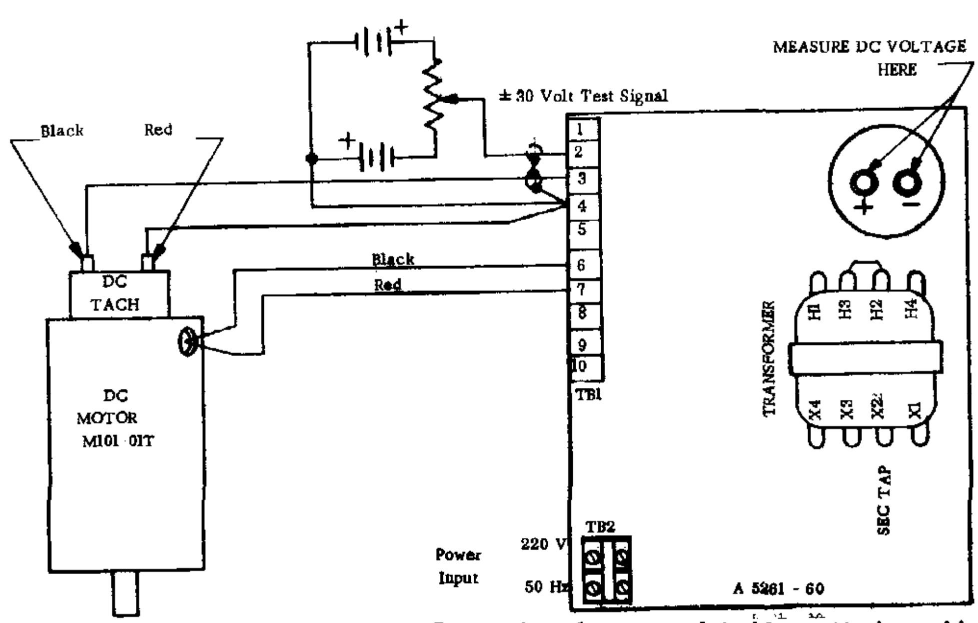


Fig. 1 Typical Installation and Test Connections for a complete Motor-Tach combination

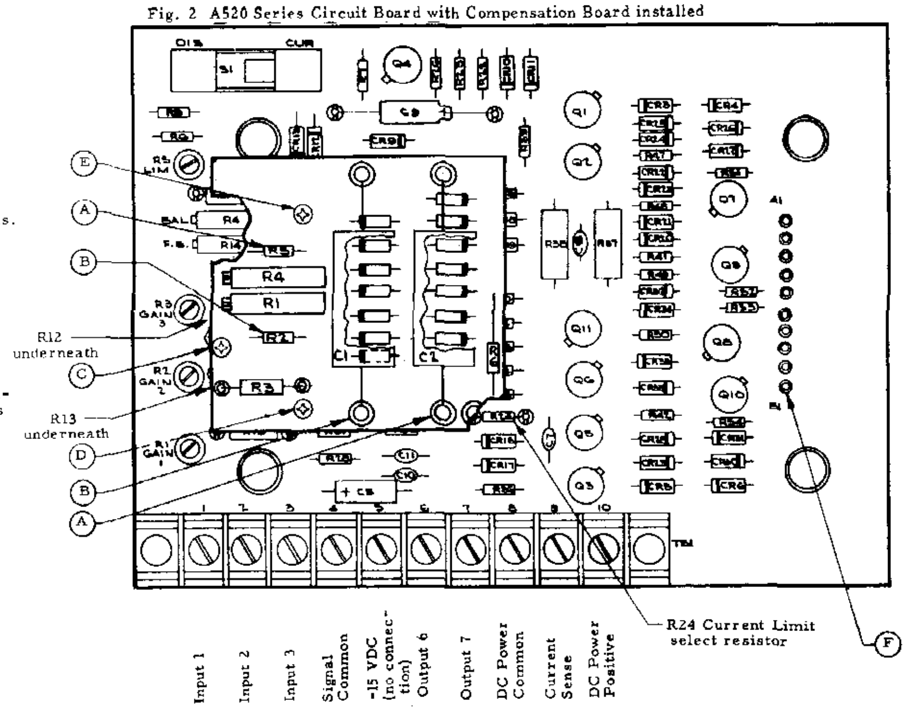
which is a negative feedback adjustment around the first op amp. The ratio of the gains for the three input channels is 1:5:25 for inputs 1, 2, and 3 respectively. When the FB pot is replaced with a fixed resistor divider, the standard gains for the three inputs will be 40; 200; 1,000; for inputs 1, 2, and 3 respectively. When the FB pot is installed in the amplifier and adjusted fully CW, then the DC gains of the three inputs can approach 100,000. It is not practical to use this high gain without a C2 capacitor installed. The BAL pot adjusts the offset of the first op amp so as to set the output voltage of the amplifier at zero for zero signal input. The BAL pot will usually require "trimming-in" after all the gains have been set to their required level. The LIM pot is for setting the maximum output current. It is referred to as the Current Limit Pot and works in conjunction with S1. S1 selects either the current limit mode of operation or the dissipation limit mode of operation as described later under Current Limit. Resistor R24 is selected at the factory so that the full clock-wise rotation of the Current Limit Pot allows a maximum output current compatible with the capabilities of the specific amplifier. The input resistors R11, R12 and R13 are mounted underneath the Compensation Board. These resistors are mounted on standoff terminals so that they may easily be changed to alter the gain capabilities of the various signal inputs. The standard values installed at the factory are 2.49 M, 500 K, and 100 K for R13, R12 and R11 respectively.

The servo system stabilization elements are mounted on the 24624 Compensation Board. These components are selected and installed in accordance with a particular customer's system requirements. Usually, a small capacitor is installed for C2 at the factory so as to control bandwidth for the purpose of testing the amplifier. However, the factory installed value of C2 is not necessarily the correct value for any system unless specifically specified by the customer. Resistor R3 replaces R11 on the circuit board when the Compensation Board is installed. Capacitor C2 and resistors R4 and R5 working in conjunction with the first amplifier stage form a Lag Network which reduces the frequency response of the amplifier. Capacitor C1 and resistors R1 and R2 serve as a Lead Network which increases the frequency response of the amplifier. The Lag Network components will almost always be used in the servo system compensation, but the Lead Network components are not necessarily always used. In addition to the components shown on the Comp. Board in Figure 2, there is also a series of diodes used for clamping the voltage output of the first op amp. These diodes are explained further in the section on the Compensation Board.

Fig. 2 A520 Series Circuit Board with Compensation Board installed

A. Measure resistance of R4 between these points.
B. Measure resistance of R1 between these points.
C.D.E. Comp. Board installation screws and circuit connections.
C. R3 pot wiper
D. A1A-5 summing junction
E. A1A-2 1st Op Amp output
F. Connections to power drivers A1234 and B1234. Pins 5 are guide pins.

CAUTION: Do not make external connections to TB1-5, 8, 9, 10. Connections are made to Output terminals 6 and 7 only when specified on detail drawing. Terminals 6 and 7 must be isolated from all other connections.



SERVO SYSTEM COMPENSATION

Sometimes it is possible to compensate a servo system empirically without any theoretical evaluation of the system, provided the specifications are not too stringent. Success at empirical stabilization usually depends upon experience and knowledge of similar systems. A better procedure is to have a knowledge of the system perameters and requirements so that a complete servo analysis can be made. To compensate a velocity loop empirically, first start with the amplifier connected to a motor-tach as shown in Figure 1.

Start with all the gain potentiometers turned CCW for minimum gain and R4 turned fully CCW. Increase the signal input pot (which in this case is Gain Pot 2) slightly, so that a small positive signal input will cause rotation of the motor. Now measure the output voltage from the tachometer at terminal 3 with respect to terminal 4 and it should be negative. If it is, then turn Gain Pot 3 CW slightly (increasing tach loop gain) so as to cause the motor speed to be reduced by the negative tach feedback. An oscilloscope should be connected to the tach output at terminal 3 with respect to terminal 4 in order to observe the response of the system.

Set the sweep speed at .1 sec/cm and adjust the vertical attenuator to make a convenient displacement in response to the signal input.

In using the empirical method, it is necessary to select some initial values.

Capacitor C2 will typically be in the range from 0.1 mf to 1.0 mf, but the range from .01 mf to 10 mf is normal. Arbitrarily select C2 equals 1.0 mf and turn R4 fully CCW. Now alternately switch the signal input on and off (step input) and observe the response of the tach on the scope. The following wave forms are typical:

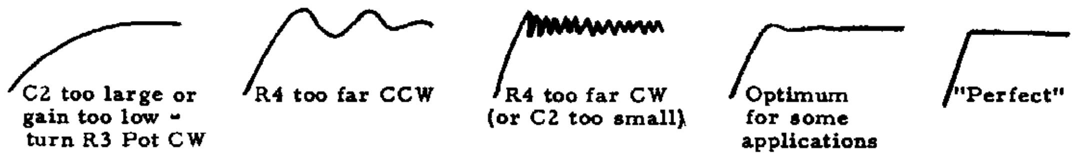


Fig. 3 Response to Step Input

In order to find the desired response, it may be necessary to select a larger or smaller capacitor and repeat the adjustments to R3 and R4.
CAUTION: Always observe the response frequently when making adjustments to avoid system oscillation. If the system does oscillate, imediately turn off power and start over with reduced gain.

Sometimes there may still be an overshoot after optimizing the adjustments above. This can be eliminated or reduced with C1 and R1 provided the overshoot is a "relatively high frequency" and there are no mechanical problems with the system. When the compensation is complete, it is then possible to turn the FB pot CW for more DC gain without readjusting the compensation.

There may be a requirement for system "stiffness". Turning the FB pot fully CW will make a very stiff system, but it will not necessarily have a fast reaction to applied loads unless the system has been compensated to have good high frequency response which wpuld be equivalent to a fast rise time to a step input in the procedures described above. A system with low frequency response will feel as if it hesitates before reacting to a torque load applied to the motor shaft. A system with high frequency response will make the motor shaft feel as if it were rigid when an attempt is made to rotate it.

In order for a system to feel "really immovable" to applied external forces, the band width must be several hundred cycles. This is easy to accomplish with low inertia motors with integral tachometers, but is not always practical in a complete system - or necessary.
The procedures above should make it possible for individuals with little or no previous Servo experience to get a working system or to give the more experienced engineer a "feel" for the location of the adjustments. However, this procedure does not account for all the anomalies of Servo systems and it may be necessary to refer to the abundance of literature available on the subject.

BLOCK DIAGRAM:

Figure 4 is a block diagram of the complete servo amplifier showing the general direction of flow of signals and power through the amplifier. It is interesting to note that the relative size of the functions as shown on the block diagram is not necessarily directly proportional to their actual physical size. For example, while A1A and A1B occupy about 20% of the space on the block diagram, the space which they occupy in the actual amplifier is probably about 1%.

The flow of signals starts at the three signal inputs and proceeds through the first amplifier, A1A, working in conjunction with the Compensation Board. The Compensation Board is an auxiliary feature and will not be included if the amplifier is to be used only as a power amplifier. The purpose of the

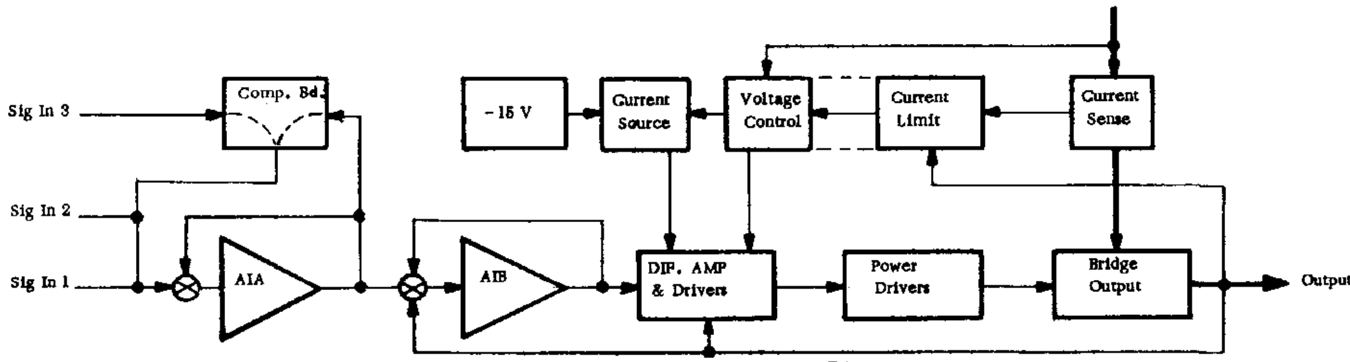


Fig. 4 Complete Amplifier Block Diagram

Compensation Board is to alter the frequency response of the amplifier in accordance with the requirements of a specific complete system including motor, drive load, and feedback element. The output of amplifier A1A proceeds to the input of amplifier A1B which provides additional voltage amplification. The output of amplifier A1V drives the Differential Amplifier and the Pre-Drivers.

The purpose of the Differential Amplifiers is to provide bi-polar drive to the output circuit. Since the output circuit is arranged in the form of a bridge, the Differential Amplifier is required to drive one arm of the bridge more positive while driving the opposite arm of the bridge more negative. The magnitude of the output of the Differential Amplifier can be clamped in response to control signals from the Current Limit Circuit.

The output of the Differential Amplifier and Pre-Drivers goes to the Power Drivers which are usually mounted on a heatsink for power dissipation and which are used to amplify the current. The output from the Power Drivers goes directly to drive the Output Bridge. The basic Output Bridge consists of four (4) transistors. However, with the A520 series of amplifiers, it is possible to parallel up to seven (7) Output Bridges for a total of 28 transistors. The output from the Output Bridge goes directly to the driven load which is usually a DC Motor. The current from the Power Supply which feeds the Output Bridge is measured and the sample sent to the Current Limit Circuit. The Current Limit Circuit can be adjusted for various maximum values of current. The Current Limit Circuit controls the output current by clamping the output of the Differential Amplifier.

COMPENSATION BOARD:

The Compensation Board is an auxiliary circuit board which may or may not be supplied along with the amplifier.

The purpose of the Compensation Board is to provide a means of altering the frequency response of the amplifier for the purpose of stabilizing a closed loop servo system. Compensation of servo systems is a special subject and the methods and procedures are not covered herein. The Compensation Board has provision for a wide variation of components and component arrangements. The flexibility of the Compensation Board is such as to enable the stabilization of very high performance, closed loop, velocity systems or position systems.

The basic function of the Compensation Board is illustrated in Figure 5. Figure 5A shows the relationship between output voltage and input voltage for an ordinary operational amplifier with an input resistor and a feedback resistor. Figure 5B shows the same amplifier as in Figure 5A, but with some capacitors added to the circuit so that the output to input relationship of the amplifier is now a function of the frequency of the applied signal. The Compensation Board uses the principals shown in Figure 5B, but all of the input impedance elements and all of the feedback impedance elements are mounted on the Compensation Board, separate from the Main Amplifier for flexibility.

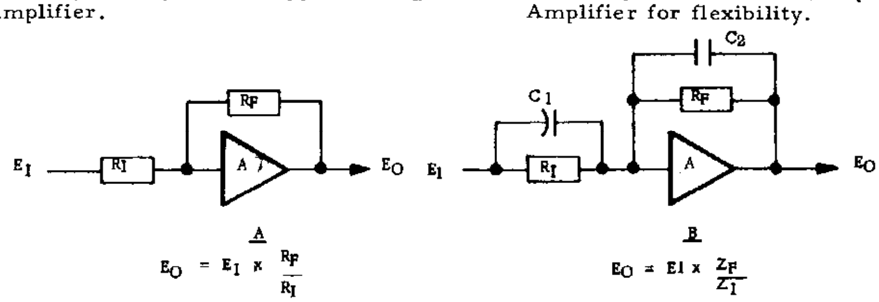


Fig. 5 BASIC COMPENSATION AMPLFIER CONFIGERATION

All of the possible elements of the Compensation Board are shown in Figure 6, including their inter-relationship with Operational Amplifier A1A, but all of the components shown in Figure 6 are not always used in the A520 series of amplifiers. On the main amplifier circuit board, there can be different numbers of input gain adjustment potentiometers from zero up to 3 and the negative feedback adjustment potentiometer may be replaced with a fixed divider. When the Compensation Circuit Board is used, then R13 is not installed on the main board and R3 on the Compensation Board takes its place. On the Compensation Board there are three groups of components; the Lead Network, the Lag Network, and the Clamping Diodes. When the Compensation Board is used, the Lag Network will usually be installed. However, the Clamping Diodes and the Lead Network are not always used and, therefore, sometimes not installed. All of the components on the Compensation Board depend upon the user's system and, therefore, cannot be installed at the factory, unless there is some knowledge of the system. However, R3 will normally be a 100 K resistor unless otherwise specified. Resistor R6 may or may not be connected to ground by means of a jumper to TB1 Terminal 4 on the main circuit board, depending upon system requirements.

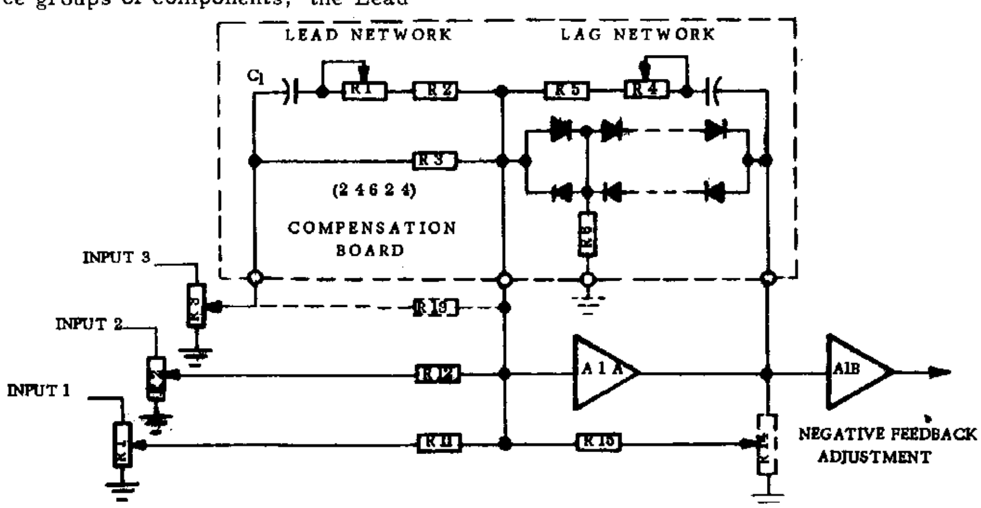


Fig. 6 FUNCTIONAL DIAGRAM OF GAIN ADJUSTMENT AND SERVO COMPENSATION NETWORK

The layout of components on the Compensation Board is shown in Figure 7. As previously mentioned, all of the parts shown in Figure 7 may not appear on every Compensation Board, since these components are selected in accordance with the user's system requirements.

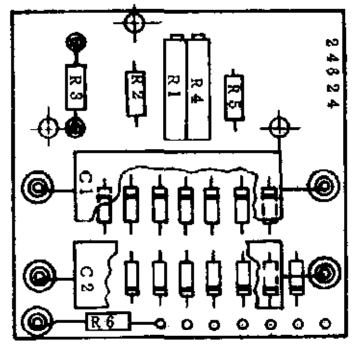


Fig. 7 COMPENSATION BOARD ASSEMBLY

OPERATIONAL AMPLIFIER:

The Operational Amplifier and Voltage Amplifier schematic diagrams are shown in Fig. 8. For clarity, only a part of the Differential Amplifier is shown and the Compensation Board and the Current Limit Circuits are not shown at all. The signals enter the Amplifier through the input gain adjustment potentiometers and appear, increased in magnitude, at Pin 2 A1A or also at one end of R27. The amplifier can be operated without the Compensation Board installed by using only inputs 1 and 2, but the frequency response will be very high and, therefore, care must be exercised with regard to possible stray pick up. If there is a DC offset in the amplifier, this may be balanced out by means of the Balance Adjustment potentiometer. The setting of the Balance Adjustment may need to be corrected when the Input Gain Adjustments are changed or if any of the input resistors are changed. Usually, the lowest value of input resistor (such as R11) which is used, is 100 K. However, from time to time it may be desirable to have substantially more gain. In this case, an input resistor as low as 10 K may be used. When a low value of input resistor is used for the benefit of a higher gain there must be a compromise with increased drift and offset which makes the Balance Adjustment more critical.

When the signal leaves Terminal 2 of A1A it goes through R27 and into amplifiers A1B for further voltage amplification in conjunction with the Differential Amplifier where Q2 and Q3 are the active elements. All of the Differential Amplifier is not shown in Fig. 8 in order to simplify the schematic. Amplifier A1B amplifies the signal in the normal way as shown in Fig. 5A, except that there is an additional negative feedback loop from the Differential Amplifier through resistors R31 and R32. When troubleshooting the amplifier, it is possible to open the connection between R35 and Pin 12 of A1B to eliminate this second negative feedback loop. Then it is possible to make gain measurements from the input up to Terminal 12 of A1B, or to inject signals into R35 so as to make gain measurements in the Differential Amplifier.

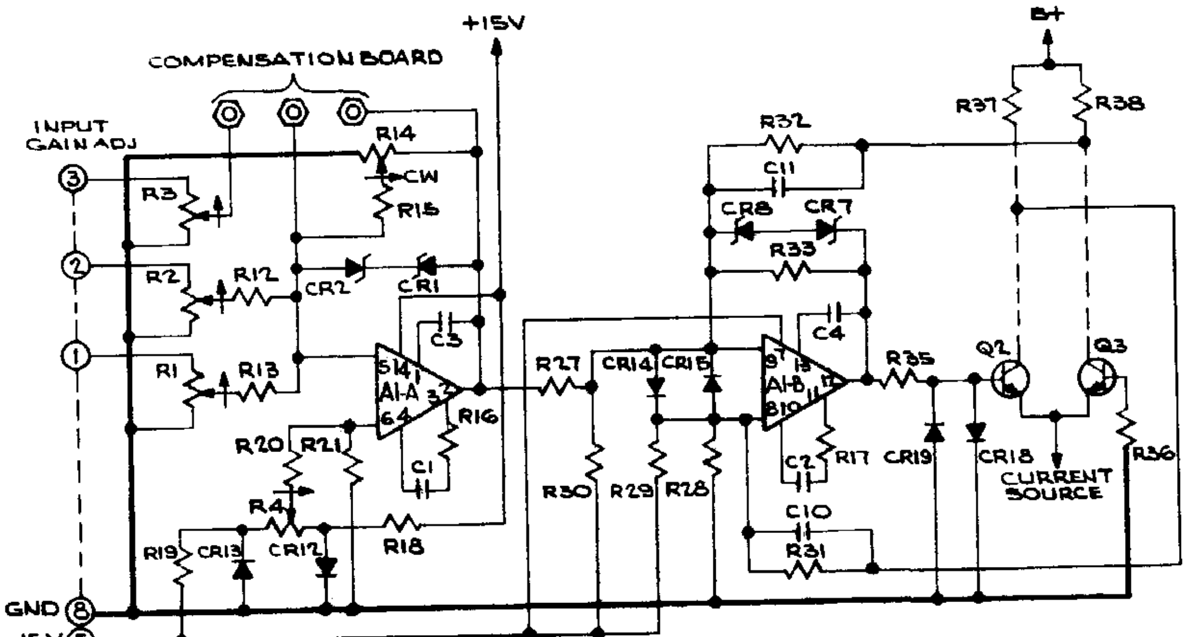


Fig. 8 OPERATIONAL AMPLIFIER AND VOLTAGE AMPLIFIER SCHEMATIC

DIFFERENTIAL AMPLIFIER:

The schematic of the Differential Amplifier and the Pre-Drivers is shown in Fig. 10. Also shown are the inter-connections with the Voltage Amplifier A1B and the signal from the Current Limit circuit, and also the Current Source for the Differential Amplifier. The Differential Amplifier consists primarily of transistors Q2 and Q3 and their load resistors R37 and R38. The signal from A1B is amplified by transistor Q2 and appears phase inverted at the collector. The signal is also coupled through the emitter to transistor Q3 and appears in phase at the collector of the transistor. The two diode arrays in the collector circuits Q2 and Q3 are for the purpose of temperature compensation and current limiting. The two transistors Q1 and Q11 form a constant current source for the Differential Amplifier. Transistor Q6 is the controlling part of the Current Limit circuit. When transistor Q6 is saturated a voltage nearly equal to the B+ voltage appears at its emitter and when transistor Q6 is cut off, the voltage at its emitter is near ground potential. The Constant Current circuit is adjusted so that the voltage at the collectors of Q1 and Q3, for zero signal input, is approximately equal to half of the B+ voltage. Pre-Drivers Q7 and Q9 are driven from the collector of Q2 and Pre-Drivers Q8 and Q10 are driven from the collector of Q3. The Pre-Drivers connect to the Power Drivers which are mounted separately on a heatsink and which in turn then drive the Power Output bridges. Resistors R46, R47, R48, and R49 are selected to set the quiescent of the output bridges on amplifiers with a B voltage higher than 40 VDC.

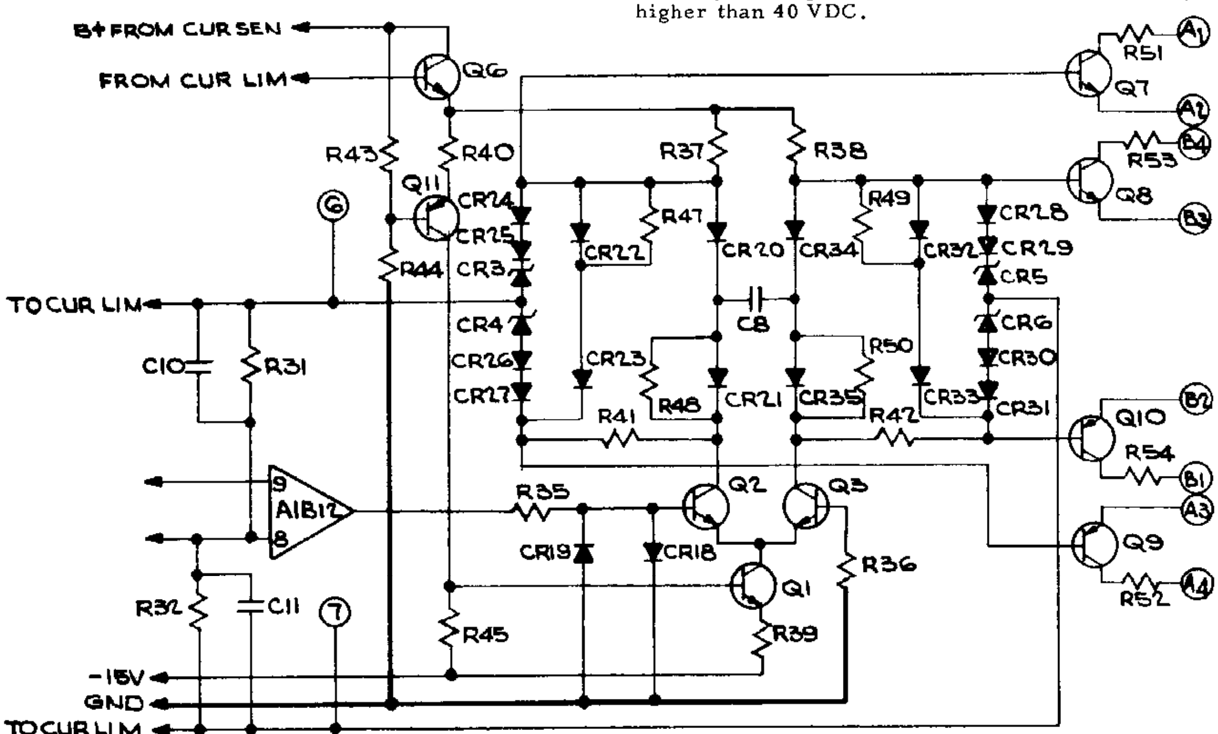
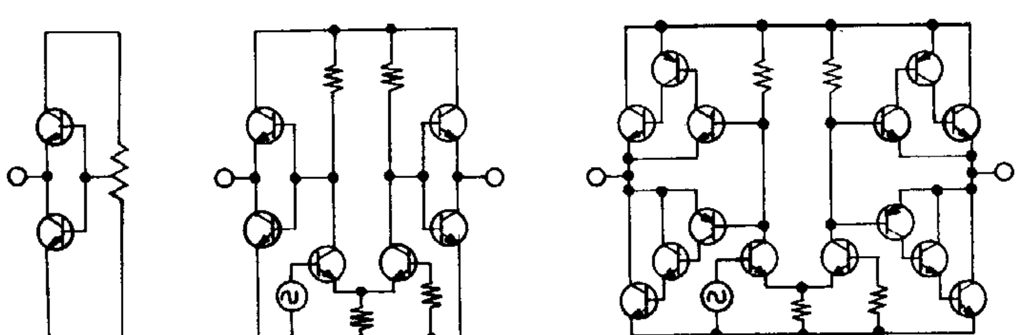


Fig. 9 DIFFERENTIAL AMPLIFIER

OUTPUT CIRCUIT:

Figure 10 is a simplified drawing showing how the full output bridge is developed from a simple 2-transistor half bridge. Figure 10 C shows the complete configuration of transistors connected for high current gain. It does not show the biasing diodes which are shown in Fig. 9 and in Fig. 11.



A. Half Bridge driven from Potentiometer

B. Elementary Bridge driven from differential Amplifier

C. Bridge with additional transistors for increased Current Gain

Fig. 10 THE OUTPUT BRIDGE

OUTPUT CIRCUIT (contd.)

The connections from the circuit board Pre-Drivers to the heatsink mounted Power Drivers and on to the Power Output bridges are shown in Fig. 11. The figure shows the Differential Amplifier and Current Source, but only one half of an output section is shown. The power train from Pre-Drivers Q8 and Q10 on through the output is shown while the connections to Pre-Drivers Q7 and Q9 are eliminated for clarity and simplification of the schematic. Transistors Q7 and Q9 will be doing exactly the same thing as transistors Q8 and Q10 with the exception that they will be 180 ° out of phase respectively. Only one set of power transistors is shown and there can be up to seven identical sets wired in parallel, making a total of 14 transistors in each half of the bridge, or a total of 28 transistors for seven complete bridges in parallel.

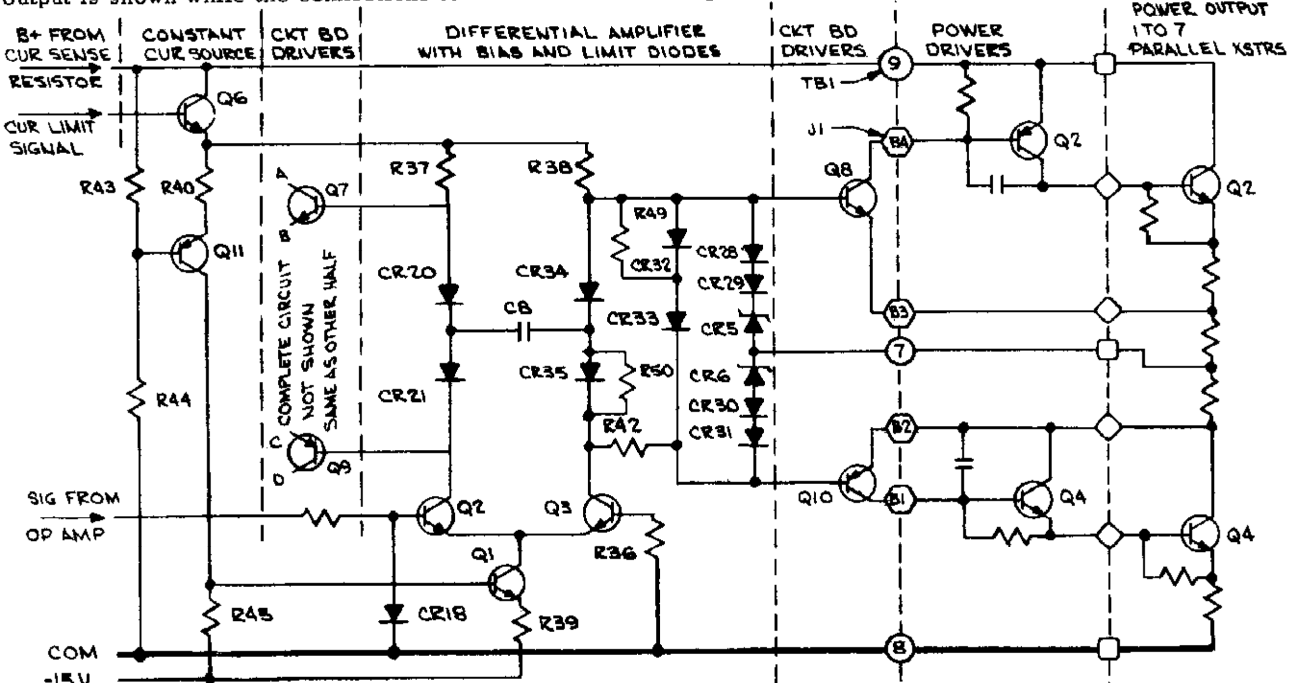


Fig. 11 Output Circuit Connections to One Half of Power Bridge

CURRENT LIMIT:

The Current Limit Schematic is shown in Fig. 12. The Current Limit Circuit has two modes of operation which can be determined by the position of selector switch, S1.
The switch is shown on the schematic in the up position which is the Current Limit Mode. When the switch is moved to the down position it will be in the Dissipation Limit Mode. The Current Limit mode of operation provides a constant maximum output current provided the load resistance is not so high that the IR drop exceeds the amplifier output voltage at that current. With the selector switch in the Current Limit position, it is possible to exceed the power dissipation capability of the output heatsinks if the value of the load resistance is allowed to get too low. The reason for this is that with a very low value of load resistance, most of the power supply voltage will be dropped across the output transistors thereby making the power dissipated equal E x I a very high value. When the switch is thrown into the down, or the Dissipation Limit Mode of Operation position, then the current is limited to a value proportional to the magnitude of the output voltage. Therefore, it is not possible to have high output current when the output voltage is low, and so the dissipation in the output transistors cannot be exceeded. The Dissipation Limit Circuit has a time delay override from Capacitor C9 and R34 to allow momentary high peak currents into low resistive loads which will gradually fade out if the voltage does not increase while the current is still at a high value. The current sensing resistor is usually mounted on the Power Driver heatsink.

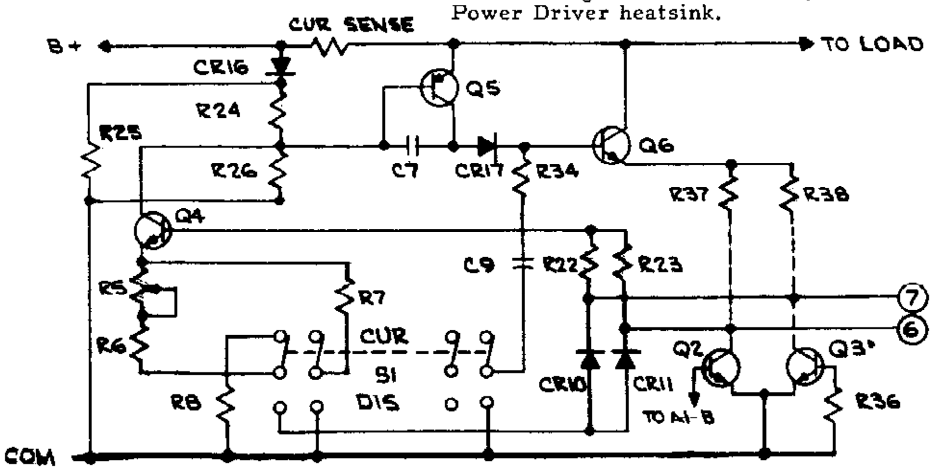
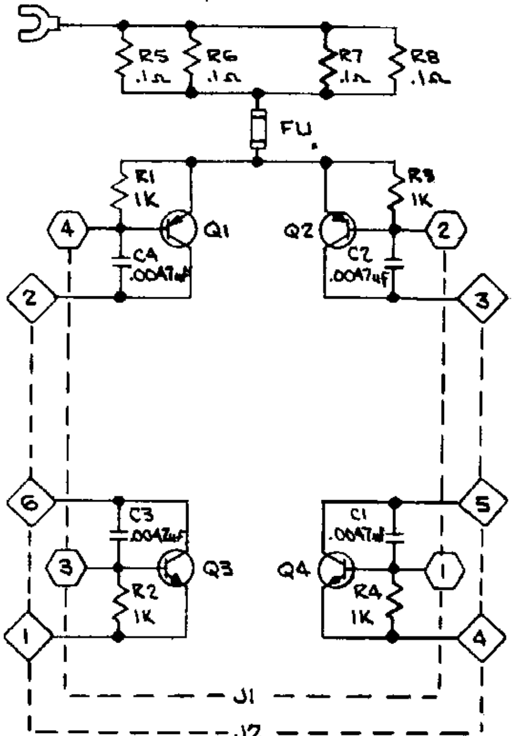
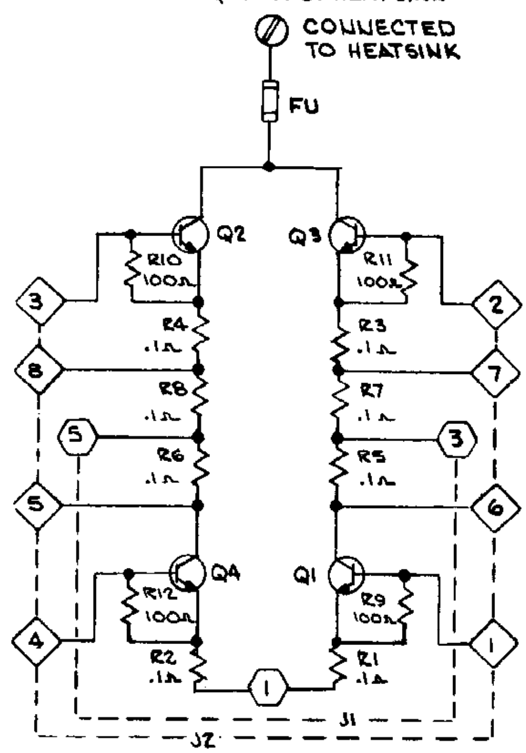


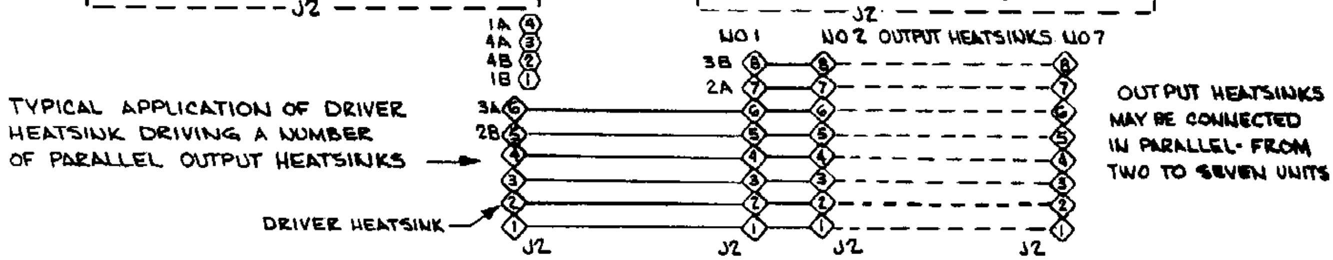
Figure 12 Current Limit Circuit

SCHEMATIC, DRIVER HEATSINK

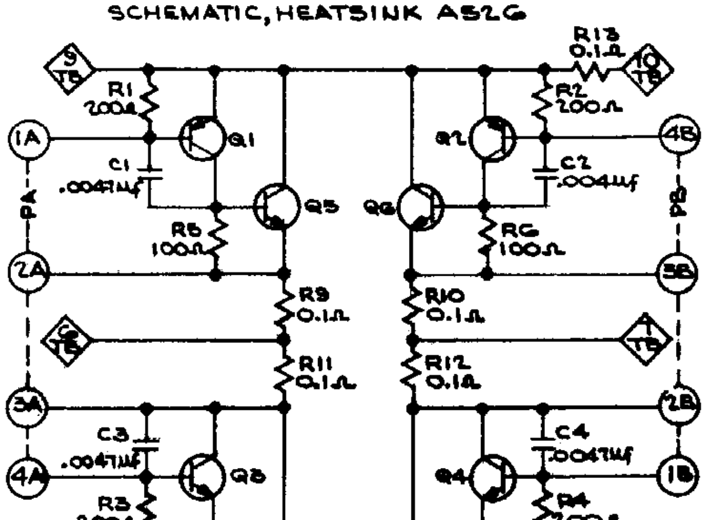


SCHEMATIC, OUTPUT HEATSINK

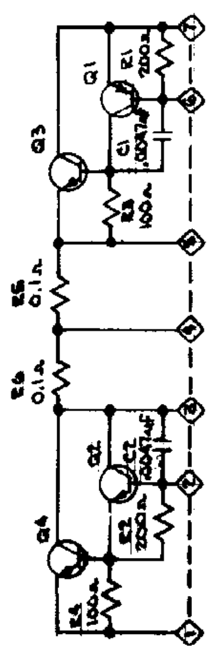




SCHEMATIC, HEATSINK A52G



A5211, A5212
HEATSINK
(2 PER AMPLIFIER)



MAINTENANCE AND TROUBLESHOOTING

This section is written in general terms to be applied to the whole A520 series without necessarily referring to specific values. The amplifier is considered in four major sections: The Op Amp (Fig. 8), the Differential Amp (Fig. 10), the Power Drivers and Output Bridges (Fig. 12), and the Current Limit (Fig. 14). The Compensation Board can be removed and tested by visual inspection or with an ohmmeter.

FIELD ENGINEER'S QUICK TEST

The following is a quick test procedure for field engineers to quickly isolate probable faults and make an evaluation of whether repair in the field will be practical, or if major sub-assemblies should be replaced or returned to the factory.

1. The most common fault on heatsink assemblies is collector to emitter short circuits. Ohmmeter test all power driver and power output transistors. Replace defective transistors.

2. Disconnect output plugs A and B from the circuit board. Remove all connections from TB1-6 and 7. Apply power and check for presence of B+, -15 VDC and + 15 VDC in accordance with schematic.

3. With power still on, apply a signal input to one of the amplifier inputs being sure that the gain control is turned up. Connect a 50 Volt DC meter from R37 to R38. It should be possible to get a positive and negative voltage swing, depending upon signal polarity, equal to 80% or more of the B + voltage. If proper voltage swing is not attainable, refer to detailed procedure.

4. Ohmmeter test transistors Q7, Q8, Q9 and Q10 and all Diodes in the Differential Amplifier. Replace defective units.

5. If the fault is not easily isolated by the above procedures, it is best to continue on with the full procedure described below.

GENERAL. The basic amplifier design utilizes direct coupling and multiple feedback which makes simple logical fault isolation very difficult. Accordingly maintenance and troubleshooting operations should economically be based on a cause elimination process as described herein. Before starting any maintenance activity visually inspect the unit and allow your experienced eye to check the proper connections etc. It is embarrassingly true that most faults are obvious by inspection or after a novice points them out.

PERIODIC MAINTENANCE. Clean the amplifier and blower from time to time with a high pressure air hose to remove any accumulated dust. Units equipped with blowers require periodic lubrication, instructions for which are printed on the blower motor housing.

TEST DATA SHEETS. Data sheets are filled out for each unit after factory test to determine typical operating characteristics. A copy of the test data sheet is shipped with each amplifier.

TEST EQUIPMENT. The following items of test equipment are required to isolate the fault-cause in these amplifiers.

a. Multimeter, Simpson Model 260 or equivalent.
b. Oscilloscope, Tektronix Model 502 A or equivalent.
c. Production Acceptance Test Data Sheet for unit.
d. Schematic diagram for unit.
e. DC Signal Simulator
f. PCB Dummy Load
g. Driver/Output Heatsink Tester
h. Suitable load resistor

Note: - see appendix for e, f, g.

FAULT ISOLATION METHOD. The basic economics of field repair dictate fault isolation to a replaceable component or assembly, its repair or replacement and restoration of the unit to service in less than one half hour. Examination of the amplifier design, its components, their failures and the field failure experience indicates that this repair time can easily be achieved. The most common failures are in the heatsink assembly due to prolonged operation into a shorted load, connecting 110 VAC into the output terminals, misconnecting the power supply and connecting grounded test equipment across the output. The power supply failures are obvious but the circuit board failures are obscured by the multiple feedback paths. Accordingly once a fault has been isolated to the circuit, this board should be replaced as a component. The circuit board can be repaired at the factory or depot with a special circuit board test position and experienced technicians with time.

Step 1 - Conduct the prescribed system checkout per the production acceptance test data sheet for the unit. Complete failure of this test usually indicates power supply or heatsink failure. Deviation of a few numbers only could indicate a circuit board failure.

Step 2 - Supply Voltages. B + and - 15 VDC, which are provided on the DC power amplifiers are externally applied to the amplifier module. An internal + 15 VDC is provided by a 15 volt Zener Diode (CR9) and should be + 15 ± 1.1 VDC under all conditions of normal input signal.

Step 3 - Check out the heatsink assembly and wiring with power off by using an Ohmmeter.

Step 4 - Check out the circuit board voltages as indicated below.

a. The ± 0.7 volt null bias supply is derived from the ± 15 VDC supplies. These voltages are provided by two diodes (CR12, CR13) and may be ± 0.7 ± 0.1. They provide voltage for the balance network.
b. Preamplifier. The preamplifier is one-half of operational amplifier A1. The gain of the preamplifier may vary with the model dash number. Offset is compensated for by the balance network, the sensitivity of which varies with the amplifier gain. The maximum offset with the balance pot in mid position may range from 40 MV for low gain preamp to 1200 MV for high gain preamp. Other irregularities in the preamplifier such as nonlinearity or oscillations may be caused by defective components (i.e. open or shorted capacitors, resistors, diodes or a defective printed circuit board.)
c. First Power Amplifier. The second half of operational amplifier A1 drives the differential amplifier and has a diode limited output swing and a gain of 200 ± 20. The differential amplifier drives the output stage of the amplifier module and may be divided into two sections. Q2 and Q3 are the differential section transistors and Q1 and Q11 are the sliding constant current section transistors. To test and partially isolate:

   (1) Jumper R37 and R38 common side (high side) to B +. (Current limit disabled). Disconnect plugs A & B to Driver Heatsink. Remove connections from TB1 6 &7.
   (2) Vary balance pot and observe that ± 30 % min. of B + voltage swings across R 37 and R 38.
   (3) If test fails, Ohmmeter test Q1, Q2, Q3, Q11 and all diodes on right half of circuit board starting with CR10 and CR11.

e. The output stage consists of Q7, Q8, Q9, Q10 and may be tested by meter testing in the involved components. R41 and R42 provide for a method of adjusting the amplifier quiescent current. If the voltage across J1-A2 or J1-A3 or J1-B4 to J1-B3 goes to zero or is greater than 20 MV, oscillations or false limiting may occur. This voltage should be kept between 2 and 20 MV by selecting R41 and R42 at zero output volts. (Factory selection.)
f. Limiting Circuits. Because of wide tolerances on components, the limiting circuits may require selection of certain resistors to meet specifications after repair. Variation in these components prior to selection should cause no more than ± 30 percent variation in maximum limiting levels and ± 50 percent variation in minimum levels. Current and dissipation limiting should be tested prior to selecting any components. Test as follows:

   (1) Complete amplifier should be functioning and specified test load connected to output.
   (2) Measure 50 percent B + volts at emitter or base of Q4 under all conditions of limiting or output level.
   (3) Measure approximately equal change in voltage across R24 and TB1-9 to TB1-10 as output level changes.
   (4) Measure less than 100 MV drop across Q5 collector to emitter with limiting pot set to maximum CW and under no load conditions.

(5) Measure 0.45 to 0.65 volts drop across CR16.
(6) Measure 1.0 to 1.6 volts from CR7 anode to Q6 emitter under all conditions of output level and loading.
(7) With S1 in DIS position, measure equal voltage at Q6 base and C7 plus side.
(8) With S1 in DIS position, liming pot fully CCW, load off, and signal input sufficient to saturate amplifier, measure an output level within 6 volts of B + voltage (Use oscilloscope).
(9) Failure in any part of step f should be followed by a meter test of the involved components: Q4, Q5, Q6, R5, R6, R7, R8, R22, R23, R24, R25, R26, R34, CR10, CR11, CR16, CR17, C7 and C9. If oscillation occurs during both current and dissipation limiting, suspect capacitor C7.

h. Limiting levels are controlled by R5, R6, R7, R8 and R24 as follows:

Component	Function
R5 (Pot)	Adjust level of limiting for both modes of limiting.
R6	Controls maximum level of dissipation limiting.
R7	Controls minimum level of dissipation limiting.
R8	In series with R6, sets maximum level of current limiting.
R24	This resistor is common to both modes of limiting and should be changed if both modes have minimum or maximum levels out of spec. R24 should be changed no more than ± 30 percent from the value on the parts list.

i. To set limiting levels if irregularities occur:

(1) Change R6 while in the dissipation mode to get maximum level in spec.
(2) Change R7 while in the dissipation mode to get minimum level in spec.
(3) Change R8 while in current limiting mode to get maximum level in spec.
(4) Change R24 to increase or decrease both levels.

j. Peak current is controlled by a network of twelve diodes: CR3, CR4, CR5, CR6, CR24, CR25, CR26, CR27, CR28, CR29, CR30, and CR31. If peak current is not high enough, meter test the involved diodes. These diodes, if shorted, may also affect the steady state limiting circuits.

SIGNAL TRACING POINTS - SIMPLIFIED: The following table lists a few strategic signal tracing points to attempt quick fault isolation, before going on to detailed procedures. The data is on a board with 60 V B +. Signal was applied to Input No. 2 which has a gain of 200 to the amplifier Output. Read down columns.

Test Point	Voltage				**	**
Input	0	+ .28	+ 1.0	- 1.0	+ 1.0	- 1.0
A1 - 2	0	- 3.9	- 10.0	+ 10.0	+ 10.0	- 10.0
A1 - 12	0	+ .55	+ 1.2	- .96	1.44	1.5
Q2 - 13	- .2	+ .06	+ .46	- .95	.52	1.45
Q2 - C (R37)	* 30.5	2.9	2.3	58	11.0	48.0
Q3 - C (R38)	* 30.5	55	58	2.3	48.0	11.0
Q6 - E	* 60	60	59	58		
TB1 - 6	* 30	2.6	2	58		
TB1 - 7	* 30	55	58	2.1		
TB1, 6 to 7	0	50	55	55		

** These two columns are with circuit board plugs A&B removed and all wires to TB1 - 6 &7 disconnected.

* These voltages will be about 2/3 this value for a 40 V amplifier.

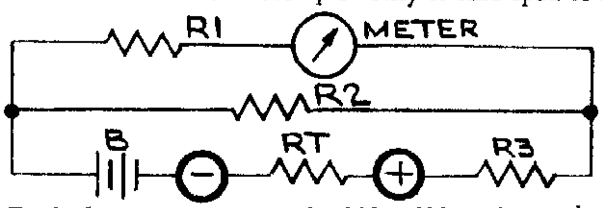
CIRCUIT BOARD - POWER OFF - OHMMETER TESTS.

The following tests can be made on the circuit board to quickly identify open or shorted semi-conductors. The meter used for the tests was a Simpson 260 on the X 100 scale. Other meters or other scales may be used, but the readings will have to be calibrated on a few "known to be good" parts. For example, on another meter, 1 meg ohm may be equivalent to infinity, or 4 ohms may be equivalent to 8 ohms. See the Appendix for testing semi-conductor with an Ohmmeter.

Q	POL	CB	BC	EB	BE	CE	CR	KA	AK	CR	KA	AK
1	+	∞	8	40	8	∞	1	-	-	19	-	-
2	+	∞	8	∞	8	∞	2	-	-	20	∞	8
3	+	∞	8	∞	8	∞	3	45	9	21	∞	8
4	+	∞	8	500	8	∞	4	65	9	22	∞	8
5	-	∞	8	∞	8	∞	5	50	9	23	∞	8
6	+	∞	8	∞	8	∞	6	60	9	24	∞	8
7	+	∞	8	∞	8	∞	7	45	9	25	∞	8
8	+	∞	8	∞	8	∞	8	70	9	26	∞	8
9	-	∞	8	∞	8	∞	9	35	9	27	∞	8
10	-	∞	8	∞	8	∞	10	∞	8	28	∞	8
11	-	150	8	∞	8	15	11	∞	8	29	∞	8
							12	40	8	30	∞	8
							13	60	8	31	∞	8
							14	8	8	32	∞	8
							15	8	8	33	∞	8
							16	8	8	34	∞	8
							17	8	8	35	∞	8
							18	8	8			

note: MULTIPLY ALL READINGS X 100
C = Collector
B = Base
E = Emitter
K = Cathode
A = Anode

OHMMETER TEST OF SEMICONDUCTORS: The semiconductors in the A520 series of amplifiers may be tested safely with a Simpson 260 meter which has a maximum potential of 21.5 V and various resistor dividers, or with an equivalent meter. The Ohmmeter test is used primarily to find open or shorted semiconductors, but sometimes "leaky" devices can be detected.



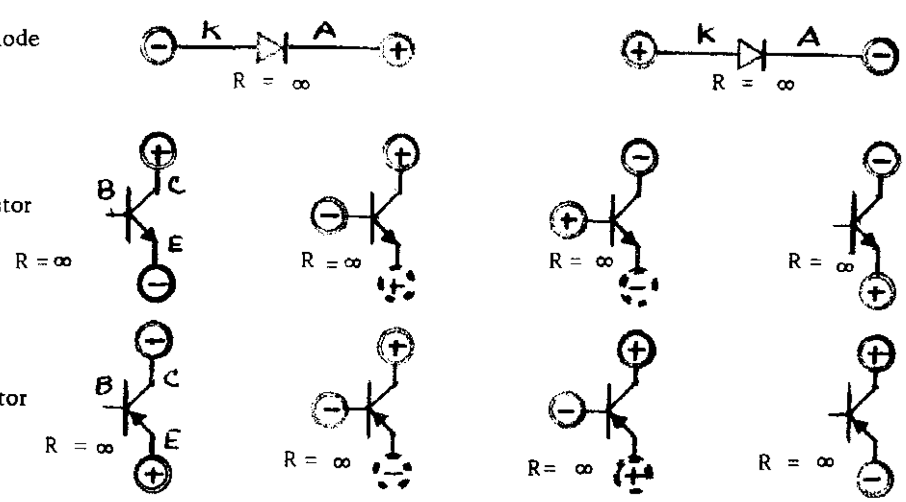
The resistors R1, R2, R3 have values selectable with switches to select the range. RT is the external resistor being measured. The 260 has a switch to reverse the polarity at the terminals.

Typical measurements on the 260 X 100 Scale are shown below with meter polarity as indicated circle:

CR Silicon Diode

Q NPN Transistor

Q PNP Transistor



The resistances given above are approximate, but a defective device will usually vary substantially from the stated value. Semiconductors installed in circuits frequently have resistors shunting their terminals. The amplifier Test Tables reflect the effect of these shunting resistors.

TEST SET - DRIVER/OUTPUT HEAT SINK - A 520 SERIES

The purpose of this test set is to be able to test the driver/output heat sink portion of any of the A520 series of amplifiers without having to use a circuit board. The output bridge portion of the amplifier consists of four quadrants and this test set will enable the user to isolate a trouble to any one of the four. The test set is useful for locating the following kinds of trouble:

1. Shorted transistors 2. Open transistors 3. Low grain

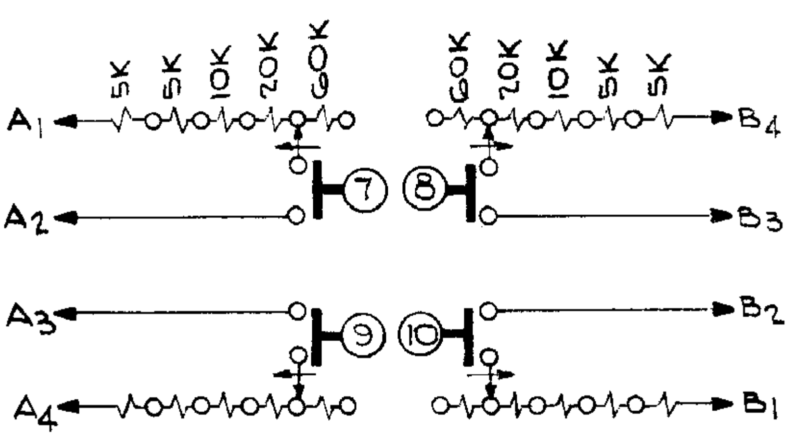
The test set is designed to provide base drive to the driver transistor and this is accomplished by supplying positive DC to the base through a resistor. The amount of resistance used is selected with a selector switch which connects the same base input resistance to each of the four driver quadrants. This test should always be done by starting with the highest resistance first and then decreasing the resistance step by step until the proper output is obtained. The test indication is obtained from a DC ammeter connected in series with the power supply to the heat sink. In addition, it may be desirable to use a resistor in series with the DC supply in the range from 1 ohm to 5 ohms to limit the ultimate maximum current which may pass through the unit under test.

CAUTION. This test can be destructive since it is essentially a short circuit test. In the short circuit condition, small currents cause high power dissipation and, therefore, the test buttons should be pressed momentarily so as to get a reading on the ammeter.

The buttons on the tester labelled 7, 8, 9, and 10, correspond to the equivalent transistors on the circuit board identified as Q7, Q8, Q9, and Q10. The vertical button pairs, 7 and 9, and pair 8 and 10 turn on transistors in the bridge which are directly in series across the DC power supply. Button pairs 7 and 10 and pair 8 and 9 turn on transistors in the arrangement which would be turned on for normal operation of the amplifier. In order to get a complete test when pressing these diagonal pairs, it is necessary to either short the output terminals of the amplifier, or connect a load resistance.

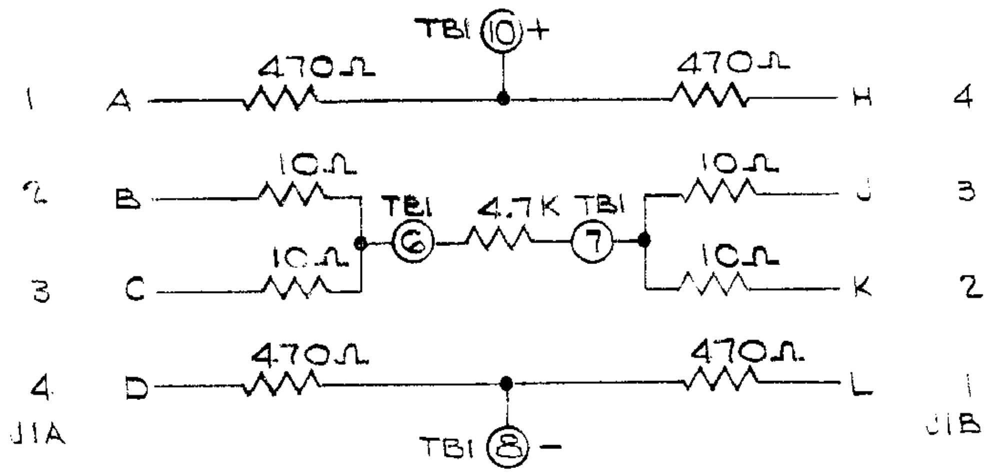
The normal procedure for operating the tester is to connect the two plugs "A" and "B" into the matching plugs from the heat sink. Then connect the heat sink to the DC power supply with an appropriate ammeter, and a series resistor if desired. Do not connect a load resistor yet. Now, press buttons 7 and 9 and decrease the resistance to the base of the transistors by turning the switch clockwise from position 1 towards position 5 in order to get an adequate reading on the ammeter. However, if there are some shortened transistors, there may be readings on the ammeter for the first few positions of the switch. Now, press buttons 8 and 10 and there should be about the same current reading on the ammeter. By pressing only one button, a current reading indicates that there are shorted transistors in the associated part of the bridge. If it is not possible to get any current reading, then there are open transistors in the associated part of the bridge. Now, an additional check can be made by either connecting a load resistor or shorting the output terminals and repeating the test by pressing buttons 8 and 9 and checking for a current reading.

The value of current for each kind of amplifier will vary. High voltage amplifiers with many parallel heat sinks will have a much higher current than single heat sinks operating at low voltage. For the test with the output shorted, the current for any of the four combinations of buttons should be approximately equal. If one pair appears to have a much higher or a much lower reading for a given heat sink, than the other three pairs, then there should be additional investigation.

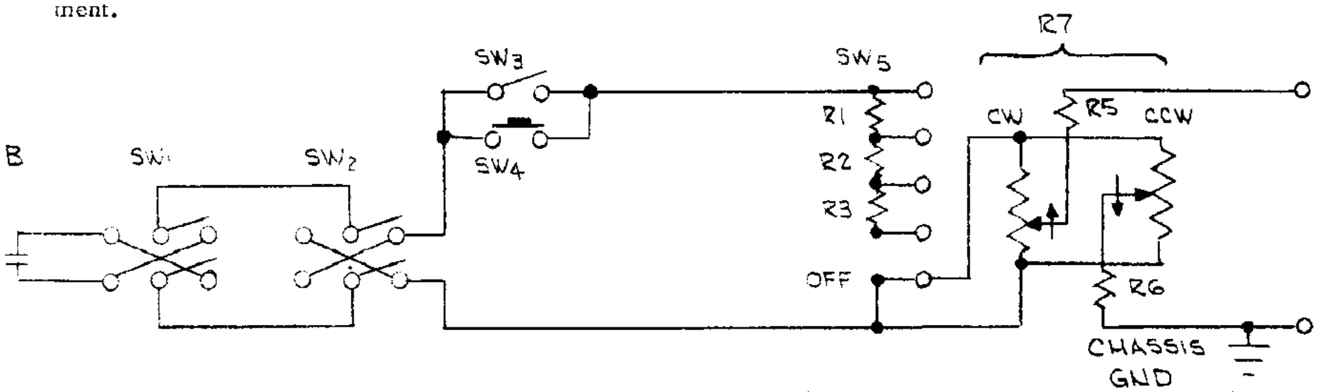


Shown to the left is a schematic for a heat sink tester using four push buttons and a 4 pole 5 position selector switch.
For a quick test in field service, if it is possible to use two resistor decade boxes connected alternately to the different terminal pairs to be tested.

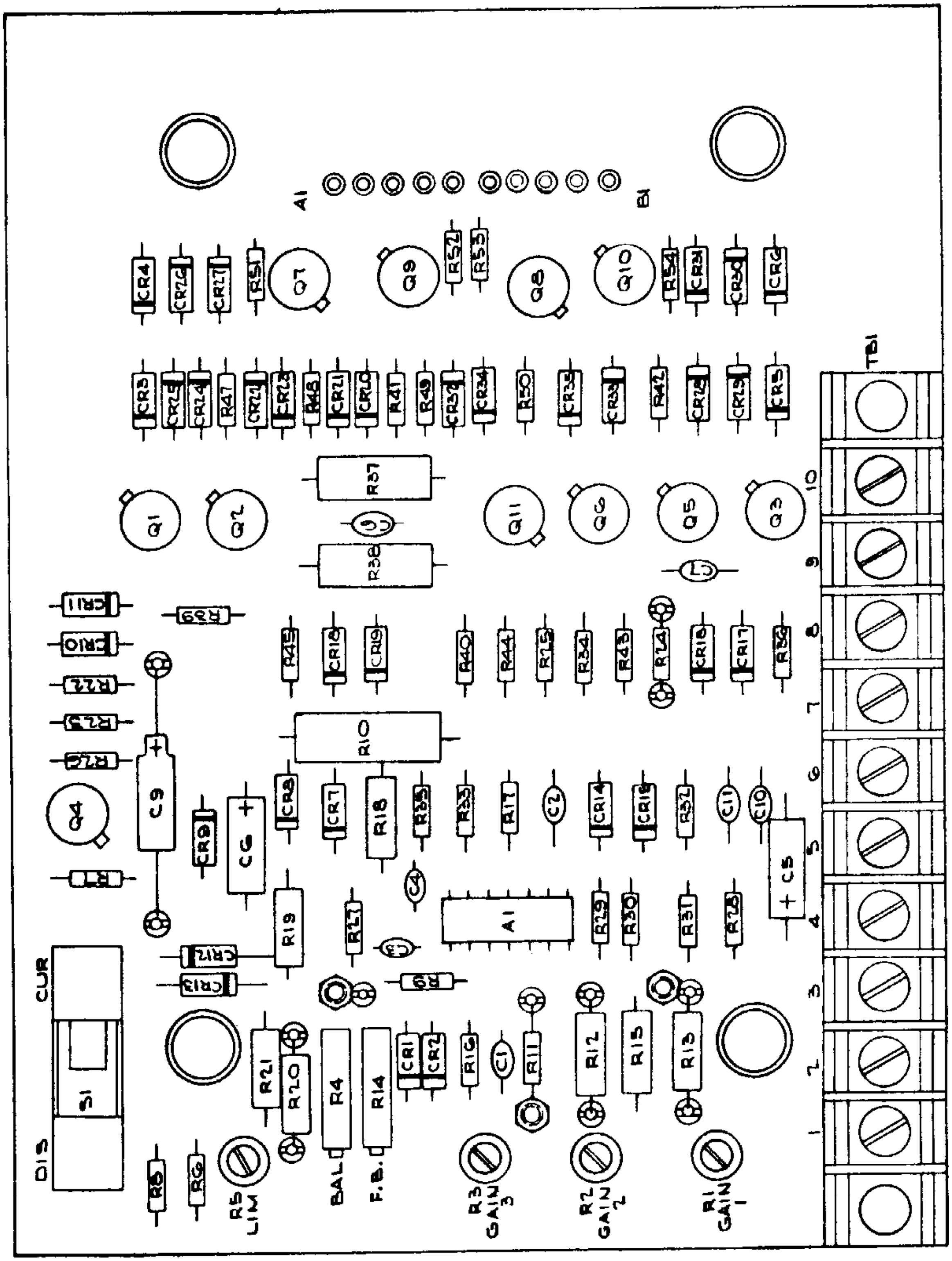
DUMMY LOAD - A520 SERIES CIRCUIT BOARD: Shown below is a schematic for a Dummy Load to be used in testing the circuit board with the Power Driver and Output transistors. Troubleshooting of the amplifier is simplified when the circuit board and the power transistors are tested separately. Preliminary troubleshooting of the circuit board can be done with output plugs A&B removed and all connections to TBl - 6 &7 removed. However, to test for full output voltage swing and symmetry at TBl - 6 &7, it is necessary to have the dummy load connected.



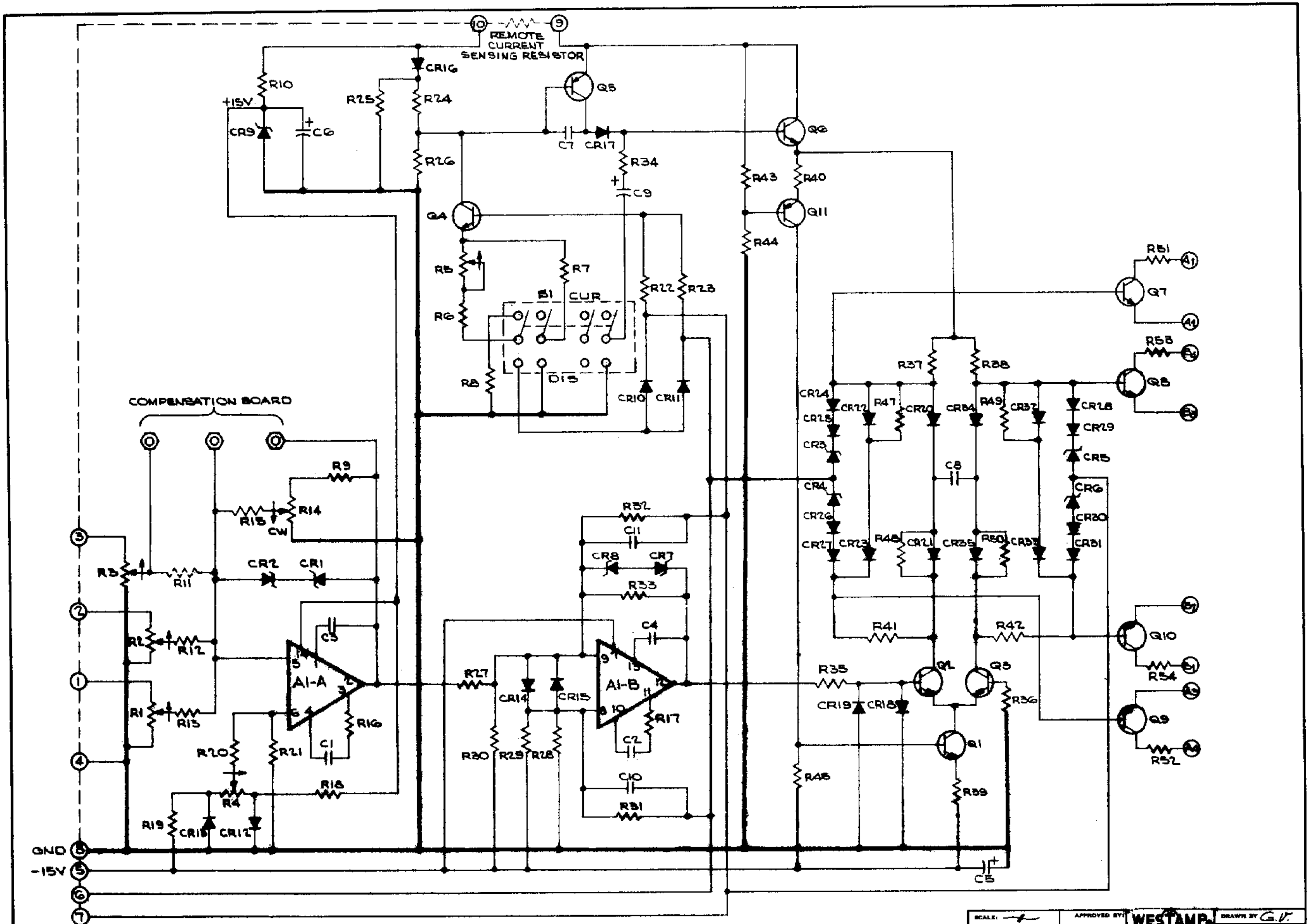
DC SIGNAL SIMULATOR: Shown below is a schematic for a DC signal source for providing + and - variable amplitude signals. The unit also has a push button switches to create step outputs and reverse signals useful for servo system alignment.



SW1	DPDT	Toggle	R1	18K	1/4 W	R5	470 Ω	1/4 W
SW2	DPDT	Mom. Pushon	R2	180 K	1/4 W	R6	470 Ω	1/4 W
SW3	SPST	Toggle	R3	1-8 M	1/4 W	R7	5 K	Dual
SW4	SPST	Mom. Pushon	R4	delete		B	9V Battery	
SW5	2P6P	Rotary						



A 520 Series PRINTED CIRCUIT BOARD



SCALE: —	APPROVED BY:	WESTAMP INCORPORATED	DRAWN BY G.V.
DATE: 2/1/72			REVISED
SCHEMATIC-DC AMPLIFIER ASSEMBLY			
MODEL:			DRAWING NUMBER M 28106

TABLE OF NORMAL DC VOLTAGE LEVELS

This table lists DC levels with no input signal and output balanced for zero output. All voltages to ground, unless indicated as WRT (with respect to). If measured resistance is outside normal values, replacement of the suspected component is indicated.

Measurement Point	DC Voltage	Suspected Components
CR9	+ 15 ± 1.1 V	CR9, CR6, R10
* TB1-10	40 V	P.S.
TB1-9	-11 ±9 mv (WRT)TB1-10	H.S. R7
TB1-8	PWR GND	Wiring
* TB1-7	19 ± 2V	Q6, R38, Q8, CR28, CR29, CR5, CR6, CR30, CR31, Q3
* TB1-6	19 ± 2V	Q6, R37, Q7, CR24, CR25, CR3, CR4, CR26, CR27, Q2
TB1-5	- 15 ± 1 V	P.S., C5
TB1-4	SIGNAL GND	PC path to TB1-8
TB1-3	- 1 ± 0.5 mv	Wiring
TB1-2	- 1 ± 0.5 mv	Wiring
TB1-1	- 1 ± 0.5 mv	Wiring
CR12	+ 0.7 ± 0.1 V	CR12, R18, CR9, C6, R10
CR13	- 0.7 ± 0.1 V	CR13, R19, P.S.
A-1-1	See note 2	-
A1-2	0 ± 100 mv	Preamp output
A1-3	See note 2	-
A1-4	See note 2	-
A1-5, 6	- 15 ± 7.5 mv	Preamp input
A1-5	0 ± 10 mv	Preamp input
(WRT) 6	See note 2	
A1-7	- 15 ± 1.1 V	C5, P.S.
A1-8	± 0.35 ± 1 V	Preamp No. 1 input
A1-9	+ 0.35 ± 1 V	Preamp No. 1 input
A1-8	0 ± 10 mv	Preamp No. 1 input
(WRT) 9	See note 2	
A1-10	See note 2	-
A1-11	See note 2	-
A1-12	0 ± 100 mv	Preamp No. 1 output
A1-13	See note 2	-
A1-14	+ 15 ± 1.1 V	CR9, C6, R10, P.S.
Q1-C	- 1.0 ± 0.3 V	Q2, Q3, CR21, CR20, CR34 CR35
Q1-B	- 2.8 ± 1.5 V	Q11, Q6
Q1-E	- 0.8 ± 0.1 V (WRT) Base	Q2, Q3

Measurement Point	DC Voltage	Suspected Components
*Q2-C	18.3 ± 2 V	
Q2-B	- 0.2 ± 0.1 V	
Q2-E	- 0.7 ± 0.1 V (WRT) Base	
*Q3-C	+ 18.3 ± 2.0 V	
Q3-B	- 0.2 ± 0.1 V	
Q3-E	- 1.0 ± 0.3 V	
Q4-C	-0.7 ± 0.1 V (WRT)TB1-10	
*Q4-B	+ 19 ± 1 V	
Q4-E	- 0.7 ± 1.0 V (WRT) Base	
Q5-C	- 30 ± 20 mv (WRT) TB1-10	
Q5-B	- 0.7 ± 0.1 (WRT) TB1-10	
Q5-E	- 11 ± 9 mv (WRT) TB1-10	
Q6-C	- 11 ± 9 mv (WRT) TB1-10	
Q6-B	+ 0.7 ± 0.1 V (WRT) TB1-10	
Q6-E	- 1.4 ± 0.3 V (WRT) TB1-10	
Q7-B	+ 0.7 ± 0.1 V (WRT) TB1-10	
Q7-B	+ 0.7 ± 0.1 V (WRT) Emitter	Q3, CR20, R37, Q6, CL
*Q7-E	+ 19 ± 2 V	Q7, CL, BAL
Q7-E (WRT) Q9-E	+ 11 ± 9 mv	
Q8-C	- 0.7 ± 0.1 V (WRT) TB1-10	
Q8-B	+ 0.7 ± 0.1 V (WRT) Emitter	
Q8-E	+ 19 ± 2 V	
Q8-E (WRT) Q10-E	+ 11 ± 9 mv	
Q9-C	+ 1.4 ± 0.3 V	
Q9-B	- 0.7 ± 0.1 V (WRT) Emitter	
*Q9-E	+ 19 ± 2 V	
Q10-C	+ 1.4 ± 0.3 V	
Q10-B	- 0.7 ± 0.1 V (WRT) Emitter	
Q10-E	+ 19 ± 2 V	
Q11-C	- 2.8 ± 1.5	
*Q11-B	+ 20 ± 2.0 V	
Q11-E	+ 0.7 ± 0.1 (WRT) Base	

NOTES: *Voltage level varies proportionally with supply voltage. Amplifiers with 60 volt power supply can usually be set at 40 V for this test.

1. B = Base, C = Collector, E = Emitter
2. Connecting test equipment to certain terminals of operational amplifier A1 may disturb amplifier.