Model 710

Automatic loudness controller

OPERATING AND MAINTENANCE INSTRUCTIONS

Prepared For

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CBS LABORATORIES

Stamford, Connecticut
A Division of Columbia Broadcasting System, Inc.

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SECTION I

INTRODUCTION

1-1 GENERAL

The new solid-state Automatic Loudness Controller is the latest addition to the CBS Laboratories family of quality control systems for the professional broadcaster.

Whereas the function of the Audimax TM is to control the average program level, and the Volumax TM functions as a peak controller, the new Automatic Loudness Controller guards against the well-known problem of markedly different loudness levels.

In recent years, the FCC has become increasingly concerned with the problem whereby certain segments of a program sound conspicuously louder than the rest of the program despite the broadcaster's careful control of level. The Automatic Loudness Controller solves this problem for the broadcaster by continuously monitoring the loudness level of the program and reducing the program level whenever a pre-set "Loudness Threshold" is exceeded. The device thus functions as a loudness limiter, which reduces the level of excessively loud program segments so that the resulting program level is of uniform loudness.

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Figure 1-1. The Automatic Loudness Controller

1-2 WARRANTY

A standard warranty card with a return post card has been included with your Automatic Loudness Controller. Please complete the card and return it to CBS Laboratories as soon as possible in order to validate your warranty.

1-3 FACTORY SERVICE AND REPAIR

If you should experience difficulty in installing or operating the Automatic Loudness Controller, please contact CBS Laboratories, Professional Products Department, Stamford, Connecticut, 06905. Within the continental limits of the United States call collect, Area Code (203) 327-2000.

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1-4 SPECIFICATIONS

Dimensions:	Fits standard 19-inch rack. 3-1/2 inches high; 9-5/8 inches deep.
Frequency Response:	± 1/2 dB, 30 to 20,000 Hz
Harmonic Distortion:	Less than 1/2 percent from 50 to 15,000 Hz throughout entire control range.
Input Level:	-4 to +16 dBm
Maximum Output Level:	+25 dBm
Input and Output Impedance:	600 ohms, or 150 ohms balanced or unbalanced.
Noise Level:	Below -70 dBm
Gain:	0 dB
Attack Time:	100 milliseconds
Recovery Time:	2.5 seconds
Maximum Operating Temperature:	55° C
Power Required:	15 watts at 115-230 volts, AC, 50-60 Hz
Shipping Weight:	18 lbs.

NOTE:

Due to the wide variation in LDR (light dependent resistors) characteristics, it is impossible to generate a uniformly accurate indication of gain reduction on the Loudness Controller Meter. The Meter reading is an approximate indication of gain reduction and its accuracy is ± 1 dB.

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SECTION II

INSTALLATION INSTRUCTIONS

2-1 UNPACKING

Unpack your Automatic Loudness Controller carefully and examine the unit for evidence of possible shipping damage. If the unit is damaged, file a claim immediately with the carrier. If future transportation of the unit is anticipated, save the shipping carton.

2-2 POWER SUPPLY (See Figure 2-1.)

The Automatic Loudness Controller is equipped with a power transformer which permits selection of either 115-volt or 230-volt operation.

If 230-volt operation is required, remove the jumpers on the power supply board which connect lugs 1 to 2 and 3 to 4. Reconnect a single jumper between lugs 2 and 3. Replace the fuse with a type 3AG-0.15 Amp.

2-3 INSTALLATION

Figure 2-2. shows a system block diagram for a typical Automatic Loudness Controller installation.

The Automatic Loudness Controller is designed to be mounted in a standard 19"-wide rack. It requires 3-1/2" panel space and is slightly less than 10" deep. As with all transistorized equipment, the unit must be installed in a reasonably well-ventilated position, with no high heat-producing equipment beneath it.

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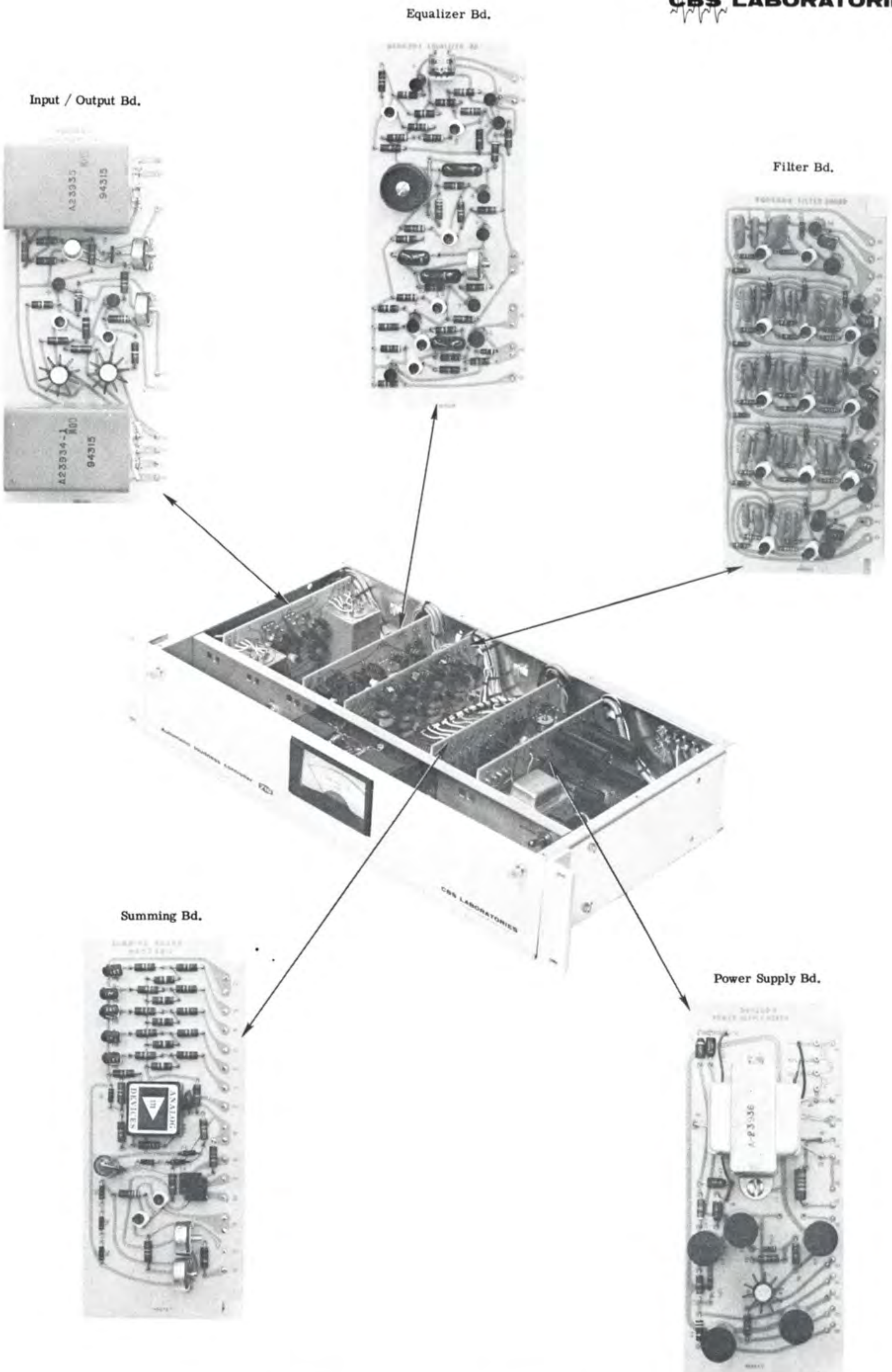

Figure 2-1 Circuit Board Layout

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CAUTION:

Ambient Temperature should not exceed 130° F.

It is expected that the Automatic Loudness Controller will be installed at the transmitter site. It must immediately follow the limiter and thus become the last piece of audio processing equipment in the chain. Consequently, if the peak limiter is installed at the studio, it is permissible for the Automatic Loudness Controller to be installed there also. However, as any automatic signal processing device will largely negate loudness control, it is imperative that the Automatic Loudness Controller follow any other audio controls.

The Automatic Loudness Controller is designed for use with a well-controlled audio level. Therefore, the use of an automatic level control such as CBS Laboratories' Audimax ™ is highly recommended.

The unit has been designed as a unity gain device. This means that when the input signal is below the pre-set loudness threshold, the output is the same as the input. When the input signal exceeds this threshold, gain will be reduced sufficiently to bring the program loudness level down to the threshold value.

Figure 2-2. Block Diagram - Typical Installation

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2-4 ELECTRICAL CONNECTIONS

Input and output leads should be connected to the five-terminal strip at the rear of the chassis. Terminals 1 and 2 are for input and terminals 4 and 5 are for output. The unit may be connected for balanced or unbalanced operation. Terminal 3 is the chassis ground.

The device is designed for either 600 or 150-ohm operation. It is supplied strapped for 600-ohm operation. If 150-ohm operation is desired, remove the jumper between pin 2 and 3 of T2, the input transformer. Connect a jumper between terminals 1 and 2 and another jumper between terminals 3 and 4 of T1. In a similar manner remove the jumper between terminals 7 and 8 of T3, the output transformer. Connect a jumper between terminals 6 and 7 and another between terminals 8 and 9.

After connecting the unit in the program chain, turn the CONTROL switch to OFF and make sure that the Threshold Control is turned fully counter-clockwise. The unit may now be switched on and will function as a unity gain amplifier.

Figure 2-3. Controls - Automatic Loudness Controller

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SECTION III

SET-UP PROCEDURES

3-1 GENERAL

As mentioned earlier, the Automatic Loudness Controller is designed to work with well-controlled input levels. The set-up instructions are predicated on this fact. The user should pick the method for the operation which most nearly duplicates his own.

3-2 OPERATION WITH NORMAL FLAT INPUT (e.g., following a Volumax Model 400 or a Conventional Limiter)

Turn the unit ON and ensure the LOUDNESS THRESHOLD (Figure 2-3.) control is completely counter-clockwise and CONTROL switch is ON. Allow the unit to reach stable operating temperature by waiting 15 minutes before making the following adjustments and make sure that the unit is terminated with its appropriate load impedance. Break the audio chain at the transmitter input and feed normal program material into the Automatic Loudness Controller. Monitor the program level at the input and output of the unit with conventional Volume Indicators. Record the input VU level. Make sure that the output level is the same as the input. If a significant difference is apparent (greater than 1 dB) after warm-up, R58 should be adjusted to eliminate the difference. R58 is a small black multi-turn trimming potentiometer located on the Summing Board. (Figure 2-1.)

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Replace the program source with an audio oscillator set at a frequency of 2.5 KHz. (This frequency has been found to be the optimum set-up frequency. Care should be taken to set the oscillator accurately.) Set the level so that the input Volume Indicator reads the same in dBm as the program VU. For example, for an 8 VU line, the input signal at 2.5 KHz should read 8 dBm. Slowly increase the LOUDNESS THRESHOLD control until the Volume Indicator at the output of the Automatic Loudness Controller shows 1 dB of gain reduction. The front panel meter should read approximately half way between the 0 and 2 dB graduations. The Loudness Threshold has now been set for the desired program level. The oscillator can now be disconnected and program material reintroduced with the output of the Automatic Loudness Controller feeding the transmitter.

3-3 OPERATION WITH MODIFIED FM VOLUMAX

Many broadcasters who use FM Volumax have disconnected its de-emphasis network and the pre-emphasis network of their transmitter. This action prevents frequency error and possible phase distortion. However, the output of the FM Volumax is pre-emphasized in this case. To compensate for this, the 6800 pF capacitor supplied with the Automatic Loudness Controller should be soldered across the pair of lugs on the Equalizer Board as indicated in Figure 3-1. The set-up should then proceed as detailed in paragraph 3-2.

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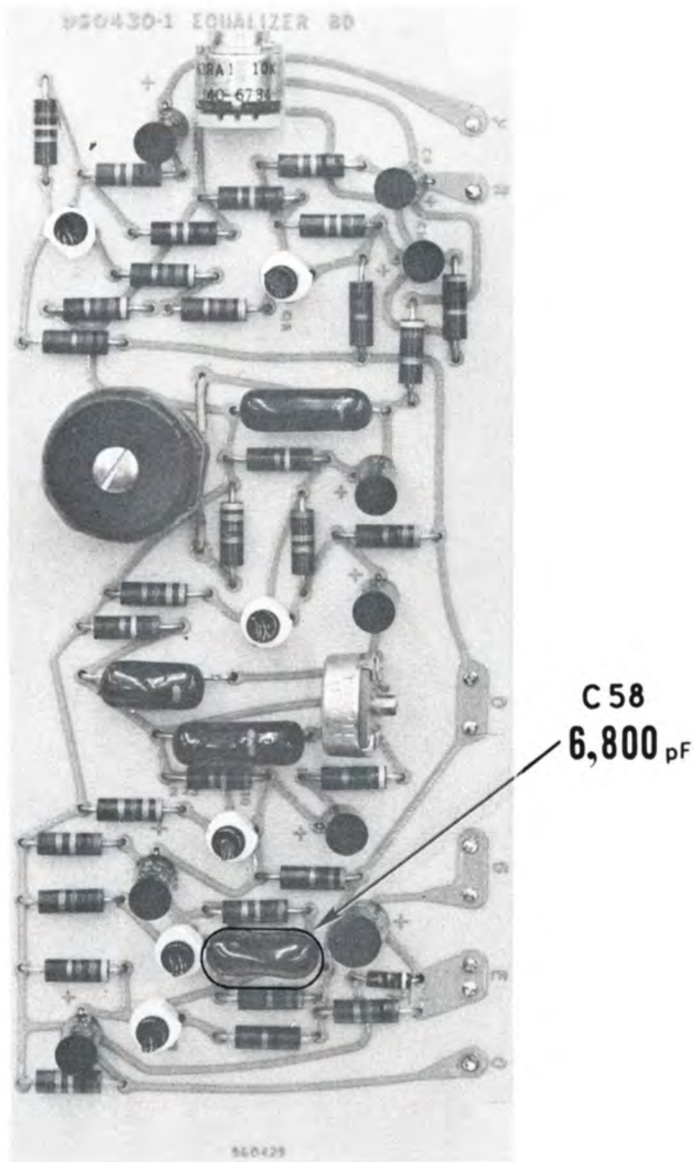

Figure 3-1. Capacitor Location - Equalizer Board

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SECTION IV

PRINCIPLES OF OPERATION

4-1 VOLUME VERSUS LOUDNESS

To control the magnitude of the audio program, the broadcast engineer uses a Volume Indicator (VI). The VI is a rectifier type AC voltmeter with a movement fast enough to reach reference deflection in 0.3 seconds, and damped well enough to prevent more than 1% overshoot. It is well known, however, that the VI does not measure loudness. Programs exhibiting equal VI readings often differ greatly in loudness.

Loudness is defined as the "intensive attribute of an auditory sensation." In other words, the intensity ascribed by the brain to a perceived sound. This is not an easy measurement, especially since a perceived sensation can be dependent on its information content. Thus, two types of loudness have been recognized:

1. Perceptual or Psychological Loudness - which includes the annoyance or emotional content of the message.
2. Sensory or Physiological Loudness - resulting from the action of the physical properties of sound upon the individual's hearing mechanism.

It is evident that the measurement of the psychological factors in loudness is not readly adaptable to automatic means. Therefore, the Automatic Loudness Controller operates on a basis of sensory factors.

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4-2 PARAMETERS OF LOUDNESS

The study of loudness can best be characterized as a large exercise in applied statistics. Psychologists have devised well-tested statistical methods of determining subjective parameters. Balanced test panels of subjects are used to determine the factors influencing loudness. The technique of loudness balance testing where a "louder" or "softer" decision is made between dissimilar sounds is the basis on which loudness statistics are developed.

Several major factors contribute to the loudness sensation:

1. Frequency Content - The influence of frequency on loudness has been known for many years. One of the earliest studies of the phenomenon is incorporated in the well-known Fletcher-Munson equal loudness contours. Because of instrumentation difficulties, these contours were derived by the use of calibrated earphones. CBS Laboratories has obtained a new set of equal loudness contours under a simulated living room environment, using a loudspeaker, not earphones. In order to break up standing waves, octave bands of "pink noise" were used instead of steady-state tones. The composite 70-Phon contour, derived from the separately obtained male and female contours, is shown in Figure 4-1.

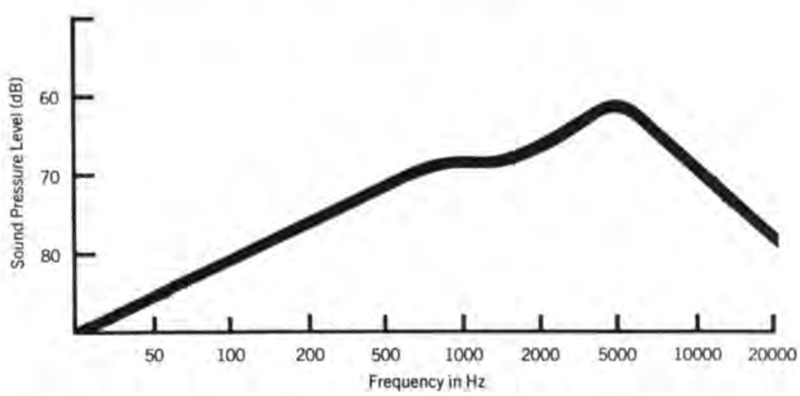

Figure 4-1. CBS Laboratories 70-Phon Composite Equal Loudness Contour.

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2. Summation of Loudness Levels - The method of adding the loudness levels of several octave bands of noise heard simultaneously was studied. It was found that the separate components should be added arithmetically and not as the root-mean-square addition which results when the component bands are all present in a single complex wave which is rectified and measured with a DC meter. To obtain true arithmetic addition of octave bands, it is necessary to separate the complex signal into separate octave bands by band-pass filtering, rectifing of the individual components, and linearly sum the individual voltages.

3. Ballistic Response - Although the frequency response and band summation would suffice to describe complex waves of continuous tones, very little program material takes this form. Program material is discontinuous by nature. Information is transferred by rapid changes, and therefore, the loudness response to impulsive sounds can usually be defined in terms of attack and decay times. It was found that the ear's response can effectively be characterized in this way.

   The rise time of the hearing response can be measured in the following manner. A long burst of tone at 1000 Hz is taken as a reference. This burst is long enough so that no loudness difference is discerned between it and a continuous tone of the same peak sound pressure level. If progressively shorter bursts of the same peak level are weighed against the reference burst they will begin

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to sound less loud. Therefore, in a loudness balance test it is necessary to increase the level of these progressively shorter tone bursts an increasing amount for them to sound as loud as the reference burst. This behavior is shown in Figure 4-2. As the customary definition of attack time is the time to reach 63% of the final value, it can be stated that the ear has an equivalent attack time of 100 milliseconds.

Similarly, the decay time can be evaluated by varying the spacing between tone bursts. Repeated short tone bursts are spaced by increasing intervals of silence. As the time-off gradually increases, the loudness level begins to approach that of a single burst. A decay time of 500 milliseconds best approximates the experimental results obtained.

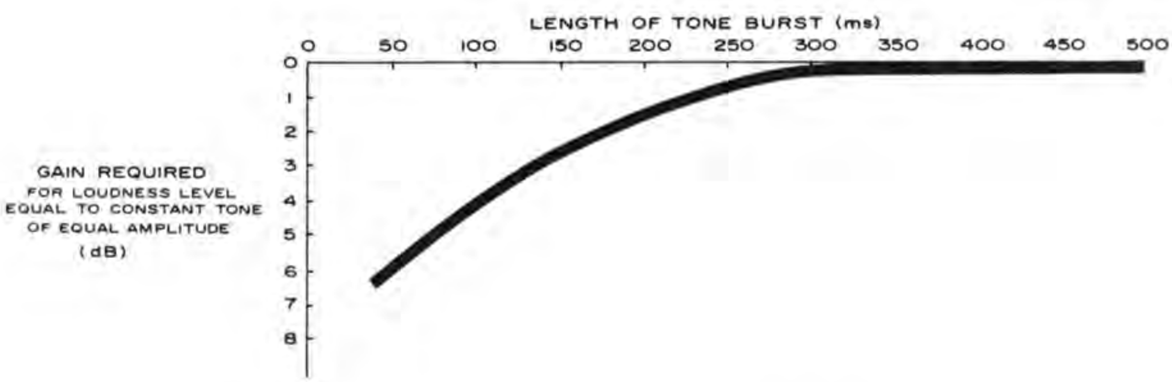

Figure 4-2. Response of Ear to Tone Bursts

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4-3 SUMMARY

It can be stated that the most prominent factors in the determination of sensory (physiological) loudness are the frequency content, linear summation of components, and the ballistics of the hearing mechanism. All of these factors have been applied in the development of the Automatic Loudness Controller. The response of the Equalizer board duplicates the CBS Laboratories Equal Loudness Contour; octave band filtering, rectification, subsequent addition duplicates the linear summation characteristics of the ear; and the ballistic factors are compensated for by selection of appropriate attack and decay times.

4-4 CIRCUIT DESCRIPTION OF AUTOMATIC LOUDNESS CONTROLLER (See Figures 4-3, 4-4, and 5-1)

The Automatic Loudness Controller may be visualized as a novel type of limiter. Whereas conventional limiters utilize an AGC loop based on voltage sensing, the Automatic Loudness Controller makes a loudness judgment on the signal and reduces gain only if the loudness exceeds a pre-set threshold.

Signal is applied to the input transformer T2 and coupled through a variolosser network (R13, R14, and Q2) to the output amplifier (Q3-6). Q2, the active element of the variolosser network is a "Raysistor," which is a sealed device consisting of a light-sensitive resistor optically coupled to an incandescent light source. When the built-in loudness sensing circuitry

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demands gain reduction, a control signal is applied to the light source which emits light, causing the light-sensitive resistor to decrease in value. This increases the insertion loss of the variolosser and the necessary gain reduction is accomplished.

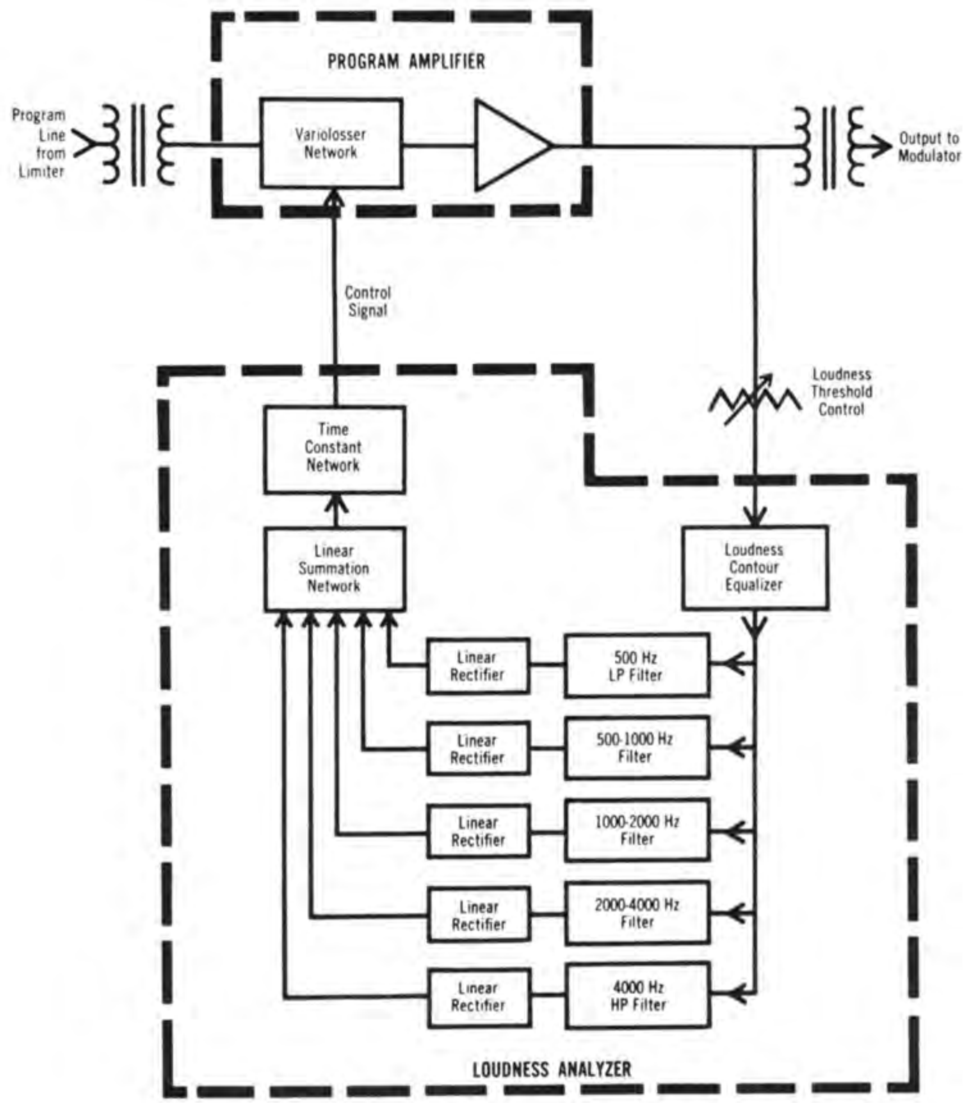

Figure 4-3. Block Diagram - Automatic Loudness Controller

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A balanced signal to drive the loudness sensing circuitry is picked off at the primary of the output transformer. The balanced signal is applied to the differential amplifier Q7-8, amplified, and a single ended signal retrieved at the collector of Q8. The signal is then passed through the equalizing amplifier Q9-11 where the frequency response is tailored to represent the CBS Laboratories Equal Loudness Contour shown in Figure 4-1. L1, R36, and C12 comprise a parallel tuned circuit which forms the shunt arm of a series shunt equalizer. The tuned circuit resonates at approximately 4 KHz, thereby yielding the "peak" in the response at the frequency in Figure 4-1. Q10 and its associated components comprise a bass equalizing circuit which is used to accurately set the shape of the bass end of the response. Q11 is a common emitter voltage amplifier which then feeds Q12, an emitter-follower, which provides a low impedance drive for the active filter bank.

The filter board consists of five filters which classify the signal into octave bands. These filters are all active filters which eliminates the need for bulky inductors. The outputs of each of the filters are rectified by doubling rectifiers and the subsequent DC signals are linearly summed using an operational amplifier. In order to maintain linearity of component addition it is essential that the doubling rectifiers are linear. Because of non-linearity inherent in any practical rectifier, compensating networks (R69-85, CR14-18) are used to linearize the rectifiers.

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The output of the operational amplifier feeds a Darlington emitter-follower (Q13, 14) through a threshold and limiting circuit (CR11a and CR11b). CR11a is a zener diode threshold gate (i. e., it does not pass the control voltage until its voltage is exceeded). CR11b functions as a control voltage limiter. When its zener voltage is exceeded, it breaks down, limiting the control voltage to that necessary for 6 dB of gain reduction. The output of the emitter-follower feeds the meter and the "Raysistor" control lamp, thereby completing the control loop.

Figure 4-4 shows a typical output versus input curve for the Automatic Loudness Controller measured with constant frequency. It is seen that we have limited the maximum gain reduction to 6 dB.

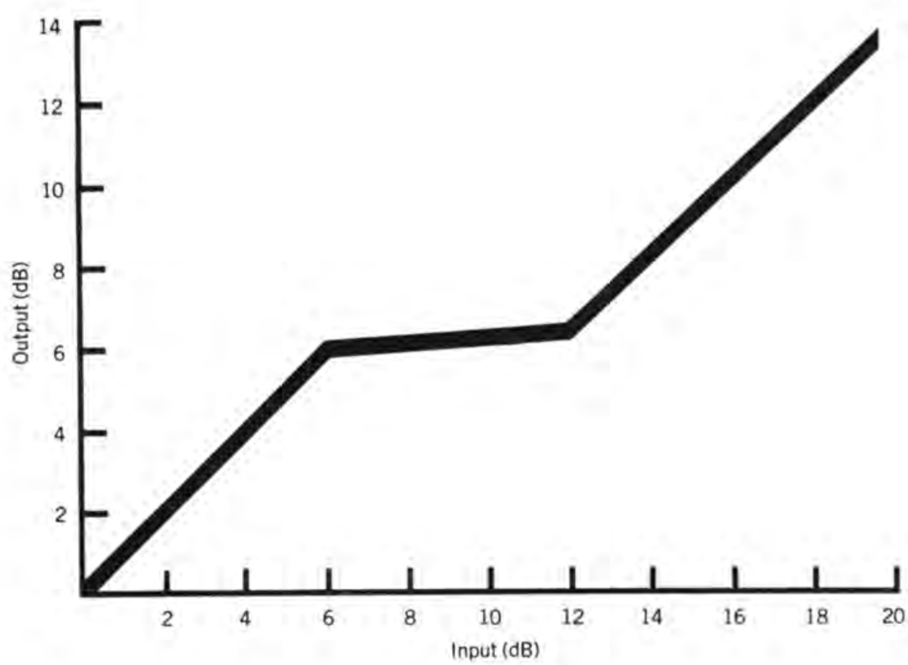

Figure 4-4. Automatic Loudness Controller Response - Steady-state Output vs. Input Characteristics

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4-5 PROOF-OF-PERFORMANCE MEASUREMENTS

Due to the presence of the equalizing network in the AGC loop, a frequency response run made in the CONTROL mode is not indicative of dynamic operation. When the unit is passing a complex program wave, the gain reduction at any one instant of time is a function of program loudness at the instant and the frequency response is completely flat at any gain reduction setting.

Sine wave testing at constant amplitude input will cause varied gain reduction, thus giving a false impression of frequency response of the unit. THEREFORE, WHEN CONDUCTING PROOF-OF-PERFORMANCE MEASUREMENTS, THE CONTROL SWITCH SHOULD BE PLACED AT OFF, which opens the AGC loop.

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SECTION V

MAINTENANCE

5-1 ALIGNMENT PROCEDURE

The following steps are suggested as a comprehensive alignment procedure. Such alignment is usually performed to compensate for normal component tolerances. It should not be necessary to completely re-align your unit unless certain component changes are made. However, an occasional meter realignment or distortion improvement may be required. For these purposes steps 5, 11, & 13 may be performed separately.

1. Terminate the unit with a 600-ohm load and drive it with a 600-ohm signal source. Set R12, R33, R58, and R56 fully counter-clockwise, R110 fully clockwise, and R17 at mid-position. Turn CONTROL switch to ON. Allow the unit to reach thermal equilibrium by permitting it to warm up for at least 15 minutes.
2. Apply a 14 dBm signal at a frequency of 1000 Hz.
3. Slowly increase R12 until the output reads +17 dBm.
4. Increase R58 until the output drops to +14 dBm.
5. Increase R56 until the Gain Reduction meter reads full scale.
6. Increase R33 (LOUDNESS THRESHOLD Control) until the output drops 5 dB.

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7. Drop input frequency to 350 Hz and adjust R41 until the output drops 1/2 dB.

8. Drop input level to +12 dBm and switch back to 1000 Hz.

9. Readjust R33 for 5Db output drop.

10. Switch back to 350 Hz and readjust R41 for 1/2 dB drop.

11. Drop to 50 Hz and adjust R17 for minimum distortion. (Should be less than 0.5% Total Harmonic Distortion).

12. Increase frequency to 2 KHz and note by how many dB gain reduction exceeds 6 dB.

13. Turn Loudness Threshold potentiometer fully counter-clockwise and, if necessary, reset R58 for zero gain reduction.

14. Turn R110 clockwise until gain drops by amount noted in step 12.

15. Readjust R58 for zero gain reduction.

16. Reset R56 for full-scale meter deflection.

17. Set-up unit as outlined in Section III.

5-2 TROUBLESHOOTING

Troubleshooting of any apparent malfunction of the Automatic Loudness Controller should begin with a check of the power supply. DC Voltages,

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as measured with a VTVM, should fall between the upper and lower limits as shown in Figure 5-1. Accidental shorting of the +20 V supply could cause Q1 to develop a collector-emitter short, thereby impressing an unregulated 28 V at Point D. If this transistor is replaced, do not neglect to install the heatsink on the new transistor. Check for open decoupling capacitors in the event of excessive 120 Hz hum. If the power supply appears to be functioning correctly, proceed with the following recommended checks.

As the Automatic Loudness Controller is a unity gain device, there is comparatively little circuitry in the direct signal path. In the event that there is no output, and the power supply is behaving correctly, check the wiring harness to determine if any leads have fractured. If visual inspection does not indicate broken leads examine transistors Q3-5.

If input-output continuity exists with no insertion loss, but the device is not controlling loudness, signal tracing through the Equalizer Board should indicate any faults therein.

After the Equalizer Board the Filter Board should be traced. The easiest way to do this is to monitor the outputs of the individual filters as the frequency spectrum is traversed. Apply a 1 KHz 10 dBm signal to the unit and set the LOUDNESS THRESHOLD control for 1 volt rms output between point 0 and ground (Equalizer Board). At points 2 and 3 (Filter Board) you should be able to measure a DC voltage of approximately 1 volt. Increase frequency to 3.5 KHz and read approximately 2.5 V at points 4 and 5. Drop to 250 Hz. You should read approximately 0.65 volt V at point 1. If these points all check, the problem must lie in the Summing Board.

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If the preceding analysis discloses no faults but no gain reduction is obtainable with any setting of the LOUDNESS THRESHOLD control the fault can lie with:

a. The Operational Amplifier, AR-1

b. The Threshold Diode, CR11a

c. The Emitter-Follower Q13, 14 and associated components

d. The Raysistor, Q2

If the Gain Reduction meter indicates that the unit is working, but no noticeable gain reduction takes place, or can be measured by comparison of input and output Volume Indicators, the Raysistor is probably at fault. For any of these faults, replacement units are available from CBS Laboratories, and can readily be substituted.

If any components are replaced, unit should undergo the alignment procedure to ensure correct operation.

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Notes:

1. Resistor values in ohms K = 1000, Meg = 1, 000, 000
2. Capacitor values in microfarads = (uf), pf = picofarads.
3. Inductance values in MH = Millihenrys.
4. Unless otherwise specified:
   a. All resistors are 1/2 watt ± 5%
   b. All capacitors are 50 volts
5. (screwdriver symbol) Indicates screw driver adjustment.
6. (dashed circle) Indicates heat sink mounted component.
7. CR14 - CR18 are "Conant Voltage Doublers" Type F142-16.
8. CR19 - CR23 are "Conant Voltage Doublers" Type AF121-16.
9. All DC Voltages measured with VTVM.
10. Partial board ref. designations are shown. For complete designation prefix with appropriate unit designation number as indicated. Eg., A1R8, A1Q3, A2R23, A2Q7, etc.
11. For stereo operation:
    a. Add C58 .0068 uf to equalizer boards A2
    b. Install J92 to frames and add wires as follows:

       from J92-1 to S2-1 See detail "X"
       from J92-3 to A5-G

    c. Connect left unit and right unit with stereo cable assy. 200354.
12. (1/2) Voltage Range - Minium-Maximum

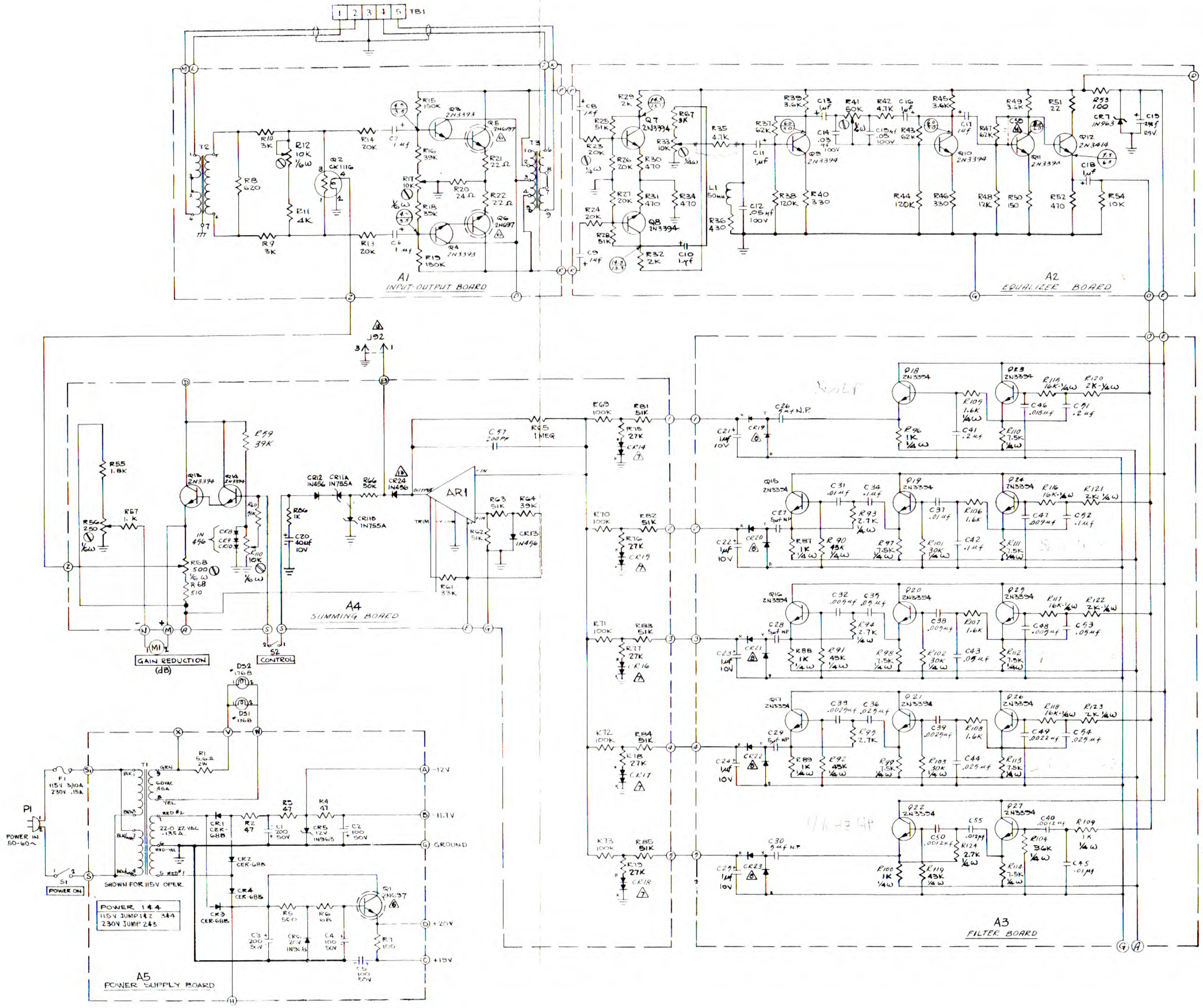

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Figure 5-1 Schematic Diagram - Automatic Loudness Controller

SECTION VI

PARTS LIST

CAPACITORS

REF. (SYMBOL)	DESCRIPTION	MFR. AND PART NO.
C1, C3	Electrolytic, 200 mf/50V	IEI HPC-200-K-O
C2, C4, C5	Electrolytic, 100 mf/50V	IEI HPC-100-L-O
C6, C7, C8, C9, C10,		
C11, C13, C16, C17, C18	Electrolytic, 1 mf/50V	Callins 3-85-PSS-1-50
C12, C15	.05 mf/100V, ±5%	Elmenco 1DP-2-503
C14	.03 mf/100V	Elmenco 1DP-1-303
C19	Electrolytic, 20 mf/25V	Callins 2-85-PSS-20-25
C20	Electrolytic, 15 mf/20V	Callins 2-85-PSS-15-20
C21, C25	Electrolytic, 10mf/10V	Callins 1-85-PSS-10-10
C26, C30	Electrolytic, 5 mf/N.P.	Aerovox BCD 10005
C31, C37, C45 *	.01mf/50V, ±5%	
C32, C38, C48 *	.005 mf/50V±5%	
C33, C39 *	.0025 mf/50V±5%	
C34, C42, C52 *	Type P.C. .05 mf/50V±5%	
C35, C43, C53 *	Type P.C. .05 mf/50V±5%	
C36, C44, C54 *	Type P.C. .025 mf/50V±5%	
C40, C50 *	Type P.C. .0012 mf/500 ±5%	
C41, C51 *	Type P.C. .20 mf/50V ±5%	
C46 *	Type P.C. .018 mf/50V ±5%	
C55 *	Type P.C. .012 mf/50V ±5%	
C57	Electrolytic, 15 mf/20V	Elmenco DM-15-201K
C47 *	Type P.C. .009 mf/50V	
C59 *	Type P.C. .002 mf/50V	

* Not to exceed .650" L X .250" W

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RESISTORS

REF. (SYMBOL)	DESCRIPTION	MFR. AND PART NO.
R1	5.6 ohms, 2W @ 70° C	
R2, R3, R7	100 ohm	
R4	47 ohm	
R5	560 ohm	
R6	68 ohm	
R8	62 ohm	
R9, R10	3000 ohm	
R11	4000 ohm	
R12, R17, R110	Pot. 10K ohm, 1/6W ±20%	CTS XPE-200-1
R13, R14, R23, R24, R26, R27, R66	20 K ohm	
R15, R19	150 K ohm	
R16, R18, R59, R64	39 K ohm	
R20	24 ohm	
R21, R22, R51	22 ohm	
R25, R28, R60 R62, R63	51 K ohm	
R29, R32	2 K ohm	
R30, R31, R34, R52	470 ohm	
R33	Pot. 10K ohm, 1/4 W ±20%	
R35, R42	4.7 K ohm	
R36	430 ohm	
R37, R43, R47	62 K ohm	
R38, R44	120 K ohm	
R39	3.6 K ohm	
R40	330 ohm	
R41	Pot. 50 K, 1/6 W ±20%	
R45, R49	3.6K ohm	
R46, R53	330 ohm	
R48	12 K ohm	
R50	150 ohm	
R54, R81, R85	10 K ohm	
R67	3 K ohm	
R55	1.8 K ohm	
R56	Pot. 250 ohm, 1/6 W ±20%	

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RESISTORS (Cont'd.)

REF. (SYMBOL)	DESCRIPTION	MFR. AND PART NO.
R57	1 K ohm	
R58	Pot. 500 ohm, 1/6 W ±20%	
R61	33 K ohm	
R65	1 Meg Ohm	
R69, R73	100 K ohm	
R75, R79	5.6 K ohm	
R68	510 ohm	
R87, R89, R96,		
R100, R110, R114	7.5 K ohm, 1/4 W ±5%	
R90, R92	36 K ohm, 1/4 W ±5%	
R93, R95	2.7K ohm, 1/4 W ±5%	
R101, R104	30 K ohm, 1/4 W ±5%	
R105, R108	1.6 K ohm, 1/4 W ±5%	
R109	1 K ohm, 1/4 W ±5%	
R115, R119	16 K ohm, 1 4 W ±5%	
R120, R124	2 K ohm, 1/4 W ±5%	

NOTE: All resistors carbon composition 1/2 W ±5%. Allen Bradley or equivalent, unless otherwise noted.

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TRANSISTORS

REF. (SYMBOL)	DESCRIPTION	MFR. AND PART NO.
Q1, Q5, Q6	2N697	
Q2	CK1116	Raytheon Raysistor
Q3, Q4	2N3393	
Q7, Q8, Q9, Q10, Q11 Q13, Q14, Q15, Q27	2N3394	
Q12	2N3414	

DIODES

CR1, CR2, CR3, CR4	Rectifier, Silicon 250 MA 100 PIV	Solitron CER-68B
CR5	Zener, 400 MW, 12V ±5%	Comp Diode 1N963B
CR6	Zener, 400 MW, 20V±5%	Comp Diode 1N968B
CR7	1N93	
CR8, CR10	1N456	
CR11a, CR11b	1N755A (Pair matched within ± 1%)	
CR12, CR13	1N456	
CR14, CR18	F142-16 (Diode bridge)	Conant Labs-Yellow Lead Deleted
CR19, CR23	AF121-16 (1/2 wave rectifier bridge)	Conant Labs

COMPLETE ASSEMBLIES

A1	Input Board Assembly	CBS 960344-1
A2	Equalizer Board Assembly	CBS 960430-1
A3	Filter Board Assembly	CBS 960434-1
A4	Summing Board Assembly	CBS 960348-1
A5	Power Supply Board Assembly	CBS 960210-1
	Harness Assembly	CBS 960451

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MISC. AND ELECTRICAL

REF. (SYMBOL)	DESCRIPTION	MFR. AND PART NO.
L1	Toroid 50 mH	Allen Organ Co., 50 mH NCT
XF1	Fuse Holder	Littlefuse 342012
F1	Fuse 3AG .3A	Littlefuse 312.300
S1	Switch, Toggle SPST	Cutler-Hammer 8381-K7
S2	Switch, Toggle SPST	Cutler-Hammer 8381-K8
TB1	Barrier Strip	Jones 5-140Y
T1	Power transformer	CBS A-23936
T2	Input Transformer	CBS 9604431
T3	Output Transformer	CBS 960442-1
DS1, DS2	Lamp Mig. SC 6V	GE or Chic. Min 1768
	Lampholder	Lee Craft 16-26
	Line Cord -6 ft.-tinned No. 18 SPT2	Royal Electric Line Cord
M1	Meter (CBS face 710128)	IMAFS 960447-1
	Meter Bracket	CBS C23912
	Heat Sink	Wakefield NF-207

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