Variable Electronic Crossover and Biamplifier

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The author describes a combined variable electronic crossover and a biamplifier that has a mid high-frequency power output of 20 watts and a low-frequency power output of 50 watts.

MANY AUDIOFANS who build their own hi-fi equipment, and some who purchase kit-type components, soon realize that the cabinet space allotted to the system becomes too small. The author's system went through the usual series of speaker additions and associated L-C crossover networks. The frequency of crossover could not be varied so there was always a question as to whether the speaker performance could be improved with a change in crossover frequency.

Recently, a new component—a Variable Electronic Crossover—appeared on the market. The electronic crossover seemed to have some desirable features and some not so desirable. The good features are that it contains a method of changing the crossover frequency, reduces intermodulation distortion, absorbs no audio power, and does not affect speaker damping. Undesirable features are that it requires another amplifier (one for each channel), and if not properly designed and constructed it can produce hum and noise. There are other pro's and con's that will not be taken up here.

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There are two general types of electronic crossover units. One has a fixed crossover frequency, the other type contains a method of varying the crossover frequency. To the author, the type having a variable crossover seemed most desirable. The first model constructed contained a switch that was used to change capacitor values in the variable portion of a low-pass and a high-pass filter, resistor values remaining fixed. An old amplifier was brought out of retirement and the system placed in operation. The speakers seemed to take on a new brillance not heard before. Results were excellent until the crossover frequency switch was changed to another crossover frequency—the thud that came from the speakers was powerful enough to toss the speaker cones into the middle of the living room! Another undesirable feature was pointed out by the little wife—she didn't want a chassis (electronic crossover) to remain on top of a choice piece of furniture (no space in the cabinet), nor did she approve of an amplifier (additional amplifier for treble) on the floor behind a chair.

Since the original space for the amplifier could not be enlarged, consolidation of components was necessary if the electronic crossover was to be retained. After many hours at a drawing board and trying different arrangements of parts on various shapes of chassis, the combined electronic crossover and biamplifier shown in *Fig.* 1 was constructed. The complete schematic is shown in *Fig.* 2.

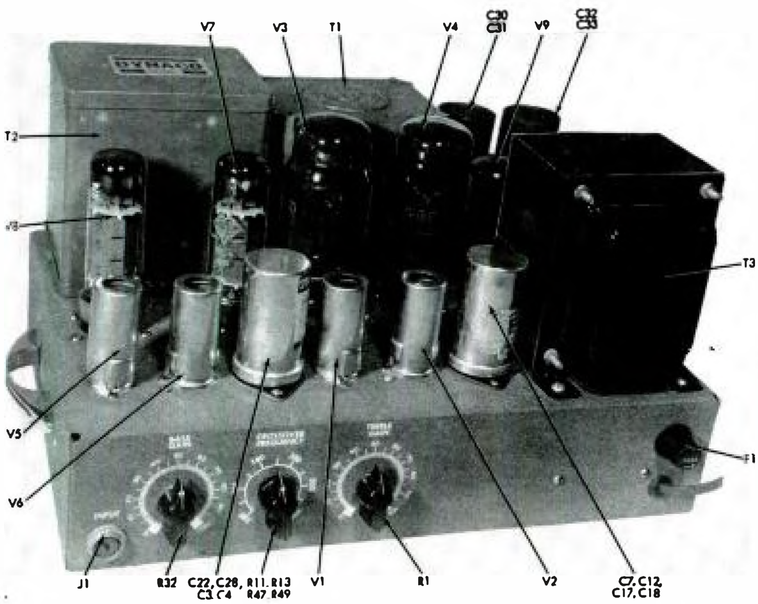


Fig. 1. The author's biamplifier, showing placement of major parts.

Electronic Crossover Section

A block diagram of the variable electronic crossover portion of the biamplifier is shown in *Fig.* 3. The output of a preamplifier feeds two level controls, one for the high-frequency channel (for the purpose of this article, the high-frequency channel is called the *treble* channel although it may contain frequencies below several hundred cps), and one for the low-frequency, or bass, channel. Each channel is then coupled to a voltage amplifier where the program material is amplified and passed on to a cathode follower. So far, both channels are the same with the exception of the coupling capacitors (C_1, C_2, C_{15}, and C_{16}, in *Fig.* 2), but here the similarity ends. Negative feedback is provided through resistors R_5 and R_{39} to improve frequency response and to reduce stage gain to about four.

Cathode follower V_{1B} feeds a high pass filter, (B) in *Fig.* 4, consisting of two R-C sections. The impedance ratio of the first section to the seeond section is 1 to 4. Therefore the slope of the curve is approximately 8 db per octave. Cathode follower V_{2B} feeds a low pass filter, (A) in *Fig.* 4, which attenuates high frequencies at the same 8-db-per-octave rate. The filters present curves that are inversely symmetrical, (C) in *Fig.* 4. When gain controls R_1 and R_{35} are adjusted so that the flat portions of the curves are at the same level, the point where each curve is down 3 db (half-power point) is the crossover frequency. At the 3-db point, each filter is delivering half power and the two filters together deliver full power resulting in an overall curve that is flat.

The crossover frequency is changed by varying the crossover control which has four variable resistances (R_{11}, R_{13}, R_{47}, and R_{49}) combined into one control. When the control is in the counter-clockwise position (resistances at maximum) the filters are adjusted to a crossover frequency of 100 cps. The full clockwise position of the control adjusts the filters to about 1200 cps. Types of resistances required for the crossover frequency control are given under "construction details."

Treble Amplifier

The output of the high-pass filter net-

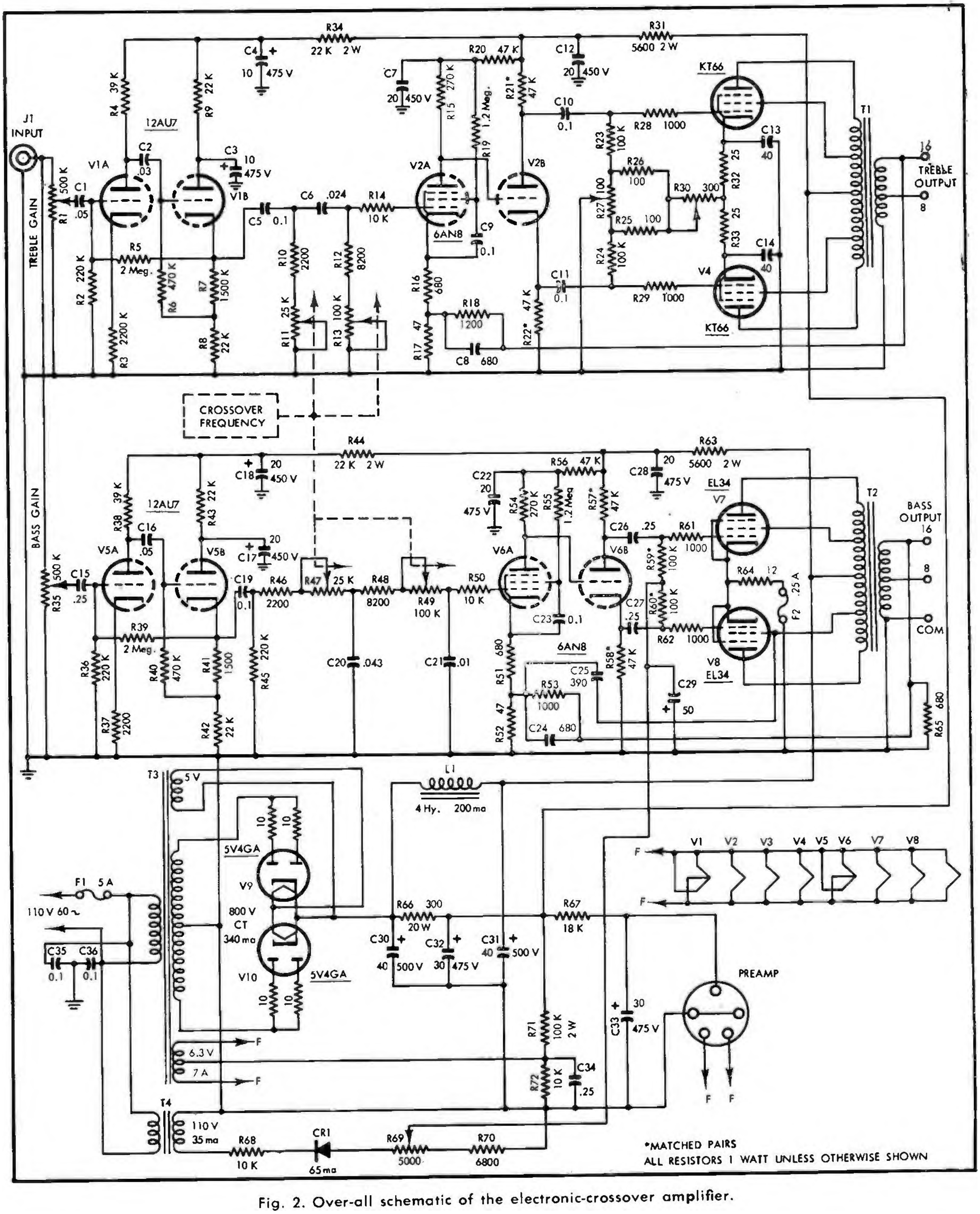


Fig. 2. Over-all schematic of the electronic-crossover amplifier.

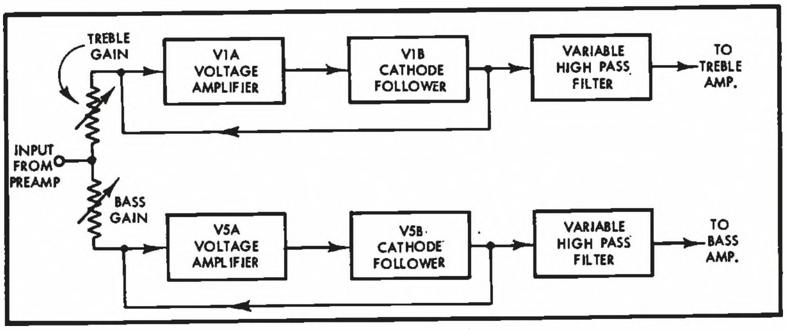


Fig. 3. Block diagram of variable electronic crossover.

work is connected directly to the input of the treble amplifier, *Fig.* 2. This particular amplifier circuit, which is essentially that of the Dynakits was used because of its simplicity and excellent performance. The treble amplifier contains only three tubes and a relatively small number of parts. Power output is 20 watts with slightly less than 1 per cent total harmonic distortion. Intermodulation distortion is 1.3 per cent at 20 watts output and is under 0.5 per cent at 10 watts.

(Note: Since the photograph in *Fig.* 1 was taken, transformer T_1 has been changed from a Linear Standard LS-63 to an Acrosound TO-300. Plate-to-plate impedance of the LS-63 was found to be too high for the KT-66 type tubes when operated in the Ultra-Linear connection.)

A few eyebrows may be raised when seeing a 20-watt amplifier being used for the "Treble" range. However, when using a crossover frequency of 200–300 cps, some rather low frequencies must be amplified by the treble channel. A 20-watt amplifier seemed to be a good companion to back up the bass amplifier which is rated at 50 watts.

Tube V_2 is a pentode-triode. The pentode (section A) is used as a high-gain voltage amplifier. It is directly connected to the triode (section B) which is used as a cathodyne or split-load phase splitter. Grid return for V_{2A} is through part of the high-pass filter, R_{12} and R_{13}. The output of the phase splitter is connected to V_3 and V_4 (KT-66's) which are operated in Ultra-Linear push pull. Total plate current of 120 milliamperes (60 ma per tube) is obtained by adjusting the slider on resistor R_{20}. Resistor R_{27} is used to balance plate currents. A balance is obtained when the voltage across resistors R_{32} and R_{33} is zero. Plate current is the correct value when the voltage across each of these resistors is 1.5 volts. Resistor R_{18} provides about 18 db of negative feedback. Taps on the primary winding of transformer T_1 provide the necessary screen feedback for Ultra-Linear operation of the output tubes.

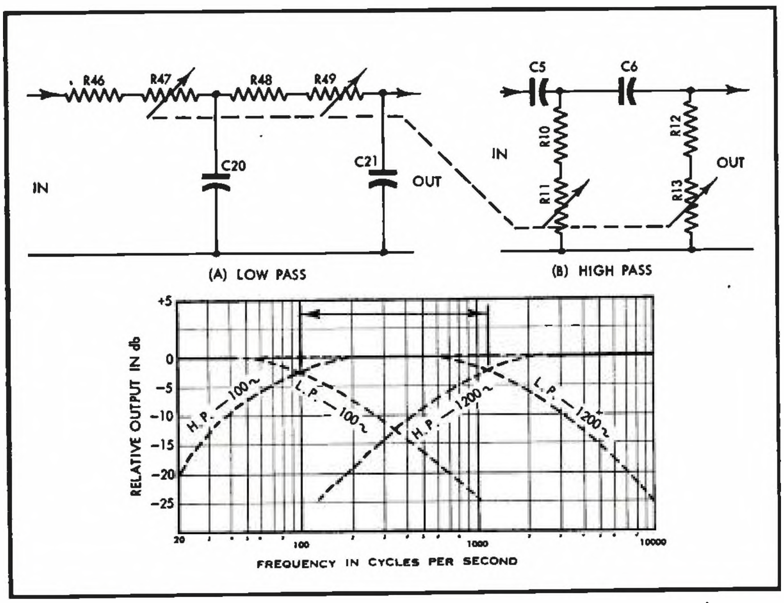


Fig. 4. Configuration of RC filter networks used in the biamplifier: (A), the low-pass section, and (B), the high-pass section. (C), response curves of the two sections at maximum and minimum crossover frequencies.

The circuit of the bass amplifier is similar to that of the treble amplifier. Tube V_5 is used as a voltage amplifier and phase inverted which drives two EL-34 tubes also in push pull Ultra-Linear operation. Fixed bias is obtained from a rectifier in the power supply. The bass amplifier develops 50 watts at 0.76 per cent intermodulation. Resistor R_{62} serves two purposes: It provides a test point for proper plate current (1.56 volts) which in effect is added to the fixed bias, and since R_{62} is unbypassed it produces a small ampunt of current feedback. Any unbalance in grid signal or a.c. plate current causes a negative voltage across the resistor. The feedback voltage reduces distortion that may be caused by the unbalance. Resistor R_{51} provides the necessary feedback.

Power Supply

The power supply furnishes 130 ma at 420 volts for the treble amplifier, 140 ma at 450 volts for the bass amplifier, 20 ma at 300 volts for a preamplifier, and 30 to 50 volts bias for the EL-34's.

Full-wave rectification with two 5V4GA tubes, each having its plates connected in parallel, (the 10-ohm resistors, R_{73}-R_{76} balance current through the two halves) was used to obtain the 280 ma required by the amplifiers. A separate 1-to-1 transformer, T_4 and a half-wave rectifier CR_1 furnishes the 30-to-50 volt negative bias. Capacitor C_{29} filters the bias supply. The two B-plus voltages are filtered through separate circuits. The filament circuit is positively biased to about 40 volts by a voltage divider of resistors R_{71} and R_{72}.

Construction Details

The amplifier is constructed on a heavy-gauge steel chassis base 3 in. high by 14 in. wide by 10 in. deep and has a grille type metal cover. The chassis must be made of heavy steel because two of the transformers each weigh about 14 pounds. The completed amplifier weighs 48 pounds.

Location of parts (*Figs.* 1 and 5) is very important. The power-supply components are mounted at one end of the chassis, the treble amplifier in the middle section, and the bass amplifier at the other end as far away from transformer T_3 as possible. A steel shield is mounted on the underside of the chassis to isolate the external fields of transformer T_4 and filter choke L_1. The shield also provides valuable space for mounting parts of the power supply. Tube shields are used on the 12AU7's and the 6AN8's to prevent hum pickup from the partially shielded power transformer.

Filaments were wired by two separate pairs of twisted wires from the power supply section, one pair supplying the power output tubes, and the other supplying the small tubes. The

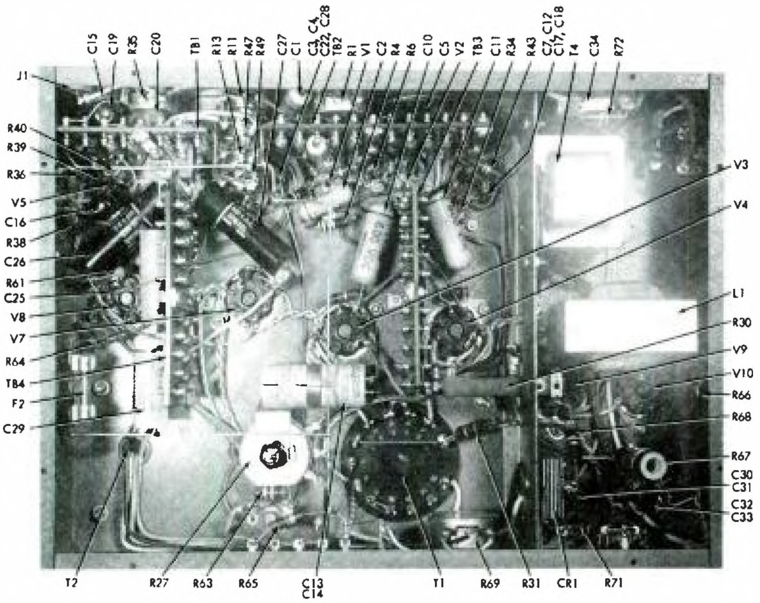


Fig. 5. Underside of amplifier chassis showing parts placement.

filaments were wired first, keeping the leads close to the chassis.

Because of the large number of parts in the amplifier, terminal board construction was used where possible. Two terminal boards are mounted along the front apron of the chassis. These boards mount most of the parts required in the input circuits and the electronic crossover networks. Parts associated with the crossover frequency control are mounted on the boards as close to the control as possible. This allows short leads to the cathode followers and to the grid of the 6AN8's where hum is likely to be picked up. Two other terminal boards mount parts associated with the bass and treble amplifiers. Coupling capacitors were put in last. Terminal board construction makes removal of parts easy, does not clutter the socket pins, and if properly assembled actually reduces capacitance between parts and chassis. The boards were assembled *on the bench,* then mounted on the chassis and wiring completed.

The crossover frequency control is assembled by using one IRC "PQ" control and three "M" sections all having a linear taper. The control consists of one 25-k "M" section IRC (M11-120), two 100-k "M" sections (M11-128) and a 25K "PQ" standard control (PQ11-120). R_{11} (standard control) is the basic control and is next to the front apron. Instructions for adding the "M" sections to the "PQ" control are packed with the control. Particular attention must be given to wiring this control since with clockwise rotation of the shaft, resistance must *decrease* thereby *increasing* the crossover frequency.

Capacitor C_5 and C_6 in the high-pass filter and capacitors C_{20} and C_{21} in the low-pass filter are selected values that are within 1 per cent of desired value. C_6 was made up by paralleling .02-µf and .004-µf units then measuring the combination on a capacity bridge. C_{20} is an .047µf unit that actually measured the desired value of .043µf. Resistors R_{10}, R_{12}, R_{56}, and R_{58}, although standard values, were measured and selected to be within 1 per cent of the desired value. (The author's parts dealer loaned a handful of capacitors and resistors so the correct values could be selected, allowing return of the parts that could not be used, my thanks to him.) Resistor pairs such as R_{21} and R_{22}, R_{57} and R_{58}, R_{59} and R_{60}, and R_{32} and R_{33} were matched to within 1 per cent. Such exactness may not be necessary but on an overload test, it's nice to see clipping at both grids of each power amplifier take place at exactly the same level.

Some preamplifiers have the 117-volt power switch leads within the cable that carries power to the preamplifier. These leads were run separately because the primary current of transformer T_3 is about 2 amperes. Ground throughout the amplifier is a #14 tinned bus wire which is connected to the chassis near the input jack. All electrolytic capacitors are mounted on insulating wafers and the shell connected to the ground bus wire. Speaker connections, bias control R_{69}, and preamplifier power socket are mounted on the rear apron of the chassis. An unusual feature of this amplifier is that it does not contain a single half-watt resistor! It is true that the current in some circuits warrant the use of a half-watt, or even a quarter-watt, resistor but *this* audiofan has encountered several sad experiences with them.[1]

Adjustments

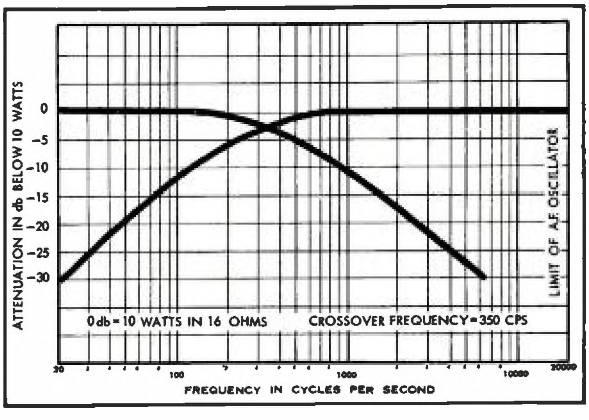
The only adjustments required are bias for the EL-34's and balancing the KT-66's. Proper bias (and correct plate current) for the EL-34's is obtained by adjusting R_{69} until a voltage of 1.56 volts is measured across R_{64}. The correct balance and plate current for the KT-66's is obtained as follows: Connect a low-range voltmeter across resistors R_{32} and R_{33} (pins 8 of V_3 and V_4) and adjust resistor R_{27} for *zero* voltage. The voltmeter is now connected across R_{32} (or R_{33}) and the slider of resistor R_{30} adjusted until an indication of 1.5 volts is obtained on the meter. The balance adjustment should be checked by repeating the zero-voltage measurement previously described.

Several "tests" were made on the overall amplifier such as power output and frequency runs at different crossover frequencies. *Figure* 6 shows the results of one "run" and indicates the over-all response at an output of 10 watts. Calibration figures on the frequency control (*Fig.* 1) are approximate only, since in operation the exact value does not mean much.

(*Continued on page 83*)

[1] One experience similar to that explained by Walter Richer, in "The sad tale of a half-watt resistor," AUDIO, December, 1957.

Fig. 6. Response of the two sections of the biamplifier with the crossover control set for 350 cps.



Operation

Selection of the best crossover frequency is done by listening tests only. The gain controls should be adjusted for best balance of treble to bass. These controls should be readjusted each time the crossover frequency control changed. It is best to adjust the gain controls to a high level, and cut the input signals by turning down the level controls in the preamplifier. The author recorded all settings of the gain controls for each setting on the crossover frequency control so that previous listening tests could be duplicated for comparison.

A few words about the speakers used with this amplifier. The author's speaker system includes four speakers. A good quality 15-inch woofer in a back-loaded folded horn is directly connected to the bass amplifier. The middle- and upper-frequency speakers include two 8-inch speakers mounted in the upper section of the same cabinet. Within the same compartment as the 8-inch speakers is a horn type tweeter with a 3000 cycle L-C high pass filter. This arrangement is connected directly to the treble amplifier.

Building the amplifier described in this article was quite a job. However, results have shown that it was well worth while. Until somthing new comes along, I think this is it!—and the little wife hopes so. Æ

PARTS LIST

All resistors are 1 watt unless otherwise specified.

R_1, R_{35}	500 k-ohm pot, linear
R_2, R_{36}, R_{45}	220 k ohms
R_3, R_{37}	2200 ohms
R_4, R_{38}	39 k ohms
R_5, R_{39}	2.2 megohms
R_6, R_{40}	470 k ohms
R_7, R_{41}	1500 ohms
R_8, R_9, R_{42}, R_{43}	22 k ohms
R_{10}, R_{46}	2200 ohms, 1%
R_{11}, R_{47}	25 k-ohm pot (see text)
R_{12}, R_{48}	8200 ohms, 1%
R_{13}, R_{49}	100 k-ohm pot (see text)
R_{14}, R_{50}	10 k ohms
R_{15}, R_{51}	270 k ohms
R_{16}, R_{52}, R_{65}	680 ohms
R_{17}, R_{53}	47 ohms
R_{18}	1200 ohms
R_{19}, R_{55}	1.2 megohms
R_{20}, R_{56}	47 k ohms
R_{21}, R_{22}; R_{57}, R_{58}	47 k ohms (matched pairs)
R_{23}, R_{24}	100 k ohms
R_{25}, R_{26}	100 ohms
R_{27}	100-ohm, 4-watt pot
R_{28}, R_{29}, R_{61}, R_{62}	1000 ohms

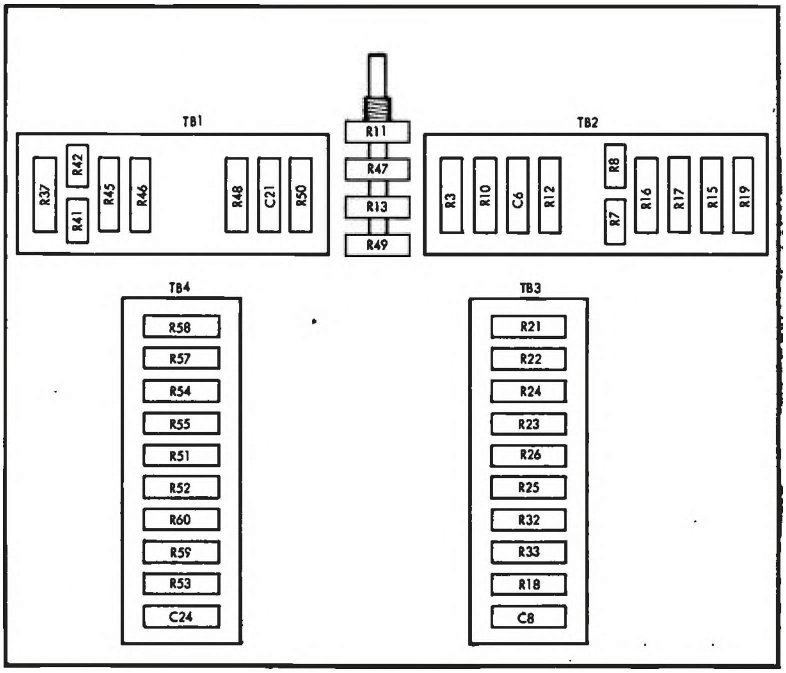


Fig. 7. Layout of components on the resistor mounting boards, and the indicated sections of the crossover-frequency control.

R_{30}, R_{66}	300 ohms, 20 watts, adjustable
R_{31}, R_{63}	5600 ohms, 2 watts
R_{32}, R_{33}	25 ohms (matched)
R_{34}, R_{44}	22 k ohms, 2 watts
R_{43}	1000 ohms
R_{59}, R_{60}	100 k ohms (matched)
R_{64}	12 ohms, 1%
R_{67}	18 k ohms, 2 watts
R_{68}, R_{70}	10 k ohms, 2 watts
R_{65}	5000-ohm pot, 4-watts
R_{70}	6800 ohms, 2 watts
R_{71}	100 k ohms, 2 watts
C_1, C_{16}	.05 μf, 600 volts
C_2	.03 μf, 600 volts
C_3, C_4	10 μf, 475 volts, electrolytic
C_5	0.1 μf, 600 volts, 1%
C_6	.024 μf, 600 volts, 1%
C_7, C_{12}, C_{17}, C_{18}	20 μf, 450 volts electrolytic
C_8, C_{24}	680 μμf, 400 volts
C_9, C_{10}, C_{11}, C_{19}, C_{23}	0.1 μf, 600 volts
C_{13}, C_{14}	40 μf, 150 volts, electrolytic
C_{15}, C_{34}	.25 μf, 600 volts
C_{20}	.043 μf, 600 volts, 1%
C_{21}	.01 μf, 500 volts, 1%, mica
C_{22}, C_{28}	20 μf, 475 volts, electrolytic
C_{25}	390 μμf, 1000 volts, ceramic
C_{26}, C_{27}	.25 μf, 600 volts (matched)
C_{29}	50 μf, 50 volts, electrolytic
C_{30}, C_{31}	40 μf, 500 volts, electrolytic
C_{32}, C_{33}	30 μf, 475 volts, electrolytic
C_{35}, C_{36}	0.1 μf, 600 volts, bathtub 2 × 0.1
F_1	5 amperes, Littelfuse 3AG
F_2	¼ ampere, Littelfuse 3AG

L_1	4-Hy. choke, 200 ma
T_1	Ultra-Linear output, Acrosound TO-300
T_2	Ultra-Linear output, Dynaco A-430
T_3	Thordarson 22R35
T_4	117-v primary to 117-v secondary, 35 ma
CR_1	Selenium rectifier, Federal 1002A, 65 ma
V_1, V_3	12AU7 tube
V_2, V_4	6AN8 tube
V_5, V_6	KT66 tube
V_7, V_8	EL34 tube
V_9, V_{10}	5V4GA tube
J_1	Phone jack, Amphenol 80-C

TECHNICAL DATA

Power output:
- Treble channel . . . 20 watts
- Bass channel . . . . 50 watts

Power input . . . . 222 watts, 117v

Input voltage for 12 watts output, crossover at 500 cps:
- Treble channel . . . 0.7 volts
- Bass channel . . . . 0.9 volts

Hum:
- Treble channel . . . 95 db below 20 watts
- Bass channel . . . . 80 db below 50 watts

Crossover data:
- Frequency range . . 100 to 1,200 cycles
- Attenuation . . . . . 8 db (approx.) per octive

Note: Test equipment was not available for intermodulation tests.
Total harmonic distortion was less than 2%. However this was for the entire system (using a Test Record).