Front End Control Unit for Williamson Amplifier

By
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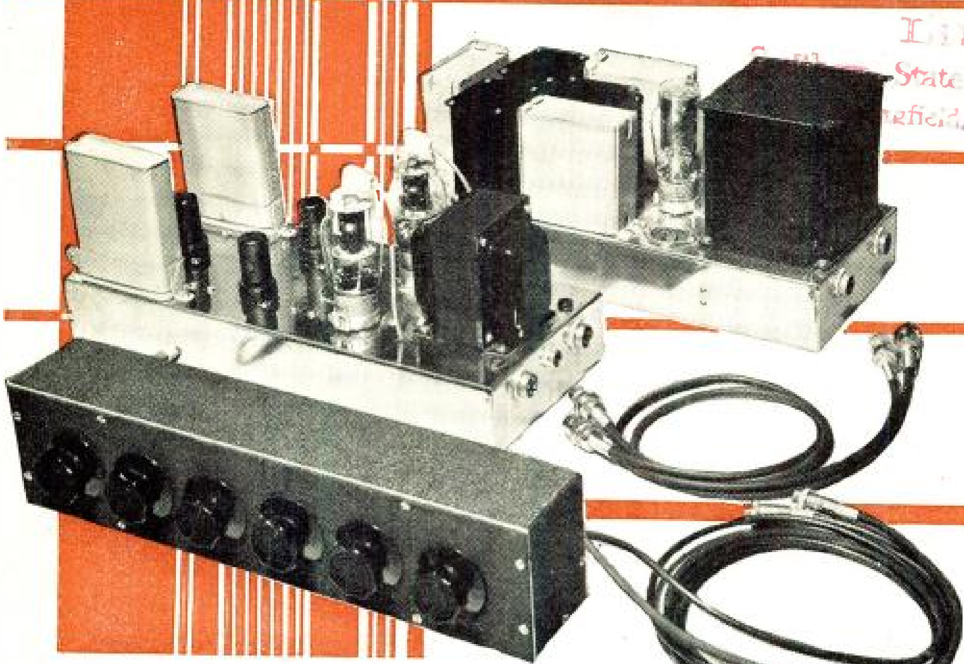


Fig. 1. Preamplifier with Williamson filter shown with heavy-duty Williamson amplifier. This preamp was built along the lines of the unit diagrammed in Fig. 4, although two cables are used here. Cabinet measures 3" x 4" x 17". Amplifier in background has 300 ma. power supply for stable 450 v. required. Lower rated supplies restrict bass output.

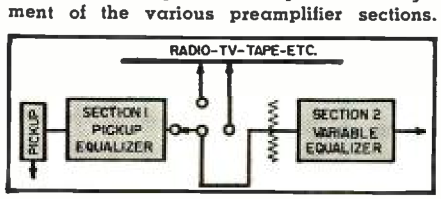
Preamplifiers—covering complete design details on two well-engineered units along with important points to consider when building your own preamp.

AN INHERENT disadvantage of triode output stages is actually put to work in the equalizer-preamplifiers to be described. Although the units are designed for use with the Williamson amplifier and contain some of D.T.N. Williamson's circuitry, they will perform equally well with many other final amplifiers. Variations will be outlined and the individual can choose the particular combination that best suits him. Each has the same features that provide equalization for all types of recordings and other program material. Distortion is not added in any perceivable degree to the over-all system.

Equalizers must provide a lot of bass boost. A recording properly equalized for its low-frequency, constant-amplitude characteristic and for hearing losses may require as much as 40 db of bass boost. 40 db more are required to increase the level of a magnetic cartridge output to drive the final amplifier. This brings the total voltage gain to 10,000. Obviously, it is very easy to introduce hum with such a system. Elaborate precautions are necessary and it is almost impossible to eliminate this disturbance by conventional means. Even a few microvolts of hum admitted into the initial stages of a high gain amplifier will be audible by the time it reaches the speaker. The usual compromise is either to accept the hum or settle for lower gain. In addition, instability at low frequencies prevails with high gain. However, that malfunction is easier to cure. A well-designed decoupling network will eliminate tendencies towards instability and motorboating.

Hum is most commonly admitted through the heaters or heater wiring. Power supply ripple needn't be considered because it is a fairly simple matter to reduce ripple to a fraction of a per-cent. When considering an equalizer with high gain, the surest way to avoid grief is to keep the unit completely isolated from all hum sources. By operating the heaters with d.c., hum is virtually eliminated and 99% of the precautions that usually have to be taken can be disregarded. Heater leads need not be twisted and carefully dressed. Grid and plate leads can be long and unshielded. In fact, the designer can place parts and wiring for the most pleasing appearance and ease of construction.

Fig. 2. Block diagram showing basic arrangement of the various preamplifier sections.



Triodes are notorious for their large current drain. At best they are inefficient. In spite of this, the superlative results obtained with circuits such as the Williamson keeps them popular. The triode-connected KT-66's, 807's, or 5881's used in that amplifier draw about 120 ma. of the smoothest d.c. that can be supplied. Advantage is taken of the large drain by diverting it to the filaments of the preamplifier tubes. There is no need for a separate rectifier and the advantages of d.c. heaters are easily realized. Any tube with a 150 ma. heater can be used.

All is not yet golden. Once hum has been wiped out, an unpleasant "rushing" noise remains. There is only one way to eliminate this particular enemy of high gain amplifiers and that is to use wirewound resistors in all plate and unbypassed cathode circuits. All that now remains is tube thermal noise in the form of high frequency hiss. Its magnitude varies slightly from tube to tube, but substantial reduction of this disturbance is accomplished only at the expense of bandwidth or gain. Fortunately, tube hiss is not objectionable enough to warrant the elaborate procedures necessary for its elimination.

Schematics for two preamplifiers are shown in Figs. 4 and 9. They are cut to the barest essentials and are trouble-free. Each unit is in two sections (Fig. 2): fixed equalization de-

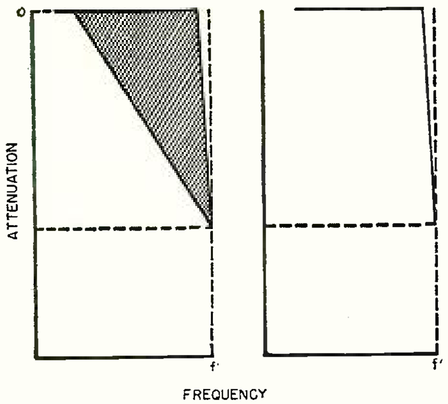


Fig. 3. Comparison of slow and sharp rates of attenuation for noise filters. For an equivalent amount of attenuation at some particular frequency, f', the sharp cut-off version is the more desirable one.

termined by the recording and type of pickup, and variable equalization to alter the flat response to suit the listener. The major difference between the units is the type and location of the scratch suppressor.

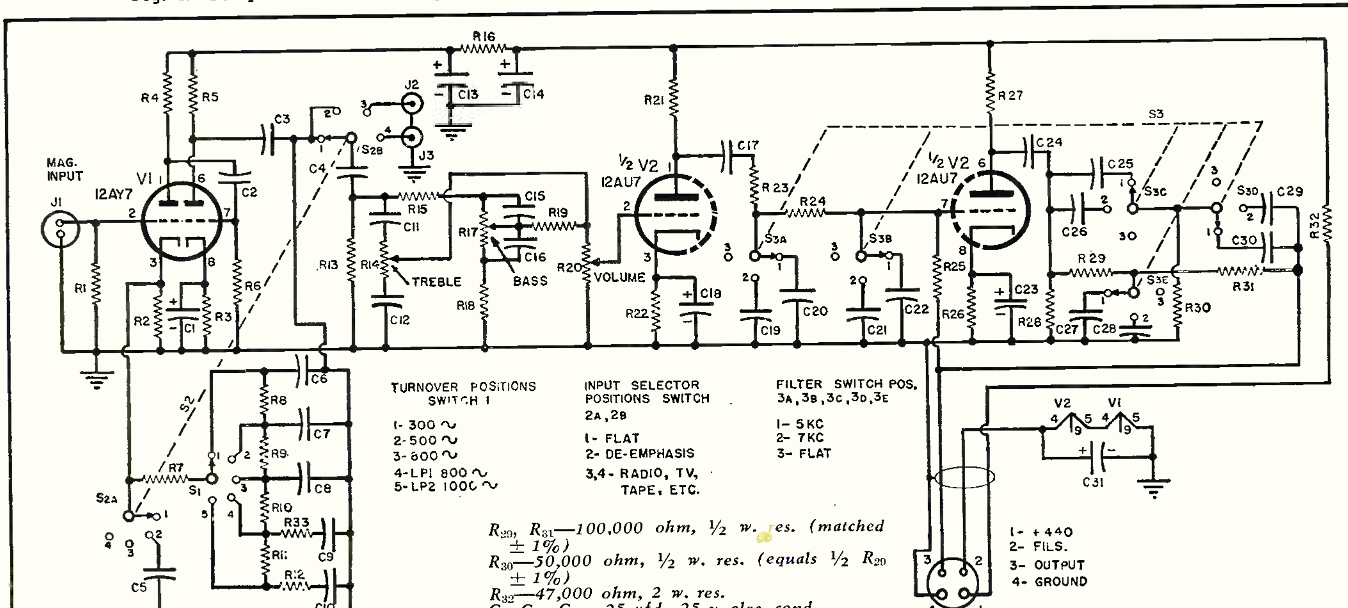
The first section incorporates a 6 db-per-octave boost below a selection of turnover frequencies for constant velocity pickups such as the *Pickering, G-E, Audax,* etc. For constant amplitude pickups such as the *Pfanstiehl* "Strain Sensitive," the reader is referred to the manufacturer's literature regarding proper equalization for the particular cartridge. If the use of such a unit is contemplated, it will be necessary to substitute the recommended circuit for the first sections given in this article. In addition to fixed boost, a de-emphasis network can be included in the first section although it is not mandatory. De-emphasis can be provided later on as will be described. As an extra refinement, a boost in over-all gain can be provided to compensate for the lower output of Microgroove recordings. This is worked into the turnover selector switch as a special *LP* position.

Following the low-level pickup equalizer section, further equalization is necessary to accommodate hearing differences at various volume levels. This accommodation is necessary to overcome scale distortion—a form of distortion due to the fact that the playback is generally at a different volume than the original. Consequently, the frequency response is altered to match the ear response at the playback level to the response it has at the original level. The necessary compensation is determined by the *differences* of response and proper application is dictated by the nature of the material being reproduced. For example, a symphony played at medium room volume requires a fair degree of bass and treble boost while a performance of lower intensity, such as a piano solo played at the same volume as the symphony, requires considerably less boost because the playback level is close to the original. Voice requires droop in many instances where it is reproduced above natural volume.

It appears then that a flexible system that will alter the bass and treble response for *any* setting of the volume control will best accommodate a wide variety of program material. The familiar "loudness" control offers only one degree of fixed boost for any given sound level. While this type of control offers perfect compensation for music of originally loud proportions where the response of the ear is nearly flat, it falls short where accurate reproduction of less intense material is required. It is totally unsuitable for louder-than-original playback. Bass and treble compensation systems employed in the second section consist of infinitely variable boost and droop. A modification to boost only is satisfactory as bass droop is almost never used in playback and treble droop is used only rarely. Turnover frequencies are based on average hearing curves similar to those derived by Fletcher and Munson. A channel selector precedes this section and a volume control is inserted in the grid circuit.

Finally, because noisy records are often encountered, some form of scratch filter must be considered. The extent of circuit elaboration for the removal of record hash is limited only by individual resources. Schemes have been devised ranging from simple treble attenuators to complex variable bandpass filters. Success of each is determined by the amount of highs that remain or *apparently* remain after the scratch is eliminated. Excellent results have been obtained with high-frequency cut-offs between 20 and 60

Fig. 4. Complete schematic diagram of a preamplifier using a Williamson filter and including boost-droop controls.



R_1—27,000 ohm, ½ w. res.
R_2, R_3, R_{22}—2200 ohm, ½ w. wirewound res.
R_4, R_5, R_{21}, R_{27}—100,000 ohm, ½ w. wirewound res.
R_6, R_{13}, R_{24}, R_{25}—470,000 ohm, ½ w. res.
R_7, R_{12}, R_{15}, R_{19}, R_{23}, R_{33}—100,000 ohm, ½ w. res.
R_8, R_9, R_{10}, R_{11}—10 megohm, ½ w. res.
R_{14}, R_{17}—1 megohm audio taper pot.
R_{16}—33,000 ohm, 1 w. res.
R_{18}—10,000 ohm, ½ w. res.
R_{20}—500,000 ohm linear pot.
R_{26}—3300 ohm, ½ w. res.
R_{28}—1 megohm, ½ w. res.
R_{29}, R_{31}—100,000 ohm, ½ w. res. (matched ± 1%)
R_{30}—50,000 ohm, ½ w. res. (equals ½ R_{29} ± 1%)
R_{32}—47,000 ohm, 2 w. res.
C_1, C_{18}, C_{23}—25 µfd., 25 v. elec. cond.
C_2—.02 µfd., 600 v. cond.
C_3, C_4, C_{17}, C_{24}—.05 µfd., 600 v. cond.
C_5, C_{10}—500 µµfd. mica cond.
C_6—.0035 µfd., 400 v. cond.
C_7, C_{15}—.002 µfd., 400 v. cond.
C_8, C_{12}—.0015 µfd., 400 v. cond.
C_9—750 µµfd. mica cond.
C_{11}—150 µµfd. mica cond.
C_{13}, C_{14}—20 µfd., 450 v. elec. cond.
C_{16}—.02 µfd., 400 v. cond.
C_{19}—200 µµfd., mica cond. ± 1%
C_{20}—300 µµfd. mica cond. ± 1%
C_{21}—50 µµfd. mica cond. ± 1%
C_{22}—100 µµfd. mica cond. ± 1%
C_{25}, C_{30}—150 µµfd. mica cond. (matched ± 1%)
C_{26}, C_{29}—100 µµfd. mica cond. (matched ± 1%)
C_{27}—300 µµfd. mica cond. (equals twice value of C_{25} ± 1%)
C_{28}—200 µµfd. mica cond. (equals twice value of C_{26} ± 1%)
C_{31}—50 µfd., 50 v. elec. cond.
S_1—S.p. 5-pos. shorting-type rotary sw.
S_2—D.p. 4-pos. shorting-type rotary sw.
S_3—5-pole, 3-pos. shorting-type rotary sw.
J_1—Two-contact shielded receptacle
J_2, J_3—RCA-type phono jack
V_1—12AY7 tube
V_2—12AU7 tube

db-per-octave. A comparison of the response curves of Fig. 3 will illustrate why sharp cuts yield better results. With a majority of recordings, scratch predominates above some particular frequency. There is no need to attenuate below that frequency. To do so would destroy brilliance unnecessarily and result in a muddy sound that is as undesirable as the scratch. Removal of scratch starts with 6 db attenuation. That much will give an indication that something is being done. Actually, effective removal requires a much greater cut. It is reasonable to assume that the sharp rate of attenuation will cut frequencies in the noise range without removing those below. A slower rate will attenuate as much in the desired region, but the cut has to have a much greater "head start." The shaded area illustrated in Fig. 3 shows the unnecessary loss of high frequencies with a slow rate of attenuation.

Preamplifiers built by the author have included cuts ranging from 20 to 60 db-per-octave with increasing effectiveness. The simpler type of filter giving about 20 db-per-octave is the familiar *RC* shunt across the magnetic cartridge. Filters such as these are merely *LC* low-pass filters with the *"Q"* lowered by the addition of the shunt resistor to smooth out the peak. The inductance is furnished by the pickup coil and calculations are based on *"Q's"* from .8 to 1 to determine the correct resistor to use.

A more complex, but exceedingly effective, filter giving attenuations starting at 40 db-per-octave and rapidly turning to 60 db-per-octave, is based on the parallel-T network. In essence, this circuit takes the very narrow bandpass characteristic of the parallel-T (Fig. 6A) and removes the upper pass region by the application of negative feedback via a phase-shifting network. The result is the sharp cut-off, low-pass filter of Fig. 6B. This configuration is described in detail elsewhere by D. T. N. Williamson.[1] The author has simplified the arrangement to three-position switching and adapted it to American tubes. Experience has shown that additional cut-offs above 7 kc. are unwarranted. Because of its location in the preamplifier unit, this filter may be used on broadcast programs—a boon to the long suffering listeners of noisy records and transcriptions from FM stations.

For constructors who desire the ultimate in preamplifiers, the choice of the unit with the Williamson filter is recommended. For those who want an excellent unit, but do not believe that their present equipment demands the refinements of a more ambitious undertaking, the other preamplifier is suggested. Parts of the units may be interchanged. For example, the variable bass and treble sections are equally good and are adaptable to

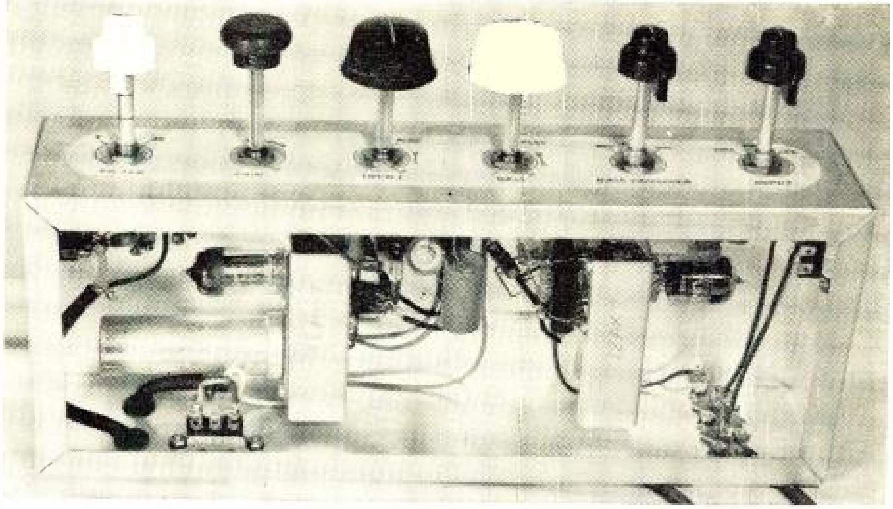


Fig. 5. Close-up view of preamp of Figs. 1 and 4. Coaxial cable is used for the output and two-wire lamp cord is employed for "B+" and heater supply.

either preamplifier. The simpler circuit shows boost only, while the more elaborate unit is shown with "center position flat" boost-droop controls. If the constructor feels that droop will never be used, then the straight boost type is to be preferred since a finer adjustment can be effected with full pot. rotation. Front end refinements may also be used in the simpler unit. These include a de-emphasis switch and the special *LP* positions in the turnover switch.

While the selection of parts for these units is perhaps more arduous than ordinarily required, the ensuing construction need only be a subdivision of methods commonly termed "straightforward." Wirewound resistors must be used where indicated. Do not use the metallic film type resistor as they give almost as much noise as carbons. It is necessary to match several resistors and condensers closely for the Williamson filter. Their absolute values may be within 10% of those listed, but they must be within 1% of each other. Within the housing of the units, no special techniques are required. However, the entire preamplifier must be fully enclosed in a metal box.

When choosing components for your unit, take advantage of the many miniatures now offered, such as "Discaps," for values up to .02 μfd., "Aerolites" and other very small condensers from .02 up, and "Ceramicons" for low values in the filter circuit. Small wirewound resistors in the 100,000 range are made by *Shallcross* and *IRC* as precision resistors. They can be purchased from surplus for very little as odd values, *e.g.*, 112,300 ohms. Accuracy is not important here. Resistances below 10,000 ohms are available wirewound in the standard form as type BW.

Heater supply connections for the Williamson output stage are shown in Fig. 7. Note that only a three-wire shielded cable is needed from the amplifier to the preamplifier with this arrangement. This connection can be

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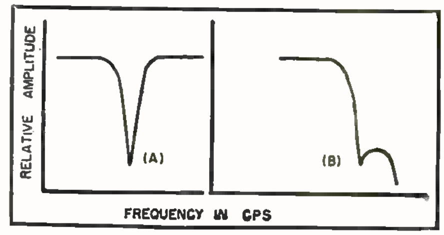


Fig. 6. Typical parallel-T narrow bandpass characteristic (A) transformed into low-pass filter and (B) by application of a negative feedback through the network.

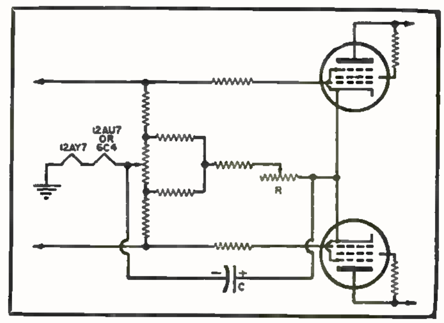
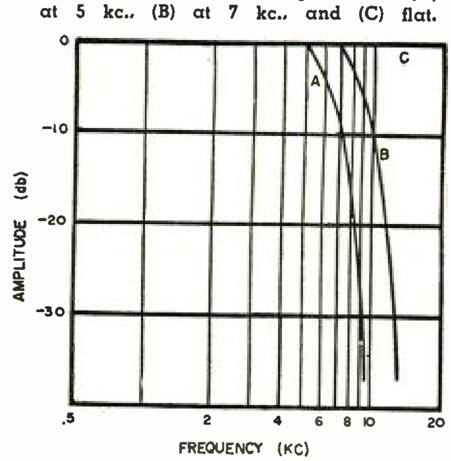


Fig. 7. Method of obtaining heater current from Williamson output stage. Adjustment of R affects tube drain and should be set for proper heater operation. Cathode bypass, C, is returned to center arm of balance pot. for stability and protection in event of an open in filament string.

Fig. 8. Williamson filter positions. (A) at 5 kc., (B) at 7 kc., and (C) flat.



[1] "Design of Tone Controls and Auxiliary Gramophone Circuits," *Wireless World*, Oct.-Nov. 1949.

Front End Control Unit

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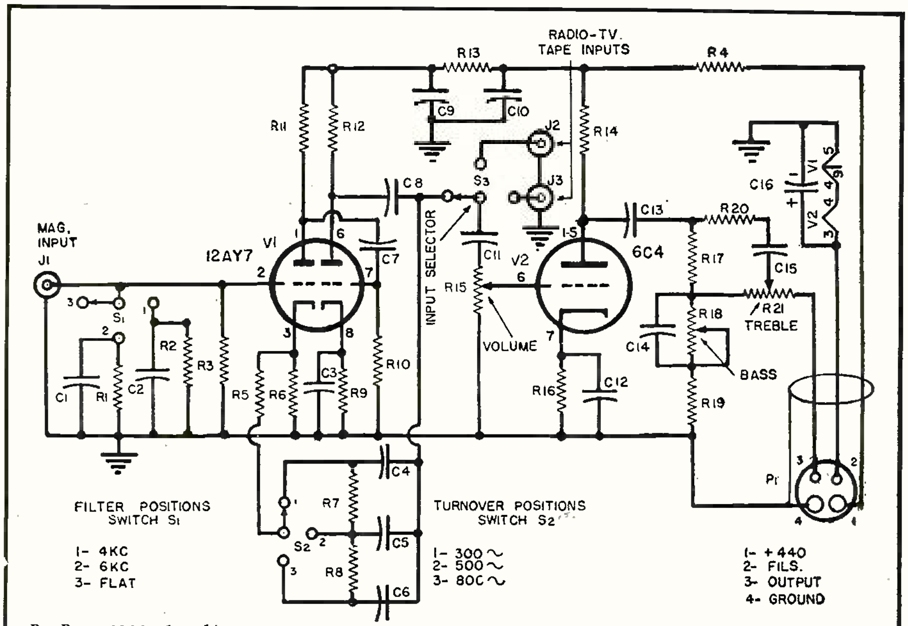
used with other output stages provided that their quiescent current drain is at least 115 ma. For drains larger than about 130 ma. it will be necessary to shunt the heaters with a suitable resistor. For amplifiers that do not have the minimum output stage drain, but draw that much total current, the filaments can be wired in the center tap of the power transformer's high voltage winding. This will necessitate a floating ground, but difficulty can be avoided by heavily bypassing the heaters. The filter condensers should be returned to the center tap.

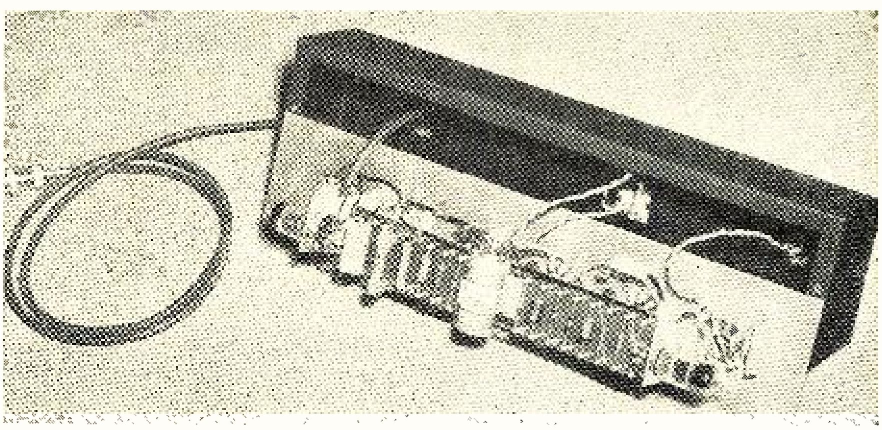
When the unit is placed in operation, the listener will immediately recognize the advantages of d.c. heater operation and use of wirewound resistors by the completely hum-free output and lack of noise. If the magnetic pickup introduces hum, the connections and shielding to the cartridge should be checked for ground loops and improper orientation of the turntable. Be sure that both sides of the a.c. line are bypassed to the amplifier chassis. A mechanical ground system that connects the pickup arm, motor frame, and all amplifier chassis to a water pipe will do much to eliminate any induced hum. Some turntables have proven themselves unfit for high



R_1, R_{19}—6800 ohm, ½ w. res.
R_2—4700 ohm, ½ w. res.
R_3—27,000 ohm, ½ w. res.
R_4—47,000 ohm, 2 w. res.
R_5, R_{17}—100,000 ohm, ½ w. res.
R_6, R_9, R_{16}—2200 ohm, ½ w. wirewound res.
R_7, R_8—10 megohm, ½ w. res.
R_{10}—470,000 ohm, ½ w. res.
R_{11}, R_{12}, R_{14}—100,000 ohm, ½ w. wirewound res.
R_{13}—56,000 ohm, 1 w. res.
R_{15}—500,000 ohm linear taper pot.
R_{18}—1 megohm audio taper pot.
R_{20}—10,000 ohm, ½ w. res.
R_{21}—100,000 ohm linear taper pot.
C_1—.005 µfd., 400 v. cond.
C_2—.01 µfd., 400 v. cond.
C_3, C_{12}—25 µfd., 25 v. elec. cond.
C_4—.0035 µfd., 400 v. cond.
C_5—.002 µfd., 400 v. cond.
C_6—.0015 µfd., 400 v. cond.
C_7—.02 µfd., 600 v. cond.
C_8, C_{11}, C_{13}, C_{14}—.05 µfd., 600 v. cond.
C_9, C_{10}—20 µfd., 450 v. elec. cond.
C_{15}—150 µµfd. mica cond.
C_{16}—50 µfd., 50 v. elec. cond.
S_1, S_2, S_3—S.p. 3-pos. shorting-type rotary sw.
J_1, J_2, J_3—RCA-type phono jack
V_1—12AY7 tube
V_2—6C4 tube

Fig. 9. Preamplifier with simplified filter and "boost only" bass and treble controls.

Fig. 10. Preamplifier with simple filter, built according to schematic of Fig. 9. An aluminum sub-assembly forms the basis for the mounting of resistor boards and tubes.



quality work. Even with their motors suspended 10" below the turntable, the magnetic field is still strong enough to cause hum. The solution is to replace the turntable unit with one of better quality.

There is wide latitude for satisfying individual preferences and applying recommended compensation in the finished unit. The turnover selector is set for the particular record in use, then the variable equalizers are adjusted to suit the listener's taste. Usually, the bass and treble will have to be boosted at lower volume levels and run flatter as the loudness increases. The treble control will compensate amply for any pre-emphasized recordings if the de-emphasis circuit is not used. Coincidental use of the scratch filter and the treble control will bring a balance between record noise and highs. The best procedure is to start with the treble flat and adjust the filter to the point where scratch is reduced noticeably. Then by advancing the treble until the scratch is just barely heard, the balance is effected and the maximum permissible amount of highs will be present without the annoyance of record noise. Use the filter with discretion and in the highest possible position.

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U.H.F. Conversion

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the frequency of operation. Consequently, if the signal can be introduced to the first vacuum tube at a low frequency a better ratio can be obtained. Inasmuch as the signal output is so very low at the crystal mixer (and crystal mixing has not added a high noise level), the signal-to-noise ratio of the tuner is set by the first i.f. tube. A satisfactory ratio can be obtained because of the lower applied frequency. If an r.f. amplifier stage or vacuum tube mixer were employed it would be more difficult and more costly to obtain a comparable ratio because of the much higher signal frequency.

To summarize, a higher signal-to-noise ratio per cost factor can be obtained by introducing a lower frequency signal to the first vacuum tube circuit. Thus vacuum tube amplification or mixing in the u.h.f. range is not used. Instead, a low noise crystal mixer is used to reduce the signal frequency before it is introduced to the first vacuum tube circuit at a much lower frequency. To obtain the very best signal-to-noise relation with this system the i.f. stage must be designed with care to keep hum and noise level at a minimum. The new cascode type amplifier with its low noise content and effective shielding will be almost universal in u.h.f. converters.

Local oscillator radiation is not as trying a problem as in the v.h.f. band despite the absence of an r.f. amplifier stage. The crystal mixer in addition to its attenuation characteristic also requires much less local oscillator