SE400S—FRONT VIEW

JAMES B. LANSING SOUND, INC. | MODEL SE400S SOLID STATE ENERGIZER

JBL SE400S
SE408S
SERVICE MANUAL
REPLACEMENT PARTS
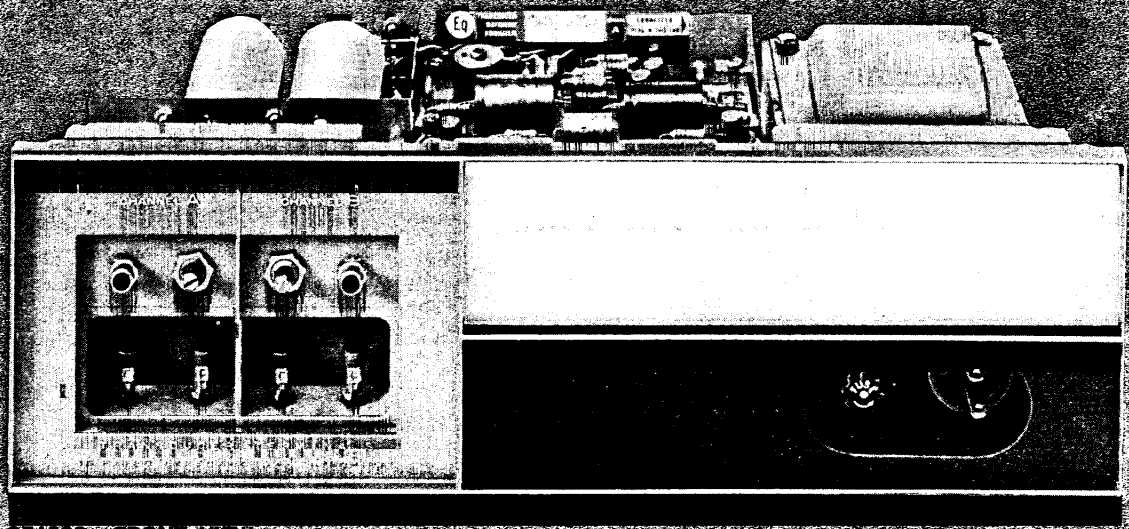
SE408S—FRONT VIEW

INDEX

1.0 DESCRIPTION OF CONTROLS AND CONNECTIONS

1.1 INPUT JACKS

Two standard jacks provide input connection to the Energizer. Channel "A" is normally used for the left channel and Channel "B" corresponds to the right channel input.

1.2 GAIN CONTROLS

Adjustment of the amplifier input sensitivity. These controls should be adjusted to provide a convenient preamplifier volume control setting.

1.3 TRANSDUCER TERMINALS

Provide connection to the loudspeaker system. If the SG250 and accessory F22 relay are used, the black energizer terminals will be connected to the F22. Do not connect the black terminals together for use with either speaker switches or headphone jacks. Use of equalizer boards, Sect. 1.2.1, requires separate leads be run to both terminals of both speaker systems.

1.4 FUSE

For operation from 110-120 volt power sources, a 2-amp. slo-blo fuse should be used. Operation with 220-240 volt sources requires a fuse of 1 amp. slo-blo type.

1.5 EQUALIZER BOARDS

1.5.1 FUNCTION

The exclusive Equalizer boards provide an optimum match between amplifier, transducer and enclosure. Both passive equalization and current feedback are used to tailor the performance of the entire amplifier — transducer chain for the most uniform acoustical output. Measurements on the amplifier must be made with equalizer boards placed in the "flat" position.

1.5.2 CHANGE OF EQUALIZER BOARDS

1.5.2.1 SE400S — remove the four mounting feet, then take off the bottom and front panel. FIG. 4-2.

1.5.2.2 SE408S — no steps are required.

1.5.2.3 HOW TO CHANGE BOARDS

A. Each equalizer board is clearly marked with the name of the loudspeaker and directions for equalized or non-equalized operation. Because the two boards are separate, each channel can be equalized independently of the other. To replace either or both halves:
Remove the two black phillips-head screws which hold the halves of the equalizer board in place. These are the two screws at the opposite end from the connector strip. **Do not** remove the screws which attach the contact strip to the Energizer chassis.

B. Either half of the board can now be removed by first sliding it out from the contact strip. Slide the board as far as possible before lifting it otherwise the contact fingers may be damaged.

C. Reverse this procedure to install the new board. Notice that proper insertion of the board depends upon whether it is used in channel A or channel B; When both halves are set for equalized operation, the circuit components will be on the front side of one and the back side of the other. If the two halves of the board are designed for different loudspeaker systems, make sure that each channel is equalized to match the loudspeaker system connected to **that** channel.

D. When both halves of the equalizer are properly inserted, replace the two mounting screws.
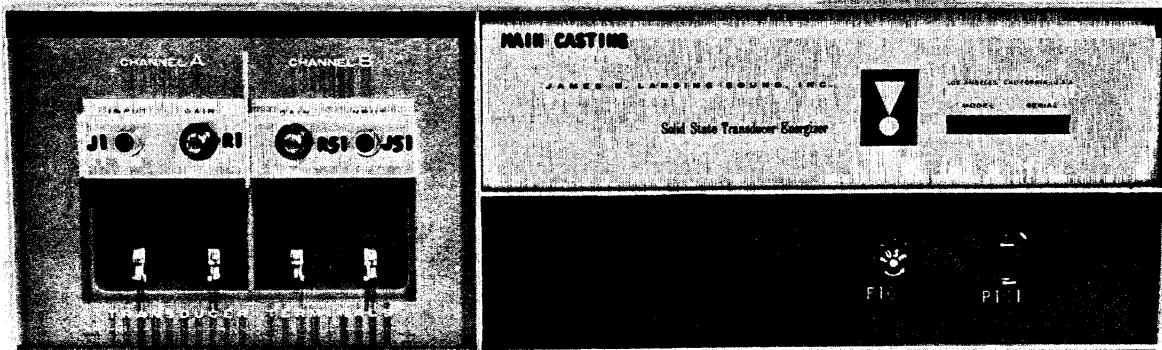
1.5.2.4 EQUALIZED OR NON-EQUALIZED OPERATION

Normally, each half of the equalizer board will be marked with the model number of the loud-speaker system connected to that channel, and both halves will be plugged in for equalized operation. The non-equalized mode of operation must be used when checking performance specifications.

2.0 SPECIFICATIONS

2.1 INTRODUCTION

The specifications which follow are measured under the following conditions:
1. Both channels operating simultaneously with 8-ohm resistive load.
2. AC line voltage 117 volts 50/60 cps or 234 volts 50/60 cycles depending upon transformer connection.
3. Equalizer boards installed in Unequalized "flat" position.

Power Output: 80 watts continuous RMS power, 40 watts per channel, at any frequency from 10 cps to 30,000 cps.

Frequency Response: ±0.25 db from 20 cps to 20,000 cps. ±1.5 db from 3 cps to 175,000 cps. Low frequency response is attenuated below 3 cps by a capacitor in the input circuit of the first amplifier. The T-Circuit itself operates down to zero cps.

Harmonic Distortion: Less than 0.15% from 20 cps to 20,000 cps at 80 watts

Intermodulation Distortion: Less than 0.15% at 80 watts or any level less than 80 watts (IHF standard — 60 7,000 cps 4:1 ratio).

Sensitivity: 0.8 input for rated output, will vary from 0.8 to 3.0 volts in equalized mode depending upon the particular equalizer boards installed.

Hum and Noise: 90 db below rated output.

Transient Response: With the equalizer boards set in "Flat" position rise time is 2.0 microseconds from 10% to 90% of square wave signal at 160 watts peak power or any lower power level. Response to such square wave signals is free from detectable overshoot or ringing, as observed on an oscilloscope.

Overload Recovery: Less than 1/10 of one cycle to recover from 100% single cycle overload at any frequency from 20 cps to 20,000 cps.

Input Impedance: 25,000 ohms.

Load Impedance: 8 ohms rated impedance. 4 to 16 ohms nominal impedance. When driving a 16 ohm load, the unit meets all published specifications except that power output is reduced to 64 watts. When driving a 4 ohm load, the unit produces 130 watts of power for brief periods of time. Prolonged operation at more than 40 watts per channel however will trigger the built-in auto-matic overload devices. It should be noted that the actual impedance of a loudspeaker varies with frequency and may deviate considerably above and below its nominal impedance rating. Because the Energizer is completely stable under any load conditions, it will operate satisfactorily with any dynamic loudspeaker having a nominal impedance rating within the range from 4 to 16 ohms.

Damping Factor: With the proper equalizer boards inserted for equalized operation, damping is set for optimum results with the particular loudspeakers used. With the equalizer boards in the "flat" position, generator impedance at the output terminals is 0.3 ohms, equivalent to a damping factor of 27 when connected to an 8 ohm load. Damping remains uniform through the full audible frequency range and is unchanged by abrupt transient peaks.

Stability: The circuit is completely stable when connected to any dynamic loudspeaker system or even to a capacitive load. Specified distortion and stability without oscillation are maintained through extreme variations in output load, whether resistive, capacitive or inductive. Moreover, AC line surges do not affect the stability of the T-Circuit.

Transistors: 22 silicon transistors plus 20 silicon diodes.

2.2 MEASUREMENT TECHNIQUES

Most of the commonly available instruments used in testing audio amplifiers have higher distor-tion and/or noise than the SE400s or SE408s. In order of preference we recommend for the audio oscillator a Radford Low Distortion Oscillator or a Hewlett Packard Model H20-200CD. Use of Hewlett Packard Model 333 Harmonic Distortion Analyzer is preferred. For ease of making IM Distortion measurements we recommend the Audio Instrument Company Model 168 Analyzer.

Because the residual distortion, hum and noise of these amplifiers is so low, the measuring techniques recommended below should be used.

2.2.1 TOTAL HARMONIC DISTORTION

1. Connect the oscillator to either of the input jacks with a standard shielded cable.
2. Connect the harmonic distortion analyzer and an 8 ohm non-inductive load resistor to the red and black output terminals.
3. Both the oscillator and the distortion analyzer should be "floated" or isolated from the power line grounding. This can be done by using a two-blade power plug adaptor which disconnects the instrument's power cable ground pin. If the Hewlett Packard oscillator is used, the output terminal ground strap should be disconnected so that the output is floated from the instrument chassis ground. Do not connect a ground between the oscillator and analyzer.
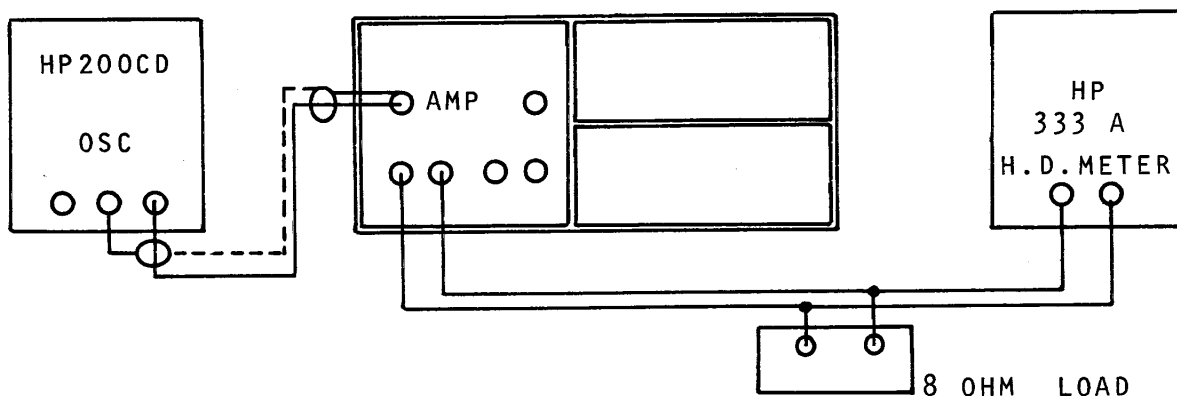
2.2.2 INTERMODULATION DISTORTION

1. Connect the "Oscillator Out" terminals of the intermodulation analyzer to the input.
2. Connect a non-inductive 8 ohm load resistor to the red and lack output terminals.
3. Connect the hot "Analyzer Input" terminal to the red output terminal. Make no connection between the analyzer ground terminal and the black output terminal. This precaution avoids the ground loop that would be completed through the analyzer common input-output connection.
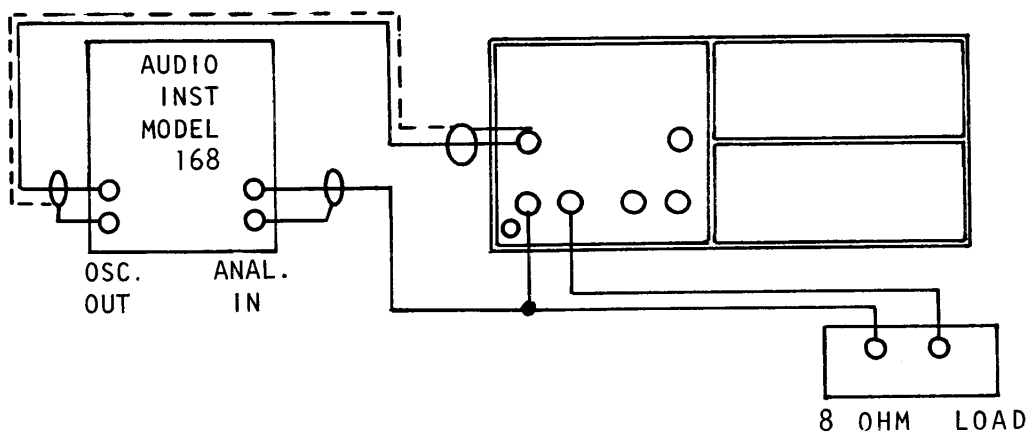
2.2.3 HUM AND NOISE

1. Connect an AC vacuum tube voltmeter to the red and black output terminals.
2. Terminate the input with a phono plug containing a 1000 ohm resistor. The resistor should have short leads to the phono plug and should be shielded by the plug body. Switchcraft 3502 plug; $\frac{1}{4}$ watt resistor is recommended.
3. Turn the gain control to maximum and measure the noise output on the VTVM. Express the noise reading in decibels below full output (17.9 volts across the 8 ohms is 40 watts).

SWITCHCRAFT 3502 or Eq.

1,000 OHMS $\frac{1}{4}$W5%

SHORTING PLUG

H.P. 400H

8 OHM LOAD
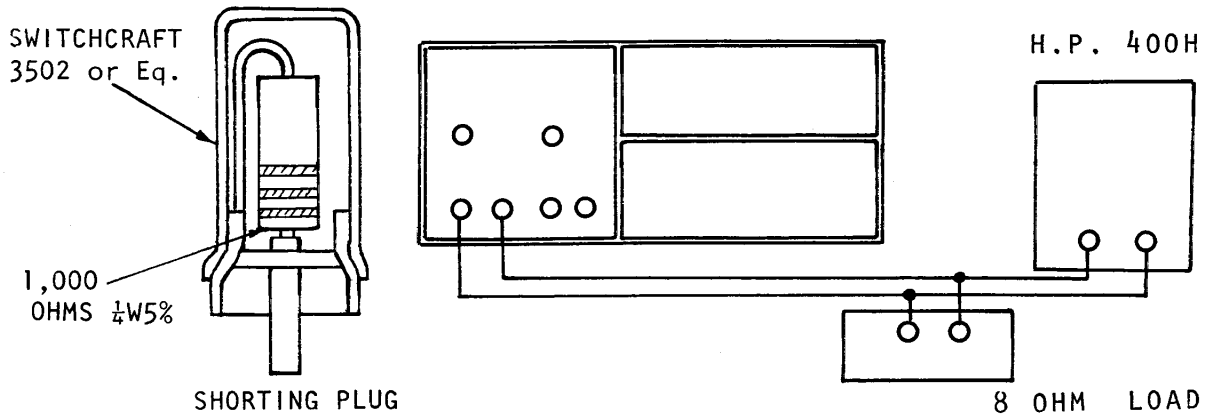
3.0 THEORY OF OPERATION

A detailed discussion of the "T" circuit is contained in the SA600 Service Manual.

3.1 POWER AMPLIFIER

Both the SE400S and SE408S utilize the JBL "T" circuit output stage. Excellent transient response, wide bandwidth and very low distortion are obtained with the entirely direct coupled operational amplifier design.

3.2 OUTPUT STAGE

A series of complementary emitter followers are cascaded in a symmetrical configuration. Use of emitter followers provide a large current gain and effectively multiply the output load by a factor of 100,000. A small loss is encountered, the actual voltage gain being typically 0.92. Source impedance is typically 5,000 ohms assuring that a constant voltage drive is provided to the output stage.

3.3 BIAS DIODE

A small forward bias for the output stage is accomplished by a string of 5- silicon diodes: These diodes are installed in the heat sink casting providing excellent thermal compensation.

3.4 DRIVER STAGES

Cascaded differential amplifiers provide a voltage gain of 1200 with a frequency bandwidth in excess of 100 kc. The actual circuit consists of a PNP differential amplifier direct coupled to an NPN differential amplifier which in turn drives the "T" circuit.

3.5 INPUT EMITTER FOLLOWER

A PNP emitter follower provides a high input impedance to the feedback summing junction reducing the effective input current requirements and allowing the use of relatively high resistances in the feedback loop.

3.6 EQUALIZER BOARD CONNECTIONS

Provision for both current and voltage feedback exists at the summing junction. The voltage feedback loop is closed through the driver circuit board while connection for the current feedback loop is made through the equalizer board. Additional contacts allow insertion of passive equalization

between the input level control and amplifier input.
(illlus. block sum & loop)

3.7 POWER SUPPLY

A total of six operating voltages are obtained from the power transformer. The voltages are balanced to ground and consist of ±37.5V, ±42.1V and ±46.8V. A diode bridge is used for the high current ±37.5 volt supply while voltage doublers are used in the ±42.1 and ±46.8 volt supplies.

4.0 F22 RELAY — CIRCUIT DESCRIPTION AND OPERATION

The DC activating signal for the F22 relay is applied between the chassis ground of the SG520 preamplifier and the shield connection of the channel A output cable. Although the shield of the channel A cable operates at ground potential for the AC signal, a DC potential of about ±20 volts between the CHA shield and the chassis ground. The polarity of the DC signal determines the mode of operation of the two relays.

The AC power relay, Ry1, is connected through a full wave bridge, D2, so that a DC signal of either polarity will energize the relay. The 500 MFD capacitor, C1, supplies enough delay so that any momentary interruption in voltage as the polarity is reversed will not cause the relay to drop out.

This stereo balance relay, Ry2, is connected through a single diode, D1, so that it is polarity-sensitive. The relay operates **only** if there is a positive DC voltage at the channel A ground connection.

When the Graphic Controller is first turned on, a control signal of —20 volts appears at the shield of the channel A output. This operates the AC power relay to turn on the Energizer or power amplifier. The A-B relay, Ry2, is not actuated because of the series diode. Tracing the connections through the A-B relay contact, indicates that both loudspeakers are connected in the normal manner exactly as if the relay were not in the circuit at all.

When the Graphic Controller "test" pushbutton is depressed, the polarity of the control signal is reversed so that a +20 volt signal appears at the shield of channel A. The AC power relay remains closed and the A—B relay is now actuated. If you will trace the connections through the contacts FIG. 3-3, you will find that both of the Energizer black output terminals have been disconnected and the speakers are now connected in series between the two red Energizer output terminals. This effectively causes the speakers to respond only to an A—B or difference signal, enabling the aural null feature to be used.

When trouble-shooting the operation of the F22, remove the cover and see if the two relays are operating as described FIG. 3-2. In other words, whenever the Graphic Controller is turned on, the armature of the power relay should be pulled in, but the A—B relay should not be affected. When the test button is depressed, the power relay should remain pulled in and the A—B relay should also be actuated. If the two relays seem to be operating properly, then the only possible source of trouble in the system is in the connections between the A—B relay, the loudspeakers, the power amplifier or Energizer. On the other hand, if the relays are not actuated in the proper sequence, can check the operating voltage and polarity with an ordinary voltmeter.

NOTE: That it is vitally important that the shield of the channel cable be continuous, and that it **not** be connected to the chassis.

SE400S, SE408S TROUBLESHOOTING GUIDE

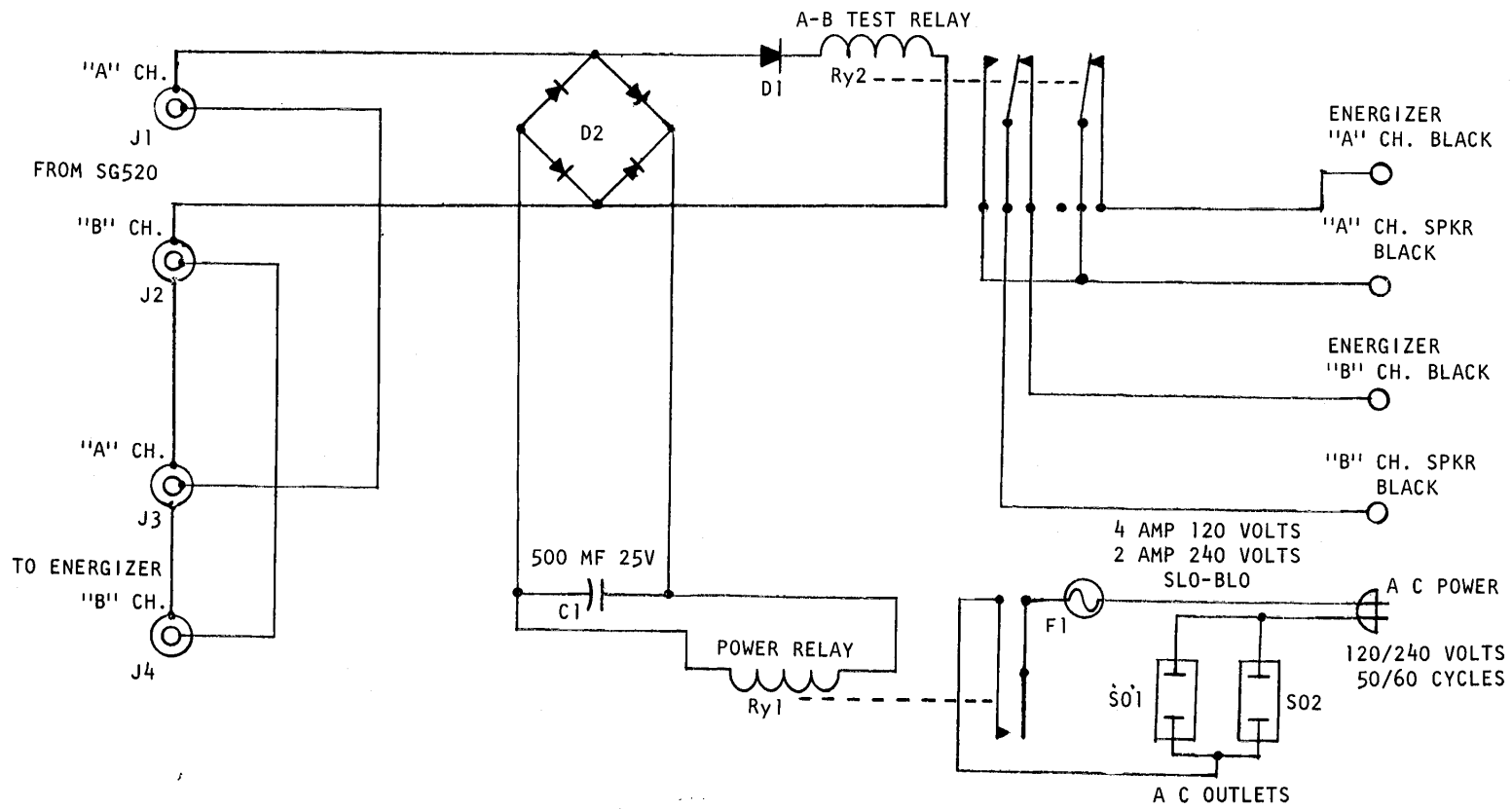| SYMPTOM	POSSIBLE CAUSE—REMEDY
Inoperative (No Pilot Light)	1. Check power connections 2. Fuse Blown 3. F22 Relay not operating 4. Interlock not activated (SE400S only)
Fuse Blows	1. Check the following: A. Output transistors B. D101, 102, 103, 104 C. Diode Assembly D. Line Voltage conversion

Figure 4-1 F22 RELAY SCHEMATIC

Output Transistors Defective	1. Replace after checking:
	  A. Driver Transistors
	  B. Diode Assembly
	  C. D.C. Resistance of load
	    (should be 2 ohms minimum)

D.C. at Output	1. $\pm$ 0.1 Volt normal. 2. $\pm$ 3 volts adjust R9 for 0 volt D.C. 3. Over 3 volts check Q1, 2 or 11 for leakage, replace as required. Adjust R9 for 0 output.

Noise	Check the following:
	  1. R9
	  2. Components for visible signs of overheating
	  3. Clean equalizer board and connector contacts

Low output	1. Check D.C. power supply voltages 2. Check circuit breaker
Low Sensitivity	1. Amplifier gain is 24 $\pm$ 10% when equalizer board is set "flat" and gain control is at "max" position. 2. Up to 3 volts will be required with equalizer boards set in equalized position.
Oscillates	Oscillation or prolonged high power operation at frequencies above 80 KC will discolor R13. 1. Check installation for good engineering practice Check equalizer board for connection and components

4.1 SE400S COVER REMOVAL

Step 1. Remove mounting feet from bottom cover and front panel assembly. This will defeat the AC interlock.

Step 2. Remove four slotted head machine screws located between casting and case. Lift case off power amplifier assembly.

Note: Interlock can be defeated by wedging a toothpick or similar non-metallic object in opening illustrated in figure 4-2.

4.2 INTERLOCK REMOVAL

Step 1. Remove two phillips machine head screws and then lift interlock plate away from casting. (figure 4-3)
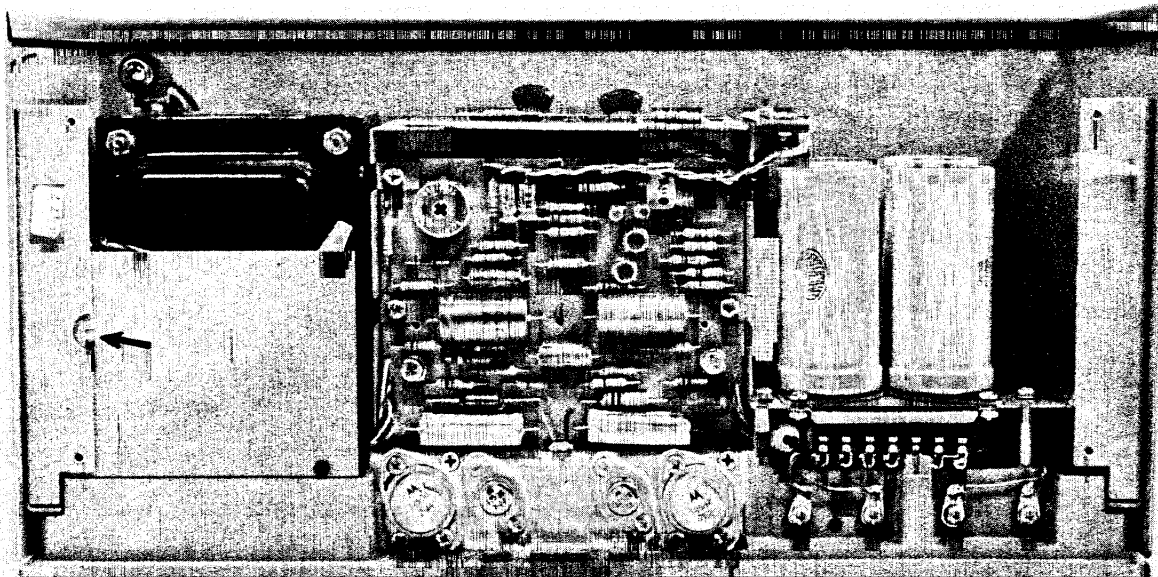

Figure 4-2   SE400S SIDE VIEW

4.3 SE408S REMOVAL FROM ENCLOSURE

FRONT MOUNTED TRANSDUCERS

Step 1. Remove transducer to gain access to rear panel.
Step 2. Remove output lead from energizer.
Step 3. Release 4 energizer mounting screws and remove two mounting clamps from energizer.
Step 4. Remove energizer from enclosure.

REAR MOUNTED TRANSDUCERS

#1 Remove transducer leads from energizer
#2 Remove enclosure back panel repeat steps 3 and 4
Note: When replacing energizer make certain that white tubular gasket is placed on the casting.
At this point all instructions refer to both SE400S and SE408S.

4.4 CAPACITOR BRACKET REMOVAL

Step 1. Remove 4-machine screws maintaining the assembly to casting.
Remove 4-spacers and set aside.
Step 2. Lift capacitor bracket and place in position illustrated in fig. 4-3.
Note: When replacing capacitor bracket, lock washers are installed between machine screw head and bracket. Check clearances between terminal strips and casting.
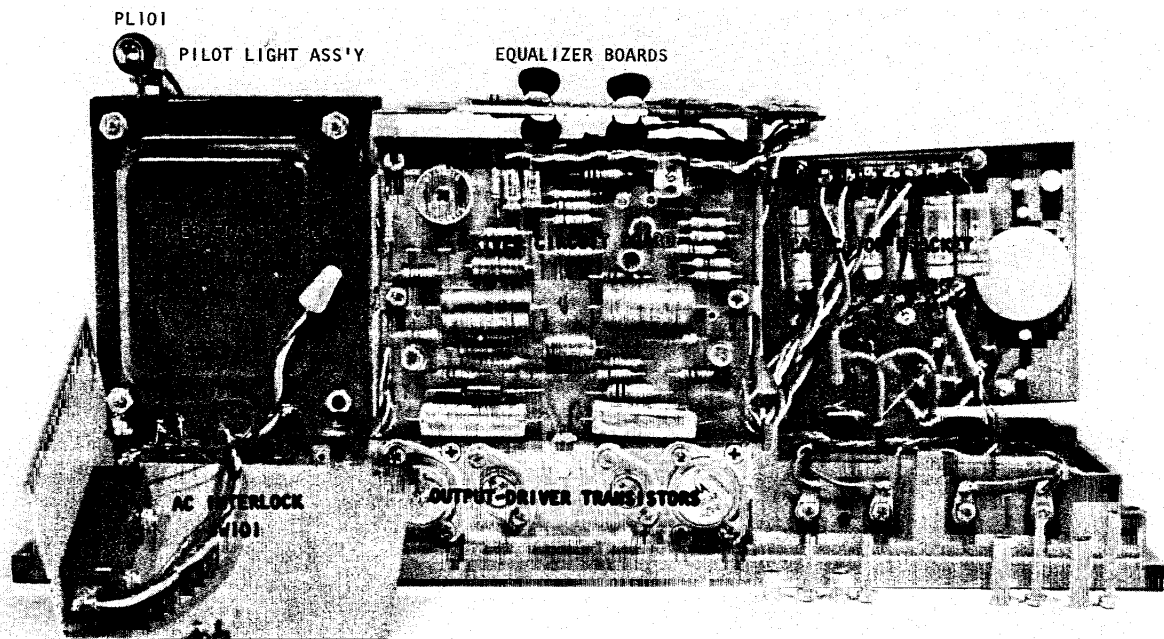
Figure 4-3   SE400S INTERLOCK REMOVAL

4.5 DRIVER CIRCUIT BOARD REMOVAL

Stp 1. Remove output and driver transistors.
Step 2. Remove equalizer boards
Step 3. Remove 4-flat machine screws from transistor mounting area.
Step 4. Remove 4-machine screws located on driver circuit board
Step 5. Remove 2-machine screws retaining mounting bracket nearest power transformer and 2-machine screws securing bracket to opposite circuit board.
Step 6. Remove bracket and driver circuit board, assisting diode assembly from casting.
Note: When reinstalling note lead orientation and determine that connecting leads are not pinched between casting and mounting surfaces.

EQUALIZER BOARDS
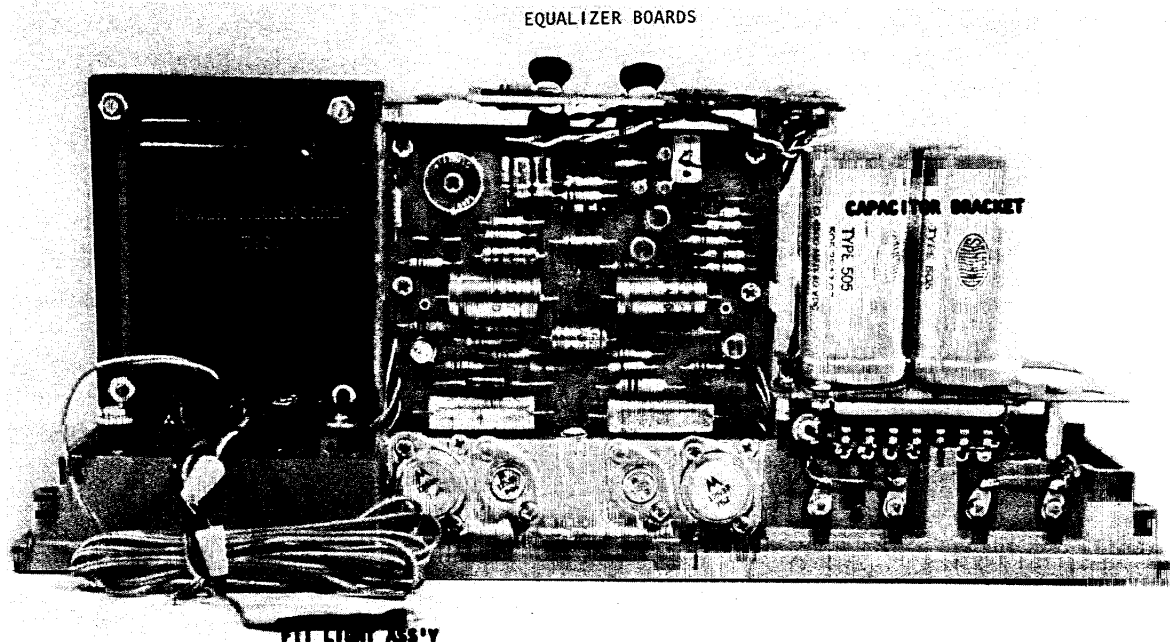
Figure 4-4 SE408S SIDE VIEW

4.6 REPAIR PRECAUTIONS

Some special care must be taken when replacing components. These precautions are outlined below.

4.7 TRANSISTOR GREASE

The white grease under each of the power transistors is necessary to assure heat flow from the transistor to the heat sink. If the grease is accidentally wiped away, Dow Corning No. 340 must be applied. See figure 4-5.

4.8 BIAS DIODE REMOVAL AND INSTALLATION

The power amplifier bias diode assembly (figure 4-6) is designed to slide out of the heat sink when the drive circuit board is removed. The diode assembly is greased for good thermal contact. Be very careful to not break the connection. Note long diode assembly lead should have red sleeve and must be connected to left circuit board terminal.

4.9 REPLACEMENT OF RESISTORS AND CAPACITORS

Resistors and capacitors on the circuit boards must be replaced in the following manner:

Step 1. When a component is suspected, clip one of the leads at midpoint to remove it from the circuit.

Step 2. Check the component

Step 3. If faulty, clip the other component lead at midpoint

Step 4. Loop the new component leads over the old stub leads and solder

CAUTION

DO NOT APPLY HEAT DIRECTLY TO THE PRINTED CIRCUIT BOARD. THIS MAY CAUSE CIRCUIT FOIL TO LIFT FROM THE BOARD.

4.10 REPLACEMENT PARTS AND SCHEMATICS

Replacement parts for the Solid State Amplifier are listed in the following pages. It is recommended that only JBL replacement parts be used in this high-quality amplifier.

4.11 RESISTORS

All resistors are deposited carbon film type. Any defective components should be replaced with the same type. Replacements are available directly from JBL.

4.12 CAPACITORS

Most of the electrolytic capacitors used in the SA600 are specially made. Replacements should be ordered directly from JBL by part number or reference number. Under no circumstances should inferior-rated electrolytics be substituted. Lower capacities in any circuit will impair performance. Lower working voltage ratings will cause premature failure. Capacitors have been selected for low noise specifications.

4.13 TRANSISTORS

All transistors are selected for current gain and low noise and other important characteristics.

Experience has shown that the current gain from one transistor to the next in any production batch varies so much that sometimes one will not work well in the circuit. For this reason, all transistors carry special part numbers and must be ordered from JBL.
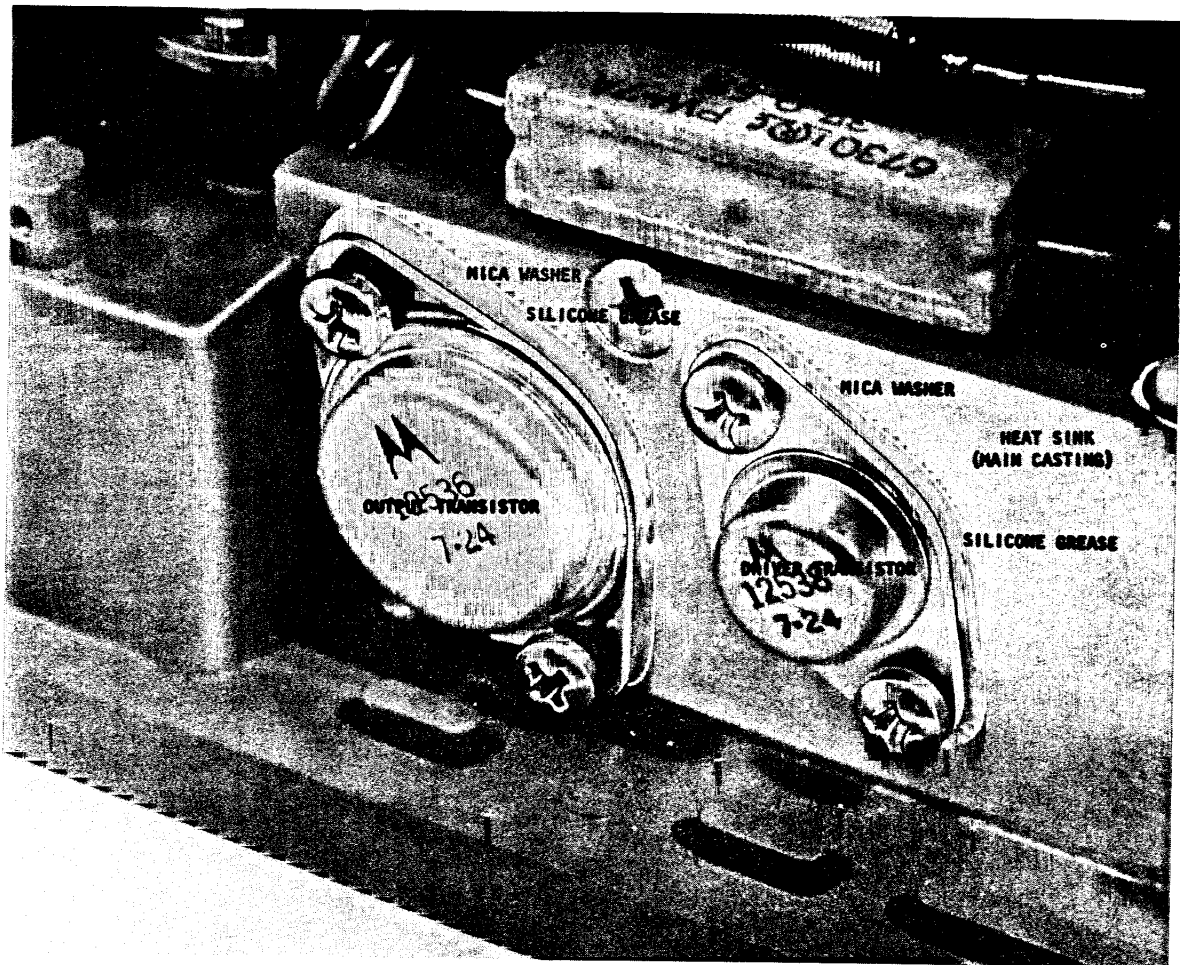
Figure 4-5   TRANSISTOR MOUNTING DETAIL
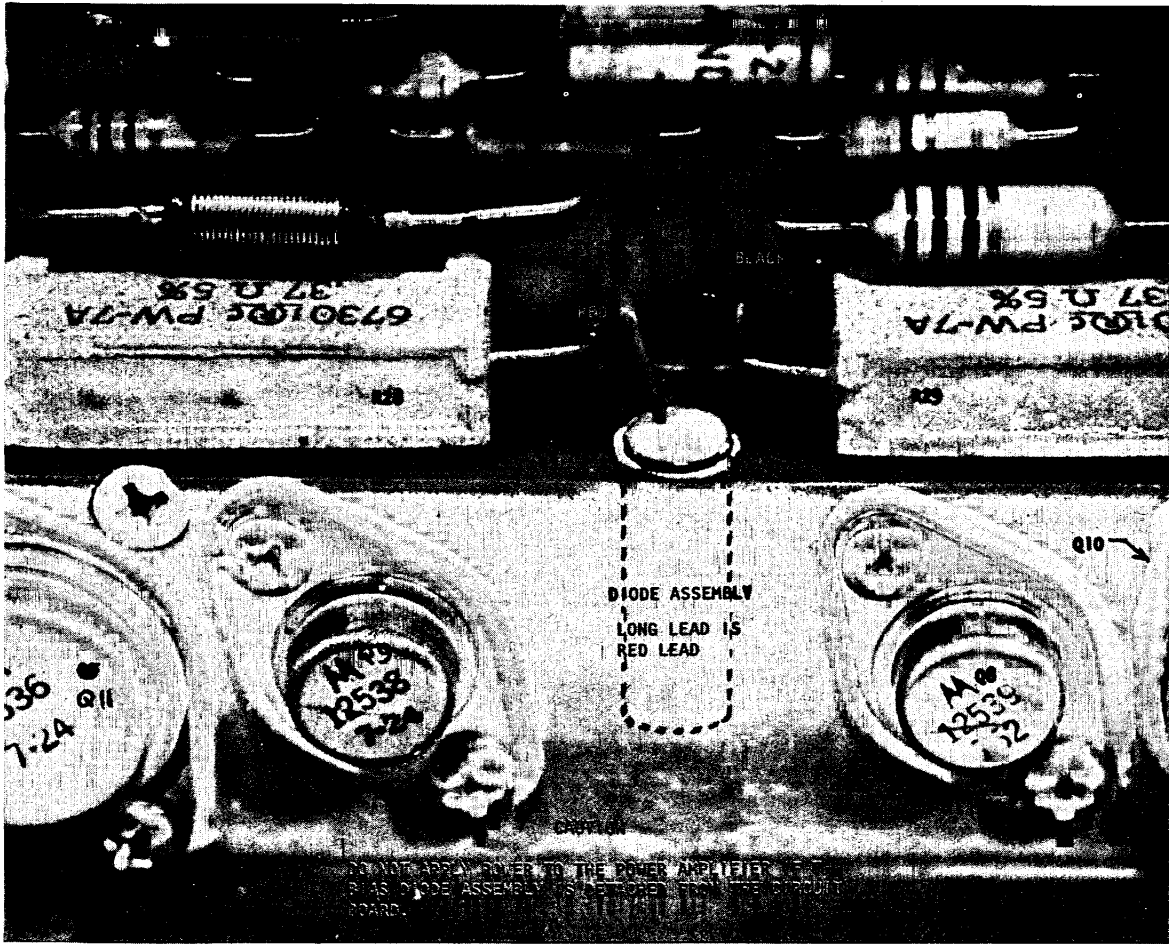
Figure 4-6 DIODE ASSEMBLY

5.0 INFORMATION SERVICE

Information on parts and service tips can be obtained from the JBL Factory Service Department.

Write a letter explaining any unusual problem to:

JBL Service Department
3249 Casitas Avenue
Los Angeles, California 90039

If it is necessary to return the complete amplifier, first request shipping permission. Then pack the equipment in an oversize carton, completely surround it in cushioning material, and ship by Railway-Express or truck express. Be sure to insure the shipment and prepay the shipping charges. Mark the carton: Fragile—Delicate Electronic Equipment.

5.1 D.C. OPERATING VOLTAGES

CHANNEL A			
TRANSISTOR	EMITTER	BASE	COLLECTOR
Q1	0.75	-40.0	----
Q2	1.25	-40.0	0.75
Q3	1.25	-40.1	0.75
Q4	----	0	-40.0
Q5	----	-1.75	-40.1
D6	10.0		

CHANNEL B			
TRANSISTOR	EMITTER	BASE	COLLECTOR
Q6	1.2	46.8	1.75
Q7	-1.2	-46.8	-1.75
Q8	0.51	42.1	1.2
Q9	-0.51	-42.1	-1.2
Q10	----	37.5	0.51
Q11	----	-37.5	-0.51

CONDITIONS: +Vcc1 = 46.8
              +Vcc2 = 42.1
              +Vcc3 = 37.5

CONDITIONS: -Vcc1 = 46.8
              -Vcc2 = 42.1
              -Vcc3 = 37.5

OPERATING VOLTAGES: NO SIGNAL EQ. BOARD IN FLAT POSITION, 100,000 OHMS/VOLT METER, AC LINE VOLTAGE 117 OR 234 VOLTS.

Figure 5-1 SCHEMATIC SE400S, SE408S
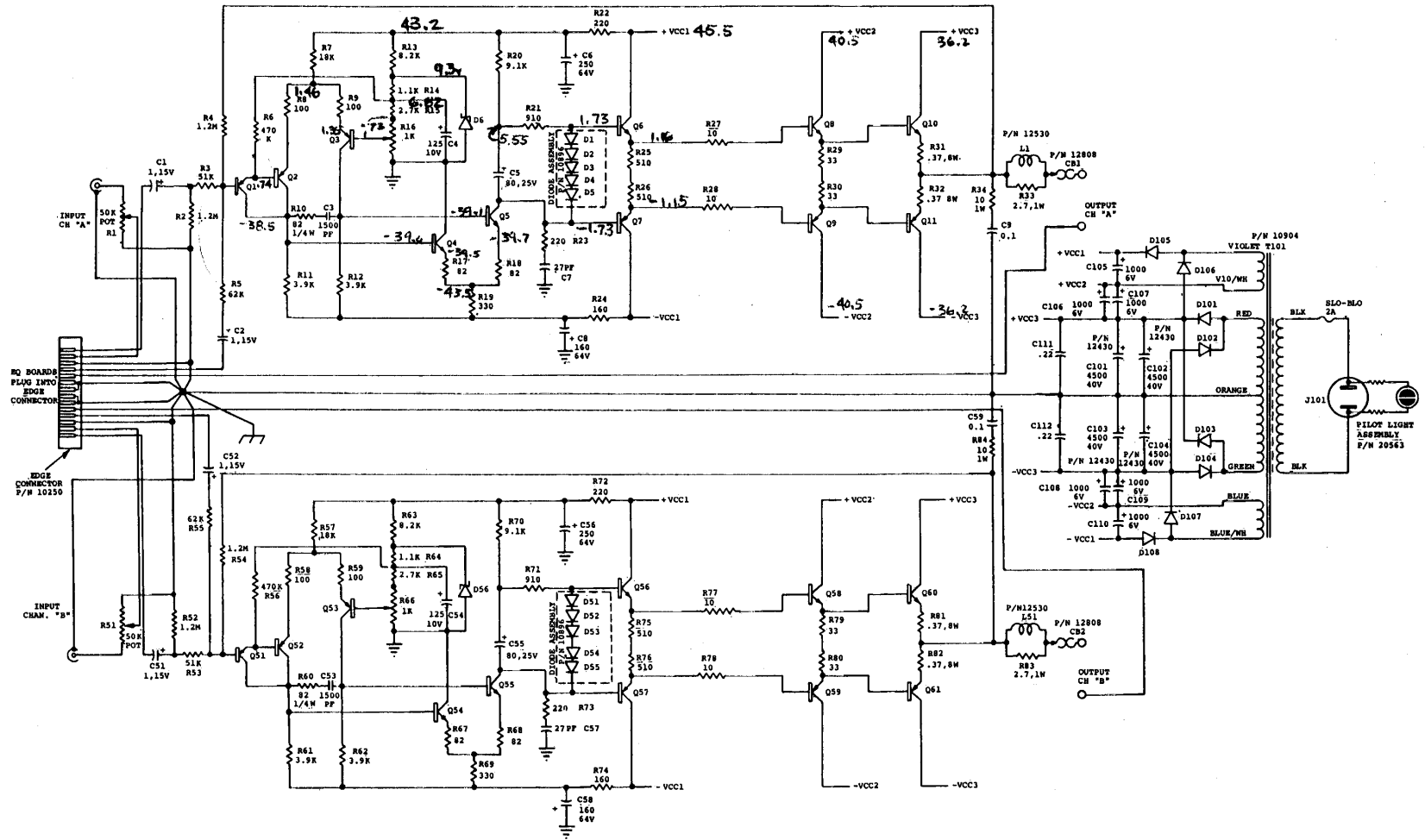
Figure 5-1   SCHEMATIC SE400S, SE408S
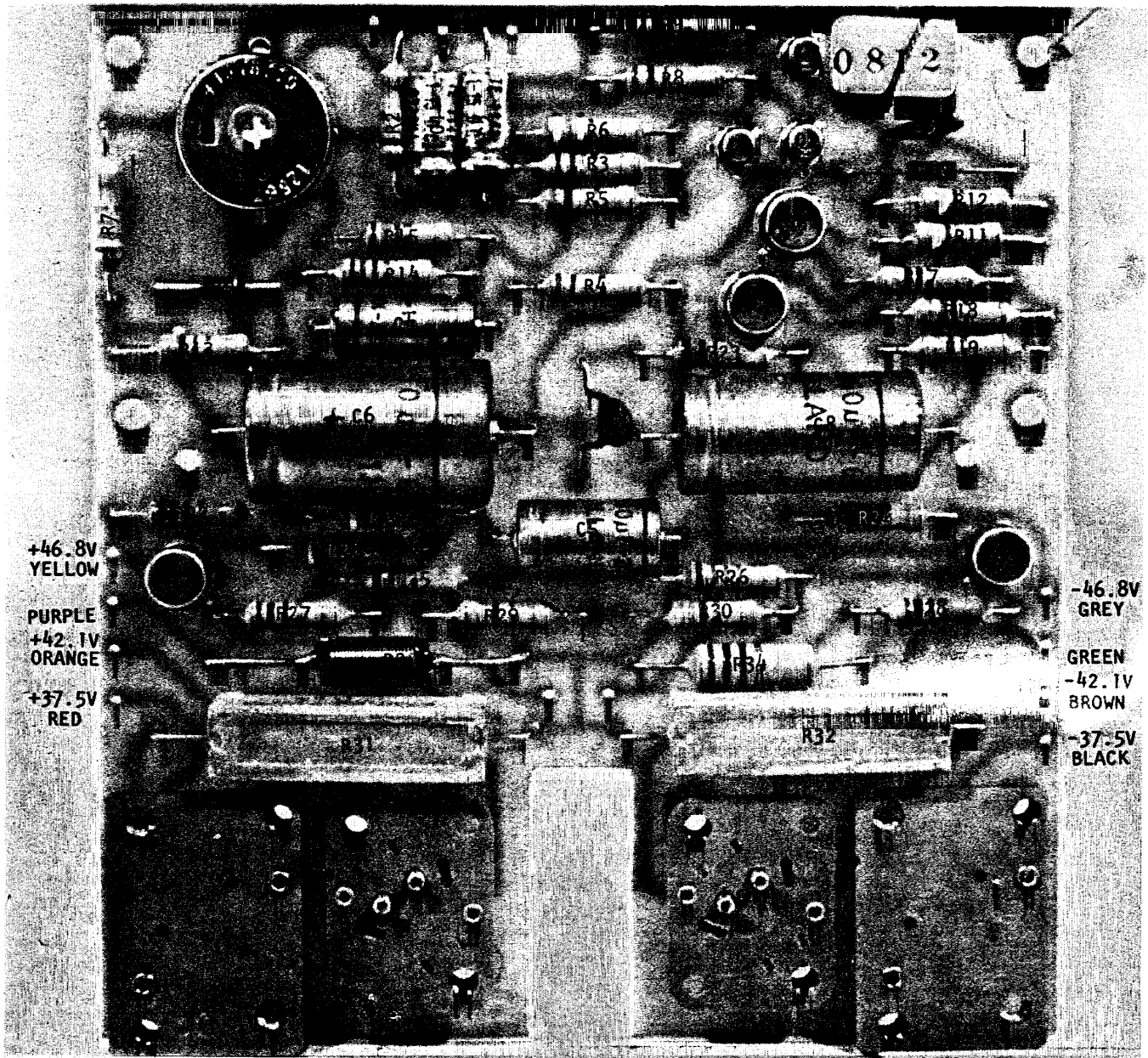
Figure 5-2   DRIVER CIRCUIT BOARD
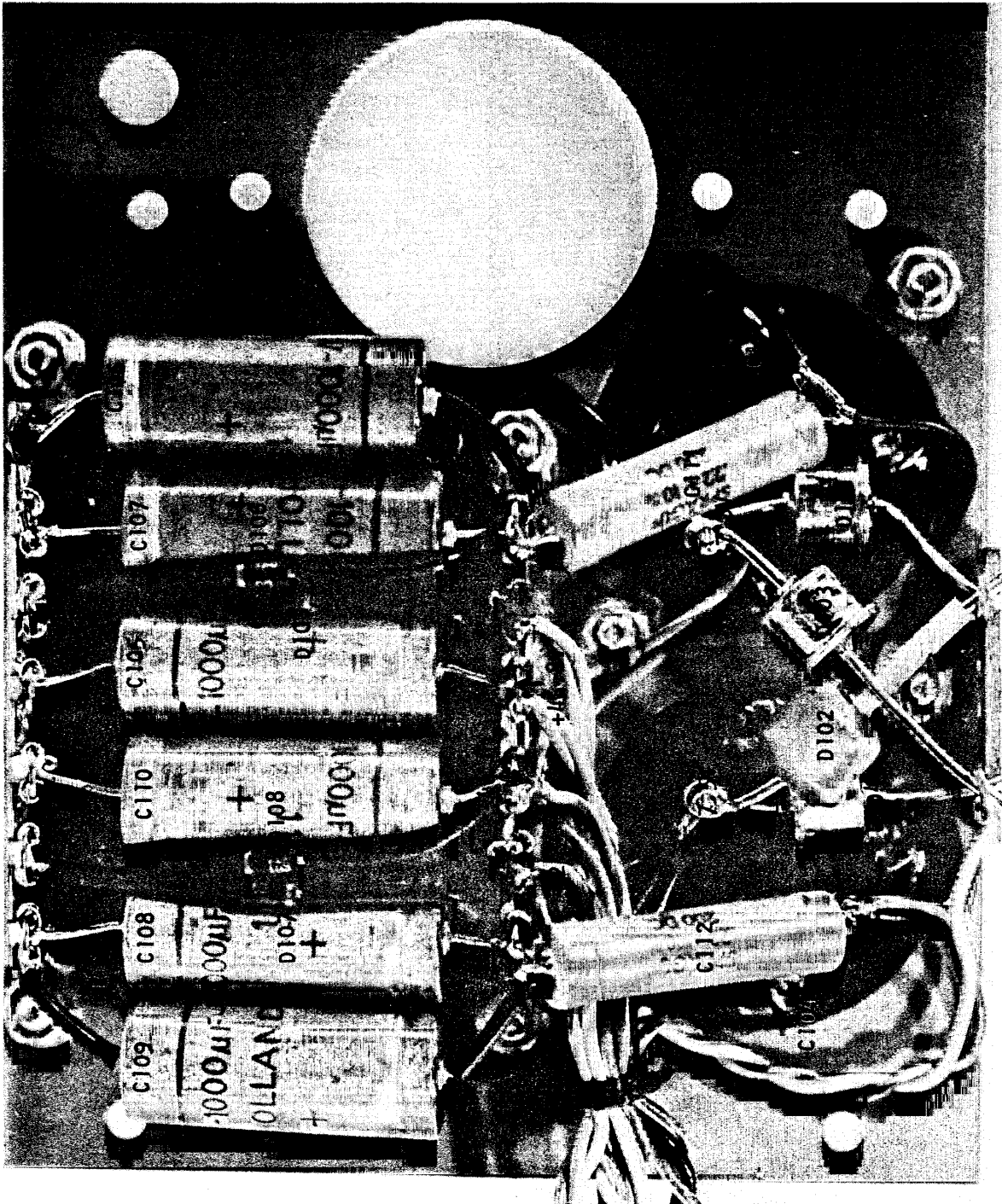
Figure 5-3 CAPACITOR BRACKET

Figure 5-4 F22 DETAIL

CH A

CH B

to black energizer terminals

to black speaker leads

CH A

to energizer

150 W
max

CH B

F22 STEREO BALANCE
AND POWER RELAY

JBL

JAMES B. LANSING SOUND, INC.

LOS ANGELES, CALIF.

CH A

from graphic
controller

150 W
max

CH B

FUSE
4 amp
slo-blo
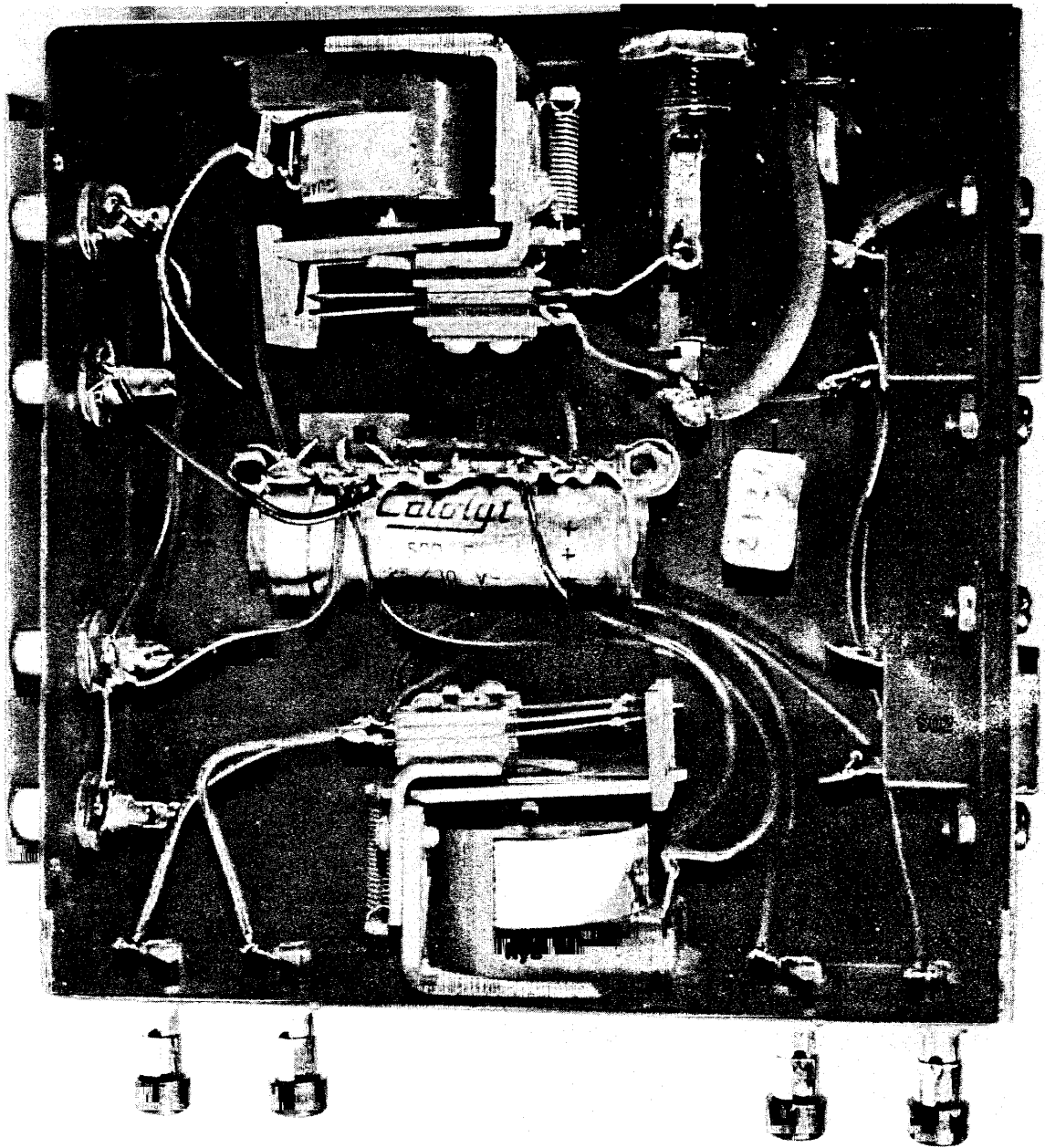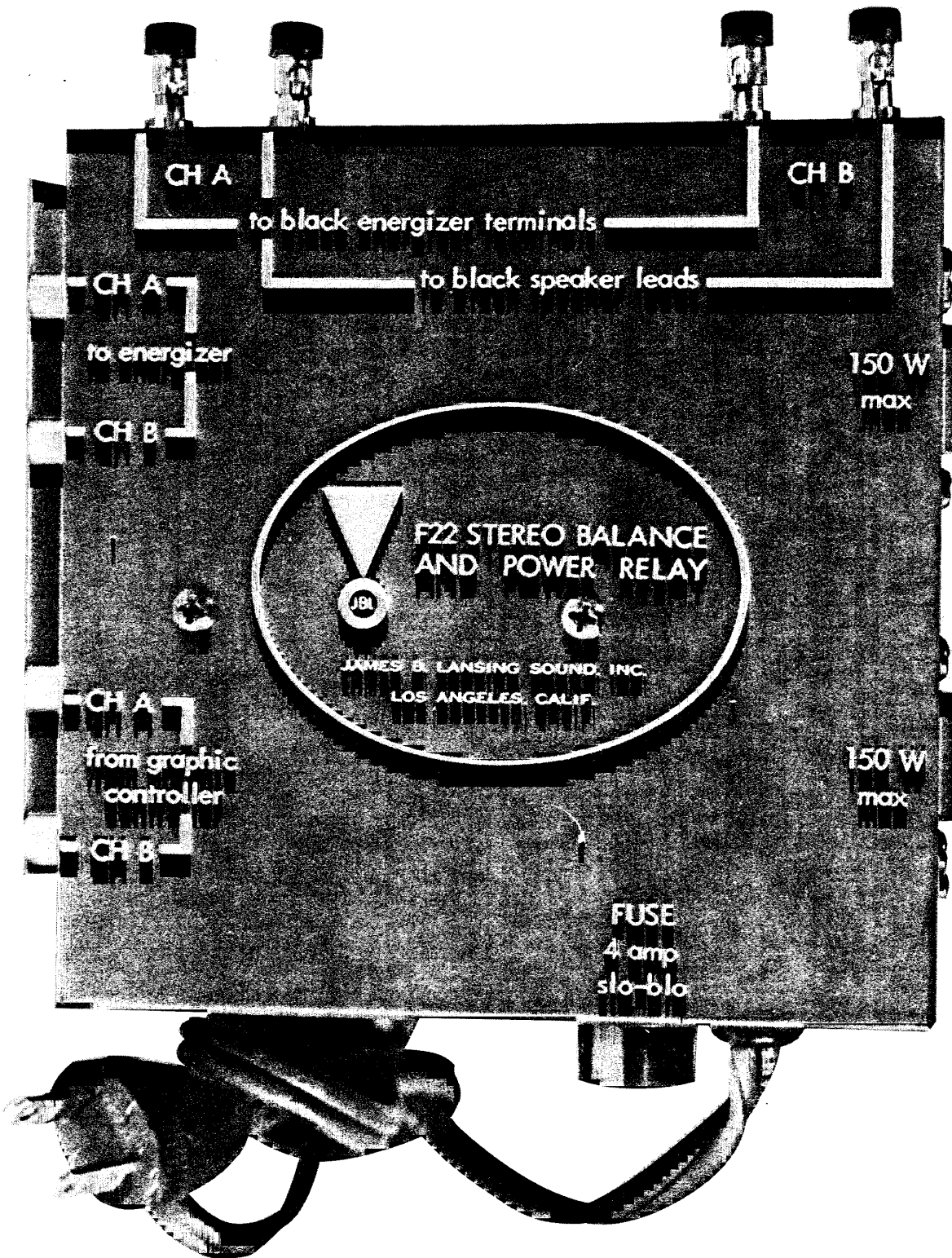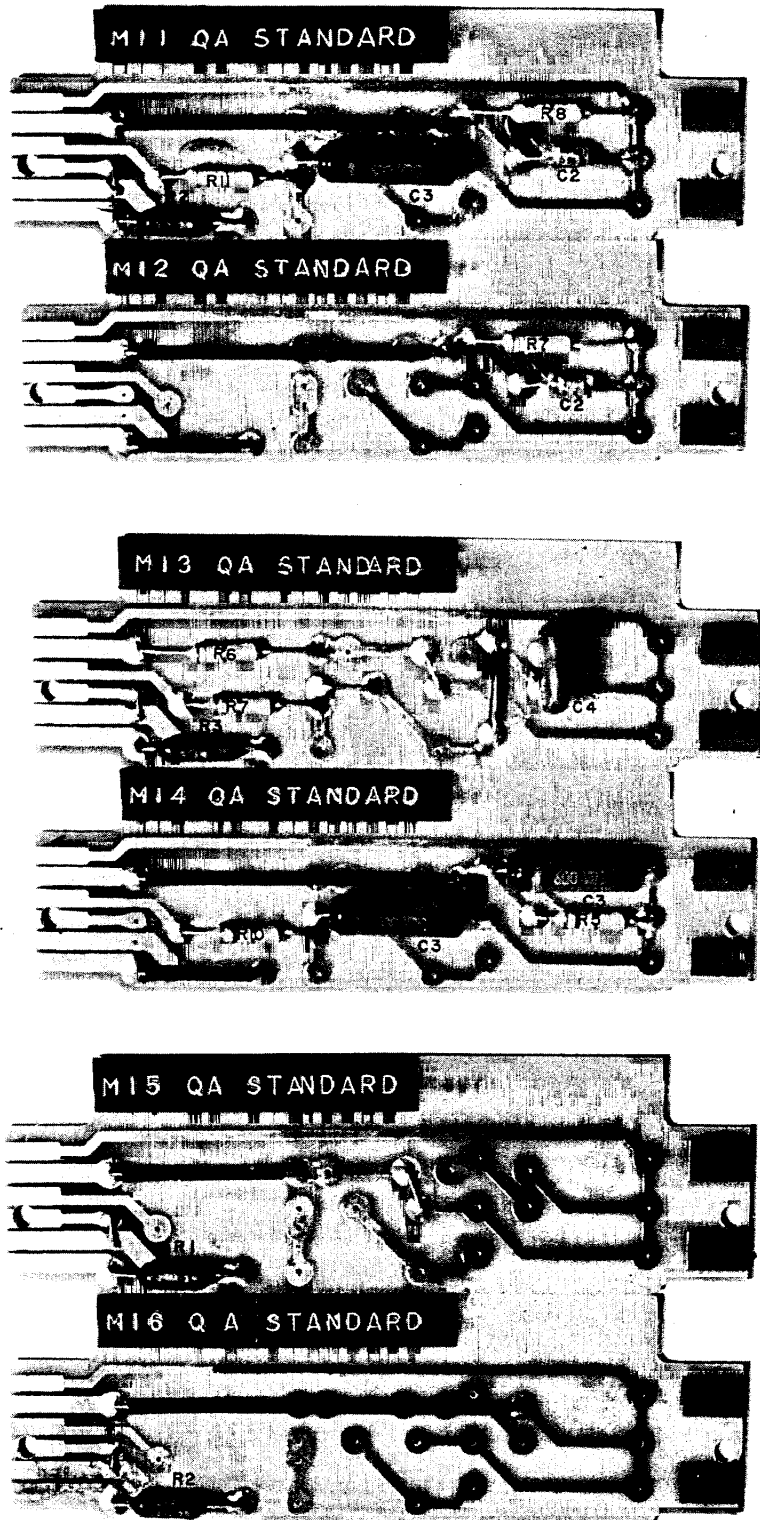
Figure 5-5   F22

Figure 5-6 EQUALIZER BOARDS   M11 through M16
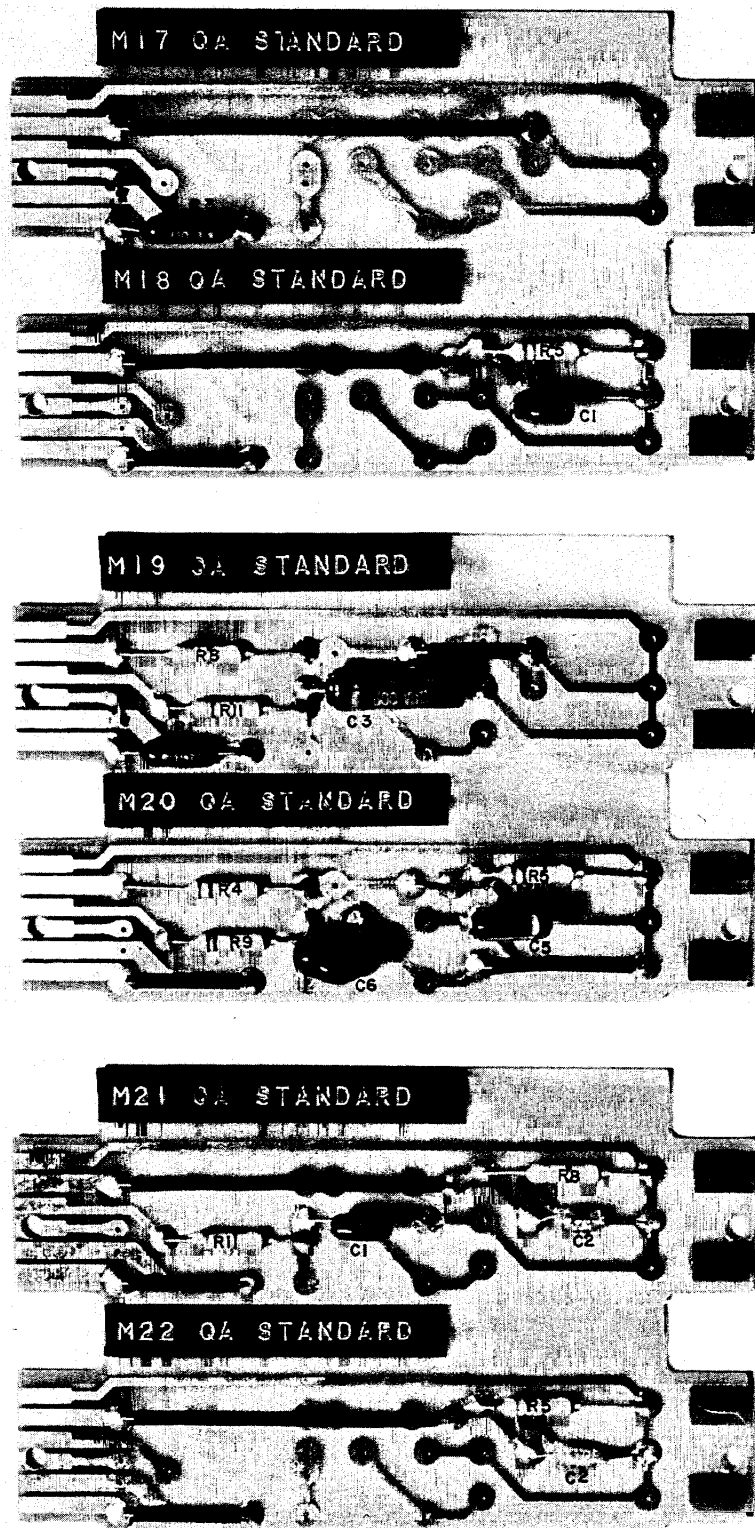
Figure 5-7 EQUALIZER BOARDS   M17 through M22
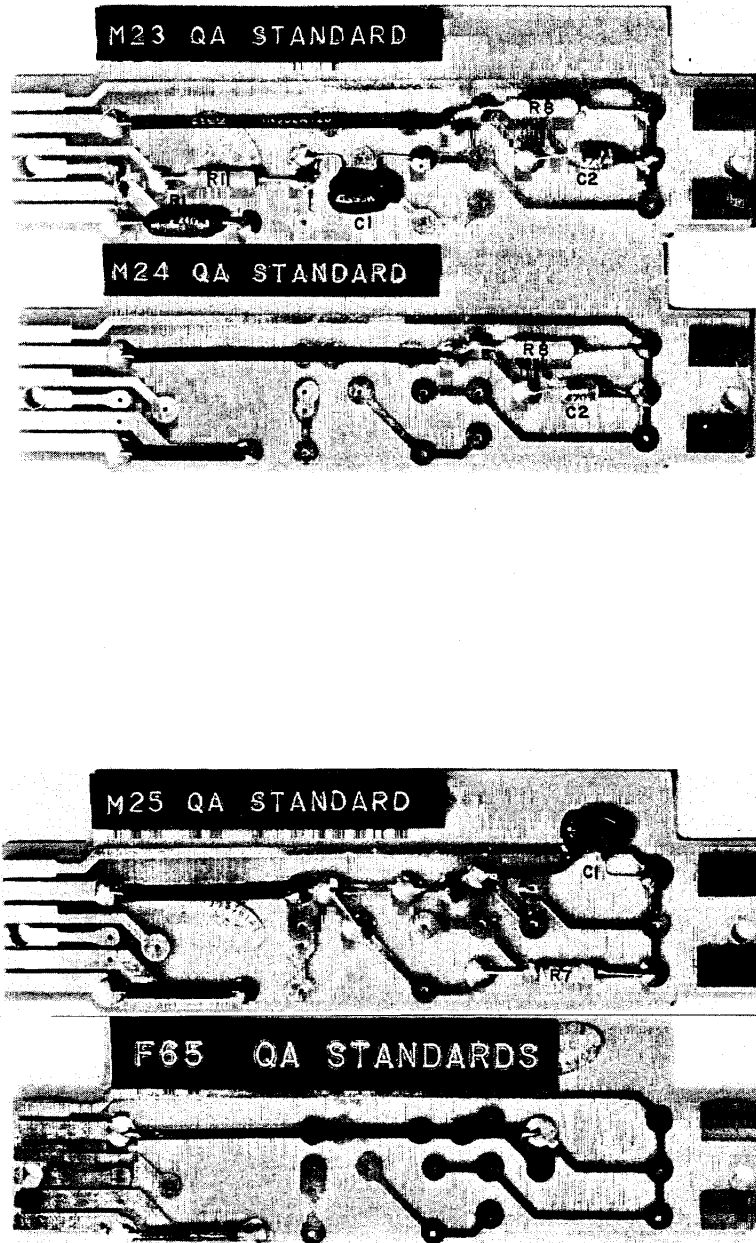
Figure 5-8 EQUALIZER BOARDS M23 through M25 and F65

F22 PARTS LIST

REFERENCE NO.	DESCRIPTION
J1, 2, 3, 4	Input Jack
Ry1	Power Relay
Ry2	A-B Relay
D1	Silicon Diode
D2	Diode, Bridge
C1	Capacitor 500mf 25V
F1	4 Amp. Slo-Blo
	2 Amp. Slo-Blo
	Fuseholder
	Binding Post Black

RESISTORS

R1	0.24 OHM 3 Watt
R2	0.5 OHM 3 Watt
R3	0.75 OHM 3 Watt
R4	15K OHM ½ Watt
R5	22K OHM ½ Watt
R6	24K OHM ½ Watt
R7	27K OHM ½ Watt
R8	36K OHM ½ Watt
R9	51K OHM ½ Watt
R10	62K OHM ½ Watt
R11	75K OHM ½ Watt

CAPACITORS

C1	390 pF
C2	470 pF
C3	.001 mF
C4	.0047 mF
C5	.02 mF
C6	.03 mF

NOTE: Complete equalizer boards available only as standard products. Damaged circuit boards are not serviced.

REPLACEMENT PARTS LIST AND PRICES   SE400S,SE408S

REFERENCE NO.   DESCRIPTION

TRANSISTORS & DIODES

Q, 1, 2, 11 51, 52, 61	PNP
Q 3, 4, 5 53, 54, 55	NPN
Q 6, 56	PNP
Q 7, 57	NPN
Q 8, 58,	PNP
Q 9, 59	NPN
Q 10, 60	PNP
D 1-5 51-55	Reference Diode Assembly
D 6, 56	Diode, Zener
D 101, 102 103, 104	Diode, Rectifier High Current
D 105, 106 107, 108	Diode, Rectifier Boost Supply

REFERENCE NO.   DESCRIPTION

RESISTORS

R 1, 51	50K OHM Potentiometer Audio Taper
R 2, 21 51, 71	1.2 Meg OHM ½W 5%
R 3, 53	18K OHM ½W 5%
R 4, 5	100 OHM ½W 5%
R 6, 7 56, 57	3900 OHM ½W 5%
R 8, 58	2700 OHM ½W 5%
R 9, 59	1000 OHM Potentiometer Wirewound
R 10, 11, 25 60, 61, 75	82 OHM ½W 5%
R 12, 62	330 OHM ½W 5%
R 13, 63	10 OHM 1W 5%
R 14, 64	9100 OHM ½W 5%
R 15, 65	910 OHM ½W 5%
R 16, 31 66, 81	220 OHM ½W 5%
R 17, 18 67, 68	510 OHM ½W 5%
R 19, 69	160 OHM ½W 5%

R 20, 34 70, 84	10 OHM ½W 5%
R 22, 72	51K OHM ½W 5%
R 23, 73	62K OHM ½W 5%
R 24, 74	470K OHM ½W 5%
R 26, 27 76, 77	33 OHM ½W 5%
R 28, 29 78, 79	0.37 OHM 7W
R 30/L1 80/L51	Output Choke Assembly
R32, 82	8200 OHM ½W 5%
R33, 83	1100 OHM ½W 5%

CAPACITORS

C 101, 102 103, 104	4500 mf 40V
C 105, 106, 107 108, 109, 110	1000 mf 6V
C 111, 112	.22 mf 200V
C 1, 51	0.1 mf 200V
C 2, 52	80 mf 25V
C 3, 5 53, 55	1 mf 15V
C 4, 54	250 mf 64V
C 6, 56	160 mf 64V
C 7, 57	1500 pF
C 8, 58	125 mf 10V
C 9, 59	27 pF

REFERENCE NO.   **DESCRIPTION**

TRANSFORMERS AND HARDWARE

T 101	Transformer, Power
CB 1, 51	Circuit Breaker
	Input Jack
	Equalizer Board Connector
	AC Socket
	Fuseholder
	Binding Post, Red
	Binding Post, Black
	Wafer, Capacitor Mounting
Q 9, 10, 55 60	Mica Washer
Q 7, 8, 57 58	Mica Washer
	Fuse 1 amp. Export
	Fuse 2 amp. Domestic
	Power Cord
SE400S	Cover
SE400S	Front Panel
SE400S	Interlock

SE400S	Lamp Bracket
SE400S	Pilot Light
SE408S	Pilot Light Assembly

HARDWARE

Driver Board	Sockets
Capacitor Bracket	Terminal Strip 7-Terminal
	Terminal Strip 6-Terminal
Main Casting	Insulating Washer
	Terminal Strip 6-Terminal
	Mounting Foot
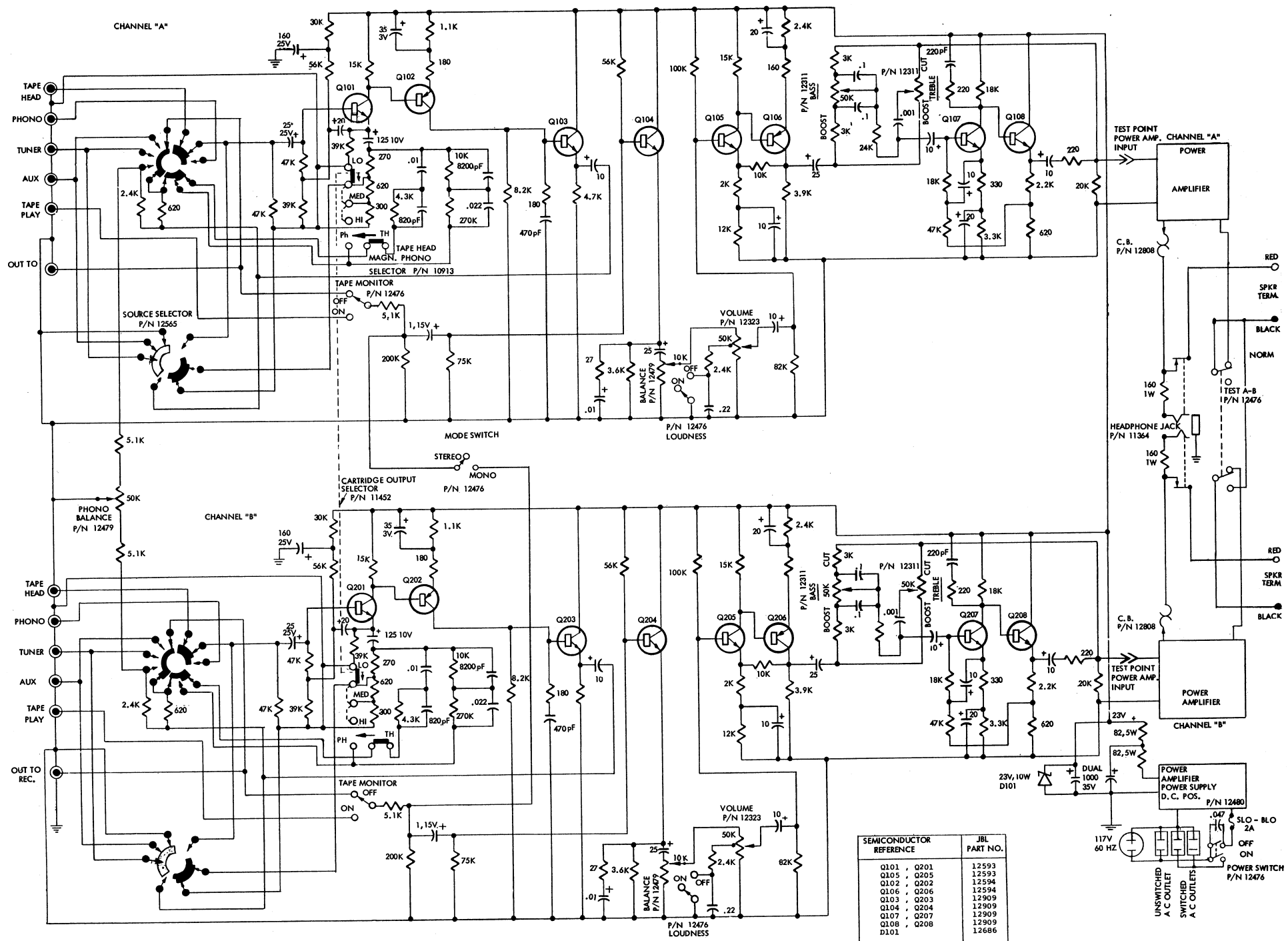
SEMICONDUCTOR REFERENCE	JBL PART NO.
Q1, Q2, Q51, Q52	12888
Q3, Q4, Q5	12546
Q53, Q54, Q55	12546
Q6, Q56	12545
A7, Q57	12538
Q8, Q58	12539
Q9, Q59	12536
Q10, Q60	12537
D101, D102, D103, D104	12550
D105, D106, D107, D108	10909
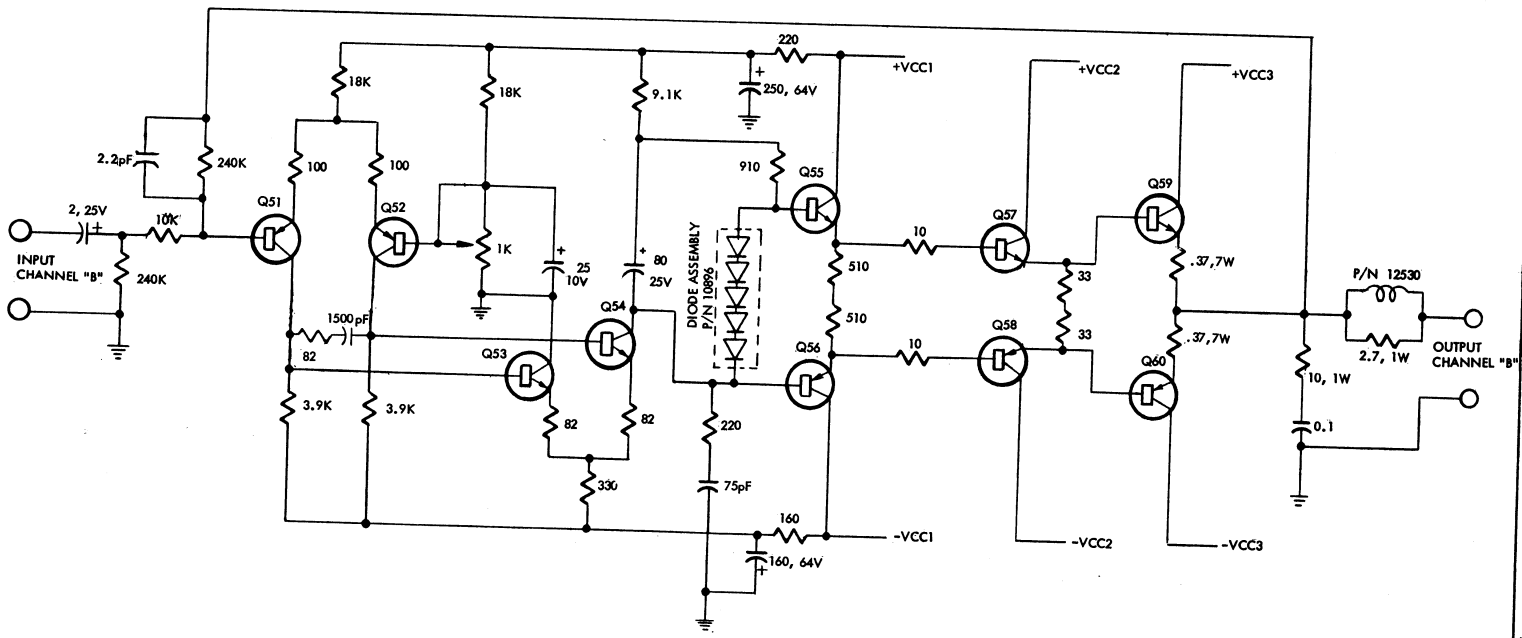
This schematic diagram shows the internal circuitry of your SA600 Solid State Amplifier

P/N denotes JBL part number. These are specifically designed parts for which equivalents are difficult or impossible to obtain. To replace these parts, order directly from JBL, referring to the part number

Resistors are shown in ohms, 1/2 watt 5%, unless otherwise specified.

K = x 1,000 ohms
M = x 1,000,000 ohms (1 megohm)

Capacitors are shown in microfarads or picofarads.

MF = 1 microfarad
pF = 1 picofarad (1/1,000,000 microfarad)

JBL Publication SD600-2   Sept. 1966

JBL
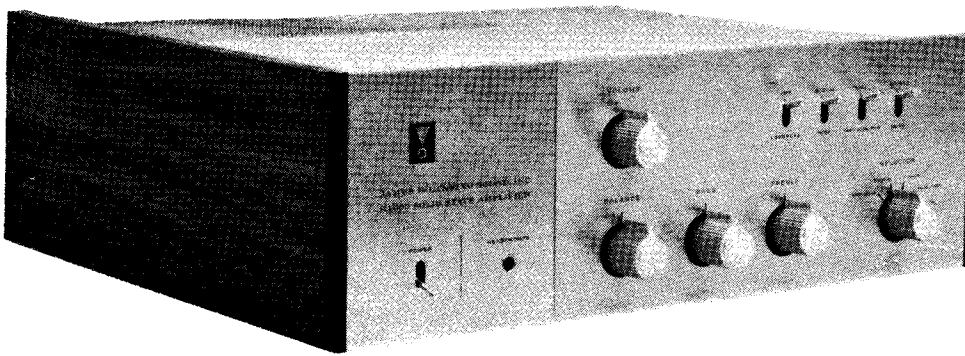
Front-panel view of new "T-circuit" integrated stereo amplifier unit.

Operational Amplifier Circuit for Hi-Fi

By B. N. LOCANTHI / Vice President, Engineering, James B. Lansing Sound, Inc.

Technical details on the "T circuit" as employed in the new JBL ultra-low distortion audio power amplifier.

AS we gain more and more insight into the performance of the human ear, the design of sound recording and reproducing apparatus grows correspondingly more sophisticated. Whereas the critical audiophile was once satisfied if his power amplifier could produce 10 watts at 1000 Hz with less than 1% distortion, he now expects at least 25 watts per stereo channel with less than 0.5% distortion at any frequency from 20 to 20,000 Hz.

By making full use of today's electronic technology, it is possible to build an audio amplifier of such quality that its complete performance cannot be accurately measured, even with the best test equipment presently available. The "T circuit" developed by the author is such an amplifier.

In a number of respects, the "T circuit" is unusual, and a United States patent is pending on the circuit. The basic design philosophy, however, is an old one worth restating. We believe that an amplifier should be designed for low distortion and wide bandwidth *without feedback*. Negative feedback is then added to make an already good design perform even better; it is *not* used to "clean up" problems in the basic design.

Some engineers think this is an old-fashioned idea. They feel that by using great amounts of negative feedback, desired performance can be obtained even from essentially non-linear amplifying circuits, and that it is the performance of the complete design that counts. This approach can result in an amplifier which has impressive figures in all of the standard specifications but which develops serious performance faults when more elaborate testing techniques are used.

In the circuit to be described, the operating parameters of every stage are chosen for maximum transfer linearity, which is just another way of saying lowest possible distortion. And the operating mode of each stage is held constant, irrespective of signal level. This means that we don't "shift gears" to take care of varying power levels, nor do we

try to make the circuit "pretend" it is doing something which in fact it is not.

The Amplifier Circuitry

The output circuit of the amplifier (Fig. 1) consists of three cascaded complementary-symmetry emitter-follower stages. The configuration has somewhat the appearance of a bridged-T circuit, which accounts for its name.

The advantages of the complementary-symmetry emitter-follower output stage, using one p-n-p and one n-p-n transistor, are well known. Its output impedance is low so that loads in the 4- to 16-ohm range can be driven without the need for an output transformer. Transistor idling current can be controlled so that the efficiency of class-B operation is approached but without the notch distortion common to class-B amplifiers.

Most important, the complementary-symmetry configu-

Fig. 1. Three-stage output circuit. Note "T" configuration.

Underside view shows two jumper leads between preamp and amp.

ration does not require a separate phase-splitter stage. When a signal is applied to the common driving point, one transistor draws more current and the other draws less. In the "T circuit," the three cascaded emitter-followers in each group all operate together as if the output circuit were a single stage. (In practice, the transistors are biased close to cut-off so that one group conducts primarily during positive half-cycles while the other group conducts mainly during negative half-cycles.)

What are the special advantages of this arrangement? First, the output circuit has exceptionally low drive requirements. While the emitter-follower has no voltage gain, it does provide considerable power gain. In this respect, it is similar to the familiar vacuum-tube cathode follower. The three output stages multiply output load impedance by a factor of 100,000 as it is reflected back to the collector driving point. Even though voltage gain is less than unity (about 0.9), the power gain of the three stages is therefore almost 100,000.

Another important characteristic of the circuit is its excellent thermal stability. Output transistors Q5 and Q6 are connected directly to a high-current power supply of about 35 volts plus and minus potential. Each base of the output stage has a low-resistance path for the collector-to-base leakage current to flow through its opposite emitter driver stage. Because the input driver collector load resistance is about

9000 ohms and because the output load impedance is multiplied by a factor of 100,000, the d.c. stability factor of the circuit is better than 10. Thus, d.c. thermal runaway problems are essentially non-existent.

A single bias supply consisting of diodes D1 through D5 provides the necessary forward bias for all three cascaded emitter-followers. The bias supply operates at a low current level and dissipates very little signal power, yet it provides all the advantages of diode biasing.

One disadvantage of the circuit is that successively higher collector supply voltages are required for each driver stage to take care of the saturation voltage drops of the preceding transistors. The individual supply voltages are indicated in Fig. 1.

This requirement leads to a rather complicated-looking power supply but not an inordinately expensive one. By using two additional low-current secondary windings for the driver power supplies, a symmetrical "package" is obtained which turns out to be somewhat smaller, physically, than would be expected for an 80-watt amplifier.

Performance of Output Stages

Before going into details of the associated driver stages, let's take a brief look at the performance of the output circuit alone. Because each pair of transistors has a higher *beta* cut-off frequency than the following pair, the over-all frequency limitation of the circuit is determined almost entirely by Q5 and Q6, and the bandwidth of the three cascaded stages turns out to be greater than 100,000 Hz. With this kind of frequency response, the classic textbook rules regarding reduction of distortion and noise by negative feedback do apply, as we shall see a little further on.

Distortion measurements of the output circuit without feedback indicate that at very low signal levels, total harmonic distortion stabilizes at about 0.2% or 0.3% and then increases to about 2.5% at 50 watts output per channel. This certainly is not phenomenal in itself, but remember that we are talking about performance *without feedback*.

An interesting thing happens to our distortion measurements when the driver amplifier is added to the circuit. This is a two-stage direct-coupled differential amplifier consisting of four silicon transistors, Q7 through Q10 respectively (Fig. 2).

The differential driver circuit was chosen for its insensitivity to supply-voltage changes. The symmetry of the output circuit makes it likewise largely immune to a.c. power-line surges.

Measuring the distortion of the complete five-stage am-

Fig 2. Schematic diagram of one of the two identical stereo power-amplifier channels using the new amplifier circuit.

plifier, still without feedback, we find that the figures are lower than for the output circuit alone! Harmonic distortion at 1000 Hz and 50 watts output measures less than 1%. Even at 20,000 Hz the circuit produces only about 1.5% distortion (Fig. 3).

Why should the distortion of the whole amplifier be less than that of the output circuit alone? It may be that the distortions of individual stages tend to be slightly complementary, but the main reason appears to be that we are now driving the output circuit with a partial-current generator instead of a zero-ohms source impedance.

Now let's see what happens when the feedback loop is connected. Fig. 2 is a schematic of one channel of the complete stereo power amplifier. Note that the only coupling capacitor is located at the input and that from this point on the entire power amplifier is direct-coupled. Also note that the feedback loop extends all the way from the output of the amplifier back to the input terminals. No stage, no part of any stage, is left outside the feedback loop.

The circuit therefore falls into the classification of d.c. operational amplifiers, devices that are widely used in telemetry and computer applications. Properly designed, such an amplifier can be made to exhibit unconditional stability under any load condition and to maintain uniform gain and low distortion down to d.c. The marginal stability at subsonic frequencies which afflicts many amplifier designs is notably absent.

When we try to pin down the performance of the complete circuit, a rather interesting problem arises. In essence, the amplifier is as good as or better than any available test equipment. For example, we know that the total harmonic distortion of the amplifier without feedback is about 0.5% at 1000 Hz when the amplifier is producing 30 watts into an 8-ohm load. With a feedback factor of 50, distortion should be reduced proportionately, resulting in a figure of about 0.01%.

But even with the most sensitive equipment and the greatest care in excluding stray signals from the test hookup, distortion can be measured accurately only down to 0.015% or so. Because of this, the measurements graphed in Figs. 4 and 5 are probably accurate only where the curves climb above 0.05%. Until the circuit is driven into clipping, distortion is so low that it cannot be specified with any degree of exactness.

Fig. 6 shows the frequency response of the complete amplifier at 40 watts and one watt and with an open output circuit. The open-circuit response curve cannot be seen because it lies exactly along the one-watt curve, showing that the open-circuit stability of the amplifier is excellent.

The circuit is stable under any passive load, resistive or reactive. The inductor (actually only a few turns of very low resistance wire) in series with the output is sufficient to act as a buffer for certain capacitive loads which might otherwise cause some ringing. Even without the inductor, however, the circuit will not oscillate.

Overload Protection

We have already explained that the amplifier's design makes it largely immune to a.c. line-voltage surges. Its performance when momentarily overdriven is equally impressive. The circuit recovers from a 100% single-cycle overload in less than one-tenth of a cycle—at any frequency from 20 to 20,000 Hz. As far as we have been able to determine, the unit recovers almost instantly from any overload at any frequency inside or outside the audio spectrum.

What about prolonged overload, such as might result from accidentally shorted loudspeaker connections? The output transistors used in commercial versions of this circuit have a d.c. power dissipation capability of about 150 watts each. It should be emphasized that this refers to continuous power, not brief pulses. Because of this high power dissipation capability, no exotic high-speed protective devices are
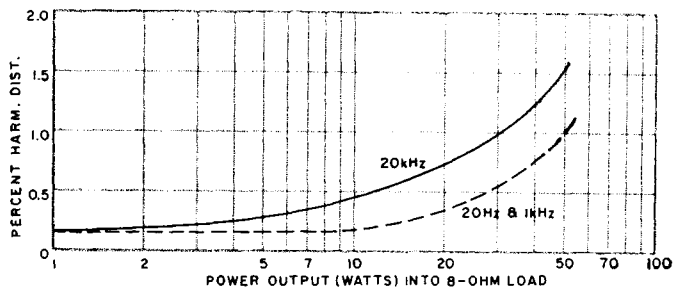

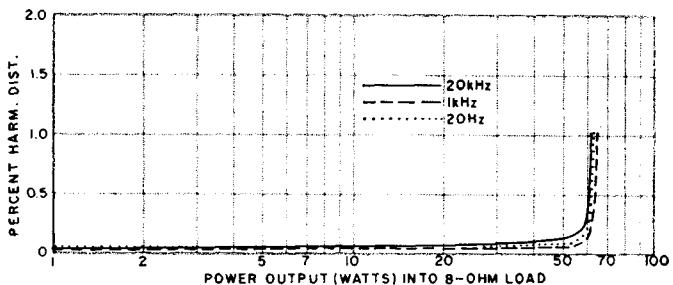Fig. 3. Harmonic distortion of power amplifier without feedback.

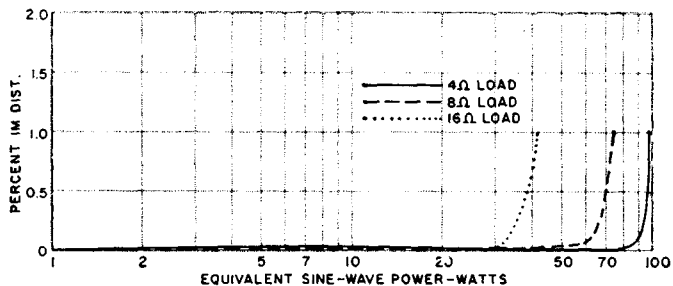Fig. 4. Harmonic distortion with feedback loop connected.

Fig. 5. Intermodulation distortion with feedback connected.

required. The output circuit has a thermal breaker (not shown in the schematic) which opens in one to 60 seconds if excessive current is drawn. This is all that is needed to protect the output transistors in the event of a short circuit.

As long as the amplifier is operated within the maximum current-handling capacity of the output stage, any kind of loudspeaker system, with almost any impedance rating, can be connected without degrading the signal quality.

As described in this article, the "T circuit" is used in the JBL Model SA-600 preamplifier/amplifier. It is also found in JBL Models SE-400S and SE-408S. These are sophisticated power amplifiers called "Energizers" because their performance is tailored to match the requirements of the particular loudspeaker systems with which they are used.

In all three models, however, the "T circuit" provides 80 watts of continuous sine-wave power (40 watts per channel) with both channels operating simultaneously, with power-line voltage as low as 110 volts, and with less than 0.2% distortion at any frequency from 20 to 20,000 Hz. (Also see our "EW Lab Tested" on the SA-600 amplifier in the December, 1966 issue.—Editors) ▲

Fig. 6. Frequency response into open circuit and 8-ohm load. The input coupling capacitor has been shorted out to show the good low-frequency performance of the complete amplifier.